HyWays

SECOND PHASE OF THE PROJECT

ENVIRONMENTAL ANALYSIS FOR HYDROGEN DEPLOYMENT
PHASE 1

(DELIVERABLE D3.09)

VERSION NO. 2

FINAL

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Disclaimer

The results in this report are a reflection of a non-final stage of the HyWays project, with substantial stakeholder consultation still under way. Significant modifications are still due, and consequently none of the results given in this report should in any way be considered as final HyWays results.

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Summary

The introduction of hydrogen technologies for mobile and stationary applications has the obvious advantage of reducing end-of-pipe emissions. The effects can be positive both for global and local emissions particularly whenever fuel cell technologies are used.

For CO_2, consistent beyond the already considerable reduction in the HyWays baseline scenario (due to the CO_2 policies assumed) are possible for the transport sector. If hydrogen is produced from fossil fuels, the reduction leans heavily on the application of carbon capture and sequestration. For other global pollutants such as N_2O and CH_4 the reduction of more than 50% is not conditional on the source for H_2, and hence the benefits from the introduction of hydrogen are real.

At local level the benefits are very relevant for the air quality, especially in urban areas, as the use of the hydrogen provides no pollutant emission whenever is processed in fuel cells, while only NO_x emissions are produced in the internal combustion engines and often in very low quantity. Therefore the emissions of local pollutants are considerably lower respect to the baseline scenario and this is very important as the reductions can be evaluated in terms of orders of magnitude.

The emissions have been calculated by means of COPERT III model [1, 2], which is run using the results provided by MARKAL model. COPERT model calculated the emissions of the road transport sector, considering it he one where hydrogen has the largest deployment. This is clearly a simplification, but at this stage some of the input data for the energy production and residential sectors (as especially the hydrogen territorial deployment) cannot be easily provided. In any case this acts in the safe side, as if the hydrogen benefits are consistent looking just to road transport, they will more remarkable if the overall market is considered.

Quite a lot of input data are required to characterize the vehicle information for the entire time frame that is to be considered for HyWays Project. In particular it is important to provide an accurate representation of the vehicle fleet composition from 2000 to 2050. To this end a synergy has been activated with TREMOVE model that provides the information, country by country, on the vehicle fleet composition in a way consistent with COPERT, together with the theoretical information to extend the vehicle fleet forecast to future years**.** This is needed as TREMOVE provides the vehicle fleet forecast only up to 2020. The resulting vehicle fleet forecast is then normalized to MARKAL resulting vehicle fleet size to make the environmental analysis fully coherent with MARKAL outcomes. This is done for the years from 2010 to 2050, while for 2000 MS vehicle statistics have been used.

Two new EURO legislations (V and VI) have been added to cars, with changes on pollutant limits (EURO V) and in fuel consumption for both of them (i.e. as result of Voluntary Agreements between car manufacturers and EC, Kyoto protocol and other possible future initiatives to counteract climate changes). The two new legislations have been considered to start respectively on 2010 and 2015.
For hydrogen vehicles, due to lack of information on specific emissions (i.e. NO_x for ICE vehicles), no pollutant emission has been considered; this assumption is not very critical, considering that for road transport most of the share in the long term is taken by fuel cell vehicles, whose emissions are zero. New limits on fuel content of SO_2 have been introduced starting from 2010

COPERT has been used to calculate, in addition to the reference scenario, the high and low hydrogen penetration scenarios for all the six MS which have been considered in the first phase of HyWays Project. The results show that very consistent environmental effects are achieved under the high penetration scenario, as the pollutant emission reductions are in most of the case higher than 50%. For the low penetration scenario the effects are delayed and reach a lower target in the considered .timeframe. It is important to underline that the pollutant emission reductions are higher

in urban areas where there is a larger population density and this helps to redevelop the livability of such places.

Under the assumption of large use of FCV vehicles the analysis shows also consistent advantages in terms of reduction of conventional fuel consumption and CO_2 emissions at point of use.

The overall reduction effects are calculated including also the emissions provided by trucks and two-wheelers. Such vehicles are not interested to the hydrogen transition and therefore try to make higher the emission level. Therefore the environmental effects could be more relevant if special provisions could be identified for such vehicles (i.e. a portion of trucks could be also converted to hydrogen, etc.).

The document is organized according the following scheme.

Chapter 2 is providing a description of COPERT model and the procedure that has been created to perform the environmental task

Chapter 3 describes the process to feed COPERT model with the data provide by MARKAL and the other sources, and the way to create an equivalence among the different model parameters

Chapter 4 provides the results of COPERT runs for all the six Member States considered under phase I of HyWays project. High and low penetration scenarios have been carried out. The results of the different countries have been also compared each other to see which can have more advantages from hydrogen transition

Chapter 5 provides an indication of open question, i.e. the lack of consideration of trucks in the hydrogen transition

Chapter 6 gives indication on the main lesson learnt, i.e. the need to evaluate environmental results more as order of magnitude than point indications

Chapter 7 gives the main conclusions

The Appendices are describing at very detailed level the equivalence tables among the data provided by the different models and used by COPERT and the procedures to automatically interface such data to COPERT and create the outputs from it.

