# Publishable summary

The FP7 EC MEGAPOLI (*Megacities: Emissions, urban, regional and Global Atmospheric POLlution and climate effects, and Integrated tools for assessment and mitigation*) project brings together leading European research groups, state-of-the-art scientific tools and key players from non-European countries to investigate the interactions among megacities, air quality and climate. MEGAPOLI will bridge the spatial and temporal scales that connect local emissions, air quality and weather with global atmospheric chemistry and climate.

The main MEGAPOLI objectives are the following:

- to assess impacts of megacities and large air-pollution "hot-spots" on local, regional, and global air quality and climate;
- to quantify feedbacks between megacity emissions, air quality, local and regional climate, and global climate change;
- to develop and implement improved, integrated tools to assess the impacts of air pollution from megacities on regional and global air quality and climate and to evaluate the effectiveness of mitigation option.

In order to achieve these objectives we have been taking the following steps:

- Develop and evaluate integrated methods to improve megacity emission data
- Investigate physical and chemical processes starting from the megacity street level, continuing to the city, regional and global scales
- Assess regional and global air quality impacts of megacity plumes
- Determine the main mechanisms of regional meteorology/climate forcing due to megacity plumes
- Assess global megacity pollutant forcing on climate
- Examine feedback mechanisms including effects of climate change on megacity air quality
- Develop integrated tools for prediction of megacity air quality
- Evaluate these integrated tools and use them in case studies
- Develop a methodology to estimate the impacts of different scenarios of megacity development on human health and climate change
- Propose and assess mitigation options to reduce the impacts of megacity emissions

We are following a pyramid strategy of undertaking detailed measurements in one European megacity, Paris, performing detailed analysis for up to 12 megacities (first of all the European London, Paris, Po Valley and Rhine-Ruhr urban agglomerations, and other selected world-largest megacities) with existing air quality datasets, and investigating the effects of all megacities on global atmospheric chemistry and climate. The results will be disseminated to authorities, policy community, researchers and other stakeholders in the corresponding megacities.

MEGAPOLI includes both basic and applied research, and bridges the spatial and temporal scales that connect local emissions, air quality and weather conditions with global atmospheric chemistry and climate.

In order to fulfil the objectives the following **scientific questions** are being addressed:

Q1: What is the change of exposure of the overall population to the major air pollutants as people move into megacities? What are the health impacts of this exposure? (Objective 1)

Q2: How do megacities affect air quality on regional and global scales? What is the range of influence for major air pollutants (ozone, particulate matter, etc.)? (Objective 1)

Q3: What are the major physical and chemical transformations of air pollutants as they are moving away from megacities? What happens to the organic particulate matter, volatile organic compounds, etc? (Objective 1)

Q4: How accurate are the current emission inventories for megacities in Europe and around the world? What are the major gaps? (Objective 1)

Q5: How large is the current impact of megacities on regional and global climate? (Objective 2)

Q6: How will the growth of megacities affect future climate at global and regional scales? (Objective 2)
Q7: What is the impact of large-scale dynamic processes on air pollution from megacities? (Objective 2)
Q8: What are the key feedbacks between air quality, local climate and global climate change relevant to megacities? For example, how will climate change affect air quality in megacities? (Objective 2)
Q9: How should megacities (emissions, processing inside megacities, meteorology) be parameterised in regional and global models? (Objective 3)
Q10: What type of modelling tools should be used for the simulation of multi-scale megacity air quality - climate interactions? (Objective 3)
Q11: Which policy options are available to influence the emissions of air pollutants and greenhouse gases in megacities and how can these options be assessed? (Objective 3)

In order to answer the above questions and achieve the main objectives we are performing the following **tasks**:

