PROJECT FINAL REPORT

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1 Executive Summary - Derived from earlier ideas quantifying some of the health benefits of greenhouse gas (GHG) policies, this project used as a starting point the EU targets such as a reduction in the total GHG emissions by 20% from 1990 to 2020 and the Chinese Government 2020 target of a 40-45 % cut in CO_2 emissions from 2005 levels relative to gross domestic product. The scope of this project was the public health and well-being impact of urban scale implementation of city GHG-mitigation policies already identified, involving five EU and two Chinese cities (e.g. public transport or building/planning investments, cycling, fuel changes in cars and industry, energy generation modes and cost). The temporal scale was +10 years from the 2010 baseline, to allow comparison to the EU and Kyoto-Copenhagen targets while also enabling realistic assessment of longer term policies. A modelling platform and a related database for urban impact assessment were developed, exploiting Geographical Information Systems (GIS) and covering energy generation and use, spatial data, building stock, transportation and population factors (i.e. socio-economic, demographic, exposure, health and well-being). Reference/business as usual (BAU) scenarios were generated for 2010 as the base year and for 2020. Other scenarios were then modelled to study the possible GHG policy outcomes. While open-source GIS was an intended medium, cities had their own systems and hence the GIS work was focussed upon a dissemination tool to assist them in communicating their results to policy makers, primarily to enable visualizations. For the energy model, a full energy balance was obtained or generated for a current year, describing the flow and transformation of energy carriers within the city and the surrounding country. For buildings, the output was the 'Building Model', an on-line model for building stock assessments that functions in the Opasnet open source web workspace, using selected indoor environment quality (IEQ) indicators for health impact assessment and building-related well-being. For transport, it was concluded that no new traffic model was required for the cities involved, using local traffic projections or the TREMOVE database or, for Chinese cities, open source data with local traffic counting and road capacity applied to forecast future traffic volume. The cities were supported with their air quality and noise assessments. The annual average concentrations of NO_2 (nitrogen dioxide) $PM_{2.5}$ (the mass of particles smaller than 2.5 µm), PM_{10} (the mass of particles smaller than 10 µm), all regulatory components in Europe, and elemental carbon (EC) were modelled in all cities and night noise levels were modelled for two of them. Air pollution in the Chinese cities is a factor 3 to 5 higher than in the European cities in 2010 and 2020-BAU. It is expected that from 2010 to 2020 air pollution emissions will reduce due to cleaner technology in all sectors, reducing regional background concentrations of all pollutants in the European cities while in the Chinese cities these concentrations are likely to remain constant for $PM_{2.5}$ and PM_{10}, to decrease for EC and to increase for NO_2 as a result of economic growth. Summary tables of parameters were produced for Health outcomes and Well-being outcomes. Outcomes from most policy scenarios showed marginal additional health benefits, with an example of a potential 1.5 million euros saved from total costs of 33 million per year caused by $PM_{2.5}$ exposure in one EU city contemplating moves to biomass in combined heat and power, bio-fuels in transport and improvements to buildings insulation. Well-being effects of the policy scenarios were found to be positive but were generally expressed less strongly than health benefits. In China, the impact of all scenarios on air quality was found to be negligible compared to that of ongoing economic development. However, as an example of other work carried out there, a Chinese survey on well-being indicated the importance given by local people to health, social life and safety, with implications noted for policy development for healthcare and communities.

2 Context & Objectives

This project originated from the earlier works of Davis *et al.* (1997), Wang and Smith (1999), and Künzli (2000), identifying and quantifying some of the health benefits of greenhouse gas (GHG) policies to reduce carbonaceous fuels in heat and power generation, heating, and transport. The lowest socio-economic groups are typically the most adversely affected because they often live and work in the areas of the highest ambient air pollution and suffer poor building quality, crowding, heating and ventilation, as demonstrated by the EXPOLIS and LARES studies. Such effects should be directly assessed and considered in policy development, implementation and follow up (Jantunen 1997, Rotko *et al.* 2000, Rotko *et al.* 2001, WHO 2007).

In our previous assessments, it had become evident that urban decisions are crucial in global GHG-policies, so impact assessments of the public health and well-being of GHG-policies should be done on the urban level. This project used as a starting point the EU-wide target of reducing the total GHG emissions by 20% from 1990 to 2020, the emissions included in the European emissions trading system (EST) by 21% from 2005 to 2020 (Directive 2009/29/EC), and limiting the member state level non-ETS emissions by burdens distributed between the members states according to their potential and capacities. The Chinese Government on November 26 2009 announced a 2020 carbon intensity target, a 40-45 % cut in CO_2 emissions from 2005 levels relative to gross domestic product, which will not mean an actual drop in emissions unless China's economy stops growing at its current rapid pace but will slow the growth of emissions. All participating cities had their own GHG policies in place before the Copenhagen COP-15 meeting, and at least two of the cities, Kuopio and Rotterdam, have much more ambitious GHG-reduction goals than the EU. The city-wide GHG reduction targets of the alternative policies assessed in this project either complied with the national policy targets or the city targets, whichever had a higher ambition. The alternative policy packages were tailored for each city and assessed by the cities in collaboration with the research institutes, using the assessment tools provided by the methodological work packages, thus enabling unique solutions together with comparisons.

It may be noted that the exposure to, and health effects of, urban air pollution are not distributed equally across the socio-economic strata. The lowest socio-economic groups are usually the most exposed because they often reside, go to work and school in the areas of the highest ambient air pollution. Even when this is not the case, the indoor air quality experienced by these groups may still be inferior due to poor building quality, crowding, heating and ventilation, as demonstrated by the EXPOLIS and LARES studies. Burdens and benefits of different GHG policies may thus treat the different socio-economic groups differently, and so such effects should be directly assessed and considered in policy development, implementation and follow up (Jantunen 1997, Rotko *et al.* 2000, Rotko *et al.* 2001, WHO 2007).

The scope of this project was the public health and well-being impact of urban scale implementation of GHG-mitigation policies. The spatial scale of the project is an urban area - a conurbation. For electrical power demand exceeding the power generated and supplied from within the metropolitan area, the scale is national electric power generation. The temporal scale is 10 years from 2010, to allow comparison to the EU and Kyoto-Copenhagen targets while also enabling realistic assessment of longer term policies.

The methodological project objective was to develop a modelling platform and a related database for urban impact assessment. The platform had to be robust, easily transportable to new cities and usable for draft or detailed assessment depending on the availability of data. The topics covered were: urban energy generation and use, with GHG and other pollution release; urban spatial data including the urban spatial plan, building stock, transportation and population; socio-economic, demographic, exposure, health and well-being of the population.

Specific objectives set against project Work Packages were as follows:

- To design and develop an urban energy balance analysis tool and methodology to apply to specific urban greenhouse gas (GHG) policies regarding their expected influence on emission reduction, changes in energy demand and supply and changes in other relevant activities in the cities, providing training and guidance in simulation and assessment of GHG reduction scenarios.
- To provide standards and tools for a modern GIS for health service architecture for implementation in the project, with demonstration materials to enable assessment and use of the methodology.
- To prepare a database for buildings and urban structure assessment in the cities using appropriate indoor environment quality (IEQ) indicators, with training and guidance.
- To operate with the cities a traffic mode model for integrated assessment of health and well-being based on GIS-traffic, estimating the change in transport-related emissions of air pollutants and noise against reduction in transport-related CO_2 emissions.
- To offer methodologies and tools for the modelling and assessment of population distributions of exposure, health and wellbeing to show the impacts of changes in exposures related to various GHG mitigation scenarios in the cities, providing training and guidance. Alongside this, to update methodologies for health impact assessment (HIA) of conventional pollutants, to define relevant well-being parameters, to identify the distribution of the impacts across sub-populations and to contribute generalised lessons from the work.
- To apply all of the above within the participating cities, providing learning for them and understanding for potential application or policy guidance elsewhere, the main practical project objectives for each participating city being to:

➢ Evaluate the current contributions of heat and power use in the urban building stock, urban traffic and transportation needs, and the overall spatial plan of the city with respect to GHG-emissions, other environmental stressors, environment quality, public health and well-being of the population.

➢ Evaluate the future public health and well-being impacts of the local implementation of alternative GHG-policies which would meet the locally applicable national, EU and/or international GHG-reduction targets specifically in each city.

➢ Based on the above, to develop and assess an optimised, i.e. maximum net public health and wellbeing benefits, GHG-mitigation policy package for each city.

➢ Prepare a roadmap to this optimised GHG-policy future.

3 Scientific & Technical results

3.1 INTRODUCTION

A consortium of scientists in the areas of health risk assessment, urban energy demand and supply scenarios, urban planning, environmental science and epidemiology has developed and applied a methodological framework for the assessment of the overall risks and benefits of alternative greenhouse gas (GHG) emission reduction policies for health and well-being in cities. They have worked in close collaboration with city partners in both Europe and China, thus providing detailed case studies to aid these cities and to provide models for others. Specific work areas have been in energy balances, buildings and transport, supported by analysis of health and well-being indicators and an open-source GIS database and tools that may be used to apply the process in any urban centre. A conceptual view of the linkage between these components is shown in Figure 1 below. There follow descriptions of the development work in these areas, with particular detail on health and wellbeing as the ultimate outcome, and the application to actual urban scenarios.

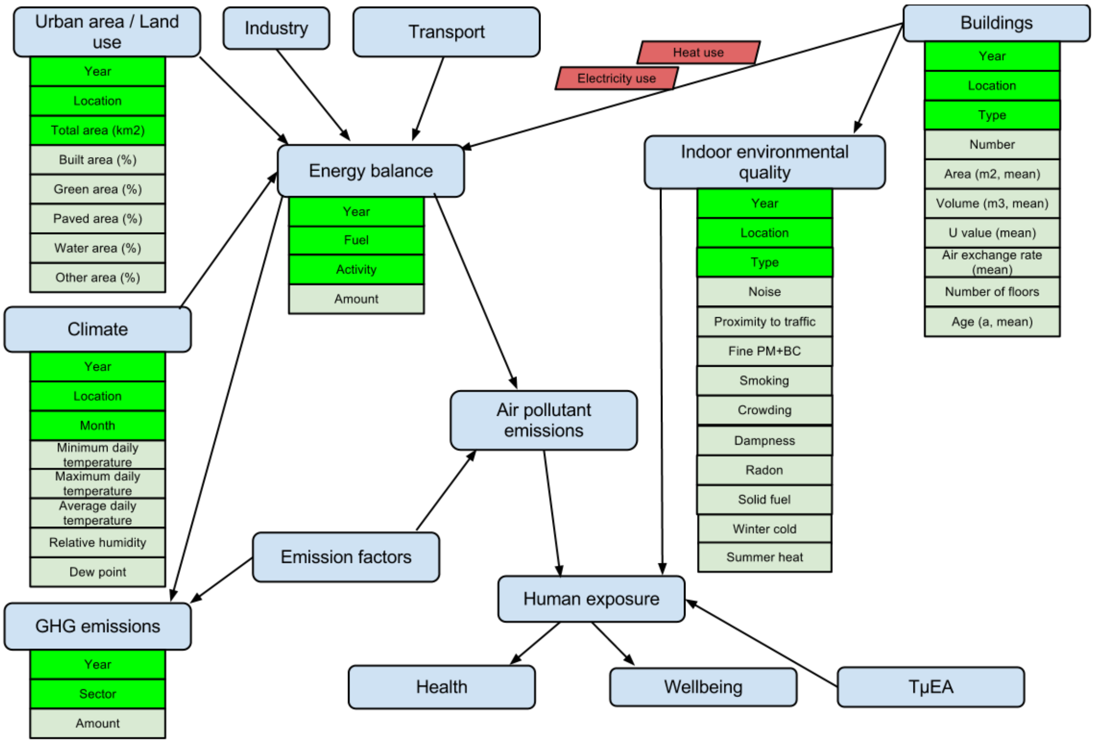


Figure 1 URGENCHE conceptual model

Appendix 1 provides schematic demonstrations of the data-gathering for the four areas of energy, buildings, transport, and 'health and well-being' for each city.

3.2 ENERGY BALANCES

The objective here was to develop and apply a model and tool for analysing energy-related policies and measures for reducing greenhouse gas emissions and/or emissions of air pollutants; the model should be capable of including upstream processes into the assessment and of simultaneously assessing impacts of GHG emissions and air pollutants. As a starting point for developing the model, a full energy balance for a current year was generated or, if already available, obtained. An energy balance describes the flow and transformation of energy carriers within the city, the region and the area surrounding the city. The first task is then to couple the energy balances of the different spatial scales by firstly determining the import and export of energy carriers across the city boundary and then using the regional and/or national balance to describe the activities related to this import or export outside of the city. The resulting 'full energy balance' describes a certain state of the energy system. As the aim is to assess changes of the energy system, such as increasing use of bio-fuels, increasing use of biomass in domestic heating, fuel shifts, etc., the energy balance data is then transformed into a system of linear equations that depict the energy flows and transformation processes within a city. Starting from energy demand, the market allocation shares for the different supply chains are fixed, e.g. if heat demand for domestic heating is met by a certain percentage from oil fired boilers, this share will stay constant if the heat demand is changed. However certain restrictions have to be taken into account. First, the maximum amount of secondary energy that a conversion plant, e.g. a power plant or a refinery, can produce is limited by its capacity. Secondly, for CHP (combined heat and power production) plants that are operated according to heat demand, the electricity produced is a fixed share of heat production. Both conditions can be formulated as limiting boundary conditions.

Emission factors for GHGs and air pollutants are applied to the processes in the energy balance. As long as emission factors are related to energy consumption or production, emission factors can be directly allocated to the energy data of each process in the energy model. A reference for the energy system was developed for a future year (as measures and policies usually need some time before they are implemented). This assumed the development of demand, market shares and emission factors in the model. Policies and measures were analysed by defining a policy scenario and changing energy demand and/or market allocations. The model then estimates the emissions of greenhouse gases and air pollutants in and outside of the city, and these can be compared with the reference scenario emissions. Emissions of air pollutants can then be further assessed by estimating health impacts using the impact pathway approach. The energy balance model was generated and used for one Chinese city, Suzhou (see example in Figure 2 below) and for three European cities: Kuopio, Stuttgart and Basel. Reference/business as usual (BAU) scenarios were generated for the year 2010 as base year and the year 2020. For the development of demand and supply data from 2010 to 2020, results of a Europe-wide energy model (TIMES) were used. Based on the BAU scenario, a number of policy scenarios were constructed. Examples of anticipated future changes in Stuttgart and Basel are shown in Appendix 2.

As an example of the kind of question raised for policy-makers, for Stuttgart the use of more wood pellet boilers for heating was analysed. Pellet boilers contribute to reduce CO_2 emissions by replacing fossil energy sources at a global scale. However, at a local scale, higher particulate matter emissions could be associated with additional local human health impacts. Thus the emission factor of the technology used is decisive for whether the climate protection effect outweighs the health impacts or not.

