CityZen

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The regional and global impact of selected megacity areas due to future changes of traffic infrastructure

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

The regional and global impact of selected megacity areas due to future changes of traffic infrastructure

The transportation and domestic sectors are dominant emission sources in urbanized areas. For many decades they have been among the main contributors to low air quality in and around urbanized regions, and they may also contribute to climate change through their emissions of greenhouse gases and particles. CityZen had as one of its aims to look at possible mitigation scenarios in order to improve air quality and reduce climate warming. In this deliverable, a special focus was put on traffic emissions. In the following sections, emission scenarios, model experiments and results are described.

Emission scenarios

Within the CityZen project, several scenarios for future development of anthropogenic emissions have been considered. Figure 1 shows as an example the future development of NOx emissions in Western Europe for three scenarios, which have been widely used for CityZen modelling studies (see, e.g., deliverable reports D2.3.1, D3.4.1, and D3.5.1).

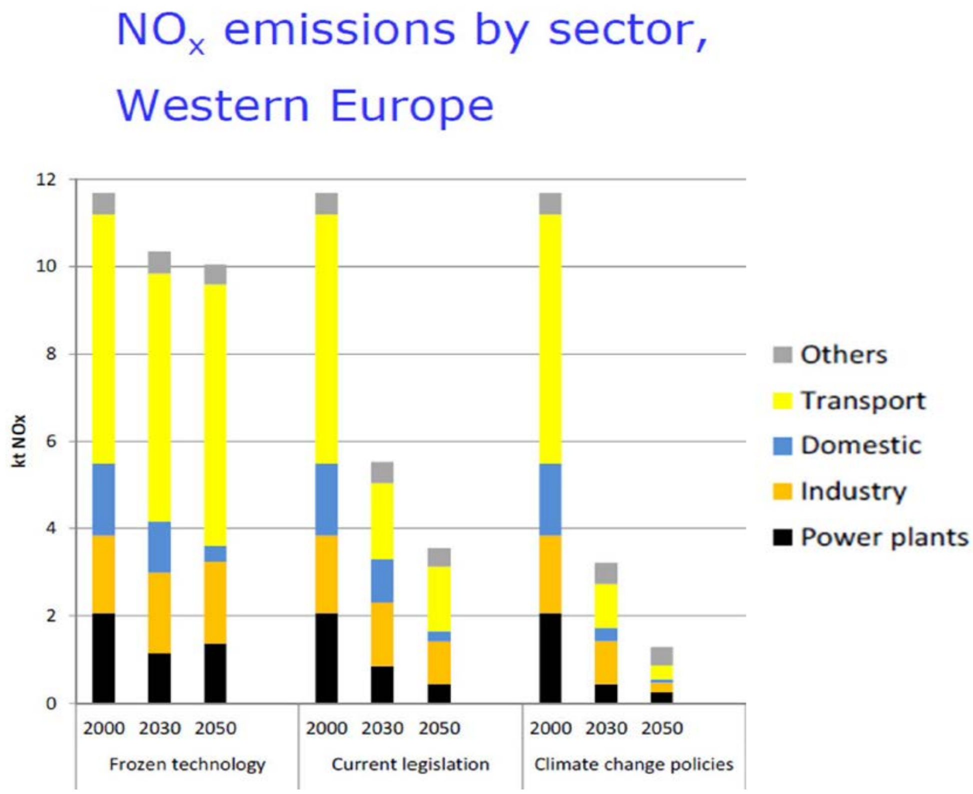

Figure 1: Changes in Western European NOx emissions by sector for three different scenarios: Frozen technology, Current legislation, and Climate change policies (in deliverable reports D2.3.1 and D3.5.1 these are referred to as 'HIGH FROZEN', 'HIGH CLE' and 'LOW CLE', respectively).

Detailed information about these scenarios is given in deliverable reports D3.3.2 and D3.3.4. Here, only the main features are summarized:

The *frozen technology* scenario (in CityZen referred to as ‘HIGH-FROZEN’) assumes that there is no change in future pollution policies relative to 2005. The combustion technologies/abatement measures are assumed not to change beyond the year 2005 technologies. There is also no implementation of policies on energy access (although increasing economic growth leads to a slowly declining use of dirty solid fuels for cooking and heating in developing regions).