1. Introduction

One of the main goals related to the use of the hydrogen and its market penetration at European and national level is the improvement of the environment, as very low or zero emissions of noxious and greenhouse gases are associated to this energy carrier, at least at the point of use. Therefore special attention is to be paid to understand which can be the environmental benefits whenever the hydrogen roadmap activities are carried out.

The main effects that could be analysed under the hydrogen environmental task are:

- Reduction of atmospheric pollutant emissions
- Reduction of Green House Gas emissions (GHGs)

The above emissions have effects that are important at different territorial level, as the pollutants act normally at local level (although can have also impact at regional level) creating conditions that endanger the human health together with the flora and fauna of the ecosystem, while GHGs have impact at global level and can be responsible for non-reversible Climate Change effects. It is to be underlined that the hydrogen benefits are very relevant at local level for the air quality, especially in urban areas, as the use of the hydrogen provides zero pollutant emissions at the exhaust whenever is processed in fuel cells, while only few of the pollutants are produced in the direct combustion process and often in very low quantity. The lack of noxious emissions can contribute to redevelop the urban areas, where the traffic effects are very harmful for the people health.

The quantification of the emission benefits is the aim of the environmental task. This analysis can provide a clear idea of the real benefits that can be achieved by the hydrogen deployment and can contribute to take sound decisions on the choices of the most effective options available in the energy market. In order to do this the results of the task are to be evaluated both in absolute and in relative way, comparing them to the baseline scenario. In this way it is easier to understand the improvements that can be achieved and plan the policies and measures that are mostly effective, identifying at the same time the best conditions for their applications.

The environmental analysis is to be carried out taking its main inputs from the energy and economic models used to select the chains and the technologies most suitable for the hydrogen deployment (for HyWays Project MARKAL model) and has to use them to calculate the emissions resulting from the sectors where the hydrogen is used.

In the environmental task an important item to be addressed is related to the fact that the emissions resulting from the use of fuels are not provided at the same time and above all at the same place. It is therefore important that this issue be properly addressed, in order to understand the best possible routes to be followed for a wide scale hydrogen deployment. In addition, provided that data be available, the aim should be to evaluate the emissions from the fuel primary source up to the end-user (or well to wheels for road transport), considering, if possible, the territorial domains where the fuel phases are geographically located. The emission analysis should be organised to address all the phases that interest the fuel life, i.e.:

- Fuel production
- Fuel transport and delivery
- Fuel use

Of course the analysis should address the primary sources and hydrogen chains considered by the different Member States involved in the hydrogen roadmap, under HyWays Project.

Just to give an idea, considering the conventional fuels used in the Transport sector, the localization of the above phases is situated in different geographical areas and their impact is shown in the following table. This means, in terms of emission effects, that it is important to evaluate both the local and global pollutants at urban level, while at regional domain the main interest is on global pollutants. Looking at the table, it is quite evident that the use of conventional fuels is the main responsible of local effects, while all the phases are important for the global effects.

Table 1.1 - Territorial impact of conventional fuel phases

Phase\Domain	**local**	**regional (global)**
Fuel production	typically no	yes
Fuel transport and delivery	low	yes
Fuel use	yes	yes

Of course the same approach has to be applied if, instead of conventional fuels, we consider hydrogen. To reach quantitative figures of the emissions connected to hydrogen economy many parameters are to be considered. In particular, at fuel production phase, the emissions can be calculated from the primary source used to produce hydrogen: to this end it is to be realized that in this phase both the feedstock extraction and the hydrogen production process are included. For the feedstock extraction the typical parameters to be used are the extraction efficiency, the quantity of fuel, the distance from the hydrogen production plant, the means of transport to the processing site, the portion of transport that can interest urban areas, etc. In the hydrogen production plant the information required is related to the process (i.e. steam reforming, partial oxidation, etc. if the fossil is methane), its efficiency, the size of the plant, etc.

For hydrogen transport and delivery attention should be paid to the means of transport to the delivery site (in case the production is not on-site), the average distance, the delivery efficiency, the portion of transport route that can interest urban areas, etc.

Finally, looking at the final use phase, the data required differ substantially in dependence of the sector. As an example, for the transport sector, the methodology used by the European Environmental Agency can be used in order to estimate the emissions at local and regional level. Such methodology considers the information related to the circulating vehicle fleet, subdivided per type of vehicles (passenger cars, light duty vehicles, heavy duty vehicles, mopeds and motorcycles), type of fuel (gasoline, diesel oil, compressed natural gas, liquefied petroleum gas, etc.), age and size or total weight of the vehicles. The information includes the annual average mileage travelled, the share of the domain where travel is carried out (urban or regional domain), the average speed, etc.; other information is related to ambient temperature, which is dependent on seasons, and length of travel (emissions are different whenever the vehicles engines are cold).

The structure of the document is organised in the following way.

Chapter 2 describes the methodology, i.e. COPERT model and the process that has been created to perform the environmental task.

Chapter 3 gives a description on the data that have been used for COPERT model. In particular the way it is interfaced to MARKAL results and the approached followed to create the fleet forecast is described.

