CityZen

megaCITY - Zoom for the Environment

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Scientist(s) responsible for this deliverable: Z. Klimont, Ch. Heyes, M. Amann

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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)	

Report on the definition of mitigation scenarios which could be proposed to deal both with air quality in megacities and climate change

The CityZen deliverable report D.3.3.2 described the baseline and policy scenarios where various air quality and climate futures were included. These scenarios relied on the energy projections developed within the Global Energy Assessment (GEA) coordinated at IIASA[1], where the IIASA MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impact) model was used; http://www.iiasa.ac.at/Research/ENE/model/message.html (Messner and Struberger 1995) while air quality legislation assumptions (CLE) until 2030 originated from the GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies) model (Amann, Bertok et al. 2011); http://gains.iiasa.ac.at. The scenarios are conceptually summarized in Figure 1. The scenarios extend to 2050.

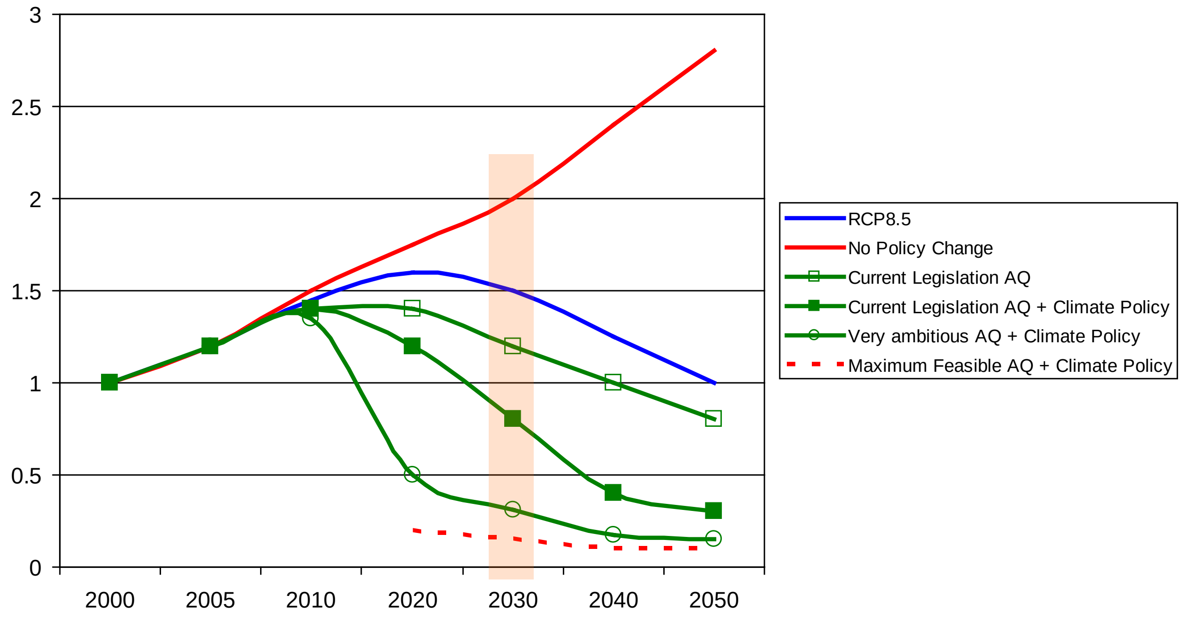

Figure 1. Example of the types of scenarios prepared for the CityZen analysis (this figure is not based on real numbers, it is only an illustration).

The starting point (year 2000) in terms of global aerosols and greenhouse gases emissions has been harmonized with the RCP 8.5 scenario which is also shown in Figure 1. The scenarios used in CityZen project assume a combination of different stringency of air quality legislation and climate policy. The dashed red line in Figure 1 indicates the maximum technically feasible scenario (based on the GAINS model technology database) for air quality only to show the lower constraint on the emissions of air pollutants but was not used. The scenarios include several air pollutants and greenhouse gasses.