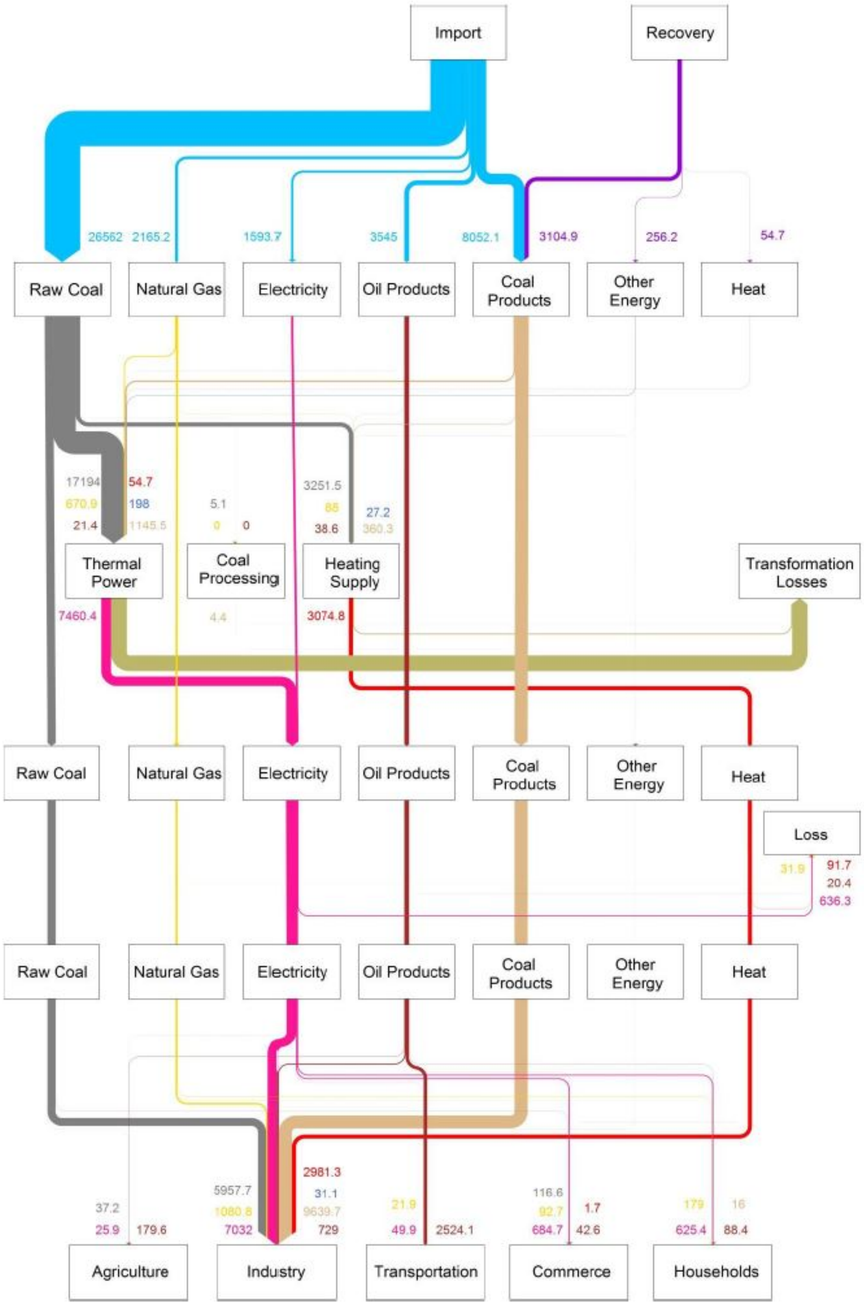


Figure 2 Energy Balance for Suzhou city 2010

3.3 GIS CITY

The aims of this work were to provide a central database holder for each of the cities, to develop a prototype based on open source projects and to help to facilitate the training and dissemination of activities within URGENCHE. Three outputs were specified at the start:

- *Collation of urban spatial data for GIS database.*
- *Prototype GIS system and model for City analyses.*
- *A peer-reviewed paper on the utility of the GIS analysis tool in the project.*

The data that was required for the Energy Balances, Health & Well-being, Urban Traffic (TNO) and GIS-Buildings components was achieved separately for each city analysis, by

TNO for traffic and by THL for buildings. Due to the diversity of the datasets that were used by each city, it was decided that the cities would handle their own datasets independently. Where appropriate (eg for Xi'an city) open-source GIS datasets (from openstreetmap) were sourced to supplement their own datasets. The University of Exeter has developed a web-based GIS tool based on open-source tools. However, following feedback during consultation with the cities it was clear that they each had their own GIS tools that had greater functionality than a web-based tool can provide. Therefore work was directed to adapting some of the developed systems to provide a dissemination tool that can help cities communicate their results to policy makers. Visualisations were produced focusing on communicating the energy policies for the cities.

3.4 BUILDING STOCK

This work focussed upon use of data for building and urban structure assessment and the modelling of selected indoor environment quality (IEQ) indicators, developing tools and refining the methodology from the learning from the case studies. The main outputs are as follows:

a) The Building Model - This is an on-line model for city-level building stock assessments that functions in the Opasnet open source web workspace, based upon the project requirements. It offers defined data requirements and developed data templates. The concept is flexibility and applicability in different situations and therefore the data requirements are suggestive rather than strictly defined. The methodology has been refined according over time.
b) Output on IEQ for health impact assessment and building-related well-being.

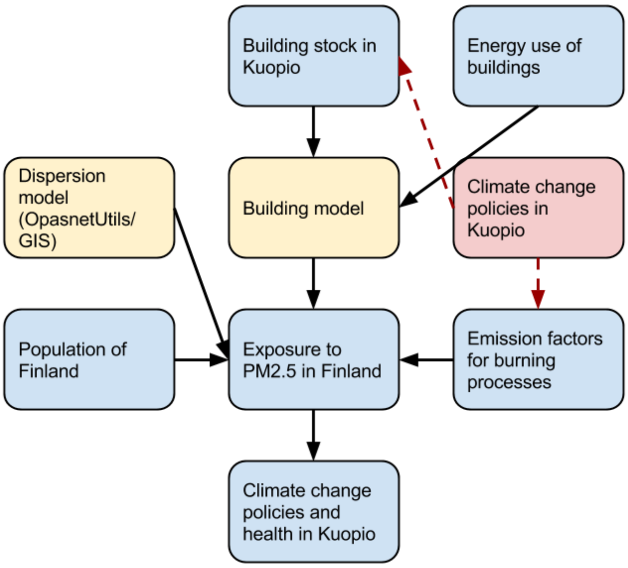


Figure 3 Relationship of different data within the Building Model (example: Kuopio)

3.5 URBAN TRAFFIC

The overall aim of the Traffic component was to review and to harmonise the Geographical Information System (GIS) methodology to assess the effect of GHG policies on road traffic-related air pollution and noise to support integrated assessment of health risk and well-being in urban areas. The following activities were identified and pursued:

- identification of existing GIS-traffic applications by the city partners;
- output requirements for integrated assessment of health and well-being;
- provision of a simple-data city-level traffic mode model to cities;
- estimation of expected changes in emissions of air pollutants and noise;
- development, dissemination and support GIS-traffic methodology and
- refinement of GIS-traffic methodology.

The outputs included a review of existing GIS-traffic modelling and the requirements for health and well-being assessments, described in a document entitled 'the GIS-traffic methodology'. It was, however, concluded that no traffic model is required for the cities involved in URGENCHE. For the European cities, either local traffic projections or the TREMOVE database were used to estimate future traffic volume. For Chinese cities, open source data in combination with local traffic counting and the maximum road capacity was applied to forecast future traffic volume. The cities were supported by air quality (all cities) and noise (only Basel and Rotterdam) assessment. All cities have finalized the air quality assessment for a recent year and 2020-BAU. All European cities have defined CO_2 reduction plans for road traffic in 2020. In Chinese cities, no specific CO_2 reductions plans have been defined and therefore, two European scenarios have been applied in China. In addition to the methodological development in the 'Traffic' output, the cities have been supported with their air quality and noise assessment in case studies.

The case studies concerned different scenarios: the introduction of biofuels in Kuopio, more public transport by extending the metro system in Thessaloniki and Xi'an, a bundle of traffic measures in Stuttgart and two specific traffic scenarios in Rotterdam, Basel, Xi'an and Suzhou. The traffic policies for Basel are shown as an example in Appendix 3. These traffic scenarios were a 10% reduction of private vehicle kilometres (I) and the other scenario the introduction of 50% electric-powered private vehicle kilometres (II). The effects on air quality were both compared to a 'business-as-usual' scenario: 2020-BAU. The annual average concentrations of NO_2 (nitrogen dioxide) $PM_{2.5}$ (the mass of particles smaller than 2.5 µm), PM_{10} (the mass of particles smaller than 10 µm) and elemental carbon (EC) were modelled in all cities. The air pollutants NO_2, $PM_{2.5}$ and PM_{10} are regulatory components in Europe, while EC is a sensitive indicator for exhaust emission from road traffic. In the cities Rotterdam and Basel the impact on the noise levels were also modelled during the night to assess sleep-disturbance and during the day to assess annoyance. The air quality data were used to conduct a health impact assessment, while the noise data were applied in a well-being assessment. More specific details about the case studies in the cities are as follows:

- *City-Thessaloniki:* The air quality (AQ) assessment and associated health impact for 2010 and 2020 were produced. The impact of the introduction of a metropolitan underground rail system was assessed and the results presented during the ISEE-conference in Basel 2013.
- *City-Rotterdam and city-Basel*: The AQ, noise and population-weighted exposure were produced for 2010, 2020 and 2020+two traffic measures. In collaboration with the city of

Basel, a local traffic scenario was updated and recalculated for the impact on air quality and noise.

- *City-Stuttgart*: The AQ and population-weighted exposure were developed for 2010 and 2020. For 2020, a bundle of measures to reduce CO_2 emissions is envisaged and the impact on air quality has been assessed.
- *City-Kuopio:* The AQ and population-weighted exposure were produced for 2010 and 2020. For 2020, the introduction of biofuels in road traffic is envisaged in 2020 and the impact on air quality has been assessed.
- *City-Xi'an:* The air quality in 2010 and 2020 was modelled for NO_2, $PM_{2.5}$, PM_{10} and EC. Also, the impact of two traffic measures (similar as in Basel and Rotterdam) on air quality was modelled. A thesis was delivered on the impact of a metro on the AQ in Xi'an.
- *City-Suzhou*: Similar to Xi'an, for Suzhou the impact of traffic scenarios on AQ in 2010 and in 2020, including two traffic measures, was modelled.

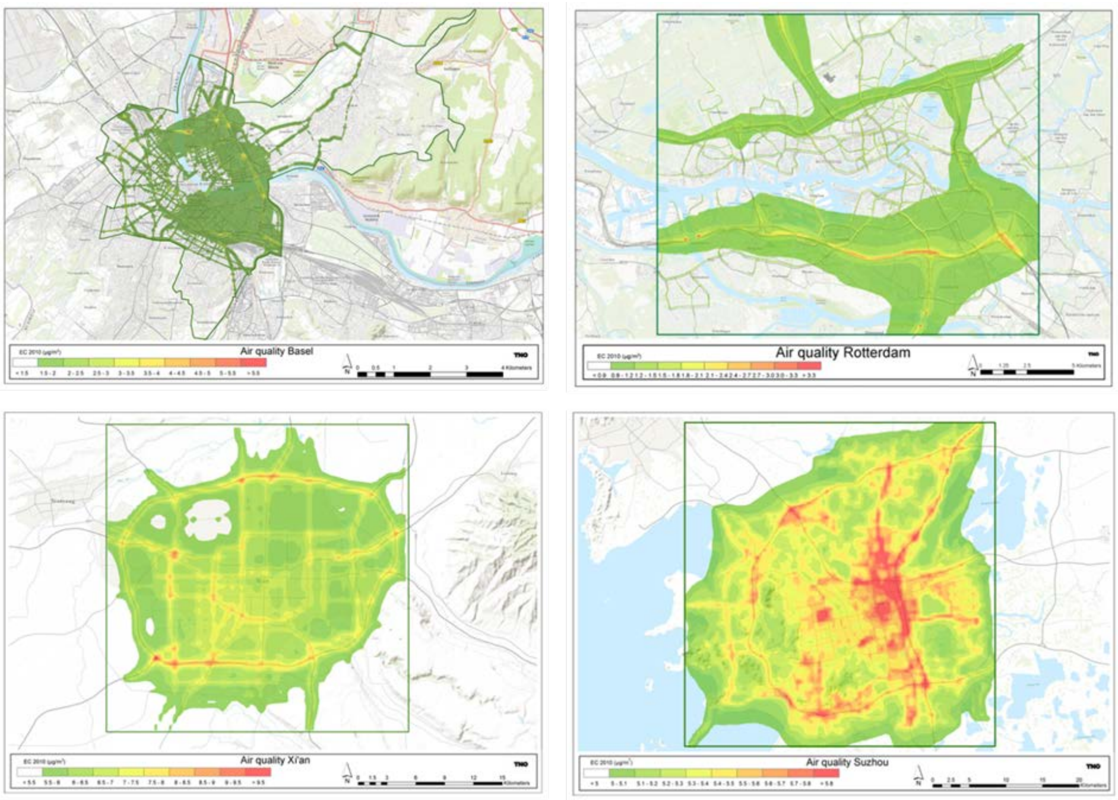


Figure 4 Annual average elemental carbon (µg m^{-3}) Basel, Rotterdam, Xi'an & Suzhou (2010)

Air pollution in the Chinese cities is a factor 3 to 5 higher than in the European cities in 2010 and 2020-BAU. It is expected that in the period 2010-2020 air pollution emissions will reduce due to cleaner technology in all sectors. This will reduce regional background concentrations of all pollutants in the European cities. In the two Chinese cities, regional background concentrations are likely to remain constant for $PM_{2.5}$ and PM_{10}, to decrease for EC and to increase for NO_2 as a result of economic growth. The two traffic scenarios in Basel, Rotterdam, Suzhou and Xi'an may reduce traffic-related CO_2 emissions in the order of 5% (scenario I: '10% reduction of personal cars') and 25% (scenario II: '50% personal cars at inner-urban roads') compared to 2020-BAU. The impact of the two traffic scenarios on air quality in the four cities was studied separately in three zones: near streets with more than 10 000 vehicles per day, within 100 m of motorways and in the remainder of the urban area.

A major constraint for modelling air quality in China is access to the input data required and lack of measurements at ground level for validation. The use of open data (e.g. www.openstreetmap.org) is a practical alternative to collect the required data (road structure; traffic data; air quality background concentrations; meteorology).

The results demonstrated that traffic-related CO_2 emissions in 2020-BAU will stabilize in European cities and increase by approximately 40% in Chinese cities compared to 2010. The main reason for the latter is the expected growth in the volume of road traffic in China. It was concluded that the two local traffic scenarios will do little to improve air quality over and above 2020-BAU and also their impact on noise level was limited.

3.6 EXPOSURE, HEALTH & WELL-BEING

For the definition of the elements to be included in the project, two summary tables of parameters were produced for 'health outcomes' and 'wellbeing outcomes'. For each parameter a form summarises the following: exposure indicator; data needed; level at which it applies; health effects of short-term and long-term exposures; more susceptible population sub-groups. In practice it was not possible to model all these. Thus the decision was made to focus on mitigation of greenhouse gas emissions rather than adaption (e.g. flooding, heat island effects) due to the call for research that funded the project, and health impacts via air pollution due to the expertise of academics involved in the project. The literature on the effects of the changes in buildings, transport and energy on air pollution and the effects of air pollution on health is well established but there is less known about wellbeing. A review of existing exposure/response (E/R) functions was completed to create the health impact assessment (HIA). Agreed health endpoints for E/R functions were available from other European projects such as: INTARESE, HEIMTSA, CAFE, EnVIE, URBIS, TRANSFORM, HRAPIE, REVIHAAP, TRANSPHORM. The relevance and validity of available E/R functions depends on the study design, policy question and local setting. Chinese cities present a slightly different situation due to high air pollution levels. The calculation of the impacts on health is only possible when various data are available. The validity of available E/R functions depends on the study design, policy question and local setting. In Europe and North America they have been used for many years, while only recently in China and Asia. Population and health data is also required, split by age and gender. The yearly average concentrations of $PM_{2.5}$, PM_{10} and elemental carbon (EC) were used for HIA in all European cities. Also impacts of noise levels were modelled when significant and noise data were also used for well-being assessment.

