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Horizon 2020

Societal Challenge: Improving the air quality and reducing the carbon footprint of European cities

Project: 690105 – ICARUS

Full project title:

Integrated Climate forcing and Air Pollution Reduction in Urban Systems

D1.5 – A critical review on methodologies for integrated urban impact assessment in support of air quality and climate change governance in EU Member States

WP1 Methodological framework development

Lead beneficiary: JSI

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EXECUTIVE SUMMARY

This report provides information on the work performed with regard to a critical review on methodologies for integrated urban impact assessment in support of air quality and climate change governance in the EU. An extensive literature search (ELS) has been made for this purpose. Different types of literature have been reviewed, e.g. research papers, project reports, policy documents, reviews, altogether 92 research and review papers, 20 EU projects and 5 policy documents.

It can be summarised that a truly integrated assessment related to urban and transport development and planning in cities is currently lacking or is deficient in one or more aspects of integration. In majority of studies a propagation from emission identification through pollution, exposure and consequently health assessment is present, but the uncertainties and approximations in these analysis is relatively large. Even though the impact assessment methodologies and measures/policies were the main foci in this literature review, only a few studies have addressed these issues in a wide participative manner with conducted communication with the city representatives and administrative bodies (local, regional, national). Also the feasibility of the measure/policy implementation was not present in the majority of studies. Cost benefit analysis (or other forms of monetary evaluation) were referred to in only a handful of examples. Apart from the review articles which have focussed on the implementation of policies/measures in an integrative manner it is indicative that the overall practice is different – i.e. it lacks the integrative implementation aspect. In general, the studies were oriented towards developing emission and air pollution models for the measures/policies in question with described health consequences (sometimes through the elements of HIA). The results were mainly presented in a qualitative manner with a couple of examples which have expressed the results in reduced mortality rate or DALY. With regard to climate change and governance the reviewed literature is scarce, except specific EU projects.

It should be also noted, that although some specific advances in assessment modelling approaches have supported policy development in relation to air pollutants and greenhouse gases, the proposed mitigation scenarios/measures/policies still need to go through the approval process in the concrete society, represented either by administrative bodies, city councils, regional agencies or general population. This then becomes the truly integrative process.

Most of the studies do not provide much detail on integral urban impact assessment approaches. ICARUS project in this regards has a great potential to introduce and demonstrate a truly integrative approach, which would be supported by scientific evidence along with a societal acceptability component, so forming a fundament for air quality and climate change governance in the EU.

1 INTRODUCTION

The ICARUS project (http://icarus2020.eu) aims to develop innovative tools for urban impact assessment in support of air quality and climate change governance in the EU. In this context two components serve as fundaments: i) a critical review on methodologies for integrated urban impact assessment being supportive of air quality and climate change governance in the EU, and ii) development of the methodological approach that will allow to properly evaluate the efficacy of policies aiming at mitigating both air pollution related to health effects and GHGs emissions contributing to climate change. Both components serve as key orientation factors for future ICARUS work. They are also important reference point for establishing and performing a process evaluation plan aimed at guiding and monitoring the overall ICARUS work towards ultimate goals.

This report provides information on the work performed with regard to the first component, i.e. the critical review on methodologies for integrated urban impact assessment. An extensive literature search (ELS) has been made for this purpose. Different types of literature have been reviewed, e.g. research papers, project reports, policy documents, reviews. The information searched focus on whether there have been applied integral assessments of urban adaptations and developments in Europe and elsewhere related to air quality and public health improvements in the cities, and which specific approaches and methods for such a strategic evaluation have been utilised. The following specific topics were explored:

- Integrative character of the approaches from both substantial and organisational point of view
- Scope of integrated urban impact assessment: local, regional, national, EU level, global
- Methods for the evaluation of the efficacy of policies aiming at mitigating both air pollution related health effects and GHGs emissions;
- Data fusion for environmental and health impact assessment;
- Interactions between activity sectors and the respective behavioral changes under conditions of environmental and socioeconomic change;
- Health impact assessment which incorporate internal dosimetry methods that take into account source specific characteristics of the emitted pollutants;
- Stakeholders' views on how to explore solutions aiming concurrently at urban air quality improvement and climate change mitigation in different socio-economic settings (promotion of the participatory development of the advances focusing on community-based research).

The overall aim of the review is to consolidate the ICARUS integral method in terms of making it consistent, comprehensive, transparent, and effective in supporting long-term political decisions for developing clean and healthy cities, i.e ensuring wellbeing of urban citizens. The work and its outcomes are tightly connected with other activities in

From the organisational point of view the ICARUS integral method follows project's working packages. There are nine of these and are organised in a way that, following the consequtive and looping approach as presented in Figure 1, and applying specific methods and tools in each of the WPs, delivers a method for integral assessment on large urban areas (the ICARUS cities) in terms of their orientation, aspiration, and policy implementation towards green, healthy cities desired to live in. Strong connections are made between activities in WP1 as to commonly achieve an overview on technologies and methods for determining external exposures, including GPS-enabled personal sensors, remote sensing, agent-based models and influence of SES in relation to exposure and disease causation and state of the art modelling tools for air quality (AQ) and carbon footprint (CFP). In this context the organisation of this report is as follows. Section 1 provides an introduction about the critical review performed on methodologies for urban impact assessment. Section 2 describes integrated urban impact assessment in the context of the ICARUS. A monitoring approach on how to ensure integrated evaluations in ICARUS is emphasized through a reference to process evaluation plan which is presented in detail in D5.1 (a part of WP5). Section 3 provides an insight into literature search. Results are presented in Section 4. Section 5 is dedicated to the summary of findings and recommendations for performing integrated urban impact assessment. Both views are addressed, methodology as a state of the art and its purpose as a support for decision-making.

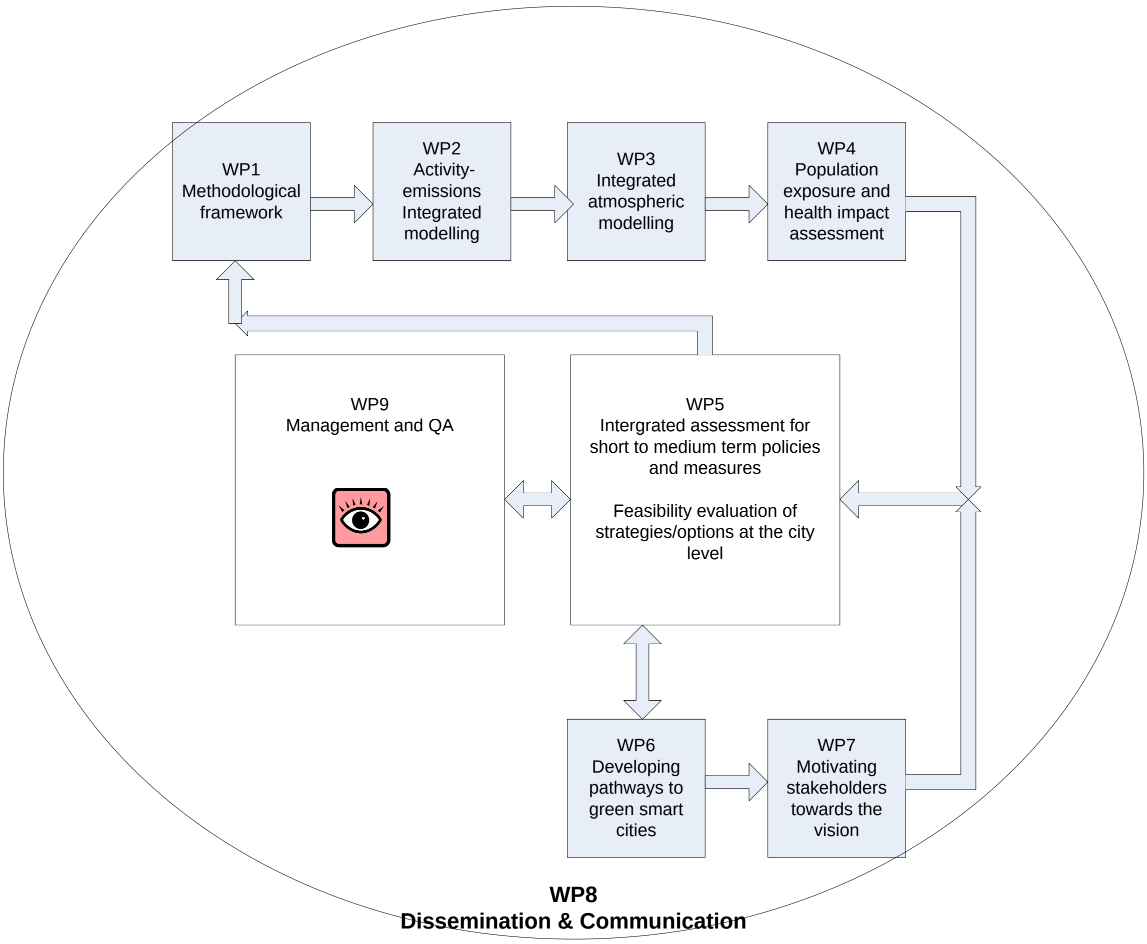

Figure 1: ICARUS consecutive and looping approach throughout nine WPs. One of the loops connects activities from WP1 to WP5, where impacts and measures/policies for avoiding them are analysed, the other connects WP5, WP6, and WP7, where cities' long-term development visions are discussed. Both are to be performed iteratively.

2 INTEGRATED URBAN IMPACT ASSESSMENT

2.1 Approach

The methodological framework development builds on worldwide experience on one side (the literature review) and ICARUS work on the other. In the context of the latter the framework development is to be continuously updated based on the project findings and recommendations. The looping is to be achieved based on the process evaluation activities.

The methodological framework is expected to enable proper evaluation of the efficacy of policies aiming at mitigating both air pollution related health effects and GHGs emissions. Different components of the integrated methodological approach will need to be brought together in an assessment framework that will support their development and interaction. Stakeholders' views on how to explore win-win solutions aiming concurrently at urban air quality improvement and climate change mitigation in different socio-economic settings are to be an integral part of the methodology.

2.2 ICARUS contribution to the framework

The specific project objectives are to quantitatively assess the impact of current and alternative national and local policies on reducing greenhouse gas (GHG) emissions and improving air quality through a full chain approach and evaluate the future public health and well-being impacts of these policies in European cities. For each policy analysed the following effects/impacts need to be evaluated in an integrative manner:

- Change in emissions of air pollutants including life cycle emissions in/outside cities for selected activities.
- Change in emissions of greenhouse gases including life cycle emissions in/outside city (thus changes in the carbon footprint caused by changes in sectorial activities).
- Changes in ambient concentration of air pollutants and greenhouse gases.
- Changes in the exposure to air pollutants taking into account important indoor sources.
- Changes in the associated impacts on human health.
- Societal and economic impacts, including costs for the emission source operator and for other actors of society, including health impacts, time losses or gains and wider impacts.
- Demands regarding implementation of the policies with the consideration of indirect effects (e.g. changes in urbanization and land-use in the cities which support physical activity by extending cycling infrastructure and changes in modal split).

In ICARUS, state-of-the-art technologies for fusing the necessary environmental and other information will be employed to allow for cost-effective air pollution monitoring and assessment. The tools developed will allow the analytical accounting of the main industrial and area emission sources in the area and the creation of precise and updated emission inventories, i.e. source apportionment. An integrated approach will be used for air pollution monitoring combining ground-based measurements, atmospheric transport and chemical transformation modelling and air pollution indicators derived from satellite, airborne and personal remote sensing. Thus, air quality will be readily assessed across different spatial scales in the participating cities.

Research in ICARUS will be user-driven, scientifically innovative and it is designed to engage local communities in the participating cities. The perspective of meeting policy makers and stakeholders needs has a profound analytical and methodological implications. The ICARUS project embraces the current perceptions and vulnerabilities of decision-makers, while also embedding interaction between researchers and stakeholders in all aspects of research, implementation and dissemination. City partners have a strong role in the project activities and impact evaluation framework development.

The ICARUS methodical framework serves as a reference tool when evaluating approaches, methods, and tools that have been applied in Europe and elsewhere for moving towards green, healthy cities. The key characteristic of the ICARUS framework, against which other approaches and methods are evaluated, is its integrative character. In this context the integral components of the ICARUS methodical framework are:

a) Emission data (activity specific, city level);

b) Imission/pollution data (city level);

c) Exposure data (individual and population, city level);

d) Contribution/importance of a particular emitter, or an activity as a source of emission, to health impact and the "baseline situation" of public health status in the cities; the contribution is a basis for elicitation, i.e., identification of effective measures/policies for improving the situation;

e) Contribution/importance of the emitters to health impact and "future situations" of public health status in the cities after implementing measures/policies for reducing emissions and improving air quality; before implementation the measures/policies are selected based on cost-benefit analysis (CBA);

f) The difference between d) and e) in terms of the improvement of public health status is the key input for evaluating the adequacy and effectiveness of the measures/policies for reducing emissions and improving air quality. Such an evaluation is credible and trustworthy only if is it performed in an integrative manner between the components a) to f). This makes the ICARUS methodical framework "fit for purpose".

Additional description of the ICARUS methodical framework is provided in Figure 2, where inputs and basis for ELS on comparable approaches and evaluations are indicated.

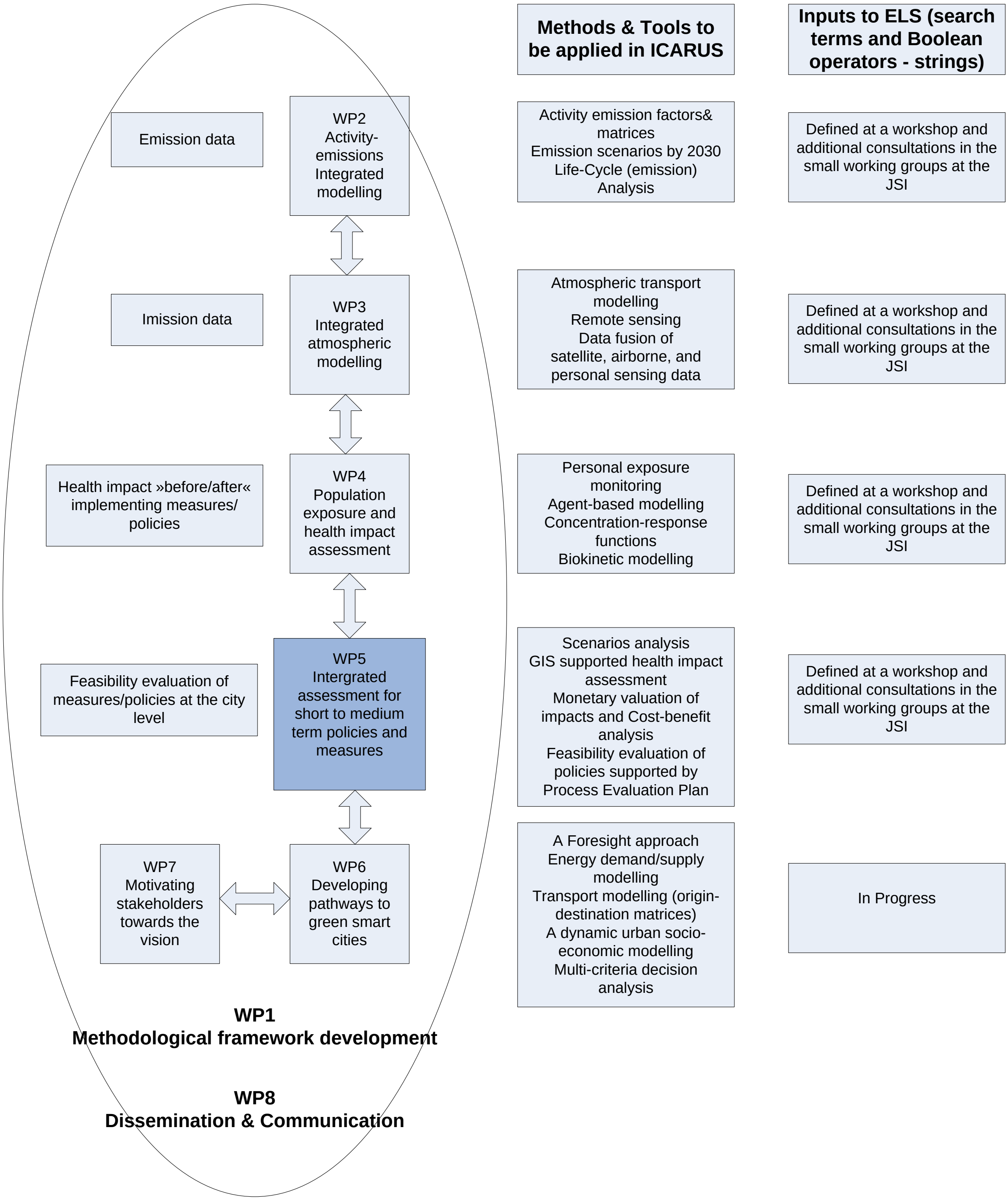

Figure 2: Associations between ICARUS methodical framework and ELS. The WP5 presents the practical and ultimate integration point of the framework.