T1: Develop and evaluate integrated methodologies to improve emission data from megacities on regional through global scales; (Objective 1)
T2: Investigate physical and chemical processes starting from the street level in a megacity, continuing to the megacity scale, and then to the regional and global scales; (Objective 1)
T3: Assess regional and global impacts of megacity plumes, including: atmospheric transport (local pollution build-up and its regional/global transport) and chemical transformation of gas and aerosol pollutants emitted in megacities; (Objective 1)
T4: Quantify impacts of polluted air-masses on larger scale atmospheric dynamics (physics and chemistry, hydrological processes, long-range/hemispheric transport, etc.); (Objective 2)
T5: Determine the main mechanisms of regional meteorology/climate forcing due to megacity plumes; (Objective 2)
T6: Assess global megacity aerosol/pollutant forcing and its effects on global climate; (Objective 2)
T7: Examine feedback mechanisms including effects of climate change on megacity environment and emissions; (Objective 2)
T8: Develop improved 'integrated' tools for prediction of air pollution in megacities; (Objective 3)
T9: Evaluate these integrated modelling tools and use them in case studies for selected megacities; (Objective 3)
T10: Develop and apply a methodology to estimate the impacts of different scenarios of megacity development on human health and climate change; (Objective 3)
T11: Propose and assess mitigation options to reduce the impacts of megacity emissions: provide support for European Commission's new air pollution and climate change strategy and policies. (Objective 3)

The first 18 months of work performed since the beginning of the project has been focused on:

- Field campaigns in Paris: (i) Summer - July 2009; (ii) Winter - January/ February 2010; (iii) analysis and modelling;
- Emissions database and future megacity scenario development;
- Continued model development from urban to global scale, analysis and interactions;
- Bringing these various activities together with first steps towards integrated modelling and mitigations scenarios;
- Modelling to quantify feedbacks among megacity air quality, local and regional climate, and global climate change.

The main scientific results achieved/finalised during the reporting period include the following:

1. Two intensive measurement campaigns were performed in the Ile de France region during a one-month summer and a one-month winter period (July 1 – 31, 2009 and January 15 to February 15, 2010, respectively). The campaigns aimed at better quantifying primary and secondary organic aerosol sources on the example of a big European Megacity (the Paris region). The campaign design included 3 primary and 7 secondary fixed ground measurement sites, an aircraft and 5 mobile platforms. In total, more than 25 research laboratories participated. One of the interesting results from airborne primary pollutant measurements was that the pollution plume was still well defined at more than 100 kilometres downwind

from the agglomeration. This will give a “safe” framework for later studying secondary organic aerosol build-up in the plume. Significant new particle formation events were observed in the area during the whole month of the campaign. During the winter campaign, large PM levels were observed both due to a strong local wood burning source and due to continental advection.
2. A consistent base year 2005 anthropogenic emission inventory (prototype) for Europe with 6 km resolution was compiled and made available to the partners. Natural regional and global fire emissions have been generated and a sea salt aerosol model has been evaluated and can be used to predict SS aerosol emissions. For the 1$^{st}$ level megacities (Paris, London, Rhine-Ruhr area, Po Valley) high-resolution emission data have been collected. The local megacity emissions are being compared with default estimates, gridded and currently prepared for insertion in the final European scale emission map. The Large scale Urban Consumption of energY model (LUCY), simulating all components of anthropogenic heat flux from the global to individual city scale at 0.25 x 0.25 arc-minute resolution, was developed and the anthropogenic heat flux inventories for the European region and for London as an example were calculated.
3. In studies of the megacity environments: features, processes and effects the following results were achieved: (i) Morphology database for a target megacity (Paris), (ii) Hierarchy of urban canopy parameterisations for different scale models, (iii) Evaluation of surface flux balance modelling and urban features needed for climate and air quality models.
4. For multi-scale model improvements and applications a few physical and chemical parameterisations and zooming approaches were implemented and are being tested in several megacities (e.g. Paris, Mexico City, and Po Valley). The first results of the performance evaluation of these tests are already being analysed and revealed clues about the relative importance of the various parameterisations when examining megacity air quality and especially its relation to meteorology. Interactions between megacity air quality and meteorology/climate were analysed by using online coupled ACT-NWP models with two-way feedbacks. Classification of meteorological patterns favouring development of urban air pollution episodes in main European megacities and urban agglomerations was suggested. It was shown that urban aerosols from megacities can significantly affect certain meteorological variables (temperature, inversion layers, radiation budget, cloud processes, precipitation, fog, etc.) in and far from urban agglomerations due to the direct and indirect effects.
5. For studies of the regional and global atmospheric composition from megacity emissions a substantial progress in developing and evaluating the satellite-based methods for the measurement of tropospheric gases and aerosols was achieved. The MPIC team has developed, e.g., a retrieval algorithm for tropospheric $NO_2$ vertical column densities for GOME-2 on METOP, adapted and refined the satellite retrieval algorithms, validated tropospheric trace gas products, and correlated $NO_2$ observations with wind data. For construction of a regional model ensemble the harmonization of European domain parameters, input data and other modeling details was realized.
6. To quantify the effects of megacities on climate from the regional to the global scale coupled and uncoupled global and regional chemistry-climate models and observation data were used and analysed. Determination of radiative forcing from megacity emissions on the global scale was realised. Generally, the contribution of megacities to global pollutant emissions is on the order of 2% to 5% of the total global annual anthropogenic emission flux. The impact of megacity pollutants was assessed via a direct radiative forcing from ozone, methane and aerosols. Megacity pollutants were found to contribute a radiative forcing of $+6.3\pm0.4$ mW/m$^2$ from an increase in the ozone burden due to pollutant photochemical oxidation. The change in methane lifetime and consequently the change in the $CH_4$ abundance in the atmosphere contributes a forcing of $-1.0\pm0.5$mW/m$^2$. The aerosol forcing from megacity pollutants amounts to $-15.3\pm0.6$mW/m$^2$ in the short-wave spectrum and $+2.0\pm0.1$ mW/m$^2$ in the long-wave spectrum. The combined effect of all of these individual terms is a slightly negative forcing, that is a cooling, of $-8.0\pm1.6$ mW/m$^2$ of the climate at present-day conditions.
7. Progress on producing a European framework for online and offline coupling meteorological and atmospheric chemical transport models for air quality and climate studies is already underway and a report has been produced.