Review of existing approaches to definition and measurement of well-being – A conceptual model was developed relating greenhouse gas reduction policies and wellbeing. Approaches to wellbeing conceive the concept on three dimensions. The first dimension is the subjective-objective dimension; subjective wellbeing is 'psychological functioning and affective states' and objective wellbeing involves 'a comparison of life circumstances with social norms and values'. The second dimension is the hedonic-eudemonic dimension. Hedonic wellbeing involves emotions and eudemonic wellbeing is achieved through finding purpose meaning and fulfilment. The third dimension is the mental health-satisfaction dimension. This refers to the extent to which wellbeing is seen as synonymous with mental health or whether it is outside the field of health and can be measured as satisfaction. This dimension can alternatively be seen as a pathway: an experience leads to a level of satisfaction which leads to cognitive processes which then produce an emotional response affecting mental health. The level of mental health may then alter cognitive processes which may affect levels of satisfaction arrived at from later experiences.

The way that wellbeing is conceptualised will reflect how it is measured: subjective wellbeing tends to be measured as a Likert scale whereas objective wellbeing can be measured through national or local statistics of life conditions. If an emotional or mental health approach is taken to subjective wellbeing we recommend the WHO-5 scale, if a cognitive/evaluative approach is taken we recommend WEBWMS or the Satisfaction with Life scale. If a satisfaction approach is taken, the WHO Regional Office for Europe recommend measuring subjective wellbeing through a single item on satisfaction with life. Mental health is a huge cost to governments and the tax payer, so a mental health approach to wellbeing was adopted and thus the WHO-5 scale was used in further development of subjective wellbeing in our conceptual model. The full conceptual model is supplied in Figure 5 below. Climate change policies either attempt to alter energy demand or energy supply. Within these, policies tend to fall within buildings, urban planning, transport or industrial arenas. These policies have various implications for objective wellbeing (measurable life conditions): for example a policy to insulate a house will have implications for indoor levels of damp and thermal comfort, a policy to promote active transport has the potential to change levels of social capital, noise and air pollution and accessibility, a policy to encourage renewable power generation may have employment implications. These life conditions are thought to affect people's internal subjective wellbeing. For instance electric cars may reduce noise disturbance which may increase the likelihood of waking up feeling rested – an important part of subjective wellbeing. More detail is provided about the wellbeing impacts of tightening the building envelope, promoting active and public transport, encouraging non fossil fuels in cars and industry, increasing the cost of energy and encouraging renewable power generation in the published article derived from this work (*Hiscock et al, 2014*).

Other policies, although under consideration by at least one of the URGENCHE cities, were not in the end evaluated by any of the cities through the URGENCHE project. These were discouraging the use of air conditioning and building smaller housing at high density (air conditioning may particularly affect wellbeing through the ability to control indoor temperature, while building smaller housing at high density may reduce wellbeing through overcrowding). Additionally green and blue space was a late reinstatement to URGENCHE so could not be included in the above article. Green space has a strong effect on wellbeing though time spent outdoors and provision of opportunities to be active and socialise.

<u>Estimating the impact on population (and sub-population) environmental exposures of policies to reduce GHG emissions</u> - E/R functions for health outcomes were agreed but a review of the literature for wellbeing revealed very few E/R functions and there were concerns about the validity of the few in existence. Thus, in addition to cities' own wellbeing assessments (sleep disturbance was modelled in Thessaloniki and heat stress was assessed separately in Rotterdam), a new methodology was developed for well-being impact assessment using EQLS data. EQLS estimates of wellbeing (measured using the WHO-5 index) and noise annoyance were linked to noise data for three cities (Basel, Rotterdam and Thessaloniki) and housing data for Kuopio. For two cities (Suzhou and Kuopio) primary data collection took place in the form of a cross sectional wellbeing survey. Significant predictors of wellbeing (measured using the WHO-5 index) were identified in multivariate regression analysis.

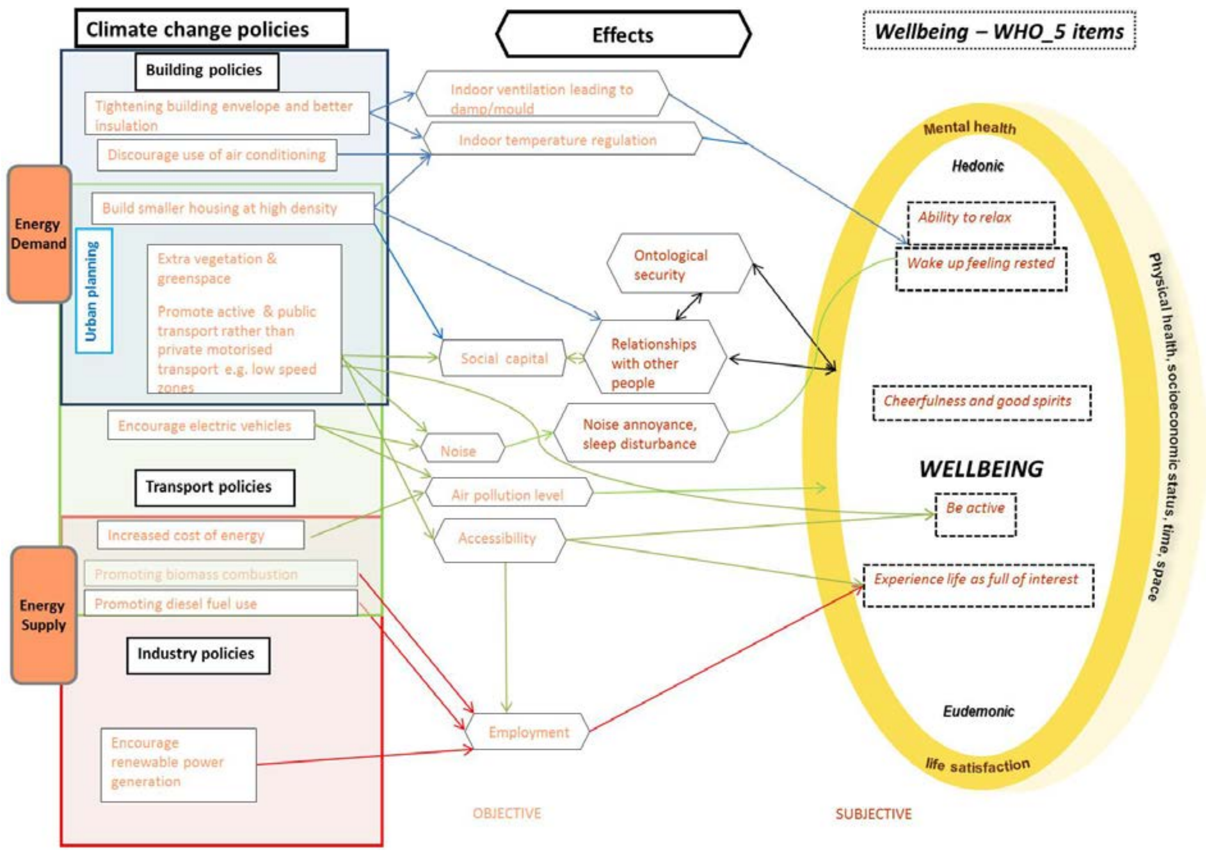


Figure 5 Wellbeing impacts of GHG reduction policies - a conceptualisation

Modelling conditions in the city in 2020 - The main focus was the modelling of conditions in the future (for most cities in 2020), comparing business as usual (BAU) with one or more scenarios in which further GHG reduction policies had been implemented. In the most part each scenario involved a combination of policies. Future conditions were modelled from actual conditions measured at a baseline (usually 2010). Exposure response functions (ERFs) were used to estimate future air pollution and health. The modelling platform developed is shown at Appendix 4. For some cities, such as Basel, there were already new GHG-reduction policies that the city planned to implement so these were included within the BAU scenario. All seven case studies included transport scenarios but the scenario chosen was unique to each city. The annual average concentrations of particulate matter (PM) and other pollutants were used for health impacts calculations. Population weighted exposure to air pollution was calculated and the impact on health of air pollutant levels has been assessed in terms of 'disability adjusted life years' (DALY), expressed per 1,000 inhabitants, when data were available. A major constraint for modelling Chinese data is the lack of data. The use of open data (e.g. www.openstreetmap.org) has been a practical alternative to model required data for rough exposure estimations. In the Kuopio case study only the impact of making buildings more energy efficient was also calculated and in Thessaloniki air exchange was included in the scenarios. Replacing fossil fuel energy with wood industrially or domestically was included in scenarios for three cities. In some cities the impacts of policies on noise levels (during the whole day to assess annoyance and during the night to assess sleep-disturbance) was calculated. Noise has been related to cardio-vascular disease.

The seven case studies concerned different transport and housing scenarios. The annual average concentrations of particulate matter (PM) and elemental carbon (EC) were used for health impacts calculations. Population weighted exposure to air pollution was calculated and the impact on health of $PM_{2.5}$ has been assessed in terms of ‘disability adjusted life years’ (DALY), expressed per 1,000 inhabitants, when data were available. In Kuopio the cost impact assessment of CO_2 reduction measures was also estimated. In Basel and Rotterdam the impacts on the noise levels (during the whole day to assess annoyance and during the night to assess sleep-disturbance) were used. The noise data were also applied in a wellbeing assessment (in Basel, Rotterdam and Thessaloniki), as well as thermal comfort and heating data from Kuopio. In cities with a long history of sustainability governance, current planned local transport measures are typically sensible from a climate change and public health perspective. Change in physical activity patterns can be one of the major contributors for health promotion for GHG reduction policy in urban areas. A major constraint for modelling Chinese data was the lack of data. The use of open data (e.g. www.openstreetmap.org) has been a practical alternative to model required data for rough exposure estimations. Some brief details about the case studies results relating to health and well-being are as follows:

- *City of Basel*: The results of the scenarios show marginal additional health benefits. Wellbeing effects were calculated but they are under final revision.
- *City of Thessaloniki:* Attributable deaths to $PM_{2,5}$ (and NO_2) show a relevant decrease in the 2020 scenario (approximately 14%). Wellbeing effects of the policy scenarios are found to be positive but are expressed less strongly than health benefits.
- *City of Rotterdam*: Benefits of emission reduction measures may be partially offset by the increase in vehicle kilometres. It is assumed that the noise levels in Rotterdam will increase due to 2% more cars each year. Wellbeing effects were found to be extremely low for the same reason. Thus noise exposure will remain an important aspect to be considered.
- *City of Stuttgart*: Interventions in the traffic sector account for small human health effects reductions at a local scale.
- *City of Kuopio:* Cost impact assessment of CO_2 reduction measures indicate that around 1.5 million euros (from total costs of 33 million per year caused by health effects of $PM_{2.5}$ exposure) in Kuopio urban area could be saved yearly as a result of health benefits achieved with decreased $PM_{2.5}$ levels. For wellbeing, slightly positive impacts of thermal insulation of the housing stock were found.
- *City of Xi’an:* Short-term effects in terms of excess deaths on all-cause mortality, short-term effect on cardiovascular mortality and long-term effect on lung cancer mortality due to road traffic-related ambient $PM_{2.5}$ in Xi'an, as calculated by the School of Public Health, Peking University.
- *City of Suzhou:* The impact of both scenarios on air quality is negligible compared to autonomous development. A local survey on wellbeing was administered and data is being analysed within the city by the School of Environment Nanjing University.

The analysis carried out in case studies represent various elements of novelty, primarily:

- Inclusion of Elemental Carbon (EC)
- Integration of different impacts
- Characterization of the different levels of policy and their impacts
- Development of well-being impact assessment.

The modelling of the health effects of the scenarios in URGENCHE shows that the expected quantitative impacts (in terms of mortality and morbidity) are fairly small in the European cities, with the exception of Thessaloniki. For example, in Rotterdam comparing the 2010 scenario with the BAU scenario results in 0.7 μg/m^3 less EC which could prevent 67 (46;98) DALYs (per 1,000 people 7.0 DALYs could be saved). A reason for these results is that there are already high environmental standards and an expected decrease in air pollution from the adoption of Euro-6 emission factors. Exposure maps for air pollution in the European cities provide details for population near streets with high traffic, close to motorways, and in the rest of the urban area. Nevertheless, this provides an expected improvement in the well-being of the populations. The 'initial' condition and level of urban transformation of the Chinese cities make them very different cases. For example, measures of air pollution are 3 to 5 times higher than in the European cities in 2010 and 2020-BAU. Sourcing of data presents a major challenge. It is likely that traffic scenarios will not positively affect air quality and noise in 2020.

For wellbeing, four city assessments were carried out, also using three scenarios for each city (Baseline2010; BAU2020, and Intervention2020). Three of the cities provided similar features, as they focused on transport interventions that will have an impact on noise exposure (which is more likely to affect wellbeing perception than air quality, which gives less reliable data from perception surveys). The city interventions are listed below, providing information on their objectives and differences to the respective BAU scenario.

Table 1 Summaries of wellbeing-related interventions in three cities

Basel	*A so-called "Z9 scenario" developed by the city that accounts for additional local transport measures beyond a Business-as-Usual scenario (BAU2020) to further reduce private car road traffic by 4% on inner roads. This local scenario complies with a successful citizen referendum requiring further traffic reduction. It includes a series of traffic measures targeted at channelling traffic along main avenues, reducing traffic levels and enforcing moderate speed limits in residential areas.* *The BAU2020 scenario in Basel does already include a range of measures adopted by the city by 2010 which will be implemented before 2020 such as tram line extensions or expanding the capacity of main highways. Due to expected growth in the Basle region, an increase of 8% of vehicle kilometres has been estimated by 2020. The Intervention2020 scenario "Z9" therefore only includes additional measures as described above.*
Rotterdam	*50% of local car fleet will be electric cars (excluding motorbikes, vans and trucks). The BAU2020 scenario does not include specific interventions but accounts for expected changes in fleet composition related to Euro emission classes. It assumes zero growth of the traffic volume at inner-urban roads and 2% growth of the traffic volume at motorways as compared to the Baseline 2010 situation.*
Thessaloniki	*A local metro built in central Thessaloniki will reduce private road transport by an expected 33-44% in the city center while the main road axes leading to the outskirts of the city are expected to experience a 22% reduction in traffic. The Intervention2020 scenario also includes a higher share of diesel and hybrid, but only a small (2%) share of electric vehicles in the fleet compared to the Baseline 2010. The BAU2020 scenario does not include specific interventions and serves as an extrapolation of the Baseline 2010 situation.*

The fourth city assessment evaluated the potential wellbeing impacts of the energy policies in Kuopio, focusing on thermal comfort and wellbeing impacts of housing insulation.

No other wellbeing assessments were carried out due to the following reasons:

1) In Kuopio, transport interventions focused on eco-fuels and thus were not likely to have an impact on noise levels.
2) In Stuttgart, relevant transport interventions with a potential impact on noise were carried out, but the city was not able to provide noise model data for the BAU2020 and Intervention2020 scenarios, making an assessment of the wellbeing impacts impossible.
3) In Suzhou and Xi'an, data were lacking for both the noise-wellbeing linkage as well as the noise impacts of the foreseen transport interventions.
4) No other cities provided data on housing insulation campaigns or other interventions for which environment-wellbeing linkages could be assessed.