2.3 The role of ICARUS process evaluation plan in integral impact assessment

Once general measures for air pollution reduction, climate change mitigation and public health improvement from interventions in sectors such as transport at the city level are known, and have been proven successful, for example a change of modal split towards increased walking, cycling and public transport, or increased share of low emission vehicles (hybrid, electric, Euro6) in public fleet, etc. the question remains whether these measures are going to be implemented in a particular city and at what total societal costs. The latter include political and economic justification among all involved stakeholders, as well as changes in the urbanization of the cities, refurbishment of existing and construction of new infrastructure, changes in mode of goods transport, etc. New urban plans will require citizens engagement and participation; this will eventually allow to understand which set of measures will be perceived and accepted as the most effective and eventually acceptable by the civic society. Similarly, consideration of changes in other activities/sectors in the city, for example industry, energy provision, and other services towards lower pollution and energy consumption will constitute alternative strategies for long-term environment and public health improvements. The comparative evaluation of alternatives in WP5 are expected to deliver a basis for developing the strategies/options that are most appropriate for a particular city. These strategies will then be a subject of final integrated modelling and assessment in ICARUS.

Additional aim of integral evaluation is to get insight into drivers and barriers during the preparation, implementation and operation of the measures/policies. This knowledge will enable the development of approaches and strategies towards providing efficient support to drivers and avoidance of barriers at both the city level and in the wider context. The latter include assessment of the transferability potential of the policies from one city to another and to a region/EU level, as appropriate.

Following the understanding given above the following working steps in ICARUS are envisaged:

1. Identification of possible options (policy/measure combinations/individual measures) for reducing air pollution in cities, reducing GHG emissions, improve satisfaction of citizens in terms of living and working in particular urban areas. Both technical (e.g. changing emission factors due to improved technologies in transport, industry, etc.) and non-technical measures (that influence the citizens behaviour) will be covered. The following types of measures are distinguished:

    – short term measures that can be implemented in the near future (e.g. traffic restrictions, expansion of bus lanes network, use of bicycles, change of fuel shares, penetration of renewable energy sources);

    – medium-term measures that include changes of infrastructure or a certain time for market penetration and are thus fully effective after 2020 or 2030.

In a screening process, a set of policy/measure options will be identified as seemingly (potentially) effective, based on the inputs from WP4↔WP3↔WP2 (see Figures 1 and 2 for reference).

2. Gathering and analysis of the experience and knowledge of the ICARUS participating cities about effectiveness of the measures/policies; close communication with the cities is envisaged

- What has been implemented in partner cities in the past – lessons learned; experiences with policies they have implemented and policies they have tested but has then assessed as not feasible/rationale;
- What is currently planned to be implemented (plans, programmes, policies).

3. Overview/assessment of effective measures/policies implemented in the EU (based on ELS):
   - Related EU projects: AIRUSE, OPERA, Civitas Initiative, Citi-Sense, EVIDENCE, Challenge, etc.;
   - Strategies and plans of institutions such as the European Commission, national authorities and transport and energy providers (e.g. SUMPs, ERTICO, CONCAWE, etc.);
   - Scientific literature search.

   The review should focus on the potential for reduction of air pollution and/or greenhouse gases emissions without incurring extraordinarily high costs. The societal acceptability shall be considered.

4. Organisation of a workshop/conference to discuss/determine the initial selection of measures

   The key criteria in the assessment process of the options will be: the extent to which these options bring improvements in (1) compliance of both AQ values and WHO health-based guidelines, and (2) reduction in long-lived GHG and short-lived climate relevant pollutant emissions.

5. Provision of results usable by cities – fit for purpose; evaluation of measures to clarify how good, effective, acceptable/implementable, and practicable they are in the context of the needs and affordability (financial, spatial, political, etc.) of a particular city. Also, a practical dimension of the measures' implementation is to be discussed (e.g., requirements/needs for land-use changes in a particular city, agreement between neighbouring municipalities about common infrastructure, elections at the municipality level, etc.).

The process evaluation plan (see D5.1) is aimed at monitoring the implementation of the activities specified above with the aim to recognise barriers in their implementation as soon as possible, and properly intervene. On the other hand, the information about drivers are to be widely distributed as further support in the implenetation of the activities elsewhere.

3 LITERATURE SEARCH AND REVIEW

Literature review has been made following the ELS principles and guidance, i.e. an approach that allows transparency and reproducibility of the outcomes (EFSA, 2010; Kocman et al., 2016). The main steps were:

- *Search* which entails an extensive and sensitive review of several data sources performed in order to retrieve as many studies as possible, fitting the eligibility criteria;

- *Selection* which consisted of two consecutive steps: i) a first screening of the information contained in titles and abstracts, and ii) a selection based on full-text reports;

- *Data collection* aiming at collecting information which answer previously defined research questions;

- *Quality assessment/control* which covers the design, execution, analysis and outcomes of the ELS, and

- *Data synthesis and reporting* through which the large amount of information collected was clearly structured to make their interpretation transparent, consistent, and auditable.

The information searched were about extent the urban impact assessments in the review reflect the integration aspect – and to what extent they are similar to the approach envisaged within the ICARUS project. On the other hand the literature review can serve as tool to identify which elements of ICARUS methodology can potentially be improved, based on the barriers and drivers experienced so far and are reported in the reviewed studies. Based on this the review was oriented towards the following topics/themes, i.e. components of the integral methodology framework:

- Pollution emissions (related to ICARUS WP2 - Integrated emission modelling at the regional and urban scales)
- Air pollution concentrations (related to ICARUS WP3 - Integrated atmospheric modelling for connecting pressures to the environment to concentrations at the regional and urban scales)
- Population exposure to air pollutants and health impact assessment (related to ICARUS WP4 - Population exposure and health impact assessment)
- Implication of measures and policies (related to ICARUS WP5 - Integrated assessment for short to medium term policies and measures)

The main review questions were:

- Which of the following topics are investigated (emissions, imissions/pollution concentrations, health, measures/policies)?
- How are specific topics analysed?
- Are the topics presented in an integrative manner?

More specific questions were, for example:

EMISSIONS (WP2)

- Are the contributors to specific emissions identified and described, e.g. GHG?

- Are policies/technical measures for reduction of emissions described and justified?

- Is the link between emissions and imissions (pollution concentrations) provided and clearly described?

IMISSIONS/POLLUTION (WP3)

- Are the sources of pollution identified, described, and their significance (relative importance) evaluated in terms of AQ and climate change?

- Are the activities in terms of their contribution to AQ pollution identified and described?

- Are tools, e.g. models and codes, for pollution dispersion and its dynamics specified?

- Is the link between pollution - health impacts provided?

EXPOSURE /HEALTH IMPACTS (WP4)

- Is exposure assessment clearly presented?
- Are the population target groups identified and described? What is their socio-demographic, socio-economic status?
- Are mitigation measures/policies identified and described?

MITIGATION MEASURES/POLICIES (WP5)

- Are there policies and measures available/adopted?
- How, i.e. at which level were these policies/measures developed?
- Are the arguments for selection of mitigation measures/policies described?

Questions and other supporting tools for specific topics in the second phase of the review were:

- EMISSONS (Emission factors; emission data (qualitative, quantitative), data source; parameter measured, measurement units; Are measures/policies for decreasing emissions described? Life cycle assessment: yes/no)

- IMISSIONS / POLLUTION CONCENTRATIONS (Approach; atmospheric modelling, source apportionment, data fusion, radiative forcing; Parameters modelled; Data presentation/ visualisation/processing; Source of pollution; is the contribution to pollution from specific source described?

- HEALTH (Combined with AQ data/sensors/ information: if yes, which parameter; Application of agent-based modelling (ABM); if yes, which parameter, GIS; Exposure assessment; if YES describe; Health effects estimation; Mitigation measures/policies; are they described in terms of reducing heath impact?)
- MEASURES/POLICIES (Proposed mitigation measures/policies; Description of health/environmental impacts of the proposed measures/policies; Monetary evaluation cost-benefit-analysis (CBA); communication with city, regional, national administration bodies; Implementation at city, regional, national level; are arguments for decision-making provided?)
- INTEGRATION ASPECT: Are the topics presented in an integrative manner: yes/no, please describe?

Based on the outcome suggestions were made for future work.

3.1 Data sources

In order to identify relevant research studies first the SCOPUS database has been preliminary examined. Articles in English language from Jan 1990, to December 2017, were selected using the search terms: "**regional *or* urban *or* city" "impact assessment", "air quality" , "air pollution" "emissions", "imissions", "pollution", "modelling", "source apportionment", "climate change", "health", "policy", "mitigation", "measure".**

Additionally, search through Google has been made to also include publications other than research papers related to "integrated urban assessment", Air Quality Plans, and Air Quality related EU funded projects and studies.

3.2 Search method

Published peer-reviewed literature was searched through SCOPUS database platform, using the search terms and Boolean operators as given below. Additional studies and their sources were checked based on the references in the literature considered. The outcome of the overall search was then summarized following the approach and example provided by Jensen (2016).

Keywords included:

INTEGRATED IMPACT ASSESSMENT

"regional OR urban OR city " "impact assessment"

POLLUTION

"air quality" OR "air pollution" AND "emissions OR imissions OR pollution OR modelling" OR "source apportionment" OR "climate change"

POPULATION EXPOSURE TO AIR POLLUTANTS AND HEALTH IMPACT ASSESSMENT

"health impact assessment"

IMPLEMENTATION OF MITIGATION MEASURES AND POLICIES

"policy OR mitigation OR measure"

The strings were integrated into a single search string to avoid duplications:

TITLE-ABS-KEY (((regional OR urban OR city) "impact assessment" ("air quality" OR "air pollution") AND (emissions OR imissions OR pollution OR modelling OR "source apportionment" OR "climate change" OR health) AND (policy OR mitigation OR measure)))

The total number of hits was 398.

Since the results were not geographically limited to European Union, the additional search filters were applied in order to limit the acquired results to EU Member states. Since the geographic information for the articles was not consistent both LIMIT-TO and EXCLUDE functions were used - the boolean string for the filter is the following:

(LIMIT-TO (AFFILCOUNTRY , "Italy ") OR LIMIT-TO (AFFILCOUNTRY , " Spain ") OR LIMIT-TO (AFFILCOUNTRY , " France ") OR LIMIT-TO (AFFILCOUNTRY , " Netherlands ") OR LIMIT-TO (AFFILCOUNTRY , " Germany ") OR LIMIT-TO (AFFILCOUNTRY , " Switzerland ") OR LIMIT-TO (AFFILCOUNTRY , " Austria ") OR LIMIT-TO (AFFILCOUNTRY , " Denmark ") OR LIMIT-TO (AFFILCOUNTRY , " Greece ") OR LIMIT-TO (AFFILCOUNTRY , " Finland ") OR LIMIT-TO (AFFILCOUNTRY , " Portugal ") OR LIMIT-TO (AFFILCOUNTRY , " Sweden ") OR LIMIT-TO (AFFILCOUNTRY , " Poland ") OR LIMIT-TO (AFFILCOUNTRY , " Belgium ") OR LIMIT-TO (AFFILCOUNTRY , " Czech Republic ") OR LIMIT-TO (AFFILCOUNTRY , " Hungary ") OR LIMIT-TO (AFFILCOUNTRY , " Ireland ") OR LIMIT-TO (AFFILCOUNTRY , " Estonia ") OR LIMIT-TO (AFFILCOUNTRY , " Lithuania ") OR LIMIT-TO (AFFILCOUNTRY , " Romania ") OR LIMIT-TO (AFFILCOUNTRY , " Slovakia ") OR LIMIT-TO (AFFILCOUNTRY , " Undefined ") OR EXCLUDE (AFFILCOUNTRY , " United States ") OR EXCLUDE (AFFILCOUNTRY , " China ") OR EXCLUDE (AFFILCOUNTRY , " Canada ") OR EXCLUDE (AFFILCOUNTRY , " Australia ") OR EXCLUDE (AFFILCOUNTRY , " Japan ") OR EXCLUDE (AFFILCOUNTRY , " New Zealand ") OR EXCLUDE (AFFILCOUNTRY , " Brazil ") OR EXCLUDE (AFFILCOUNTRY , " Russian Federation ") OR EXCLUDE (AFFILCOUNTRY , " Cambodia ") OR EXCLUDE (AFFILCOUNTRY , " Cuba ") OR EXCLUDE (AFFILCOUNTRY , " India ") OR EXCLUDE (AFFILCOUNTRY , " Libyan Arab Jamahiriya ") OR EXCLUDE (AFFILCOUNTRY , " Nepal ") OR EXCLUDE (AFFILCOUNTRY , " Nigeria ") OR EXCLUDE (AFFILCOUNTRY , " Saudi Arabia ") OR EXCLUDE (AFFILCOUNTRY , " South Africa ") OR EXCLUDE (AFFILCOUNTRY , " Trinidad and Tobago ") OR EXCLUDE (AFFILCOUNTRY , " Norway ") OR EXCLUDE (AFFILCOUNTRY , " Serbia "))

After the application of filters, the final number of studies/papers for the first screening was 137.

Additional search through Google (and related results from ScienceDirect, Research Gate and PubMed) has yielded 20 additional scientific publications.

The results acquired through Google serarch included also the sources for 19 air quality related EU funded projects/studies and 12 study reports related to Air Quality Plans.

3.3 Study selection

Only studies that passed the application criteria at title and abstract screening stage have been selected for the full-text screening. In the process of full papers reading studies which did not meet general criteria – i.e. relation to the criteria described in introductory section - were excluded. Also, the studies which passed the screening at the title and abstract stage and for which full text was not available/accessible, and therefore could not have been thoroughly examined, were excluded from further review.

A flow chart in Figure 3 depicts the process of the literature search. Following this procedure a total of 92 references were included for analyses. Out of 92 studies 78 are scientific articles, 7 are conference papers and 7 are review papers. Although no time restrictions were applied during search, the studies included have been published after year 2000, with 2 exceptions dating back to 1997.

Papers excluded in the first screening phase (54) include the papers of which abstracts proved to be off the desired topic, the studies where full paper could not be accessed or the studies which were removed due to language barriers. The papers excluded in the second phase (7) comprise of those where reading of full paper revealed a discussion that is limited to description of methods without any expected data provided, without actual application involving the integrated air-quality related assessment (in terms of health impact assessment) etc.

The following information was extracted from the selected studies: first author's last name, year of publication, journal name, type of paper (PAP-paper, PRO-conference proceeding, REW-review, BOOK-book or book chapter).

