PROJECT FINAL REPORT

Grant Agreement number: 243406

Project acronym: TRANSPHORM

Project title: Transport related Air Pollution and Health impacts - Integrated Methodologies for Assessing Particulate Matter

Funding Scheme: Collaborative Project (Large-scale integrating project)

Date of latest version of Annex I against which the assessment will be made:

Period covered: from January 2010 to June 2014

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Contents

1 Executive Summary

Exposure to particulate matter (PM) is a key contributor to adverse health impacts. Quantification of health impacts resulting from air pollutants such as PM relies on a number of factors including reliable emissions, knowledge of their characteristics and composition and prediction of concentrations and exposure levels.

As part of an extensive collaboration between 21 European organisations, TRANSPHORM has led to innovative developments and improvements in measurements, modelling and assessment approaches for quantifying the health impact of airborne particulate matter (PM) on city and continental scales. In addition to developing improved emission inventories, measurements of PM and its constituents in European cities have been undertaken and analysed to determine contributions to $PM_{2.5}$ from transport and other source sectors. With the aid of advanced local and European scale models combined with the latest health impact assessment approaches, an integrated approach for estimating population exposure and health impacts resulting from air pollution from traffic has been developed. Health impacts have been quantified for different diseases and causes of death associated with transport related PM_{10}, $PM_{2.5}$, elemental carbon (EC), benzo(a)pyrene (BaP) and particle number (PNC). Outreach activities have included a number of special sessions at major international conferences and a special workshop for stakeholders held in Brussels in May 2014 highlighting key recommendations from the project on European air quality and implications for policy makers.

Measurements of $PM_{2.5}$ and PM_{10} for a number of European cities have been used for source apportionment to quantify contributions from transport and other source sectors. Emission factors for shipping and road traffic have been updated and European wide emission inventories have been developed. Concentrations of PM species have been predicted for 2005 and 2020 and 2030 with regional scale models (WRF/CMAQ, SILAM, LOTOS-EUROS and EMEP). PM species and related health impacts deaths have been predicted for 2008 and 2020 using OSCAR, CAR-FMI, URBIS, MARS and EPISODE for Athens, Helsinki, London, Oslo and Rotterdam.

Within cities, $PM_{2.5}$ and PM_{10} levels are particularly sensitive to regional contributions whereas local measures are important near road and for urban background concentrations. EC and PNC are more sensitive indicators to evaluate the impact of these measures on air quality compared to the mass-based PM indicators $PM_{2.5}$ and PM_{10}. In order to reduce the levels of $PM_{2.5}$ and PM_{10} European wide measures are required, rather than just local measures, for effective mitigation strategies. For the case of autonomous development in particular, the introduction of Euro 5 and 6 between 2008 and 2020 will improve considerably the air quality resulting from traffic-related combustion emissions in urban areas across Europe. Locally implemented measures will only have limited effects on particulate matter concentrations on an annual basis.

Land use regression models, to predict concentrations at home addresses, have been extensively used for health risk assessment in ESCAPE. After comparison and assessment of these models using monitoring and modelling data in TRANSPHORM it is recommended that dispersion modelling, in conjunction with measurements, be used for future health risk assessments, in particular for the population living near intense road traffic and using transport-relevant indicators such as EC, PNC and heavy metals like copper from brake wear.

Exposure analysis was used to quantify the effects of population mobility, time-activity, near field exposures and impact of buildings and the change of building stocks on population exposure distributions. Allowing for the exposure in various indoor and outdoor micro-environments, instead of only considering the exposure at residential locations or the population weighted concentrations, substantially improves the accuracy of exposure and health estimates.

2 Summary Description of Project Context and Objectives

The main aim of TRANSPHORM has been to improve the knowledge of transport related airborne particulate matter (PM) and its impact on human health and to develop and implement assessment tools for scales ranging from city to the whole of Europe. In this regard TRANSPHORM has fully met its aim. In order to undertake this project TRANSPHORM has brought together internationally leading air quality and health researchers. As a major output for users and policy makers, TRANSPHORM has developed and implemented an integrated methodology to assess the health impacts of particulate matter (PM) resulting from transport related air pollution covering the whole chain from emissions to disease burden. Primarily, the aim of the project has been achieved through a number of advances have been made including enhanced understanding of sources, improved emission factors, increased knowledge of particle characteristics and processes, new targeted air quality and exposure campaigns, improvements in multiscale modelling of particulate matter and analysis of mitigation and adaptation strategies for policy response. TRANSPHORM builds upon and cooperate closely with the achievements of key projects in particular ESCAPE, HEIMTSA, INTARESE and MEGAPOLI.

The overall work plan of the consortium was organized into the following subprojects (lead and co-lead partners are shown):
SP1: Transport and emission sources (AUTH, USTUTT)
SP2: Air quality and exposure (FMI, NILU)
SP3: Relationships between transport related PM and Health (UU, JRC)
SP4: Integrated assessment methodology and tool (TNO, UH)
SP5: Mitigation and adaptation strategies and measures (USTUTT, NILU)
SP6: Management and dissemination of project outcomes (UH, TNO)

The key objectives of TRANSPHORM were:

i. To improve our understanding of transport sources of size-resolved and speciated (primary and secondary) particulate matter air pollution including non-exhaust, shipping and aviation.
ii. To determine improved emission factors of ultrafine particle number (PNC) and mass fractions of $PM_{2.5}$ and PM_{10} through new and existing data for key transport sources;
iii. To conduct targeted measurement campaigns in Rotterdam, Helsinki and Thessaloniki for source apportionment, exposure assessment and model evaluation.
iv. To quantify airborne particulate matter in urban environments resulting from road, shipping, rail and aviation.
v. To develop, improve and integrate air quality dispersion and exposure models for urban and regional scales.
vi. To use latest concentration-response (CRF) to quantify the health impacts of PM for key health endpoints.
vii. To develop and implement an integrated assessment methodology to investigate and analyse the whole chain of processes for selected cities and Europe.
viii. To incorporate micro-environmental concentrations, time-activity patterns into exposure assessment.
ix. To conduct integrated health assessment of a number of selected European cities;
x. To design and implement mitigation and adaptation strategies for European and international policy refinement and development.
xi. To exploit the results of TRANSPHORM through global dissemination and interactions with European and international stakeholders.

An Integrated methodology has been developed and implemented for assessing the health impact of particulate matter over Europe and European cities, for current and future years, including the impact of local and EU-wide transport related scenarios (shown in Figure 1). A key feature of the integration methodology has been the combination and coupling of state of the art local and regional models allowing high resolution prediction of particulate matter and related species for current and future years. Such a capability provides a major advance over previous approaches particularly for assessing health impacts on multiple scales and for multiple pollutant species.

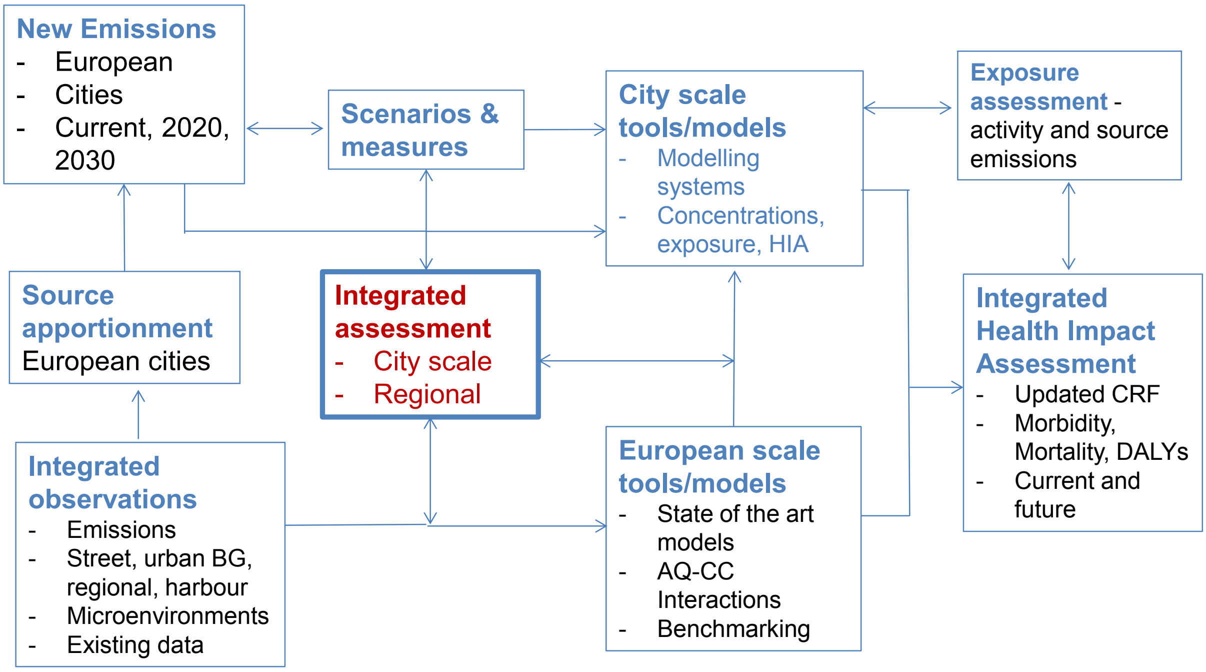


Figure 1 Integrated methodology to quantify the health impacts of particulate matter on city and European scales.

A refined chain of models from emissions to health effects has been developed for both urban and European scales. Selected health-relevant indicators of pollutant loads responsive to traffic source changes have been modelled for a first time on this scale for PM_{10}, $PM_{2.5}$, elemental carbon (EC), benzo(a)pyrene (BaP) and particle number (PNC). Dispersion models have been further improved and developed to predict spatially and temporally resolved concentrations of particle number for exposure and health applications. The refined modelling systems have been used for policy analysis in the five participating cities Helsinki, Oslo, London, Rotterdam and Athens and they are available for future policy relevant work, collaboration with local and national authorities.

The integrated assessment entails emission inventories, source apportionment, modelling the dispersion from local to European scale and health impact assessment of different PM matrices including EC, BaP and PNC. Several of these results are new in most of the target cities, such as the predicted concentrations of elemental carbon (EC), benzo(a)pyrene (BaP) and PNC. The project has also evaluated quantitatively the contributions of various source categories on these concentrations. The measured data in cities Helsinki, Oslo, London, Rotterdam and Athens has been used to validate the methodologies developed within the project at an urban scale.

Health impact assessment requires information on the spatial and temporal exposure of the population to PM concentrations. The performance of land-use regression models, often used in epidemiological studies to estimate exposure, has been compared both to available measurement data and against the results of detailed dispersion modelling in collaboration with ESCAPE, a pan-European research project studying the relation between human health and air pollution. The results provide new information that will serve to improve exposure assessment, especially as they also address the contribution of the main urban particulate matter sources to ambient concentrations and individual and population exposures.

Measurement campaigns were directed to investigate transport-related PM emissions near air strips (Schiphol), a harbor area (Rotterdam) and road traffic. In particular, elevated concentrations of PN were found near airstrips while EC and PNC were the most sensitive indicators for harbor and road traffic emissions. Dedicated monitoring campaigns were targeted to PM emissions from sea and inland shipping, source apportionment of transport-related PM emissions and PM levels in various micro-environments of commuters in urban areas (bicycle, bus and passenger car). In collaboration with ESCAPE, sampling and analysis of PM were performed in 20 study areas across Europe.

Source apportionment modelling studies in a selected number of cities show that the largest contribution to $PM_{2.5}$ exposure is from long range transport, not from local sources. The contribution from local transport was highest for exhaust and non-exhaust traffic emissions and in some cities from shipping. The contribution of transport emissions to the regional background from these cities was as high as 35%. In some cities, then, the non-local transport contribution was as large, or larger, than the local transport contribution. This indicates that European wide measures for transport, rather than just local measures, are required for effective mitigation strategies.

Land use regression models, to predict concentrations at home addresses, have been extensively used for health risk assessment in ESCAPE. After comparison and assessment of these models using monitoring and modelling data in TRANSPHORM it is recommended that dispersion modelling, in conjunction with measurements, be used for future health risk assessments. If land use regression is to be used further, then changes to the methodology are required.

Exposure analysis was used to quantify the effects of population mobility, time-activity, near field exposures and impact of buildings and the change of building stocks on population exposure distributions. Allowing for the exposure in various micro-environments (instead of only evaluating, e.g., the exposure in residential locations or the population weighted concentrations) substantially improves the accuracy of exposure and health estimates.

In TRANSPHORM, the health effects of transport measures and scenarios such as low emission zones, electric vehicles and more physical and public transport, were compared to autonomous development in 2020. In SP4, the results of the assessment performed in SP1 (emissions), SP2 (modelling), SP3 (health impact) and SP5 (transport measures and scenarios) were presented in an on-line “viewer”. Also, the uncertainty related to the whole chain of integrated assessment in TRANSPHORM was investigated in SP4. Analysis of a large number of measures applicable on city and European scales has been conducted.

Through the use of improved emission factors for shipping and road traffic and the latest European wide emission inventories concentrations of PM species have been predicted for 2005 and 2020 with five regional scale models (WRF/CMAQ, SILAM, LOTOS-EUROS and EMEP). Figure 2 shows the avoided Disability Adjusted Life Years (DALY) based on WRF/CMAQ predictions of $PM_{2.5}$ over Europe. City scale models (e.g. OSCAR and URBIS) have been used to predict 2008 and 2020 population weighted concentrations for Rotterdam, Helsinki, Oslo, Athens and London. Health impacts in terms of DALYs and attributable deaths have been calculated for PM_{10}, $PM_{2.5}$ and EC for selected cities and for Europe.

Within cities, PM levels are sensitive to regional contributions and to local measures which affect near road and urban background concentrations. The overall analysis has shown that autonomous development which relies on technological based emission reductions, such as the introduction of Euro 5 and 6, will improve considerably levels of traffic-related levels of $PM_{2.5}$ in urban areas across Europe between 2008 and 2020. On-top of the autonomous development, further improvement of air quality by local measures by 2020 will be limited except near roads and the general impact on urban background.

Figure 3 shows results from the OSCAR air quality assessment system for urban increments arising from road traffic and other sources compared to regional background affecting $PM_{2.5}$ levels at different location types in London for 2008.

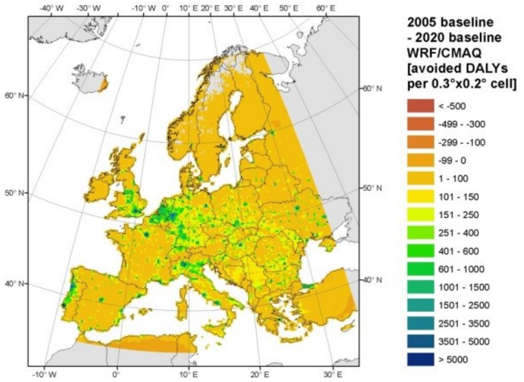


Figure 2 Avoided DALYs over Europe for 2020 relative to 2005 using $PM_{2.5}$ annual mean concentrations predicted with WRF/CMAQ.

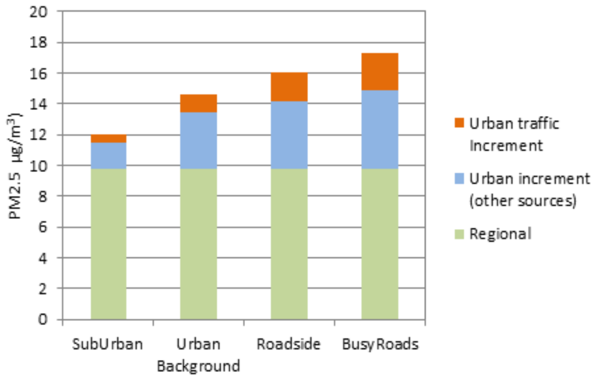


Figure 3 Urban increment due to traffic and other sources and regional contributions to $PM_{2.5}$ at different location types over London for 2008 using OSCAR.

3 Key Messages and Recommendations from TRANSPHORM

3.1 Policy orientated messages and recommendations

(i) An integrated approach is recommended for a full chain assessment and analysis of the effects of policy measures on health impacts of particulate matter.

(ii) Process orientated, deterministic high resolution models should be used in preference to empirical methods where possible to support air quality policy development and monitoring incorporating multipollutant and multiscale capabilities to capture non-linear linkages and responses of pollutants to emission, meteorological and climate changes and spatial and temporal variabilities for current and future timescales. Such advanced approaches are essential as there is considerable seasonal and spatial variation in particulate matter levels and because climate change effects on air quality of Europe will become more important as air pollutant emissions reduce.

(iii) Modelling studies within TRANSPHORM are indicating that approximately 15% of $PM_{2.5}$ across Europe arises from transport sources (monthly data for 2005). In order to control city and regional air pollution in the future, greater emphasis should be placed on reducing emissions from shipping (e.g. NOx, particle number), non-exhaust (e.g. tyre and brake wear, road wear, re-suspension), coarse fraction (e.g. windblown dust and other non-exhaust sources), agricultural contributions and residential combustion sources.

(iv) While monitoring networks exist across Europe, these measurements are not sufficiently detailed to help quantify the large range of particulate matter sources. Measurements designed specifically for process and sources apportionment studies are needed to improve the quantification of transport and other source contributions to particulate matter concentrations within and outside cities. Dedicated monitoring campaigns are needed targeted to particulate matter emissions from sea and inland shipping, source apportionment of transport-related PM emissions and PM levels in various micro-environments of commuters in urban areas (bicycle, bus and passenger car).

(v) While preliminary particle number emission inventories exist, their improvement is essential for reliable predictions within cities and the European region as a whole. There is also a severe lack of representative, long-term datasets of urban measurements of particle number concentrations, which along with model predictions, could be used for epidemiological studies, model evaluation and health impact assessment.

(vi) Exposure of people living close to roads to particle number concentrations and elemental carbon will be more reflective of the strength of the traffic sources than the regulated metrics such as $PM_{2.5}$ or PM_{10}. In particular, elevated concentrations of PN were found near airstrips while EC and PNC were the most sensitive indicators for harbour and road traffic emissions. Near busy roads, particle number shows the highest concentration gradients of all the traffic-sensitive metrics.

(vii) Health impact for population groups spending more time near sources such as road traffic may be underestimated significantly. Hence, when quantifying exposure and health impacts resulting from particulate matter, account should be taken of how much time people spend near busy streets (e.g. travelling, shopping, working), sensitivities to different pollutants and patterns of spatially and temporally dependent activities.

(viii) Health impact assessment requires detailed information on the spatial and temporal exposure of the population to airborne particle concentrations. Dispersion models are better suited to simulate gradients across complex cities than empirical approaches such as LUR models which rely on the availability of extensive measurement datasets. Given the deterministic nature of dispersion models, they should be the preferred option for air pollution health impact assessment studies especially where a range of indicators and metrics are being used.

(ix) Health impact of specific components of particulate matter, such as coarse and ultrafine, should be examined in epidemiological studies leading to improved or new concentration response functions. This will help to improve the understanding of the relative health impacts calculated with different metrics associated with particulate matter (e.g. PM_{10} and $PM_{2.5}$, PNC, EC and metals).

(x) Largest improvements in annual mean particulate matter concentrations across Europe are likely to arise from Europe-wide technological changes (e.g. Euro 5 and 6) by 2020 in emissions and not locally implemented measures (e.g. low emission zones). It is assumed here that the expected technological measures will be fully implemented across Europe.

(xi) Local measures, however, will be more effective for short term episodes (e.g. hotspots caused by emissions) and for reducing the general urban increment but will have less effect on long term levels of particulate matter. In cities, local measures will be particularly important for people spending time near road traffic. It is recommended to use specific indicators (instead of $PM_{2.5}$ and PM_{10}) such as EC, PNC and Cu (brake wear) to evaluate the effectiveness of these local measures on air quality in cities.

(xii) Regional background contributions to $PM_{2.5}$ in cities can be dominant (50-70%) and furthermore, reduction of particulate matter requires a multi-pollutant/component response. Measures to reduce regional background of PM will be particularly important to reduce the overall burden of PM in cities and Europe on the longer term. In order to reduce PM levels in cities a *combined approach* is required bringing together control of local and European-wide regional contributions and taking account of the associated chemical and physical properties of particulate matter.

(xiii) As regional contributions of $PM_{2.5}$ can be dominant in cities, further understanding of the role of regional background particulate species is needed to improve quantification of the overall health impacts of particulate matter.

3.2 Research orientated messages and recommendations

(i) A priority should be given to improvement of regional models to predict particulate matter and its components, in particular for correcting the substantial under-prediction exhibited by currently available models, thus allowing policy makers and other users to take full advantage of their capabilities.

(ii) Further research is needed on how the different components of traffic-related particulate matter including chemical species, non-exhaust versus exhaust pollutants and different size fractions affect exposure and associated health impacts of people within cities.

(iii) While some studies exist on source apportionment of particulate matter, specifically designed measurements should be undertaken to provide detailed information of all major sources of particulate matter including various fractions and source categories, such as coarse fraction and non-exhaust within cities, small-scale combustion and the influence of natural sources, such as wild-land fires, desert dust and sea salt to the regional background.

(iv) Knowledge of particle number is still limited for Europe and further research is needed in terms of their sources, long term measurements in urban areas and models for predicting their concentration distributions and associated health effects across Europe.

(v) Studies to understand the relationship between health impact assessment based on different particulate matter metrics (e.g. $PM_{2.5}$, PM_{10}, PNC, EC) are needed. This type of knowledge will help improve the scientific underpinning for questions such as which policy-relevant metrics should be used in the future European Union air quality guidelines and limit values?

(vi) The usefulness of model ensemble approaches for air quality policy should be assessed taking account of practical constraints, reliability of ensemble performance, uncertainties of model predictions and process deficiencies of any individual model.