Transport interventions and wellbeing

The wellbeing impact assessment methodology developed and applied for Basel, Rotterdam and Thessaloniki is based on the linking of country-specific survey data providing noise-wellbeing associations in urban residents with the noise models provided by the city. Merging both datasets enabled the derivation of wellbeing predictors for different noise perception categories (high, medium, low) and thus the assessment of wellbeing changes reflecting the noise effects of the transport interventions. Details of this approach are summarised in *Braubach et al (2015); Development of a quantitative methodology to assess the impacts of urban transport interventions and related noise on wellbeing; To be submitted to the Int. J. Environ. Res. Public Health (special issue: Sound and QoL).* The wellbeing impact results for Basel, Rotterdam and Thessaloniki transport interventions are shown in Figure 6 below, indicating the increase or decrease of the likelihood for the urban population to be in 'good' wellbeing between the different scenarios.

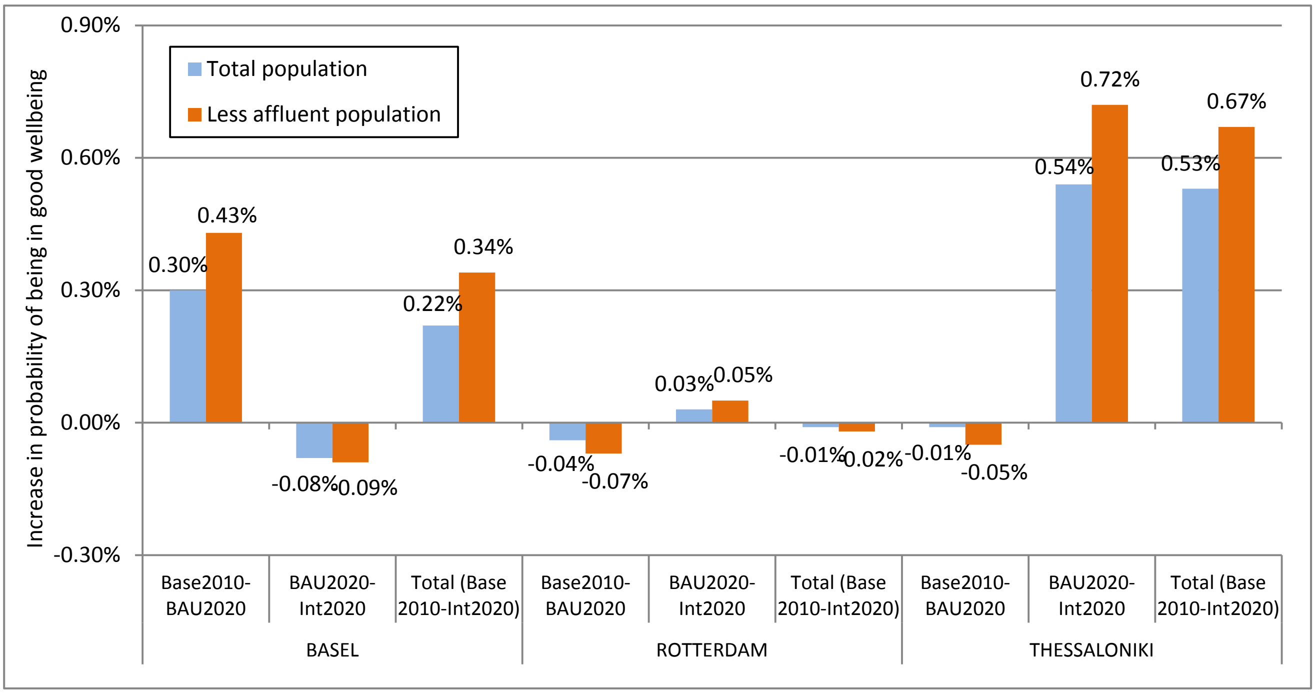


Figure 6 Changes in probability of being in 'good' wellbeing due to transport-related interventions

Traffic and wellbeing: The overall findings suggest that the noise reduction effects of urban transport interventions are limited but may still trigger slight wellbeing benefits. The fact that urban transport interventions have positive impacts on wellbeing should not be taken for granted, especially as wellbeing was not explicitly considered a relevant factor for selection and implementation of the city interventions which actually focused on climate change mitigation. However, the results also indicate that within a given city population, wellbeing benefits are mostly realized among residents reporting high noise levels, while the wellbeing benefit is only slightly higher for less affluent residents in two of the three cities when compared with the total population. This is an important indication in relation to potential equity effects of urban interventions, but needs to be substantiated by further studies. The work on transport interventions and wellbeing showed that, despite various methodological constraints and gaps in evidence, an exploratory assessment of wellbeing effects of urban climate change mitigation policies is possible even though the results are relatively indicative. However, the merit of this work is rather in identifying the missing components for a more accurate and valid wellbeing assessment and provoking further research in response to this work, making future wellbeing assessments increasingly reliable.

Housing interventions and wellbeing: The separate wellbeing assessment carried out for housing insulation in Kuopio aimed at the reduction of energy demand. The BAU2020 foresees building renovation according to most recent energy standards with a rate of 3% building stock per year. Two intervention scenarios were compared with the BAU2020: the ‘active renovation scenario’, increasing the quantity of building rehabilitation and energy efficiency (from 3% to 4.5% per year); and the ‘intense renovation scenario’, increasing the energy efficiency level of the renovations (3% renovation rate per year). The effect of the interventions is mostly visible on the exposure side as the interventions are indeed effective in reducing the population percentage reporting cold problems in winter. The BAU2020 is already likely to reduce this problem from 7.7% to 7.1%, but the intervention scenarios further decrease the prevalence of cold problems to 6.8% (active renovation scenario) and 6.1% (intense renovation scenario). However, the exposure changes hardly translate into wellbeing improvements for the total population level: the probability of being in good wellbeing increases from 87.0% to 87.1% only for the intense renovation scenario.

Table 2 Exposure and wellbeing perception related to low temperatures and buildings interventions

	2010 baseline	**BAU 2020** (each year +3%)	**Active renovation** (each year +4.5%)	**Intense renovation** (each year 3% but more efficient)
Pop with cold problems	7.7%	7.1%	6.8%	6.1%
Pop without cold problems	92.3%	92.9%	93.2%	93.9%
Population likely to be in ‘good’ wellbeing	87.0%	87.0%	87.0%	87.1%

In conclusion, the building interventions will provide thermal comfort benefits and these may trigger associated health effects, but in terms of wellbeing there is no real benefit at all. This might be explained by the fact that:

(a) the perception of thermal comfort is very subjective and may affect wellbeing only in a very marginal way, compared to the variety of other wellbeing determinants

(b) the housing stock is already well-insulated in Finland, so that additional improvement may slightly affect the perception of thermal comfort but not to a degree that also affects wellbeing.

The main findings of this exploratory wellbeing assessment are summarized below:

- The expected noise exposure changes resulting from the urban transport interventions are rather limited in all three cities, and affect only a small proportion of the total population.
- Across all three cities, the noise-related wellbeing improvement associated with the urban transport interventions is rather limited. The strongest increase in probability of being in 'good' wellbeing is found for Thessaloniki (increase of probability of 'good' wellbeing by 0.5%).
- Larger wellbeing benefits are found for residents reporting high noise levels at baseline. This is valid for all three cities and for total as well as less affluent populations, but most expressed in Thessaloniki with increased probability of being in 'good' wellbeing beyond 3.5%.
- The wellbeing benefit of transport interventions is slightly higher for the less affluent population in Basel and Thessaloniki, but not in Rotterdam.

3.7 ASSESSMENTS OF CITIES

3.7.1 SUZHOU, CHINA

a) Impacts of Suzhou's traffic related GHG mitigation policies on health

Based on the local data of road map, traffic volume and local development plan, three scenarios have been designed for the urban area of Suzhou as follows: (1) autonomous development (2020-BAU). (2) A reduction of private vehicle kilometres by 10% on urban streets (2020-I). (3) The introduction of 50% electric-powered private vehicle kilometres on urban streets (2020-II). Moreover, in all scenarios the resident population will be around 11.8 million by 2020 according to the documents from Suzhou's population and family planning commission. It was assumed that the distribution of population density would remain unchanged during the period 2010-2020.

Under these three scenarios, the CO_2 emissions from road traffic in the cities of Suzhou were derived from the traffic volume, fleet composition and CO_2 emission factors for the reference year 2010 and the three scenarios mentioned: 2020, 2020-I and 2020-II. It is expected that total CO_2 emissions from urban transportation in 2020_BAU will increase by approximately 45% compared to 2010 and around 16 million tons in our study area. The main reason for this is the expected accelerated traffic volume of Suzhou. The traffic scenarios in Suzhou may reduce traffic-related CO_2 emissions in the order of 6.3 % (2020_I) or 18.8% (2020_II) compared to 2020_BAU. These reduction percentages reflect the fact that about half of the traffic volume in Suzhou is on urban streets (and the rest on motorways), where the scenarios were expected to have an impact. Meanwhile, the annual average concentrations of NO_2, $PM_{2.5}$, PM_{10} and elemental carbon (EC) were modelled separately in busy street canyons, near urban motorways and in the remainder of the urban area.

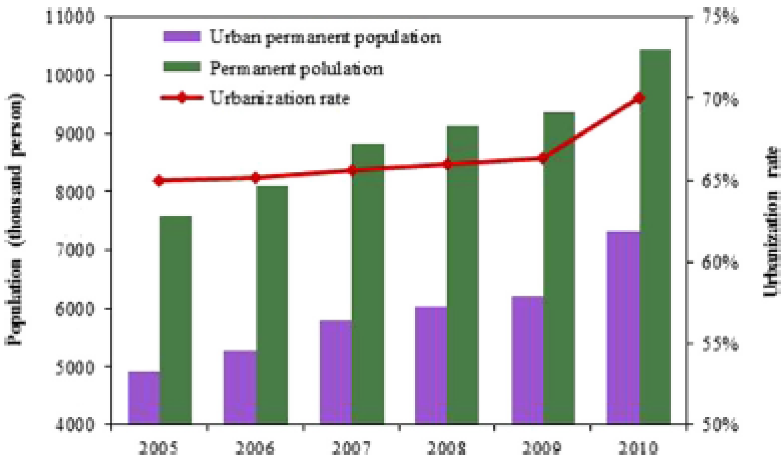


Figure 7 Changes in population and urbanisation rate in Suzhou 2005-2010

The impact of both scenarios on air quality was found to be negligible compared to autonomous development. It is expected that more stringent emission standards for road traffic will improve air quality, particularly near busy roads. However, the concentrations near these roads are still elevated in 2020 compared to the urban background, as a result of the volume growth. The reasons for this are that firstly the emissions from petrol-fuelled private cars in China are less than half those from diesel-fuelled light and heavy duty vehicles and, secondly, the two traffic scenarios have little effect on the latter's emissions.

Before the exposure estimation, the air quality map was processed to a 1 km resolution, similarly with the population density map. Then the air quality map was combined with the population density map to calculate the population weighted exposure at the 1 km resolution. It was found that the population exposed to $PM_{2.5}$ above 51.0 ug/m^3 had decreased from 0.14 million in 2010 to 0 in 2020_BAU, 2020_I and 2020_II. The population weighted exposure in the urban area of Suzhou had also reduced from 50.40 ug/m^3 in 2010 to 50.17 ug/m^3, 50.15 ug/m^3 and 50.16 ug/m^3 in 2020_BAU, 2020_I and 2020_II, respectively, which seems to be negligible. Finally, stroke and lung cancer were selected as health endpoints. The exposure-response functions were from the latest research on an Integrated Risk Function. According to the analysis, the total extra stroke deaths caused by air pollution in 2010 had reached 1814.3 in the urban areas of Suzhou. This will increase to 2031.1, 2030.6 and 2030.9 in 2020_BAU, 2020_I and 2020_II, respectively, though the population weighted exposure will decrease by 2020 in all scenarios. The slight decrease of exposure due to traffic-related GHG policies will not offset the effects of increased population. Similarly, total extra lung cancer deaths caused by air pollution in 2010 had reached 374.8 in the urban areas of Suzhou. This will increase to 419.4, 419.3 and 419.4 in 2020_BAU, 2020_I and 2020_II, respectively.

b) Impacts of Suzhou's GHG mitigation & adaption policies on wellbeing

Based on our wellbeing survey at the end of August in Suzhou, a random sample of 775 people living in Suzhou was asked to fill the questionnaire with the help of our volunteers, including WHO_5 Wellbeing questions, health variables, satisfaction variables, ontological security variables, home environment variables and others. All the questionnaires were returned, about 70% of which were valid. Then the multivariate analysis was conducted using Generalized Estimating Equations (a form of generalized linear model) to establish the link between these factors and the wellbeing index. It could be seen that respondents' scores ranged from 0 to 100 and the inter-quartile range was 44 to 68. The mean was 55 and the median was 56. The scale was significantly negatively skewed. The highest wellbeing was in under-23 year olds and the lowest among the 40 to 59 year olds. Respondents who were smokers had significantly lower wellbeing than other respondents. Of the seven satisfaction variables tested, only satisfaction with job, satisfaction with health and satisfaction with social life significantly predicted wellbeing. Of the ten ontological security variables tested, four were significant predictors: i.e. ‘other people would like a life like mine’, ‘I feel safe’, ‘I feel I am doing well in my life’, ‘my life has a sense of routine’. Of the seven home environment variables tested only ‘distance to busy road’, ‘noise annoyance’ and ‘exhaust fan in kitchen’ were significant predictors. Combined with local GHG mitigation & adaption policies in Suzhou, there are some key findings:

(1) On the one hand, the increase of tertiary industry and high-tech industry will lead to the elimination of traditional industries which offer lots of employment opportunities for residents and immigrants in Suzhou. Therefore, this policy will reduce the employment for the low- or mid-SES respondents. But it will have no effects on wellbeing because the employment does not affect the wellbeing significantly. On the other hand, more people will be employed in tertiary industry, high-tech industry and be expected to be more satisfied with their job, which are associated with higher wellbeing. Moreover, the improvement of air quality resulted from this policy will not affect the wellbeing.

(2) The use of renewable energy in the building will not only improve the indoor air quality but also make people feel more satisfied with their apartment. However, both the air quality and satisfaction with the apartment do not predict the wellbeing well. Though the air quality improvement resulted from the use of renewable energy in the building would not affect the wellbeing directly, it will reduce people’s dependence on the fan in the kitchen and hence affect it indirectly. It is expected that, overall, the increased use of renewable energy in the building is associated with higher wellbeing.

(3) The limitation of total vehicle population will change the transport mode and reduce the air pollution, but not affect the wellbeing in itself. The annoyance from traffic noise will be reduced and hence provide higher wellbeing.

(4) Increasing population awareness of climate change and Increasing green spaces and vegetation seem to have no effects on wellbeing.

(5) The two most important elements of satisfaction for wellbeing were satisfaction with health and satisfaction with social life. Thus policy makers need to work to keep their populations healthy. That satisfaction with social life, rather than, for example, family, was important suggests that policy makers should also work to develop social capital in their communities. Protection (‘I feel safe’) is one aspect of feelings of resilience. Policymakers need to help their population to feel safe and develop a sense of self-worth in order to develop their resilience.

