Traffic policy impact assessment: Simulation & Modelling

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Abstract

In a period where environmental issues on local, interlocal and global scale become very important, the relation between transport and environment has to be clarified. Many noxious emissions are indeed caused by transport, particularly in urban areas. Also, in the field of rational use of energy, policy measures have to be defined, due to the finiteness of natural resources.

Within this scope, the use of alternative powered means of transport like electric and hybrid vehicles should be taken into consideration; the efficiency and the feasibility of this option has to be determined. For this purpose a simulation programme has been developed for the Belgian federal government, in order to assess a set of policies in favour of hybrid and electric vehicles. Their impact on energy usage, mobility and pollution are being investigated.

Keywords: city traffic, emissions, environment, EV, simulation

1 Objectives

In a first step a set of measures promoting the introduction of electric (EV) and hybrid (HEV) vehicles, in regard of the specific case of the Brussels Capital Region, is defined.

In the second step the simulation tool is created. It has to be able to implement the possible policies and must give a clear overview of the results allowing the user to make a comparison to interpret the impacts of the different traffic measures, regarding emissions and energy consumption.

Finally a synthesis of all these aspects and a combination of technological and ecological aspects will be presented.

2 Scenarios

It is not sufficient to define a number of stand-alone measures: single measures will only have limited effects. Therefore it is important to implement a comprehensive package of measures through a scenario which synthesises and tunes different aspects of these measures.

The best way to achieve this is by dividing Brussels into three parts:

- *Centre*: The city centre, that contains the main tourist, historical, commercial and administrative areas and which will be the subject of restrictions in various scenarios.
- *Brussels Region*: The area between the inner and outer ring road, roughly equivalent to the remainder of Brussels Capital Region. This area is important for the implementation of car-sharing stations and good distribution centres.
- *Outside*: The area outside the outer ring road. It represents the rest of Belgium and is important because more than 25% of the vehicles in the Brussels Capital Region have their origin in this area. The percentage of lorries having their origin in this area is even bigger.

The scenarios can be divided into different levels to get a clearer overview of the impact of the several policies:

2.1 Level 0: Default scenario

In this first level the current situation in the Brussels Capital Region can be investigated. The data available concern the period between 7.30 and 8.30 AM, which means around 200 000 vehicles on the Brussels' roads.

In general the following subdivision can be made:

Private transport:	88 % cars	8.5 % delivery vans	and	3.5 % trucks
Cars:	26 % diesel	74 % petrol		
		(others are too small in percentage to be taken into account)		
Vans:	69 % diesel	31 % petrol		
		(others are too small in percentage to be taken into account)		
Lorries	100 % diesel			

These values can be tuned according to changes in traffic or according to the wishes of the user (introduction of LPG, CNG, EV, HEV,…).

For this default reference scenario no electric nor hybrid vehicles are taken into account (only a few are currently present).

2.2 Level 1: Introduction of electric and hybrid vehicles

This category indicates the arbitrary introduction of electric and hybrid vehicles without additional measures. The importance of these scenarios is to illustrate direct connection between the number of electric and hybrid vehicles and the decrease of emissions and energy consumption.

The introduction can be done differently in the 3 areas:

	Centre	*Brussels Region*	*Outside*
Electric Vehicles	X_1 %	X_2 %	X_3 %
Hybrid Vehicles	Y_1 %	Y_2 %	Y_3 %
Thermal Vehicles	$100 - (X_1+Y_1)$ %	$100 - (X_2+Y_2)$ %	$100 - (X_3+Y_3)$ %

Table 1 : Introduction of electric and hybrid vehicles

Where $X_1 \rightarrow X_3$ and $Y_1 \rightarrow Y_3$ can be tuned according to the wishes of the user of the software tool or the expectation for the future. It is clear that the penetration of electric vehicles will be bigger in the city centre than outside.