One of the tasks of the CityZen project was to develop and explore the scope for air quality improvements with climate-friendly sets of measures, i.e., resulting in reduced radiative forcing. Such strategies were subsequently used to define a set of scenarios where either all territory or only urbanized areas were affected by the concerned strategies. Examples of this analysis are shown in CityZen deliverable reports D3.3.1 and D4.5.1.

[1] http://www.iiasa.ac.at/Research/ENE/GEA/index_gea.html

Since the development of these strategies was performed by the GAINS model at a fairly detailed regional and sectoral level, the direct application of these to the GEA MESSAGE scenarios was not possible owing to quite aggregated spatial resolution and sectoral structure of MESSAGE model. Therefore, we have developed for each pollutant the region- and sector-specific ratios between the *LowGWP* and baseline scenario; see brief characterization of the scenarios and ratios in the next sections.

GAINS Reference scenario

The GAINS reference scenario makes use of the global projections of the International Energy Agency (IEA) presented in the World Energy Outlook 2009 (OECD/IEA 2009) and assumes successful implementation of current air pollution control policies, i.e., policies that were in force or in the final stage of the legislative process as of mid-2010 in each country. Major influenced sectors are mobile sources, power generation and industrial production processes. The degree and stringency of regulation varies across regions and countries, however; strongly controlled sectors tend to converge in the longer time horizon to a comparable implied emission rate largely independent of the region. Implementation of air pollution legislation, fuel efficiency standards, installation-specific emission limit values, and international agreements (e.g., the LRTAP Convention) and laws implies changes in emission factors over time.

These changes will vary across regions and sectors, reflecting the stringency of legislation but also its actual enforcement. In this study, it has been assumed that the measures will be installed in a timely manner and will achieve designed emission levels to comply with the law. The only exception is the transport sector, where we explicitly consider high-emitting vehicles (or superemitters) and make assumptions about their region-specific shares and technology-specific deterioration factors. The same reference scenario has been used in the UNEP Black Carbon and Tropospheric Ozone Assessment (UNEP, 2011) and its more detailed characterization can be found in Chapter 2 of that report.

GAINS climate-friendly 'LowGWP' scenario

The goal of this scenario is to mitigate the impacts of several pollutants emitted from anthropogenic activity not solely on climate, but also on public health and on the wider environment. For that purpose the GAINS database of nearly 2000 measures has been evaluated considering different degree of reduction of specific pollutant species. For example, energy efficiency measures would be expected to reduce emissions of all pollutants several other technical measures will reduce various species to a varying degree. As a result, to understand the full climate and public health implications of each measure, it is important to look at the suite of pollutants affected by any given measure. This integrated approach is particularly relevant in this assessment as traditional pollutants and climate forcers are often emitted from the same sources and many emitted substances affect both climate and air quality.

An integrated approach is also necessary because co-emissions associated with both BC and tropospheric ozone (TO) will differ markedly from one sector and source to another, an important consideration in deriving effective mitigation strategies to reduce climate impacts. As has been noted earlier, the behaviour of organic carbon (OC) as a 'white' (cooling) aerosol can potentially offset the climate benefits of reducing BC depending on the relative amounts of the two pollutants in each source/sector emission profile, as well as the location of the emission source. Similarly, addressing TO by mitigating methane or nitrogen oxides (NO_X) will have different climate impacts.

The analysis estimated, for each of the 2000 mitigation measures included in GAINS, their impacts on the emissions of all pollutants that are affected (i.e., CH_4, CO, BC, OC, SO_2, NO_x, VOC, CO_2) in each source region. In a further step, the net effect of these emission changes on radiative forcing at the global scale has been estimated for each measure, and measures have been ranked accordingly. These radiative forcing calculations used a globally uniform estimate of forcing per unit emission with the ranking based on the difference in forcing from emissions with and without the control measures integrated over a 100 year period. The GWP values used for screening the measures are presented in Table 2.