4 Description of the Main S&T Results

In order to meet the objectives listed below the work programme was organised into six subprojects (SP) each coordinated by a lead and co-lead partner:
SP1: Transport and emission sources (AUTH, USTUTT)
SP2: Air quality and exposure (FMI, NILU)
SP3: Relationships between transport related PM and Health (UU, JRC)
SP4: Integrated assessment methodology and tool (TNO, UH)
SP5: Mitigation and adaptation strategies and measures (USTUTT, NILU)
SP6: Management and dissemination of project outcomes (UH, TNO)

The subprojects collectively addressed each of the objectives as listed below.
(i) To improve our understanding of transport sources of size-resolved and speciated (primary and secondary) particulate matter air pollution including non-exhaust, shipping and aviation (SP1, SP2).
(ii) To determine improved emission factors of ultrafine particle number (PNC) and mass fractions of $PM_{2.5}$ and PM_{10} through new and existing data for key transport sources (SP1).
(iii) To conduct targeted measurement campaigns in Rotterdam, Helsinki and Thessaloniki for source apportionment, exposure assessment and model evaluation (SP2).
(iv) To quantify airborne particulate matter in urban environments resulting from road, shipping, rail and aviation (SP2).
(v) To develop, improve and integrate air quality dispersion and exposure models for urban and regional scales (SP2).
(vi) To use latest concentration-response (CRF) to quantify the health impacts of PM for key health endpoints (SP3, SP4).
(vii) To develop and implement an integrated assessment methodology to investigate and analyse the whole chain of processes for selected cities and Europe (SP4, SP5).
(viii) To incorporate micro-environmental concentrations, time-activity patterns into exposure assessment (SP2).
(ix) To conduct integrated health assessment of a number of selected European cities (SP4, SP5);
(x) To design and implement mitigation and adaptation strategies for European and international policy refinement and development (SP5).
(xi) To exploit the results of TRANSPHORM through global dissemination and interactions with European and international stakeholders (SP6).

Before highlighting the main results from each of subprojects an overview is given below.

The work performed in SP1 has focused on improving emissions factors for PM and PNC. Collation and parameterisation of traffic activity data have been performed and are being used for urban scale modelling in SP2. Measurements of shipping emissions have been completed and these have led to the development of new ship emission factors. The work performed in SP1 has culminated in the development of baseline European emission inventories for the present (2005) and future years (2020 and 2030).

A number of measurement campaigns have been completed as part of SP2, including micro-environment and emission profile measurement campaigns in Helsinki, Rotterdam and Work Thessaloniki. Initial receptor modelling using PM_{10} and $PM_{2.5}$ datasets from TRANSPHORM and ESCAPE on a large number of European cities has shown that more detailed campaigns were required to improve our understanding of PM sources. The PMC approved these new detailed campaigns in Thessaloniki and Rotterdam, two cities generally representing situations in northern and southern Europe. These campaigns were funded through the contingency budget and were additional to the previously agreed programme of work.

Model development work in SP2 has been carried out including work on receptor and particle number models. A range of simplified modelling options have been considered and model development work has resulted in the peer reviewed publication of one such methodology.

Microenvironmental infiltration model to account for particle size distribution and mass-concentration modification by buildings was developed and evaluated. Furthermore, the model was integrated with a previously developed particle size specific human respiratory tract model (ICRP, 1994) for estimation of accumulated lung deposition by respiratory tract regions and to estimate PM doses in the human lungs in the FINRISK cohort in Helsinki metropolitan area.

Work as part of SP3 has included the XRF analysis of filter samples taken in collaboration with the ESCAPE project. Analysis of new data and literature has led to new and revised concentration response function which will be used for undertake HIA of PM at city and European scales.

Work package 4.3 has led to the development of the Integrated Assessment Tool prototype. The IAT tool has been applied for the city of Rotterdam to demonstrate it capabilities. The HIA methodology was fully developed integrated into models. Urban models with HIA capability have been tested for Rotterdam and London and regional models have been applied to predict air quality for 2005 and 2020 and 2030 for the whole of Europe.

The majority of the work undertaken in SP5 has been focused on the development and analysis of a range of pollution reduction measures and strategies. The main output from SP5 in this reporting period has been defining the policies and measures that will be considered in the air quality modelling scenarios that will be run later in the project. The process of engagement with stakeholders has also been initiated in SP5.

SP6 progressed including in establishing feedbacks from stakeholders on mitigation measures being developed in SP5. A special workshop on Transport related air pollution – science and policy was held at the International Conferences on Air Quality, held in Athens, 19-23 March 2012 and 24-28 March 2014 in Garmisch-Partnerkirchen. Newsletters and articles to promote the project have been produced and circulated. TRANSPHORM partners have also made contributions to the EC review of European Air Quality policy (2013) and to several partners contributed to the WHO Health Risks of Air Pollution in Europe (HRAPIE) project report.

4.1 SP1 Transport and emission sources (AUTH, USTUTT)

SP1 focused on improved and new emissions factors of PM_{10}, $PM_{2.5}$, ultrafine fraction for sources such as shipping, aviation and road traffic including non-exhaust emissions particularly in those areas where existing data was uncertain or lacking. The SP included an extensive and detailed review of the current methodologies, identifying where new approaches could improve the emission estimates. The main target was the improvement of our understanding of transport sources of size-resolved and speciated (primary and secondary) PM air pollution and, consequently, the development of an up-to-date database of transport activities and emissions for the baseline scenario (1990-2030) that is to be used as model input in SP2 and SP5.

WP 1.1 Emission factors for road transport (AUTH)

WP1.1 was related with the identification of the relevant parameters that influence road transport PM-related emission. The main outcome of this WP was a methodology for particulate matter emission quantification in relation with transport activity situations.

An analysis of the assessment of the impact of traffic conditions on emissions with emphasis on PM emissions was conducted. The methodology was based on the collection and analysis of the existing traffic data for the participating cities and by implementation of traffic situations and typologies developed. A complete database of traffic activity for all case-study cities (Rotterdam, London, Oslo, Helsinki and Athens) is now available.

A comprehensive methodology was developed and applied for determining emission factors (EF) for different vehicle categories taking into account for all EU countries. It includes:

- Four types of Emissions Factors (EF) (highway, rural and urban peak and urban off peak)
- Five vehicle classes of engine capacities available: Passenger cars, Buses, LDVs, HDVs, MC and mopeds
- EFs for the basic TRANSPHORM pollutants, that is PM_{10}, $PM_{2.5}$, PNC (total and solid) and size distributions, EC and B(a)P along with EFs for gaseous pollutants, various PAHs and metals

The focus of this task was on the contribution of the non-exhaust PM emission. The procedure followed included:

- Analysis of model needs (SP2) in terms of emission factors resuspension modeling
- Analysis and comparison of existing resuspension models
- Collect new literature/experimental data and collate data owned by the project partners
- Organization of the EMEP/EEA emission factors into a structure/format to be used by TRANSPHORM models
- Extension of the database to cover the weak areas identified (studded tyres, weather effects, asphalt wear)
- Fill gaps and produce a quality indicator for the emission factors delivered

The overall methodology was applied for the quantification of road transport non-exhaust PM-emissions in terms of EFs for $PM_{2.5}$, PM_{10}, various PAHs and metals with the following contributing components:

EFnon-exhaust=tyre wear + brake wear + road wear + re-suspension

WP 1.2 Emission factors for non-road transport (IVL)

This work package related to the emission factors for the non-road traffic modes: Shipping, aviation and rail traffic. These factors cover PM number and mass, size distribution and chemical composition. Variability of emission factors with operation mode of vessel or vehicle and with fuel and technology has been investigated.

Emission factors of particulate matter were determined in terms of mass ($PM_{2.5}$, PM_{10}, TSP), particle number (PNC) and chemical compounds elemental carbon (EC), organic carbon (OC), metals and PAHs from shipping. The emission factors were determined for different marine fuels (heavy fuel oil with different content of sulphur, marine diesel, marine gasoil, and biofuels), different types of marine engines and different operation modes. Effect of cleaning technologies and overview of IMO's and EU's legislation concerning international and national maritime shipping and inland shipping were included in the study to enable assignment of fuels and engine technologies when the emission scenarios are calculated.

A study of processing of PM in plumes and contribution of gas-phase emissions to PM on plume and urban scale was carried out with a 1-dimensional plume process model complemented with simulations of dispersion and chemistry of ship emissions on urban scale with an Eulerian model.

Emissions of both gas-phase species, $PM_{2.5}$, EC and OC were modelled for Baltic Sea with STEAM2 emission model based on Automatic Identification System. This bottom-up emission inventory is available for comparison with baseline inventory calculated in SP1.

Eurostat data on aircraft activity at European airport were used for the determination of arrivals and departures from Amsterdam Airport. Real time-in-mode data for Amsterdam Airport were received from NLR. Based on times-in-mode and airport activity data, the First Order Approximation (FOA) Version 3 as proposed in the IACO Airport Air Quality Guidance manual was used to calculate emission factors for all species and compounds listed in the IACO Engine Emissions Data Bank. The emission factors for the airport machinery were calculated in accordance with the aircraft emissions following an approach developed by Cambridge University and MIT. This approached is based on a min/max estimation of ground vehicle emission factors from Zurich airport.

With regard to emission factors of PM from rail traffic, both exhaust emissions and wear particles were examined. The emission factors were determined for different types of locomotives and compared with the EU's and US EPA's emission limits. For wear particles only very limited data were available.

WP 1.3 Emission baseline (TNO)

This WP combines the current information from inventories for the current situation (base year 2005) for all sources and completes the emission inventories for substances and activities where necessary. Generic baseline emission projections for future years 2020 and 2030 have been made for all sources.

Detailed traffic data was collected for selected case studies cities including Rotterdam, Athens, Helsinki, Oslo and London. The criteria employed included:

(i) The datasets have the necessary spatial detail to allow for local air quality modelling.

(ii) Datasets are in line with driving parameters for the emission factors identified in WP 1.1 & WP 1.2.

(iii) The datasets have the necessary temporal dimension to allow for time-differentiated air quality modelling.

Data for all modes have been collected (i.e. road, rail, air, maritime) and transport activity is expressed in line with emission factor definitions. For road, data were collected from existing city traffic counting systems and government owned city transport models whereas for non-road modes government statistics were used.

A baseline emission inventory for main air pollutants has been created for the years 2005, 2020 and 2030. This UNECE-Europe wide inventory covers all relevant anthropogenic emissions. The existing TNO-MACC inventory for 2005 has been used as the baseline for the non-transport sectors, and has been further extended by including BaP and EC emissions for all sectors.

A full gridded emission inventory for 10 substances (including PM10, PM2.5, EC and BaP) to the modellers in SP2 is now available. Furthermore, baseline gridded emission inventories have been calculated for 2020 and 2030 by applying scaling factors to the 2005 grid at the detailed source sector level.

Non-anthropogenic emissions were also examined for mass closure and model-measurement comparison. These include, biogenic organic compounds, biomass burning smoke, wind-blown dust and sea-salt. Depending on the regions and specific episodes, one or more of these sources could be dominant. The task concentrated on actual modelling of these emission fluxes and resulting concentrations of the released pollutants.

A global inventory of emissions from transport modes has been constructed and complementary data to cover all other sources have been collected. This task fell back on existing and on-going research in this field for transport emissions (e.g., QUANTIFY) and overall anthropogenic emissions (IPCC AR5 and the RCPs). The global inventories and emission calculations will be applied in the global modelling activities in SP2.

Emphasis has been put on advancing the spatial detail of emission allocation to allow for improved air quality modelling Therefore, transport-related baseline emissions have been allocated to a 1 by 1 kilometre grid using state-of-the science methods for allocating emissions at a continental scale. The approach underwent continuous improvements over the last years and has proved its potential by being used for the European Pollutant Release and Transfer Register (E-PRTR). The transport activity determined in previous tasks in this WP, combined with the emission factors in the earlier WP's in this SP allow for the construction of an emission baseline. Assessment of EU maritime transport activity, with special attention to port activity, and air transport activity was carried out. It is now possible to account for different loads of main and auxiliary engines as well as for the resulting levels of emissions. This also yielded an improved spatial allocation of in-port emissions to more than 1900 coastal ports based on Eurostat proxy data. For air transport activity, detailed activity rates based on flight plan data have been used for 2005 and projected to future years. Emissions have been calculated for the whole Landing-and-take-off (LTO) cycle including not only from aircrafts at different stages in the cycle (Taxi, Approach, Take-off, Climb-out) but also for ground service equipment.

There considerable advantages of the improved emission baseline dataset including:

i. A higher level of spatial and temporal detail for urban areas has been attempted as a result of detailed data inventory for the case cities and application of the city transport meta-model.
ii. Increased level of spatial detail compared to the state-of-the-art emission inventories for EU-wide transport activity has been reached. The emission baseline with detailed transport emission grids and speciated PM (EC, BaP, PN) is the main output of this SP. It is currently being used in all consequent SP's: as input for air quality modelling (SP2), exposure modelling (SP3), relations and integrated assessment (SP4) and the baseline for mitigation measures assessment (SP5).

Key Results from SP1

i. A state-of-the-art methodology for the quantification of transport PM exhaust and non-exhaust emissions, using emission factors or profiles.
ii. A major dataset containing PM emissions of transport with different levels of detail with respect to spatial distribution. The database was a key input for air quality and exposure models (SP2, SP4 and SP5).
iii. A major dataset with transport activities per mode, and vehicle stocks per age class and technology. This data set was used for analysis of the impact of mitigation measures in SP5.

iv. A new PNC inventory for UNECE Europe for 2005 and the projection years 2020 and 2030. The new inventory focuses on the contribution of the transport sectors.
v. Total PN emissions are projected to halve in the future (Figure 4 and 5).
vi. Land-based transport emissions will change significantly over time. Road transport emissions will decline strongly and will no longer be dominant.
vii. International shipping is the dominant source in 2005, but is expected to decline due to the introduction of low sulphur fuels.
viii. Aviation is recognized as a significant source of (semi-volatile) PN.
ix. Although road vehicle PN EFs are better documented, further work is necessary to account for a number of parameters (such as climatic conditions, mean trip distance evaporation losses) specific to each country. However, although increased accuracy may be achieved by a more detailed procedure, significant differences are not expected given the evolution of vehicle, fuel and after treatment technology. More important is the fact that data for non-road vehicles (shipping, in particular) are limited and need additional research.

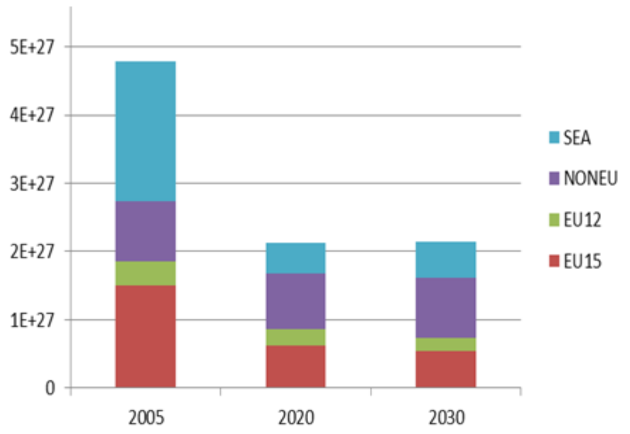


Figure 4 Total particle number emissions for 2005, 2020 and 2030 by country group (Sea is international shipping)

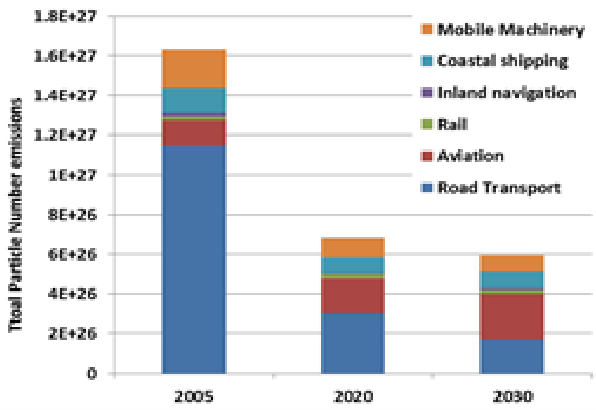


Figure 5 Transport sector total particle number emissions in 2005, 2020 and 2030 excluding International shipping. (Aviation = airport LTO's upto 1000 m)

4.2 SP2 Air quality and exposure (FMI, NILU)

The objectives of SP2 included conducting new measurement campaigns to provide size and chemically resolved information on the contributions from transport related emission sources of particulate matter (PM) with enhanced chemical analysis on the ESCAPE filter samples. These measurements have been used to extend the source apportionment studies based on PM data sets, including size resolved data sets from the TRANSPHORM measurement campaigns and the ESCAPE filter samples. A key objective of SP was to refine and improve the modelling systems currently in use across different spatial and temporal scales, including the treatment of particle number and components of PM.

WP 2.1 Air quality and transport related micro-environment measurements (TNO)

Measurement and analyses of samples was conducted in cooperation with the European ESCAPE (European Study of Cohorts for Air Pollution Effects) project. In total 1200 $PM_{2.5}$ and 1200 PM_{10} samples were collected and both $PM_{2.5}$ and PM_{10} have been analysed on Si, Fe, K, Cu, Ni, S, V and Zn, and only $PM_{2.5}$ samples on EC/OC; eight PAH, including BaP; oxidative potential; hopanes/steranes; oxy-PAH and levoglucosan.

A monitoring campaign in Rotterdam, was undertaken in September 2010. Emission profiles of road traffic, harbour area and airport for size-resolved particle numbers, EC, PAH and elemental composition (i.e. XRF analysis) have been established. Also, the aerosol dynamics of size-resolved particle numbers down-wind of a motorway were studied.

Extra measurement campaigns were conducted in Rotterdam and Thessaloniki on $PM_{2.5}$ and PM_{10} at regional and urban background locations, as well as near transport locations (e.g. road traffic and harbour area). The 24-h samples collected during two months in October-December 2012 have been analysed on black carbon and elemental composition. These data were used for Source Apportionment analysis.

Field measurements were complemented with microenvironment campaigns in Helsinki and Thessaloniki have been completed in April 2011 and the Rotterdam campaign in May 2011. PM was measured during several tracks through these three cities by bus, in a car and by bicycle in order to measure exposure of urban commuters in various transport modes.

Emission measurements of particulate and gas phase species were conducted on-board of sea-going vessels. These campaigns were designed to fill gaps in knowledge on the emission factors from ship engines, in particular EF for engines using the low-sulphur (1% fuel S content) marine fuels imposed by the IMO legislation and the new EU Fuel Directive and EF for PM compounds BaP and other PAH species, metals, EC and OC. Additionally a detailed chemical, physical and microscopic characterisation of PM emissions has been performed involving a number of novel analytical techniques in a broad international collaboration where also researchers outside the TRANSPHORM project participated.

The data of the monitoring campaigns are available on the TRANSPHORM website. The monitoring data collected in the 10 ESCAPE cities (Oslo, Helsinki, Copenhagen, London, various cities in the Netherlands, Munich, Paris, Rome, Catalonya and Athens) are presented as an Excel file on the website of TRANSPHORM.

WP2 has provided concentration and exposure information (source and compound specific) for the project. These measurements and analysis provide a unique database for assessing the health impacts of particulate matter through ESCAPE cohort studies (SP3) and for source apportionment studies. Furthermore, the measurement data in combination with existing measurement data have provided the basis for emission profiles (both chemical and size distributed) used in TRANSPHORM modelling and health impact studies.

WP 2.2 Source apportionment of particulate matter (NILU)

Receptor modelling (statistical analysis of PM chemical composition) has been carried out on the ESCAPE measurement dataset to explore its potential for source apportionment. A significant amount of effort was put into analysing these data but the results did not generally provide the level of certainty required to quantify the individual sources due mainly to long averaging times and limited number of samples. It was found that the spatial variability of the samples and the resulting chemical analyses was not optimal for traditional receptor modelling applications. Only in some cases, such as Oslo, where additional analysis of organic compounds were applied, could the uncertainty in the results be reduced. For this reason additional campaigns specifically designed for source apportionment, were conducted in Rotterdam and Thessaloniki.

It was found that the regional background (long range transport from outside of the city) was the largest contributor to the long term $PM_{2.5}$ exposure within the five cities (see Figure 6). The regional background ranged from 50 - 90% of the total $PM_{2.5}$ exposure. The highest contribution was for the city of Rotterdam whilst the lowest was for Oslo. The contribution of transport to the total regional background $PM_{2.5}$ concentrations was found to vary from city to city. In general the largest single contributor was shipping (5 - 14%) followed by traffic (3 – 7%). Rail was also found to have a non-negligible contribution (2 – 3%). In addition to the individual source contributions the interaction of these separate source sectors in the formation of secondary inorganic nitrate aerosols meant that the total transport contribution was larger than the sum of its parts. In total transport was found to contribute between 12 – 32 % of the total regional background $PM_{2.5}$ at these five cities.

Within the cities the local contribution to the total long term $PM_{2.5}$ exposure was also assessed. In general traffic was the dominant transport contributor to the total $PM_{2.5}$ exposure, ranging from 28% (Oslo) to 3% (Rotterdam). In cities where non-exhaust traffic emissions were explicitly modelled (e.g. Oslo, London and Helsinki) it was found that up to half of the traffic contribution was from non-exhaust emissions. Shipping was found to be as large a contributor as traffic in both Athens (15%) and Rotterdam (2%). Other emissions within the cities also contributed significantly, e.g. 15-20% in Oslo and London, but these emissions were not consistently modelled across the cities.