3.7.2 XIAN, CHINA

Health impact analyses (HIA) were carried out for traffic related $PM_{2.5}$ in Xi’an using our own method. The health effects of $PM_{2.5}$ considered were: 1) Short-term effect on all-cause mortality; 2) Short-term effect on cardiovascular mortality; 3) Long-term effect on lung cancer mortality. The processes of analyses were as follows:

Estimated exposure-response relationships were obtained between the increase in short-term (daily or several-days average) $PM_{2.5}$ level and the acute change of daily population mortality, including all-cause mortality and cardiovascular mortality, based on previous studies;

Estimated exposure-response relationship were obtained between the increase in annual '$PM_{2.5}$' level (in fact TSP as a substitute, as there is no cohort study about $PM_{2.5}$-health effects in China yet) and the change of annual lung cancer mortality based on previous study;

Estimations were made of excess non-accidental deaths, cardiovascular deaths and lung cancer deaths due to ambient $PM_{2.5}$ pollution (under different scenarios with different ambient $PM_{2.5}$ levels, population size and background all-cause, cardiovascular and lung cancer mortalities);

The contribution ratio was estimated of local traffic to ambient $PM_{2.5}$ in Xi'an (based on an investigation conducted in Beijing);

1) Calculations were made of the excess non-accidental deaths, cardiovascular deaths and lung cancer deaths caused by traffic related $PM_{2.5}$ pollution in Xi'an (under different scenarios with different ambient $PM_{2.5}$ levels, population size and background all-cause, cardiovascular and lung cancer mortalities).

The main results of the HIA are as follows: Based on the monitoring data collected, the annual average concentration of ambient $PM_{2.5}$ was 78μg/m^3 in Xi'an city in 2010, while the premature (extra) deaths due to ambient $PM_{2.5}$ pollution could be 726 cases according to the exposure-response functions between the $PM_{2.5}$ level and total mortality of the population in Xi'an city. The premature deaths due to ambient $PM_{2.5}$ pollution would be 857 cases in 2020 if the ambient $PM_{2.5}$ concentration should remain the same as in 2010, and the expected population could remain about 10 million in Xi'an. On the other hand, if it is assumed that the local government of Xi'an reaches their goal of reducing ambient $PM_{2.5}$ concentration to 50μg/m^3, and the expected population is 10 million, the premature deaths due to ambient $PM_{2.5}$ pollution will be 549 cases. As it was not yet possible find reference to the source distribution of $PM_{2.5}$ pollution in Xi'an yet, information for Beijing was used instead. In Beijing, in 2006, 6% of ambient $PM_{2.5}$ came from vehicles and 9% came from traffic dust. In addition, 14% came from Nitrate, a secondary product of NOx, which is also considered to be mainly from car emissions. Therefore, in total, we consider that 29% of ambient $PM_{2.5}$ in Xi'an came from road traffic. Therefore, the premature deaths due to road traffic-related ambient $PM_{2.5}$ pollution would be 211 cases in 2010, 249 cases and 159 cases in 2020, respectively, if the $PM_{2.5}$ concentration remains the same or has been successfully reduced. This suggests that the reduction of GHG emission would not only decrease the ambient $PM_{2.5}$ level, but would also give significant health benefits to the exposed population in Xi'an city.

3.7.3 BASEL, SWITZERLAND

Introduction: In the city of Basel, policies aimed at reducing Greenhouse Gas (GHG) emissions are predominantly governed by the energy and air quality policy regulations. As part of the latter, measures to reduce the impact of traffic emissions, the main cause of air pollution in residential areas in the city of Basel, have to be proposed to the local government by the Department of Air Hygiene. At the same time, any traffic measure implemented in Basel needs to be in accordance with a sustainable mobility programme in the region that the city adheres to, and to fulfil the requirements of a citizen referendum that took place in 2010 and that requires that traffic in urban roads in the city of Basel be reduced by 10% by 2020. This political context has generated a unique situation in which there is a full and synergetic collaboration between the energy, traffic and air hygiene departments. Integrating health aspects into this local policy dialogue has been identified as valuable to improve policy-making.

Methods: For the year 2020, differences were modelled in health impacts between current conditions (reference), assumed as status quo, and under different GHG-labelled transport policy scenarios of relevance to Basel. Four scenarios of policy change were considered:

(1) Business-As-Usual scenario (BAU) that includes all transport-related measures already planned and accepted by the local government to be developed up to 2020;

(2) a scenario developed by the city that accounts for additional local transport measures beyond BAU to further reduce traffic by 4% on inner urban roads (Z9);

(3) a scenario with 10% reduction of traffic on any inner urban roads (p10) compared to BAU;

(4) a scenario that hypothesises that in addition to the p10 scenario, 50% of the private car fleets would be electric (p50).

For each of these scenarios, comparing to the reference and following standard methodologies, changes in population exposure to regional pollution (represented by $PM_{2.5}$), traffic-related pollution (represented by elemental carbon -EC), noise and active commuting patterns were modelled and associated changes in health impacts calculated. The primary impact metric of this analysis is the changes in number of premature deaths per year that can be postponed (or brought forward) by each policy scenario compared to the reference. A comparative risk assessment approach was also conducted by using, as a secondary metric, life-long changes in 'disability adjusted life year' (DALY) expressed per 1,000 inhabitants. Based on these results, a semi-quantitative evaluation was performed to estimate if the selected policy scenarios have different gradients of cumulative impacts due to exposures, given the contrast in socio-economic status existing in the city.

Finally, given the public concern related to cancer risk, further evaluation was carried out of the excess cancer risk, for current levels and subsequent scenarios, due to exposure to EC assimilated as diesel exhaust particles. Several environmental and international agencies have classified exposure to diesel exhaust particulates as a probable human carcinogen. In 2012, the International Agency for Research on Cancer (IARC) re-classified diesel engine exhaust as carcinogenic to humans (Group 1), as it considered that there is sufficient human evidence that shows that exposure is associated with an increased risk for lung cancer. A unit risk expressed in terms of diesel particulate of 3 x 10-4 (ug/m3)-1 has been established by the California Environmental Agency. This unit risk represents an excess of 3 cancers in a population of 10,000 if exposed to 1 ug/m3 during their lifetime (70 years). This unit risk was applied to estimate the changes in lifelong individual risk and excess cancer cases for the population in Basel, resulting from changes in EC exposure due to hypothetical local GHG policy mitigation strategies by multiplying EC population-weighted concentration (for 2010 and subsequent GHG scenarios) with the unit risk. Estimations were conducted for both the whole population and the population living near streets. Changes in excess cancer risk and cases were compared from 2010 and successively by scenarios.

Results: $PM_{2.5}$ and EC population exposure under a BAU scenario compared to reference could be reduced by 38% and 66% by 2020. Similar changes were obtained for p10, p50 and Z9 scenarios. Under the Z9 scenario it was estimated that, compared to current levels of daily active travellers, there could be 2% more cyclists and 10% more walkers.

Under BAU, it was estimated that 6% of total deaths per year could be reduced given reduction in air pollution, translating into a reduction of 3.8 DALYs per 1,000 population and per year. The local scenario Z9 however, if accounting for potential increase in active commuting, contributed to almost double the benefits already gained by the BAU scenario and any other scenario (-6.8 DALYs per 1,000 population). The results also showed that this local scenario, in addition to promoting additional health benefits, may also have an added benefit of leveraging environmental inequity across the study area.

It was found that chronic exposure to current levels of EC result in cancer risk exceedance of the acceptable lifetime risk of 1 additional cancer in 1,000,000 population, with 609 excess cases of cancer cases over 70 year, or respectively 2 additional cancers per year. This risk was reduced by a third under the 2020-BAU scenario. Although less large, additional reductions in excess cancer risk could be obtained under the subsequent scenarios 2020-BAU+10% and 2020-BAU+50% and Z9.

3.7.4 KUOPIO, FINLAND

The City of Kuopio assessment included a full health and wellbeing assessment of CO_2 emission reduction measures defined by representatives of the city of Kuopio in areas of traffic planning, land use planning, the power plant company Kuopion Energia Ltd and environmental services in accordance with the objectives of the City’s Climate Policy Programme 2009 - 2020. Selected policies (i.e. interventions, GHG-emission reduction actions) can be classified under three topics:

1) Production of heating energy
   a. Increased use of biomass in the local Haapaniemi CHP-plant
   b. Increased small scale combustion of wood
2) Energy efficiency in buildings
   a. Better insulation of houses (renovated and new)
3) Traffic
   a. Increased use of biofuels in traffic (estimated as lower emitting cars because of lack of emission factor data for biofuels)

Assessment was based on a comparison of the 2010 baseline scenario with the 2020 BAU (business-as-usual) scenario and with the 2020 CO_2 interventions scenario. Extensive data sets on buildings, traffic fleet and network, population, energy use, air quality, traffic noise, energy balance of the city and basic health and wellbeing data were reviewed, collected and structured for modelling purposes. Dispersion modelling was performed to produce future estimations of air quality for 2020 scenarios. A health, wellbeing and living condition questionnaire for Kuopio residents was carried out to collect missing information. Health impacts were assessed with the defined project methodology and boundaries, i.e. Exposure, Health & Wellbeing. Results were calculated in DALYs and as cases per year for each scenario and the achievable maximal benefits were estimated. Simple economic analysis of health effects was also performed. Wellbeing analysis was based on the questionnaire data collected in December 2013 with basic quantitative statistical analysis and by qualitative analysis.

The effects of CO_2 emission reduction measures in the City of Kuopio have been reported, including implications of the results as recommendations for city authorities on the usability of the assessed reduction measures. The main implications were that increase of biomass in the local CHP-plant would result in a major reduction on CO_2 emissions in Kuopio. However, increased use of small scale combustion of wood would slightly decrease CO_2 emissions but would increase local $PM_{2.5}$ emissions causing negative health effects.

3.7.5 ROTTERDAM, NETHERLANDS

The Rotterdam Climate Initiative (RCI) has set some ambitious goals for the reduction of CO_2-emissions in Rotterdam. Rotterdam is currently responsible for about 16% of carbon emissions in the Netherlands. At the start of the RCI, Rotterdam's total carbon emissions amounted to around 29 megatons (MT), compared to 24 MT in 1990. One of the main objectives of the Rotterdam Climate Initiative is to emit no more than 12 MT of carbon dioxide in 2025, which is 50% of the 1990 emission level. In order to reduce carbon emissions by half, emission levels must have been reduced by 27 to 34 MT in 2025. In the URGENCHE project, firstly data were collected about the Rotterdam energy use, transport sector, background concentrations, green spaces, etc. An inventory has been made of climate measures that were planned in Rotterdam and in other cities. Measures with the largest impact on CO_2 emissions were selected to investigate further:

Electric mobility: One of the measures taken in Rotterdam is the strong promotion of electric mobility. Within the URGENCHE programme, an estimation was made by the Traffic and Health studies of the health impact of: a) 10 percent reduction in traffic from personal car use; b) 50% electric-powered vehicle kilometres for passenger cars. The annual average concentrations of NO_2, $PM_{2,5}$, PM_{10} and elemental carbon (EC) were modelled, as well as the impact of the reduction of noise levels. It was concluded that the two local traffic scenarios will reduce traffic related CO_2 emissions in the order of 5% and 25 % compared to a 2020-business as usual scenario (BAU 2020). These scenarios, however, do little to improve the air quality compared to BAU 2020. The reason for this is that the BAU scenario predicts a considerable decrease in concentrations as a result of the introduction of new emission standards for cars. As both the air quality and noise impacts are low, the Health study has shown that the health impact of these scenarios is also limited.

Housing insulation and use of waste heat from industry for domestic heating: The impact on the air quality of reduced energy consumption by households has been investigated and shown not to be great. This is caused by the fact that households in the Netherlands almost exclusively use natural gas. The health impact of less energy consumption is therefore estimated as being very limited. Conclusions could, of course, be totally different if other cities were to be evaluated that use wood or coal as the main domestic fuels.

Wellbeing and heat stress: The heat distribution in the city of Rotterdam has been modelled in great spatial detail in time. As a result, city areas that are uncomfortable during heat waves have been identified. Such high summer heat makes a city area less liveable. Policy measures that try to influence this parameter, such as increasing green space or water in the city, can be evaluated based upon the information obtained. A paper has been prepared on the health effects of heat stress and air pollution over the period 1995-2010 in Rotterdam.

Pollutant concentrations have also been modelled in Rotterdam in great spatial detail in time. Because spatially detailed mortality rates also were available, it was possible to determine the separate effects of heat and air quality on mortality. The outcomes of the heat stress study were presented at the ISEE conference in Seattle in August 2014.

Conclusions: Although the investigated climate measures did indeed contribute significantly to a CO_2 emission reduction, the associated health impacts were small. The difference between the BAU 2025 and Optimised-2025 was therefore also very small, such that an optimised 2025 scenario was not very meaningful.

3.7.6 STUTTGART, GERMANY

In Stuttgart the PM_{10} limit values are heavily exceeded, while the city aims for a substantial reduction in CO_2 emissions. This has led to a range of policies to reduce emissions of both air pollutants and greenhouse gases. For the URGENCHE project, two of the policy sectors were chosen for analysis towards health impacts, i.e. domestic heating and road transport.

Due to rising fossil fuel prices coupled with policy measures promoting biomass fuels, the number of installed wood pellet stoves has increased rapidly to more than 2000 in the region of Stuttgart at the end of 2010. Although pellet stoves have lower emissions than manually loaded wood fireplaces or older wood boilers, they produce higher dust, CO and VOC emissions than modern oil and gas firings due to incomplete combustion. To analyse possible health impacts, the emissions produced by pellet stoves in the city of Stuttgart for the year 2010 and for two scenarios for 2025 were estimated. The two scenarios for the year 2025 consist of the ‘Substantial Growth Scenario (SG)’, where pellet boilers are installed throughout the entire city with growth rates as expected by the DEPV (German Wood and Pellets Fuel Association), which estimates 1 million units by 2020 in Germany, and a ‘legal ban scenario’ which assumes a legal ban of new wood pellet installations in the inner city. In the substantial growth scenario, the PM emissions from small combustion plants will increase by 4% compared to the emissions in 2010. The legal ban of new wood fuel in the inner city would reduce the total PM emissions by less than 1%.

In the urban traffic sector, four measures were assessed:

1) Introduction of a congestion charge in the City of Stuttgart: a distance-related charge for passenger cars is introduced. An amount of 0.10 € per km is collected.
2) Extension of parking management: an expansion of the area where parking management is installed to the districts surrounding the city centre of Stuttgart.
3) Improved public transport; the frequency of light rail trains (S-Bahn) during the off-peak times is increased, so that is equal to the frequency in peak hours.
4) Improved cycling network: further cycle lanes are installed, these increase comfort with faster cycling and increase safety if cyclists are separated from cars and pedestrians.

A fifth scenario combining the four aforementioned measures was estimated for assessing potential synergies between the different scenarios.

The estimated emission reductions for each scenario compared to the emission levels in the business as usual scenario 2025 are shown in Table 3. As expected, the largest emission reductions were estimated for the congestion charge since it is the more restrictive measure. The combination of all scenarios did not show clear synergies across the measures and the improvement in public transportation and cycling networks resulted in small emission reductions.

Although relevant emission reductions were achieved through the policy implementations, the effects on air quality were not of the same magnitude. The change in concentration, when implementing all four traffic related measures is shown in Figure 8.

Table 3 Emissions reductions in the transport sector for each scenario compared to BAU 2025

Scenario	PM_{10}	NO_2	NO_X	CO_2
All Measures	-18.1%	-22.7%	-20.2%	-15.6%
Congestion Charge	-16.2%	-21.1%	-18.4%	-14.0%
Parking Management	-2.2%	-2.2%	-2.2%	-1.8%
Improved Public transport	-0.1%	-0.1%	-0.1%	-0.1%
Improved Cycling network	-0.2%	-0.3%	-0.3%	-0.1%

The main reasons for this small change in concentration is, that the vehicle fleet in 2025 consists nearly entirely of modern Euro VI and EURO VII cars and trucks with very low emissions and that PM_{10} concentrations are largely caused by primary and secondary PM_{10} stemming from other sources than transport.