Table 1. GWP values used for screening the measures

Pollutant	100 yrs (mean)	Range	Source
CO2	1		(Forster, Ramaswamy et al. 2007) - IPCC-AR4
CH4	25	16 to 34	(Forster, Ramaswamy et al. 2007) - IPCC-AR4
SO2	-40	-24 to -56	(Schulz, Textor et al. 2006; Fuglestvedt, Shine et al. 2009)
CO	1.9	1 to 3	IPCC-AR3, cited in (Forster, Ramaswamy et al. 2007) - IPCC-AR4
BC	680	210 to 1500	(Bond and Sun 2005)
OC	-69	-35 to -104	(Bond and Sun 2005; Schulz, Textor et al. 2006)
NMVOC	3.4	2 to 7	(Forster, Ramaswamy et al. 2007) - ref to (Collins, Derwent et al. 2002)
NOx	~ 0		

Figures 2 and 3 show simplified examples of the procedure to identify measures using GWP20 and only emissions of BC and OC. As can be seen, some measures might result in actually higher net CO2eq emissions than the current technology (Figure 2) and the degree of reduction varies strongly between the measures. Using such results for all measures a short list of key measures bringing biggest benefits has been identified and is presented in Table 2.

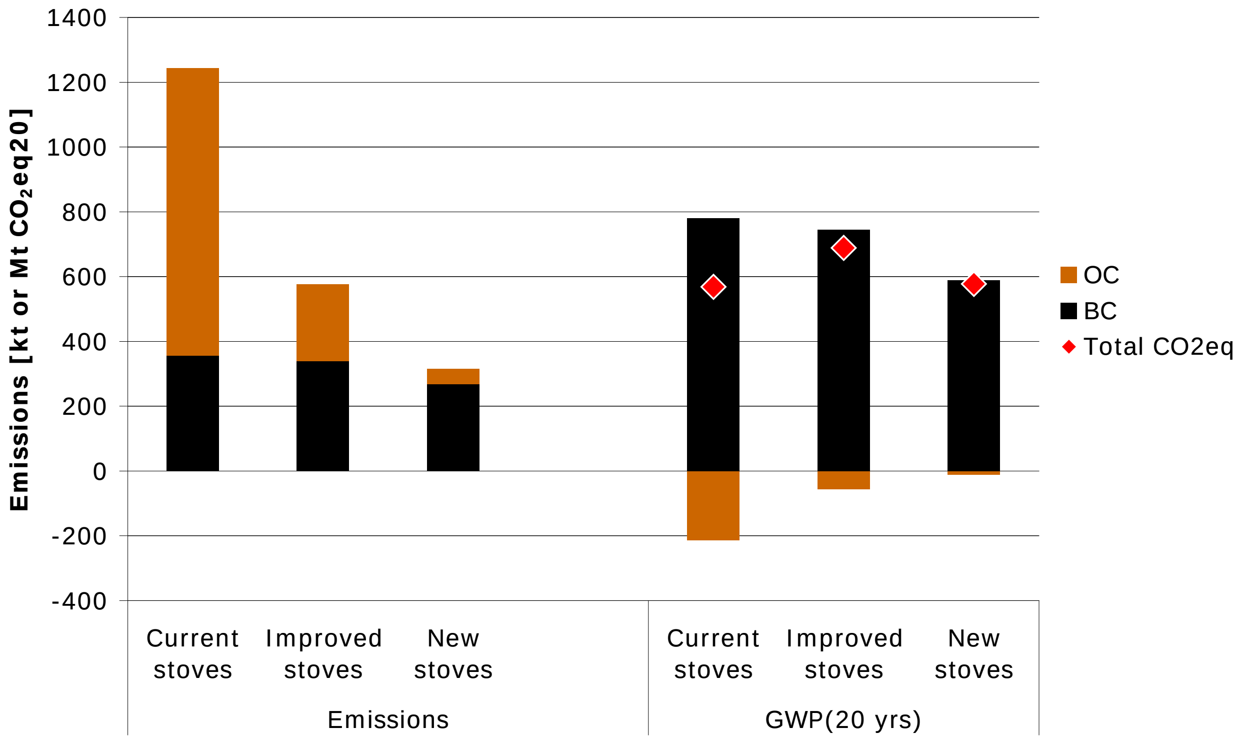

Figure 2: Net GWP20 of BC mitigation; Example: Biomass (agricultural residue, dung, fuelwood) cooking stoves in India. Assumed GWP20 values for BC and OC are 2200 and -240 after Bond and Sun (2005).

