# Executive summary

## 1. General context

This project was carried out at the Centre for Economic & Social Studies of the Environment (CESSE) of the *Université Libre de Bruxelles* and comes under the general heading of the support to decision making for the control of photochemical pollution in urban and suburban areas.

Taking into account the particular nature of tropospheric ozone - secondary pollutant formed from precursors such as nitrogen oxides and volatile organic compounds -, the complexity of the chemical reactions taking part in its formation and its destruction and the number of implied polluting sources, the definition of strategies of control of photochemical pollution is not easy and requires the development of adequate tools which are often difficult to implement.

The measures taken for the control of photochemical pollution are often corrective and relate to the short term. They consist of a reduction in the peaks of pollution by a drastic limitation of the traffic in the urban areas. Measures of long term are currently still slightly developed.

Among the measures likely to improve the long-term situation, the promotion of the electric and hybrid vehicles which only emit very little or no ozone precursors constitute a potential preventive solution.

## 2. Objectives

The main objective of this project is to clarify the definition of strategies of control of photochemical pollution, by specifically analysing a technological-type measure consisting of the introduction of electric or hybrid vehicles into the Brussels-Capital Region.

A more general objective of the undertaken study relates to the development of a tool of support to decision-making likely to help the decision makers in term of control of photochemical pollution. A particular attention was thus carried to the methodological developments necessary to approach these problems seriously.

From this point of view, the undertaken study developed according to an economic section, on the one hand, and an environmental section, on the other hand, in order to be able to compare these two significant aspects of the evaluation of new technologies of transport.

Concerning the economic aspects, taking into account the data available at the moment of this study, only the electric vehicles could be the subject of a detailed economic analysis. Within the framework of this analysis, the costs of implementation specific to the electric vehicles first of all were evaluated and compared with those of their internal combustion counterparts. The costs of implementation of various scenarios of integration of these vehicles in the Brussels-Capital Region were then evaluated.

Within the framework of the environmental analysis, the potential contribution of the electric and hybrid vehicles in the general context of the evolution of road traffic emissions in the Brussels-Capital Region since 1990 is first determined. To this end, the emissions of the electric and hybrid vehicles are first of all compared with those of their internal combustion counterparts. The effects of various scenarios of introduction of these vehicles into the Region are then evaluated in terms of reduction of the atmospheric pollutants emissions. Next, the methodology developed for the evaluation of photochemical pollution and its application for the evaluation of various general strategies of reduction are presented. The potential effects of the introduction of electric vehicles into the Brussels-Capital are also evaluated.

# 3. Analysis of the economic aspects

This part of the study aimed to carry out an economic assessment relating to the use of the electric vehicles within the Brussels-Capital Region.

A first part of this analysis concerns thus the cost-in-use specific to the electric vehicles. These costs, expressed in terms of fixed costs and variable costs, are compared with those relating to the traditional gasoline and diesel vehicles. It is also held account in this part of the influence of the average annual course carried out by the vehicles as well as the influence of the amortisation period. Moreover, one scenario by 2010 is considered. This scenario takes account of the trend of the price of electricity (taking into account the liberalisation of the markets of energy) as well as the trend of the price of the fuels. Finally, various incentive political measures in favour of the electric vehicle are also analysed in this part.

A second part of the economic analysis considers the costs of implementation of various scenarios of introduction of electric vehicles in the Brussels-Capital Region. These scenarios were defined by the team of Professor Maggetto of the VUB.

To finish, a short outline of the obstacles preventing the mass production of electric vehicles was drawn up.

At the end of this analysis, it could be concluded that at the present time, being given the narrowness of the market of the electric vehicles, it is difficult to imagine a massive introduction of this type of propulsion into the Brussels-Capital Region. The absence of mass production of these vehicles, involving purchase prices much too high, remains indeed a major obstacle for any potential buyer of this type of vehicle.