The *current legislation* scenario (in CityZen referred to as ‘HIGH-CLE’) is identical to the case described above in terms of energy structure, and no specific policies on climate change and energy access. However, it assumes full implementation of all current and planned air pollution legislation world-wide until 2030.

The *climate change policies* scenario (in CityZen referred to as ‘LOW-CLE’) has a stringent climate policy corresponding to a 2-degree global temperature target is implemented. In addition, it assumes a moderate energy access policy, as well as full implementation of all current and planned air quality legislation until 2030.

As seen from Figure 1, the ‘HIGH-FROZEN’ scenario does not reduce transport emissions by any significant amount, while current legislation (‘HIGH-CLE’) allows notable reductions until year 2030. Between 2030 and 2050 there is, however, only limited potential for further reductions of current emissions with current technology. Such reductions can be achieved by electrical cars and fundamental structural changes, such as energy supply, transport infrastructure, transport fuels, behavior, etc.).

In addition to these three scenarios, IIASA provided ratios that mimic ‘climate friendly air quality mitigation ratios’, i.e. measures that are meant to improve air quality but at the same time do not enhance climate change. A list of these measures is given in Box 1.

The ratios are derived from the emissions in the UNEP so-called lowGWP scenario which involves technical control measures applied to sources of air pollutants (primarily PM in this case). The set of measures was selected with the aim of reducing the global warming potential (GWP) (broadly, to reduce BC as far as possible while reducing SO2 and OC as little as possible). The ratios are explained in more detail in CityZen deliverable report D3.3.4.

Within CityZen these ratios (in CityZen referred to as ‘IIASA ratios’) have been used to modify the HIGH-CLE scenario. Technically, the emission numbers in the HIGH-CLE scenario are multiplied by the IIASA ratios in each grid cell, to represent the implementation of the measures given in Box 1.

Key measures to reduce radiative forcing from short-lived substances

Group 1: Technical measures for methane emissions:

- Extended pre-mine degasification and recovery and oxidation of ventilation air methane from coal mines
- Extended recovery and utilization (instead of venting) of associated gas and improved control of unintended fugitive emissions from production of crude oil and natural gas
- Measures to reduce gas leakage from long-distance gas transmission pipelines, including electrical start-up and improved inspection and maintenance to secure compressor seals and valves
- Separation and treatment of biodegradable municipal waste through recycling, composting and anaerobic digestion
- Upgrading primary wastewater treatment to secondary/tertiary treatment with gas recovery and overflow control
- Control of methane emissions from livestock, mainly through farm-scale anaerobic digestion of manure from cattle and pigs with liquid manure management
- Intermittent aeration of continuously flooded rice paddies

Group 2: Technical measures for reducing emissions of incomplete combustion:

- Diesel particle filters for road vehicles and off-road mobile sources (excluding shipping)
- Replacing coal by briquettes in cooking and heating stoves
- Pellet stoves and boilers to replace current wood burning technologies in the residential sector in industrialized countries
- Introduction of improved biomass cook and heating stoves in developing countries
- Replacing traditional brick kilns with vertical shaft kilns and Hoffman kilns where considered feasible (in developing countries)
- Replacing traditional coke ovens with modern recovery ovens, including the improvement of end-of-pipe abatement measures (in developing countries)
- Catalysts for stationary engines

Box 1: ‘Climate-friendly air quality measures’ as included in the ‘IIASA ratios’

The traffic mitigation experiment

We have used the EMEP/MSC-W chemical transport model (hereafter referred to as ‘EMEP model’) on 0.22x0.22 degree resolution on the European domain for the year 2030 and have applied the IIASA ratios to the road transport sector (i.e. SNAP sector 7 - Road transport) in the High CLE scenario. As can be seen from Box 1 the measure reducing traffic emissions directly is the introduction of Diesel particle filters. Although this measure is targeted at particles, also other co-emitted species can be reduced. The effect on emissions largely depends on the level of current legislation. E.g. in Germany and other parts of Western Europe the implementation of particle filters has already progressed considerably so that further emission reductions are limited, at least by the year 2030.

The emission reductions achieved by implementing the climate-friendly air quality mitigation measures (Box 1) to transport only is seen in Tables 1 and 2 for Russia and Germany, respectively. The emission reduction potential is larger in Russia than in Germany.