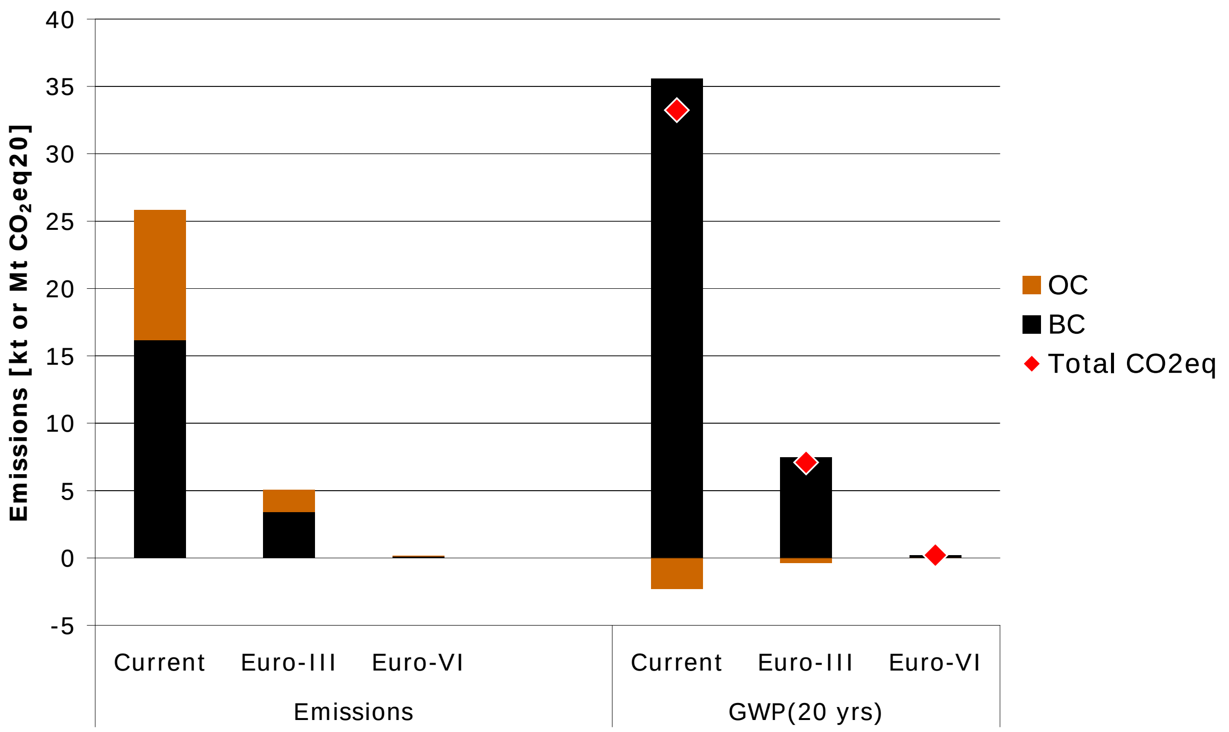

Figure 3: Net GWP20 of BC mitigation; Example: Diesel heavy duty vehicles in India. Assumed GWP20 values for BC and OC are 2200 and -240 after Bond and Sun (2005).