Chapter 4 provides the results for each of the Member States included in phase I of HyWays Project for both the high and low penetration scenario. A comparative analysis of the resulting effects has been also provided, allowing to understand in which countries there are the higher benefits from hydrogen deployment.

Chapter 5 is dealing with the open questions, i.e. if some categories of vehicles such as the trucks could be interested by hydrogen deployment

Chapter 6 describes the lesson learnt, in particular that the environmental effects are to be considered mainly as order of magnitude and not as point indications

Chapter 7 gives the main conclusion of the task

The Appendices are instead providing at very detailed level how data required by COPERT at its level of granularity have been made compatible with the data provided by MARKAL, TREMOVE, etc. and the software procedures that have been created to make easier and less prone to mistakes the data transfer process from the different sources and to create the output results from each run

2. Methodological approach

The environmental analysis is mainly based on the results provided by the emission models, which take their main inputs from the energy models and calculate the emissions on the basis of the fuel used. This approach will be followed also for the hydrogen roadmap, where the energy analysis is carried out by MARKAL model which provides the energy demand and supply for all the sectors.

Before extensively describing the methodology selected to carry out the environmental analysis, it is to be given a clear framework of the extent of the work, making clear its main positions.

As first point, considering that the use of hydrogen provides almost no pollutant emissions at the point of use and this happens both for global and local pollutants, the calculations should mainly interest the upstream phases of the hydrogen chains, as soon as a reference scenario has been calculated. But, considering that it is quite straightforward for the energy model to calculate the main global pollutants as they are mostly depending on to the feedstock used for hydrogen production; it has been decided that the environmental analysis task could split in two parts, whose the first one was looking at the global pollutants, while the second could address the local effects and the impact on atmosphere. On the basis of this approach the global pollutants have been provided by MARKAL model.

As second point, considering the larger deployment of hydrogen on the transport sector respect to the residential one and the difficulty to provide a clear representation of the hydrogen territorial deployment in such sector, the main emphasis has been given to the impact of the road transport. From the environmental point of view this decision is not to be considered a rough approximation, a as it acts in a safe direction; in fact, including the benefits provided by hydrogen on the residential sector can just increase the overall benefits to a higher level. In fact, if the benefits provided by hydrogen in the road transport are already enough to justify a large energy market for such carrier, adding the residential and commercial sector can only make the hydrogen more attractive. Therefore leaving out from the environmental analysis the residential sector doesn’t limit too much the overall scope, under the condition that the transport sector gives by itself enough benefits.
This simplified approach has been selected for the Phase I of HyWays Project, as for the residential an commercial sectors the level of detail required on the input data (as especially the hydrogen territorial deployment cannot be easily handled) is not available and not coherent with the one required for road transport. In any case, if data will be provided for such sectors during Phase II, the analysis of them could be taken into account and provide a better approximation of the final results.

On the basis of the above considerations, the natural conclusion is that the present document covers the environmental analysis related to local emissions. The work has been done using COPERT III software to calculate the atmospheric pollutant emissions produced by the road transport sector.
With this in mind, a reference list for the pollutants to be calculated in the task looks at Nitrogen Oxides (NO_x), Carbon Oxide (CO), Particulate Matter (PM), Non Methane Volatile Organic Compounds (NMVOCs), Sulphur Dioxide (SO_2), for the local pollutants. The model, in any case, is able to calculate also the Fuel Consumption (FC) and the pollutants whose effects are global, such as Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O); this allows also to check the results of the energy model, but just looking at the point of use and not to the entire hydrogen chain.
The software program COPERT III, which has been financed by European Environment Agency, in the framework of the activities of the European Topic Centre on Air and Climate Change, is a widely used model to calculate the road transport emissions and has the specific aim to provide support to EU policy in the field of air pollution and climate change. Principally, COPERT is used from the National Experts to estimate emissions from road transport to be included in official

annual national inventories. One from the main advantages of COPERT is that it is available for free use in any research, scientific and academic application. The large use of COPERT implies also that such model is continuously improved in terms of new functionalities, capabilities and removal of possible deficiencies, as consequence of additional requirements asked from model users. Another important feature, related to COPERT use, is that it makes also available very useful data both for its input and result comparison, as for instance AUTOIL Programme (European Commission *et al*., 1999).

COPERT methodology provides the emission estimation on the basis of input data such as the circulating vehicle fleet, subdivided per type of vehicles (passenger cars, light duty vehicles, heavy duty vehicles, mopeds and motorcycles), type of fuel (gasoline, diesel oil, liquefied petroleum gas, etc.), age and size or total weight of the vehicles. The information includes the annual average mileage travelled, the share of the domain where travel is carried out (urban or regional domain), the average speed and the functions of fuel consumption, depending also from season and length of travel (emissions are different whenever the vehicles engines are cold).

For the purpose of COPERT III, a detailed vehicle category splitting has been created. The splitting is function of the engine and after treatment devices, implemented to comply with the emission standards. The main COPERT III categories can be allocated to the UN-ECE classification as follows:

o Passenger Cars	M1;
o Light Duty Vehicles	N1;
o Heavy Duty Vehicles	N2, N3;
o Urban Buses & Coaches	M2, M3;
o Two Wheelers	L1, L2, L3, L4, L5.