The achieved results have been reported in 15 scientific MEGAPOLI reports and in a number of publications (*see on the project web-site*).

The expected final results and their potential impacts of MEGAPOLI are the following. The project will contribute to the strategic goal of promoting sustainable management of the environment and

its resources. It will do this by advancing our knowledge on the interactions between air quality, climate and human activities related to large urban centres and hotspots. Megacities constitute major sources of anthropogenic air pollution and hence, affect the lives of hundreds of millions of people in the world directly by the quality of air that they breathe and through complex interactions resulting in climate change. Research within the project will lead to improved modelling and assessment tools. In particular, MEGAPOLI will formulate a European methodology for integrated air quality and climate assessment over multiple scales (urban to global).

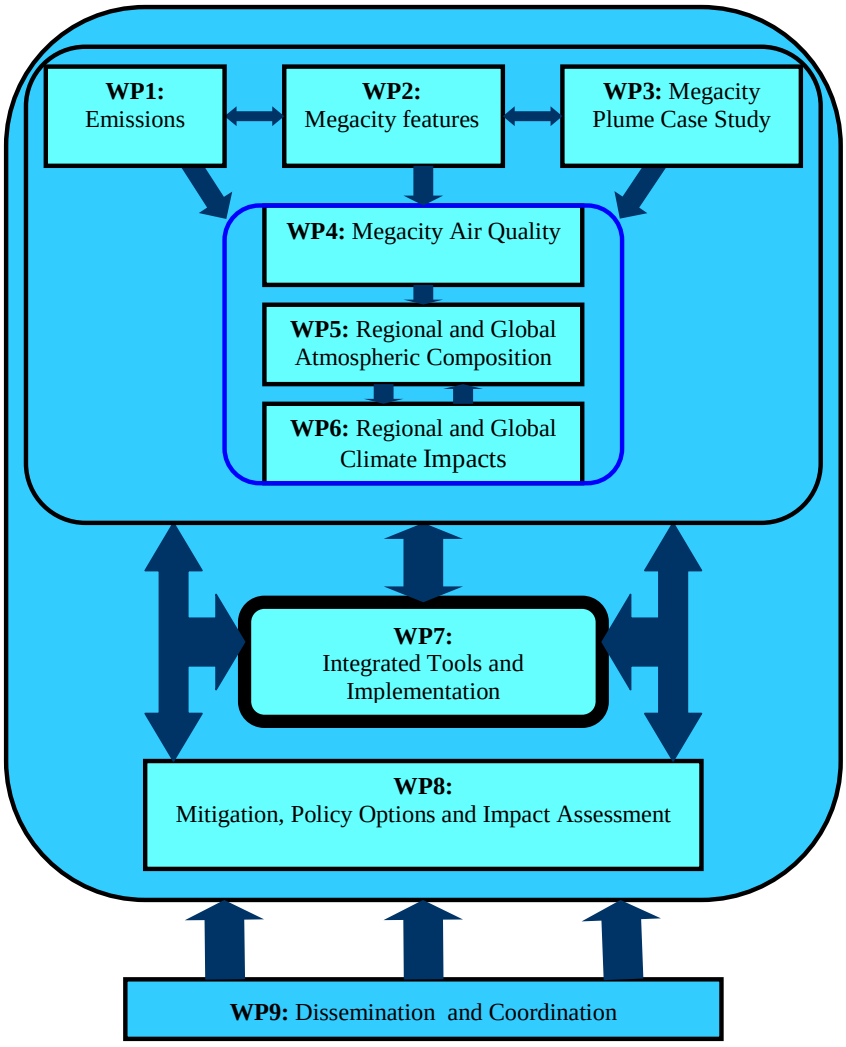



**Figure 1.1**: Work Packages (WPs) structure and integration.

MEGAPOLI will place particular emphasis on the interactions between air quality and climate change impacts resulting from megacities on regional to global scales and potential mitigation options. It will further lead to an integrated methodology and corresponding tools to assess these impacts both in Europe but also elsewhere.

MEGAPOLI will lead to significant scientific innovations including:

(i) Integration of the interactions and processes affecting air quality and climate change on regional to global scales coupled with the capability of estimating the human, ecosystem and economic impact of air pollution resulting from megacities;

(ii) Development of an integrated European methodology and tools to assess the impacts within and from megacities on city to global scales;

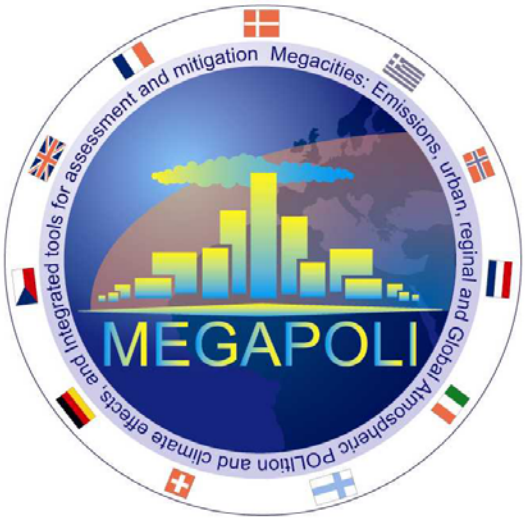
(iii) Integration of ground-based, aircraft and satellite technologies with state-of-the-art modelling tools;

(iv) Integrated approaches for addressing the feedbacks and interlinkages between climate change and regional air quality related to megacities;