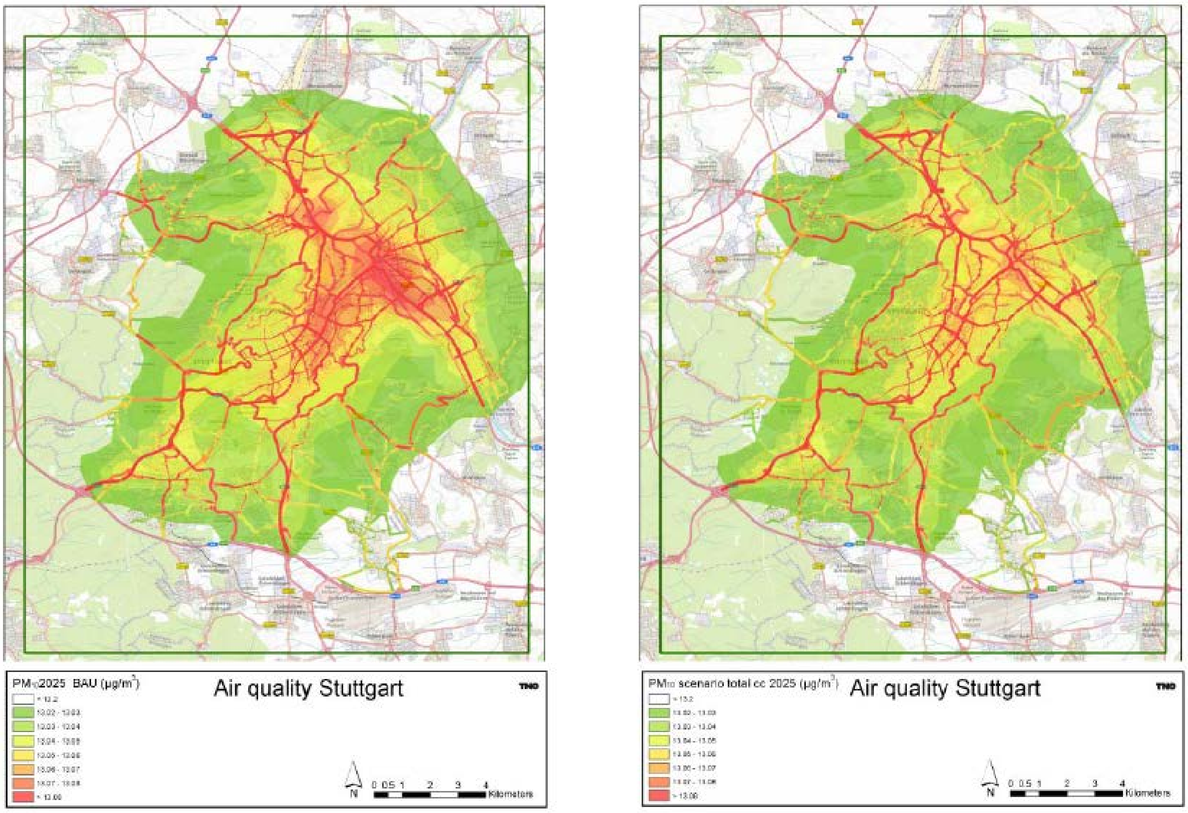


Figure 8 PM_{10} concentrations in Stuttgart comparing local transport emissions for BAU (left) with the four reduction measures implemented by 2025

(N.B. pollution stemming from sources outside of Stuttgart and from other sources than transport are not taken into account)

3.7.7 THESSALONIKI, GREECE

The effect of feasible traffic and building policies in year 2020, were assessed and their potential effect upon air pollution (outdoors and indoors) and ambient noise was computed. In particular, four policies and numerous scenarios were investigated, including the operation of a metro in the city centre, changes in fleet composition, better building insulation and increases in light oil and gas taxation in residential heating. The effect of these policies on human health (mortality and morbidity) has been computed, utilizing state of the art Concentration Response Functions to PMx, NO_2, C_6H_6 and ambient noise. With regard to traffic policies, several scenarios were considered taking into account the two feasible cases, the service of the underground rail and change in traffic fleet composition.

The first traffic scenario considered (MIT-1), includes an optimal combination of the two policies, where the underground rail in the city centre will be coupled with a high penetration of the diesel fuelled vehicles, a conservative increase in hybrids and an economically feasible penetration of electric cars, in accordance with projected economic figures. Simulations show a noticeable improvement in air quality in the city centre (Municipality of Thessaloniki) as the result of a reduced traffic load. Comparisons to the Business as usual (BAU) scenario with regard to PM_{10}, $PM_{2.5}$ and NO_2 show a reduction in mortality cases respectively of 137, 10, 64 or 17, 13 and 9 less DALYs. Municipalities with the highest reduction in mortality cases include the municipalities of Kalamaria (5%), Thessaloniki (4%) and Pilaia (4%). Similarly, for the leukaemia cases in the municipality of Thessaloniki, 0.16 fewer cases are computed or 2.4 less DALY are attributed to the first scenario which corresponds to a 22% reduction from the BAU scenario. Other municipalities with high reductions in morbidity include the municipalities of Eukarpia (51%), Stavroupoli (37%), Evosmos (35%) and Kalamaria (35%). With respect to noise, noticeable differences are identified in the municipality of Thessaloniki (the area of influence of the city's metro), where there is a 29% reduction in cases of myocardial infarction, 34% reduction in heavy sleep disturbance and 2% in sleep annoyance. Other municipalities with noticeable change in morbidity (i.e. myocardial infarction) include the municipalities of Menemeni (57%), Sikes (30%) and Kalamaria (23%).

The second traffic scenario considered (MIT-2), included the high penetration of electric passenger vehicles, associated with a series of fiscal policies to promote this mode of transportation (tax relief, reduced retail cost). Simulations show that, with respect to the deaths attributed to PM_x and NO_2 pollution, reductions in the municipality of Thessaloniki, are 4% (PM_{10}), 4% ($PM_{2.5}$), 2% (NO_2) and 21% for the morbidity (C_6H_6). The number of avoided DALYs for the municipality of Thessaloniki, are 152 (PM_{10}), 83 ($PM_{2.5}$), 75 (NO_2) and 2.5 (C_6H_6). For the remaining municipalities, the highest reduction in DALYs attributed to PM_{10} and $PM_{2.5}$ are identified in the municipalities of Kalamaria (161 and 127), Evkarpia (151 and 121), Pilaia (133 and 104). Similarly, the highest reduction in DALYs attributed to NO_2 are identified in the municipalities of Evkarpia (123), Stavroupoli (84) and Kalamaria (78). With respect to noise in the municipality of Thessaloniki, significant reductions are identified in myocardial infarction (49%), heavy sleep disturbance (80%) and in sleep annoyance (50%).

The first building policy involves the implementation of an Energy Certificate scheme in new buildings and retrofit. This information is directly associated with energy saving and hence a reduction in greenhouse gas emission. Five scenarios (different indoor/outdoor air exchange rates) and four emission sources (only background, biomass burning, second hand smoke and combination of the last two) were taken into consideration. Results show that the number of additional deaths attributed to PM exposure varies from 524 for the scenario 5 (AER=0.1 h^{-1}) without combustion sources, to 1,334 for scenario 5 with simultaneously biomass burning and second-hand smoke as additional indoor PM emissions. Furthermore, the number of additional deaths attributed to PM exposure is higher in houses with side-stream smoke when combined with biomass burning. With regard to the case of no combustion sources, impacts gradually decrease (from scenario 1 to 5), reflecting the improvement in indoor air quality due to the decrease of the indoor/outdoor air exchange rate. Similar results are computed for the morbidity indices, new cases of chronic bronchitis dominate adverse health outcomes, followed by respiratory and cardiovascular hospital admissions.

With respect to the second building policy, i.e. the increase in liquid fuel and gas taxation, results showed an increase of about 200 additional deaths (for a population of almost 900,000 inhabitants) in all-cause mortality for the 2012-2013 period compared to the 2011-2012. Regarding the scenarios, impacts gradually decrease (from 600 to 250 cases for the cold period) reflecting the improvement of ambient and indoor air quality resulting from the reduction of biomass and the increase of natural gas and electricity use for space heating.

1.3.8 CONCLUSIONS

Appendix 5 lists for information the formally tested scenarios within the project. The tools have been extensively trialled with the partner cities, providing a variety of applications to the differing strategies encountered. The output provides examples for use by any metropolitan authority to add depth of understanding to decision-making in the drive for a greener future. Unsurprisingly, significant differences emerged between EU and Chinese cities. For the main part, the EU investigations were registering fairly modest differences between proposed strategic options, based upon comprehensive available data. This was partly due to a recent history of ‘cleaning up’ urban environments that gave an advanced platform for progress. The Chinese conurbations, however, were deemed to provide very significant variations in potential health and well-being, but this was not analysed to the same depth due to a paucity of data collection. These cities are facing huge growth trends, giving great importance to strategic planning decisions taken in the near future. As may be seen from sections (6) and (7), once the data-gathering and modelling processes are applied to actual cities, the outputs are extremely varied due to the different characteristics and strategies in play. As described above, health effects in the scenarios modelled in URGENCHE show that the expected quantitative impacts (in terms of mortality and morbidity) are fairly small in the European cities, with the exception of Thessaloniki. The noise reduction effects of urban transport interventions are limited but may create some wellbeing benefits. Wellbeing benefits are mainly amongst residents reporting high noise levels and are only slightly higher for less affluent residents in two of the three cities when compared with the total population. An assessment of traffic-related wellbeing impacts from urban climate change mitigation policies is possible but the results are relatively indicative. For buildings, the impact is mostly visible on the exposure side as the interventions reduce the population percentage reporting cold problems in winter. There may be health effects associated with the building interventions, but in terms of wellbeing there was no real benefit identified, possibly due to a well-insulated existing housing stock in the Finland study along with the subjective nature of perception of thermal comfort.

Some overarching policy-related themes have emerged from all this work and are summarised as follows:

Energy

- Most cities, at least in Europe, already have an energy balance. These cities can easily use the methodology developed here to estimate changes in greenhouse emissions and emissions of air pollutants for any energy policy they wish to analyse. The impacts of air pollution control can then be further assessed, either using own tools or an integrated assessment tool such as ECOSENSE (www.ExternE.info).
- Use of biomass usually reduces CO_2 emission but increases emission of air pollutants, especially in smaller firings, and thus increases health impacts. Only recent technologies with the lowest emission factors should be permitted.
- Improving energy efficiency is very important, as in many cases it combines lower emissions of as well greenhouse gases as air pollutants with lower costs.
- Replacing fossil fuels by electricity will reduce air pollution in cities, but the effect on greenhouse gases and air pollution outside the cities depends on the technology mix for electricity generation. Only new renewable energy capacity for extended use of electricity will have a certain positive impact upon environmental pressures.

Buildings

- Natural gas produces low ambient air pollution and half of the CO_2 compared to solid fuels. Bio-fuels are often considered 'greenhouse neutral', but over its life cycle biowaste-based fuel may exhibit negative GHG emissions and wood combustion emit more than coal.
- The implementation times of CO_2 reduction policies range from short (indoor temperature reduction, lower emission heat source, more efficient appliances, occupant behaviour) to intermediate (renovation of windows, doors, insulation and ventilation) and long (replacement with zero or near zero energy buildings).
- Particle emissions from alternative sources of energy range over several orders of magnitude. Domestic solid fuel combustion is the most harmful while natural gas, electricity and district heat are the most benign, with fuel oil in the middle.
- The health and wellbeing impacts of energy renovation policies are mediated via indirect pathways. They can be positive for the occupants in certain buildings, negative in others, irrespective of the amount of conserved energy. This highlights the need for more advanced experimental and epidemiological research on building renovation, as well as related training and auditing.

Traffic

- Traffic-related CO_2 emissions in 2020 will stabilize in the European cities and will increase by approximately 40% in the Chinese cities compared to 2010. Air pollution in the Chinese cities is a factor 3 to 5 higher than in the European cities in both 2010 and 2020.
- In the period 2010-2020, air pollution emissions will reduce due to cleaner technology in all sectors in China and Europe. In Europe, this will result in lower regional background concentrations of all pollutants. In China, regional background concentrations are likely to remain constant for $PM_{2.5}$ and PM_{10}, to decrease for EC and to increase for NO_2 as a result of economic growth.
- More stringent CO_2 emission standards (zero-emission) for road traffic is the most effective measure to reduce CO_2 emissions from urban road traffic. This requires action at the level of the European Union and the central Chinese Government and is beyond the control of local authorities;
- Stimulation of physical (cycling, walking) and public transport is the most effective local policy to reduce CO_2 emissions and improve air quality, health and well-being. These measures and local transport policies are within the control of local authorities.

4 Impact & Dissemination

There follows a review of the dissemination and impact of the URGENCHE project. This commences with descriptions of the technical components of the work and goes on to describe application to the cities themselves, wherein the greatest impact from this activity to date may be seen in supporting their work on greenhouse gas (GHG) mitigation, with particular potential identified in China. It is intended that policy briefings and published papers will carry this to a wider audience. The concluding section describes a cohesive approach to providing a permanent policy reference for civic authorities that represents the major formal outreach initiative from this project.

4.1 Impact of the research components

A journal paper relating to the work on Energy Balances entitled *'Health Impacts and Greenhouse Gas Reduction Caused by Using Wood Pellets for Domestic Heating in the City of Stuttgart'* has been submitted for peer review to the journal 'Energy for Sustainable Development'.

The GIS analysis tool that has been developed can be used and extended after the project has been completed. It has applications in any domain where a user would like to explore their datasets visually and interactively.

The visualisations that have been produced for dissemination have been presented on a web blog that can be accessed by a wide audience including those outside the project. In addition to promoting the results of work completed in relation to energy within the project it has also helped to promote the project to a wider audience.

A paper on the GIS analysis tool that has been developed entitled *'Exploring the unknown – Analysing data through interactive visualisations'* has been submitted for peer review to the journal 'IEEE Transactions on Visualisation and Graphics'.

Regarding work on the Building Stock, in addition to application to the actual partner cities, the following specific dissemination activities have contributed thus far to the impact of the work:

a) In education related to climate change policies, URGENCHE and related Opasnet methods have been explained to university students during the courses 'The Health Effects of Energy Production - Health and Climate Change' and 'Decision Analysis and Risk Management', at the University of Eastern Finland.
b) An oral presentation at the ISES/ISEE/ISIAQ conference, 21st August 2013, Basel, Switzerland: Matti Jantunen; Conceptual model linking urban GHG policies to health and wellbeing (URGENCHE), as well as a poster: Marjo Niittynen, Erkki Pärjälä, Jouni T. Tuomisto: Increased use of biomass in combined heat and power production: health impacts due to PM2.5 emissions.
c) An oral presentation (in Finnish) at Tuesday Seminar Series of the National Institute for Health and Welfare, Department of Environmental Health, Kuopio, Finland. 17th September, 2013: Marjo Niittynen; Climate change policies and health: URGENCHE project in China and Europe.
d) An oral presentation at the 'Open event for policy-makers, authorities, and experts in Kuopio' (part of URGENCHE Kuopio workshop). 18th February, 2014: Jouni T. Tuomisto; Policy Briefing: What have we learnt from the Building case-studies?

The Building model and its results concerning Kuopio have been made available to the city authorities for planning activities.

A paper entitled *'Building related health impacts in European and Chinese cities – scalable assessment method'* has been submitted to the journal 'F1000 Research' for peer review. A related extended abstract entitled 'Climate change policies and building related health impacts in European and Chinese cities' has been produced.