If we compare the cost-in-use per kilometre of an electric vehicle to that of its internal combustion counterparts, the additional cost for the electric vehicle is evaluated at 40%. This of course results from the high purchase price, which lies 70% higher than a similar petrol vehicle and 52% higher than a diesel. On the contrary, if you only consider other items such as insurance, maintenance, taxes and consumption, then the electric vehicle is getting much cheaper than the other propulsion modes. In conclusion, this is even more so, if we analyse the situation with a view on 2010. Indeed, both liberalisation of electricity markets and the expected increase of petrol prices will have favourable effects on electric vehicles use, as far as consumption is concerned.

As a consequence, if the authorities really wish to promote the use of electric vehicles in town, they absolutely have to introduce political incentives. We notably think of possible subsidies by the authorities for electric vehicles buyers, or a reduction of taxes or insurance premiums on this type of vehicle. Those different measures have already been experimented in other countries.

Furthermore, as seen before, the use of electric-driven transport is closely correlated to electrical infrastructure and town planning. Thus this type of propulsion needs to be supported, in its initial phase, by political measures to accelerate the installation of new infrastructures for the recharging terminals. The introduction of electric vehicles also largely depends on the implementation of policies aiming to stimulate new transport concepts. At this stage, different possible scenarios have been taken into consideration.

These scenarios concerned:

- the implementation of a network of stations of automatic hiring of electric vehicles inside the Brussels-Capital Region in complement with the public transport;
- the introduction of x% of the electric vehicles into the fleets of public or private companies;
- the access restriction in certain areas of the city giving a priority for the public transport and the electric vehicles;
- the implementation of goods distribution centres using of the electric vehicles in order to reduce the traffic of the heavy vehicles in the centre town in favour of the electric vans.

The economic analysis of these scenarios shows again that the purchase of electric vehicles is the highest financial burden, at least as far as scenarios such as a hiring network of electric vehicles or a goods distribution network are concerned.

This leads to the conclusion that, if they wish to favour the use of electric vehicles in the Brussels-Capital Region, the authorities first have to focus on smaller-scale scenarios. In fact, scenarios like access restrictions in certain areas in favour of zero emission electric vehicles, or replacement of internal combustion vehicles by electric vehicles in private as well as public captive fleets, seem to be the most financially viable at present. However, the other scenarios should not be excluded right away. They can be taken into consideration later on, insofar the experience generates a favourable return in the very case of the Brussels-Capital Region. The implementation of the two other scenarios will indeed allow us to analyse the behaviour of electric vehicles and recharging terminals users. The consequential analysis of this behaviour will help implementing more efficiently both a network of goods distribution and a network of electric vehicles hiring.

However, our conclusions remain very mitigated as for the eventuality of an expansion of the electric vehicles resulting in mass production. And yet, this mass production is indispensable for the development of this type of propulsion. However, we have seen that there remain many obstacles and that car producers do not benefit of economic incentives to encourage them to go over to mass production of electric vehicles.

To be complete, let us also point out the fact that we have not taken into account here the eventual promotion cost related to electric vehicles. We think of the cost of promotion campaigns aiming to initiate the public and promote these vehicles. Such expenses have of course to be taken into account and are to be added to the other costs evaluated in this part of the study.

# 4. Analysis of the environmental aspects

The analysis carried out within the framework of this project was twofold.

First, it was a question of approaching the problems of the air pollution in a global way by developing a tool allowing the modelling of episodes of photochemical pollution and the evaluation of the related damage. Various general strategies of reduction of precursors emissions thus could be evaluated to allow a better understanding of the situation around Brussels.

Second, the analysis considered a specific measure of introduction of electric vehicles into the Brussels-Capital Region in order to determine its potential benefits from the point of view of the reduction of pollution on the various scales (local, regional and global).

## 4.1 Methodology

With respect to the assessment of the effects of photochemical pollution in terms of its harmful effects on public health, damage to buildings and vegetation and the reduction of agricultural yield, for example, the overall methodology employed has as its basis an assessment of the damage costs. Also known as the ‘impact pathway’ approach, this methodology traces the progress of pollutants from their point of emission to their point of impact by following a series of logical steps.

The assessment of the external effects caused by the transport sector is thus the result of an analysis with four principal stages:

- the assessment of pollutant emissions caused by road traffic;
- the determination of the resulting concentrations of pollutants in the atmosphere (immissions);
- the calculation of the physical damage;
- its expression in financial terms.