COPERT III estimates emissions of all regulated air pollutants (CO, NO_x, VOC, and PM) produced by different vehicle categories (passenger cars, light duty vehicles, heavy duty vehicles, mopeds and motorcycles) as well as CO_2 emissions on the basis of fuel consumption. Furthermore, in COPERT III, the emissions are calculated for an extended list of non regulated pollutants, including CH_4, N_2O, NH_3, SO_2, heavy metals, Poly Aromatic Hydrocarbons (PAHs) and Persistent Organic Pollutants (POPs). Finally, the software of the program provides NMVOC emissions allocated to several individual species. Fuel consumption is also computed.

It is to be stressed that, in any case, the reliability of the results is not at the same level for all the pollutants. This can lead, whenever there are quite a lot of indicators to be analyzed, to a higher difficulty to understand the real benefits of the hydrogen deployment process. Therefore it is convenient to rely just on a subset of the above indicators, i.e. the ones whose calculation is more reliable and for which specific legislations have been enacted. In conclusion, the evaluation of the hydrogen scenarios will be mainly based on the regulated pollutants, together with the fuel consumption and the pollutants which are contributing to greenhouse effects (CH_4, N_2O).

An important item to be considered to make real sound forecasts is the enactment of new legislations on emissions for the future vehicles. This matter is under responsibility of the European Commission which makes specific directives where the new targets on the vehicle emissions are indicated. Presently, the latest targets are the ones contained in EURO IV directive which provides the maximum emission limits to be respected by all the new vehicles sold after 2005, while discussions on new regulations (EURO V) are in progress and probably will end in new limits for 2010. Considering that the emission levels of the new vehicles are already low and the main contribution to urban pollution is mostly provided by the oldest vehicles that are still circulating, it is quite hard that the present trend continue to cut the limits in the long run, especially because can be physically impossible to detect too low quantities of pollutants. Nevertheless this does not mean that no other directives after EURO V will be enacted as there are requirements the vehicles should respect in terms of fuel consumption. In fact, in the Voluntary Agreement between the European

Commission and the different groups of car manufactures (ACEA, JAMA and KAMA), new targets for specific fuel consumption of the new vehicles have been stated, even if in an indirect way. In fact under such agreements the CO_2 emission targets have been specifically addressed.

At the end it is clear that both efficiency and environmental issues should be pursued at the same time, considering that more consumption of conventional fuels implies also higher releases of CO_2 from vehicles, with the result to make harder to meet Kyoto protocol and other future agreements on the reduction of greenhouse gases. To this end it has been anticipated that at least an additional new EURO directive (EURO VI) could be enacted after 2010 whose aim is to take care to reduce fuel consumption and GHG emissions.

The above considerations could be very important to indirectly promote hydrogen vehicles, as they are clean and potentially GHG free (not only at the point of use), increasing their margin of competitiveness.

As presently hydrogen vehicles are not included in COPERT III vehicle categories, some work on the model has been required to take care correctly in the forecasts of the resulting impact of hydrogen vehicles in road transport. The analysis of the hydrogen scenarios can be provided very easily through a post processing model that takes care of the hydrogen vehicles deployed in the country under examination. For the H_2 scenarios the environmental impact is calculated taking away the H_2 vehicles from the total vehicle fleets, running COPERT for the fleets of the remaining conventional vehicles and a specific spreadsheet for H_2 vehicles and, at the end, integrating the results. The hydrogen vehicle spreadsheet could be even not required if their specific pollutant emissions are negligible for all the technologies under consideration. In the other cases it could be very easy to calculate the impact of hydrogen vehicles in terms of pollutant emissions just multiplying the specific emission factors for the hydrogen vehicles and the travelled mileage.

At the end, having as reference the baseline scenario and comparing it with each new hydrogen scenario, the benefits provided by the hydrogen vehicles can be easily seen. As COPERT considers different territorial domains, the results can be observed also for urban areas, where the traffic effects are very negative and this allows additional important insights.

In the following figures 2.1. and 2.2. the schemes used to calculate the emissions are shown, respectively for the reference baseline and for each of the hydrogen scenarios. In both the figures the main input information for COPERT are provided by MARKAL model (vehicle number, traveled mileage, fuel consumption, etc.), while other data are provided by TREMOVE database [3], [4], especially for the data related to the internal composition of the vehicle fleets, and from other sources. Whenever the reference scenario is ready, the hydrogen scenarios can be calculated, merging the results provided by COPERT for the conventional vehicles and from the hydrogen spreadsheet for the hydrogen vehicles.

Some processing of the input information is also required to fit COPERT requirements. In particular MARKAL information is related to aggregated fleets, normally organized in dependence of the fuel used, while, in COPERT, it is required to split such information for all the different types of cars that are considered in the model, looking also at their fuels and technologies. For instance, for the internal combustion engine gasoline cars, the list of technologies that characterise such vehicles is shown in Appendix 1.