The selection of studies related to EC funded on other air quality related projects consists of:

- APHEKOM (Improving Knowledge and Communication for Decision Making on Air Pollution and Health in Europe), 2008-2011
- ESCAPE (European Study of Cohorts for Air Pollution Effects)
- APPRAISAL
- AIRUSE
- CLEAN AIR
- CHALLENGE
- OPERA
- HRAPIE (Health risks of air pollution in Europe), (WHO+EU)
- iSCAPE
- CITEAIR II
- CITI-SENSE
- EVIDENCE
- CIVITAS II (2008-2012)
- PURGE (Public health impacts in URban environments of Greenhouse gas Emissions reduction strategies)
- TRANSPHORM (Transport related Air Pollution and Health impacts – Integrated Methodologies for Assessing Particulate Matter)
- NACLIM, 7FP, 2012-2017

- CLIMSAVE, 7FP, 2010-2013
- AIRCLIM – Air Pollution and Climate Secretariat, http://www.airclim.org
- MAPLIA - Moving from Air Pollution to Local Integrated Assessment, National Project (Portugal), 2013-2015
- Inventory and effectiveness of measures to improve air quality – German Federal Environment Ministry (Umwelt Bundesamt), 2015

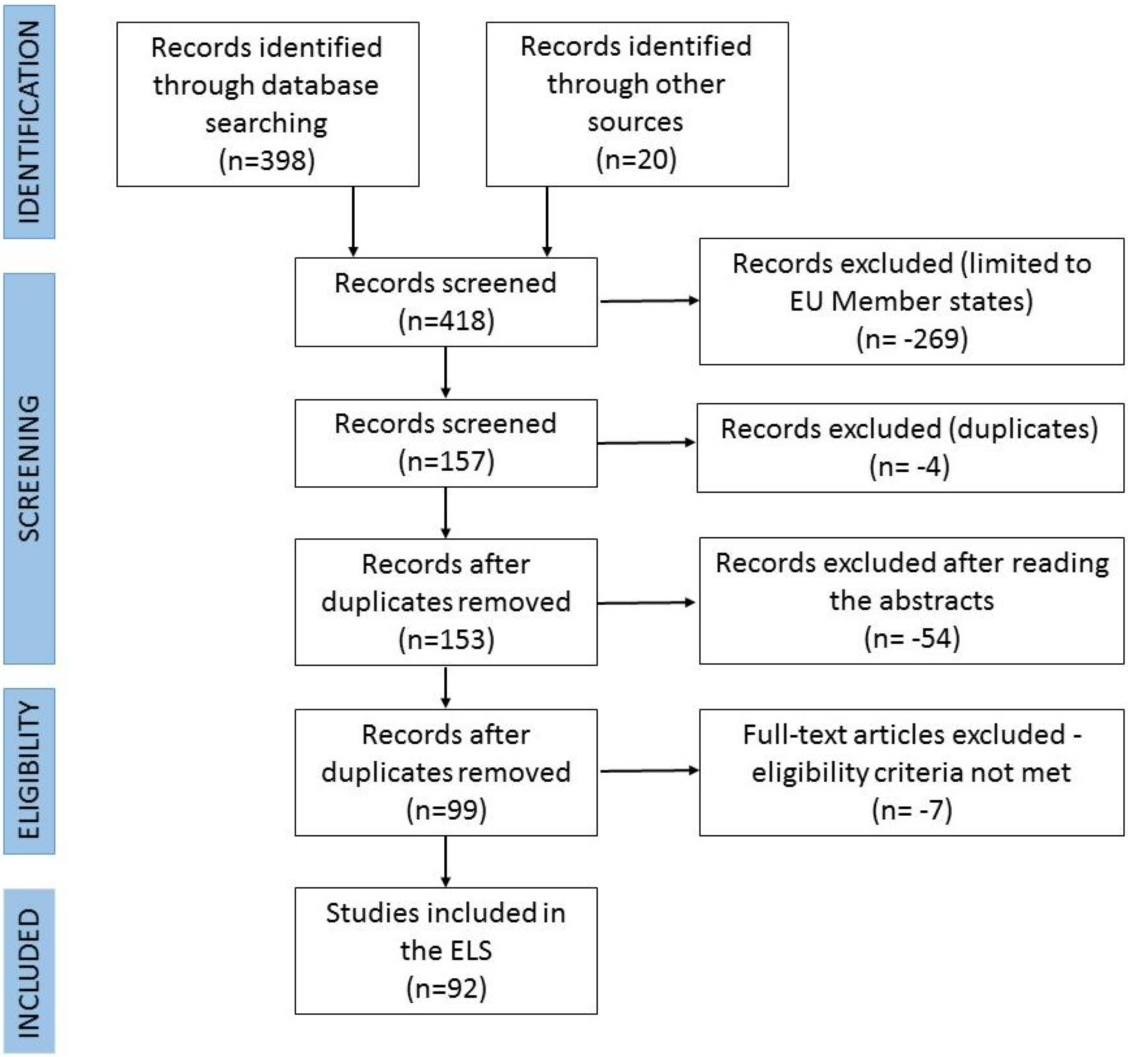

Figure 3: A flow chart of literature search and selection process

4 RESULTS

4.1 Literature review results

4.1.1 Pollution emissions – parameters investigated

The data to describe emissions are both qualitative and quantitative. The data are available in a form of fuel consumption, as activity data, or according to pollutants as SNAP (Selected Nomenclature for Air Pollution). Parameters that were investigated in selected studies are: PM10, PM2,5, NOx, SO_2, CO, CO_2, NMVOC and CH_4 as well as Dioxin, PAH, TSP, Acetaldehyde, Acetylene. In Figure 4, summary of parameters and their frequency in the studies is given. Particulate matter (expressed either as PM10 or PM2.5) is the most often analysed parameter, followed by nitrogen oxides (either NO_2, N_2O or NOx), sulphur dioxide, NMVOC, CO and CO_2, C_6H_6 and O_3.

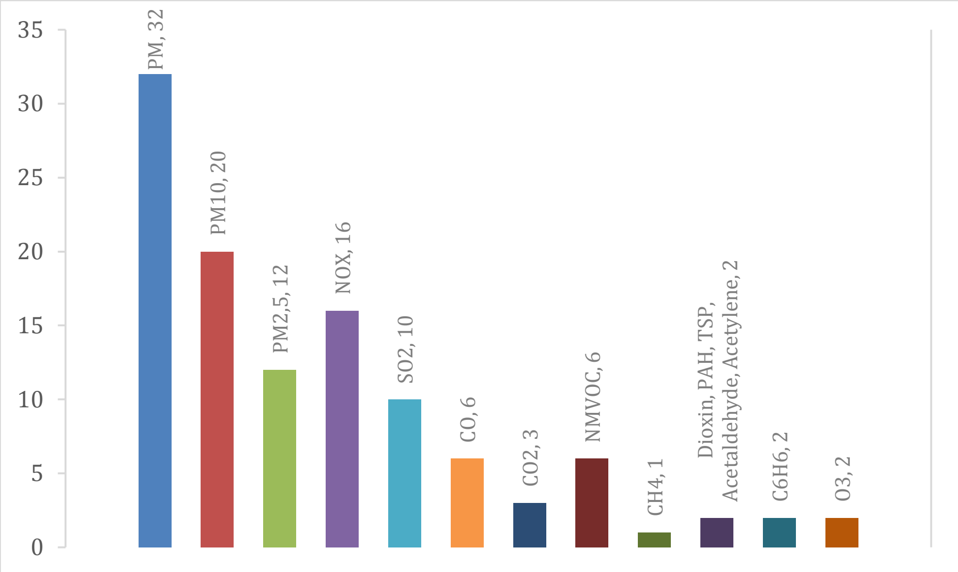

Figure 4: Representation of emission parameters included in reviewed studies

Sources are described with a geographical reference, either as a selected area (related to building heating), transport network or as stationary emission sources (industry).

Measures for reduction of emissions are described in approximately half of the studies reviewed. Often the pathway from the emissions to proposal of measures in an integrative manner is presented, however, only a few studies include a support by a health impact assessment or cost-benefit/cost-effectiveness analysis (or other form of monetary evaluation). Life cycle assessment was included in two studies.

4.1.2 Air pollution – measurements and modelling

Air pollution concentrations in studies were obtained by field measurement (monitoring) or by application of air pollution dispersion models. Detail model descriptions as well as their specific use are presented in the Table 1 below.

Due to the diversity of topics covered modelling results presentation is provided in the forms, which are most suitable for the topic in question. The presentations can be aggregated in the following groups:

1) plots, tables indicating the emission amount with contribution of different sources (e.g., transport mode); charts showing different temporal variations of pollution concentrations (in some cases presented as AQI)
2) time and space coverage of concentrations measured or modelled on a geo-referenced maps (GIS) for a designated study area.
3) synoptic weather maps for dispersion models, other maps for air pollution models of the Gaussian plume and box modelling

Table 1: Detail model descriptions

AUTHORS	TITLE	MODEL NAME	MODEL TYPE	MODEL DESCRIPTION	SPECIFIC USE
Alcamo J., Mayerhofer P., Guardans R., Van Harmelen T., Van Minnen J., Onigkeit J., Posch M., De Vries B.	An integrated assessment of regional air pollution and climate change in Europe: Findings of the AIR-CLIM project	RAINS IMAGE	integrated pollution model	The framework is made up of components of two existing integrated models, Regional Acidification Information and Simulation (RAINS) and Integrated Model to Assess the Greenhouse Effect (IMAGE) 2. RAINS is an integrated model of acid deposition in Europe which links energy scenarios with their production of country-scale emissions of sulfur, nitrogen and oxidant precursors. The IMAGE 2 model is RAINS' counterpart for global climate change and links regional-scale changes in energy use and agricultural production with emissions of greenhouse gases, oxidant precursors and sulfur dioxide.	AIR CLIM modelling framework
Amann, M., Bertok, I., Borken–Kleefeld, J., Cofala,J.,Heyes, C., Hoglund–Isaksson, L., Klimont, Z., Nguyen, B., Posch, M., Rafaj, P., Sandler, R., Schopp,W.,Wagner, F.,Winiwarter,W.,	Cost–effective control of air quality and greenhouse gases in Europe: Modeling and policy applications.	Greenhouse gas - Air pollution Interactions and Synergies (GAINS) model		Integrated assessment models, such as the GAINS (Greenhouse gas e Air pollution Interactions and Synergies) model, have been developed to identify portfolios of measures that improve air quality and reduce greenhouse gas emissions at least cost. Such models bring together scientific knowledge and quality-controlled data on future socio-economic driving forces of emissions, on the technical and economic features of the available emission control options, on the chemical transformation and dispersion of pollutants in the atmosphere, and the resulting impacts on human health and the environment. The GAINS model and its predecessor have been used to inform the key negotiations on air pollution control agreements in Europe during the last two decades.	
Asikainen A., Pärjälä E., Jantunen M., Tuomisto J.T., Sabel C.E.	Effects of local greenhouse gas abatement strategies on air pollutant emissions and on health in Kuopio,	LIISA 2011	traffic model	Software was developed to calculate traffic exhaust emissions for municipalities, provinces and the whole of Finland, and the car fleet information for Kuopio was available in the "Road traffic exhaust emissions calculation model" module (LIISA, version 2011 used).	

AUTHORS	TITLE	MODEL NAME	MODEL TYPE	MODEL DESCRIPTION	SPECIFIC USE
	Finland				
Boldo E., Linares C., Lumbreras J., Borge R., Narros A., García-Pérez J., Fernández-Navarro P., Pérez-Gómez B., Aragonés N., Ramis R., Pollán M., Moreno T., Karanasiou A., López-Abente G.	Health impact assessment of a reduction in ambient PM2.5 levels in Spain	Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system	Emission processing model	Emissions were initially processed with the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system. The EPA's Community Multiscale Air Quality model (CMAQ v4.6) was then applied to simulate PM2.5 (μg/m3) concentration levels using a grid with a spatial resolution of 18×18 km2 (4032 cells). Using the HIA tool (BenMAP), air pollution changes in each cell were calculated by subtracting air pollution levels resulting from CMAQ (control–baseline).	
Borrego C., Monteiro A., Sá E., Carvalho A., Coelho D., Dias D., Miranda A.I.	Reducing NO 2 pollution over urban areas: Air quality modelling as a fundamental management tool	TAPM (The Air Pollution Model)	Prognostic meteorological and air pollution model	3-D Eulerian model with nesting capabilities, which predicts meteorology and air pollution concentrations in a Graphical User Interface. The model has two components: the meteorological prognostic, and the air pollution concentrations component.	To evaluate the impact of the selected measures on the improvement of atmospheric NO_2 levels
Borrego C., Sá E., Carvalho A., Sousa S., Miranda A.I.	Plans and Programmes to improve air quality over Portugal: A numerical modelling	TAPM (The Air Pollution Model)	Prognostic meteorological and air pollution model	3-D Eulerian model with nesting capabilities, which predicts meteorology and air pollution concentrations in a Graphical User Interface. The model has two components: the meteorological prognostic, and the air pollution concentrations component.	Model was applied for reference situation with the current PM10 emissions; and, for the reduction scenario with PM10 emissions re-estimated considering the implementation various measures, in order to investigate the impact on air quality of all Plans and Programmes (PP) measures according to

AUTHORS	TITLE	MODEL NAME	MODEL TYPE	MODEL DESCRIPTION	SPECIFIC USE
	approach				European legislation.
Carnevale C., Finzi G., Pisoni E., Volta M.	Modelling assessment of PM10 exposure control policies in Northern Italy	TCAM (Transport and Chemical Aerosol Model)	3D eulerian model	TCAM(Transport and Chemical Aerosol Model) is amultiphase three-dimensional eulerian model, in a terrain-following co-ordinate system. The model formalizes the physical and chemical phenomena involved in the formation of secondary air pollution.	
Caroleo B., Pautasso E., Osella M., Palumbo E., Ferro E.	Assessing the Impacts of Electric Vehicles Uptake: A System Dynamics Approach	System Dynamics model	exposure assessment	A System Dynamics model has been developed to perform an ex-ante evaluation of the impacts stemming from replacing conventional vehicles with electric vehicles (BEVs and PHEVs). As anticipated, the investigated impacts cover the three dimensions of sustainability. The model analyses: - the environmental sphere in terms of reduction of GHG and pollutant emissions (CO2 for BEVs, and both CO2 and PM10 for PHEVs); - the social dimension in terms of impacts on the health of people residing in the area (i.e. reduction of cardio/respiratory pathologies related to air quality); - the economic sphere in terms of reduction of public health spending associated to such pathologies.	The System Dynamics simulation herein documented allows decision makers to perform what-if analyses able to evaluate ex-ante the three-pronged environmental / health / economic impacts of distinct electric vehicles uptake scenarios. Hence, the proposed model has what it takes to act as a decision support tool for policy makers involved in the definition of Sustainable Urban Mobility Plans (SUMP) of a smart city.
Fensterer et al., 2014	Evaluation of the Impact of Low Emission Zone and Heavy Traffic Ban in Munich (Germany) on the Reduction of PM10 in Ambient		semiparametric regression model	The effects of measures on mass concentrations were investigated with a semiparametric regression model for modeling PM10 levels adjusted for time, background pollution, public holidays and wind direction.	

AUTHORS	TITLE	MODEL NAME	MODEL TYPE	MODEL DESCRIPTION	SPECIFIC USE
	Air				
Figueiredo M.L., Monteiro A., Lopes M., Ferreira J., Borrego C.	Air quality assessment of Estarreja, an urban industrialized area, in a coastal region of Portugal	BSC-DREAM8b model	Regional Atmospheric Model	Model predicts the atmospheric life cycle of the eroded desert dust and was developed as a pluggable component of the Eta/NCEP (National Centers for Environmental Prediction) model. It solves the Euler-type partial differential nonlinear equation for dust mass continuity and it is fully inserted as one of the governing prognosis equations in the atmospheric Eta/NCEP atmospheric model equations. Source: http://www.bsc.es/projects/earthscience/visor/bases_datos/image_viewer/docs/BSC_DREAM8b_model_description.pdf	The contribution of different emission sources and meteorological conditions to pollution episodes is investigated and a set of measures to improve air quality regarding ozone and PM10 levels is proposed as an air quality management strategy for the study region.
G. Kiesewetter, J. Borken-Kleefeld, W. Schöpp, C. Heyes, P. Thunis, B. Bessagnet, E. Terrenoire, A. Gsella, and M. Amann1	Modelling NO2 concentrations at the street level in the GAINS integrated assessment model: projections under current legislation	Greenhouse gas - Air pollution Interactions and Synergies (GAINS) model		In order to assess the effects of future emission control regulations on roadside NO2 concentrations, a downscaling module has been implemented in the GAINS integrated assessment model. The module follows a hybrid approach based on atmospheric dispersion calculations and observations from the AirBase European air quality database that are used to estimate site-specific parameters. Pollutant concentrations at every monitoring site with sufficient data coverage are disaggregated into contributions from regional background, urban increment, and local roadside increment. The future evolution of each contribution is assessed with a model of the appropriate scale: 28×28 km grid based on the EMEP Model for the regional background, 7×7 km urban increment based on the CHIMERE Chemistry Transport Model, and a chemical box model for the roadside increment.	GAINS is able to estimate pollutant concentrations for a numerous monitoring stations.
Hodges N.	Intelligent transport systems and the health impact of traffic	OPANA Air Quality Model	Various models as part of the Urban Traffic and Management	OPANA model is the operational version of the research model ANA (Atmospheric mesoscale Numerical pollution model for regional and urban Areas) source: https://link.springer.com/chapter/10.1007%2F978-94-010-0932-	Assessment of the impact of traffic on air and noise quality, the environment and health, as well as informing the Climate Change Strategy

AUTHORS	TITLE	MODEL NAME	MODEL TYPE	MODEL DESCRIPTION	SPECIFIC USE
	in Leicester (UK)	NAME Air Quality Model ADMS-URBAN Air Quality Model SATURN and TRIPS Traffic Model	Control	4_52 NAME (Numerical Atmospheric dispersion Modeling Environment) is a Lagrangian air pollution dispersion model for short range to global range scales. Source: https://en.wikipedia.org/wiki/NAME_(dispersion_model) ADMS-URBAN comprehensive system for modelling air quality in large urban areas, cities and towns. It is a three dimensional quasi-Gaussian model nested within a trajectory model. SATURN is a "meso" or middle tier traffic model. It stands for Simulation and Assignment of Traffic on Urban Road Networks and it allows the user to undertake a variety of area wide strategic through to more detailed local area assessments. Source: http://www.flownz.com/WhatWeDo/TransportModelling/SATURN.aspx	and the City's Carbon Footprint.
Holnicki P., Tainio M., Kałuszko A., Nahorski Z.	Burden of mortality and disease attributable to multiple air pollutants in Warsaw, Poland	CALPUFF	dispersion model	To simulate pollution dispersion processes, the Gaussian puff model CALPUFF v.5 was applied in regional/urban scale analysis of air quality. It is a multilayer, non-stationary model designed for calculating concentrations of many substances, emitted by different types of sources. Meteorological fields were re-analyzed by the Weather Research and Forecasting Model (WRF) model, and the National Center for Atmospheric Research and assimilated to the final resolution grid by the CALMET meteorological, cooperating preprocessor.	To obtain the spatial maps of the average concentrations of the main urban pollutants, to show districts/areas where the pollution limits were exceeded and to identify emission sources responsible for these violations.