	NOx	**Sox**	**CO**	**VOC**	**OC**	**BC**	**NH3**
High CLE	1723	956	4451	1700	60.1	63.9	637
Traffic mitigation scenario	1524	956	4090	1660	55.6	60.0	637

Table 1a: Annual emissions in Russia (Gg/yr) in the High CLE and traffic mitigation scenario (that includes the climate-friendly measures listed in Box 1) in 2030. Note: only the part of Russia that is included in the EMEP model domain is considered, as visualized in Figures 2 to 6).

	NOx	**Sox**	**CO**	**VOC**	**OC**	**BC**	**NH3**
High CLE	654.1	130	1105	858	7.70	16.42	830
Traffic mitigation scenario	653.7	130	1104	858	7.70	16.40	830

Table 1b: as table 1a, but for Germany (Gg/yr).

Two model runs have been performed: a) one base case with the HIGH-CLE scenario, and b) one perturbation case ‘traffic mitigation’, where the IIASA ratios are applied to the road transport sector.

Figure 2 shows a horizontal map of the emission change at the example of NOx. NOx emissions are mainly reduced in populated areas in Russia, but also in parts of Northern Africa. Noticeable reductions are also found in the Po Valley and some other regions within the European Union. The reductions are small or non-existent in France, Germany and Northwestern and Northern Europe, reflecting that the potential from particle filters is small as most vehicles, even the oldest ones, are already using particle filters by 2030.

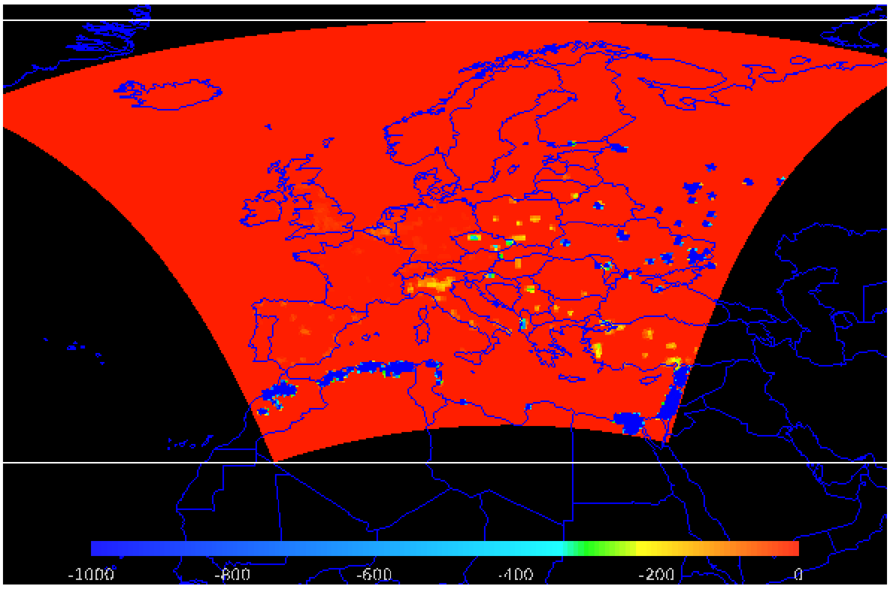

Figure 2: Δ NOx emissions (mg/m2/year), i.e. the difference 'traffic mitigation minus HIGH-CLE' in 2030.

In order to filter out effects from inter-annual variability in meteorology the two model simulations were integrated for 11 years, with meteorological data from a climate model prediction for the period 2025-2035.

Figures 3 and 4 show monthly-mean surface concentrations of black carbon, sulphate aerosols, nitrogen dioxide and ozone for January and July (averaged over the 11-yr period), while Figures 5 and 6 show changes in these concentrations due to the emission reductions described above.

Black carbon is reduced (Figure 5). As black carbon is an important air pollutant and also leads to climate warming, the reduction of black carbon can be seen as a co-benefit for both air quality and climate policy. The climate-friendly air quality measures successfully reduce black carbon. At the same time they do not reduce sulphate to any significant amount. Indeed sulphate is increased somewhat, which would lead to negative radiative forcing and likely a cooling. It is important to note, however, that increases in sulphate should not be considered as a recommendation from CityZen to prevent climate change, as they also lead to a reduction of air quality.