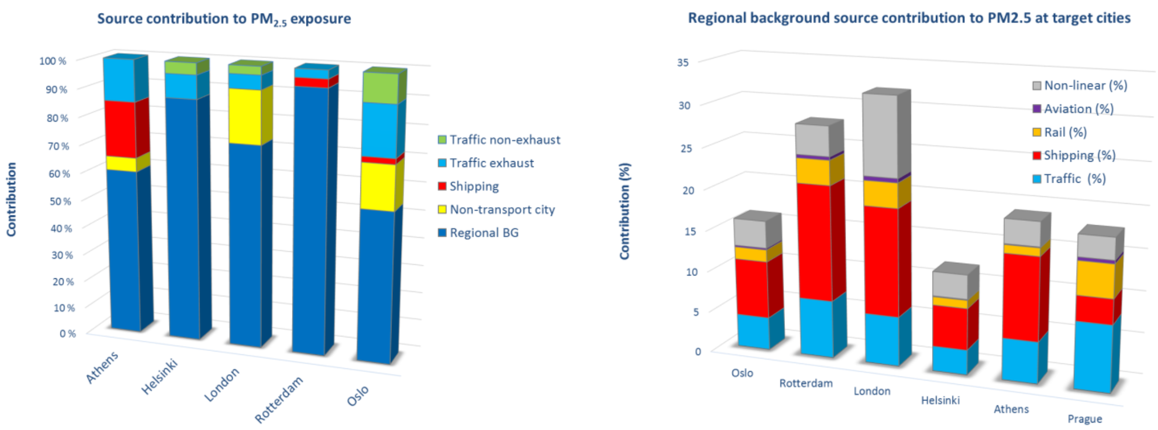


Figure 6 Left: Relative source contributions in the TRANSPHORM target cities for $PM_{2.5}$ for the year 2008, calculated using local dispersion modelling. Source contributions are calculated based on population weighted concentrations. Not all cities differentiate between regional background and non-transport within the city and not all cities differentiate between exhaust and non-exhaust emissions. Regional background concentrations are derived from a combination of regional scale modelling and observations. Right: Relative regional background (LRT) contribution of transport sectors to the total regional background concentrations of $PM_{2.5}$ at six cities in Europe.

In Oslo source apportionment using models was also carried out for PM_{10}, elemental carbon (EC), BaP and particle number concentrations (PNC). This assessment provided insight into the challenges facing authorities when deciding on mitigation strategies. For example PM_{10} reductions in Oslo would be best achieved by reducing the non-exhaust emissions (mostly associated with studded tyres) whilst EC and PNC would be best reduced by reducing exhaust emissions. BaP and $PM_{2.5}$ on the other hand could be reduced by addressing domestic heating emissions.

Comparison was made between the dispersion modelled and receptor modelled source contributions at ESCAPE monitoring sites for Oslo. However, the results of the receptor modelling based on ESCAPE datasets have significant uncertainties so no concrete conclusions could be drawn. With the use of an optimisation technique, the modelled source contributions for Oslo were assessed against fixed monitoring site measurements of $PM_{2.5}$. The results show that the modelled source contributions are close to optimal but that the model may be over predicting the traffic contribution to some degree. This implies that the traffic contribution to $PM_{2.5}$, in Oslo at least, is an upper estimate.

Though originally intended to provide source specific and spatially distributed dispersion model concentrations for health risk assessments carried out in ESCAPE and in SP3, this was not possible given the competing time frames of the projects. Instead, this deliverable assessed the spatial distribution of dispersion models by comparing them with the ESCAPE monitoring data and by comparison with the Land Use Regression (LUR) models developed in ESCAPE. In some cases LUR and dispersion models compared favourably with each other (e.g. London and Rotterdam) but in others (e.g. Oslo) this was not the case.

The comparison of modelling approached was extended to assess the uncertainty of both LUR and dispersion models. The results provide an alternative insight into the LUR methodology, indicating that the homogenous methodology applied in ESCAPE, optimally selecting and fitting a large number of explanatory variables, can easily result in over fitting of the data. It was possible to explain a large part of the correlation found in the ESCAPE LUR models to noise fitting of non-relevant explanatory variables. As a result the spatial distributions produced by LUR models and applied to cohort studies to determine health risks may not be providing suitable concentration fields for these studies. It is argued that dispersion models, especially in combination with observations, should provide more meaningful concentration maps for health risk assessment studies.

WP 2.3 Improved air quality modelling of transport related pollution on the urban scale (AUTH)

A review of the current status regarding the treatment of transport emissions in urban scale air quality modelling was carried out. A main focus was on the application and further development of resuspension emission models available within TRANSPHORM but several other approaches were analysed as well, based on the need for accurate emission data from the transport sector at different spatial and temporal scales. Multi-scale approaches involving combinations of different model types (e.g. nested Eulerian models and sub-grid street level models) were reviewed as a means to better incorporate transport sector emissions into dispersion models. Finally, recent advances in the estimation of emission data from transport sectors such as shipping and aviation were considered, mainly related to the use of GPS and AIS systems. A novel methodology of down-scaling for regional-urban-street scales and system for High-Resolution Forecast Meteorology and Chemistry was demonstrated on an example of Danish Urban Area in the city of Copenhagen (Nuterman et al., 2011).

A model inter-comparison study for the city of Rotterdam was carried out with the participation of five urban modelling groups (NILU, AUTH, TNO, UH-CAIR, FMI). Simulations in the five TRANSPHORM core cities were also carried out, based on approaches that were developed and tested during the Rotterdam intercomparison providing for the first time comprehensive performance baseline for such urban air quality models.

In order to study the relevance of aerosol dynamics in the fate of PNC emitted from traffic in urban areas, the evolution of the particle size distribution with distance from road was modelled using the multicomponent sectional aerosol dynamics model MAFOR (Karl et al., 2011). Comparison with well-documented aerosol models (MONO32 and AEROFOR) and a comprehensive observational dataset on gas phase compounds, aerosol size distribution and chemical composition have been conducted to evaluate the model (Karl et al., 2011).

PNC was also modelled for Europe on a regional scale using CMAQ 4.7.1 and a comparison of the modelled data for the Cabauw field has taken place. In line with previous studies the nucleation mechanism and size distribution of primary particle emission profiles were identified as the main areas for model improvement. The model showed some skill in representing daily and seasonal trends in PNC. This result indicates that the representation of particle number specific emissions and secondary sources could be a limiting factor in CMAQ's ability to model PNC, however more analysis is required at sites across Europe to validate this finding.

Several simplified methods have been extensively tested for the core cities of the project. A simple methodology developed by AUTH (Moussiopoulos et al., 2012) has been formulated in the form of an executable module that can be used for estimating the urban increment concentrations for many major pollutants, which will serve as a tool for quick but reliable impact assessment studies on the European scale. Alternatively, a covariance downscaling method for European wide exposure assessment has also been developed (Denby et al., 2011) and may be applied as a simplified tool for European assessment.

Within the Framework of the European Study of Cohorts for Air Pollution Effects (ESCAPE), the intra-urban spatial variation of NO_2, PM_{10}, $PM_{2.5}$ and its elemental composition was measured in 20 study areas across Europe. LUR models were developed based on these measurements. LUR models for PM_{10}, $PM_{2.5}$ and $PM_{2.5}$ absorbance have been published (Eeftens, 2012). LUR models were successfully developed in the majority of the 20 study areas across Europe, for 8 a priori selected trace elements: copper (Cu), iron (Fe), potassium (K), Nickel (Ni), vanadium (V), sulphur (S), silicon (Si) and zinc (Zn) in both the PM2.5 and PM10 size fractions. Potential predictor variables for LUR model development covering a range of potential emission sources were extracted for all study areas, at the monitoring site locations, using a geographical information system (GIS). A detailed description of the geographical input data used can be found in Eeftens et al (2012).

A direct comparisons between LUR and dispersion modelling (DM) has been made for NO2, PM10 and $PM_{2.5}$, to gain a better understanding of the differences or agreements between LUR and DM estimates for use in epidemiological studies (de Hoogh, 2014). In thirteen ESCAPE study areas we were able to apply dispersion models; 10 study areas used a Gaussian plume model, whereas 3 study areas a Eulerian/chemical transport model for estimating dispersion from localized sources. We compared LUR and DM at the residential addresses of the participants of 13 cohorts for NO_2; 7 for PM_{10} and 4 for $PM_{2.5}$. LUR and dispersion model estimates correlated better for NO2 than for PM10 and $PM_{2.5}$. DM predict a moderate to large portion of the variation measured across the ESCAPE measurement sites, again more so for NO_2 than for PM_{10} and $PM_{2.5}$.

WP 2.4 Regional and global scale air quality modelling (DMI)

Several methods for regional downscaling have been investigated within the project. Two cases were examined where enhanced resolution modelling is applied to improve the level of spatial detail, using the EMEP and Enviro-HIRLAM models. In addition three different sub-grid downscaling methods, intended to improve the exposure assessment at the urban scale for all of Europe, were considered. These involve the redistribution of concentrations based on fine scale emission data, on the statistical covariance of population and on a parameterised model for determining the urban increment. The EMEP model has been run with enhanced resolution of 1/8 x 1/16 degrees latitude – longitude resolution (~7 km, the native resolution of the emissions) for a full year. For this report the calculations have been made for the year 2009. The fine scale model run shows clear improvements in the level of detail.

As a test case for Oslo the regional EMEP 0.2 x 0.2 degrees (~20 km) model output has been downscaled for the city of Oslo into a 0.05 x 0.05 degrees grid (~4 km). This downscaling method redistributes the EMEP concentrations according to the fine scale emission distribution, based on a bottom up emission inventory for Oslo. Compared to the regional model calculations for Oslo, $PM_{2.5}$ concentrations in the most polluted grids are approximately doubled.

A covariance downscaling method is applied that converts gridded regional model PM_{10} concentrations to a gridded population weighted concentration using finer scale information concerning the covariance of the population density, emission data and altitude data. The method is applied to all of Europe to determine the population weighted concentrations of PM_{10} originally calculated by the EMEP model with a 50 x 50 km^2 resolution, effectively attaining a resolution of ~5 km. Application of this method results in an increase of 15% in the total population weighted concentrations for all of Europe.

The third downscaling method by AUTH attempts to define functional relationships between local meteorological parameters, city characteristics and urban emissions to derive an 'urban increment'. The relationships are determined from measured urban increments at a number of locations for key cities. The derived functional relationship (parameterisation) can then be used to estimate the urban increment for any arbitrary location.

A baseline simulation (2005) with the DLR global aerosol model EMAC/MADE was performed by applying the global emission data set generated within the project. The model run was evaluated in detail on the basis of observational data. A method to generate boundary condition data for regional models from the global model output was developed and applied to provide boundary conditions for the regional model ensemble base simulation. The boundary condition data comprise information on the concentration, size distribution and composition of anthropogenic and natural particles as well as the concentration of particle precursors.

Analyses of possible AQ-Climate interactions and mechanisms of climate change influence on transport-related pollution were initiated. Studies of changes in climate and its relationship to air quality are carrying out in several collaborating projects including MEGAPOLI and CITYZEN, PEGASOS and EnsCLIMA. In particular within the Nordic EnsClima network (lead by SMHI) DMI, FMI and Met.no are realising simulations of climate change effects on atmospheric pollution over Northern Europe for 2010-2050 (Langner et al., 2012). The aim of TRANSPHORM was not to directly study this relationship, but to examine results from these projects on the effects of climate change on the policy measures designed for reducing the health effects of transport emissions. As a research outcome, a new version of the online coupled model suitable for climate time-scale long-term simulations (EnvClim), is developed; it is under testing and evaluation at the current stage.

WP2.5 Exposure modelling (THL)

One of the most significant exposure modifiers is size dependent infiltration of particles from outdoor air indoors. Two extensive population based data sets were used in the model development and evaluation: $PM_{2.5}$ mass concentrations (ULTRA data, Helsinki, Finland) or particle number concentrations (EPA STAR2 data, Augsburg, Germany). Particle size dependent infiltration of ambient particles in indoor environments was quantified for subsequent exposure and lung deposition modelling.

Ultrafine particles have high thermokinetic velocities and coarse particles have substantial gravimetric settling velocities as function of increasing particle size. Both factors lead to higher deposition rates indoors and thus lower concentrations of suspended particles. Moreover, the infiltration depends significantly on the ventilation rate, which was accounted for as part of the mass-balance approach.

The infiltration model was integrated with a time-activity model and exposures estimated for other environments including traffic. Additionally, physical activity, corresponding breathing rates, and subsequent uptake of particles in the human respiratory tract were estimated. Time-activity data from previous ULTRA and EPA STAR2 studies was used together with the ambient and personal exposure measurement data from these studies for the model development. The respiratory tract model was adopted from ICRP (1994) and Voutilainen (2004). The developed model is capable of estimating both infiltration and respiratory tract uptake of particles by size in number, surface area and mass metrics.

The results of numerical exposure modelling obtained through the use of air quality models and static and moving populations as well those obtained using deterministic and probabilistic exposure models were evaluated against ambient monitoring and exposure measurements and ESCAPE results, where land use regression models have been applied for the same purpose.

More detailed exposure modelling was performed for the cities of London and Helsinki, allowing also for the movements of the population, and their exposure in various micro-environments. The population exposure model EXPAND was substantially refined, and the latest model version was applied to evaluate the micro-environmental and source category – specific exposures in the Helsinki Metropolitan Area (Soares et al., 2014). Similar analysis was also performed in case of London (Singh et al., 2014). It was found out, e.g., that allowing for the exposure in various micro-environments (instead of only evaluating, e.g., the exposure in residential locations) substantially improves the accuracy of exposure estimates.

The high scientific potential of the developed methods was demonstrated by applying the developed exposure and uptake models from on estimation of exposures and uptakes of ESCAPE cohort members. Originally it was considered as an option to perform these calculations for all five TRANSPHORM target cities and the ESCAPE cohorts located in them. However, as there is no ESCAPE cohort in London and due to the limitations in the availability of geographical location data from the cohorts in Oslo, Rotterdam, and Athens, the calculations were performed only for the ESCAPE FINRISK cohort in Helsinki.

The particle uptakes were estimated in five different regions of the human respiratory tract (including extra thoracic, bronchiolar, alveolar), and in five alternative metrics including besides mass, also particle number and particle surface area that have been suggested as relevant for the health risks. The results showed that especially indoor doses of ambient originating particles are strongly dominated by accumulation particles, which typically have long-range origin and consist of secondary inorganic components. The actual database of size disaggregated annual doses for the 5700 cohort members is provided as an electronic appendix of the report.

Key results from SP2

i. New measurements in Rotterdam and Thessaloniki have provided detailed source apportionment of PM.
ii. The measurement campaigns from TRANSPHORM, in combination with existing measurement data have provided the basis for emission profiles (both chemical and size distributed) in TRANSPHORM modelling and health impact studies.
iii. Collectively these data provide an improved basis for modelling and health impact assessment.
iv. Source apportionment studies in cities and for Europe have highlighted the significance of long range transport in determining $PM_{2.5}$ on local scales. The contribution of the transport sector within these cities, both local and long range, has been determined.

v. The measurements carried out in WP2.1 provide some of the necessary improvements in indoor air quality modelling required for the application to direct exposure-response and dose-response modelling.

vi. Studies comparing LUR with dispersion models have shown that LUR models are not always optimal as spatial predictors of air quality and methodological improvements are required.

vii. Allowing for the exposure in various micro-environments (instead of only evaluating, e.g., the exposure in residential locations or the population weighted concentrations) substantially improves the accuracy of exposure and health estimates.

viii. Integrated exposure and human respiratory tract dose estimation tools were developed for better understanding of particle size dependent doses and analysis of their health relevance in human populations.

On a European scale, we have constructed a model ensemble that contains the results of five European chemical transport models. The advantages of using a model ensemble, instead of any individual model, include (i) a better model performance, (ii) the reliability, variability and uncertainties of model predictions can be readily evaluated, and (iii) the final result is less dependent on possible deficiencies of any individual model. The model ensemble has been used to evaluate European air quality both for the current years and the future.

Four regional-scale dispersion models have been applied to assess air quality in Europe in 2005. A regional model ensemble was constructed based on these model predictions. The objectives of this exercise were (i) to conduct a joint evaluation of the TRANSPHORM regional models, (ii) to understand the uncertainties of scenario computations and disagreements between the model predictions, (iii) to assess optimally the present situation and base-case scenario. Five regional models participated: EMEP, HIRLAM-CAMx, LOTOS-EUROS, SILAM and WRF-CMAQ. Two global models (EMAC, MATCH) were used for assessing the boundary conditions. Emissions were provided by from IER/TNO, and scenarios from USTUT. Each model applied their own meteorological data.

Two procedures were developed for understanding better, and for allowing for the under-prediction of the $PM_{2.5}$ concentrations by the regional models. A so-called “bias correction” was computed that describes the difference of predicted and measured concentrations, in terms of European regions, seasons of the year, and for a whole year. A data assimilation method was also developed for providing for the best possible predictions of $PM_{2.5}$, taking into account both the measured data and modelling.

4.3 SP3: Relationships between transport related PM and health (UU, JRC)

The work plan for SP3 is partly based on using existing literature on health effects of transport related pollution as a basis for the health impact assessment, partly on using and enhancing the recently funded large European Study of Cohorts for Air Pollution Effects (ESCAPE). The first part is self-evident and is in principle available to all projects. The second part is unique to TRANSPHORM and is explained below. The ESCAPE study includes 33 cohorts, subdivided in four major groups:

(1) birth cohorts on pregnancy outcomes, allergy and asthma, and developmental effects;
(2) cohorts on adult respiratory disease outcomes;
(3) cohorts on adult cardiovascular disease outcomes;
(4) cohorts on cancer incidence and mortality outcomes.

The collaboration represents an investment of well over 100 million Euros in the ongoing cohort studies, from a wide range of local, national and international funds. ESCAPE adds assessment of air pollution exposure to these studies, with an emphasis on spatial contrasts in PM and NOx from road transport. Measurements of $PM_{2.5}$, PM_{10} and NOx are being conducted in 20 different areas; measurements of NOx only are being conducted in an additional 16 areas. PM measurements are being conducted on 20 different sites in each area to investigate spatial contrasts while NOx is measured at 40 sites per area.

The funded contribution from TRANSPHORM provided the following new information:

(1) Analysis of the collected PM_{10} filters for elemental content using XRF to have full data on composition of coarse and fine PM. As ESCAPE samples are taken at roadside as well as urban and regional background, this will allow differentiation of tailpipe and non-tailpipe emissions as the tailpipe PM emissions will be almost exclusively in the fine fraction, and the non-tailpipe largely in the coarse mode. The XRF analysis has been completed as planned.
(2) Further chemical and toxicological characterization of PM in a number of ESCAPE study areas that are most informative with respect to impacts of PM from the various transport sectors of interest.
(3) Specifically measurement of characteristic 'markers' for transport related PM will be performed and the results used in source apportionment study as proposed in SP2, WP2.2 to isolate the contribution of the various forms of transport of interest to this study.
(4) Estimation of exposure to PM and possibly other pollutants from various transport sectors for the cohort members, using the exposure models resulting from the Land Use Regression (LUR) models.
(5) Analysis of exposure response functions in participating cohorts, using the specific new exposure data generated by the previous steps.

The decision about which areas are 'most informative' in ESCAPE have been based first on how informative the areas are with respect to the priorities of the current call (road, shipping and air transport), and second on availability of cohort data (some ESCAPE study areas have more and/or larger cohorts than others). The areas chosen are The Netherlands, Barcelona, Munich, Oslo, Copenhagen, Helsinki, London, Rome, Athens and Paris.

With the new information on exposure response functions that will be generated in the previous steps, the impacts of transport related PM pollution on health can be assessed. It should be noted that the effects of long-term exposure (for which we will have new C-R functions) are by far the dominant ones in terms of public health overall. As explained further in SP4 and 5, TRANSPHORM will develop methods for estimating the health impacts (and associated disease burden) of transport-related PM, understood as the health impacts – irrespective of how far in the future they may occur – attributable to (changes in) transport emissions in any one selected year. (TRANSPHORM uses especially the years 2020 and 2030.) This will give a methodological basis for assessing the effects of policies and measures that involve sustained pollution changes). The WPs are briefly described here.

WP3.1 Effects of transport related ambient PM on pregnancy outcomes and childhood diseases (KI)

This WP quantifies the relationship between transport related ambient PM air pollution and pregnancy outcomes and with childhood disease and development. A detailed analysis of literature on quantitative relationships between transport related PM ambient pollution and pregnancy outcomes, childhood asthma, allergy and infections, and child cognitive development has been conducted. TRANSPHORM produces novel concentration response relationships and will form the basis for the assessment of the impact of transport related PM on these health outcomes. A choice has been made to analyze lung function and respiratory infections. The key results are shown in Tables 1 and 2.

Table 1 shows that most of the elemental concentrations in $PM_{2.5}$ and PM_{10} were negatively associated with lung function (expressed as FEV_1). Only the relationship with Ni in PM_{10} reached statistical significance.

Table 2 shows that all elements in $PM_{2.5}$ and PM_{10} were positively associated with pneumonia in the first years of life. The associations with Fe, K and Zn in PM2.5, and of Ni, S and Zn in PM_{10} reached statistical significance in the meta analyses.
These results have been published in the meantime (Eeftens et al., Epidemiology. September 2014; 25(5):648-57 and Fuertes et al., Int. J. Hyg. Environ. Health. 2014 May 29. pii: S1438-4639(14)00043-1. doi: 10.1016/j.ijheh.2014.05.004. [Epub ahead of print]).

A general assessment of the elemental analyses results follows after the section devoted to WP3.4.

Table 1: Crude and adjusted associations [a] between estimated air pollution levels at the current address and FEV1: results from random-effects meta-analyses expressed as percent change with 95% confidence intervals, I^2 and p-value of heterogeneity of effect estimates between cohorts.