One interesting feature of MARKAL model is that its list of road vehicles is mainly depending from their territorial use, while in COPERT the main item is the size of the engine. This makes impossible to transfer directly MARKAL data to COPERT. In Appendix 2 the list of MARKAL vehicle categories is provided, of which not all are really activated for the HyWays analyses. Each category of vehicle, for instance the passenger cars, is selected according to criteria looking at the fuel and the domain where they are mostly used (city, regional, interregional), although the circulation in the other domains is allowed for each vehicle. This means that there are normally three types of different vehicles for each fuel. In any case, the resulting types of MARKAL vehicles are quite less than COPERT. To give an example, looking at gasoline passenger cars, there are just

Fig. 2.1. COPERT procedure for baseline scenario

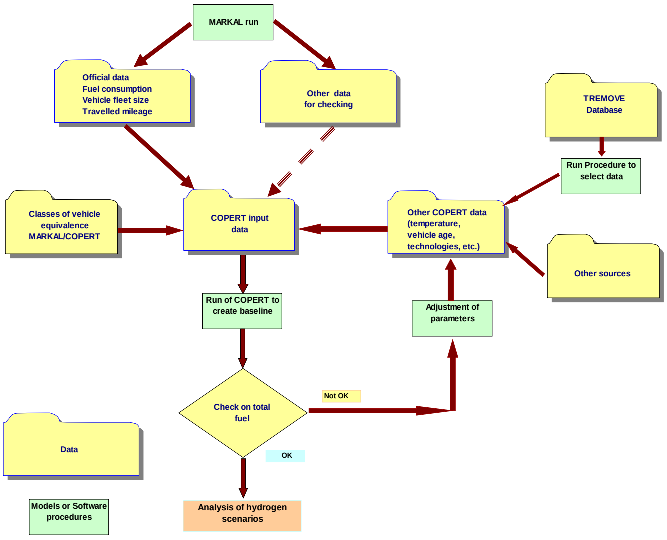
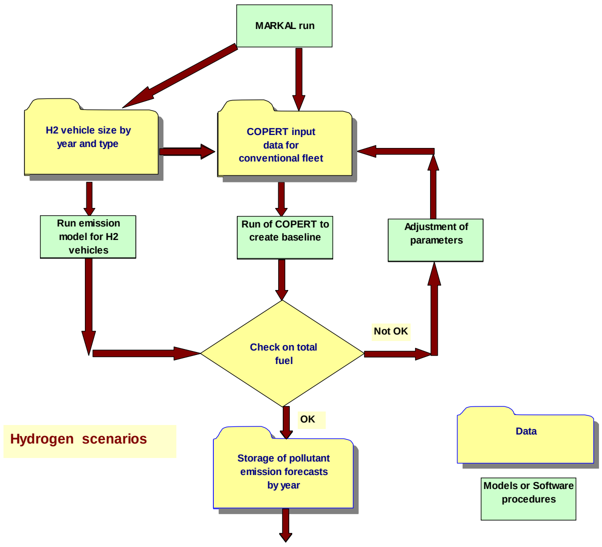


Fig. 2.2. COPERT procedure for hydrogen scenarios



three types of vehicles (gasoline car local, regional and interregional) in the MARKAL list, while a corresponding matrix of (3 x 13) types are to be provided to COPERT III for the same category of vehicles, as the 3 rows correspond to different sizes of vehicles (engines < 1.4L, 1.4 – 2L, > 2L) and the 13 columns to the different technologies that are presently considered in COPERT model. Even this number is in some way underestimated, as in the reality, COPERT requires that the vehicles are also to be characterised in dependence of the domain where they are used (urban, extra-urban, highway). This means that the number of inputs is to be multiplied by three; at the end we need to provide a set of 117 input data to fully describe the three MARKAL vehicle types.

From the above example it is clear that it is not easy to find a general rule that makes possible a correct and effective overlapping between the two schematizations indicated above. Fortunately a simple solution can be given to this issue, as the total number of vehicles for each fuel should be the same for both the schematizations. Starting from this consideration and taking MARKAL as the reference for the vehicle number, it is then possible to use it in COPERT schematization. Therefore COPERT vehicles are constrained to respect such MARKAL figures, while COPERT is keeping the same shares, resulting from TREMOVE database and its extrapolation to 2050.

2.1. Vehicle data

Quite a lot of input data are required to characterize the vehicle information for the entire time frame that is to be considered for HyWays Project. A sound representation of the vehicle fleets and their internal composition is required to get a reliable estimation of the pollutant emissions. At first glance, looking at HyWays time frame and considering that:

- the forecasts are to be provided for each decade from 2000 to 2050;
- at least for the passenger cars there is an average life of about 10 years

we could simply think that after one decade the specific fleet under consideration is completely substituted by new vehicles. But this would lead to very inconsistent results, as the above considerations are to be done in statistical way and therefore after 10 year we have quite a lot of circulating vehicles older than 10 years. It is important to take into consideration these vehicles as they are normally quite polluting and their contribution to the overall emissions is large. To make a very extreme example, if we would have a generation of completely clean vehicles (such the fuel cell hydrogen ones), after 10 years and under the above simplification, we could say that there is not any more pollution provided by road transport. Instead it is clear that the old vehicles present in the fleet give non negligible emissions and only after a much longer time interval the zero pollutant target could be reached. It is therefore important that a quite accurate representation of the vehicle fleet composition be provided for the environmental analysis. Of course, the data required to characterize the vehicle fleets are to be taken from existing reliable data sources. To this end a synergy has been activated with **TREMOVE DB** [4] that provides the information, **country by country**, on the **vehicle fleet composition** in a way consistent with COPERT, together with the theoretical information to extend the vehicle fleet forecast to future years**.** In particular, such forecast model is required, as the data provided by TREMOVE cover only a time span up to 2020, while under HyWays the timeframe is to be extended to 2050. To this end TREMOVE can:

- Provide directly the input data for the involved Member States up to 2020, as the model makes already a forecast up to this year
- Be the basis for the extrapolation up to 2050, as required under HyWays Project

Using TREMOVE database, for each class of vehicles, through the selection of related data (vehicle type, technology and year), it is possible to build the curves of vehicle of the function which implements survival probability to be used to make the fleet forecast. Such function is specific for the different categories of vehicles (passenger cars, LDVs, buses, etc.), is different for each Member State and it is to be determined on the basis of statistical information.

The survival probability trends are held constant during the entire forecast period for all the technologies belonging to the same vehicle category, independently from the fuels used in the vehicles. Some new TREMOVE vehicle types are merged with existing types; in particular hybrid vehicles are put together with corresponding ICE vehicle types, as they are not yet covered in COPERT.

The fleet forecast model includes also a function to generate the new vehicles, which are simply taken from TREMOVE up to 2020 and extrapolated from 2020 and 2050, on the basis of the average increase in the first period of time. Of course the new vehicles are assigned to the last technology (legislation) in force at that specific year.

Starting then from year 2000, applying year by year the survival probability function to the existing vehicles and adding the new ones, the forecast of the fleet composition can be carried out.

Except for year 2000, where statistics are available and COPERT has been constrained to fit them, the total results of the vehicle fleet forecast model for each category are compared with the corresponding MARKAL data and automatically adjusted to them, in order to have the complete consistence with MARKAL. Of course, the share for all the technologies included in each category of vehicles is not changed. In this way it is possible to complete the COPERT input and to calculate the emissions for the years from 2000 to 2050.

This is done both for the baseline scenario and for all the specific hydrogen scenarios to be analyzed under HyWays.

2.2. Equivalence procedure between MARKAL and COPERT structures

One important step of the methodology is the definition of an effective and unambiguous way to use MARKAL forecasts for COPERT input, making both set of data consistent each other. This requires that a correspondence matrix between MARKAL and COPERT be created. This has been done considering vehicle aggregated structures at level of the single categories and fuels. Therefore the sum of all COPERT vehicles are forced to match the MARKAL data, but keeping the same share for all the technologies included in each class of vehicles. The MARKAL-COPERT correspondence matrix is shown in Appendix. 3. In the left side the MARKAL categories are shown and in the right side the equivalent COPERT technologies are listed, so creating the one-way link to assign MARKAL data to COPERT vehicle types.

3. Input data

COPERT needs that an input file is created [2], in order to allow the calculation of pollutant emissions for each MS. The list of the inputs required by COPERT is provided in Appendix 5. It is evident that quite a lot of input data are required for each run of the model. The issue to create all COPERT input data sets is very critical, as for each scenario it is required to create six COPERT input data sets (from 2000 to 2050) per each Member State. This requires a lot of care and time, especially to avoid as much as possible that the data transfer from the original sources can introduce mistakes that potentially burn the quality of the COPERT output results. To this end, where possible, most of the data are transferred through automatic software procedures to COPERT database, but in any cases checks have been carried out before starting the model execution.

Some of the input parameters taken from TREMOVE database have been held constant for the entire HyWays time frame, as there is no reason for instance to change the monthly temperature or stuff like this. Also for the fuel specifications no relevant changes have been considered in addition to what is already provided in COPERT. For all the calculations beyond year 2000 COPERT uses the new year 2005 fuel specifications. The new requirements for SO_2 content in vehicle fuels (10 ppm as maximum content) have also been implemented, starting from 2010 and according with what has been indicated in the specific EC Directive.

One important input is related to the fuel quantities that have been really consumed in each country. In fact, these data are to be used as reference to calibrate COPERT, as the model provides an estimation of the consumed fuels too among its outputs. Comparing the real and the estimated fuel consumptions and acting on some model parameter it is possible to have a complete identity between them. This is an important step to make realistic the results on the pollutant emissions. It is clear that this check has been performed only for 2000, where statistics are fully available. All the adjusted parameters have been held constant for all the other years of the time frame. For the next years the use of MARKAL results on fuel consumption has been used just for comparison, as such calculation is based on a model less detailed than COPERT one. The reference fuel consumption data for year 2000 have been taken from IEA [5], but some work has been required in order to determine the fuel consumed in road transport, as not always all the information was explicitly available.