Changes in NO_2 (Figure 6) mainly reflect the emission reductions, especially in Russia and North Africa, while changes in ozone are a result of the interplay between changing emissions and photochemistry. Although the changes are small and well within half a ppb in most areas, they are slightly positive over large regions in January. This is probably related to reductions in NOx emissions mainly occurring in polluted areas, where non-linear effects (often referred to as titration effects in urban areas) can lead to increased ozone production following the reduction of NOx emissions. In summer, when photochemistry is more active, ozone production in remote areas becomes more dominant, so that reductions in NOx emissions also lead to reductions in ozone, except for the most polluted areas, e.g. the megacity of Moscow.

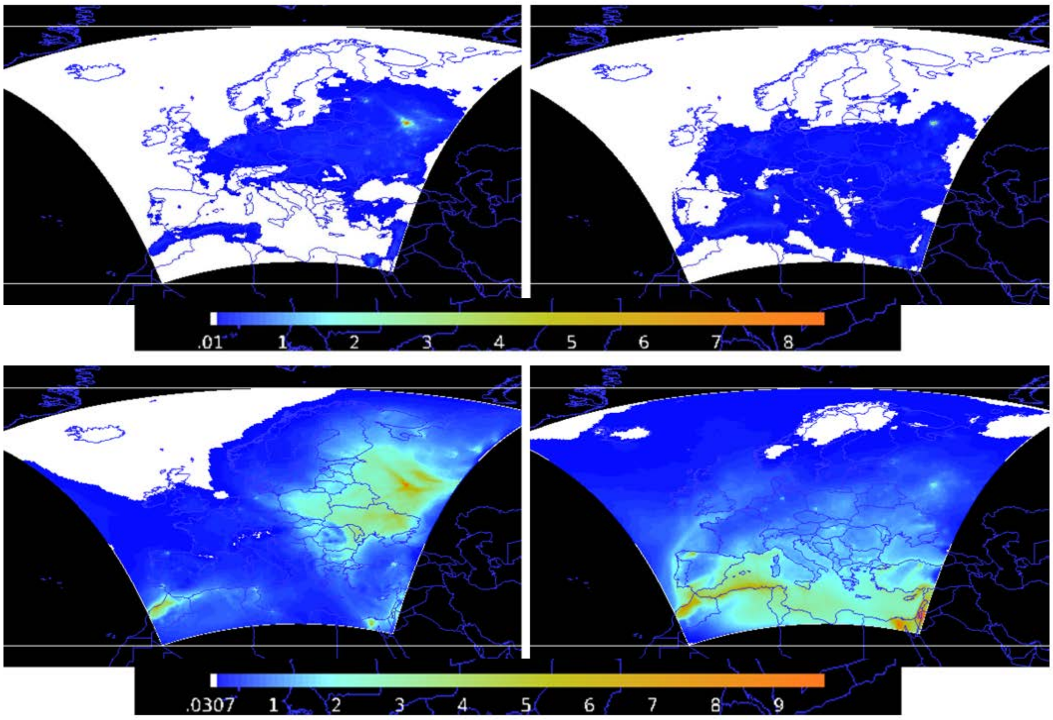

Figure 3: Monthly-mean concentrations of black carbon (top panels) and sulphate aerosols (bottom panels) at the surface for January (left) and July (right), as modelled by the EMEP model, averaged over the 2025-2035 period. Unit: µg/m3.

