

## Ultra low emitting vehicles and air quality in urban areas

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### 1 Introduction

Energy saving techniques and clean technologies are already widely used. Energy consumption and pollution due to the industrial and domestic sectors have consequently diminished in most developed nations. By contrast, emissions from land transport are still rising, thus becoming the dominant cause of atmospheric pollution all around the world (Jefferson, 1996). Nowadays, mobile emitters and particularly road traffic, form the most important source of atmospheric emissions in the majority of the densely populated and highly industrialised areas. As a result, air quality standards are often exceeded in a significant number of urban regions, especially during the summer period of the year.

Legislative measures such as the introduction of three-way catalysts for passenger cars and light duty vehicles and several incentives favouring retrofitting of old vehicles resulted in decisive reductions of the NO<sub>x</sub> and VOC emissions. As a consequence, primary pollutant concentrations in ambient air and near 'hot spots' were significantly reduced. However, this reduction did not result into similar benefits in the case of secondary pollutants (e.g. ozone), where the situation is different and more difficult to control (e.g. Moussiopoulos et al., 2000). Previous studies have showed that short-term local scale interventions (i.e. cutting off the circulation of the conventional passenger vehicles or the trucks) may lead to major air quality improvements with regard to NO<sub>x</sub> and other primary pollutants levels, but only to minor changes in peak ozone concentrations (Moussiopoulos et al., 1997).

This paper investigates the impact of advanced engine technology vehicles on urban air pollution levels, the aim being to quantify the additional improvements that could result from the introduction of ultra low emitting vehicles in the fleets of major cities, taking in parallel into account the particular features (orographical, structural and meteorological) of the regions examined.

### 2 Areas selected & case specification

The impact of advanced engine technology vehicles on air pollution levels was analysed in three urban areas with the European Zooming Model system (henceforth EZM; Moussiopoulos, 1995). In particular, wind-flow patterns and pollutant transport and chemical transformation over the densely populated metropolitan areas of Athens (Greece), Tokyo (Japan) and Los Angeles (US) were simulated with the aid of the meteorological model MEMO and the photochemical dispersion model MUSE.

For each of the above regions, model simulations were performed for selected multi-day summer periods characterised by stagnant meteorological conditions (i.e. conditions which favour the occurrence of air pollution episodes). More specifically, simulations for the Greater Athens area (GAA) were carried out for the 3-day period starting on the 24<sup>th</sup> of May, 1990, while the calculations for the so-called Kanto area (which includes the Tokyo metropolis and six surrounding prefectures) were performed for 17-19 of July, 1990. As regards the Los Angeles basin, the summer period of August 27-29, 1987 was selected.

The impact of ultra low emitting vehicles on the urban air pollution levels was investigated by building-up two local-scale emission scenarios for each area examined. These scenarios assume the

fractional and total replacement of the gasoline powered vehicles with vehicles equipped with advanced engine technology ('100% clean fleet' and '50% clean fleet', respectively). The lack of vehicle fleet projection data for both the Kanto and the Los Angeles regions, imposed the need of applying the clean fleet scenarios on top of the base-case corresponding situations (i.e. years 1990 and 1987, respectively). In the case of Athens, however, simulations were performed at two time horizons, namely 1990 and 2004. Consequently, four emission situations were analysed in total: The base-case situation (year 1990), the '2004 reference scenario' which pictures the expected emission situation in the specific year and the 'clean fleet' scenarios that were applied on top of the '2004 reference scenario'. As the results produced so far for the Los Angeles basin are only preliminary, the discussion in the following paragraphs is limited to the Athens and Kanto areas.