The modelling of the "emission-immissions" relationship required a specific approach in the case of the photochemical pollution which requires to resort to deterministic models of pollutant dispersion as well as chemical models able to account for the physical and chemical phenomena leading to the ozone formation.

Use was made of the METHPHOMOD model developed by the numerical modelling group in the Atmospheric & Land Pollution Laboratory of the Lausanne Ecole Polytechnique Fédérale.

The use of this model required the establishment of a register for Belgium covering hourly emissions for a series of 36 pollutants such as methane, carbon monoxide, nitrogen monoxide, nitrogen dioxide and sulphur dioxide as well as 31 types of non-methane volatile organic compounds.

In terms of damage, the approach was limited to short-term effects (episodes) for which exposure-response functions were available. The analysis pays specific attention to repercussions on health in terms of acute mortality and hospital admissions as the result of respiratory problems during periods of photochemical pollution.

To begin with, the methodology enabled a photochemical pollution episode to be modelled. This episode, which occurred on 10$^{th}$ and 11$^{th}$ August 1998, was taken as reference case, and the methodology enabled the damage associated with it to be calculated over a 120 sq. km. zone centred on Brussels. The assessment produced external costs of 2.2 M€, 80% of which were associated with acute mortality.

On the basis of this methodology, various strategies and scenarios could be evaluated in the second part of the analysis.

## 4.2 General strategies of control of photochemical pollution

Within the framework of the evaluation of general strategies of reduction of precursory gas emissions, three scenarios involving the reduction of precursory gas emissions (nitrogen oxides and volatile organic compounds) were analysed. The strategies considered consisted of reducing the total emissions in the Brussels-Capital region in three ways, namely NOx emissions alone by 50%, COV emissions alone by 50%, and NOx and COV emissions together by 50%.

On the basis of this analysis it was not easy to decide univocally on the most efficient strategy to adopt with a view to improving the situation. In fact, as far as the most efficient strategy to reduce photochemical pollution is concerned, different conclusions can be arrived at depending on the criterion selected for assessment purposes and the geographical zone involved.

Whereas the reduction of COV emissions in the Brussels region seems to be the most efficient strategy to reduce the peak values observed in the area, the reduction of NOx is the most efficient approach in terms of decreasing the average values over the 8 hours associated with health effects.

The various scenarios considered all point to increases in ozone concentrations in the major urban areas (Antwerp, Brussels, Gent, Charleroi and Mons-Borinage), a factor which indicates that these areas are saturated in NOx and COV.

In the case of the Brussels-Capital region, the least deleterious strategy, i.e. the one which leads to the lowest increase in the concentrations, is that of reducing COV emissions alone.

In terms of damage to health, only the scenario involving a reduction in NOx emission results in a reduction in the external costs associated with the episode in comparison with the reference case. The two other scenarios result in slight increases (less than 1%) in this damage despite the overall effect of reductions in ozone concentrations.

This is explained by the fact that only damage to health is included in the assessment, and that the greatest increases in photochemical pollution occurs in major urban areas. Since the positive effects of a reduction in the precursors in the Brussels region are felt mainly in rural areas, the incorporation of the long term effects on vegetation and crops might well lead to different conclusions.

## 4.3 Environmental effects associated with the introduction of electric and hybrid vehicles in the Brussels-Capital Region

The general analysis of the environmental aspects which was carried out initially made it possible to highlight the principal advantages which have electric and hybrid technologies.

Two general scenarios of introduction of light vehicles using these technologies made it possible to estimate the reductions of pollutant emissions which can be expected from an introduction of 10% of electric vehicles and hybrid vehicles respectively into the road traffic in the Brussels-Capital Region. This general analysis also made it possible to highlight the potential environmental benefit - reduction of the external costs - which can be expected from a penetration of these technologies. Each % of market share of these technologies would represent an environmental benefit of 5.5 M€ in term of reduction of the annual external costs associated with the local damage. These scenarios also highlight significant reductions in the emissions of greenhouse gases (-5.9% for the electric vehicles and -3,6% for the hybrid vehicles) as well as precursors of tropospheric ozone.