AUTHORS	TITLE	MODEL NAME	MODEL TYPE	MODEL DESCRIPTION	SPECIFIC USE
Jensen et al., 2001	A Danish decision-support GIS tool for management of urban air quality and human exposures	Operational street pollution model (OSPM) AirGIS	street pollution model GIS based model	Concentration levels are determined using the operational street pollution model (OSPM) which calculates ambient hourly concentration levels of CO, NO2,NOx(NO+NO2),O3 and benzene, based on inputs of street configurations (physical appearance of the street) and hourly inputs of traffic, meteorological parameters and urban background concentrations. 'OSPM model is a practical street pollution model, developed by the Department of Environmental Science at Aarhus University (the former National Environmental Research Institute, Department of Atmospheric Environment). AirGIS is a human exposure modelling system for traffic air pollution. It was developed for application in Danish air pollution epidemiological studies, human exposure studies, as well as urban air quality assessment and management. It has been developed by the National Environmental Research Institute in Denmark.	
Judl J., Koskela S., Korpela T., Karvosenoja N., Häyrinen A., Rantsi J.	Net environmental impacts of low-share wood pellet co-combustion in an existing coal-fired CHP (combined heat and power) production in	FRES (Finnish Regional Emission Scenario) model Gaussian UDM-FMI	Emission model Dispersion model	Emission model describes transportation emissions at a 1 x1 km horizontal grid resolution based on summed traffic densities on each road segment and the emission factor for different types and ages of vehicles. Exhaust tailpipe and non-exhaust road dust emissions were calculated separately This model was developed by the Finnish Meteorological Institute (FMI) as an integrated Gaussian urban scale model intended for regulatory pollution control. It handles multiple point, line, area	Assessment of the net environmental impacts of the co-combustion and changes in urban air quality connected to pellet transport, and to identify environmental hotspots relevant to possible future higher-share co-combustion.

AUTHORS	TITLE	MODEL NAME	MODEL TYPE	MODEL DESCRIPTION	SPECIFIC USE
	Helsinki, Finland	model		and volume sources and it includes chemical transformation (for NO2), wet and dry deposition (for SO2), and downwash phenomena (but no building effects). Source: https://en.wikipedia.org/wiki/List_of_atmospheric_dispersion_models	
Mediavilla-sahagún*A., M. Apsimon H. and Warren R.F.	Integrated assessment of abatement strategies to improve air quality in urban environments, the USIAM model.	Urban Scale Integrated Assessment Model (USIAM), ASAM model		Urban Scale Integrated Assessment Model (USIAM) is based on the same principles as the ASAM model, was designed as a tool to investigate and assess a variety of potential strategies to reduce air pollution in Major Urban Developments.	
Mensink, C., Colles, A., Janssen, L., Cornelis, J.	Integrated air quality modelling for the assessment of air quality in streets against the council directives.	AURORA MODEL	pollution and street canyon model	Integrated air quality model AURORA was used to evaluate the concentration levels of NO2,SO2, PM10 (1999/30/EC), CO and benzene (2000/69/EC) in 11 selected streets in the city of Antwerp. Together with the emission module, the analytical street box module of AURORA was used for the assessment of pollutant concentrations in street canyons.	
Miranda A.I., H. Relvasa, P. Viaeneb, S. Janssenb, O. Brasseurc, C. Carnevaled, P. Declerckc, G.	Applying integrated assessment methodologies to air quality plans: Two European	Air pollution Integrated Assessment Models (IAM)	various	IAM was developed at the European scale and has been adapted to the national scale to be used to optimize emission reductions, e.g. the RAINS-Italy, the RAINS-Netherlands, the FRES-Finland or the AERIS (applied to Spain and Portugal. The USIAM, the OTELLO and the RIAT+ (models were specifically developed to address regional and urban areas, but a more extended use of IAM in the	

AUTHORS	TITLE	MODEL NAME	MODEL TYPE	MODEL DESCRIPTION	SPECIFIC USE
Maffeise, E. Turrinid, M. Voltad	cases			scope of AQP would better support policy-makers.	
Miranda et al., 2016 (STE)	A cost-efficiency and health benefit approach to improve urban air quality	The Air Pollution Model" (TAPM)	3-D Eulerian model	The model selected to perform the air quality simulation over the study region was "The Air Pollution Model" (TAPM), developed by the Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO). This model is a 3-D Eulerian model, composed of two modules which predict meteorology and air pollution concentrations based on fundamental fluid dynamics and scalar transport equations.	
Mueller N., Rojas-Rueda D., Basagaña X., Cirach M., Hunter T.C., Dadvand P., Donaire-Gonzalez D., Foraster M., Gascon M., Martinez D., Tonne C., Triguero-Mas M., Valentín A., Nieuwenhuijsen M.	Urban and transport planning related exposures and mortality: A health impact assessment for cities	(ESCAPE LUR) model	Land use regression model	annual mean PM2.5 data were available through the European Study of Cohorts for Air Pollution Effects Land Use Regression (ESCAPE LUR) model	
Nedellec V., Mosqueron L., Desqueyroux H., Jeannee N.	Effects of European Euro IV and V standards on the health impact of urban road traffic in France. III. Health	GIS model	3D Eulerian model with GIS interface	The model is used for estimation of NO2 and PM10 exposures. The national territory is cut into 4 × 4 km meshes in which the information essential to the health impact assessment are grouped together by means of a Geographic Information System (GIS).	

AUTHORS	TITLE	MODEL NAME	MODEL TYPE	MODEL DESCRIPTION	SPECIFIC USE
	impact assessment and comparison of the years 2000 and 2010				
Oxley et al., 2013	Modelling future impacts of air pollution using the multi-scale UK Integrated Assessment Model (UKIAM)	FRAME (Fine Resolution Atmospheric Multi-pollutant Exchange) model Greenhouse gas - Air pollution Interactions and Synergies (GAINS)	Lagrangian atmospheric transport model	The FRAME (Fine Resolution Atmospheric Multi-pollutant Exchange) model is a Lagrangian atmospheric transport model used to assess the long-term annual mean deposition of reduced and oxidised nitrogen and sulphur over the United Kingdom. The model was developed from an earlier European scale model, TERN (Transport over Europe of Reduced Nitrogen). FRAME was developed initially to focus in particular on transport and deposition of reduced nitrogen and was named the Fine Resolution Ammonia Exchange model. Recent developments in the treatment of sulphur and oxidised nitrogen mean that it may now be considered as a robust multi-chemical species tool. The new name reflects these changes whilst preserving the familiar acronym. The GAINS model explores cost-effective emission control strategies that simultaneously tackle local air quality and greenhouse gases so as to maximize benefits at all scales.	Used within the integrated Assessment Model (UKIAM) has been developed to investigate strategies for reducing UK emissions by bringing together information on projected UK emissions of SO2, NOx, NH3, PM10 and PM2.5, atmospheric dispersion, criteria for protection of ecosystems, urban air quality and human health, and data on potential abatement measures to reduce emissions,which may subsequently be linked to associated analyses of costs and benefits. The GAINS tool offers three ways to reveal policy interventions with multiple benefits: Simulation of the costs, health and ecosystems benefits of user-defined packages of emission control measures; Cost-effectiveness analysis to identify least-cost packages of measures that achieve user-defined policy targets; and Cost-benefit assessments that maximize (monetized) net benefits of policy

AUTHORS	TITLE	MODEL NAME	MODEL TYPE	MODEL DESCRIPTION	SPECIFIC USE
		model			interventions.
Pelliccioni A., Gariazzo C., De Dominicis M.	Definition of novel health and air pollution index based on short term exposure and air concentration levels	FARM	dispersion model	The chemical transport model (FARM) has been applied to study primary and secondary gas/aerosol pollutants concentrations. It has allowed the determination of the spatial distribution, on a regular grid 61x61 cells of extension equal area to 1 km2, of the concentrations of pollutants in the area of study during the three examined episodes. It provided the concentrations of primary and secondary pollutants both as gas and aerosol in the urban area of Rome.	
Quaassdorff C., Borge R., Pérez J., Lumbreras J., de la Paz D., de Andrés J.M.	Microscale traffic simulation and emission estimation in a heavily trafficked roundabout in Madrid (Spain)	HBEFA COPERT	traffic emission model	Mesoscale air quality models and traffic emission estimations have been used to define the air quality levels at national level with a focus in Madrid city.For that, traffic-situation models such as HBEFA were applied to Madrid. This model includes specific emission factors for every traffic situation and is representative of a variety of driving patterns making simplifications for the parameters that affect the processes at micro-level. Also, the average speed model COPERT was implemented.	This model is considered as the reference tool to compute emissions at national or regional and urban scale.
Sarigiannis D.A., Kontoroupis P., Nikolaki S., Gotti A., Chapizanis D.,	Benefits on public health from transport-related greenhouse gas	COPERT IV	traffic emission model	The exposure modelling framework employed for estimating urban transport-related greenhouse gas emissions and air pollution in Thessaloniki consists of a computation chain that uses an Origin-	The hourly variation in emissions for PM, NOx and VOC can be computed, based on the hourly fleet composition (differentiated between passenger cars, lorries, buses and

AUTHORS	TITLE	MODEL NAME	MODEL TYPE	MODEL DESCRIPTION	SPECIFIC USE
Karakitsios S.	mitigation policies in Southeastern European cities			Destination (OD) matrix for a typical week-day in year 2010; the OD matrix was imported in the transport model PTV-VISUM, whereby the hourly variation in traffic flow and speed for the Thessaloniki road network was reckoned.	motorbikes) for a large number of streets in the city. This results in a detailed estimation of emissionf from particular vehicle types.
Schucht S., Colette A., Rao S., Holland M., Schöpp W., Kolp P., Klimont Z., Bessagnet B., Szopa S., Vautard R., Brignon J.-M., Rouïl L.	Moving towards ambitious climate policies: Monetised health benefits from improved air quality could offset mitigation costs in Europe	Climate – air quality modelling chain	pollutant transport modelling	The Atmospheric Chemistry Climate Model Intercomparison Project (ACCMIP) provided boundary constraints for modelling the air quality in Europe. Climate fields are based on RCP runs from the Climate Model Intercomparison Project CMIP55 used in the IPCC/AR5 that were downscaled over Europe using a similar setup as in the COordinated Regional Downscaling EXperiment (CORDEX). Based on these input data, the European chemistry-transport model CHIMERE produced air pollutant concentration fields that can be interpreted in terms of population weighted annual average PM2.5 concentrations and SOMO358 that were used in the subsequent health impact assessment.	Air quality results from CHIMERE are used in the health impact assessment (HIA) framework Alpha-RiskPoll (ARP) to derive monetised sanitary benefits from reduced exposure to fine particulate matter and ozone.
Silveira C., Roebeling P., Lopes M., Ferreira J., Costa S., Teixeira J.P., Borrego C., Miranda A.I.	Assessment of health benefits related to air quality improvement strategies in urban areas: An Impact Pathway Approach	TAPM (The Air Pollution Model)	Prognostic meteorological and air pollution model	In order to assess the air quality improvements based on the reference scenario. the TAPM was applied with a 1-km2 spatial resolution and 1-h temporal resolution, and the modelling results were validated against measured data from air quality monitoring stations.	Based on the achieved air quality state for the different abatement measures/scenarios, the human health impacts were quantified. These impacts were analysed through morbidity and mortality indicators associated with short and longterm exposure to PM10 concentrations. For each health indicator a survey of the associated external costs per case/daywas carried out.
Stedman J.R., Grice S., Kent A., Cooke S.	GIS-based models for ambient PM exposure and health impact assessment for	pollution climate mapping	GIS based model	A model of ambient particulate matter concentration across the UK has been developed within a Geographical Information System (GIS). This model is known as the Pollution Climate Mapping (PCM) model. Maps have been calculated on a 1 km x 1km grid for	

AUTHORS	TITLE	MODEL NAME	MODEL TYPE	MODEL DESCRIPTION	SPECIFIC USE
	the UK			the whole of the UK land area for PM10 and PM2.5	
Vlachokostas et al., 2009	Decision support system for the evaluation of urban air pollution control options: Application for particulate pollution in Thessaloniki, Greece	COPERT 4	source emission model	For road traffic sector an emission calculations are based on the COPERT 4 methodology is applied. PM10 concentrations were estimated with OFIS model, which has been proved to be a reliable tool for air quality assessment and management. For the BAU-2010 runs, both initial and lateral boundary conditions were derived from 3-hourly concentration averages predicted by the Unified EMEP model at a spatial resolution of 50 km.	

4.1.3 Population exposure to air pollutants and health impact assessment

In the majority of studies exposure assessment and/or health impact assessment was not described in detail; the most considered pollutants in the studies was particulate matter, which was based either on measured results or by the application of models (Chanel O. et al, 2016; Mueller N., et al, 2017, Boldo E. et al , 2014, Rojas-Rueda D, 2014). The health conditions described in studies were mostly limited to main effects on general physical health and illness, mental health, respiratory health, mortality and social parameters.

The expected health benefits were presented in monetary values (EUR/year) or as Loss of Life expectancy (LLE) (premature mortality/deaths) (in years) or as increased hospital admission rate (for respiratory, cardiovascular conditions).

In most examples the exposure response functions (ERF) quantifying the association between exposure and mortality were obtained from literature; risk related to exposure was rarely calculated (for example, Mueller N., et al, 2017).

Specific findings of selected studies are as follows: Studies carried out on national level (Boldo et al., 2011 and Boldo et al., 2014 for Spain; Stedman et al., 2009 for UK) compare baseline air quality with projections for the future considering national strategies for reduction of air pollution and then carry out health impact assessments for the projected values of PM2.5 and/or PM10. They conclude that effective implementation of air quality measures would amount to an appreciable decline in fine particle concentrations, and this would lead to notable health-related benefits. Concrete measures for improvement of air quality are not mentioned, these studies address general policies.