### **3 Built-up of emission inventories**

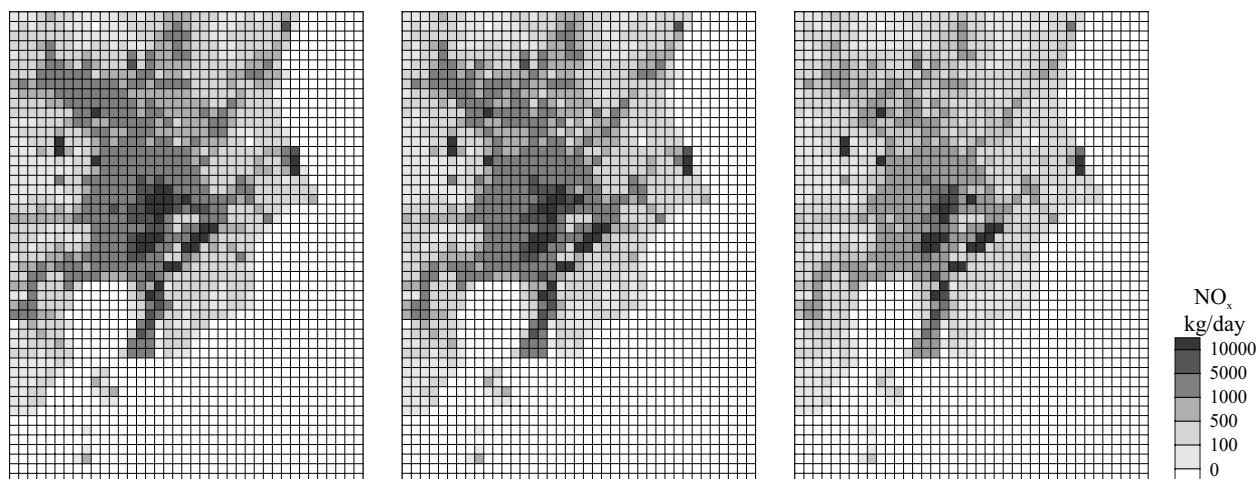
#### *3.1 Base-case emission inventories*

The base-case emission inventories for the three regions examined were constructed on the basis of existing data on the emission situations for the specific years. They comprise of all available NO<sub>x</sub>, CO, SO<sub>2</sub> and VOC emission estimates, the latter being allocated to selected groups of hydrocarbon compounds according to the source categories considered. More specifically, total VOC emissions were subdivided into 43 organic species by applying appropriate splitting factors as these have been proposed by Veldt (EMEP/CORINAIR, 1996) for transport emissions and Middleton et al. (1990) in the case of industrial emitters. The 1990 emission inventory for the GAA was built-up on the basis of available data for the specific year at a temporal and spatial disaggregation level of 1 h and 2 km, respectively. With regard to the Kanto and the Los Angeles regions, the corresponding base-case emission inventories (years 1990 and 1987) were constructed using emission data supplied by the Honda R&D department (Japan) at a temporal and spatial resolution of 1 h and 5 km, respectively.

#### *3.2 Emission projections and clean fleet scenarios*

As already noted, for the GAA an additional emission inventory was constructed for the year 2004 illustrating the expected emission situation in the specific year. The emission inventory for the '2004 reference scenario' takes into account all public works which are currently under construction or are planned to be soon implemented in Athens (i.e. addition of new road axes, operation of the new metro lines, re-allocation of the Athens airport, etc.). Detailed description of the methodology followed for the synthesis of the 2004 emission inventory may be found elsewhere (Moussiopoulos and Papagrighoriou, 1997).

In order to simulate the impact of advanced engine technology on emission levels, appropriate emission factors were applied to the gasoline-powered vehicles (conventional and catalytic passenger cars as well as light duty vehicles) of the vehicle fleets of the areas examined. Average emission factors were provided separately for NO<sub>x</sub>, CO, CH<sub>4</sub> and VOC emissions (the latter were allocated into a number of components) by the Honda R&D department. It is worth mentioning that the resulting reductions in pollutant emissions per vehicle and km driven as compared to the base-case situations exceed 90% for CO, NO<sub>x</sub> and NMVOC emissions in all three regions. It is pointed out that only in the case of Athens the clean fleet scenarios were simulated for a future year. In the remaining areas, ultra low emitting vehicles were introduced to the vehicle fleets of the base-case situations. An illustrative example of the resulting emission inventories for the Kanto region is given in Figure 1.

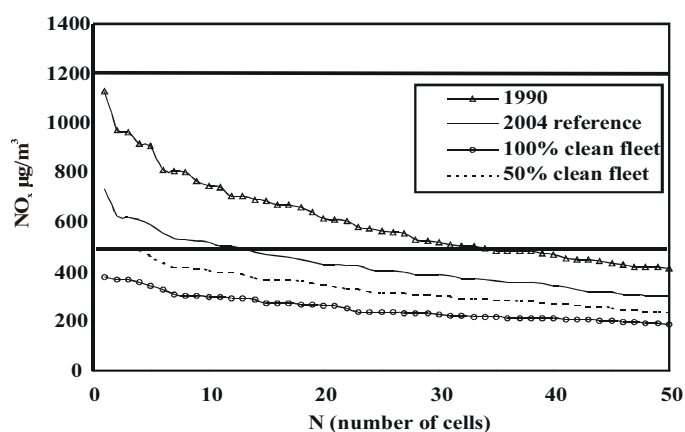


**Figure 1** Spatial distribution of the total daily NO<sub>x</sub> emissions in the Kanto area in 1990 (left part) and according to the 50% and 100% clean fleet scenarios (middle and right parts, respectively) applied on top of the 1990 situation.