Exposure	N of cohorts	Model 2[b]	I^2 (p-value)
Cu $PM_{2.5}$	5	-0.72 (-3.87 , 2.43)	71 (0.0076)
Fe $PM_{2.5}$	5	-0.88 (-2.90 , 1.15)	62 (0.0337)
K $PM_{2.5}$	3[c]	0.50 (-1.04 , 2.04)	0 (0.9448)
Ni $PM_{2.5}$	4[d]	-0.57 (-2.45 , 1.31)	33 (0.2173)
S $PM_{2.5}$	5	-1.69 (-5.17 , 1.80)	54 (0.0672)
Si $PM_{2.5}$	5	-1.28 (-4.83 , 2.26)	53 (0.0733)
V $PM_{2.5}$	4[e]	-1.11 (-3.54 , 1.31)	14 (0.3236)
Zn $PM_{2.5}$	5	0.00 (-1.48 , 1.48)	40 (0.1546)
Cu PM_{10}	5	-0.33 (-1.32 , 0.66)	0 (0.5982)
Fe PM_{10}	5	-0.43 (-1.31 , 0.46)	0 (0.8573)
K PM_{10}	5	0.06 (-0.54 , 0.66)	0 (0.7052)
Ni PM_{10}	5	**-1.57 (-2.74 , -0.40)**	8 (0.3597)
S PM_{10}	5	-2.3 (-4.71 , 0.12)	38 (0.1682)
Si PM_{10}	5	-0.98 (-3.43 , 1.47)	44 (0.1267)
V PM_{10}	5	-0.15 (-3.62 , 3.32)	48 (0.1037)
Zn PM_{10}	5	-0.6 (-1.59 , 0.39)	0 (0.4663)

[a] Associations are presented for the following increments: 5 ng/m³ Cu $PM_{2.5}$, 20 ng/m³ Cu PM_{10}, 100 ng/m³ Fe $PM_{2.5}$, 500 ng/m³ Fe PM_{10}, 50 ng/m³ K $PM_{2.5}$, 100 ng/m³ K PM_{10}, 1 ng/m³ NIi $PM_{2.5}$, 2 ng/m³ Ni PM_{10}, 200 ng/m³ S $PM_{2.5}$, 200 ng/m³ S PM_{10}, 100 ng/m³ Si $PM_{2.5}$, 500 ng/m³ SIi PM_{10}, 2 ng/m³ V $PM_{2.5}$, 3 ng/m³ V PM_{10}, 10 ng/m³ Zn $PM_{2.5}$, 20 ng/m³ Zn PM_{10}
[b] Model 2: adjusted for recent respiratory infections, non-native ethnicity/nationality, parental education, allergic mother, allergic father, breastfeeding, maternal smoking during pregnancy, smoking at home, mould/dampness at home, furry pets at home.
[c] Not available for GINI/LISA North and MAAS
[d] Not available for BAMSE
[e] Not available for GINI South.

Table 2: Association between pneumonia (0-2 years) and elemental composition of PM: Results from random-effects meta-analyses (ORs and 95%-CIs) and I^2 (p-value) of test for heterogeneity of effect estimates between cohorts[a]

Constituent	N of cohorts	Model 3[b]	I^2 (p-value)[c]
CU $PM_{2.5}$	7	1.55 (0.92, 2.61)	0.62 (0.01)
FE $PM_{2.5}$	7	**1.60 (1.08, 2.38)**	0.62 (0.02)
K $PM_{2.5}$	5[d]	**2.58 (1.21, 5.51)**	0.69 (0.01)
Ni $PM_{2.5}$	6[e]	1.14 (0.94, 1.37)	0 (0.59)
S $PM_{2.5}$	7	2.07 (0.72, 5.94)	0.75 (0.00)
Si $PM_{2.5}$	7	1.93 (0.75, 5.01)	0.74 (0.00)
V $PM_{2.5}$	6[f]	2.10 (0.69, 6.44)	0.49 (0.08)
Zn $PM_{2.5}$	7	**1.60 (1.33, 1.92)**	0.04 (0.40)
CU PM_{10}	7	1.13 (0.89, 1.44)	0.24 (0.25)
FE PM_{10}	7	1.29 (0.95, 1.76)	0.53 (0.05)
K PM_{10}	7	1.45 (0.96, 2.19)	0.50 (0.06)
Ni PM_{10}	7	**1.26 (1.01, 1.58)**	0 (0.95)
S PM_{10}	7	**2.15 (1.12, 4.12)**	0.61 (0.02)
Si PM_{10}	7	1.74 (0.95, 3.18)	0.63 (0.01)
V PM_{10}	7	1.54 (0.84, 2.85)	0.28 (0.21)
Zn PM_{10}	7	**1.62 (1.28, 2.05)**	0.11 (0.35)

[a] Information was collected at 12 and 24 months of age for BAMSE, GINIplus, and PIAMA, at 6, 12, 18, and 24 months for LISAplus, at 6 and 15 months for GASPII, at 18 months for INMA, and at 36 months for MAAS (information before three years was not available for this latter cohort). ORs are presented for the following increments: 5 ng/m³ Cu $PM_{2.5}$, 20 ng/m³ Cu PM_{10}, 100 ng/m³ Fe $PM_{2.5}$, 500 ng/m³ Fe PM_{10}, 50 ng/m³ K $PM_{2.5}$, 100 ng/m³ K PM_{10}, 1 ng/m³ NIi $PM_{2.5}$, 2 ng/m³ Ni PM_{10}, 200 ng/m³ S $PM_{2.5}$, 200 ng/m³ S PM_{10}, 100 ng/m³ Si $PM_{2.5}$, 500 ng/m³ SIi PM_{10}, 2 ng/m³ V $PM_{2.5}$, 3 ng/m³ V PM_{10}, 10 ng/m³ Zn $PM_{2.5}$, 20 ng/m³ Zn PM_{10}
Model 3: Adjusted for sex, region (BAMSE), older siblings, breastfeeding, parental atopy, daycare, smoking during pregnancy, environmental tobacco smoke in home, parental SES (parental occupation) gas, mold and intervention (GINIplus, PIAMA, MAAS)
[c] Test for heterogeneity for Model 3
[d] Not available for GINI/LISA north (Wesel city) nor MAAS
[e] Not available for BAMSE
[f] Not available for GINI/LISA south (Munich city)

WP3.2 Effects of transport related ambient PM on adult respiratory disease (STI)

The relationship between transport related ambient PM air pollution and chronic bronchitis, COPD and the incidence of asthma has been quantified using NO2 and Black Carbon as traffic markers within ESCAPE. It was noted that no clear associations with these markers were found, and cohorts were relatively small compared to cohorts in other work packages.

For the respiratory health outcomes in adults, intense analyses for an assessment of associations between the markers of air pollution (provided by TRANSPHORM) and respiratory health in adults has been completed. This involves respiratory symptoms, lung function, chronic obstructive lung diseases (COPD) and asthma. The focus is both on incidence and prevalence. In the data cleaning and preparation phase, it became evident that the spatial model outputs for the studies with data on adult respiratory health were not including the entire samples of the involved cohorts, namely ECRHS, EGEA, E3N, NSHD, SALIA and SAPALDIA. This comes with the challenge of reduced statistical power and non-convergence of some of the models. Further details can be found in the Deliverable.

WP3.3 Effects of transport related ambient PM on adult cardiovascular disease (HMGU)
This WP quantifies the relationship between transport related ambient PM air pollution and various cardiovascular disease markers and outcomes including blood pressure and prevalence of hypertension and incident coronary events. A choice has been made to analyze the incidence of coronary events, and the levels of systemic markers of inflammation as endpoints. The key results are shown in Tables 3 and 4.

Table 3 shows generally positive associations between elements in PM2.5 and PM10 on CRP and fibrinogen. Some of these (Cu in PM2.5 and Fe in PM10 for CRP, and Zn in PM2.5 for fibrinogen) reached statistical significance in the meta analyses.

Table 4 shows that all elements in PM2.5 and PM10 were positively associated with the incidence of coronary events. Only the associations with K in PM2.5 and PM10 reached statistical significance.

The results of these analyses have been submitted for publication.

Table 3: Effects of PM components on C-reactive protein (CRP) and fibrinogen: Results from random-effects meta-analyses (percent changes from the outcome mean and 95%-CIs) and I^2 (p-value) of test for heterogeneity of effect estimates between cohorts.

	CRP (KORA, HNR, SAPALDIA, FINRISK, TWINGENE)			**Fibrinogen** (KORA, HNR, SIXTY, FINRISK)		
		Model 1[b]			**Model 1**[b]	
Exposure[a]	N cohorts	%change (95%-CI)	I^2 (p-value[c])	N cohorts	%change (95%-CI)	I^2 (p-value[c])
Cu $PM_{2.5}$	5	6.3*(0.7-12.3)	0 (0.59)	4	0.6 (-1.5-2.7)	61 (0.1)
Fe $PM_{2.5}$	5	3.4 (-0.3-7.2)	0 (0.69)	4	0.7 (-0.3-1.8)	37 (0.18)
K $PM_{2.5}$	4[d]	-3.4 (-12.7-6.8)	52 (0.13)	3[d]	-1.1 (-2.6-0.5)	0 (0.49)
Ni $PM_{2.5}$	3[e,f]	2.4 (-10.9-17.7)	77 (0.1)	3[e]	-0.3 (-2.6-2.1)	40 (0.23)
S $PM_{2.5}$	4[f]	0.9 (-6.1-8.4)	10 (0.34)	4	0.0 (-3.0-2.9)	58 (0.34)
Si $PM_{2.5}$	4[f]	2.5 (-2.2-7.4)	6 (0.45)	4	0.5 (-2.0-3.0)	76 (0.01)
V $PM_{2.5}$	3[f,g]	2.9 (-3.1-9.3)	0 (0.68)	3[g]	-1.8 (-4.4-0.9)	0 (0.62)
Zn $PM_{2.5}$	5	2.1 (-2.8-7.2)	7 (0.34)	4	1.2*(0.1-2.4)	8 (0.52)
Cu PM_{10}	5	2.7 (-1.2-6.7)	0 (0.6)	4	0.4 (-1-1.8)	56 (0.15)
Fe PM_{10}	5	3.6*(0.3-7.1)	0 (0.86)	4	0.2 (-1.3-1.6)	68 (0.03)
K PM_{10}	5	3.4 (-5.3-13.0)	75 (0.02)	4	0.5 (-2.5-3.5)	87 (0.01)
Ni PM_{10}	4[f]	2.0 (-5.9-10.5)	28 (0.31)	4	0.6 (-4.0-5.2)	84 (0.07)
S PM_{10}	4[f]	0.3 (-6.5-7.7)	12 (0.32)	4	0.0 (-2.4-2.5)	44 (0.32)
Si PM_{10}	4[f]	2.3 (-3.4-8.3)	53 (0.18)	4	0.4 (-2.3-3.1)	85 (0.01)
V PM_{10}	3[f,g]	0.8 (-10.1-13.1)	21 (0.31)	3	-0.3 (-2.4-1.7)	0 (0.82)
Zn PM_{10}	5	-0.1 (-4.5-4.4)	0 (0.51)	4	0.8 (-0.4-1.9)	14 (0.31)

[a] Percent changes are presented for the following increments: 5 ng/m³ Cu $PM_{2.5}$, 20 ng/m³ Cu PM_{10}, 100 ng/m³ Fe $PM_{2.5}$, 500 ng/m³ Fe PM_{10}, 50 ng/m³ K $PM_{2.5}$, 100 ng/m³ K PM_{10}, 1 ng/m³ Ni $PM_{2.5}$, 2 ng/m³ Ni PM_{10}, 200 ng/m³ S $PM_{2.5}$, 200 ng/m³ S PM_{10}, 100 ng/m³ Si $PM_{2.5}$, 500 ng/m³ SIi PM_{10}, 2 ng/m³ V $PM_{2.5}$, 3 ng/m³ V PM_{10}, 10 ng/m³ Zn $PM_{2.5}$, 20 ng/m³ Zn PM_{10},

[b] Model 1: adjusted for age, body mass index, sex, education, smoking status, physical activity, and alcohol intake;

[c] Test for heterogeneity, [d] Not available for RECALL, [e] Not available for TWINGENE/SIXTY, [f] Not available for SAPALDIA, [g] Not available for KORA, *p-value of pooled effect estimate<0.05

Table 4: Association between incidence of coronary events and elemental composition of PM in ten European cohorts (FINRISK, SNAC-K, SALT, TWINGENE/SIXTY, SDPP, DCH, HNR, KORA, SIDRIA Turin, SIDRIA Rome): Results from random-effects meta-analyses (hazard ratios and 95%-CIs) and I^2 (p-value) of test for heterogeneity of effect estimates between cohorts.

	Coronary events Base confounder model[b]		
Exposure[a]	N cohorts	Hazard Ratio (95%-CI)	I^2 (p-value[c])
Cu $PM_{2.5}$	10	1.04 (0.94-1.16)	5 (0.39)
Fe $PM_{2.5}$	10	1.06 (0.98-1.15)	16 (0.41)
K $PM_{2.5}$	9[d]	1.17 (1.04-1.31)	0 (0.51)
Ni $PM_{2.5}$	6[e]	1.03 (0.82-1.29)	21 (0.21)
S $PM_{2.5}$	10	1.02 (0.80-1.28)	0 (0.87)
Si $PM_{2.5}$	10	1.09 (0.87-1.36)	73 (0.08)
V $PM_{2.5}$	9[h]	1.21 (0.66-2.25)	76 (0.10)
Zn $PM_{2.5}$	10	1.08 (0.92-1.26)	0 (0.59)
Cu PM_{10}	10	1.02 (0.92-1.14)	47 (0.19)
Fe PM_{10}	10	1.06 (0.94-1.21)	58 (0.08)
K PM_{10}	10	1.06 (1.00-1.12)	0 (0.98)
Ni PM_{10}	10	1.09 (0.94-1.26)	2 (0.42)
S PM_{10}	10	1.18 (0.99-1.42)	0 (0.76)
Si PM_{10}	10	1.08 (0.94-1.24)	69 (0.58)
V PM_{10}	9[f]	1.09 (0.92-1.29)	0 (0.82)
Zn PM_{10}	10	1.08 (0.96-1.21)	3 (0.86)

[a] Hazard ratios are presented for the following increments: 5 ng/m³ Cu $PM_{2.5}$, 20 ng/m³ Cu PM_{10}, 100 ng/m³ Fe $PM_{2.5}$, 500 ng/m³ Fe PM_{10}, 50 ng/m³ K $PM_{2.5}$, 100 ng/m³ K PM_{10}, 1 ng/m³ Ni $PM_{2.5}$, 2 ng/m³ Ni PM_{10}, 200 ng/m³ S $PM_{2.5}$, 200 ng/m³ S PM_{10}, 100 ng/m³ Si $PM_{2.5}$, 500 ng/m³ Si PM_{10}, 2 ng/m³ V $PM_{2.5}$, 3 ng/m³ V PM_{10}, 10 ng/m³ Zn $PM_{2.5}$, 20 ng/m³ Zn PM_{10};
[b] Base confounder model: adjusted for age (time variable), year of enrolment, sex, marital status, education, occupation, smoking status, smoking duration, smoking intensity and socioeconomic area-level indicators;
[c] Test for heterogeneity;
[d] Not available for HNR;
[e] Not available for SALT, SDPP, SNAC-K, TWINGENE/SIXTY;
[f] Not available for KORA.

WP3.4 Effects of transport related ambient PM on adult mortality and cancer incidence (IC)

This WP quantifies the relationship between transport related ambient PM air pollution and adult mortality. A choice has been made to analyze natural cause mortality and cardiovascular disease mortality as endpoints. The key results are shown in Tables 5 and 6.

Table 5 shows that in the final model 3 with one exception (Cu in $PM_{2.5}$) all elements in $PM_{2.5}$ and PM10 were positively associated with natural cause mortality. In the meta analyses, associations with S and Si in $PM_{2.5}$, and K and Ni in PM_{10} were significant.

Table 6 shows that there was no clear pattern in associations between elements in $PM_{2.5}$ and PM_{10} with cardiovascular disease mortality. Papers have been accepted (Beelen et al,, EHP 2014) and published, respectively (Wang et al., Environ Int. 2014 May; 66:97-106).

Assessment of associations with elements in $PM_{2.5}$ and PM_{10}

As the six tables show, there were quite a few significant positive associations between elements in $PM_{2.5}$ and PM_{10} and health endpoints. It should be noted that the results presented so far are from analyses without adjustment for PM mass. We are still investigating to what extent these associations with PM elements are independent of those with PM mass. We should also note that the results so far are quite variable in the sense that different elements are associated with different health endpoints. It is not clear at the moment whether this reflects true underlying biological differences in mechanism or, mostly, statistical variation. Finally, the reported associations are with modeled elemental concentrations. For instance, whereas K is generally seen as a marker for biomass combustion, modeled K may be a function of other GIS variables such as traffic or population density as GIS databases generally are not adequate for pinpointing local sources of biomass combustion.

Table 5: Association between natural cause mortality and elemental composition of PM: Results from random-effects meta-analyses (HRs and 95%-CIs) and I^2 (p-value) of test for heterogeneity of effect estimates between cohorts (using main confounder models 1, 2 and 3) [a]

Exposure	N of cohorts	Model 1[b]	Model 2[b]	Model 3[b]	I^2 (p-value)[c]
Cu $PM_{2.5}$	17	1.10 (1.01-1.20)	1.01 (0.95-1.08)	0.99 (0.92-1.06)	13.4 (0.30)
Fe $PM_{2.5}$	17	1.12 (1.05-1.20)	1.05 (0.99-1.11)	1.04 (0.98-1.10)	18.9 (0.23)
K $PM_{2.5}$	16[d]	1.05 (0.96-1.13)	1.05 (0.97-1.13)	1.07 (0.98-1.17)	34.4 (0.09)
Ni $PM_{2.5}$	12[e]	1.13 (1.02-1.24)	1.06 (0.95-1.17)	1.05 (0.96-1.16)	29.7 (0.16)
S $PM_{2.5}$	16[f]	1.32 (1.11-1.57)	1.17 (1.08-1.27)	1.15 (1.06-1.25)	0 (0.94)
Si $PM_{2.5}$	15[g]	1.19 (1.05-1.34)	1.10 (1.01-1.20)	1.09 (1.01-1.18)	19.4 (0.24)
V $PM_{2.5}$	14[h]	1.23 (1.04-1.47)	1.08 (0.95-1.22)	1.08 (0.93-1.25)	36.6 (0.08)
Zn $PM_{2.5}$	17	1.07 (0.98-1.16)	1.04 (0.99-1.08)	1.03 (0.98-1.09)	27.2 (0.14)
Cu PM_{10}	17	1.09 (1.02-1.17)	1.04 (0.97-1.11)	1.03 (0.96-1.09)	37.0 (0.06)
Fe PM_{10}	17	1.11 (1.05-1.18)	1.06 (1.00-1.12)	1.05 (0.99-1.11)	33.0 (0.09)
K PM_{10}	17	1.06 (0.99-1.13)	1.03 (1.00-1.06)	1.03 (1.00-1.06)	0 (0.68)
Ni PM_{10}	16[f]	1.24 (1.06-1.45)	1.10 (1.00-1.21)	1.10 (1.01-1.21)	29.6 (0.13)
S PM_{10}	16[f]	1.30 (1.10-1.53)	1.12 (1.01-1.25)	1.12 (0.99-1.26)	33.2 (0.10)
Si PM_{10}	16[f]	1.17 (1.02-1.34)	1.05 (0.97-1.14)	1.04 (0.96-1.13)	52.9 (0.01)
V PM_{10}	16[f]	1.09 (0.93-1.28)	1.04 (0.94-1.14)	1.03 (0.94-1.13)	15.2 (0.28)
Zn PM_{10}	17	1.09 (1.01-1.18)	1.05 (1.00-1.11)	1.04 (0.98-1.10)	38.6 (0.05)

[a] HRs are presented for the following increments: 5 ng/m³ Cu $PM_{2.5}$, 20 ng/m³ Cu PM_{10}, 100 ng/m³ Fe $PM_{2.5}$, 500 ng/m³ Fe PM_{10}, 50 ng/m³ K $PM_{2.5}$, 100 ng/m³ K PM_{10}, 1 ng/m³ NIi $PM_{2.5}$, 2 ng/m³ Ni PM_{10}, 200 ng/m³ S $PM_{2.5}$, 200 ng/m³ S PM_{10}, 100 ng/m³ Si $PM_{2.5}$, 500 ng/m³ SIi PM_{10}, 2 ng/m³ V $PM_{2.5}$, 3 ng/m³ V PM_{10}, 10 ng/m³ Zn $PM_{2.5}$, 20 ng/m³ Zn PM_{10}

[b] Model 1: adjusted for gender and calendar time; Model 2: adjusted for Model 1 + smoking status, smoking, smoking duration, environmental tobacco smoke, fruit intake, vegetables intake, alcohol consumption, body mass index, educational level, occupational exposure, employment status, marital status; and Model 3: adjusted for Model 2 + area-level socio-economic status

[c] Test for heterogeneity for model 3

[d] Not available for SALIA

[e] Not available for SNAC-K, SALT/Twin gene, 60-yr/IMPROVE, SDPP, SAPALDIA

[f] Not available for SAPALDIA

[g] Not available for SAPALDIA, EPIC-Athens

[h] Not available for KORA, VHM&PP, SAPALDIA

Table 6: Association between CVD mortality and elemental composition of PM: Results from random-effects meta-analyses (HRs and 95%-CIs) and I^2 (p-value) of test for heterogeneity of effect estimates between cohorts (using main confounder models 1, 2 and 3) [a]