Studies carried out on city level (Cardaba Arranz et al., 2014, Mueller et al., 2017 for Barcelona) analyse health impacts of particular matter in genereal (Sarigiannis et al, 2015), PM 2.5 (Mueller et al., 2017, Rojas-Rueda et al, 2011, 2012, 2013, 2016)), PM10 (Glorennec P., Monroux F., 2007) or PM2.5, PM10 (Baccini et al, 2013) and O_3 (Cardaba Arranz et al., 2014, Schucht et al 2015); they compare current recommended exposure levels with levels in compliance with international air quality guidelines (WHO Air Quality Guidelines (both papers) and Directive 2008/50/EC (Cardaba Arranz et al., 2014)). Mueller et al. (2017) showed that the greatest portion of preventable deaths was attributable to increases in physical activity, followed by reductions of exposure to air pollution, traffic noise, and heat. Access to green spaces had smaller effects on mortality. Cardaba Arranz et al. (2014) conclude that health benefits are higher when assuming 'target' concentrations proposed by WHO Air Quality Guidelines than those of Directive 2008/50/EC. Proposed measures are general - reduction of motorized traffic through the replacement by zero and low-emitting modes of transport and the provision of urban greening.
Rojas-Rueda et al. (2011) focus on health impacts of a specific measure – bike sharing in Barcelona. They compare users of bicycle sharing scheme with those who travel by car in an urban environment. They conclude that public bicycle sharing initiatives have greater benefits than risks to health and reduce carbon dioxide emissions.

Chanel et al. (2016) focus on development of HIA methodology for assessment of acute and long-term health impacts of air pollution and do not address measures for improvement of air quality and public health.

Exposure assessment, which provides input into HIA is often considered as the weakest part in the HIA chain, particularly if it does not fully incorporate the full characteristics of the exposure, including its sources, pathways and variations (Nieuwenhuijsen M.J. et al. 2015). These characteristics are important as the source and means of the exposure are an important input for the adoption of mitigation measures/policies. For example, traffic indicators such as distance to roads, surrounding road length, traffic density, and urban indicators such as household density, industry and natural outdoor environments including green space explain a large proportion of the variability of air pollution levels within urban areas, while from the studies included in the review such detailed exposure assessment is scarce.

There is also an important aspect of geo-tempral parameters in exposure assessment, as people do not simply stay at home but move around the city, which could cause considerable variation in personal exposures (Nieuwenhuijsen et al., 2017). Further work is needed to incorporate the mobility of people and related exposures to obtain better exposure estimates and reduce uncertainty, as for example air pollution exposures during commuting may be much higher than when at home (Nieuwenhuijsen et al., 2015). These patterns of exposure may be hard to model, and to some extent we may have to rely on measurements which are generally more difficult and costly to obtain. (Nieuwenhuijsen M.J. et al. 2015, 2017, Caroleo et al. 2017).

Castro et al. (2017) have also pointed out that quantitative health impact assessments of changes in air pollution have been conducted at various levels (urban, regional, national and global), but assessments of observed air pollution changes associated with specific clean air policies at a local or regional scale remain scarce.

Policies promoting active transportation may produce health benefits to a large extent, but these depend of the existing characteristics of the cities. Increased collaboration between health practitioners, transport specialists and urban planners help to introduce the health perspective in transport policies and promote active transportation. As such, HIA is gaining on importance as being a crucial element of assessment of policies, programmes and plans/projects. However, the majority of examples did not focus on air quality related health benefits directly, but more often the health benefits observed were the aggregation of better living conditions, better economic status, increased physical activity (through walking, cycling) and better access to services. The studies also show that public transport and supporting sustainable modes of transport was beneficial to health. It has been proven that HIA can influence public policy.

It is evident that integrated health impact assessment models to assess the overall burden of mortality and morbidity related to urban and transport development and planning in cities are currently lacking (Nieuwenhuijsen M.J. et al. 2017). The availability of such participatory, integrated health impact assessment would allow policy makers to estimate the positive and negative health impacts of current and future policy scenarios. A good understanding of the linkages between urban and transport planning, exposures to environmental factors, human health and related pathways is crucial in order to focus the implementation of appropriate abatement actions (measures/policies). Also, a dialogue with the public and other stakeholders, creating an environment of collaboration and feedback and guaranteeing public acceptance of proposed policy measures is a prerequisite.

4.1.4 Measures and policies

Most policies related to health improvement are focused on transport issues. To a smaller extent the studies are oriented towards reduction of building heating related energy consumption and industrial activity.

TRANSPORT

Evidence presented in the selected studies suggests that urban and transport planning indicators such as road network, distance to major roads, and traffic density, household density, industry and natural and green space explain a large proportion of the variability in terms of transport related air quality and related health status. Personal behaviour (physical activity) including mobility contributes to further variability to personal exposures. Namely, physical activity was the most important issue considered in a number of studies – the fact behind this is that exposure to the traffic originating pollution has less of a negative effect on the public health and wellbeing than the lack of recreation and physical inactivity which is a major risk factor for non-communicable diseases (cardiovascular conditions, diabetes etc.) (Gerike R et al, 2016). Policies that stimulate active transportation (walking and bicycling) have been related to health benefits.

Transport related abatement measures and policies are heterogeneous but in an overview the following groups of measures can be identified:

1) reduction of emissions:

- Introduction of new vehicle propulsion technologies; for example, hybrid vehicles (HYB), electric cars
- Introduction of a low emission zone (LEZ) or emission control areas for designated areas (the restrictions are applied for entire motorised traffic or for vehicles with specific characteristics in terms of emissions – e.g. vehicles below EURO3 standard)
- Reductions in emissions from road transport through vehicle downsizing and reducing overall demand for travel
- Introduction of low-emission vehicles for commercial passenger (including public transportation) and freight transport
- Attracting new users of public transport, enhancing user satisfaction (better service)
- Introduction of low emission fleet in public transportation and improvement of public transport network;
- Renewal of the municipal fleet (e.g., solid waste management)
- Decrease of heavy vehicles circulation in the urban areas;
- Increased cycling (bike sharing initiative, better cycling infrastructure)
- Increased walking (better walking environment)
- underground railway

2) reduction of exposure:

For reducing exposure, the measures most often discussed in studies were construction of deviation, bypass roads in order to dislocate the traffic pollution sources from the population. Introduction of active mobility (walking, cycling) is another effective approach, while these two transport modes usually pass through the areas less burdened by pollution from traffic. Provision of urban green areas additionally stimulates the latter.

Another important approach for improving the transport related air quality on a strategic level is the preparation/adoption and execution of sustainable urban transport plans and personalised travel planning which stimulate the use of sustainable means of transport and tackle the travel demand which in turn results in less traffic and less emission generating traffic. Air Quality Action Plans are also applied to reach the air quality objectives of specific air quality management areas. For a detailed insight on those, please refer to Chapter 4.3.

BUILDING HEATING

In terms of domestic heating the most evident measure is a replacement of coal with domestic wood pellets which yield positive environmental implications, particularly concerning fossil fuel depletion, climate change and acidification impacts. Other measures in this regard include use of filtration system, replacement/reconversion of the conventional fireplaces with more efficient equipment – i.e. use of certified combustion appliances with PM emissions reduction.

Another important measure is also reduction in demand for energy consumption for heating/cooling – better isolation of buildings or decrease/increase in room temperature.

The results of the implication of building heating measures/policies indicate that the fuel replacement can be more efficient in reducing health impact related to air quality than the building renovation policies which, in turn, can improve the energy efficiency of buildings and reduce greenhouse gas emissions significantly, but this requires systematic policy sustained for decades (Tuomisto J.T., et al, 2015).

INDUSTRY

Within the selected studies, the industry sector was represented to a lesser extent. The measures/policies presented were mainly a part of broader scenarios describing the air quality related measures/policies. The measures listed include application of clean technologies that allow a certain share of reduction of emissions (for example, PM10 retention systems) from production processes and industrial combustion, a shift towards renewable energy production from small power stations (Oxley T., et al, 2013). Administrative measures also played an important part in the selected studies – these can be summarised as an establishment of emissions standards for industrial clusters and business activities in urban areas combined with the reinforcement of the inspection/surveillance of stationary industrial emission sources.

OTHER

Within the agriculture sector measures for a reduction of NH3 emissions were referred to in terms of reduction of consumption of meat which would contribute to the decrease of livestock numbers (Oxley T., et al, 2013).

It should also be noted that the measures to tackle climate change can also influence air pollution and vice-versa (Asikainen A. et al., 2017). In this regards, an integrated modelling can aid an inmplementation consistent climate and air pollution policies, driven by the desire to achieve certain environmental goals. According to an analysis of scenarios with various combinations of climate and regional air pollution policies the quantitatively most relevant interactions are the effect of climate change policies on the energy mix and the resulting air pollution emissions. Thus it can be concluded that in terms of health impacts the reduction of the air pollutant emissions is more important than the effect of climate change (Mayhofer P. et al., 2002, Sarigiannis D., 2017)

4.1.5 Integration aspect

The integration concept was presented in approximately half of the reviewed studies. The studies that included the integration aspect, had the string from emissions-pollution-health impact-implementation of mitigation measures/policies adequately described. The approaches were presented as AQ (emission or pollution) models which were applied over the study region, for the reference situation with the current emissions (PM10, PM2.5, NO2) taking into consideration the estimated population exposure (health impact) and then re-evaluated after the implementation of mitigation scenarios (Borrego et al, 2012, Costa S. et al, 2014, Aunan K., 1998, Stedman J.R., et al, 2009, Boldo E., et al, 2011, Boldo E., et al, 2014). In a number of the was also emphasised that due to the increased number of diseases observed in the last decades, that can be associated with air pollution, the implementation of health impact assessments of urban pollution is necessary to provide a suitable integration of the results of this assessment in regional and national policies in order to reduce their impact on human health (Borrego et al. 2012, Khreis H et al. 2017)

Some studies took these approaches a step further, by adding a monetary evaluation (CBA; CEA) and/or Life Cycle Analysis (LCA) for argumentation of selected measures/policies.

Some of the studies also included the integrative aspect, but in a reduced manner compared to what is being the envisaged within the ICARUS project. Namely, instead of direct air quality relation to health the focus was between physical activity (active mobility) and health and the implementation of mitigation measures in this regard; studies in this selection were focusing mainly on the implementation and promotion of cycling, and walking as a transport mode.

Some studies were focusing on describing the conceptual framework of integration (also supported by examples), but the actual approach and data processing, implementation of measures was not carried out. In some cases, the calculations and AQ models may have been carried out, but the selection of mitigation measures/policies was generalised and or described only as an estimation (a potential) for improving air quality without an assessment of outcomes after the implementation (Costa et al, 2014; Hutter et al, 2013, Mediavilla-Sahagún et al. 2002).

4.2 EU projects

In addition to scientific publications, reports from 20 EU projects were also reviewed (Table 2).

Table 2: Topics covered by specific EU projects (legend: - not included, (+) partly included, + included; comments are included where appropriate)

PROJECT TITLE	TOPIC COVERED			
	EMISSIONS	IMISSIONS / POLLUTION CONCENTRATIONS	HEALTH	MEASURES / POLICIES
APHEKOM (Improving Knowledge and Communication for Decision Making on Air Pollution and Health in Europe), 2008-2011	-	-	+	-
ESCAPE (European Study of Cohorts for Air Pollution Effects)	-	-	+	-
APPRAISAL	-	+	+	+
AIRUSE	+	+	-	+
CLEAN AIR	-	-	-	+
CHALLENGE	+	+	-	+
OPERA	+	+	(+)	+
HRAPIE (Health risks of air pollution in Europe), (WHO+EU)	-	-	+	-
iSCAPE	-	+	-	+
CITEAIR II	+	+	-	+
CITI-SENSE	-	+	-	-
EVIDENCE	-	-	-	+
CIVITAS II (2008-2012)	+	+	+	+
PURGE (Public health impacts in URban environments of Greenhouse gas Emissions reduction strategies)	+	+	+	+
TRANSPHORM (Transport related Air Pollution and Health impacts – Integrated Methodologies for	+	+	+	-

Assessing Particulate Matter)				
NACLIM, 7FP, 2012-2017	- (indirectly through GCM – Global Climate Modelling)	- (indirectly through GCM – Global Climate Modelling)	- (indirectly through GCM – Global Climate Modelling)	- (indirectly through GCM – Global Climate Modelling)
CLIMSAVE, 7FP, 2010-2013	(+) (indirectly through climate change scenarios)	(+) (indirectly through climate change scenarios)	-	+
AIRCLIM – Air Pollution and Climate Secretariat, http://www.airclim.org	+	+	-	(+) (indirectly through standard for vehicles)
MAPLIA - Moving from Air Pollution to Local Integrated Assessment, National Project (Portugal), 2013-2015, http://projeto-maplia.web.ua.pt/project/	(+) (indirectly through modelling approach)	(+) (indirectly through modelling approach)	(+) (indirectly through modelling approach)	(+) (indirectly through modelling approach)
Inventory and effectiveness of measures to improve air quality – German Federal Environment Ministry (Umwelt Bundesamt), 2015	- (indirectly through source apportionment	+	-	+

Projects OPERA and PURGE focus on all four topics. However, the OPERA project considers health only partly; it is mostly focused on development of software tool (RIAT+) to support regional/local authorities in the definition, application and evaluation of air quality policies for reduction of exposure to PM10, PM2.5, NO2 and O3. The tool evaluates air quality if certain policy action is applied as well as its costs and it can also assess GHG emissions and health impacts in terms of external costs. The PURGE project is focused on strategies to reduce GHG emissions and impacts of these strategies on health.

Projects CITEAIR II and AIRUSE cover emissions, air pollution and measures for improvement of air quality but do not consider health effects. CHALLENGE and CIVITAS are focused on these topics as well, with specific aim of application of measures through sustainable urban mobility planning and application of these plans. It should be noted, that in CIVITAS the special attention was on evaluation of the measures (impact and process) which provided the feedback on how the measures performed in terms of environmental and health aspect.

The TRANSPHORM project is focused on one sector – transport; it addresses emissions from traffic and health effects of pollution from this source. Measures are not proposed.

The iSCAPE project analyses impacts of measures in urban environments (passive air pollution remediation, policy interventions and behavioural change initiatives) on air quality.

Other 7 projects are focused on one topic; 3 of them address measures for improvement of air quality (APPRAISAL, EVIDENCE, CLEAN AIR), 3 are focused on health (APHEKOM, ESCAPE, HRAPIE) and one on involvement of citizens in monitoring air quality (CITI-SENSE).

An addition to EU projects overview a detailed overview was performed for the selected projects/studies (Table 3) which have presented a greater potential to be referenced during the ICARUS lifetime and execution.

Table 3: Detailed overview of selected EU projects

PROJECT	REVIEW POINTS	COMPARISON TO- AND APPLICATION IN ICARUS
APPRAISAL – Air Pollution Policies for Assessment of Integrated Strategies At regional and Local scales, 7FP	The project objectives relevant to this review are to perform an overall review of the AQ and health assessment methodologies, to analyse the limitations of the currently available assessment methods, and to evaluate the possibility of implementing integrated assessment modelling tools. The Guidance on integrated air quality and health assessment systems which was developed and tested in seven cities/regions (Alsace region, Antwerp, Athens, Emilia Romagna, Helsinki, Northern Portugal, Warsaw agglomeration) builds on DPSIR approach (Driver/ Pressure/ State/ Impact/Response). The analysis shows that drivers and to a somewhat lesser degree the pressures and state were well treated and elaborated, while in none of the cases the health impact was considered with high level of detail and also the choice of abatement measures is mostly based on expert judgment. The approaches and tools for identifying air pollution, e.g. emission standards and factors from road traffic and industry combined with air dispersion modelling are well covered, however their transposition towards policy development for health impact reduction is scarce.	In the frame of the project an Integrated Assessment framework has been designed, classifying (in broad terms) two possible decision pathways: • Scenario analysis. Expert judgment or Source Apportionment is used to identify potential emission reduction measures, which are tested through a "scenario analysis" modelling methodology. This approach has the advantage of simplicity but does not guarantee that cost-effective measures are selected. An evaluation of costs and impacts can only be performed "ex-post". • Optimization. This approach uses optimization to identify cost-effective measures to improve air quality. During this optimization process, abatement costs and impacts are continuously compared until the least cost set of measures is found, to achieve a given air quality target. The experience gained may be applied in ICARUS, however, the APPRAISAL showed lesser integral assessment potential in the studied areas than is expected in ICARUS. More emphasis is given on emission and imission/pollution part than on exposure and health impact assessment in the studied urban areas and regions; policies and measures for AQ and public health improvements are not included in the impact assessment.