## 4 Air quality simulations: Results & discussion

### 4.1 Greater Athens Area

The detailed multi-day photochemical dispersion simulations in the GAA revealed that the impact of advanced engine technology on air quality (100% and 50% clean fleet scenarios) is quite important with regard to both the NO<sub>x</sub> concentrations and the oxidant level of the atmosphere. An example of the air quality change between the different emission situations examined in terms of the 'Top 50' curves for the NO<sub>x</sub> concentration levels in Athens, is shown in Figure 2. For the assessment two sets of target values are defined regarding model results for hourly concentrations (cf. Figure 2; Moussiopoulos and Papagrighoriou, 1997). According to Figure 2 no exceedances of the 'upper' target value are calculated for the years 1990 and 2004. The 'lower' target value is exceeded in more than 30 grid cells during 1990, while for the '2004 reference case' 13 exceedances are recorded. The application of the 'clean fleet' scenarios results in a decisive decrease of NO<sub>x</sub> levels as no exceedances of the 'lower' target value are calculated.

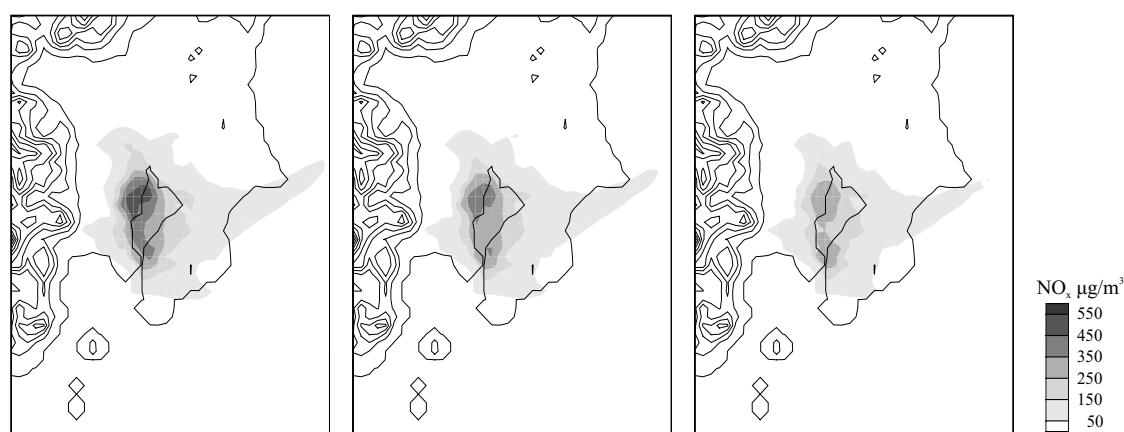


**Figure 2** 'Top 50' curves derived from MUSE results with regard to the hourly NO<sub>x</sub> levels in Athens for the period examined. The upper and lower horizontal lines denote the 'upper' (1200 µg/m<sup>3</sup>) and 'lower' (500 µg/m<sup>3</sup>) target values, respectively.

These local scale interventions do not have, however, a significant impact to the ozone levels in the GAA. Thus, maximum ozone levels remain almost unchanged as compared to the values predicted for the '2004 reference scenario'. The introduction of clean cars in the Athenian fleet has a positive effect on the share of grid cells where exceedances of the ozone threshold value of 180 µg/m<sup>3</sup> were predicted for the '2004 reference scenario'. On the contrary, the decrease of primary pollutants as imposed by the introduction of the so-called 'zero emission vehicles' results to ozone increases over the urban area.