Exposure	N of cohorts	Model 1[b]	Model 2[b]	Model 3[b]	I^2 (p-value)[c]
Cu $PM_{2.5}$	16	1.03 (0.85-1.25)	0.94 (0.79-1.12)	0.87 (0.71-1.07)	46.5 (0.02)
Fe $PM_{2.5}$	16	1.09 (0.94-1.26)	1.02 (0.89-1.17)	1.00 (0.88-1.13)	29.0 (0.13)
K $PM_{2.5}$	15[d]	0.98 (0.94-1.02)	0.98 (0.94-1.02)	0.98 (0.94-1.02)	0 (0.51)
Ni $PM_{2.5}$	11[e]	1.04 (0.84-1.28)	0.95 (0.75-1.20)	0.94 (0.76-1.17)	45.4 (0.05)
S $PM_{2.5}$	15[f]	1.24 (0.95-1.62)	1.07 (0.94-1.21)	1.05 (0.92-1.20)	0 (0.83)
Si $PM_{2.5}$	14[g]	1.26 (0.97-1.65)	1.19 (0.93-1.54)	1.15 (0.91-1.46)	53.1 (0.01)
V $PM_{2.5}$	13[h]	1.14 (0.84-1.54)	0.99 (0.78-1.26)	0.99 (0.79-1.25)	28.1 (0.16)
Zn $PM_{2.5}$	16	1.07 (0.89-1.28)	1.05 (0.90-1.23)	1.04 (0.88-1.22)	56.1 (0.003)
Cu PM_{10}	16	1.01 (0.88-1.16)	0.95 (0.82-1.11)	0.93 (0.81-1.08)	48.7 (0.02)
Fe PM_{10}	16	1.06 (0.94-1.20)	1.00 (0.87-1.15)	0.98 (0.85-1.12)	49.9 (0.01)
K PM_{10}	16	1.03 (0.92-1.16)	1.01 (0.92-1.10)	1.01 (0.90-1.12)	22.7 (0.20)
Ni PM_{10}	15[f]	1.12 (0.94-1.35)	1.01 (0.89-1.15)	1.01 (0.88-1.15)	0 (0.68)
S PM_{10}	15[f]	1.31 (1.00-1.73)	1.15 (0.90-1.46)	1.13 (0.87-1.46)	45.6 (0.03)
Si PM_{10}	15[f]	1.12 (0.93-1.35)	1.04 (0.89-1.22)	1.02 (0.88-1.17)	44.6 (0.02)
V PM_{10}	15[f]	1.04 (0.80-1.35)	0.98 (0.80-1.19)	0.97 (0.80-1.18)	20.8 (0.22)
Zn PM_{10}	16	1.08 (0.92-1.27)	1.05 (0.92-1.20)	1.01 (0.87-1.18)	57.8 (0.002)

[a] HRs are presented for the following increments: 5 ng/m³ Cu $PM_{2.5}$, 20 ng/m³ Cu PM_{10}, 100 ng/m³ Fe $PM_{2.5}$, 500 ng/m³ Fe PM_{10}, 50 ng/m³ K $PM_{2.5}$, 100 ng/m³ K PM_{10}, 1 ng/m³ Ni $PM_{2.5}$, 2 ng/m³ Ni PM_{10}, 200 ng/m³ S $PM_{2.5}$, 200 ng/m³ S PM_{10}, 100 ng/m³ Si $PM_{2.5}$, 500 ng/m³ SIi PM_{10}, 2 ng/m³ V $PM_{2.5}$, 3 ng/m³ V PM_{10}, 10 ng/m³ Zn $PM_{2.5}$, 20 ng/m³ Zn PM_{10}
[b] Model 1: adjusted for gender and calendar time; Model 2: adjusted for Model 1 + smoking status, smoking, smoking duration, environmental tobacco smoke, fruit intake, vegetables intake, alcohol consumption, body mass index, educational level, occupational exposure, employment status, marital status; and Model 3: adjusted for Model 2 + area-level socio-economic status
[c] Test for heterogeneity for model 3
[d] Not available for SALIA [e] Not available for SNAC-K, SALT/Twin gene, 60-yr/IMPROVE, SDPP, SAPALDIA
[f] Not available for SAPALDIA [g] Not available for SAPALDIA, EPIC-Athens [h] Not available for KORA, VHM&PP, SAPALDIA

WP3.5 Methods for health impact assessment of transport related PM (IOM)

It was established early in the project that modelling results for the airborne concentrations of traffic-related air pollutants would be created and provided only for certain calendar years; notably a baseline year (notionally 2008), and future years such as 2020, 2030. This implied that the framework for health impact assessment would be pinned to those years. Consideration of lagged effects raised the question of whether an assessment was for the health effects in a specific year (based on concentrations in that and preceding years) or for the health effects of on year's pollution, whenever they might occur in that and/or subsequent years. It was agreed that the latter was the appropriate approach, and consistent with the pollution concentrations being for specific years.

It was intended that an overall integrated assessment tool would be developed in WP4.1. WP3.5 was intended to develop components of that overall methodology, in particular, those components (i) linking concentration and/or exposure and/or internal dose, with risk of mortality, disease, or other health outcome; and (ii) dealing with background rates of disease or other health effect, across the EU. In this way WP3.5 was to be a bridge between the rest of SP3, and SP4, feeding methodology and concentration-response functions into WP4.1 and so into the work of SP4 and SP5, of predicting the future health impacts of current or future transport emissions and associated PM exposures.

While the TRANSPHORM project was being carried out, there was a separate and independent review of the current evidence on health effects of air pollutants, and concentration-response functions (CRFs) for those relationships. These were reviewed under the projects REVIHAAP and HRAPIE. HRAPIE, in particular, published recommendations for evidence-based CRFs for use in health impact assessments in Europe. The report distinguished core recommendations for CRFs, for which the evidence was considered reliable, and possible additions where the evidence was less secure. In the interests of European harmonization, it was agreed that TRANSPHORM would adopt the core recommendations of HRAPIE. These are detailed in Table 7 below.

For long-term effects of particulate air pollution, the only core recommendation from HRAPIE was to quantify all-cause mortality (from natural causes) as related to annual concentrations of $PM_{2.5}$. An implication of this decision was that new concentration-response functions based on finely-disaggregated PM, derived from the detailed size-fractionated and speciated modeling of transport PM planned within TRANSPHORM (SP2), would not be used in health impact assessment.

Methods for health impact assessments include the procedures or algorithms by which calculations are made. In earlier projects, a distinction had been drawn between estimating (or predicting) the pollution-related burden of a disease or mortality - how many cases or deaths - in a particular year and predicting the total impact over time of a permanent change or changes in pollution concentrations. The distinction is held important because changes in projected mortality rates or risks have the side-effect of changing the populations in subsequent years. While burden calculations can be based on standard methods for estimating attributable deaths or cases, impact predictions for mortality require more complicated methods based on life-table calculations for age-specific sub-cohorts. As modelling results were to be available only for specific year, methods were specified that estimated the numbers of pollution-related attributable deaths, and predicted the reductions in those numbers that would be associated with reduced pollution concentrations. Age-specific deaths could be converted to life-years using baseline estimates of age-specific life expectancy (or their age-weighted average as a shortcut), and economic valuations applied top those life-years.

Case studies using these methods were planned for selected European cities, and for Europe as a whole. It was decided that those for the cities would assess only mortality effects from $PM_{2.5}$, whereas the Europe-wide work, which would utilize the Ecosense system, could include other CRFs (SP5). Baseline mortality data for 2008 or close years were obtained from city representatives, while country-specific data were obtained from EU databases.

WP3.5. was planned to include two other aspects. First, work would be done to estimate internal dose and, via internal dose, to estimate risks to health, with a view to incorporating time-activity patterns, individual exposures and internal dose estimates within the full chain analyses. While being challenging, because to apply results at a European level would be data-intensive, and we anticipate important gaps in data and evidence, we consider this to be an important step forward. The methodology suggested takes into account personal exposure assessment via the integration of personal sensor measurements, time-activity patterns of the exposed population, chemical and toxicological analysis of sampled particles, and internal dose modeling especially with regard to lung deposition processes. The resulting internal dose refers not only to the inhaled particles but also toxicants such as PAHs with well-characterized, validated toxicity profiles. Coupling the biokinetics of the inhaled particles with the toxicity profile of their xenobiotic content, risk estimates by age group are derived for long-term exposure. In addition, the deposition of PM in the human respiratory tract segregated according to their size distribution was coupled to the oxidative stress potency of the respective PM fractions as quantified using the reactive oxidative species (ROS) assay. Thus, the actual toxic burden can be estimated as the integral of oxidative stress potency and the actual amount of PM deposited across the different HRT regions. This allowed us to derive a new exposure metric integrating oxidative stress potency that is different for to different regions of the human respiratory tract. Considering the importance of oxidative stress as a local, as well as systemic inflammatory mediator, this new exposure metric should allow as to derive more refined associations between exposure to PM and different health endpoints, which are affected by oxidative stress responses at the cellular level. In this way, health impact to the population of interest can be reckoned. The methodology has been applied in one of the TRANSPHORM city cases, Thessaloniki in northern Greece.

In summary, TRANSPHORM health impact assessment methodology developed calculation procedures tailored to the modelled pollution concentrations using the latest available and standardised CRFs as recommended by the REVIHAAP/HRAPIE review process.

Key results from SP3

Tables 1-6 provide significant results of the analyses of the C/R functions. HIA methods were employed in case studies for several European cities. Modellers provided population-weighted average concentrations of $PM_{2.5}$, elemental carbon and particle number counts for the cities, for a baseline year taken to be 2008 and for 2020 under selected transport scenarios. Impact assessments were made for all-cause mortality attributable to the chosen pollutants. Table 8 summarises the results for $PM_{2.5}$, from which it is seen that considerable improvements in mortality burden are achieved under the scenario of measures already agreed (aka ‘Business as Usual’), whereas the additional measures considered give little added benefit.

The novel methodology incorporating internal dose and personal exposure assessment for linking exposure to PM and adverse health outcomes was also developed.

Table 7 Summary of CRF recommendations from HRAPIE

Particulate matter, long term

Pollutant metrics	**Heath outcome**	**Group[3]**	**RR (95%CI) per 10 µg/m³**	**Range of concentr.**	**Source of background health data**	**Source of CRF**	**Comments, including justification for B Group classification**
$PM_{2.5}$, annual mean	Mortality, all cause (natural), age 30+	A*	1.062 (1.040 – 1.083)	All	WHO mortality database, http://data.euro.who.int/hfamdb/. The rates for deaths from all natural causes (ICD-10 chapters I-XVIII, codes A-R) in each of the 53 WHO EURO countries, for the latest year with available data.	Meta-analysis of 13 cohort studies with results published by Jan 3013, Hoek et al 2013	

* Component of Total

[3] For outcome pairs in Group A and B, the expert group has judged that there is sufficient evidence for causality of effects, as reviewed in REVIHAAP. For Group A there is enough available data enabling reliable quantification of effects. For Group B, there is more uncertainty in the precision of estimates being used for quantification of the effects. The effect estimates in pairs marked by * contribute to the total effect (i.e. the effects are additive).

Particulate matter, short term

Pollutant metrics	Heath outcome	Group[4]	RR (95%CI) per 10 µg/m^3	Range of concentr.	Source of background health data	Source of CRF	Comments
$PM_{2.5}$ daily mean	Hospital admissions, CVD diseases (includes stroke), all ages	A*	1.0091 (1.0017-1.0166)	All	European hospital morbidity database. http://www.euro.who.int/en/what-we-do/data-and-evidence/databases/european-hospital-morbidity-database-hmdb2 ICD10: I00-I99	APED meta-analysis of 4 single city studies and 1 multi-city study	
$PM_{2.5}$ daily mean	Hospital admissions, respiratory diseases, all ages	A*	1.0190 (0.9982-1.0402)	All	European hospital morbidity database. http://www.euro.who.int/en/what-we-do/data-and-evidence/databases/european-hospital-morbidity-database-hmdb2 ICD10: J00-J99	APED meta-analysis of 3 single city studies	

* Component of Total
** Only residual RADs to be added to Total effect, after the days in hospital, work days lost and days with symptoms are accounted for

[4] For outcome pairs in Group A and B, the expert group has judged that there is sufficient evidence for causality of effects, as reviewed in REVIHAAP. For Group A there is enough available data enabling reliable quantification of effects. For Group B, there is more uncertainty in the precision of estimates being used for quantification of the effects. The effect estimates in pairs marked by * contribute to the total effect.

Ozone, long and short term

Pollutant metrics	Heath outcome	Group[5]	RR (95%CI) per 10 μg/m^3	Range of concentr.	Source of background health data	Source of CRF	Comments
O3, daily maximum 8-hour mean	Mortality, all (natural) causes, all ages	A*	1.0029 (1.0014–1.0043)	>35 ppb (>70 μg/m^3)	WHO mortality database, http://data.euro.who.int/hfamdb/	APHENA study based on data from 32 European cities. Coefficients adjusted for PM10 in two-pollutant model	APHENA study based on all range of observed ozone concentrations, including levels below 35 ppb. Therefore the effects at the ozone <35 ppb are ignored.
O3, daily maximum 8-hour mean	Hospital admissions, CVD (includes stroke) and respiratory diseases, age 65+	A*	CVD: 1.0089 (1.0050-1.0127) Respir.: 1.0044 (1.0007-1.0083)	>35 ppb (>70 μg/m^3)	WHO European Hospital Morbidity Data http://data.euro.who.int/hmdb/index.php ; ICD9 codes: CVD 390-429, respir: 460-519 (ICD10: I00-I52; J00-J99)	APHENA study based on data from 8 European cities. Coefficients adjusted for PM10 in two-pollutant model	APHENA study based on all range of observed ozone concentrations, including levels below 35 ppb. Therefore the effects at the ozone <35 ppb are ignored.

* Component of Total

Nitrogen dioxide, long term

Pollutant metrics	Heath outcome	Group[6]	RR (95%CI) per 10 μg/m^3	Range of concentr.	Source of background health data	Source of CRF	Comments

[5] For outcome pairs in Group A and B, the expert group has judged that there is sufficient evidence for causality of effects, as reviewed in REVIHAAP. For Group A there is enough available data enabling reliable quantification of effects. For Group B, there is more uncertainty in the precision of estimates being used for quantification of the effects. The effect estimates in pairs marked by * contribute to the total effect.

[6] For outcome pairs in Group A and B, the expert group has judged that there is sufficient evidence for causality of effects, as reviewed in REVIHAAP. For Group A there is enough available data enabling reliable quantification of effects. For Group B, there is more uncertainty in the precision of estimates being used for quantification of the effects. The effect estimates in pairs marked by * contribute to the total effect.

Nitrogen dioxide, short term

Pollutant metrics	Heath outcome	Group[7]	RR (95%CI) per 10 µg/m^3	Range of concentr.	Source of background health data	Source of CRF	Comments
NO_2 daily maximum 1-hour mean	Mortality, all (natural) causes, all ages	A*	1.0027 (1.0016-1.0038)	All	WHO mortality database, http://data.euro.who.int/hfamdb/. The rates for deaths from all natural causes (ICD-10 chapters I-XVIII, codes A-R) in each of the 53 WHO EURO countries, for the latest year with available data.	APHEA2 project with data from 30 European cities. RR adjusted for PM10	
NO_2 24-hour mean	Hospital admissions due to respiratory diseases, all ages	A*	1.0180 (1.0115-1.0245)	All	European hospital morbidity database. http://www.euro.who.int/en/what-we-do/data-and-evidence/databases/european-hospital-morbidity-database-hmdb2 (ICD10: J00-J99)	APED meta-analysis of 15 studies published until 2006; coefficient from one-pollutant model. Estimate robust to adjustment to co-pollutants.	

[7] For outcome pairs in Group A and B, the expert group has judged that there is sufficient evidence for causality of effects, as reviewed in REVIHAAP. For Group A there is enough available data enabling reliable quantification of effects. For Group B, there is more uncertainty in the precision of estimates being used for quantification of the effects. The effect estimates in pairs marked by * contribute to the total effect.

Table 8 Estimates and predictions of deaths and associated years of life, attributed to average annual PM2.5 concentrations modelled for selected transport scenarios.

Attributable deaths	Rotterdam	Oslo	London	Athens	Helsinki	Prague
2008	487.8	186.2	4,211.6	3,193.8	144.3	1,232.9
2020 Agreed Measures	287.8	171.7	3,139.2	2,654.9	138.6	984.4
Difference from 2008	***200.0***	***14.4***	***1,072.4***	***539.0***	***5.7***	***248.5***
2020+measure: 50% electric	287.0	170.1	3,136.3	2,603.3	136.4	954.7
Difference from 2020 AM	***0.8***	***1.6***	***3.0***	***51.6***	***2.2***	***29.8***
2020+measure: LEZ	287.4	166.0	3,134.3	2,638.1	137.2	967.1
Difference from 2020 AM	***0.4***	***5.7***	***4.9***	***16.8***	***1.3***	***17.4***
2020+measure: 10% less traffic	287.5	169.0	3,138.3	2,630.0	138.1	975.7
Difference from 2020 AM	***0.2***	***2.8***	***1.0***	***24.9***	***0.4***	***8.7***

Attributable life years	Rotterdam	Oslo	London	Athens	Helsinki	Prague
2008	4,897	1,797	48,245	34,552	1,462	12,884
2020 Agreed Measures	2,889	1,658	35,961	28,721	1,404	10,287
Difference from 2008	***2,008***	***139***	***12,284***	***5,831***	***58***	***2,597***
2020+measure: 50% electric	2,881	1,642	35,927	28,163	1,382	9,976
Difference from 2020 AM	***8***	***16***	***34***	***558***	***22***	***311***
2020+measure: LEZ	2,885	1,603	35,904	28,539	1,390	10,106
Difference from 2020 AM	***4***	***55***	***56***	***182***	***13***	***182***
2020+measure: 10% less traffic	2,887	1,631	35,949	28,452	1,399	10,196
Difference from 2020 AM	***2***	***27***	***11***	***269***	***4***	***91***

4.4 SP4 Integrated Assessment Methodology, tool development and application (TNO, UH)

The main objective of SP4 was the development of the integrated assessment tool (IAT) based on input from the other SP's in particular SP2 (modelling), SP3 (health impact) and SP5 (transport scenarios). Over the duration of the projects the models are sufficiently integrated in stand-alone systems and the IAT has developed more into a viewer of data outputs from models and HIA calculations as part of a full-chain integrated assessment for transport policies and measures.

The integrated assessment approach has two options covering the full causal chain from transport activities, emissions, concentrations and exposure (both external and internal), to effects. Option 1 covered a suite of linked (off-line) state-of-the-art models, systems and processing tools, while option 2 offered a viewer (on-line) with the results of the complex model calculations under option 1 and the possibility to view the health outcome of different transport scenario changes at local (core-cities) and European scale. Hence, new calculations with option 1 will require involvement of TRANSPHORM partners, while option 2 is an on-line viewer enabling users to assess the health impact of different transport measures and scenarios.

In terms of temporal and spatial resolution, the IAT provides information on health impact of scenario changes on annual basis and a typical spatial resolution at street level (100*100 m), urban level (1km x1km) and European level (15km x 15km). The IAT has been developed and applied in the following four WP's below.

WP4.1 Development of overall IA methodology (AUTH)
The overall concept of the integrated assessment methodology was developed in interaction with parallel EU projects such as INTARESE and HEIMTSA in which partners of TRANSPHORM have been strongly involved including their leadership. The methodology enables the assessment of the change in health impacts of the individual PM fractions considered in TRANSPHORM ($PM_{2.5}$, PM_{10}, EC, BaP and PN) for a wide variety of transport policies (European level) and measures (core-cities). The health impacts of measures not only related to residents, using exposure-response functions, but also to commuters using different modes of transport (bus, metro, car and cycling) where the changes in exposure was the most suitable impact indicator. A special effort has been devoted to the generalisation of calculated health impacts of bundles of measures (e.g. more public transport combined with more electric cars and increasing parking fees *or* sulphur-free fuel in water transport etc.) to EU-wide health impacts.

After development of the interface, it was tested for both regional and urban model outputs. The viewer enables a user to evaluate the impact of different scenarios and measures based on pre-processed calculations. The viewer is on-line accessible via the website of TRANSPHORM.

WP4.2 Uncertainty methodology (AUTH)
The method for the calculation of uncertainty in the health impacts was developed and disseminated within TRANSPHORM via a web-based training module. This WP was also responsible for analysing the applicability of the IA viewer. The key challenge was to bridge the gap between a theoretically well-developed methodology and practical application of the methodology in integrated assessment. An uncertainty module with interactive capability was developed and included in the web-based training course.

WP4.3 Software implementation (TNO)
The integrated assessment methodology was implemented as an on-line *viewer* with the results of the off-line integrated assessment of the transport scenarios. The scenario provisions have been based on the scenario framework developed in SP5, the atmospheric models developed in SP2, including the updated emission inventories developed in SP1, the concentration/exposure-response functions for PM fractions from SP3 and the uncertainty analysis module. The software for the IAT has undergone continual design and modification resulting in a proto-type which then developed into the full version.

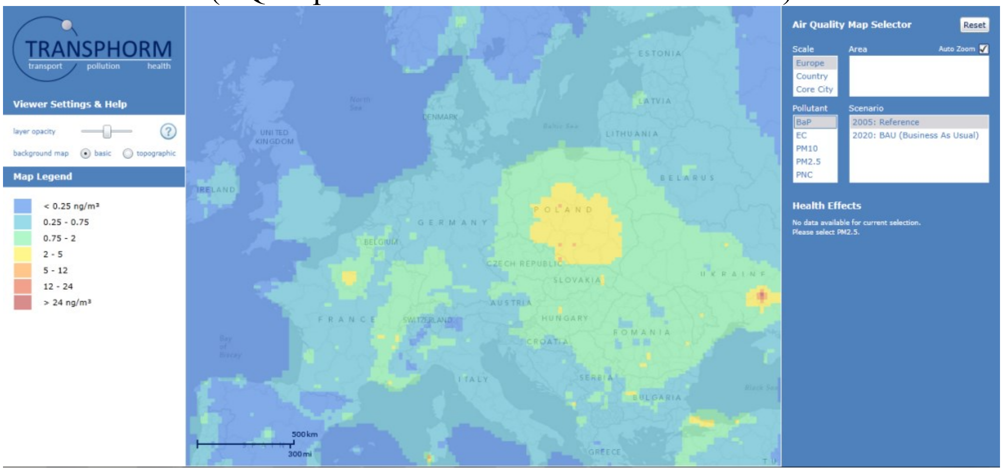
WP 4.4 Application of the integrated assessment methodology (UH-CAIR)
The overall IA methodology of TRANSPHORM has been applied to the European region as well as five target cities (Athens, Helsinki, London, Oslo and Rotterdam). A range of evaluation and analyses have been conducted showing the improved performance of models and project health impacts resulting from PM2.5 (see section below and SP3 for HIA results).