CHALLENGE project Sustainable Urban Mobility Plan (SUMP) for Brno, Ljubljana, Madrid, Milan	Generally, a number of physical and organisational measures are considered in the framework of a particular SUMP, e.g. land-use changes to support public transport, light rail systems, flexible working hours, integrated ticketing, new rails stations and lines, clean vehicles, pedestrian zones, low emission zones, speed reduction. Different tools are applied in an assessment exercise with regard to traffic calming strategies and reduction of congestion in the urban centres and their influence on air quality, e.g., KonSULT option generation tool (Brno), Infras/IWW (Ljubljana), Inventario de Emisiones y el Balance Energético (Madrid), AMAT (Milan) – scenario generation and analysis of demands, spatial and temporal distribution in transport.	The SUMP approach is conceptually similar to the ICARUS approach, with the exemption that emissions, AQ concentrations, and exposures are integrated more or less implicitly in the SUMP measures, while the ICARUS deals with these components explicitly and analytically. SUMP is concentrated on the approval and implementation of the measures and policies in transportation, while the ICARUS provides modelling results related to different air pollution sources as a basis for approval by the cities.
CIVITAS Policy Recommendations For EU Sustainable Mobility Concepts based on CIVITAS Experience, ISBN-978-80-86502-77-9, 2015	The publication presents the main findings arising from the evaluation of the CIVITAS Plus Collaborative Projects (CPs), which ran from 2008-2012. It seeks to identify factors that can boost the effectiveness and consistency of future strategies, thereby securing greater sustainability in urban mobility patterns. Policy makers are provided with contemporary facts for debating purposes, and a number of conclusions and recommendations based on lessons learnt from CIVITAS Plus are put forward. The evaluation results lend support to a number of recommendations, which are structured according to the most relevant policy aspects. Some policy measures seem to be more established in their practical implementation, while others still require further and more in-depth technical and scientific investigation. Walking and cycling measures, or measures supporting public transport, for example, are encountered widely, while measures linked to clean fuels and vehicles or to ITS are less prevalent. Other measures need to be adapted to new mobility models and lifestyles, or they provide a new perspective on urban mobility services, as has been the case with carpooling and car-sharing.	The CIVITAS Policy Recommendations are to be considered and applied in WP6 of the ICARUS. The CIVITAS experience is invaluable in terms of developing EU Sustainable Mobility Concepts and concrete SUMPs.
NACLIM, 7FP, 2012-2017	The project was aimed to better understand the effects of the North Atlantic and Arctic oceans on global climate change. Climate change is predicted to cause more frequent and higher intensity extreme weather events, such as heat waves. Within the project the scientists also tried to understand the phenomenon of more frequent and higher intensity extreme weather events, such as heat waves and in particular the urban heat island effect, so that the end-users (such as European cities) can prepare for this better. Three cities have been selected for demonstration: Almada (Portugal), Antwerp (Belgium), and Berlin	ICARUS is expected to apply knowledge developed in NACLIME in the following areas: 1. downscaling of the spatially coarse resolution CMIP5 climate predictions to the urban scale, 2. applying the urban climate model to obtain climate information at the urban scale from the CMIP5 forecast experiments, 3. investigating the relation between heat waves and the urban-rural temperature increment (urban heat island effect),

	(Germany).	4. coupling the high-resolution urban climate prediction fields to relevant socio-economic data, focusing on the health, 5. combining predicted urban climate fields with spatially explicit vulnerability maps (population density and typology, housing quality, age structure) in order to produce heat risk maps.
CLIMSAVE, 7FP, 2010-2013	CLIMSAVE was a pan-European project that developed an interactive web-based tool that allows stakeholders to assess climate change impacts and vulnerabilities for a range of sectors, including agriculture, forests, biodiversity, coasts, water resources and urban development. The linking of models for the different sectors enables stakeholders to see how their interactions could affect European landscape changes. The tool also enables stakeholders to explore adaptation strategies for reducing climate change vulnerability, discovering where, when and under what circumstances such actions may help. It highlights the cost-effectiveness and cross-sectoral benefits and conflicts of different adaptation options and enables uncertainties to be investigated to better inform the development of robust policy responses. Outputs from the linked models are translated into ecosystem services.	Project results are summarised in Policy Briefs for Europe and Scotland, respectively. Both are valuable inputs for building on in ICARUS regarding impacts to/from agriculture, forestry, and urban systems. Environmental services are linked to wellbeing to express impact to humans, however health impact has been treated only indirectly, e.g. by number of people flooded due to extreme weather events. Cost-effectiveness module of the CLIMASAVE Platform, on the other hand could be useful for comparative assessment of measures and policy options in ICARUS cities.
AIRCLIM – Air Pollution and Climate Secretariat, http://www.airclim.org	The mayors of nine EU capitals have asked the EU institutions to adopt tougher mandatory legislation to minimise air pollution from cars, including a new Euro 7 "technologically neutral" standard for vehicles, and that all vehicle sales be "zero emissions" in the coming two decades. In a letter dated 25 October 2017, the mayors of Paris, Rome, Amsterdam, Madrid, Copenhagen, Brussels, Helsinki, Vienna and Sofia wrote to the European Commission, the Council and the European Parliament, saying that they need "new tools" to cut air pollution and CO_2 emissions from public transport fleets and private vehicles. They argue that zero-emission cars, vans and buses are the future solution for cities to provide clean, energy-efficient and affordable transport for their citizens, and call among other things for the introduction of mandatory sales targets for electric vehicles and a Euro 7 emissions limit that would be technologically neutral.	The orientation of the nine EU capitals towards radical emission reduction from transport should be taken into consideration in ICARUS, particularly in the work of WPs 5 and 6.
MAPLIA - Moving from Air Pollution to Local Integrated Assessment, National Project (Portugal), 2013-2015,	Integrated assessment models for air quality planning (encompassing health impact assessment) like RAINS and GAINS models are not designed for and are not detailed enough to support the decision-makers at the sub-national	Publications (peers and others) based on this research are valuable reference points for ICARUS, since they demonstrate an integrated approach combining the effects of several emission abatement measures on air

http://projeto-maplia.web.ua.pt/project/	scale (both sector-based or geographically), particularly in urban areas where a major share of the European population lives and where health impacts are more pertinent. Integrated assessment in terms of local air quality compliance, should therefore build on a bottom-up approach which links decision making, air quality (often non-linear) dynamics, source identification and consequent health impacts in a customised but consistent way to suit each local situation. This is the rationale of the MAPLIA project: to analyse the feasibility of an impact assessment bottom-up approach for air quality planning, tailored to the local features, for which the policies defined at European or country level constitute an overarching policy constraint.	quality, impacts on human health, and associated implementation costs, which enable an effective cost–benefit analysis and an added value to the decision-making process. Basic steps and tools for integrating health into air quality assessment (health indicators, exposure-response functions) are described.
Inventory and effectiveness of measures to improve air quality – German Federal Environment Ministry (Umwelt Bundesamt), 2015	The inventory contains a description and analysis of 242 air quality plans (AQPs) and action plans published in Germany up to 30.11.2012. These plans offer an extensive overview of the current situation in Germany regarding air quality, different methods of assessment and proposed measures to improve air quality. The analysis of source apportionments shows that more and more plans compiled due to NO2-exceedances include source apportionments (77 % spatial and 69 % pollution sources). For PM10 the fraction of spatial source apportionments has been over 80 % for many years. Apportionments with respect to pollution sources have risen continuously to a current figure of 57 %. The approach of the APPRAISAL project for reviewing and consolidating methods to address and assess the impact of local or regional AQPs and their health implications has been applied for eleven air quality plans.	Due to different reasons the analysis of evidence of effectiveness made for Germany clearly shows that it is inherently difficult to determine the isolated effect of a measure or a policy – e.g. measurement data are not enough, so continuous modelling was described as an extended evaluation method. In this relation a need of further research with respect to quality assured evaluation methods that provide comparable results is emphasized. These issues have been considered and are dealt with in ICARUS.

4.3 Air quality plans

Air Quality Plans (AQP) serve as the strategy to reduce these negative effects, particularly in cities where the majority of the world population lives, it is to define air quality improvement policies. In this sense, European Union Member States are obligated to establish Air Quality Plans (AQPs) for their zones/agglomerations (Costa et al, 2014, Silveira et al., 2016). AQP based emission abatement measures have to be designed and implemented by the Member States (MS) of the European Union (EU) in accordance to the Framework Directive 96/62/EC on ambient air quality assessment and management and in accordance with the Air Quality Directive (EC, 2008) whenever exceedances of air quality limit values are recorded. (Miranda et al. 2015)

The most pronounces aspect of the AQP is therefore the identification and consequently minimisation od the intensity of the adverse effects as well as the associated costs of air pollution (DEFRA, 2004 Silveira et al., 2016). A comprehensive economic analysis starts with a clear identification of the involved air pollutants and their effects on different damage categories – primarily focused on human health effects which also contribute to the largest part of the external cost estimates. These include increased morbidity (especially respiratory and cardiovascular diseases) and premature mortality (e.g. years of lost life) (EC, 2005).

The integrated assessment of the various improvement options - emission abatement measures, in relation to their economic and technical feasibility and to their effects on the environment and human health should also be properly considered. Moreover, it is important to ensure that the air quality standards are achieved within the specified time frame in the AQP (Miranda et al, 2015).

To identify the emitting sources and to assess their individual contribution to the air pollutants concentration, source apportionment techniques are often conducted (Miranda et al, 2015, Silveira et al, 2016). This relies on a previous knowledge of the pollution concentrations, measured or modeled which in turn allows for understanding the maximum feasible air quality improvement that can be achieved by abatement measures and policies. However, in some cases the ambient concentrations are used as a starting point for the analysis without specifying the source in which case the abatement options are then presented in a generalised manner.

Atmospheric emission inventories (AEI) must be as detailed and specific as possible, aiming to contribute to a more correct characterization of the reference situation. Accordingly, at the urban scale, bottom–up approaches should preferably be used instead of top–down emission inventories (Miranda et al, 2015). In some cases the combination of the top-down and bottom up approaches are used to get more accurate results or for the purpose of verification (APPRAISAL 2013a, 2013b, Viaenea et al 2016).

AQP are usually formulated following the two approaches: scenario analysis and optimization approach. Scenario analysis approach starts with the identification of control strategy measures as a result of poor air quality results. The proposed abatement measures and policies must be transformed into emission reductions and their impacts on the air quality, quantified using modeling tools. Policy implications, technical feasibility, resulting costs and environmental and health impacts are evaluated, but rarely within an organised stakeholder/citizen engagement process. In case an optimization approach is used the cycle fully closed and measures, costs and benefits are integrated towards the optimization of the measures taking into account cost–efficiency aspects (Miranda et al, 2015, Silveira et al, 2016).

In the following section an overview of AQP from member states is presented (Table 4).

Table 4: Detailed overview of selected Air quality plans (adapted after Miranda et al, 2015, Miranda et al, 2014)

MEMBER STATES	REGION/ CITY	POLLUTANTS	AIR QUALITY MODELING			REFERENCES
			MODEL	TYPE	COMMENTS	
Belgium	Antwerp	NO_2, PM_{10}, $PM_{2.5}$, SO_2, CO	Operational Prioritary Substances Model [OPS)	Lagrangian CTM	This model has been applied to obtain concentrations on a 1 ×1 km^2 grid covering the Flemish region in which Antwerp is located.	Mensink et al, (2003)
			Danish Eulerian Hemispheric Model (DEHM)	Eulerian CTM	The model was applied at national scale (150 km ×150 km) using three nested domains with the following resolutions: Europe 150 km ×50 km); Northern Europe (16.7 km ×16.7 km); Denmark (5.6 km ×5.6 km).	
Denmark	Copenhagen, Aalborg, Aarhus and Odense	NO_x, O_3, PM_{10} and others	Urban Background Model (UBM)	Urban background pollution model	–Calculations of urban background concentrations based on emission inventories with a spatial resolution of 1 km ×1 km, to be used as an inputto the DEHM; A simplified scheme including dispersion, transport and chemical reactions of NO_x with O_3 is considered.	Brandt et al. (2012), DCE (2013)
			Operational Street Pollution Model (OSPM)	Street canyon model	Based on a combined plume and box model that can simulate in–street emissions and dispersion according to local building geometry and street configuration; Air pollution estimation at 2 m height of selected streets.	
France	Marseille and Aries	NO_2, O_3, PM, SO_2, CO	CHIMERE Model	Eulerian CTM	Multi–scale model designed from regional to urban level in order to produce O_3, forecasts (daily maximum value), aerosols and other pollutants (hourly data).	FRANCE (2013)

MEMBER STATES	REGION/ CITY	POLLUTANTS	AIR QUALITY MODELING			REFERENCES
			MODEL	TYPE	COMMENTS	
Germany	Berlin	NO_x, PM_{10}	IMMIS–Luft	Street canyon model	The model has been used to assess the air pollution related to the road traffic.	Rauterberg-Wulff A. et al, (2014)
Greece	Athens	NO_x, NMVOC	Model for the Atmospheric Dispersion of Reactive Species (MARS/MUSE)	Eulerian CTM	Regional/local scale. No more information available.	Tourlou et al. (2002)
Ireland	Several regions	NO_x, O_3, PM_{10}, $PM_{2.5}$, SO_2, CO, CO_2, VOC and others	n.a	n.a	No air quality modeling Included.	U.S. EPA (2013)
Italy	Several regions	NO_x, PM_{10}, SO_2, hydrocarbons, heavy metals and other	n.a.	n.a.	n.a.	ITALY (2005), D'Elia et al. (2009)
Latvia	Riga	NO_2, PM_{10}, $PM_{2.5}$	n.a.	n.a.	No air quality modeling included.	ECOREGION (2011)
Malta	Maltese Islands	PM_{10}, NO_2	n.a.	n.a.	No air quality modeling included.	MEPA (2010) Air4EU (2006)
Netherlands	Several regions	NO_x, PM_{10}, SO_2, CO_2 and others	Operational Priorltary Substances Model [OPS)	Lagrangian CTM	High resolution (1 km ×1 km) for large–scale predictions of various air pollutants that are subject to European air quality norms.	Priemus and Schutte–Postma (2009), NEAA (2010)
Poland	Several regions	PM, NO_2, SO_2, O_3, CO	Global Environmental Muffiscale and Air Quality (GEM–AQ) Model	Eulerian CTM	The model was applied with an horizontal resolution of 15 km over Europe, and an higher resolution, 5 km, over Poland (and surrounding countries).	Kaminski and Strulewska (2013)
Portugal	Northern Region	NO_2, PM_{10}			The model was applied for an entire year and for three domains with different resolutions using the nesting approach; Iberian Peninsula (43.2 km ×43.2 km); Northern and Central Regions (14.4 km ×l4.4 km); Northern Region (4.8 km ×4.8 km). The inner domain had an area of 120 km ×120 km.	CCDR–N and UA (2007)

MEMBER STATES	REGION/ CITY	POLLUTANTS	AIR QUALITY MODELING			REFERENCES
			MODEL	TYPE	COMMENTS	
	Braga Agglomeration	PM_{10}	The Air Pollution Model (TAPM)	Euierian CTM		CCDR–N and UA (2010)
	Lisbon and Tains Valley Region	NO_2, PM_{10}, SO_2	n.a.	n.a.	No air quality modeling included.	CCDR–LVT (2006)
Romania	Bucharest	NO_2, O_3, PM_{10}, SO_2, CO	CHIMERE Model	Eulerian CTM	Multi–scale model designed from regional to urban level in order to produce O_3 forecasts (daily maximum value), aerosols and other pollutants (hourly data).	ROMAIR (2010)
Slovenia	Ljubljana	PM_{10}	n.a.	n.a.	No air quality modeling included	COL – City of Ljubljana, 2017
Spain	Barcelona metropolitan area	NO_2, PM_{10}	Community Multi–scale Air Quality Model (CMAQ)	Eulerian CTM	Four nested domains were used to capture pollution processes from the continental to the local scale. The inner domain has 1 km^2 grid cells and temporal resolution of 1 hour.	Soret et al. (2011)
	Madrid	NO_2, O_3, PM_{10} SO_2 and others	Community Multi–scale Air Quality Model (CMAQ)	Eulerian CTM	Four nested domains were used to capture pollution processes from the continental to the local scale. The inner domain has 1 km^2 grid cells and temporal resolution of 1 hour.	MADRID (2012), Borge et al. (2014)
			Operational Street Pollution Model (OSPM)	Street canyon model	–Based on a combined plume and box model that can simulate in–street emissions and dispersion according to local building geometry and street configuration; –Air pollution estimation at 2 m height of selected streets.	
Sweden	Stockholm	NO_x, PM_{10}, CO_2	Danish Eulerian Hemispheric Model (DEHM)	Eulerian CTM	n.a.	EHA (2006, 2010)
United Kingdom	London	NO_2, PM_{10}	Pollution Climate Mapping (PCM)	Urban background pollution	Used to calculate urban (and rural) background concentrations for all pollutants on a 1 km ×1 km	Mediaviila–Sahagun et al. (2002),

MEMBER STATES	REGION/ CITY	POLLUTANTS	AIR QUALITY MODELING			REFERENCES
			MODEL	TYPE	COMMENTS	
			models	model	grid.	DEFRA (2011, 2017)
	Manchester	NO_2, PM_{10}, SO_2, CO	The NETCEN primary NO_2 model	Street canyon model	–One–dimensional representation of the interaction between NO_x and O_3 concentrations at roadside locations; –Results showed a good adjustment when compared with measurements	SCC (2005, 2006)
	Liverpool	NO_2, NOx, PM_{10}, $PM_{2.5}$, CO	n.a.	n.a.	No air quality modeling included; Merseyside Atmospheric Emissions Inventory	Liverpool City Council - Air Quality Action Plan for the City-Wide AQMA, 2011
Finland	Helsinki	NO_2	n.a	n.a	No air quality modeling Included.	City of Helsinki, 2016

Parameters mostly addressed by the AQP are particulate matter (PM_{10}), ozone (O_3), nitrogen oxides (NO/NO_2) and sulphur dioxide (SO_2). The main source of PM_{10} and NO_2 pollution can be attributed to road traffic, followed by industry, commercial and residential sources. SO_2 pollution is primarily associated with industrial activity.