Following figures will be used as indicating values:

X1, Y1, Y2, Y3	$0 \rightarrow 100$	(steps of 10 %)
X2	$0 \rightarrow 60$	(steps of 10 %)
X3	$0 \rightarrow 20$	(steps of 5 %)

This introduction scenario will always be the basic scenario for the policies to be taken. Additional measures, as described in level 2, can be defined to see their influence on situations, defined in this level.

2.3 Level 2: Additional measures

These measures can be taken as stand-alone measures but preferably they are taken in combination with other measures from this level. They always have a base scenario, defined in level 1 and their influence can be derived and compared per base scenario.

2.3.1 Tolls

The aim of this measure is, in the first instance, to discourage traffic (mainly non-ZEV) to the city centre and stimulate them to make use of environment-friendly transport instead. In this case people will have the following options: keep going with their usual car and consequently pay a serious additional cost, change to public transport, or make use of car-sharing. These tolls will be introduced in the centre area and are programmed in the traffic simulation software called TRIPS.

The tolls can be defined in three different ways:

- Parking tolls: these insert extra costs to reach the destination in the city centre. This can be done separately for thermal and other vehicles (e.g. no parking tolls for EV) and also in the form of reserved parking zones for EV.
- Traffic tolls: these are the result of a 'road pricing' policy and introduce extra costs to enter the centre, or the area in the outer ring road (for all traffic or separately for thermal and other vehicles).
- Traffic restriction: this practically means the closing of some city centre areas or roads to all traffic or to non-EV.

2.3.2 Automatic rent-a-car stations and goods distribution centres

A. Automatic rent-a-car stations

This measure implies the development of a network of automatic rent-a-car stations in the Brussels Capital Region with the intention to create a basic structure for car-sharing. This means that centres, where electric vehicles can be rented, will be located near major transport interchanges. In a next stage it's possible to extend this measure with other environment-friendly vehicles and more centres.

The rent-a-car stations are located in strategically important areas: the connection with public transport should be easy and a fast access to the suburb area is necessary; there is also the need of enough parking space.

Car-sharing and public transport complement each other while car-sharing, a system of semi-public transport, maintains the privacy and flexibility of a private car, which are the main advantages of the concept. The reservation of parking space or privileged access to certain areas for the car-sharing vehicles will make the system even more attractive.