3.1. Equivalence procedure between MARKAL and COPERT structures

In order to perform the environmental analysis of the hydrogen introduction in the road transport quite a lot of input data for COPERT are coming from MARKAL results. Among them we can insert the number of vehicles, organized in categories and types, the annual traveled mileage, the share of their use in different domains, etc. For others, such as the fuel consumption or CO_2 emissions, the use can be just for comparison as they are also COPERT outputs.

This doesn’t mean that MARKAL information can be automatically transferred to COPERT, as:

- The basic assumptions of the two models are different; therefore a simple association of MARKAL values to the corresponding COPERT structures is normally incorrect, as there is neither a mutual complete overlapping, nor easy formal ways to modify MARKAL data to fit the COPERT schematization for all the structures and the conditions of interest
- MARKAL data for road transport are typically cumulative values, while in COPERT all the technologies belonging to each vehicle category are to be represented in order to get sound results; therefore some processing is required to distribute the MARKAL figures among all the vehicle technologies
- COPERT needs other inputs in addition to MARKAL results, in particular the number of vehicles belonging to the technologies of each specific vehicle category for each

country. Therefore a model, able to determine year by year the relative share of the vehicle technologies in the fleet from 2000 to 2050, is required.

From the above considerations it comes out that the direct association of MARKAL values to correspondent COPERT structures at level of categories and types of vehicles (the technologies required by COPERT are not considered under MARKAL) is incorrect. In addition, no general rule, applicable without changes to the different vehicles and Member States, could be identified to directly associate the MARKAL values to COPERT inputs. Therefore the issue to make COPERT input data consistent with MARKAL forecasts was solved considering the aggregated structures at level of the single categories, independently of the used fuels. According to this the vehicle forecasts indicated in paragraph 3.2 were compared and normalized to the MARKAL results. In this way the sum of all COPERT vehicles are forced to match the MARKAL data, but keeping the same share for all the technologies included in each class of vehicles.

The adjustment was done for all the years considered for HyWays time frame, with the exception of 2000, as in this case the data we have used are statistical data from the real vehicle stock and there was any need of adjustments.

In order to have a better idea of the structures that have been used under COPERT and MARKAL models some information can be found respectively in Appendix 1 and 2. In Appendix 3, instead, a table with a correspondence matrix between MARKAL and COPERT is shown.

3.2 Creation of COPERT vehicle population input

The software procedure, to be used to make the forecasts of vehicle population up to 2050, requires that specific rules are followed, in order to execute it in the correct way and get reliable results from its run. A detailed description of the procedure is shown in Appendix 6.

The steps of the procedure are:

1. Activation of the ACCESS procedure to create COPERT vehicle population
2. Import of the cumulative vehicle number provided for HyWays time frame by MARKAL outputs
3. Import in the procedure of the reference COPERT database (typically built for year 2000) for the Member State scenario under examination, in order to create new input files that are fully compatible with COPERT and in principle can be run by it without any additional modification
4. Run of the ACCESS procedure, selecting the Member State and the specific functions to be performed (the procedure is also based on specific correspondence matrixes between TREMOVE and COPERT structures). At the end of the run the procedure provides two sets of files, of which the first one is just the forecast from TREMOVE data, while the second one is normalized to MARKAL results. Each file is, as previously said, a complete input dataset for COPERT
5. Storage of the output files in the proper archives in order to proceed with COPERT analyses

Without going in detail it is important to give some information on the procedure that has been used to extrapolate the vehicle data, starting from TREMOVE forecasts, whose details are reported in Appendix 7. In particular, the procedure is based, for each category of vehicles, on the function that provides the probability that a new vehicle be working after n years from the year it was sold. This function, which has been named “**Survival probability function**”, is necessary to allow to extend the forecasts after the year 2020 up to the year 2050, which is the time target of HyWays Project. As it has been checked that in TREMOVE forecasts this function is the same for all the types of vehicles inside the same category (for instance the passenger cars) independently of the fuel, the calculation has been done for HyWays just considering one of such types.

This can be done looking at TREMOVE database starting with the new vehicles sold at 2000, which are 1 year old at 2001, two years old at year 2002, etc. up to 2020. In fact, such vehicles are the old vehicles surviving after n years, i.e. the data we need to build the survival probability function. Of course normalizing such values respect to the number of vehicles at year 2000, the resulting curves can be used as an indicator of the survival probability function, which gives the probability that one vehicle is working after n years. As in many cases the survival probability is not close to zero at year 2020, a simple algorithm to extend the function for the vehicles having more than 20 years of age, has also been implemented. The survival probability trends are different for the different categories of vehicles (passenger cars, LDVs, buses, etc.) and are held constant for all the forecast time frame and for all the technologies belonging to the same vehicle category. Such functions are specific for each Member State and have therefore been recalculated for each of them.

The survival probability functions for the different Member States are shown figure 3.1.1-3.1.6 for different categories of vehicles. It is to be underlined that normally some curves are superimposed each other; this happens in particular for Buses and Heavy and Light Duty Vehicles. In the case of the Greece the curves are superimposed for all the vehicle categories for all the vehicles, except passenger cars. In particular such curves show that the survival probability function remains close to one even after a considerable number of years; this means that the average age of all the fleets are quite high compared to the other MS. This has required an additional check of the curve behavior with new data provided by the Greek representative, which have led to an important modification of the passenger car survival probability that, in the present version, is more similar to the one of the other countries.