#### 4.2 Kanto area

Figure 3 shows the spatial distribution of the near-ground daily maximum NO<sub>x</sub> concentrations for the Kanto area as resulted by EZM simulations for July 17, 1990, according to the base-case situation (year 1990) and the clean fleet scenarios. As expected, maximum NO<sub>x</sub> levels are reached over the urban and the industrial parts of the region. On the contrary, at the suburban parts of the Kanto area these levels hardly exceed 50 µg/m<sup>3</sup>. The application of the clean fleet scenarios evolves, as expected, in a significant decrease of NO<sub>x</sub> concentrations. More specifically, NO<sub>x</sub> levels decrease by approximately 18% in the case of the '50% clean fleet' scenario as compared to the year 1990. The corresponding value for the total replacement of the gasoline powered vehicles with vehicles equipped with advanced engine technology ('100% clean fleet', cf. right part of Figure 3) is of the order of 37%.

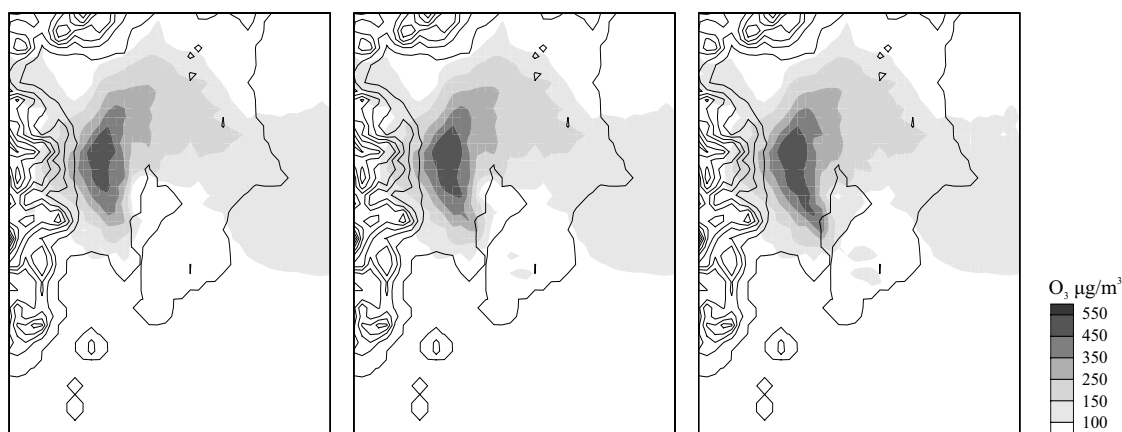


**Figure 3** Spatial distribution of the near-ground daily maximum NO<sub>x</sub> concentrations as resulted by MUSE simulations for the base-case (left part) and the 50% and 100% clean fleet scenarios (middle and right parts, respectively). Altitude isopleths (black solid lines) are contoured at 200 m intervals.

Figure 4 illustrates the near-ground daily maximum ozone concentrations for the Kanto area as resulted by EZM simulations according to the base-case situation (year 1990) and the clean fleet scenarios. In accordance to the findings of previous studies (Wakamatsu et al., 1999), the most seriously affected areas during 1990 (cf. Figure 4 - left) are those at the west part of the Tokyo area. The urban area itself is exempt from serious exposures as the ozone is depleted in the presence of the intense urban NO<sub>x</sub> emissions: thus, maximum ozone concentrations remain below 150 µg/m<sup>3</sup> over the city during the whole day. The application of the clean fleet scenarios does not have a significant influence on the ozone levels. In contrast to the NO<sub>x</sub> results, the drastical decrease of the primary pollutants as imposed by the introduction of practically zero emission vehicles in the car fleet of the region, results to slight ozone increases over the urban parts of the domain.

## 5 Conclusions

The EZM model system was successfully applied in order to investigate the impact of advanced engine technology on urban air quality in three different regions located in Europe, Asia and North America. Preliminary results indicate that the introduction of such technologies in the car fleets is quite important with regard to both the NO<sub>x</sub> concentrations and the oxidant level of the atmosphere. The results produced so far reveal a general reduction of the daily maximum NO<sub>x</sub> concentrations of the order of 35-40%. On the contrary and as expected, the decrease of primary pollutants as imposed by the introduction of the so-called 'zero emission vehicles' either leaves ozone levels unaffected or results to slight ozone increases over the urban areas. In this last case, however, no violations of air quality standards are recorded.



**Figure 4** Spatial distribution of the near-ground daily maximum O<sub>3</sub> concentrations as resulted by EZM simulations for the base-case (left part) and the 50% and 100% clean fleet scenarios (middle and right parts, respectively). Altitude isopleths (black solid lines) are contoured at 200 m intervals.

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