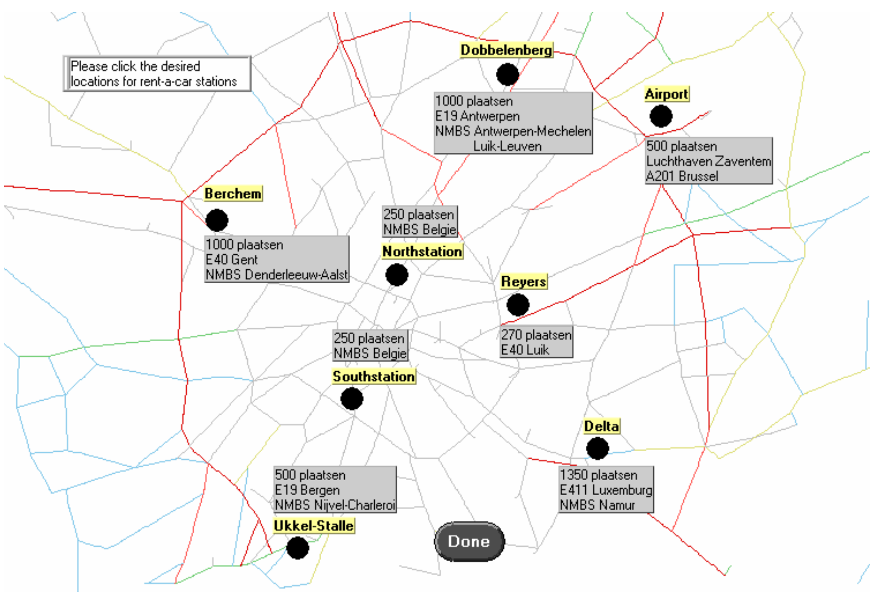

Figure 1: Rent-a-car stations

B. Goods distribution centres

The presence of heavy lorries in the city centre reduces the quality of life and causes many traffic problems. A solution for this problem can be found in the use of electric vans for the distribution of goods in the Brussels Region, replacing lorries from the city streets.
The purpose of this measure is to develop goods distribution centres at the edge of the city. This allows transshipment from lorry to electric van for distribution to the centre. Like this heavy traffic will decrease in the city and will eventually be completely eliminated, environmental pressure and noise will be reduced. The location where these centres will be established is very important and can be done on two levels:

- Near the crossings of the outer ring road and the main approach roads to Brussels, at the edge of the Brussels Capital Region. In this way heavy traffic can not only be removed out of the city centre, but also for a big part out of the area within the outer ring road, which is more or less equal to the whole Brussels Capital Region.
- Some of the distribution centres can be located in the industrial zone within the Capital Region. This area roughly encompasses a north-south belt following the canal. This gives the possibility of intermodal transport of goods - through train stations, the canal and the airport. The opportunity of intermodal transport means undoubtedly a surplus value for these centres.

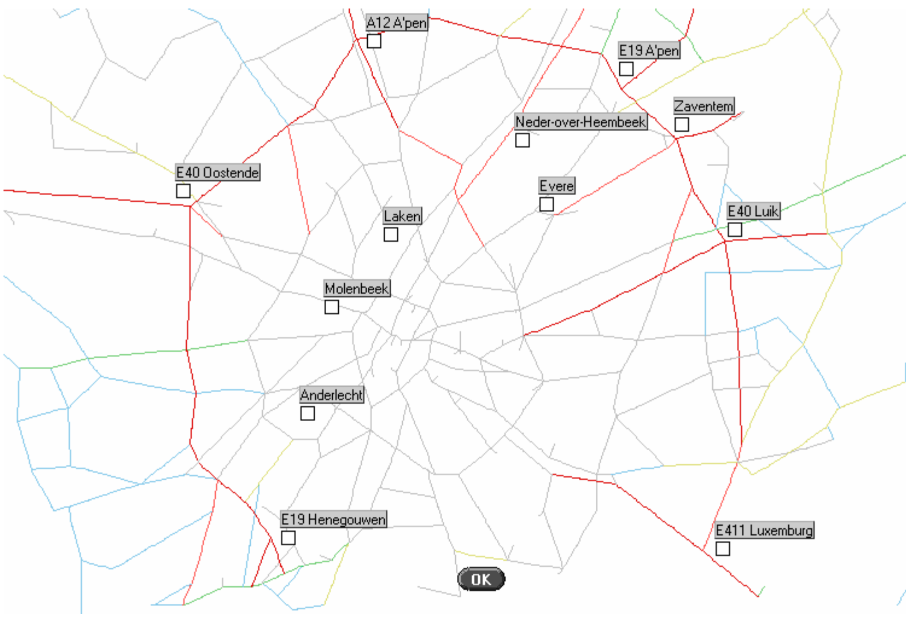

Figure 2 : Goods distribution centres in the Capital Region

2.3.3 Public transport

- Introduction of hybrid buses on different bus lines: by progressively increasing the number of bus lines that are served by hybrid buses, one can study not only the environmental impact of these introductions, but also the performances in comparison with the classic diesel buses.
  This improvement in life quality is best seen in combination with other measures.
- Implementing some of the former scenarios can result in a noticeable increase of the use of public transport and the need to modify some bus, tram or underground lines (adaptation of time schedule, new lines…). This forms part of more situation-specific scenarios and can be considered as a way of fine-tuning the scenarios.