Within the AQP the following specific areas of interest can be distinguished (Miranda et al. 2014): Costs for implementation (equipment and maintenance) of abatement measures; Effectiveness of the measures in reducing emissions is assumed to be proportional to benefits on the air quality (using only monitoring indicators); Impact on air quality of designed measures based on modelling (validation with reference observed values); Air quality impacts on the human health or air quality impacts on both human health and environment.

The definition of effective abatement measures can benefit from source apportionment to identify the geographic origin of pollutants and the contribution of sources responsible for the air pollution exceedances. Thus, AQP abatement measures have been focused on the most relevant pollution sources (Miranda et al. 2014). Abatement measures (technical and non–technical), are used and evaluated aiming to quantify their reduction efficiency and costs of their implementation and operation. Technical measures are the so–called “end–of–pipe–technologies” and they neither modify the driving forces of emissions nor change the structural composition of systems or activities, but are applied to reduce emissions before being released in the atmosphere. Non–technical measures reduce anthropogenic driving forces and can be related to people’s behavioural changes (e.g. environmental education and awareness, car sharing, cycling, walking etc.) or to technologies that, reducing the energy demand, abate the fuel consumption (e.g. the use of high efficiency boilers or building thermal insulating coats).

The largest diversity of abatement measures can be associated to road traffic: technical measures, traffic management, public transport, traffic restrictions, road construction, speed reduction, street cleaning and others. Technical measures are closely related to technological improvements to reduce emissions (introduction of electric and hybrid vehicles). Traffic management options are mainly taken to reduce the traffic in urban centers and to regulate the circulation and parking conditions. Within the public transport category the use of buses, trains, car sharing, bicycles or even walking is promoted. Traffic restrictions in certain zones can be introduced (e.g. EURO norms, fuel type, time of day and during the most polluted days). Other traffic related pollution options include the preparation and implementation of mobility plans (CHALLENGE project).

The economic analysis allows for an identification of alternatives/measures to improve the air quality, comparing their consequences or effects against their costs. These external costs (externalities) generated from air pollutants are related to the social welfare and economy, and can include both negative economic effects (damages) and positive economic effects (benefits, also described as avoided external costs) on the environment and health (EC, 2005). If benefits exceed the costs, the policy or measure is more effective and beneficial for improving air quality. The comparison of measures is examined through cost–effectiveness and cost–benefit analyses which, ideally, can prove an important decision-making parameter (Miranda et al, 2015, 2016, Carnevale C. et al., 2014, Schucht S, 2015, Mizsey P., 2009).

Air quality plans and associated assessment approaches present a useful reference for the ICARUS work process. Integrated assessment jointly addresses the environmental and health impacts of the mitigation measures, as well as their implementation costs and the economic quantification of damages/benefits. However, it must be pointed out that ICARUS has set to take the assessment one step further by introducing a detailed exposure assessment which is often lacking in the reviewed cases. Namely the population exposure is addressed as static (e.g. population density, distance from the pollution sources etc.) without considering the variations in exposure such as geo-temporal parameters (Nieuwenhuijsen et al., 2015).

It was also identified, that a number of the reviewed cases included the technical feasibility analysis of the abatement measures/policies proposed which introduces a significant level of uncertainty in terms of achieving the desired (or calculated) air improvement goals set by the AQP – other aspects of feasibility analysis should also be a part of planning for abatement measures/pocies such as political, societal (cultural), organizational, financial, spatial etc.. Also the current status of the AQP implementation could be enhanced by exposing the air quality plans into the stakeholder/citizen engagement process – from the selected examples this was rarely the case.

5 SUMMARY AND RECOMMENDATIONS

5.1 General

The evaluation of the effects measures/policies on air quality and public health is a complex field. Different factors may influence the assessment of impacts and there is an overlap of many intervention strategies that limit the interpretation of the findings. Transport policies are a key point for air quality improvements and for the reduction of public health risk; this implies that interventions planning should integrate assessment of direct and indirect effects on air quality and population health, as well as climate change.

Even though the impact assessment methodologies and measures/policies were the main foci in this literature review, only a few studies have addressed these issues in an integrative manner with conducted communication with the city representatives and administrative bodies (local, regional, national). Also the feasibility of the measure/policy implementation was not present in the majority of studies. Cost benefit analysis (or other forms of monetary evaluation) were referred to in only a handful of examples. Apart from the review articles which have focussed on the implementation of policies/measures in an integrative manner we can see that the overall practice is different – i.e. it lacks the integrative implementation aspect. In general, the studies were oriented towards developing emission and air pollution models for the measures/policies in question with described health consequences (sometimes through the elements of HIA). The results were mainly presented in a qualitative manner with a couple of examples which have expressed the results in reduced mortality rate or DALY. With regard to climate change and governance the reviewed literature is scarce, except specific EU projects.

It should be also noted, that although the advances in integrated assessment modelling approaches have supported policy development in relation to air pollutants and greenhouse gases by providing integrated simulation tools able to produce quick and realistic representations of emission scenarios and their environmental impacts without the need to re-run complex atmospheric dispersion models, the proposed mitigation scenarios/measures/policies still need to go through the approval in the concrete society, represented either by administrative bodies, city councils, regional agencies or general population. This then becomes the truly integrative process.

Most of the studies do not provide much detail on urban impact assessment approaches that would be conducted in an integrative manner. ICARUS project in this regards has a great potential to introduce and demonstrate a truly integrative approach, which would be supported by scientific evidence along with a societal acceptability component, so forming a fundament for air quality and climate change governance in the EU.

5.2 Key messages for future ICARUS work

One of the important messages extracted from the studies is that AQ measures/policies should also have a corporate backing as well as public and political acceptability, therefore multi-sectoral approach - collaboration among the city administrative bodies, transport planning, land use planning, regional and external agencies, development offices, and health authorities - is of key importance in successful implementation of proposals. It should also be noted that the various policies should be integrated in order to further increase the success rate of achieving the same goal.

6 CONCLUDING REMARKS

From the literaure reviewed it can be concluded that a truly integrated assessment related to urban and transport development and planning in cities is currently lacking or is deficient in one or more aspects of integration. In majority of studies a propagation from emission identification through pollution, exposure and consequently health assessment is present, but the uncertainties and approximations in these analysis is relatively large. For example the exposure assessments are mainly just a static model of population density or land-use regression without a detailed insight into whether the people are actually exposed to poor air conditions. The introduction of detailed exposure assessment by the use of AgentBased Modelling in ICARUS is therefore definitely an important step in the direction of more accurate and more “fit-for-purpse” air quality abatement strategies. What is also lacking in the analysed strudies is the loop-back from the proposed mitigation strategies/policies/measures to the actual improovement of air quality – namely, a rare selection of studies have included the feasibility analysis in to the proposals of abatement options. Such filter would aid in selectiong the measures which could provide the desired benefits. In the opposite case the list of unfeasible abatement options is then just a case of misleading attempt of improvement, masking the effort which could in fact lead to benefits. The evaluation of measures to clarify how good, effective, acceptable/implementable, and practicable they are in the context of the needs and affordability (financial, spatial, political, etc.) of a particular city should also be carried out after the implementation/operation. Also, a practical dimension of the measures' implementation is to be discussed (e.g., requirements/needs for land-use changes in a particular city, agreement between neighbouring municipalities about common infrastructure, elections at the municipality level, etc.). The latter includes also a future political and economic justification among all involved stakeholders, as well as changes in the urbanization of the cities, refurbishment of existing and construction of new infrastructure, changes in mode of goods transport, etc. A dialogue with the public and other stakeholders, creating an environment of collaboration and feedback and guaranteeing public acceptance of proposed policy measures is a prerequisite.

Air quality plans and associated assessment approaches present a useful reference for the ICARUS work process. Integrated assessment jointly addresses the environmental and health impacts of the mitigation measures, as well as their implementation costs and the economic quantification of damages/benefits.

An important aspect of integral assessment is also an insight into drivers and barriers during the preparation, implementation and operation of the proposed measures/policies, and this is where the current examples are lagging in terms of being a good role-models in terms of best prectices. Such knowledge would enable the development of air quality improvement approaches and strategies from one city to another and to a region/EU level, as appropriate.

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8 APPENDIX A – EVALUATION OF STUDIES/PAPERS

The evaluation of the papers is presented here in terms of to what extent the topics/elements of integrated urban impact assessment are applied in the study.

LEGEND FOR URBAN IMPAST ASSESSMENT TOPISC/ELEMNTS:

(pink)	topic not covered
(yellow)	topic mentioned or described, but no detailed data provided
(green)	data provided & the topic in relation to mitigation measures/policies clearly described

For integration aspect the evaluation marks (colours) represent the following:

LEGEND FOR INTEGRATION ASPECT:

(pink)	no integration
(yellow)	partial integration (not all topics are included/relation is not clear)
(green)	full integration; some topics may be excluded, but the relation is clearly presented

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Alcamo J., Mayerhofer P., Guardans R., Van Harmelen T., Van Minnen J., Onigkeit J., Posch M., De Vries B.	An integrated assessment of regional air pollution and climate change in Europe: Findings of the AIR-CLIM project	2002	Environmental Science and Policy					
Alcamo J., Mayerhofer P., Guardans R., Van Harmelen T., Van Minnen J., Onigkeit J., Posch M., De Vries B.	An integrated assessment of regional air pollution and climate change in Europe: Findings of the AIR-CLIM project	2002	Environmental Science and Policy					
Amann, M., Bertok, I., Borken–Kleefeld, J., Cofala, J.,Heyes, C., Hoglund–Isaksson, L., Klimont, Z., Nguyen, B., Posch, M., Rafaj, P.,	Cost–effective control of air quality and greenhouse gases in Europe: Modeling and policy applications.	2011	Environmental Modelling & Software					
Asikainen A., Pärjälä E., Jantunen M., Tuomisto J.T., Sabel C.E.	Effects of local greenhouse gas abatement strategies on air pollutant emissions and on health in Kuopio, Finland	2017	Climate					
Baccini M., Biggeri A., Accetta G., Alessandrini E.R., Angelini P., Angiuli L., Antonelli A., Arena P., Assennato G., Baldacchini F., Baldacci S., Baldini	Short-term impact of air pollution among Italian cities covered by the EpiAir2 project [Impatto a breve termine dell'inquinamento dell'aria	2013	Epidemiologia e Prevenzione					
Baccini M., Biggeri A., Grillo P., Consonni D., Bertazzi P.A.	Health impact assessment of fine particle pollution at the regional level	2011	American Journal of Epidemiology					
Ballester F., Medina S., Boldo E., Goodman P., Neuberger M., Iñiguez C., Künzli N.	Reducing ambient levels of fine particulates could substantially improve health: A mortality impact assessment for 26 European cities	2008	Journal of Epidemiology and Community Health					

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Boldo E., Linares C., Aragonés N., Lumbreras J., Borge R., de la Paz D., Pérez-Gómez B., Fernández-Navarro P., García-Pérez J., Pollán M., Ramis	Air quality modeling and mortality impact of fine particles reduction policies in Spain	2014	Environmental Research					
Boldo E., Linares C., Lumbreras J., Borge R., Narros A., García-Pérez J., Fernández-Navarro P., Pérez-Gómez B., Aragonés N., Ramis R., Pollán M.,	Health impact assessment of a reduction in ambient PM2.5 levels in Spain	2011	Environment International					
Boldo E., Medina S., LeTertre A., Hurley F., Mücke H.-G., Ballester F., Aguilera I., Eilstein D.	Apheis: Health impact assessment of long-term exposure to PM2.5 in 23 European cities	2006	European Journal of Epidemiology					
Bono R., Piccioni P., Traversi D., Degan R., Grosa M., Bosello G., Gilli G., Arossa W., Bugiani M.	Urban air quality and carboxyhemoglobin levels in a group of traffic policemen	2007	Science of the Total Environment					
Bontos M.D., Vasiliu D.	Short-term health impact assessment of air polution in Targoviste city (Dambovita County)	2016	Revista de Chimie					
Borge, R., Lumbreras, J., Perez, J., de la Paz, D., Vedrenne, M., de Andres, J.M., Rodriguez, M.E.,	Emission inventories and modeling requirements for the development of air quality plans. Application to Madrid (Spain).	2014	Science of the Total Environment.					
Borrego C., Monteiro A., Sá E., Carvalho A., Coelho D., Dias D., Miranda A.I.	Reducing NO 2 pollution over urban areas: Air quality modelling as a fundamental management tool	2012	Water, Air, and Soil Pollution					

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Borrego C., Sá E., Carvalho A., Sousa S., Miranda A.I.	Plans and Programmes to improve air quality over Portugal: A numerical modelling approach	2012	International Journal of Environment and Pollution					
Brandt, J., Silver, J.D., Frohn, L.M., Geels, C., Gross, A., Hansen, A.B., Hansen, K.M., Hedegaard, G.B., Skjoth, C.A., Villadsen, H., Zare,	An integrated model study for Europe and North America using the Danish Eulerian Hemispheric Model with focus on intercontinental	2012	Atmospheric Environment					
Cárdaba Arranz M., Muñoz Moreno M.F., Armentia Medina A., Alonso Capitán M., Carreras Vaquer F., Almaraz Gómez A.	Health impact assessment of air pollution in Valladolid, Spain	2014	BMJ Open					
Carnevale C., Finzi G., Pederzoli A., Turrini E., Volta M., Guariso G., Gianfreda R., Maffeis G., Pisoni E., Thunis P., Markl-Hummel L., Blond	Exploring trade-offs between air pollutants through an Integrated Assessment Model	2014	Science of the Total Environment					
Caroleo B., Pautasso E., Osella M., Palumbo E., Ferro E.	Assessing the Impacts of Electric Vehicles Uptake: A System Dynamics Approach	2017	Proceedings - International Computer Software and					
Carugno M., Consonni D., Bertazzi P.A., Biggeri A., Baccini M.	Temporal trends of PM10 and its impact on mortality in Lombardy, Italy	2017	Environmental Pollution					
Cassadou S., Quénel P., Zeghnoun A., Saviuc P., Prouvost H., Pascal L., Nunes C., Medina S., Le Tertre A., Filleul L., Eilstein D., Declercq C.	Health impact assessment of urban air pollution: New results for nine French cities and their relevance to public health [Évaluation de l'impact sanitaire	2003	Environnement, Risques et Sante					