(v) Integration of knowledge and practical implementation of improved tools according to level of complexity to a range of megacities and hotspots;
(vi) Improved current and future emission estimates for natural and anthropogenic sources of air pollutants;
(vii) Development of an integrated assessment methodology for supporting EU and global policy frameworks. This will be achieved through the assessment of mitigation options and the quantification of impacts from polluted air-masses on larger scale atmospheric dynamics;
(viii) Examination of the important feedbacks among air quality, climate and climate change;
(ix) A robust, global information dissemination gateway on air quality, climate change and mitigation and policy options for European stakeholders strengthening the European Research Area (ERA).

MEGAPOLI will significantly extend the current state-of-the-art in the assessment capabilities within Europe by developing and implementing reliable integrated tools on multiple scales and for multiple pollutants. These will be applied to assess directly the impact of the largest urban centres and hotspots in Europe and globally by employing highly advanced as well as simpler tools. The project will bring together current off-line approaches as well as new on-line methods enabling feedbacks to be quantified on multiple scales enabling mitigation options to be examined more effectively.

The official website of the MEGAPOLI project is http://megapoli.info. It shows structurally general information on the project, partners and collaborators involved, key megacities in focus studied; description of workpackages, working plans, and contacts. The sections "News and Publications" and "Project Results" are continuously updated with information about recent relevant news, MEGAPOLI newsletters published every 3 months, meetings, presentations, journal publications, and others.

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Megacities and regional hot-spots air quality and climate

***MEGAPOLI Project web-site***

http://megapoli.info

SEVENTH FRAMEWORK PROGRAMME

# MEGAPOLI

**Megacities: Emissions, urban, regional and Global Atmospheric POLlution and climate effects, and Integrated tools for assessment and mitigation**

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