For the work on Traffic, the policy implications of the case studies in the European and Chinese cities on air quality and noise are as follows:

a) More stringent CO_2 emission standards (*zero-emission*) for road traffic is the most effective measure to reduce CO_2 emissions from urban road traffic. This requires action at the level of the European Union and the central Chinese Government and is beyond the control of local authorities;
b) Support, facilitation and stimulation of *physical* (cycling, walking) and *public* transport provide the most effective *local* policies to reduce CO_2 emissions and improve air quality, health and well-being. These measures and local transport policies are within the control of local authorities.

The research and results from the work on Traffic were presented at the ISEE-conference in August 2013 in Basel.

This work was described in a paper entitled *'Impact on air quality of measures to reduce* CO_2 *emissions from road traffic in Basel, Rotterdam, Xi'an and Suzhou',* published in the peer-reviewed journal 'Atmospheric Environment' in September 2014.

A further paper entitled *'Health benefits and impacts of transport-related measures to mitigate climate change in Basel, Switzerland'* has been submitted for peer review to the journal 'Environment International'.

Exposure, Health and Well-being, the ultimate outcome of this project, has a synergy with a current wide interest in the factors contributing to 'well-being' within the health and occupational health professions and beyond. Potential impacts of the work done include:

a) Sharing methodologies and analysis.
b) Contributing international expertise to local policy decision-making processes.
c) Building a broader community and debate in the field of impact assessment of local policy interventions.
d) Indicating new directions on the assessment of the studied policies and on work being done by others, for example on wellbeing.
e) Focusing attention on interventions that deliver the largest public health benefit for the population.
f) Specifying interventions that could target large disparities among subpopulations.
g) Identifying problems that are not acted upon.
h) Fostering knowledge transfer activities (development of websites and activities) to engage the public and stakeholders.

i) Extending impact assessment methods from quantitative health assessments to qualitative well-being assessments.

j) Being aware of the difficulty in measuring the impact of the work through its direct social benefits, although efforts are underway by project participants to ensure their results are applied.

A number of journal papers relating to health and well-being have been developed, including:

'Extended impacts of Climate Change on Health and Wellbeing', published in 'Environmental Science and Policy'.

'Integrating Health and Environmental Impact Analysis', published in 'Public Health'.

'Data Mashups: Potential Contribution to Decision Support on Climate Change and Health' published in the '*International Journal of* Environmental Research and *Public Health'.*

'Quantifying human exposure to air-pollution - moving from static monitoring to spatially resolved personal exposure assessment', published in '*Science of the Total Environment'.*

'Wellbeing Impacts of City Policies for Reducing Greenhouse Gas Emissions', published in the '*International Journal of* Environmental Research and *Public Health'.*

More detail is provided about the health impacts of cities policies in *'Transport-related measures to mitigate climate change in Basel, Switzerland: a health-effectiveness comparison study';* submitted to Environment International in January 2015 and *'Health Impact Assessment of Transport Policies in Rotterdam: Decrease of Total Traffic and Increase of Electric Car Use';* submitted to Environmental Health Perspectives in January 2015.

1.4.2 Impact from city assessments

SUZHOU, CHINA

a) Through this programme, a lot of city-level data has been collected relating to the use of fuels and energy, urban planning, buildings and transportation, population socio-demographics, health and well-being. As with other Chinese cities, Suzhou previously lacked this kind of basic data to support its GHG policy decisions, which will help local governments in low carbon economy development.

b) The applicability of the recommended methodologies to assess the impacts of GHG mitigation and adaption policies on health and wellbeing for data-deficient cities in China has been verified in the Suzhou study.

c) Suzhou has been approved by the National Development and Reform Commission to be one of the second batches of national low carbon pilot cities. To achieve the carbon reduction targets, the Suzhou administration will adopt more and tougher GHG mitigation and adaption policies during the next decade. The final results of the impacts of Suzhou's GHG mitigation policies on health and wellbeing are expected to be submitted to local government to support their cost-benefit analysis of various policies.

d) Suzhou's experiences, via its low carbon pilot city practice, could be taken into account by other cities in China, thus stimulating the health impact studies of GHG policies in China.

e) A journal paper entitled ‘Mitigating greenhouse gas emissions from China's cities: Case study of Suzhou’ has been published in ‘Energy Policy’. Suzhou also contributed to one of the journal papers mentioned in Section 5 above.

XIAN, CHINA

By participating in the work of this project in Xi’an:

a) Colleagues and students in the group have been educated about models used in relevant research fields. For example, the dispersion modelling approach in the environmental science field, the Life Cycle Assessment in the energy balance field, and so on;

b) The use of open source data and existing literature and statistics year books may provide approaches for other researchers about available alternatives when precise local data is unavailable. The relatively difficult data and policy information collection procedure experienced has highlighted a need for a stronger requirement for the authorized right of use of publicly monitored data in China;

c) The project report may prompt more detailed investigation into traffic status in Xi’an, for example, the percentages of cars that meet different national emission standards.

d) The project report may also prompt investigation into the sources of ambient $PM_{2.5}$ in Xi’an. Based on the sources, policies about traffic control or energy structure improvement may be developed;

e) A Health Impact Assessment (HIA) could be undertaken for traffic-related air pollutants in the other cities of China.

f) Xi’an contributed to one of the journal papers mentioned in Section 5 above.

BASEL, SWITZERLAND

a) Policy-relevance - The necessity of acting at urban level for mitigating the impacts of climate change at national and global scale has been well understood and pursued by many local governments, including Basel. In Basel, it was found that the current planned local transport measures will not only reduce GHG emissions but will have very relevant public health benefits, for example by reducing the excess risk of lung cancer due to air pollution exposure. Further strengthening some aspects of these measures (i.e. promoting physical activity) could have greater benefits not only on health but also at addressing existing environmental inequities.
b) Lessons Learned - The evaluation of health aspects in the local policy process was of high interest by the city of Basel. However it has to be recognized that the usability of findings to adapt current policy processes in Basel given the URGENCHE results may be limited mostly because (1) most of measures have been decided or changed during the lifetime of the research project; and (2) choice of analytical assumptions could not follow the city of Basel normal decisional process of intergovernmental consultancy and approval. It is recommended that an earlier integration between the evaluation of city measures conducted by the city and research projects be done to avoid parallel processes of evaluation that could potentially arise to inconsistent results.
c) Reports:

- 'Climate change policies to reduce greenhouse gas emissions in Basel-City.'
- 'Health benefits and impacts of realistic and hypothesized scenarios of local greenhouse gas emission reduction measures: case study in Basel, Switzerland.'

d) Presentations

- Oral presentation to a scientific event: 'Proximity to traffic, health & wellbeing: are there conflicting climate change policies in Basel?' talk at the ISES/ISEE/ISIAQ conference, August 2013.
- Oral presentation to a scientific event. 'Reducing lung cancer risk from transport-related Greenhouse Gases reduction policies: case study in Europe and China' - ISEE conference, August 2014.
- Final results presentation meeting to local stakeholders. November 14, 2014, Basel, Switzerland. Organized by Swiss TPH and City of Basel.

e) Academic papers - Basel contributed to the two papers mentioned in Section 5 above.

KUOPIO, FINLAND

a) Clear recommendations on the usability of the assessed CO_2 reduction measures were formulated. Based on these, the City of Kuopio can enhance its environmental policies and enhance progress towards energy efficient and low emission solutions. It is clear that the increased use of biomass in the local CHP-plant will be enacted.
b) An assessment report (in English and in Finnish) has been made publicly available through the City of Kuopio web pages.
c) Project results have been presented to city authorities in several targeted presentations/seminars.
d) The local population was informed of the project results by press releases and by web news.
e) Feedback received through the health, wellbeing and living conditions survey carried out in Kuopio was distributed to relevant city authorities. These may be used to guide the upcoming plans for city structure, maintenance, public transport, health care, etc.
f) Results have been published in the national 'Environment and Health' journal and presented internationally in WHO's 'Healthy Cities' conference in October 2014.
g)

A substantial report has been prepared for Kuopio in English and in Finnish. The English version provides an interesting detailed case study for the overall project and may be viewed at: http://www.kuopio.fi/c/document_library/get_file?uuid=990128c5-6c34-4320-b20e-cc1ff8f7d98f&groupId=12141

ROTTERDAM, NETHERLANDS

a) The research had led to more knowledge about the health impact of climate measures.

b) For the measures investigated, the calculated health impacts of climate measures in Rotterdam are positive, but very small. Especially for the switch to 50% electric passenger cars this is an unexpected result.

c) It is clear that all the investigated measures contribute to a liveable city. Further research should therefore be aimed at a better understanding of 'liveability' in a city in relation to air pollution, noise and heat stress.

d) A journal paper entitled ‘Heat stress, air pollution and mortality in the city of Rotterdam, The Netherlands’ has been submitted to ‘Epidemiology’. Rotterdam also contributed to one of the journal papers mentioned in Section 5 above.

STUTTGART, GERMANY

As Stuttgart is located in a valley and local meteorology is not especially favourable to air movement, the analyses of particulate emissions carried out within the project are of special importance to the health of the population. This will feed into policy considerations, such as the potential insistence upon newer technologies such as pellet boilers with dust filters.

Designation of further extended environmental zones only permitting EURO VI, VII and electric vehicles are other potential policy considerations, although the research has revealed that this kind of vehicle fleet will exist anyway by 2025. Thus, one conclusion is that other sectors such as local agriculture would be more effective in reducing PM_{10} and $PM_{2.5}$, as well as NH_3 emissions.

Stuttgart will be the primary urban centre to feature in a paper on energy balances that is being prepared for submission, with associated potential presentations of the work.

THESSALONIKI, GREECE

The city has various policy options under consideration and the socio-economic impact varies according to the option considered:

a) The first traffic policy (a metro and changes to the traffic fleet) - savings in monetary cost resulting from the reduction in PM_{10} and $PM_{2.5}$ concentration correspond to €56.6m and €45m respectively. Similarly, from the reductions in NO_2 concentration, savings are close to €37.7m and for the case of benzene savings correspond to €1.04m.
b) The second traffic policy (a high penetration of electric vehicles) - savings in monetary cost resulting from the reduction in PM_{10} and $PM_{2.5}$ concentration correspond to €60.4m and €49.1m respectively. Similarly, from the reductions in NO_2 concentration, savings are close to €41.2m and for the case of benzene the savings correspond to €1.08m.
c) The first building policy - the cost of mortality is in the range of billions of euros while morbidity cost due to chronic bronchitis is one order of magnitude lower (hundreds of millions). Similarly, the morbidity costs related to cardiovascular and respiratory morbidity is in the range of millions of euros.
d) The second building policy - the socioeconomic cost of this policy is almost €250m (up to €1.2 billion). Morbidity, expressed in terms of new cases of chronic bronchitis, cardiovascular disease and respiratory problems, corresponds to a financial cost in the order of €50m. Considering the high socioeconomic cost, heavy taxation of light heating diesel should be re-considered.
e) The effect of biomass replacement was evaluated by an alternative scenario analysis, which showed that significant benefits can be expected from potential intervention policies bearing changes in fuel composition for residential heating. These benefits are attributable to the differences in emission potency between biomass combustion and the other competing fuels and space heating systems.

Based on the above, it is planned to disseminate these results to the local authorities in the municipality of Thessaloniki to bring to their attention the potential outcomes from the traffic and building policies. Within this perspective, the results obtained as well as the developed methodological framework covering the full chain from policy decisions to the health impacts associated and finally to monetary costs represent a valuable tool for public authorities and policy makers responsible for human health protection and urban planning.

FURTHER WORK: For the overall project, in addition to the above activity and ongoing work described below in promoting policy outputs, the nature of this project has been to predict forward developments over time and hence the potential remains for future assessments leading to papers and presentations of progress and learning. The research-based partners will remain alert to any such opportunity.

The public website may be viewed at www.urgenche.eu

4.3 Major policy briefing initiative

An initiative has been devised and planned to produce professional information sheets capturing the key policy-related messages from each project area. These are to be distributed electronically to cities and other relevant opinion-formers during the early part of 2015, with printed versions available where useful (meetings, future conferences, etc.).

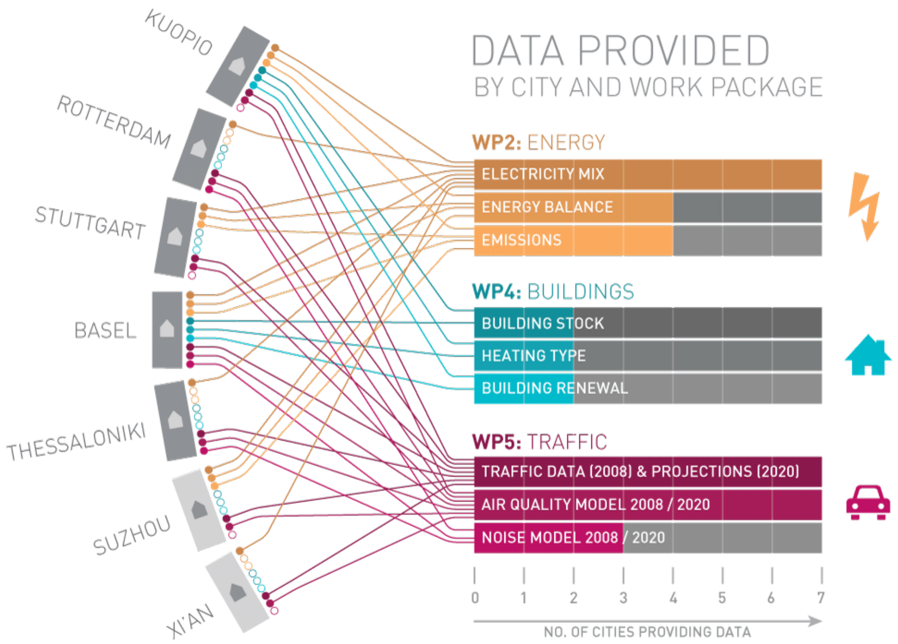
This concept was adopted by consent from the partners and advisory group on the basis that it will reach a far larger and more representative population than other approaches, such as invitations to a presentational event, a method which is often adopted but typically narrows the audience to those available by proximity and time. The information sheets will provide information around 'bullet-point' style key outputs and will give contacts, including the website address so that real-time updating of future developments thereupon will be a much more useful exercise than would otherwise be the case.

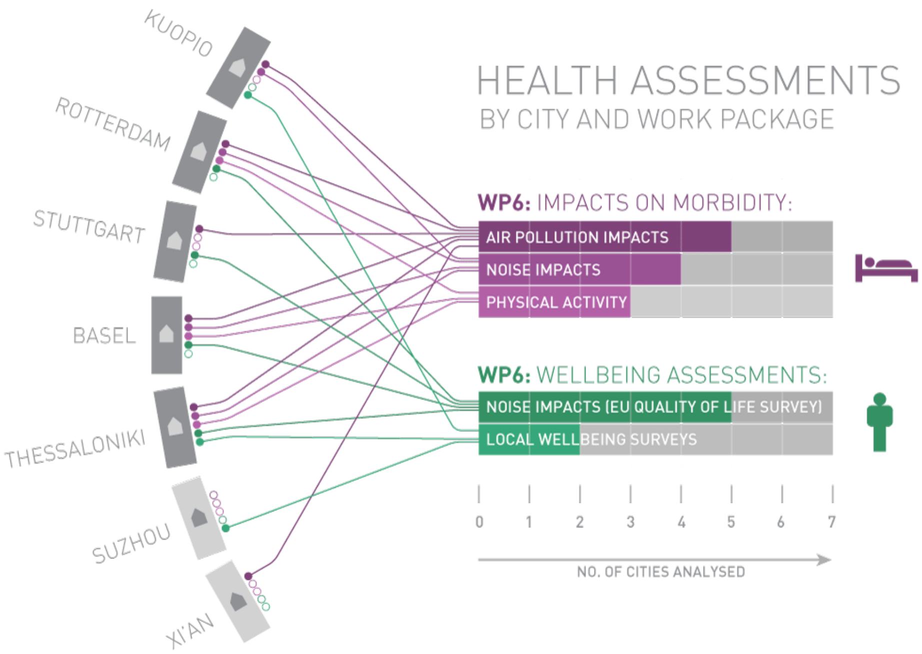
An example of the policy briefing information sheets, this one for Transport Policy, is shown in Appendix 6.