3 Simulation tool

The tool consists of the following components:

- A traffic simulation programme TRIPS;
- A dynamic vehicle simulation programme VSP, which is developed at the Vrije Universiteit Brussel and contains a database of various vehicles (thermal as well as electric and hybrid);
- A database with the static emission factors of COPERT II;
- The previous components are coupled through a user interface SCENARIO, developed at the VUB, and a graphical interface in which the results can be represented.

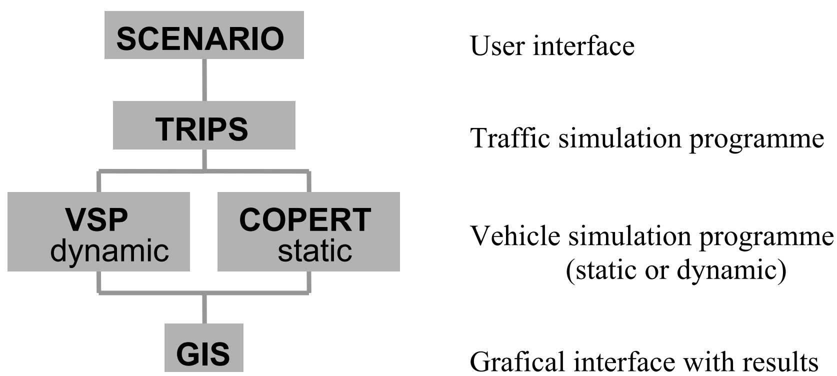

Figure 3 : Overview of the simulation tool

In the module Scenario it's possible to implement the different scenario's of the software. A user-interface was developped which makes it possible to do the required adjustments. This is the only module of the simulation programme where the user has to make adjustments which increases the user-friendliness.

4 Results

4.1 Default scenario

In a first step the default scenario - the current situation - is simulated, all other scenario's will be compared with it. The current situation contains next data and assumptions:

- only thermal vehicles
- number of displacements between 7h30 and 8h30 in the Brussels Capital Region (BCR): 193 586
- number of displacements with origin in the centre: 7009
- number of displacements with destination in the centre: 16 818
- number of displacements with origin outside the Brussels Capital Region: 36854
- average driven distance per displacement: 15.5 km

The total number of displacement in the current situation is visualised in figure 4. Here can be seen that the big ring road and the important access roads have to deal with a lot of vehicles.

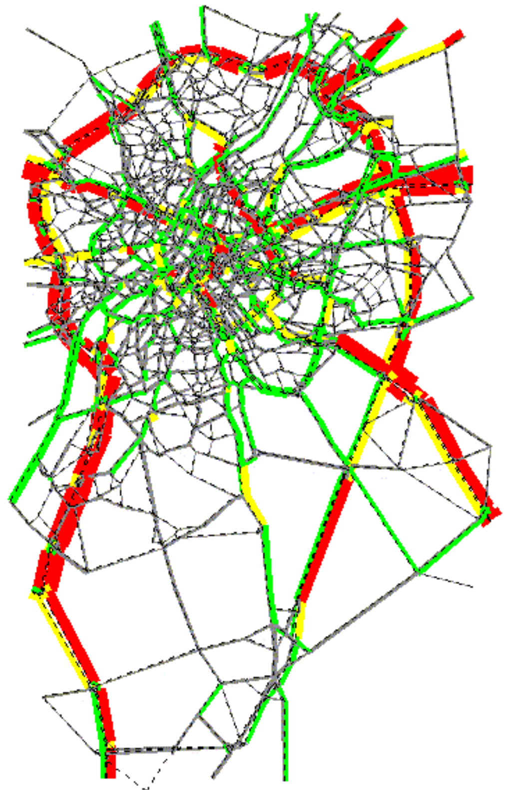

Figure 4: Displacements initial situation

The initial situation causes the following emissions and energy consumption values:

default	*total in BCR*	*average/km*
consumption (l)	169510	0.076

Tabel 2: Consumption default scenario

default	*total in BCR (ton)*	*average/km*
CO_2	622	186
CO	8.4	2.5
HC	1.3	0.4

Tabel 3: Emissions default scenario

4.2 Implemented scenario's

The following scenario's were tested:

default	▪ Current situation, that is 100 % thermal vehicles, no restrictions
EV50-20-5	▪ Penetration of 50% EVs in the centre, 20% between small en big ring road and 5 % outside big ring road
EV50	▪ Penetration of 50% EVs in the centre, 50% between small en big ring road and 50 % outside big ring road
EV50-20-5 RAC	▪ Penetration of 50% EVs in the centre, 20% between small en big ring road and 5 % outside big ring road ▪ Rent-a-car in Berchem, Dobbelenberg and Delta
EV50-20-5 RAC Tol Park	▪ Penetration of 50% EVs in the centre, 20% between small en big ring road and 5 % outside big ring road ▪ Rent-a-car in Berchem, Dobbelenberg and Delta ▪ Toll- and parkingcost of 20% for thermal vehicles, 0% for elektrical vehicles ▪ 10% reserverd parkingspaces for EVs
EV50-20-5 GOOD	▪ Penetration of 50% EVs in the centre, 20% between small en big ring road and 5 % outside big ring road ▪ Goods distribution in Anderlecht, Laken, Molenbeek and Evere
EV50-20-5 GOOD Tol Park	▪ Penetration of 50% EVs in the centre, 20% between small en big ring road and 5 % outside big ring road ▪ Goods distribution in E40 Oostende, A12 Antwerpen, E19 Antwerpen, E411 and E19 Henegouwen ▪ Trucks not allowed in city centre ▪ Toll- and parking cost of 20% for thermal vehicles, 0% for electrical vehicles ▪ 10% reserved parking spaces for EVs

4.3 Results

In table 4 the results are shown percentually per scenario for the direct emissions of the thermal vehicles in the Brussels Capital Region. These figures are during one hour in the morning and only in the Region and the near surrounding.

thermal	*consumption [%]*	*CO_2 [%]*	*CO [%]*	*KWS [%]*
default	100	100	100	100
EV50-20-5	85.7	85.8	85.7	85.4
EV50	51.2	51.2	51.2	51
EV50-20-5 RAC	87.6	87.7	87.2	87.3
EV50-20-5 RAC Tol Park	108.9	108.8	118.3	109.9
EV50-20-5 GOOD	87.3	87.4	87.7	87.0
EV50-20-5 GOOD Tol Park	111.4	111.2	121.6	112.5

Table 4: Consumption and direct emissions of thermal vehicles in BCR

A first logical conclusion is that both consumption and emissions proportionally decrease with the percentage EVs that's been introduced. Replacing fifty percent of the vehicles by electric vehicles consequently results in a reduction of 50% of fuel consumption and direct emissions. In scenario EV50-20-5 the effect is smaller but still 15% less emissions.

When introducing rent-a-car for electric vehicles or goods distribution we notice a decrease. In combination with parking costs and traffic tolls, an increase of consumption and emissions will take place. An explanation can be found in figures 5 and 6: the three centres will attract thermal vehicles so that the roads will be overloaded with emissions.