The viewer presents results for the health impact assessment in Europe and core-cities for the respective reference years 2005 and 2008, and for the future year 2020 BAU (business-as-usual), 2020 BAU plus three measures in core-cites (environmental zoning, electric vehicles and more public transport/cycling), and 2020 BAU plus twenty different transport scenarios (for Europe only).

Key results from SP4
The key outcome of SP4 was a viewer of the integrated assessment methodology which is accessible via the TRANSPHORM website: http://www.transphorm.eu/ and the link: http://transphorm-iat.tno.nl/IATViewer.html. The results of the integrated assessment method are illustrated below in Figure 7 with three examples at different scales, pollutants, scenarios and years.

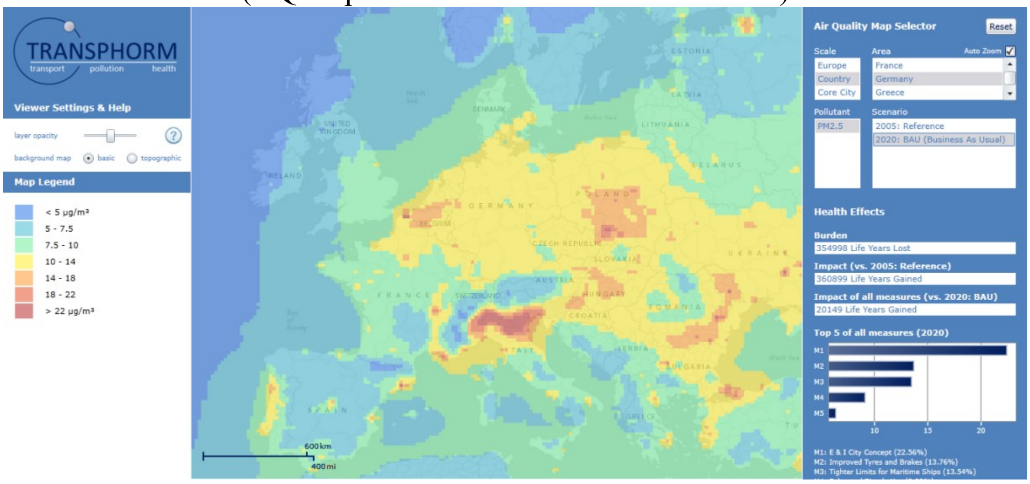
Example 1 (a)

Scale: *Europe*, *Pollutant*: *BaP*, *Scenario*: *2005*
(AQ map but *no* assessment of health effects)



Example 2 (b)

Scale: *Europe/Countries*, *Pollutant*: $PM_{2.5}$, *Scenario*: *2020 BAU*
(AQ map and assessment of health effects)



Example 3 (c)

Scale: *Core cities*, *Pollutant*: *PNC*, *Scenario*: 2020-*LEZ*
(AQ map and health effects of local scenarios in 2020)

Figure 7 Examples of the information that can be derived from the Integrated Assessment Viewer.

The air quality assessment in the five core cities concerned three traffic scenarios in 2020: 1.) low-emission-zone ("LEZ"), 2.) 50% personal cars ("50% electric") and 3.) more physical and public transport resulting in 10% less traffic on urban roads ("10%-all"). The impact on air quality was modelled in 2020 and compared to the autonomous development in 2020 and against the air quality in the reference year 2008. The results are presented in Figure 8 for the air quality indicators PM_{10}, $PM_{2.5}$, EC, Bap and PNC in Athens.

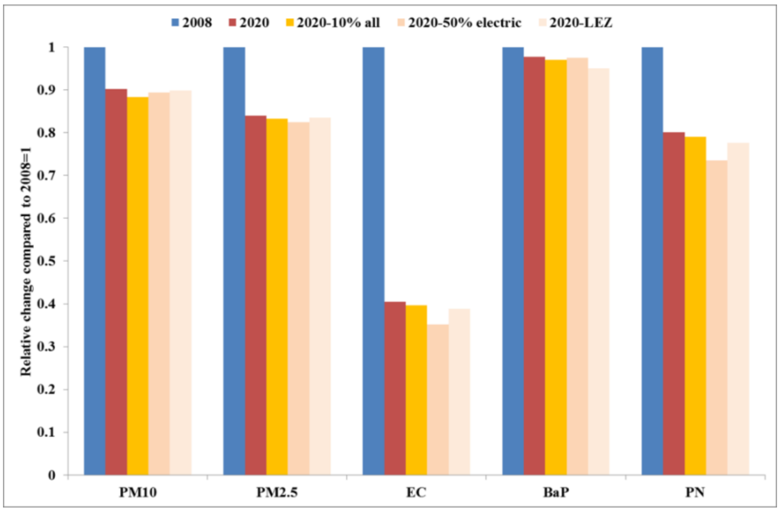


Figure 8 The relative change in the population weighted average in 2020 and in 2020 for three traffic scenarios: "10%-all", "50%-electric" and "LEZ" compared to the reference year 2008 in Athens.

Figure 8 illustrates that the concentrations of PM_{10} and $PM_{2.5}$ are expected to improve by 10% and 20%, respectively in the period 2008 to 2020 due to the autonomous development. This is mainly attributed to the reduction of secondary PM as a result of emission reductions of the gaseous precursors sulphur dioxide, nitrogen oxides and ammonia in different sectors such as shipping, energy production, heating, road traffic and husbandry. For BaP, no much improvement is expected but in contrast for EC and PN, the air quality is expected to improve by more than 50% and 20%, respectively. The latter is mainly the result of the introduction of more stricter emission standards Euro-5 and 6 by road traffic. Concentrations of PM_{10} and $PM_{2.5}$ are more dominated by large-scale emissions, while BaP is also controlled by other sources than road traffic such as energy production and heating. Consequently, (local) traffic measures are hardly effective to reduce the concentration of these pollutants. EC and PN are more controlled by exhaust emissions from road traffic. The results in Figure 8 relate to Athens but the results in the other core cities were similar. In Figure 9, the effect of local measures in the five cities is shown for EC.

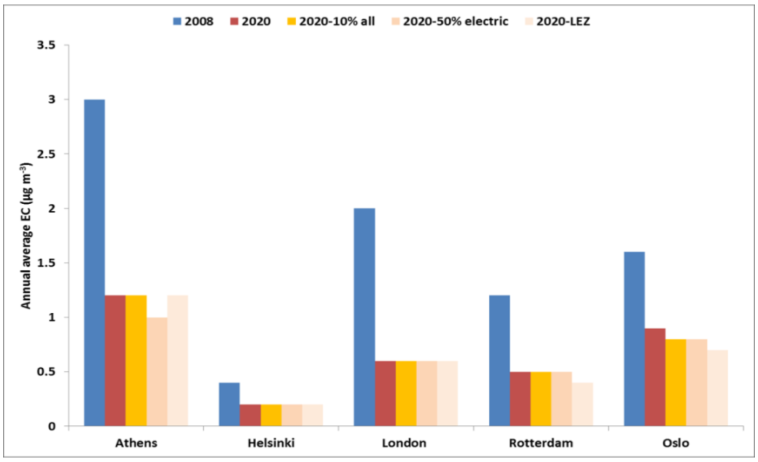


Figure 9 The population weighted annual average of EC in five core cities in 2008, 2020 and the impact of local traffic scenarios on EC in 2020.

Figure 9 illustrates that the autonomous development in particular the introduction of Euro 5 and 6 between 2008 and 2020 will improve considerably the air quality resulting from traffic-related combustion emissions in urban areas across Europe. On-top of the autonomous development, further improvement of air quality by local measures on an annual basis by 2020 will only have a limited effect except near roads and the general impact on urban background. It should be noted that Figure 9 shows the population weighted average in the five core cities. The population weighted average is dominated by the urban background and therefore do not reflect properly the air quality for people living near intense road traffic which is in the range of 5 to 10% of the urban population. In TRANSPHORM, the impact of measures was also evaluated separately for this part of the urban population. This concerns people living near 100 m from (urban) motorways or in street-canyons with over 10 000 vehicles per 24-h. From the research in TRANSPHORM, it was concluded that the exposure is 2 to 3 times higher compared to the average urban population for traffic-related PM. Local measures are more effective to reduce the exposure in particular for this part of the urban population to traffic-related PM. Currently, there is a lack of adequate concentration-response-functions to evaluate the health impact of these measures for this specific part of the urban population. The lessons learned from the air quality assessment in the core cities are summarized as follows:

- The introduction of Euro-5 and 6 for road traffic will improve in particular EC and PN concentrations near road traffic and less for PM_{10}, $PM_{2.5}$ and BaP both at the urban background and near road traffic;
- There remains a high spatial variability of air quality between cities in the north and south of Europe and also within cities with 2 to 3 higher exposure to traffic-related PM near road traffic;
- The concentrations of EC and PN are in particular sensitive indicators for traffic-related scenarios and measures compared to PM_{10}, $PM_{2.5}$ and BaP;

It is recommended to further investigate emission, dispersion and exposure of traffic-related PM in particular of ultrafine particles from exhaust and heavy metals from wear with emphasis on people living near road traffic and for commuter in traffic-related micro-environments.

4.5 SP5: Mitigation and adaptation strategies and measures (USTUTT, NILU)

TRANSPHORM has developed and applied a methodology to analyse and assess policies and measures to reduce concentrations and health impacts of airborne particles. As part of this process, a consultation exercise was implemented to obtain feedback from stakeholders such as city authorities and transport policy makers about possible policies and measures. Health relevant transport policies and mitigation measures were developed including a framework for up-scaling of effects of implementing measures to the European scale.

WP 5.1: Mitigation and adaptation strategies and measures (NILU)

A list of technical and non-technical mitigation measures for road transport and off-road transport were identified in consultation with stakeholders especially from cities. Contacts with Rotterdam, Oslo and Helsinki authorities resulted in the definition of a set of measures for pilot exercises within TRANSPHORM.

A typology of mitigation measures and policies has been developed and formed the basis for analysis with complex model and urban air quality systems. The typology starts with the respective transport mode (road, inland waterways, maritime and air). For the typology, a distinction is made in different city sizes - > 50 000 inhabitants, > 100 000 inhabitants and > 500 000 inhabitants and in different road types - all roads and non-urban roads. Furthermore, parameters were identified that are affected by the measures: emission factors, vehicle stock or vehicle mileage. Finally, in the typology, side effects on other sectors are noted (e.g. the generation of additional electricity).

WP 5.2: Analysis of policies and measures (TML)

The effectiveness of measures were tested an evaluated in the core cities and after up-scaling to an EU-wide level. The city-level parameters of measures have been identified with respect to the spatial dimension (city location and size, other regional measures being implemented) as well as a time dimension (applicable in 2020 and 2030). A comprehensive city-level database including all relevant parameters for the considered urban morphological zones (about 900 zones across Europe) was refined in this period. A tool to determine the effects of measures for cities as well as regional measures simultaneously was developed. The tool is able to determine not only the effects of applying a single transport measure all over Europe but is able to assess the effects of combined implementation of interacting measures.

WP 5.3 Assessment of transport measures, generation of strategies and recommendations (USTUTT)

By carrying out a cost-effectiveness analysis of the benefits of isolated measures it was possible to address questions about the ranking of single measures for the years 2020 and 2030. By doing so, it was possible to assess whether the realisation of an option would, in general, be a worthwhile pursuit from a societal perspective. The analysis yielded a ranking of measures based on their avoided health impacts for 2020 and 2030.

As there are about two dozen measures evaluated for two future years it was not possible to perform an analysis of each single measure using full atmospheric dispersion models. Instead a state-of-science assessment several substantial improvements have been incorporated into the integrated assessment methodology implemented in the EcoSense model. The most important of these improvements are:

(1) The incorporation of new, more fine-grained source-receptor matrices (SRMs) that were derived from the most recent version of the EMEP model. The SRMs act as a parameterised version of the atmospheric model and represent a well-established trade-off between small losses in accuracy (due to linearization) for marginal changes in emissions and a huge gain in computing-time due to the simplified formulization.
(2) An enhanced representation of generally higher PM and NO_2 concentration levels in urbanised areas by evaluating and updating the urban increment (UI) model.
(3) Incorporation of new concentration-response functions (CRFs) as recent findings of the REVIHAAP/HRAPIE projects that became available early 2014. This affects especially the substantial but previously neglected health impacts due to exposure to ambient NO_2 (for which also an urban increment had to be developed).

Incorporating these improvements into the model has, without any doubt, brought several crucial improvements to the overall assessment approach. These improvements in turn led to more reliable recommendations for decision-makers on the selection of policy measures.

Based on the integrated assessment methodology an assessment of the combined effect of measures has been carried out. Due to the nature of the project all the measures investigated in TRANSPHORM affect the transport sector, and thus are likely to overlap or interfere. Due to the thorough analysis and model development these interferences could be identified and appropriately accounted for in the assessment of strategies, i.e. when determining and evaluating bundles of policy measures. To assess the health effects due to concentration changes of simple pathway pollutants, impact functions, consisting of the concentration-response function, the background rate of disease within the population and the fraction of the population exposed, are applied. Resulting values for the different health endpoints could then be calculated using age-stratified population data along with the concentration delta. For aggregation or comparison of these results, the values derived in the previous step, given in cases or years of life lost (YOLL), have to be converted into a common metric, the disability-adjusted life years (DALYs). It combines information on both quality and quantity of life and indicates the number of healthy life years lost. To achieve this, morbidity is weighted for the severity of the disorder and the duration of the disease, mortality with years of life lost. Thus, this metric includes both effects. However, DALYs should be used to estimate the potential order of magnitude of health problems rather than being presented as representative absolute numbers.

By estimating the investment costs and monetized benefits of measures, it was possible to determine two strategies for 2020 where each can be considered optimal depending on the criterion applied:

(1) The "effectiveness" scenario was determined by evaluating the avoided health impacts but leaving costs out of the equation.
(2) The "efficiency" scenario is the results of a selection of measures by balancing benefits (i.e. monetised avoided health impacts and monetised saved CO_2 emissions) with costs (i.e. private costs, subsidies, utility and time losses).

The scenarios derived by utilizing the source-receptor relationships were then used as input for the atmospheric models for a more detailed analysis and inter-comparison of results.

Policy recommendations have been derived based on the analysis undertaken in this work package. Based on the common approach of selecting the policy measures that maximize the discounted net benefit for society, bundles of measures have been identified for the years 2020 and 2030 using the methodology that was applied in scenario (2). For all measures the specific activity data of each city and each region has been determined. Also side-effects on non-transport sectors are covered as far as reasonable in the analysis. Such effects include for instance changes in electricity demand due to more utilisation of electric cars, metros/railcars or the supply of shore-side electricity for ships at berth, as well as changes in agricultural activity levels in the case of bio-fuel usage.

In general, it is suggested to promote bicycle usage in cities as it will have the most effect on emission reduction and the resulting positive health benefits due to exposure to lower levels of particulate matter, along with co-benefits due to increased sporting activity. Also, traffic management options should be considered in cities to reduce fuel consumption of cars by optimizing traffic flows. For future bus fleets more environmental-friendly powertrains can show a reasonable potential in reducing emissions as well. Promotion of low-emission vehicles is recommended in general, especially if the tighter emission limits of Euro 7 are met as the reduction in emissions yields substantial health impact reductions. While speed limits on rural roads and motorways might yield benefits in terms of reduced emissions, they do not outweigh the substantial time losses experienced by the operators of a car. While the promotion of bio-fuel causes negative health impacts in regions were agricultural activities are increased due to fuel production, the negative impacts are out-weighed by the potential of climate change mitigation. A similar effect of the importance of climate change mitigation co-benefits is observed in the case of measures that deal with reduction of air traffic via kerosene tax or shifting traffic to rail-bound vehicles. Also, tighter limits for inland and sea-going vessel turned out to be efficient, and the reduction potential is even higher if power for ships at berth is generated shore-based at the ports rather than relying on the internal auxiliary combustion engines.

From a perspective of a social planner that aims towards maximization of welfare, the cost-efficient scenarios should be considered recommendations. However, we felt the need of assessing also the most effective measures that have not turned out to be cost-efficient (or it was not possible to estimate costs) but have a significant potential of decreasing air pollution that originates from transport activities. For instance, it was not possible to assess the costs of improved tyres and brake-wear along with optimised paving of roads. The reduction in particle emission, however, is significant and will reduce adverse health effects. While measures can be effective in reducing air quality impacts as in the case of EU-wide harmonized speed limits on rural roads and motorways, often time and utility losses are out-weighing the benefits of emission reduction and render the inefficient.

Key results from SP5

Final key results of SP5 are the scenarios developed for the years 2020 and 2030. A thorough analysis of policy measures has been conducted that comprise both technical measures (e.g. Euro 7) and non-technical measures, the latter showing big potential by aiming for behavioural changes as enhanced use of bicycles and/or public transport systems. The assessment was carried out by an innovative up-scaling approach to evaluate EU-wide effects of city-level and regional transport measures. Analysis of policy measures has shown that avoided health impacts can be properly assessed at a high level of detail and the cost-efficiency of policy options can be determined.

Even though the focus of the project is on health impacts due to exposure to particulate matter, it turned out than the assessment should not only consider the avoided health impacts but also account for climate change related co-benefits. This is key to evaluate all benefits of a measure when they are compared to its costs (i.e. private cost and subsidies, as well as utility losses and time losses), as they are likely to render a measure cost-efficient even when health benefits alone do not outweigh costs. A good example are measure that deal with air traffic. As emission causing health damages are emitted almost completely at heights below 1000 meters (i.e. during landing, taxiing and take-off), the majority of CO_2 emission of an aircraft are emitted during cruise and cannot be omitted. Also, it is important to account for relevant up-stream emissions, especially when shifts in modal transport are induced. For instance, emissions from power generation cannot be ignored when urban transport shifts from individual car traffic to metro/tram or electric vehicles of car-pooling.

Apart from the specific evaluation of the scenarios described and recommended, a great advance in developing and applying the scientific methodology of integrated assessment with focus on particulate matter and nitrogen oxides has been achieved. A tool was developed that for the first time allows for accounting for the assessment of concurrent implementation of potentially interfering transport measures. Due to the advances in the REVIHAAP/HRAPIE projects it was possible to incorporate state-of-science findings derived from epidemiological studies and use them to enhance the assessment of avoided health impacts due to policy implementation.

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Soares *et. al.* (2014), Refinement of a model for evaluating the population exposure in an urban area, *Geosci. Model Dev.*, **7**(5), 1855-1872

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6 Potential Impact and Dissemination Activities

6.1 Potential Impact

Overall TRANSPHORM has advanced the state of the art in the following ways (the subprojects where the RTD activities will reside are also indicated):

i. Enhanced understanding of processes affecting the transport of PM from the source to receptor and hence leading to health impact (whole project).
ii. Improved and new emissions factors of PM10, PM2.5 and PNC (SP1) for sources such as shipping, aviation and road traffic including non-exhaust.
iii. New measurements of size fractionated PM in three major European cities (SP2) including near the largest European harbour in Rotterdam, a major European airport (Schiphol), micro-environment exposure measurements in Rotterdam, Helsinki and Thessaloniki.
iv. Improved physical and chemical (primary and secondary) characterisation of PM, source apportionment and improved dispersion (city to regional to global scales) and exposure models (SP2).
v. Improvement and combination of state-of-the-art models for advanced analysis and simplified versions for operational efficiency (SP2).
vi. Improved understanding of exposure and health impacts and in particular, new relationships linking long-term exposure to size-resolved and speciated PM with key health outcomes (SP2, 3).
vii. Development, evaluation and application of an integrated system for health impact assessment of particulate matter (SP3, 4) for cities and Europe.
viii. Application of integrated assessment tools in a number of cities across Europe (e.g. Rotterdam, Helsinki, Thessaloniki, Oslo, London and others) (SP5).
ix. Development of policy options for mitigation and adaptation measures on city to European scales with recommendations for policy formulation and response (SP5).

Potential impacts of TRANSPHORM will include the following:

i. Improved knowledge base for the impact of transport emissions on health.

SP1 has led to improved transport (traffic, shipping, aviation and rail) emission factors and inventories for size fractionated PM including PM10, PM2.5 and ultrafine number (PNC). Improved air quality models from SP2 have been combined and coupled with exposure models and evaluated with new and existing PM measurements. The latest concentration-response functions have been used with model outputs from SP2 to quantify the health impact of PM fractions.

ii. Support for further development of policies for emission reduction

TRANSPHORM will continue to provide support to the EU for developing policies for reducing air pollution and for establishing emission reduction targets. With use of the integrated assessment tool (from SP4), policy makers and other stakeholders have new state of the art approaches to examine the impact of future changes to PM emissions under different policy regimes.

iii. Support for urban planning in a wider policy and health context

SP5 has analysed the impacts of local urban planning measures aimed at reducing PM air pollution and hence its health impact in cities. It has employed results from SP2 and SP4 using integrated assessment tools and has formulated potential measure options for European cities.

iv. Establishment of emission reduction targets for shipping and aviation

TRANSPHORM tools can be employed to examine the most effective reduction targets on European PM levels and assess the health impact of such changes (part of SP5). This type of analysis will support the development of policies for reduction of air pollution and for establishment of emission reduction targets for shipping as well as aviation.

v. Support for European air pollution policies

TRANSPHORM will continue to support the European air quality policy process including the Thematic Strategy on Air Pollution (TSAP). The integrated approaches of TRANSPHORM are particularly useful for examining the most effective and efficient options for Europe on short and long term scales. Policy makers have the confidence that TRANSPHORM approach is based on the latest science and has been subject to peer review through numerous published journal papers. Several partners have already contributed to the 2013 review of the Air Quality Policy for Europe and to the WHO project on Health Risks of Air Pollution in Europe (HRAPIE).