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Castro A., Künzli N., Götschi T.	Health benefits of a reduction of PM10 and NO2 exposure after implementing a clean air plan in the Agglomeration Lausanne-Morges	2017	International Journal of Hygiene and Environmental Health					
Chanel O., Henschel S., Goodman P.G., Analitis A., Atkinson R.W., Le Tertre A., Zeka A., Medina S.	Economic valuation of the mortality benefits of a regulation on SO 2 in 20 European cities	2014	European Journal of Public Health					
Chanel O., Perez L., Künzli N., Medina S., Aphekom group	The hidden economic burden of air pollution-related morbidity: evidence from the Aphekom project	2016	European Journal of Health Economics					
Costa S., Ferreira J., Silveira C., Costa C., Lopes D., Relvas H., Borrego C., Roebeling P., Miranda A.I., Paulo Teixeira J.	Integrating health on air quality assessment - Review report on health risks of two major european outdoor air pollutants: PM and NO<inf>2</inf>	2014	Journal of Toxicology and Environmental Health - Part B:					
Costagliola M.A., Murena F., Prati M.V.	Exhaust emissions of volatile organic compounds of powered two-wheelers: Effect of cold start and vehicle speed. Contribution to greenhouse effect and	2014	Science of the Total Environment					
D'Elia, I., Bencardino, M., Ciancarella, L., Contaldi, M., Vialetto, G.,	Technical and Non–Technical measures for air pollution emission reduction: The integrated assessment of the regional Air	2009.	Atmospheric Environment					
Diallo T., Cantoreggi N., Simos J.	Health Co-benefits of climate change mitigation policies at local level: Casestudy Geneva [Co-bénéfices pour la santé des politiques urbaines	2016	Environnement, Risques et Sante					

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Fensterer V., Küchenhoff H., Maier V., Wichmann H.-E., Breitner S., Peters A., Gu J., Cyrys J.	Evaluation of the impact of low emission zone and heavy traffic ban in Munich (Germany) on the reduction of PM10 in ambient air	2014	International Journal of Environmental Research and					
Figueiredo M.L., Monteiro A., Lopes M., Ferreira J., Borrego C.	Air quality assessment of Estarreja, an urban industrialized area, in a coastal region of Portugal	2013	Environmental Monitoring and Assessment					
Filleul L., Medina S., Cassadou S.	Urban particulate air pollution: From epidemiology to health impact in public health [La pollution atmosphérique particulaire urbaine: De l'épidémiologie	2003	Revue d'Epidemiologie et de Sante Publique					
Gaboriaud L., Noppe J., Odent P., Vinot J.-P.	Air quality impact assessment within the frame of an urban transportation scheme: Case study of the Saint-Étienne metropolitan area [Impact sur la qualité	2002	Pollution Atmospherique					
Gerike R., De Nazelle A., Nieuwenhuijsen M., Panis L.I., Anaya E., Avila-Palencia I., Boschetti F., Brand C., Cole-Hunter T., Dons E.,	Physical Activity through Sustainable Transport Approaches (PASTA): A study protocol for a multicentre project	2016	BMJ Open					
Glorennec P., Monroux F.	Health impact assessment of PM10 exposure in the city of Caen, France	2007	Journal of Toxicology and Environmental Health - Part A:					
Gotschi T., Oglesby L., Mathys P., Monn C., Manalis N., Koistinen K., Jantunen M., Hanninen O., Polanska L., Kunzli N.	Comparison of black smoke and PM2.5 levels in indoor and outdoor environments of four European cities	2002	Environmental Science and Technology					

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Holnicki P., Tainio M., Kałuszko A., Nahorski Z.	Burden of mortality and disease attributable to multiple air pollutants in Warsaw, Poland	2017	International Journal of Environmental Research and					
Host S., Chatignoux E., Leal C., Grémy I.	Health risk assessment of traffic-related air pollution near busy roads [Exposition à la pollution atmosphérique de proximité liée au	2012	Revue d'Epidemiologie et de Sante Publique					
Hutter H.-P., Wallner P.	Health effects of particulate matter in Austria [Gesundheitliche auswirkungen von feinstaub in Österreich]	2013	Internistische Praxis					
Jensen S.S., Berkowicz R., Sten Hansen H., Hertel O.	A Danish decision-support GIS tool for management of urban air quality and human exposures	2001	Transportation Research Part D: Transport and Environment					
Judl J., Koskela S., Korpela T., Karvosenoja N., Häyrinen A., Rantsi J.	Net environmental impacts of low-share wood pellet co-combustion in an existing coal-fired CHP (combined heat and power) production in Helsinki,	2014	Energy					
Kaminski, J.W., Struzewska, J.,	High resolution operational air quality forecast for Poland and Central Europe with the GEM–AQ model: EcoForecast System.	2013.	EGU General Assembly, Vienna, Austria					
Keuken M.P., Zandveld P., van den Elshout S., Janssen N., Hoek G.	Health impact assessment of PM10 and EC in 1985-2008 in the city of Rotterdam, The Netherlands	2011	WIT Transactions on Ecology and the Environment					

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Khreis H. .Warsow K.M., Verlinghieri E., Guzmana A., Pellecuer L., Ferreira A., Jones I, Heinen E, Rojas-Rueda D., Mueller N., Schepers P, Lucas K,	The health impacts of traffic-related exposures in urban areas: Understanding real effects, underlying driving forces and co-producing future	2016	Journal of Transport & Health					
Khreis, H., Warsow, K.M., Verlinghieri, E., Guzman, A., Pellecuer, L., Ferreira, A., Jones, I.,Heinen, E., Rojas-Rojas, D., Mueller, N., Schepers, P.,	Urban transport and health: understanding real impacts and co-producing future directions.	2016	Journal of Transport & Health					
Kiesewetter G., Borken-Kleefeld J., Schöpp W., Heyes C., Thunis P., Bessagnet B., Terrenoire E., Gsella A., and Amann M.	Modelling NO2 concentrations at the street level in the GAINS integrated assessment model: projections under current legislation	2014	Atmos. Chem. Phys					
Kuklinska K., Wolska L., Namiesnik J.	Air quality policy in the U.S. and the EU – a review	2015	Atmospheric Pollution Research					
Lechón Y., Cabal H., Gómez M., Sánchez E., Sáez R.	Environmental externalities caused by SO2 and ozone pollution in the metropolitan area of Madrid	2002	Environmental Science and Policy					
Lund H., Hvelplund F.	Does environmental impact assessment really support technological change? Analyzing alternatives to coal-fired power stations in Denmark	1997	Environmental Impact Assessment Review					
Martuzzi M., Krzyzanowski M., Bertollini R.	Health impact assessment of air pollution: Providing further evidence for public health action	2003	European Respiratory Journal, Supplement					

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Mayerhofer P, Alcamo J, Posch M, . Van Minnen JG	Regional Air Pollution and Climate Change in Europe: an Integrated Assessment (Air-Clim)	2001	Water, Air, and Soil Pollution					
Mediavilla-Sahagún Apsimon H. and Warren r.f.	Integrated assessment of abatement strategies to improve air quality in urban environments, the USIAM model.	2002	Water, Air, & Soil Pollution					
Medina S., Ballester F., Chanel O., Declercq C., Pascal M.	Quantifying the health impacts of outdoor air pollution: Useful estimations for public health action	2013	Journal of Epidemiology and Community Health					
Mensink, C., Colles, A., Janssen, L., Cornelis, J., 2003.	Integrated air quality modelling for the assessment of air quality in streets against the council directives.	2003.	Atmospheric Environment					
Michelozzi P., Kirchmayer U., Katsouyanni K., Biggeri A., McGregor G., Menne B., Kassomenos P., Anderson H.R., Baccini M., Accetta	Assessment and prevention of acute health effects of weather conditions in Europe, the PHEWE project: Background, objectives, design	2007	Environmental Health: A Global Access Science Source					
Miranda A. I., Silveira C, J. Ferreira1, A. Monteiro1, D. Lopes1, H. Relvas1, P. Roebeling1, C. Borrego1, E. Turrini2 & M. Volta2	Urban air quality plans in Europe: a review on applied methodologies	2014	Air Pollution XXII					
Miranda A., Silveira C., Joana Ferreir J., Monteiro A., Lopes D., Relvas H., Borrego C., Roebelin P.	Current air quality plans in Europe designed to support air quality management policies	2015	Atmospheric Pollution Research					

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Miranda A.I., Ferreira J., Silveira C., Relvas H., Duque L., Roebeling P., Lopes M., Costa S., Monteiro A., Gama C., Sá E., Borrego C., Teixeira	A cost-efficiency and health benefit approach to improve urban air quality	2016	Science of the Total Environment					
Miranda A.I., H. Relvasa, P. Viaeneb, S. Janssenb, O. Brasseurc, C. Carnevaled, P. Declerckc, G. Maffeise, E. Turrinid,	Applying integrated assessment methodologies to air quality plans: Two European cases	2016	Environmental Science & Policy					
Miranda A.I., Valente J., Costa A.M., Lopes M., Borrego C.	Air pollution and health effects	2014	Current Environmental Issues and Challenges					
Mizsey P., Delgado L., Benko T.	Comparison of environmental impact and external cost assessment methods	2009	International Journal of Life Cycle Assessment					
Moshammer H., Hutter H.-P., Neuberger M.	Fine particles and urban health risks [Feinstaub und gesundheitsrisiko in den städten]	2007	Pravention und Rehabilitation					
Moshammer H., Hutter H.-P., Neuberger M.	Fine particles and urban health risks [Feinstaub und gesundheitsrisiko in den städten]	2007	Atemwegs- und Lungenkrankheiten					
Mueller N., Rojas-Rueda D., Basagaña X., Cirach M., Hunter T.C., Dadvand P., Donaire-Gonzalez D., Foraster M., Gascon M., Martinez	Urban and transport planning related exposures and mortality: A health impact assessment for cities	2017	Environmental Health Perspectives					

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Nedellec V., Mosqueron L., Desqueyroux H., Jeannee N.	Effects of European Euro IV and V standards on the health impact of urban road traffic in France. III. Health impact assessment and comparison of	2010	Environnement, Risques et Sante					
Nieuwenhuijsen M.J.	Urban and transport planning, environmental exposures and health-new concepts, methods and tools to improve health in cities	2016	Environmental Health: A Global Access Science Source					
Nieuwenhuijsen M.J., Khreis H., Verlinghieri E., Mueller N., Rojas-Rueda D.	Participatory quantitative health impact assessment of urban and transport planning in cities: A review and research needs	2017	Environment International					
Nuvolone D., Barchielli A., Forastiere F.	Assessing the effectiveness of local transport policies for improvements in urban air quality and public health: A review of scientific literature [Valutare	2009	Epidemiologia e Prevenzione					
Oxley T., Dore A.J., ApSimon H., Hall J., Kryza M.	Modelling future impacts of air pollution using the multi-scale UK Integrated Assessment Model (UKIAM)	2013	Environment International					
Pelliccioni A., Gariazzo C., De Dominicis M.	Definition of novel health and air pollution index based on short term exposure and air concentration levels	2008	Hrvatski Meteoroloski Casopis					
Priemus, H., Schutte–Postma, E.,	Notes on the particulate matter standards in the European Union and the Netherlands.	2009.	International Journal of Environmental Research and					

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Quaassdorff C., Borge R., Pérez J., Lumbreras J., de la Paz D., de Andrés J.M.	Microscale traffic simulation and emission estimation in a heavily trafficked roundabout in Madrid (Spain)	2016	Science of the Total Environment					
Rabl A.	Interpretation of air pollution mortality: Number of deaths or years of life lost?	2003	Journal of the Air and Waste Management Association					
Rauhala K., Mäkelä K., Estlander K., Tolsa H., Martamo R., Lahti P., Perälä M.	Environmentally favourable urban form and transport system. Environmental problems, measures, object towns and methods [Ympäristövaikutuksiltaan	1997	VTT Tiedotteita - Valtion Teknillinen Tutkimuskeskus					
Renzi M., Stafoggia M., Faustini A., Cesaroni G., Agabiti N., Forastiere F.	Health effects of air pollution in Rome in December 2015 [Inquinamento atmosferico ed effetti sulla salute a Roma nel mese di Dicembre 2015]	2016	Epidemiologia e Prevenzione					
Rojas-Rueda D., De Nazelle A., Andersen Z.J., Braun-Fahrländer C., Bruha J., Bruhova-Foltynova H., Desqueyroux H., Praznoczy C.,	Health impacts of active transportation in Europe	2016	PLoS ONE					
Rojas-Rueda D., De Nazelle A., Tainio M., Nieuwenhuijsen M.J.	The health risks and benefits of cycling in urban environments compared with car use: Health impact assessment study	2011	BMJ (Online)					
Rojas-Rueda D., de Nazelle A., Teixidó O., Nieuwenhuijsen M.J.	Health impact assessment of increasing public transport and cycling use in Barcelona: A morbidity and burden of disease approach	2013	Preventive Medicine					

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Rojas-Rueda D., de Nazelle A., Teixidó O., Nieuwenhuijsen M.J.	Replacing car trips by increasing bike and public transport in the greater Barcelona metropolitan area: A health impact assessment study	2012	Environment International					
Sarigiannis D.A., Karakitsios S.P., Kermenidou M.V.	Health impact and monetary cost of exposure to particulate matter emitted from biomass burning in large cities	2015	Science of the Total Environment					
Sarigiannis D.A., Kontoroupis P., Nikolaki S., Gotti A., Chapizanis D., Karakitsios S.	Benefits on public health from transport-related greenhouse gas mitigation policies in Southeastern European cities	2017	Science of the Total Environment					
Schucht S., Colette A., Rao S., Holland M., Schöpp W., Kolp P., Klimont Z., Bessagnet B., Szopa S., Vautard R., Brignon J.-M., Rouïl L.	Moving towards ambitious climate policies: Monetised health benefits from improved air quality could offset mitigation costs in Europe	2015	Environmental Science and Policy					
Shojaei P., Karimlou M., Nouri J., Mohammadi F., Malek Afzali H., Forouzan A.S.	Ranking the effects of urban development projects on social determinants of health: health impact assessment	2014	Global journal of health science					
Silveira C., Roebeling P., Lopes M., Ferreira J., Costa S., Teixeira J.P., Borrego C., Miranda A.I.	Assessment of health benefits related to air quality improvement strategies in urban areas: An Impact Pathway Approach	2016	Journal of Environmental Management					
Stedman J.R., et al	GIS-based models for ambient PM exposure and health impact assessment for the UK	2009	Journal of Physics: Conference Series					

Authors	Title	Year	Journal	Urban impact assessment topics/elements				
				Emission calculation / modelling	Imissions / pollution concentr. / modelling	Health impact / exposure assessment	Implement. Of measures/ policies	Integration aspect
Sundseth K., Lopez-Aparicio S., Sundvor I.	Bioethanol vehicle transport in Oslo as climate policy: What are the social economic costs resulting from acetaldehyde pollution effects?	2015	Journal of Cleaner Production					
Tichavska M., Tovar B.	Port-city exhaust emission model: An application to cruise and ferry operations in Las Palmas Port	2015	Transportation Research Part A: Policy and Practice					
Tomášková H., Tomášek I., Šlachtová H., Šebáková H.	Impact assessment of pm10 concentrations on mortality and morbidity in ostrava during smog episodes [Odhad vlivu koncentrací	2011	Hygiena					
Tuomisto J.T., Niittynen M., Pärjälä E., Asikainen A., Perez L., Trüeb S., Jantunen M., Künzli N., Sabel C.E.	Building-related health impacts in European and Chinese cities: A scalable assessment method	2015	Environmental Health: A Global Access Science Source					
Venegas-Sánchez J., Rivadeneyra-Sicilia A., Bolívar-Muñoz J., López-Fernández L.A., Martín-Olmedo P., Fernández-Ajuria A., Daponte-	Health impact assessment of the San Fernando street renewal project in Alcalá de Guadaíra (Seville, Spain) [Evaluación del impacto en la salud del	2013	Gaceta Sanitaria					
Viaene P., Belis C.A., Blond N., Bouland C., Juda-Rezler K., Karvosenoja N., Martilli A., Miranda A., Pisoni E., Volta M.	Air quality integrated assessment modelling in the context of EU policy: A way forward	2016	Environmental Science and Policy					
Vlachokostas Ch., Achillas Ch., Moussiopoulos ., Hourdakis E., Tsilingiridis G., Ntziachristos L., Banias G., Stavrakakis N.,	Decision support system for the evaluation of urban air pollution control options: Application for particulate pollution in Thessaloniki, Greece	2009	Science of the Total Environment					