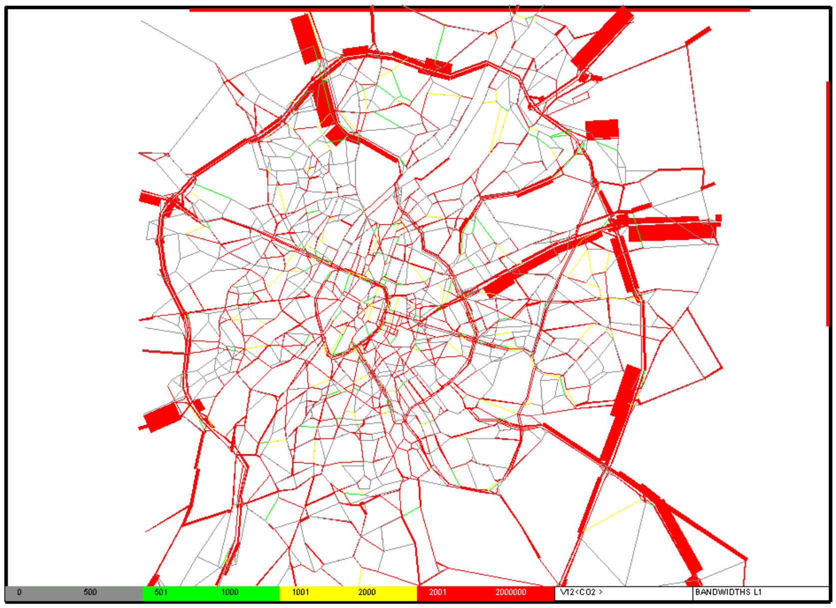

Figure 5: Rent-a-car without toll- and parkingcosts: CO_2

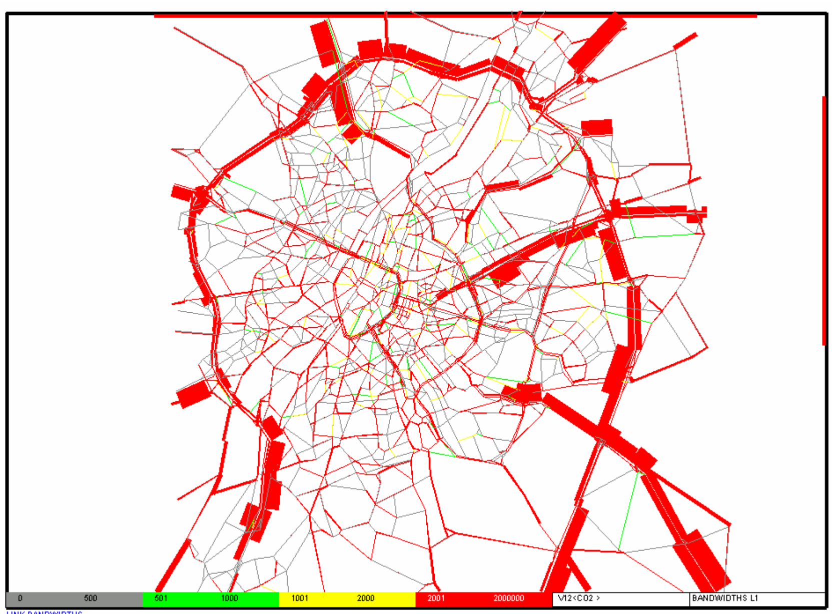

Figure 6: Rent-a-car with toll- and parkingcosts: CO_2

Table 5 give the same results, but this time for the introduced electric vehicles. The pollution is created at the electricity-production and are not emitted in the Brussels air.

EV	*consumption (MWh)*	*CO_2 (ton)*	*CO (ton)*	*HC (ton)*	*NO_x (ton)*	*SO_2 (ton)*	*PM (ton)*
default	0	0	0	0	0	0	0
EV50-20-5	69	8	0,001	0,001	0,02	0,04	0.002
EV50	188	21	0.003	0.002	0.06	0.12	0.006
EV50-20-5 RAC	68	8	0,001	0,001	0,02	0,04	0.002
EV50-20-5 RAC Tol Park	89	10	0,002	0,001	0,03	0,06	0.003
EV50-20-5 GOOD	69	8	0,001	0,001	0,02	0,04	0.002
EV50-20-5 GOOD Tol Park	91	10	0,001	0,001	0,03	0,05	0.002

Table 5: Primary energy consumption and background emissions of electric vehicles in the BCR (global)

The figures are much lower than with thermal vehicles.

To allow a global comparison between scenarios, a visual representation of each emission is given in figure 7. Figures are indexed, the current situation being index 100 for CO_2.