6.2 Exploitation and Dissemination of Results

This task was implemented in the second phase of the project and identified any potential for exploitation of the outcomes especially in relation to policy and user needs. TRANSPHORM was a mainly R&D project and no commercial exploitation was envisaged except in providing recommendations for users. Opportunities within and outside Europe were identified regarding the use of advanced modelling methods and improved health impact assessment methodology. In particular discussions have been held to promote the TRANSPHORM approach with:

DEFRA, UK Government - presentation and discussion on the TRANSPHORM approach to HIA for PM (UH-CAIR)
Cyprus local authority - local air quality assessment using TRANSPHORM approaches (AUTH)
Helsinki Metropolitan Authority - application of local scale models to Helsinki for HIA (FMI)
Rotterdam local authority - application of local scale models to Rotterdam for HIA (TNO)
USEPA - discussion of CMAQ model performance on European scale as a policy orientated model (UH-CAIR)

An important part of this task was to oversee the Intellectual Property Rights (IPR), access right and pre-existing know-how affecting the partners. Each partner had kept their own IPR and pre-existing knowledge. Almost all of the knowledge from TRANSPHORM has been disseminated openly and especially through high quality peer-reviewed scientific journals. There were a number of dissemination channels:

(i) Project web portal

The website has been created and hosted by NILU (www.TRANSPHORM.eu). It has public and members (restricted) pages as well as facility for stakeholders to register. The public web pages are being used to inform the partners, the scientific community, stakeholders and the general public about the project progress, while the restricted pages serve the information flow among the partners (project templates, progress reports, work plans, links to project data). All meeting discussion notes from SP's were uploaded on the website pages. A knowledge meta-database was created to aid management of information flow. In addition a separate database as part of SP1 was created mainly for the purposes of providing the latest emission factors relating to particulate matter and other air pollutants. This emissions database represents state of the art in the field.

(ii) Conference workshops and journal publications
A workshop on Transport related air pollution – Science for Policy was organised in collaboration with the International conference on Air Quality, 19-23 March 2012, Athens and 24-28 March 2014, Garmisch-Partenkirchen (www.airqualityconeference.org). The sessions were coordinated by Professors Ranjeet S Sokhi (UH-CAIR), Jaakko Kukkonen (FMI), Dick van den Hout (TNO) and Dr Leonor Tarrason (NILU). There were approximately 100 people who attended each of the session. The attendance for the whole conference was nearly 300. Table A2 summarise other dissemination activities and the papers that have resulted from the project.

(iii) Publicity through newsletters
Procedures for production of the project newsletters have been established. As per the DoW a number of newsletters have been published during the life-time of the project and are available via the project website. Some of the recommendations from TRANSPHORM have also been circulated globally through the WHO newsletter. In order to achieve a wider network of the public, a Facebook page has also been setup.

(iv) Science and Policy Stakeholder Forum
Science and Policy Stakeholder (SPS) Forum was held at the International Conference on Air Quality, 19-23 March 2012, Athens. A second phase of contacting potential users culminated in the Special Session for Stakeholders held in Brussels on 6 May 2014. The audience of nearly 60 participants consisted of policy makers, industrial representatives, NGOs relating to the transport sector, cities and research bodies and officers from the European Commission.

A questionnaire to receive feedback on suggested policy related measures for analysis in SP5 was sent to the Forum members. The outputs of the questionnaire served as a guide for the selection of measures to control PM levels in cities and on a European scale (part of SP5).

(v) Involvement of users in the work programme
City authority experts are already involved on local transport, air quality measures and policy as part of the first phase of the project, especially with regard to measurements in the target cities of Rotterdam, Helsinki and Thessaloniki (SP2). During the second phase the prototype of the integrated assessment tool was presented at meetings. City authority users were also present at the Special Session held for Stakeholders, 6 May 2014.

(vi) Wider involvement of stakeholders
An open session was held at the last two Air Quality conferences, 19-23 March 2012, Athens and 24-28 March 2014, Garmisch- Partenkirchen to disseminate the outcomes of the project and to seek feedback. A wed based platform has been set up for users to show an interest in the project. Approximately 90 registrations have been received.

7 Use and dissemination of foreground

The overall strategy of dissemination is based on the following strands:

(i) General publication of project outcomes through organisation such as WHO, website and newsletters.

(ii) Continual publication of the scientific results through high quality journals.

(iii) Continued interaction with stakeholders to receive feedback an comments on priority measures to reduce the impact of airborne PM resulting from transport and other sources. These include NGO's and environmental consultants, industry, scientific community, local and regional authority officers, DG Tren, DG Research and DG Environment.

(iv) Highlighting outputs and results from TRANSPHORM via international meetings, conferences and workshops.

(v) General public orientated social media dissemination via facebook

Tables A1 and A2 show the list of journal papers and dissemination activities respectively. It should be noted that the list of journal articles resulting from the project continues to grow as more papers are submitted for publication. As the project is primarily R&D in nature no patents or commercially sensitive outputs were expected. We view peer-review, and open dissemination where possible, as the best way to demonstrate the added-value and positive impact of the project on the European Union and elsewhere and helping to strengthen the credibility of European science on the global scene.

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS IN ORDER OF YEAR										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[8] (if available)	Is/Will open access[9] be provided to this publication ?
1	Inter-comparison of predicted population exposure distributions during four selected episodes in Helsinki and evaluation against measured data	Hänninen, O.	International Journal of the Environment and Pollution	40(1-3)	Inderscience	UK	2010	248-266	DOI: 10.1504/IJEP.2010.030897	
2	Evaluation of a multiple regression model for the forecasting of the concentrations of NOx and PM10 in Athens and Helsinki	Vlachogianni, A.	Science of the Total Environment	Volume 409, Issue 8	Elsevier	Published on-line	2011	1559–1571	http://www.sciencedirect.com/science/article/pii/S0048969711000064	no
3	Intercomparison of air quality data using principal component analysis, and forecasting of PM10 and PM2.5 concentrations using artificial neural networks, in Thessaloniki and Helsinki	Voukantsis, Dimitris	Science of the Total Environment	Volume 409, Issue 7	Elsevier	Published on-line	2011	1266–1276	http://www.sciencedirect.com/science/article/pii/S0048969711000052	no
4	Evaluation of a road dust suspension model for predicting the concentrations of PM10 in a street canyon	Kauhaniemi, M.	Atmospheric Environment	45	Elsevier	Published on-line	2011	3646-3654	http://www.journals.elsevier.com/atmospheric-environment/	no
5	Black Carbon as an Additional Indicator of the Adverse Health Effects of Airborne Particles Compared with PM10 and PM2.5	Janssen, N.A.H	Environmental Health Perspectives	12 (119)	Public Health Services, US Dept of Health and Human Services		2011	1691-1699	DOI: 10.1289/ehp.1003369	yes

[8] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).
[9] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

6	Evaluation of source-receptor relationship for atmospheric pollutants using approaches of trajectory modelling, cluster, probability fields analyses and adjoint equations	Baklanov, Alexander	Atmospheric Pollution Research	Vol. 2(4),	TUNCAP	Published on-line	2011	400-408	DOI: 10.5094/APR.2011.045 ; www.atmospolres.com/articles/Volume2/issue4/APR-11-045.pdf	yes
7	In-vitro cell exposure studies for the assessment of nanoparticle toxicity in the lung - A dialog between aerosol science and biology	Paur, H-R.	Journal of Aerosol Science	42(10)	Elsevier	Netherlands	2011	668-692	DOI: 10.1016/j.jaerosci.2011.06.005	
8	A European open access chemical weather forecasting portal	Balk, Taru	Atmospheric Environment	Volume 45, Issue 38	Elsevier	Published on-line	2011	6917–6922	http://www.sciencedirect.com/science/article/pii/S1352231010008447	yes
9	Seasonal patterns of outdoor PM infiltration into indoor environments: review and meta-analysis of available studies from different climatological zones in Europe	Hänninen, O.	Air Quality, Atmosphere and Health	4(3-4)	Springer	Germany	2011	221-233	http://www.springerlink.com/content/k26h4563110m373g/fulltext.pdf	
10	Editorial: Focus on exposure to air pollution and related health impacts	Hänninen, O.	Air Quality, Atmosphere and Health	4(3-4)	Springer	Germany	2011	159-160	DOI: 10.1007/s11869-011-0137-4	
11	On variational data assimilation for estimating the model initial conditions and emission fluxes for short-term forecasting of SOx concentrations	Vira, J.	Atmospheric Environment	46	Elsevier	Published on-line	2012	318–328	http://www.sciencedirect.com/science/article/pii/S1352231011010296	no
12	Microscopic characterization of individual particles from multicomponent ship exhaust	Popovicheva, O.	Journal of Environmental Monitoring	Issue 12, 2012	Royal Society of Chemistry	UK	2012	3101–3110	http://dx.doi.org/10.1039/c2em30338h	no
13	A review of operational, regional-scale, chemical weather forecasting models in Europe	Kukkonen, J.	Atmospheric Chemistry and Physics	12	European Geosciences Union	Published on-line	2012	1-87	http://www.atmos-chem-phys.net/12/1/2012/acp-12-1-2012.html	yes
14	The Environmental Impact of Megacities.	Baklanov, A.	International Innovation Environment	Feb-12	ResearchMedia	Published online	2012	12-14	ISSN 2041-4552; http://www.research-europe.com/index.php/category/environment/	yes
15	Direct and Inverse Problems in a Variational Concept of	Penenko V.	Pure and and Applied	Vol.169, No 3	Springer	Published online	2012	447-465	DOI: 10.1007/s00024-011-0380-5	no

	Environmental Modelling		Geophysics							
16	New Directions: Understanding Interactions of Air Quality and Climate Change at Regional Scales	Alapaty, K.	Atmospheric Environment	49	Elsevier	Published online	2012	419–421	http://www.sciencedirect.com/science/article/pii/S1352231011012684	no
17	Extension of an assessment model of ship traffic exhaust emissions for particulate matter and carbon monoxide	Jalkanen, Jukka-Pekka	Atmospheric Chemistry and Physics	12	European Geosciences Union	Published on-line	2012	2641–2659	http://www.atmos-chem-phys.net/12/2641/2012/acp-12-2641-2012.pdf	yes
18	Dispersion of particle numbers and elemental carbon from road traffic, a harbour and an airstrip in the Netherlands	Keuken, M.P.	Atmospheric Environment	54	Elsevier		2012	320-327	http://www.journals.elsevier.com/atmospheric-environment/	no
19	Trends in primary NO2 and exhaust PM emissions from road traffic for the period 2000-2020 and implications for air quality and health in the Netherlands	Keuken, M.P.	Atmospheric Environment	53	Elsevier		2012	313-319	http://www.journals.elsevier.com/atmospheric-environment/	no
20	Urban Climate Science, Planning, Policy and Investment Challenges	Ruth, M. and A. Baklanov	Urban Climate	26(1)	Elsevier	Published online	2012	1-3	http://dx.doi.org/10.1016/j.uclim.2012.10.001	
21	A multi-model study of impacts of climate change on surface ozone in Europe	Langner, J.	Atmospheric Chemistry and Physics	12	European Geosciences Union	Published on-line	2012	10423-10440	http://www.atmos-chem-phys.net/12/10423/2012/acp-12-10423-2012.pdf	yes
22	Elemental carbon as an indicator for the impact of traffic measures on air quality and health.	Keuken, M.P.	Atmospheric Environment	61	Elsevier		2012	1-8	http://www.journals.elsevier.com/atmospheric-environment/	no
23	Real-time air quality forecasting, part I: History, techniques, and current status.	Zhang, Yang	Atmospheric Environment	60	Elsevier	Published online	2012	656-676	http://www.sciencedirect.com/science/article/pii/S1352231012005900	no
24	Real-time air quality forecasting, part II: State of the science, current research needs, and future prospects	Zhang, Yang	Atmospheric Environment	60	Elsevier	Published online	2012	632-655	http://www.sciencedirect.com/science/article/pii/S1352231012001562	no
25	The evolution of shipping emissions and the costs of regulation changes in the northern EU area	Johansson, L.	Atmospheric Chemistry and Physics	13	European Geosciences Union	Published on-line	2013	11375-11389	http://www.atmos-chem-phys.net/13/11375/2013/acp-13-11375-2013.pdf	yes
26	The global impact of the transport sectors on atmospheric aerosol: simulations for year 2000 emissions	Righi, M.	Atmospheric Chemistry and Physics	13	European Geosciences Union	Published on-line	2013	9939–9970	http://www.atmos-chem-phys.net/13/9939/2013/acp-13-9939-2013.html	yes

27	Physical and chemical characterisation of PM emissions from two ships operating in European Emission Control Areas	Moldanová, J.	Atmospheric Measurement Techniques	Special issue Measurement s of ship emissions, Vol. 6, 2013	Copernicus publications	Germany	2013	3577-3596	www.atmos-meas-tech.net/6/3577/2013/	yes
28	A Comprehensive Inventory of the Ship Traffic Exhaust Emissions in the Baltic Sea from 2006 to 2009	Jalkanen, Jukka-Pekka	Ambio	Volume 43, Issue 3	Springer	Netherlands	2013	311-324	http://www.springerlink.com/openurl.asp?genre=article&id=doi:10.1007/s13280-013-0389-3	no
29	Source contributions to PM2.5 and PM10 at an urban background and a street location	Keuken, M.P.	Atmospheric Environment	71	Elsevier		2013	26-35	http://www.journals.elsevier.com/atmospheric-environment/	no
30	An hourly PM10 diagnosis model for the Bilbao metropolitan area using a linear regression methodology	González-Aparicio, I.	Environmental science and pollution research	Volume 20, Issue 7	Springer	Published online	2013	4469-4483	http://link.springer.com/article/10.1007%2Fs11356-012-1353-7	no
31	Urban boundary layer analysis in the complex coastal terrain of Bilbao using Enviro-HIRLAM	González-Aparicio, I.	Theoretical and Applied Climatology	113	Springer	Published online	2013	511-527	http://link.springer.com/article/10.1007%2Fs00704-012-0808-6	no
32	Urbanization influence on meteorological parameters of air pollution: Vilnius case study	Mazeikis, Adomas	Baltica	26(1)	Vilnus	Published online	2013	51-56	http://www.geo.lt/geo/fileadmin/Failai/Baltica_26_1_/Baltica_26_1_D-51-56.pdf	yes
33	Aerosol-based modelling of infiltration of ambient PM2.5 and evaluation against population-based measurements in homes in Helsinki, Finland	Hänninen, O.	Journal of Aerosol Science	66	Elsevier	Netherlands	2013	111-122	http://dx.doi.org/10.1016/j.jaerosci.2013.08.004 DOI: 10.1016/j.jaerosci.2013.08.004	
34	Indoor aerosols: From personal exposure to risk assessment	Morawska, L.	Indoor Air	23(6)	WILEY	Denmark	2013	462-487	DOI: 10.1111/ina.12044	
35	Refinement of a model for evaluating the population exposure in an urban area	Soares, J.	Geoscientific Model Development	Volume 7, Number 5	Copernicus Publications	Published on-line	2014	1855-1872	www.geosci-model-dev.net/7/1855/2014/ doi: 10.5194/gmd-7-1855-2014	yes
36	Comparison of the predictions of two road dust emission models with the measurements of a mobile van	Kauhaniemi, M.	Atmospheric Chemistry and Physics	14	European Geosciences Union	Published on-line	2014	4263-4301	http://www.atmos-chem-phys-discuss.net/14/4263/2014/acpd-14-4263-2014.pdf	yes
37	Refinement of a model for	Soares, J.	Geoscientific	7	Copernicus	Germany	2014	2335-2375	DOI: 10.5194/gmdd-7-2335-	yes

	evaluating the population exposure in an urban area		Model Development						2014	
38	Online coupled regional meteorology chemistry models in Europe: current status and prospects	Baklanov, A.	Atmospheric Chemistry and Physics	14	European Geosciences Union	Published online	2014	317-398	www.atmos-chem-phys.net/14/317/2014/	yes
39	Comparison of the predictions of two road dust emission models with the measurements of a mobile van	Kauhaniemi, M.	Atmospheric Chemistry and Physics	14	European Geosciences Union	Published online	2014	9155-9169	http://www.atmos-chem-phys.net/14/9155/2014/acp-14-9155-2014.html	yes
40	Model calculations of the effects of present and future emissions of air pollutants from shipping in the Baltic Sea and the North Sea	Jonson, J.E.	Atmospheric Chemistry and Physics	14 (15)	European Geosciences Union	Germany	2014	21943-21974	http://www.atmos-chem-phys-discuss.net/14/21943/2014/	
41	Environmental burden of disease in Europe: Assessing nine risk factors in six countries	Hänninen, O.	Environmental Health Perspectives	122(5)	NIEHS	USA	2014	439-446	http://ehp.niehs.nih.gov/1206154/	yes
42	Long-Term Exposure to Elemental Constituents of Particulate Matter and Cardiovascular Mortality in 19 European Cohorts: Results from the ESCAPE and TRANSPHORM Projects	Wang, Meng	Environment International	Volume 66	Elsevier	Published on-line	2014	97–106	http://www.sciencedirect.com/science/article/pii/S0160412014000385	no
43	PM2.5 concentrations in London for 2008 - A modeling analysis of contributions from road traffic	Singh, Vikas	Journal of the Air & Waste Management Association	Volume 64, Issue 5	Taylor & Francis	Published on-line	2014	509-518	http://dx.doi.org/10.1080/10962247.2013.848244	no
44	Indoor aerosol modelling for assessment of exposure and inhaled dose	Hussein, T.	Atmospheric Environment	In Press	Elsevier	Netherlands	2014	In Press	DOI: 10.1016/j.atmosenv.2014.07.034	
45	Analysis of Meteorology-Chemistry Interactions During Air Pollution Episodes Using Online Coupled Models Within AQMEII Phase-2	Kong, X.	Atmospheric Environment	In Press	Elsevier	Published online	2014	In Press	DOI: 10.1016/j.atmosenv.2014.09.020	
46	Impact of inland shipping emissions on elemental carbon concentrations near waterways in the Netherlands	Keuken, M.P.	Atmospheric Environment	95	Elsevier		2014	1-9	http://www.sciencedirect.com/science/article/pii/S1352231014004543	no
47	Microenvironment particle measurements in Thessaloniki,	Vouitsis, I.	Urban Climate	In Press	Elsevier	Published on-line	2014	In Press	http://www.sciencedirect.com/science/article/pii/S22120	no

	Greece								95514000261	
48	Confronting Health Effects of Particulate Matter in Life Cycle Impact Assessment	Fantke, P.	The International Journal of Life Cycle Assessment	In Press	Springer	Germany	2014	In Press	-	

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities[10]	Main leader	Title	Date/Period	Place	Type of audience[11]	Size of audience	Countries addressed
1	Oral presentation to scientific event	HGMU	Personal exposure to ultrafine particles in different microenvironments	29 Aug - 03 Sept 2010	International Aerosol Conference, Helsinki, Finland	Scientific community	100-500	International
2	Oral presentation to scientific event	THL	Simulation of Personal PNC Exposures and Analysis of the Key Exposure Determinants	29 Aug - 03 Sept 2010	International Aerosol Conference, Helsinki, Finland	Scientific community	100-500	International
3	Collaborations / Workshops	FMI	Refinement and application of emissions, dispersion, and population exposure models in the Helsinki metropolitan area	2011 – 2014	Helsinki, Finland	Scientific community, Policy makers		Finland, UK
4	Thesis	IVL	Particle Emissions from Shipping: a focus on elemental, mass and number emission factors. Diploma thesis	March 2011	Gothenburg University, Sweden	Scientific Community		Sweden
5	Poster	IVL	Parameterisation of ship plumes in regional and global models	03-08 April 2011	European Geosciences Union (EGU) General Assembly, Vienna, Austria	Scientific Community	10000	International
6	Newsletter, Flyers	IVL	IVL Swedish newsletter – Focus study on particles from shipping	29 April 2011	Sweden	Industry, Civil society		Sweden
7	Article published in the popular press	, IVL	Att minska NO_X och partiklar	August 2011	Sjöbefälen, journal of Swedish Marine Officers Association	Industry		Sweden
8	Poster	THL	Solving Apparent Particle Density from Helsinki ULTRA2 Data	04-09 Sept 2011	European Aerosol Conference, Manchester, UK	Scientific community	80-400	Europe
9	Poster	, THL	From Outdoor Particle Concentration to	04-09 Sept	European Aerosol Conference,	Scientific	80-400	Europe