Table 2: Identified measures to reduce radiative forcing from short-lived substances; 'LowGWP' case

Measure	**Sector**
Diesel particle filters for road and off-road vehicles	Transport
Replacing coal by coal briquettes in cooking and heating stoves	Residential
Pellet stoves and boilers, using fuel made from recycled wood waste or sawdust, to replace current wood burning technologies in the residential sector in industrialized countries	
Introduction of clean-burning biomass stoves for cooking and heating in developing countries	
Replacing traditional brick kilns with vertical shaft kilns	Industry
Replacing traditional coke ovens with modern recovery ovens, including the improvement of end-of-pipe abatement measures in developing countries	

A full implementation of the measures listed in Table 2 by 2030 would lead to significant reductions of short-lived climate forcers (SLCF) emissions relative to current emissions or to the 2030 emissions in the reference scenario, and also reduce a high proportion of the emissions relative to the potential offered by full implementation of all 2 000 measures in the GAINS model. The examples of impact of the measures in relation to the Reference scenario are shown in the next section. A brief characterization of identified measure categories is provided in Table 2.

Diesel particle filters for road and off-road vehicles

A number of measurements on vehicles equipped with DPF (diesel particulate filter) have shown their efficiency and durability. The current legislation in many industrialized countries requires installation of DPF on road (including cars and trucks) and most recently also non-road machinery as part of the EURO 6/VI emission standards. The technology is developed and widely available for all new vehicles. For a large proportion of existing vehicles installation of DPFs alone is also feasible although typically with lower reduction efficiency and shorter lifetime. Introduction of this technology requires ultra-low sulphur fuel, resulting in reduced sulphur dioxide emissions from transport, which has been also considered in the calculations.

Pellet stoves and boilers, using fuel made from recycled wood waste or sawdust, to replace current wood burning technologies in the residential sector in industrialized countries

The last decade has seen a significant growth in use of pellet stoves and boilers, particularly in Europe. Annual sales growth rates of 20-30% in Austria, France, Germany, Italy, Switzerland, Sweden (currently the largest market in the world) were reported. Growing demand for pellets resulted in development of significant fuel production capacity also beyond Europe in countries where pellet stoves are not yet widely used, mostly in Poland, Ukraine, and Canada.

Although in several countries there is legislation regulating emissions of PM (not BC) from small installation, the main factors leading to the introduction of pellet stoves and boilers include economic aspects such as lower fuel costs. Economic incentive programs proved successful in many countries.

Introduction of clean-burning biomass stoves for cooking and heating in developing countries

Several regional programs (stimulated by health concerns) demonstrated the technical feasibility of introducing clean cooking and heating stoves. In some countries, e.g., China and India, several hundred thousand stoves have been introduced. Beyond technical challenges, the acceptance of these non-traditional stoves has been an issue, but most recent developments have demonstrated that it is possible to develop stoves that match the requirements. However, current programs have not specifically targeted BC emissions, but focus on health benefits from reduced PM, VOC and CO emissions.

Replacing coal by coal briquettes in cooking and heating stoves

Coal briquettes is a well-established fuel and has been in use around the world, especially in regions with access to poor quality coal. In recent years, countries where large amounts of coal have been used in the residential sector also in urban areas (e.g., China) introduced programs to expand the use of coal briquettes and employ appropriate combustion technologies. The stoves burning briquettes have been shown to emit significantly lower amounts of PM and other pollutants, and could be applied to other regions with similar conditions.

Replacing traditional brick kilns with vertical shaft kilns

Traditional brick kilns, often referred to as clamp kilns, are still a widespread technology in South Asia, Central and South America. However, a number of Asian countries (e.g., Vietnam and China) managed a successful transition to more modern, much cleaner and more fuel efficient technologies. Demonstration projects have also been implemented in India and Bangladesh. Assuming appropriate transfer of technology and experience to other countries, an elimination traditional technology in the developing world appears plausible. Here we considered replacement of the traditional technology with the vertical shaft kilns (VSBK) that are characterized by significantly lower fuel consumption and consequently lower emissions.