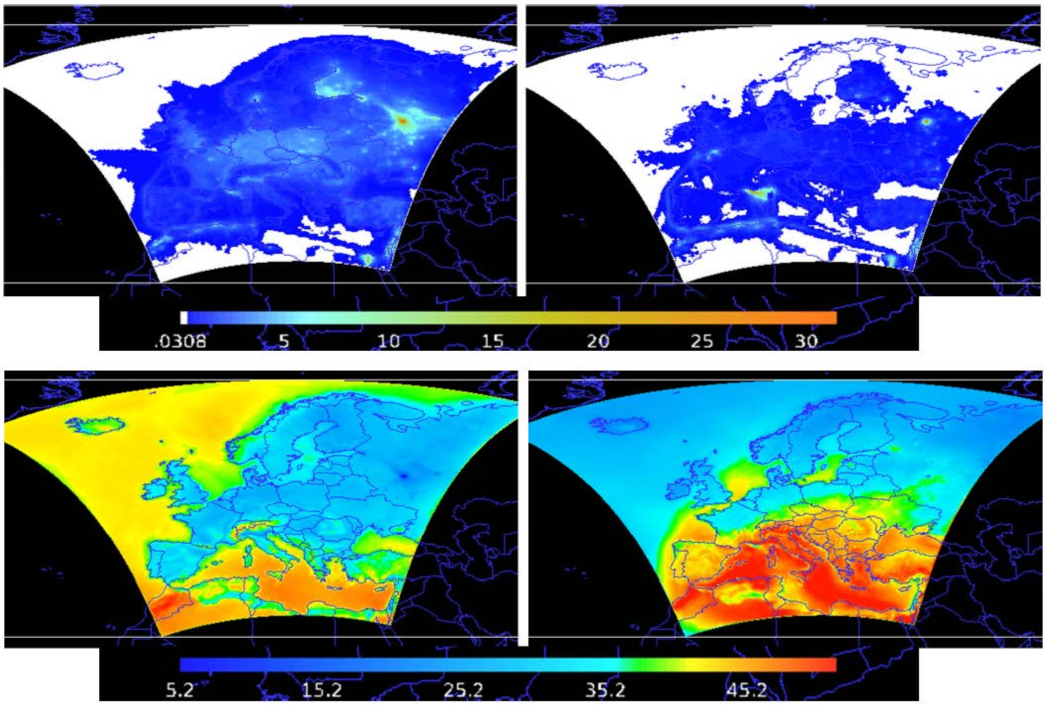

Figure 4: Monthly-mean mixing ratios of NO_2 (top panels) and ozone (bottom panels) at the surface for January (left) and July (right), as modelled by the EMEP model, averaged over the 2025-2035 period. Unit: ppbv.

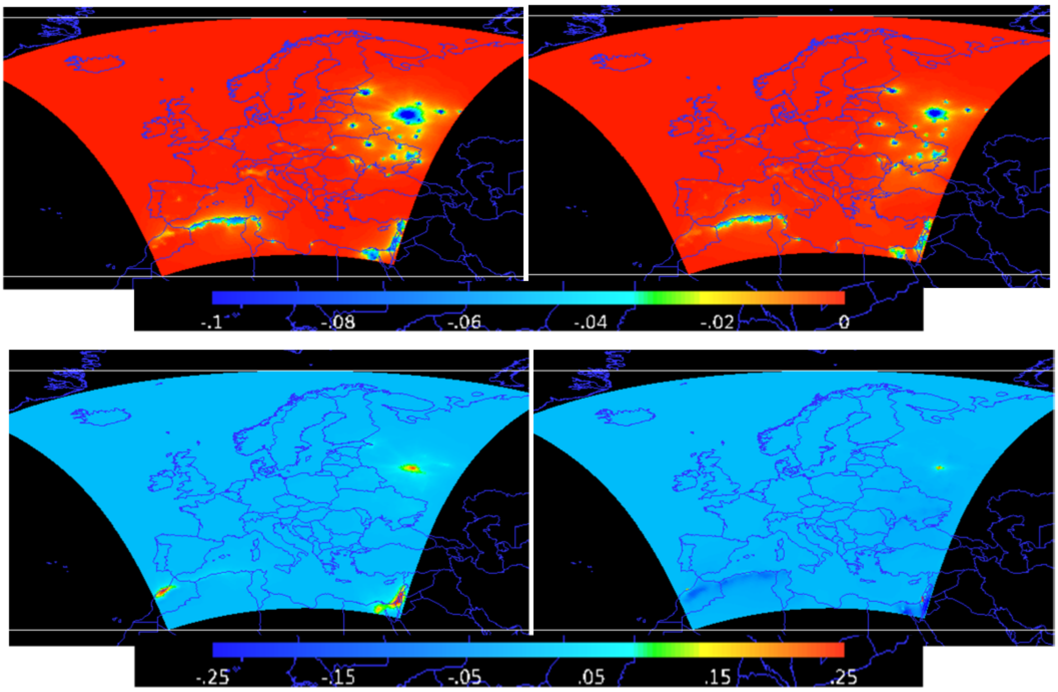

Figure 5: Change in monthly-mean concentrations of black carbon (top panels) and sulphate aerosols (bottom panels) at the surface for January (left) and July (right), plotted as the difference ‘traffic mitigation minus HIGH-CLE’ as modeled by the EMEP model for the period 2025-2035. Unit: μg/m3.