The effects of the implementation of a more voluntarist policy which would lead to a more significant penetration of the electric vehicles in the Brussels-Capital Region thanks to various suitable measures (network of vehicles hiring, access restriction to certain areas for internal combustion vehicles, etc.) were specifically analysed. This scenario considers that the "share of market" of the electric vehicles is 50% in the centre town, 20% in an intermediate zone and 5% in the surrounding area.

While considering the local impacts - i.e. on the level of the Region itself - this scenario led to a 76 M€ decrease in the external costs related to the local damage which are mainly dominated by the effects on mortality associated with the particles.

In term of reduction of the greenhouse gas emissions, this scenario led to a decrease of 8% what corresponds to an environmental benefit of 0.144 M€ in comparison with the reference situation for the year 1998.

This scenario also highlights a rather significant decrease in the emissions of precursors of tropospheric ozone: -7.3% for NOx and –13.4% for the COV. This consists in a global evaluation integrating the direct and indirect emissions associated with this scenario. Taking into account the complexity of the phenomena involved and their non-linearity, this analysis was supplemented by a simulation of the effects of these emission reductions on the photochemical pollution around Brussels.

The results of this simulation show a general decrease in the peak-values (-1.6% on average), in the maximum 8 hours average concentrations (-3.9% on average) characteristic of the effects on health as well as in the 24 hours average concentrations (-4.7% on average) representative of the damage on the crops and the vegetation. In term of health damage, this scenario of massive introduction of electric vehicles leads to a decrease of 1.8% in the external costs associated with the episode for the geographical area under study, that is to say a benefit of 40,000 € (1.6 MBEF). This significant reduction of the externalities on human health is mainly to relate to the positive effect of this scenario on the ozone concentrations in the two main urban

areas which are Antwerp and Brussels contrary with what was observed for the scenarios of general strategy.

Indeed, with regard to the effects of this scenario specifically on the situation in the Brussels-Capital Region, simulations made it possible to show significant reductions in the maximum ozone concentration during the episode and in the maximum 8 hours average concentration. These evolutions lead to damage associated with photochemical pollution estimated at 0.33 M€, which represents a decrease of almost 4% in the external costs in comparison with the reference case.

# 5. Assessment of the economic and environmental aspects

While referring to the scenario of introduction of electric vehicles of which the environmental effects are summarised above, it appears that this scenario makes it possible to improve the general situation with regard to photochemical pollution and led to significant environmental benefit in comparison with the damage caused during an episode. These benefit rise to 40,000 € (1.6 MBEF) for the geographical area considered and 12,355 € (0.5 MBEF) specifically for the Brussels-Capital Region.

As a reminder, within the framework of this study, we focused on only one episode, for a given area and that we considered only the short-term effects on human health. If one multiplies these amounts by the number of episodes or situations where ozone concentrations produce already effects on the population, the environmental benefit of such a measure could be much more significant. The integration of the short-term and long-term effects on crops and the vegetation should also lead to higher amounts.

In comparison with the environmental benefit associated with the local damage, the benefit associated with an improvement of the photochemical pollution is rather limited. For the same scenario, these benefit were quantified to approximately 76 M€ per annum. The benefit related to a reduction of the damage associated with the climate change had been estimated at 0.144 M€.

With regard to the annual costs of implementation of the various scenarios considered in the economic analysis, the economic analysis showed that they range from 0.1 M€ for the access restriction to certain areas of the Region to nearly 130 M€ for the implementation of a network of centres of distribution of goods coming by road exploited to the maximum. The annual costs of implementation of a general scenario integrating the various measures suggested but on a weaker level of exploitation as for them were evaluated with a little more than 70 M€.

To conclude, the reduction of the damage related to photochemical pollution that the introduction of electric vehicles in the Brussels-Capital Region allows does not compensate for with it only the costs of implementation of a voluntarist policy. On the other hand, the taking into account of the other positive effects which are associated with this introduction justifies such an investment mainly if one takes account of the health effects at the local level.