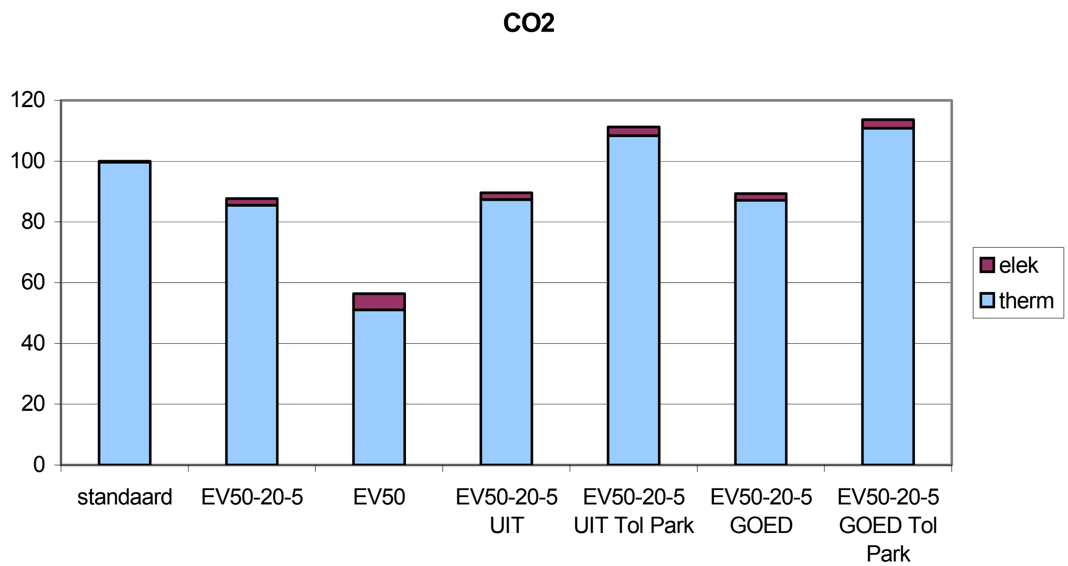

Figure 7: Comparison of scenarios for CO_2-emissions

It is clear that most scenarios yield an improvement, as could be expected. Other emission simulations will lead to the same conclusion.

In this and in the following graphs, one should however take into account that the emissions of thermal vehicles occur in the BCR itself, whereas electricity generation emissions occur at power station level.