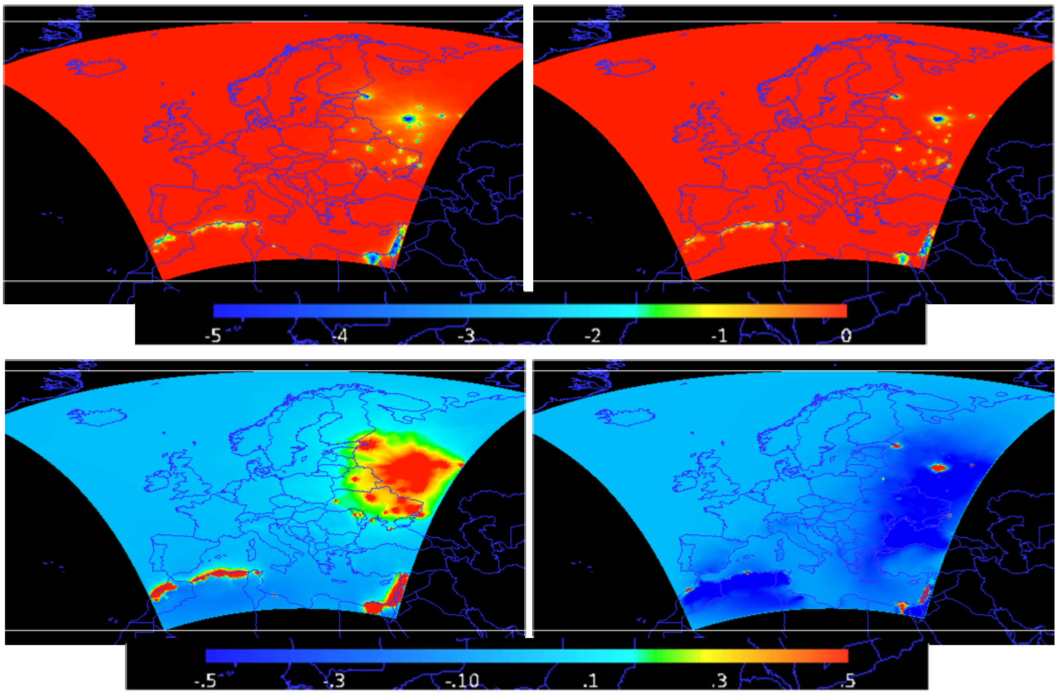

Figure 6: Change in monthly-mean mixing ratios of NO_2 *(top panels) and ozone (bottom panels) at the surface for January (left) and July (right), plotted as the difference ‘traffic mitigation minus HIGH-CLE’ as modeled by the EMEP model for the period 2025-2035. Unit: ppbv. (Note that the color bar of the plots for ozone change does not include extreme values of up to 5 ppb increases in very confined areas, that are heavily urbanized, e.g. Moscow).*

Conclusions and further work

Climate-air quality interactions and co-benefits in emission reduction policy have been one of the focus areas within CityZen. The traffic mitigation study, performed for the CityZen project, demonstrates how climate-friendly air quality mitigation measures applied to traffic can improve air quality, while not contributing to climate warming. The main measure applicable to traffic in this context is the introduction of particle filters in Diesel vehicles. As this measure has widely progressed in Western Europe by 2030, our results indicate little potential for further improvement (unless fundamental changes are implemented, such as electrical cars). In regions of the world where the use of particle filters has progressed less the effects will be larger.

Further work should involve coupled climate chemistry models or the use of a radiative transfer model to quantify the radiative forcing induced by the changes calculated by the chemical transport model. Also, population exposure needs to be assessed and reductions in BC have to be compared with increases in ozone in terms of health impact.