Replacing traditional coke ovens with modern recovery ovens, including the improvement of end-of-pipe abatement measures in developing countries

Clean manufacturing of coke has been demonstrated in industrial countries in the past decades. Currently, the major coke producing capacity exists in China where still many coke plants are using old polluting technology. However, fast growing demand resulted already in a fast technological development and new plants today are built to world standards.

Ratios of LowGWP vs REFerence scenario

The ratios of emissions of all considered pollutants in *LowGWP* and *REFerence* scenarios were calculated for the year 2030 by country and SNAP sector. These ratios represent the measure of change in emissions when climate friendly air quality measures are introduced. The smaller the ratio the larger the change between the scenarios, indicating that introducing the given measures results in significant reductions compared to the Reference case. The value of ratios will vary between pollutants, sectors, and regions.

Figures 4 and 5 illustrate such differences for selected regions and countries for road transport sector. They show change in emissions for NOx and black carbon. Figure 4 shows ratios for EU-27 countries and as expected a fairly homogeneous picture is shown both between the countries as well as pollutants. This is due to the harmonized legislation across EU-27 and the differences result from different shares of specific vehicles categories as well as ratio of gasoline to diesel fuel since emission factors vary and the *LowGWP* scenario assumes measure (EURO VI/6) for all diesel vehicles only.

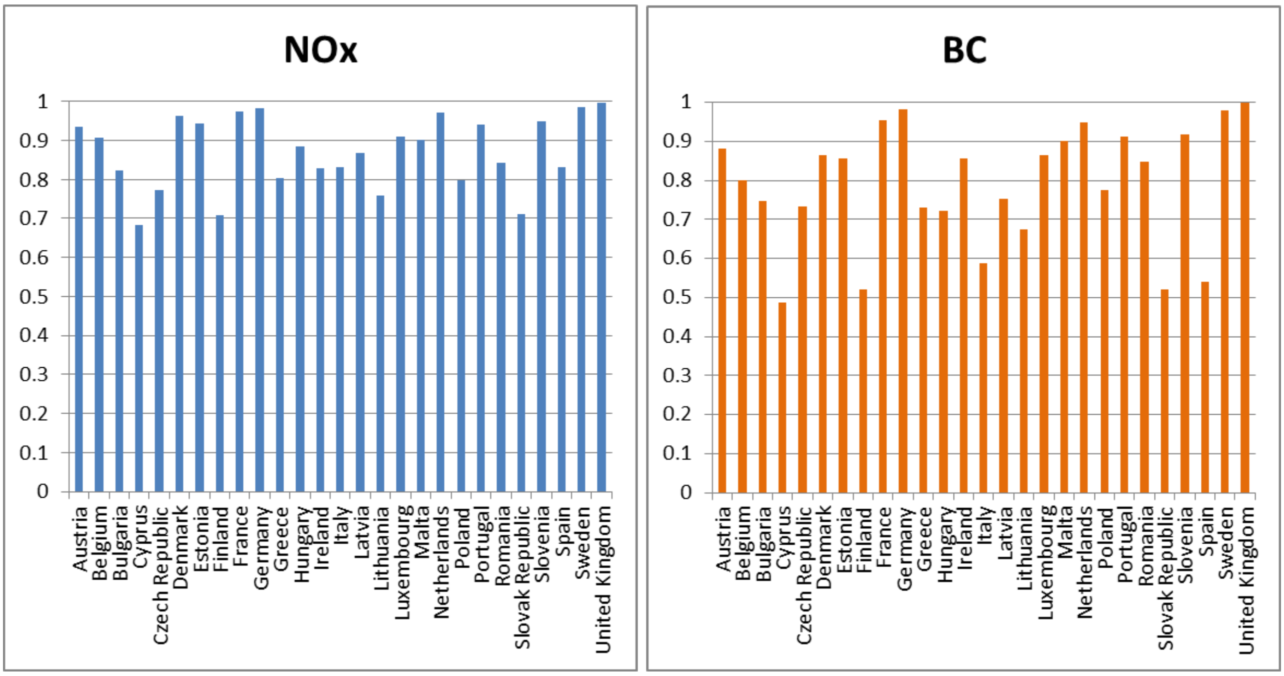

Figure 4: Ratios of *LowGWP* to *Reference* emissions for 2030 road transport sector for NOx and BC; EU-27.