Appendices to Section 1

Appendix 1

Schematics of data gathered for URGENCHE



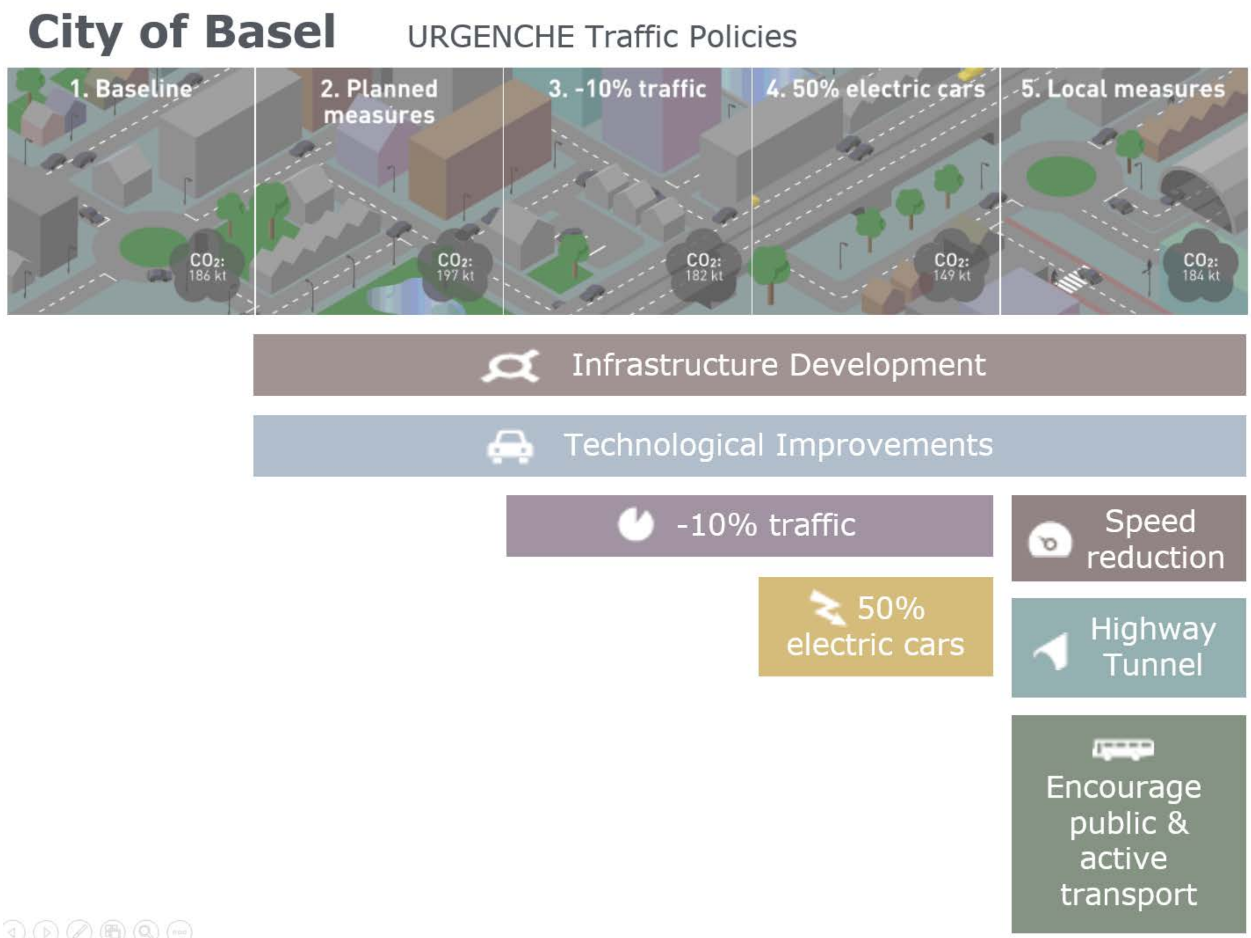


Appendix 2

Energy changes for Stuttgart (2010 to 2025) and Basel (2010 to 2020)

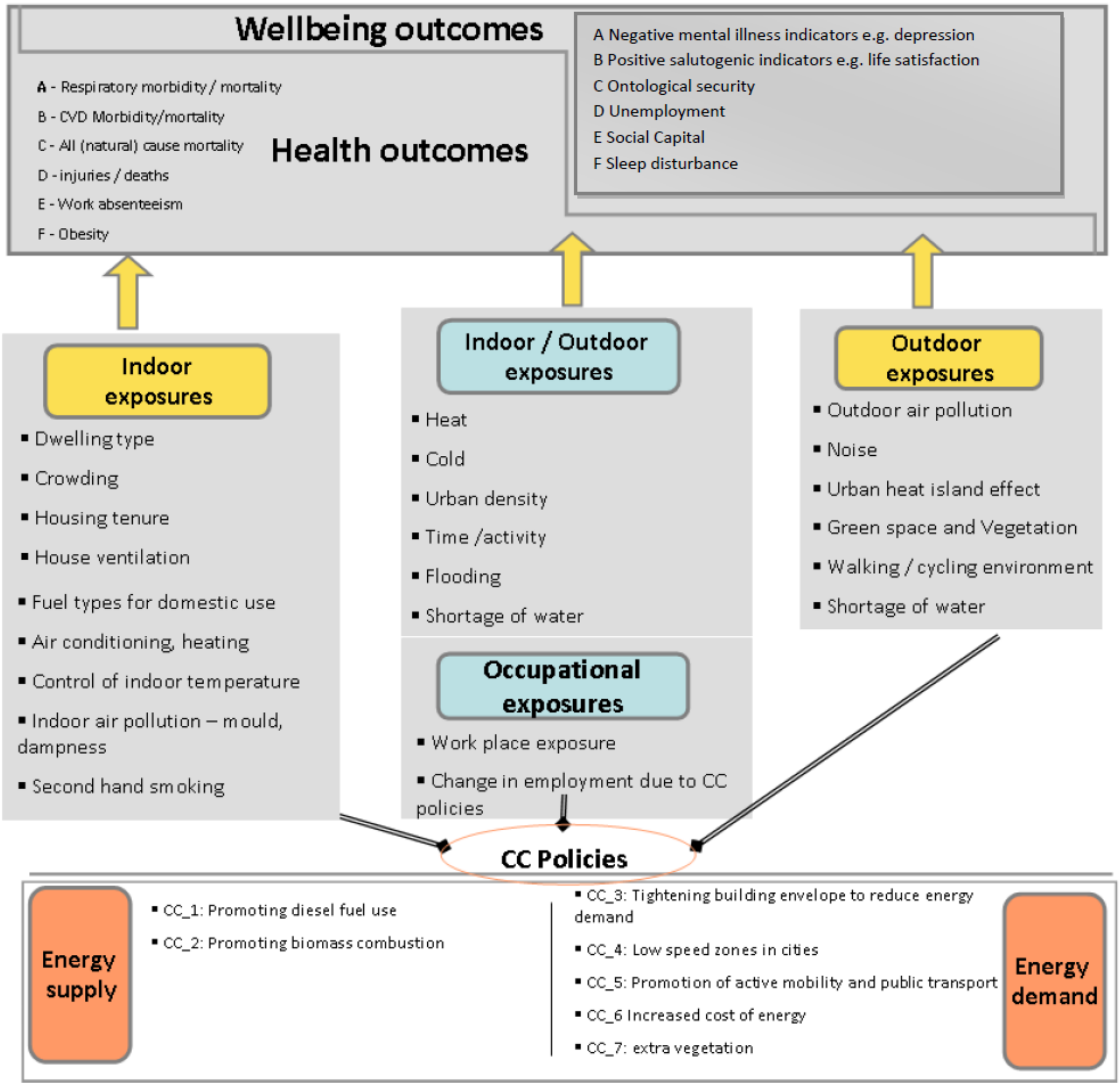
Appendix 3

Traffic policies for the city of Basel



Appendix 4

Modelling platform for Urban Impact Assessment



Appendix 5 (2 pages)

Formally tested scenarios in 2020 (or later) compared with BAU at same time period and/or baseline (2010 or earlier)

City	*Sector-scenario no.*	*Scenario details (name if provided) – note comparisons are with BAU unless otherwise specified*
Suzhou	Transport -1	A **reduction** of private vehicle kilometres by 10% on urban streets (2020-I)
	Transport -2	The introduction of 50% **electric**-powered private vehicle kilometres on urban streets (2020-II)
Xian	Transport -1	**Reducing** ambient $PM_{2.5}$ concentration to 50μg/m^3
Basel	Transport-1	4% **reduction** of traffic on inner urban roads (Z9)
	Transport-2	10% **reduction** of traffic on inner urban roads (P10)
	Transport-3	P10 scenario plus 50% of the private car fleets would be **electric** (P50)
	Buildings-1	Old building (pre 1980) **renovation** rate doubled to 2% (active)
	Buildings-2	All buildings pre 1980 **renovated** (total)
Kuopio	Energy-1	Local electricity plant burns 50% **wood** (replacing peat) (vs 4% BAU)
	Transport -1	50% increase in **biofuels** (to 30%)
	Buildings-1	Heating **energy need** of renovated and new buildings 25 kWh/m2
	Buildings-2	50% increase in building **renovation** to 4.5% (active)
	Buildings-3	Building renovation includes **sheath reform** (efficient)
	Buildings / energy	Heating energy need of renovated and new buildings 25 kWh/m2 **and** double use of wood for domestic heating
Rotterdam	Transport-1	10 percent **reduction** in traffic from personal car use
	Transport-2	50% **electric**-powered vehicle kilometres for passenger cars
Stuttgart	Energy-1	'Substantial Growth Scenario', where **pellet boilers** are installed throughout the entire city with growth rates as expected by the DEPV (German Wood and Pellets Fuel Association), which estimates 1 million units by 2020 in Germany. the PM emissions from small combustion plants will increase by 4% compared to the emissions in 2010 (SG)
	Energy-2	'Legal ban scenario' which assumes a legal ban of new wood pellet installations in the inner city The legal ban of new wood fuel in the inner city would reduce the total PM emissions by less than 1% (LB)
	Transport-1	Introduction of a **congestion charge** in the City of Stuttgart: a distance-related charge for passenger cars is introduced. An amount of 0.10 € per km is collected
	Transport-2	Extension of **parking** management: an expansion of the area where parking management is installed to the districts surrounding the city centre of Stuttgart

	Transport-3	Improved **public transport**; the frequency of light rail trains (S-Bahn) during the off-peak times is increased, so that is equal to the frequency in peak hours
	Transport-4	Improved **cycling** network: further cycle lanes are installed, these increase comfort with faster cycling and increase safety if cyclists are separated from cars and pedestrians
	Transport-5	A fifth scenario **combining** the four aforementioned measures was estimated for assessing potential synergies between the different scenarios
Thessaloniki	Transport-1	New **underground rail** in the city centre will be coupled with a high penetration of the **diesel** fuelled vehicles, a conservative increase in hybrids and an economically feasible penetration of electric cars, in accordance with projected economic figures (MIT-I)
	Transport-2	High penetration of **electric** passenger vehicles, associated with a series of fiscal policies to promote this mode of transportation (tax relief, reduced retail cost) (MIT-II)
	Buildings -1	**Energy certificate scheme** in new buildings and retrofit
	Energy -1	Increase in liquid fuel and **gas taxation** (leading to increased wood burning)

Appendix 6 (2 pages)

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Reducing carbon dioxide emissions from urban road traffic requires both technological and local measures

Dr. Menno Keuken, Netherlands Organization for Applied Research
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Professor Nino Künzli, Swiss Tropical and Public Health Institute
Dr. Pierpaolo Mudu, World Health Organization

About the research

Urban road traffic contributes about 10% of all European carbon dioxide (CO_2) emissions. Within the European-funded project *Urban Reduction of Greenhouse Gas Emissions in China and Europe (URGENCHE)*, a study was conducted on the impact on air quality of CO_2 reduction measures in urban road traffic.

Case studies included: the introduction of biofuels in Kuopio (Finland); extending the metro system in Thessaloniki (Greece) and Xi'an (China) to increase the level of public transport; a 10% reduction of private cars and the introduction of 50% electric-powered private cars in Rotterdam (the Netherlands), Basel (Switzerland), Xi'an and Suzhou (both China); and a combination of these traffic measures in Stuttgart (Germany).

The potential effects in 2020 from these scenarios on CO_2 emissions from road traffic and on air quality were compared to a "business-as-usual" scenario in 2020. This was examined in reference to 2010 figures, enabling health impact assessments to be produced for each city in 2010 and 2020.

This research examines the contribution of road traffic to CO_2 emissions in 2010 and 2020 in five European and two Chinese cities and the impact of CO_2-reduction measures on air quality and health.

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Policy implications

- **The implementation of more stringent national CO_2 emission standards (zero-emission) for road traffic is the most effective measure to reduce CO_2 emissions from urban road traffic. This is beyond the control of local authorities and requires action at the level of the European Union and the central Chinese Government.**
- **The most effective local policy to reduce CO_2 emissions and improve air quality, health and well-being is to facilitate and stimulate physical (cycling, walking) and public transport. Such measures and policies are within the control of local authorities.**

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Key findings

- Compared to 2010, traffic-related CO_2 emissions will stabilise in the European cities and will increase by approximately 40% in the Chinese cities in 2020.
- Air pollution of soot, nitrogen dioxide (NO_2) and particulate matter ($PM_{2.5}$ and PM_{10}) concentrations in the Chinese cities are a factor 3 to 5 higher than in the European cities in 2010 and 2020.
- Over the period 2010-2020 air pollution emissions will reduce due to cleaner technology in all sectors, both in China and Europe. In Europe, this will result in lower concentrations of all pollutants. In China, pollutant concentrations are likely to remain constant for particulate matter ($PM_{2.5}$ and PM_{10}), to decrease for soot (elemental carbon) and to increase for nitrogen dioxide (NO_2) as a result of economic growth (see 'further information' for an explanation of the pollutants).
- Stringent national emission standards (zero CO_2 emissions) are more effective than local measures in Europe and China.

Further information

In this study, the annual average concentrations of nitrogen dioxide (NO_2), particulate matter ($PM_{2.5}$ and PM_{10}) and soot (elemental carbon) were modelled in all cities for 2010 and 2020. The air pollutants NO_2, $PM_{2.5}$ and PM_{10} are regulatory components in Europe and China, while elemental carbon is a sensitive indicator for exhaust emission from road traffic. The population-weighted average for each pollutant was derived per city and used for health impact assessment in 2010 and 2020.

This urban road traffic-focused study forms part of the *Urban Reduction of Greenhouse Gas Emissions in China and Europe (URGENCHE)* project. Other studies have covered themes: housing and energy; and cities: five in Europe and two in China.

You can visit the project website: urgenche.eu

For further reading on this topic please see: Keuken M.P., Jonkers S., Verhagen H.L.M., Perez L., Trüeb S., W.-J. Okkerse, Liu J., Pan X.C., Zheng L., Wang H., Xu R., Sabel C. (2014) "Impact on air quality of measures to reduce CO_2 emissions from road traffic in Basel, Rotterdam, Xián and Suzhou." Atmospheric Environment 98:434-489

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