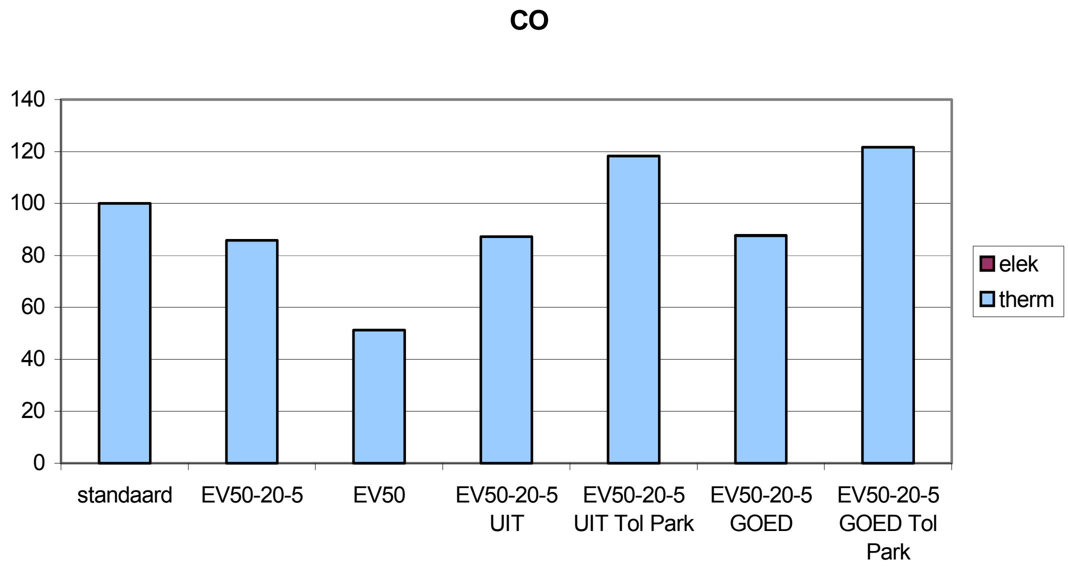

Figure 8: Comparison scenarios for CO-emissions

One particular result is that CO emission through power plants is negligible compared with vehicle exhausts, even invisible in the graph. There must be a full 100% EV penetration to have a significant CO emission from that source, which will however still be a small fraction of the thermal CO emissions.

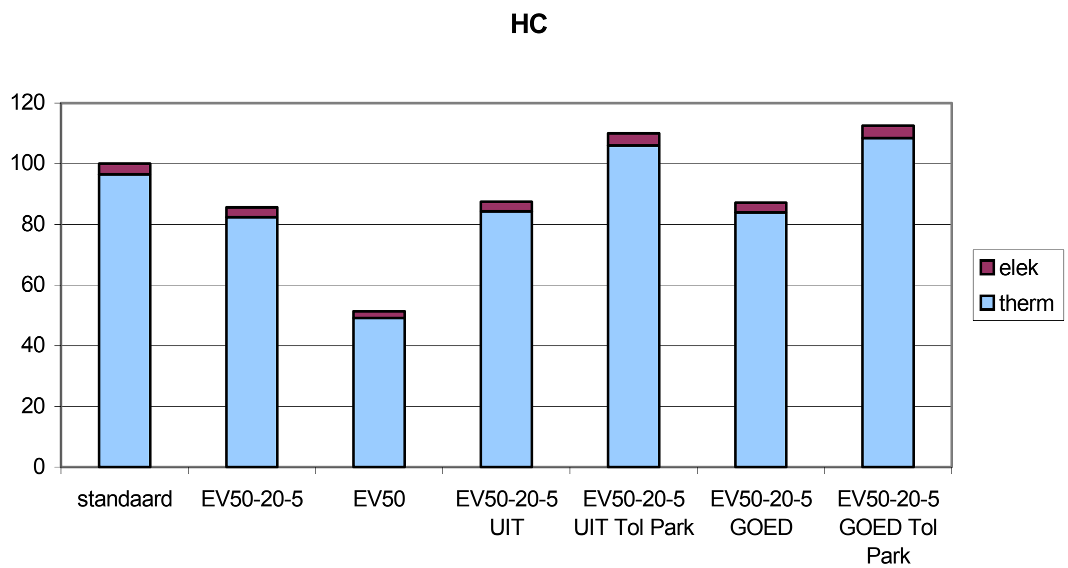

Figure 9: Comparison scenarios for Hydrocarbon emissions

Here also we can see the low hydrocarbon emissions of electric power stations.

The graphs above allow a global conclusion: the introduction of electric vehicles gives an overall improvement for the environment which is proportional to the penetration rate. Particularly concerning CO and HC, the results are very positive.

5 Conclusion

The simulation tool is user-friendly, fast and very flexible: when the data are available, it takes few additional work to implement new cities and new strategies, which makes it available for a wide range of possible studies on cities (or more expanded, countries or more detailed, city areas) regarding the impact of electric and hybrid vehicles on the environmental and energetic level. It is also very simple to add additional forms of alternative vehicles.

About seven scenarios have been proposed and implemented. The results highlight a substantial reduction of both primary energy use and emissions when electric vehicles are deployed in urban traffic.

This study proves that the introduction of electric vehicles creates a positive evolution in the framework of rational use of energy and reduction of emissions, proportional to their rate of penetration. This guarantees an improvement of air quality and an efficient use of energy resources on both local urban level as on global level.

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