Figure 5 shows, for the same sector, ratios for Asia. Here, large differences between countries are observed where some countries like Japan and South Korea show very similar ratios to most of EU-27 and a number of other countries have very low ratios indicating less advanced current legislation policy and therefore more abatement potential.

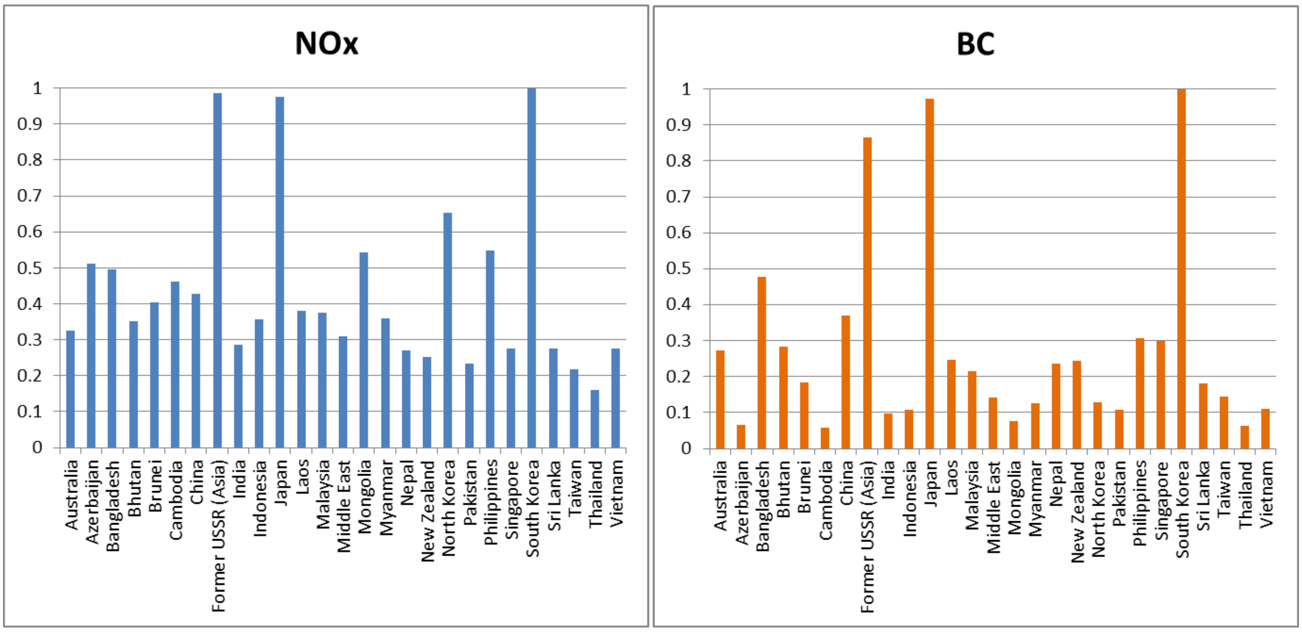

Figure 5: Ratios of *LowGWP* to *Reference* emissions for 2030 Road transport sector for NOx and BC; Asia and Pacific.

The information was provided by IIASA in the form of ratios compiled in excel tables. These ratios have been used by the modelers to scale up or down emissions within the CityZen regions. The excel tables containing the ratios were made available to the entire CityZen consortium in August 2010, with later updates in December 2010 and January 2011. The tables are located on the CityZen scientific wiki page at https://wiki.met.no/cityzen/page2/emissions_fut

For five main pollutants and 11 SNAP sectors, the Excel tables give ratios in the four selected regions in CityZen, and globally. Examples of how to use these ratios were given in CityZen deliverable report D3.3.1.

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