[10] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.
[11] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

			the Health Impact of Aerosol Particles – a Multidisciplinary Modelling Study, Part I	2011	Manchester, UK	community		
10	Poster	THL	Correction of urban PM2.5 apparent density with potential impacts of fractal aerosol in the Aitken mode	09-11 Sept 2011	Nordic Society for Aerosol Research (NOSA), Aerosol Symposium, Tampere, Finland	Scientific community	50-100	Nordic Countries
11	Poster	THL	Impact of particle density on infiltration and lung deposition	09-11 Sept 2011	Nordic Society for Aerosol Research (NOSA), Aerosol Symposium, Tampere, Finland	Scientific community	50-100	Nordic Countries
12	Newsletter, Flyers	IVL	IVL newsletter Swedish - New report on shipping emission factors	11 Dec 2011	Sweden	Industry, Civil society		Sweden
13	Newsletter, Flyers	IVL	IVL newsletter English - New report on shipping emission factors	Issue 5, December 2011	Sweden	Industry, Civil society		International
14	Oral presentation to scientific event	THL	Particle size dependence of infiltration and consequences for lung deposition	19-23 March 2012	8th International Conference on Air Quality - Science and Application, Athens, Greece	Scientific community	100-300	International
15	Poster	THL	Uptake fractions of PM mass between days of different aerosol size distributions	19-23 March 2012	8th International Conference on Air Quality - Science and Application, Athens, Greece	Scientific community	100-300	International
16	Oral presentation to scientific event, Publication	TNO	Methodology for integrated assessment of the health impact of traffic-related particulate matter	19-23 March 2012	8th International Conference on Air Quality - Science and Application, Athens, Greece	Scientific community	200	International
17	Oral presentation to scientific event, Publication	USTUTT	Integrated health impact assessment of transport policies – first results	19-23 March 2012	8th International Conference on Air Quality - Science and Application, Athens, Greece	Scientific community	200	International
18	Oral presentation to scientific event, Publication	NILU	Modelling PNC from kerbside to urban scale	19-23 March 2012	8th International Conference on Air Quality - Science and Application, Athens, Greece	Scientific community	200	International
19	Oral presentation to scientific event, Publication	UH	Sensitivity of aerosols to climate change and implications for regional air quality over Europe	19-23 March 2012	8th International Conference on Air Quality - Science and Application, Athens, Greece	Scientific community	200	International
20	Oral presentation to scientific event, Publication	NILU	Modelling PNC from kerbside to urban scale	19-23 March 2012	8th International Conference on Air Quality - Science and Applications, Athens, Greece	Scientific community	200	International
21	Oral presentation to scientific event	AUTH	Urban microenvironment measurements in Thessaloniki	20 March 2012	8th International Conference on Air Quality - Science and Application, Athens, Greece	Scientific Community, Civil Society, Media		International

22	Poster	IOM	Health Impact Assessment of traffic-related air pollution effects in cities: the TRANSPHORM project	15-17 April 2012	Health Effects Institute Annual Conference, Boston, Massachusetts, USA	Scientific community		International
23	Poster	THL	Building as a particle size dependent exposure and dose modifier	19-20 April 2012	Workplace and Indoor Aerosols Conference, Lund University, Sweden	Scientific community	50-100	Nordic Countries
24	Oral presentation to scientific event	IVL	Formation of secondary PM from ship emissions	23-24 May 2012	Conference of Gothenburg Atmospheric Science Centre, Gothenburg, Sweden	Scientific Community	~100	Sweden
25	Oral presentation to scientific event, Publication	USTUTT	A new European inventory of transport-related emissions for the years 2005, 2020 and 2030	25-28 June 2012	3rd International Conference on Transport, Atmosphere and Climate (TAC-3), Prien am Chiemsee, Germany	Scientific community	50-100	International
26	Oral presentation to scientific event	IVL	Emissions of primary and secondary pm from shipping	25-28 June 2012	3rd International Conference on Transport, Atmosphere, and Climate (TAC-3), Prien am Chiemsee, Germany	Scientific Community, Industry, Policy makers	~100	International
27	Publication	IVL	Primary and secondary PM from shipping, Extended abstract TAC III	25-28 June 2012	Proceedings of the 3rd International Conference on Transport, Atmosphere, and Climate (TAC-3) http://www.pa.op.dlr.de/tac/2012/Proceedings_of_TAC3_conference_final.pdf	Scientific Community, Industry, Policy makers		International
28	Poster	IVL	Thermo-chemical properties of fleet ship emission aerosols: relation to composition and structure	02-07 Sept 2012	European Aerosol Conference, Grenada, Spain	Scientific Community	~1000	International
29	Oral presentation to scientific event	IVL	Measurements of emission factors of PM and BC from shipping – research needed	12 Sept 2012	Shipping Symposium, Lund, Sweden	Industry, Policy makers, Scientific Community	~50	Scandinavian countries
30	Oral presentation to scientific event	IVL	Workshop on emissions related to shipping	29-30 Oct 2012	Joined MACC-II, ACCENT-Plus, ACCESS and PEGASOS meeting, Hamburg, Germany	Scientific Community	~40	International
31	Oral presentation to scientific event	Met. No	Fine scale calculations of present and future effects of different modes of transport on air quality in Europe	26-27 Nov 2012	19th International Transport and Air Pollution Conference, Thessaloniki, Greece	Scientific Community, Industry, Policy makers		International
32	Oral presentation	IVL	Formation of secondary PM from ship	26-27 Nov	19th International Transport and	Scientific		International

	to scientific event		emissions	2012	Air Pollution Conference, Thessaloniki, Greece	Community, Industry, Policy makers		
33	Oral presentation to scientific event	AUTH	Transport Emissions and their Impact on Air Quality in Athens: A Case Study in the Framework of TRANSPHORM	26-27 Nov 2012	19th International Transport and Air Pollution Conference, Thessaloniki, Greece	Scientific Community, Industry, Policy makers		International
34	Newletter, Flyers	UH	TRANSPHORM – an integrated assessment of the health impacts of transport related air pollution	December 2012	Who Newletter 2012	Scientific community, Industry, Civil society, Policy makers		International
35	Presentation and Discussion	UH	Performance of CMAQ over Europe and USE for PM2.5	2013 – 2014	Telephone Conference	Scientific community	5	Europe, USA
36	Workshop and Presentation	UH	HEI/EU health impacts of particulate matter	30-31 Jan 2013	Brussels, Belgium	Scientific community, Industry, Civil society, Policy makers	100	Europe
37	Oral presentation to scientific event	DLR	Global model simulations of the impact of the transport sectors on atmospheric aerosol and climate.	07-12 April 2013	European Geosciences Union (EGU) General Assembly, Vienna, Austria	Scientific community	1000	International
38	Oral presentation to scientific event	IOM	Health Impact Assessment of long-term exposure to particulate air pollution: methodological, spatial and practical considerations in using study results	15 April 2013	Scientific Meeting, University of Southampton, UK	Scientific community		UK
39	Oral presentation to scientific event	IVL	Seminar on black carbon for the Swedish Clean Air Society	24 April 2013	Swedish Clean Air Society, Stockholm, Sweden	Policy makers, authorities, scientific community	~50	Sweden
40	Oral presentation to scientific event	THL	Counterfactual behaviour of ultrafine particles in infiltration and lung deposition processes	19-23 August 2013	Conference of ISEE, ISES, and ISIAQ, Basel, Switzerland	Scientific community	100-800	International
41	Oral presentation to scientific event	IOM	Health Impact Assessment of long-term exposure to particulate air pollution: methodological and practical issues	19-23 August 2013	Conference of ISEE, ISES, and ISIAQ, Basel, Switzerland	Scientific community		International
42	Poster	THL	Particle size dependence of respiratory tract uptake in a population cohort	19-23 August 2013	Conference of ISEE, ISES, and ISIAQ, Basel, Switzerland	Scientific community	100-800	International

43	Poster	IVL	Physical and chemical characterisation of PM emissions from in-operation ship engines	01-06 Sept 2013	European Aerosol Conference, Prague, Czech Republic	Scientific Community	~1000	International
44	Oral presentation to scientific event	THL	Uptake of PM2.5 mass by respiratory tract region and particle size: Hypothetical estimates for the FINRISK Cohort, Helsinki, Finland	01-06 Sept 2013	European Aerosol Conference, Prague, Czech Republic	Scientific community	80-400	International
45	Oral presentation to scientific event	DLR	Global model simulations of the impact of transport sectors emissions on atmospheric aerosol and climate.	01-06 Sept 2013	European Aerosol Conference 2013, Prague, Czech Republic	Scientific community	1000	International
46	Oral presentation to scientific event	Met. No	Model calculations of the effects of present and future emissions of air pollutants from shipping in the Baltic and North Seas	17-20 Sept 2013	ACCENT-Plus Symposium	Scientific community		International
47	Workshop	DLR	The global impact of the transport sectors on atmospheric aerosol and climate.	23-27 Sept 2013	12th AeroCom Workshop, Hamburg, Germany	Scientific community	100	International
48	Oral presentation to scientific event, Publication	USTUTT	Assessment of policies to reduce greenhouse gas emissions and air pollution in Mediterranean EU countries	28 Sep - 1 Oct 2013	17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region (MESAEP), Istanbul, Turkey	Scientific community	50-100	EU27+2, with special focus on Mediterranean Region
49	Poster	IVL	Physical and chemical characterisation of PM emissions from in-operation ship engines	30-31 Jan 2014	NOSA aerosol symposium, Stockholm, Sweden	Scientific Community	~150	Nordic countries
50	Oral presentation to scientific event	IOM	Health Impact Assessment of long-term exposure to particulate air pollution: methodological and practical issues	20-24 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community		International
51	Oral presentation to scientific event	NILU	Modelling the source contribution of particulate matter in Oslo: Comparison between models and observations	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
52	Oral presentation to scientific event	NILU	Land use regression modelling for air quality exposure: A step in the wrong direction	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
53	Oral presentation to scientific event,	THL	Modelling exposure and lung deposition of particle-bound polycyclic aromatic	24-28 March 2014	9th International Conference on Air Quality - Science and	Scientific community	100-300	International

	Publication		hydrocarbons (PAHs)		Application, Garmisch-Partenkirchen, Germany			
54	Poster, Publication	THL	Uncertainties in health impact estimates due to exposure and respiratory tract deposition processes	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	100-300	International
55	Oral presentation to scientific event, Publication	THL	Outdoor air dominates burden of disease from indoor exposures	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	100-300	International
56	Oral presentation to scientific event, Publication	THL	The comparison of costs of policies aimed at reducing air quality induced health risks, health benefits and perceived values in Finland	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	100-300	International
57	Oral presentation to scientific event, Publication	FMI	An improved model for evaluating the urban population exposure	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	100-300	International
58	Oral presentation to scientific event, Publication	TNO	Impact of emissions from inlands shipping on air quality and health in the Netherlands	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
59	Oral presentation to scientific event, Publication	FMI	Can the predictions of road dust emission models be directly compared with on-site mobile measurements?	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
60	Oral presentation to scientific event, Publication	FMI	Evaluation of the present and future air quality in Europe based on TRANSPHORM multi-model ensemble	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
61	Oral presentation to scientific event, Publication	IOM	Health impact assessment of long-term exposure to particulate air pollution within TRANSPHORM. (for special session on TRANSPHORM project)	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
62	Oral presentation to scientific event, Publication	TNO	European particle number emissions for 2005, 2020 and 2030 with special emphasis on the transport sector	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International

63	Oral presentation to scientific event, Publication	Met. No	Calculations of present and future effects of different transport modes on air quality and human health in Europe	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
64	Oral presentation to scientific event, Publication	FMI	Modelling of particulate matter concentrations in the Helsinki metropolitan area in 2008 and 2010	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
65	Oral presentation to scientific event, Publication	AUTH	Refinement and evaluation of a statistical approach for determining concentration increments in urban areas	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
66	Oral presentation to scientific event, Publication	TNO	Intercomparison of urban scale air quality models	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
67	Oral presentation to scientific event, Publication	UH	Contribution of emission sources to concentrations of fine particulate matter (pm2.5) in Europe	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
68	Oral presentation to scientific event, Publication	UH	Urban and traffic contributions to pm2.5 in London	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
69	Oral presentation to scientific event, Publication	AUTH	Roadside and urban background measurements of ultrafine particles in Thessaloniki, Greece – 7 years later	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
70	Oral presentation to scientific event, Publication	USTUTT	Integrated assessment of policies for reducing health impacts of air pollution caused by transport in Europe	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
71	Oral presentation to scientific event, Publication	UH	Airborne particulate matter and associated health impacts: new developments and implications for EUROPE	24-28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific community	200	International
72	Poster, Publication	HMGU	Residential long-term exposure to particulate matter components and	24-28 March 2014	9th International Conference on Air Quality - Science and	Scientific community	300	International

			cardiovascular disease endpoints in adults		Application, Garmisch-Partenkirchen, Germany			
73	Presentation	UH	Transport related air pollution and health impacts	28 March 2014	DEFRA, London	Policy makers	10	UK, Europe
74	Poster, Publication	AUTH	Micro and Macro modelling of cold start emissions from road traffic: A case study in Athens	28 March 2014	9th International Conference on Air Quality - Science and Application, Garmisch-Partenkirchen, Germany	Scientific Community, Civil Society, Media		International
75	Poster	AUTH	Quantification of road transport particulate matter using detailed technology emission factors	15 April 2014	Transport Research Arena, Paris, France	Scientific Community, Industry, Policy makers		Europe
76	Poster	AUTH	Quantification of non-exhaust road transport PM emissions	15 April 2014	Transport Research Arena, Paris, France	Scientific Community, Industry, Policy makers		Europe
77	Poster	AUTH	COPERT Micro: a tool to calculate the vehicle emissions in urban areas	17April 2014	Transport Research Arena, Paris, France	Scientific Community, Industry, Policy makers		Europe
78	Oral presentation to scientific event	J. Moldanová, IVL	Methodologies for emission inventories for shipping	28-29 April 2014	FAIRMODE technical meeting, Kjeller, Norway	Scientific Community	~80	International
79	Oral presentation to scientific event	Brian Miller, IOM	Health Impact Assessment in TRANSPHORM: city case studies	06 May 2014	TRANSPHORM Stakeholders Meeting, Brussels, Belgium	Scientific community, Industry, Civil society, Policy makers, Media	60	Europe
80	Organisation of workshop	UH	TRANSPHORM workshop for stakeholders, quantifying health impacts of particulate matter over Europe - new approaches, implications and recommendations for policy	06 May 2014	TRANSPHORM Stakeholders Meeting, Brussels, Belgium	Scientific community, Industry, Civil society, Policy makers	60	Europe
81	Workshop	TNO	Health impact assessment of transport-related measures in urban areas	16-17 June 2014	Rotterdam, Netherlands	Scientific community, Policy makers	40	Netherlands
82	Presentation	FMI	Selected policy-relevant results from the TRANSPHORM project	19-20 August 2014	Annual Conference of the Air Pollution Prevention Association, Lappeenranta,	Scientific community, Industry, Civil	200	Finland, Europe

					Finland	society, Policy makers, Media		
83	Oral presentation to scientific event	IOM	Methodologies for Health Impact Assessment of Long-Term Exposure to Particulate Air Pollution	24-28 August 2014	International Society for Environmental Epidemiology Annual Conference, Seattle, Washington, USA	Scientific community		International
84	Presentation	NILU	Emission factor scaling for simple health impact assessment	04 Sept 2014	Oslo city council	Policy makers	4	Norway

8 Address of the project public website, contact and project beneficiaries

TRANSPHORM has developed an active and dynamic website, which enables partner to interact on day-to-day basis and upload and share relevant documents. Further external interested parties can also join stakeholder forum and to explore more about project, related issues, progress and newsletters.

http://www.TRANSPHORM.eu/

Contact of Project coordinator:
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Project beneficiaries

Part. No.	Participant Name	Short name	Country
1. (Coord.)	University of Hertfordshire	UH	UK
2. (Co-coord)	Nederlandse Organisatie Voor Toegepast Natuurwetenschappelijk Onderzoek	TNO	The Netherlands
3. (Co-coord)	Universiteit Utrecht	UU	The Netherlands
4.	Norsk Institutt For Luftforskning	NILU	Norway
5.	Ilmatieteen Laitos	FMI	Finland
6.	Deutsches Zentrum für Luft- und Raumfahrt e.V.	DLR	Germany
7.	Transport & Mobility Leuven Nv	TML	Belgium
8.	Aristotelio Panepistimio Thessalonikis	AUTH	Greece
9.	Commission Of The European Communities - Directorate General Joint Research Centre	JRC	International
10.	Institute Of Occupational Medicine	IOM	UK
11.	Ivl Svenska Miljoeinstitutet Ab	IVL	Sweden
12.	Terveyden Ja Hyvinvoinnin Laitos	THL	Finland
13	Meteorologisk Institutt	Met.no	Norway
14.	Helmholtz Zentrum Muenchen Deutsches Forschungszentrum Fuer Gesundheit Und Umwelt Gmbh	HMGU	Germany
15.	Institute of Environmental Medicine, Karolinska Institutet	KI	Sweden
16.	Danmarks Meteorologiske Institut	DMI	Denmark
17.	Imperial College of Science, Technology And Medicine	IC	UK
18.	Institute of Social and Preventive Medicine at Swiss Tropical Institute	STI	Switzerland
19.	Centre for Physical Sciences and Technology, Lithuania	CPST	Lithuania
20.	Universitaet Stuttgart	USTUTT	Germany
21.	URM - Útvar rozvoje hl.města Prahy	URM	Czech Republic

9 Report on societal implications

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	243406
Title of Project:	Transport related air pollution and health impacts
Name and Title of Coordinator:	Professor Ranjeet S Sokhi
B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	**No**
2. Please indicate whether your project involved any of the following issues (tick box) :	
RESEARCH ON HUMANS	
• Did the project involve children?	**No**
• Did the project involve patients?	**No**
• Did the project involve persons not able to give consent?	**No**
• Did the project involve adult healthy volunteers?	**No**
• Did the project involve Human genetic material?	**No**
• Did the project involve Human biological samples?	**No**
• Did the project involve Human data collection?	**No**
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	**No**
• Did the project involve Human Foetal Tissue / Cells?	**No**
• Did the project involve Human Embryonic Stem Cells (hESCs)?	**No**
• Did the project on human Embryonic Stem Cells involve cells in culture?	**No**
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	**No**
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	**No**
• Did the project involve tracking the location or observation of people?	**No**
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	**No**
• Were those animals transgenic small laboratory animals?	**No**
• Were those animals transgenic farm animals?	**No**
• Were those animals cloned farm animals?	**No**
• Were those animals non-human primates?	**No**

RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	**No**
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	**No**
DUAL USE	
• Research having direct military use	**No**
• Research having the potential for terrorist abuse	**No**

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	**0**	**3**
Work package leaders	**10**	**23**
Experienced researchers (i.e. PhD holders)	**27**	**50**
PhD Students	**10**	**12**
Other	**24**	**36**

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**7**
Of which, indicate the number of men:	**7**

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	**Yes**

6. Which of the following actions did you carry out and how effective were they?

Action	Not at all effective → Very effective
■ **Design and implement an equal opportunity policy**	○ ○ ○ ○ ●
❑ Set targets to achieve a gender balance in the workforce	○ ○ ○ ○ ○
❑ Organise conferences and workshops on gender	○ ○ ○ ○ ○
❑ Actions to improve work-life balance	○ ○ ○ ○ ○
■ **Other:**	**Equal opportunities was implemented locally according to agreed principles**

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

○ **No – X**

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

○ **No – X**

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

- ○ **Yes- please specify – X** — Website and training material
- ○ No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

- ○ Main discipline[12]: **1.4**
- ○ Associated discipline[12]: **1.1**
- ○ Associated discipline[12]: **3.3**

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	○ ○	**Yes – X** No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ○ No
- ○ **Yes- in determining what research should be performed – X**
- ○ **Yes - in implementing the research – X**
- ○ **Yes, in communicating /disseminating / using the results of the project – X**

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ ○	Yes **No – X**

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ **Yes- in framing the research agenda – X**
- ○ Yes - in implementing the research agenda
- ○ **Yes, in communicating /disseminating / using the results of the project – X**

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ **Yes – as a primary objective (please indicate areas below- multiple answers possible) – X**
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture	Energy	Human rights
Audiovisual and Media	Enlargement	Information Society
Budget	Enterprise	Institutional affairs
Competition	**Environment – X**	Internal Market
Consumers	External Relations	Justice, freedom and security
Culture	External Trade	**Public Health – X**
Customs	Fisheries and Maritime Affairs	**Regional Policy – X**
Development Economic and Monetary Affairs	Food Safety	**Research and Innovation – X**
Education, Training, Youth	Foreign and Security Policy	Space
Employment and Social Affairs	Fraud	Taxation
	Humanitarian aid	**Transport – X**

[12] Insert number from list below (Frascati Manual).

13c If Yes, at which level? ○ **Local / regional levels – Yes** ○ **National level – Yes** ○ **European level – Yes** ○ **International level – Yes (partly)**	

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?		**48 (but increasing)**
To how many of these is open access[13] provided?		**17**
How many of these are published in open access journals?		**17**
How many of these are published in open repositories?		**17**
To how many of these is open access not provided?		**20**
Please check all applicable reasons for not providing open access:		
❑ **publisher's licensing agreement would not permit publishing in a repository – X** ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[14]: ……………		
15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		**N/A**
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**N/A**
	Registered design	**N/A**
	Other	
17. How many spin-off companies were created / are planned as a direct result of the project?		**N/A**
Indicate the approximate number of additional jobs in these companies:		

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑ Increase in employment, or	❑ In small & medium-sized enterprises
❑ Safeguard employment, or	❑ In large companies
❑ Decrease in employment,	❑ None of the above / not relevant to the project
❑ **Difficult to estimate / not possible to quantify – X**	

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:* **20 (estimated)**

[13] Open Access is defined as free of charge access for anyone via Internet.
[14] For instance: classification for security project.

Difficult to estimate / not possible to quantify	❑

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ **Yes – X** ○ No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ **Yes – X** ○ No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

❑	Press Release	❑	**Coverage in specialist press – X**
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	**Coverage in international press – X**
❑	**Brochures /posters / flyers – X**	❑	**Website for the general public / internet – X**
❑	DVD /Film /Multimedia	❑	**Event targeting general public (festival, conference, exhibition, science café) – X**

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	❑	**English – X**
❑	Other language(s)		

Question F-10: Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]