In all the other MS the passenger cars show curves that generally go to zero faster than the other vehicles and this confirms that the renewal of the fleet of such vehicle fleets less time respect to the other road vehicles.

As it can be noticed the trend of curves has normally a change of slope after the age of 20 years. This happens because the long term values have been extrapolated using the above simplified algorithm; in any case this avoids that too old vehicles (with 40 years or more) are included in the analyses and to determine results that are quite inconsistent.

Knowing the behaviour of the old vehicles is not enough to make the forecast of the vehicle fleet, as also the number of the new vehicles sold after 2020 is required. For this task a simple forecast function has been used, considering the increase of vehicles over a time span from 2015 to 2020 and calculating the yearly average increase. This increment is then constantly added year by year to the new vehicles sold on 2020 and beyond to make an estimation of the new vehicles for the following years. Even if the approach is quite simple this doesn’t lead to any mismatch with the other model as the size of the different vehicle fleets are normalized to the MARKAL forecasts and this avoids any global inconsistency.

The new vehicles are then assigned to the legislation in force at the specific year (for instance, considering passenger cars, EURO V for new vehicles sold up to 2015 and EURO VI for all the other years). With the above positions all the information required to proceed for the forecast is available, with the only additional feature that, in order to avoid to excessively increase the database size, the vehicles older than 20 years are grouped together in one age item (of course if they are belonging to the same subset type). In fact at a certain year the fleet composition is given by the new vehicles and the portion of the ones sold in the previous years still working. Such contribution is easily computable considering just the new vehicles sold n years before and multiplying them for the corresponding value of the survival probability function after n years.

After the completion of the extrapolation, as COPERT does not distinguish the vehicles of different ages but belonging to the same technology, a sum of such homogeneous contributions is required. All these functionalities have been implemented in the ACCESS procedure

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Figure 3.2.1

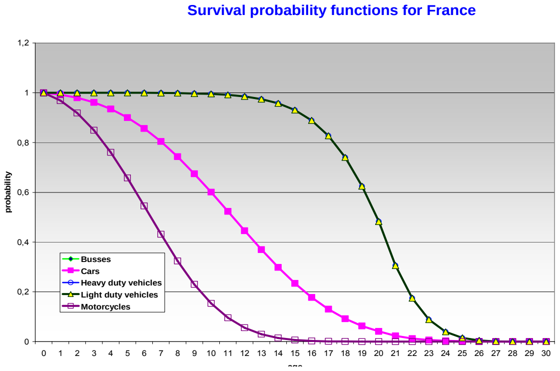


Figure 3.2.2

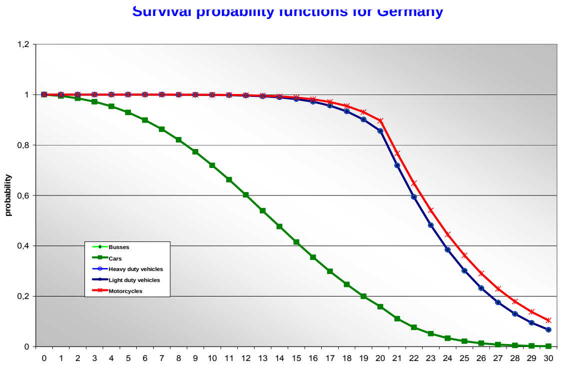


Figure 3.2.3

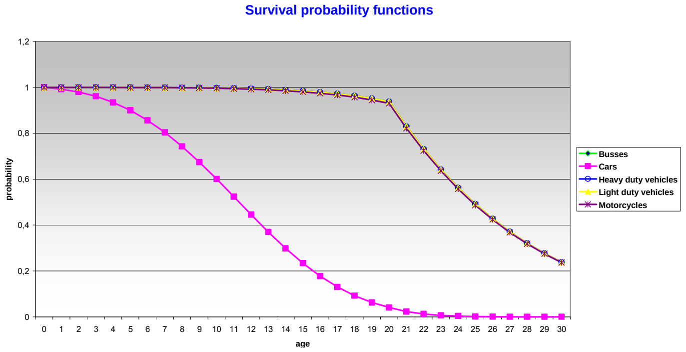


Figure 3.2.4

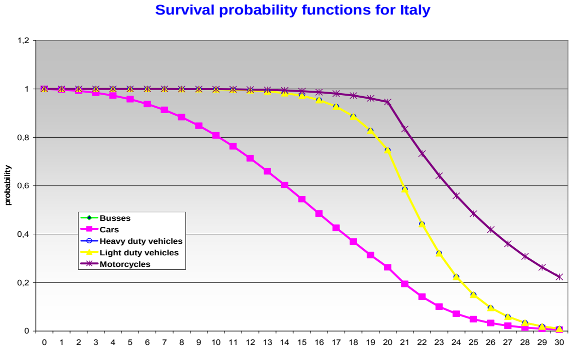


Figure 3.2.5

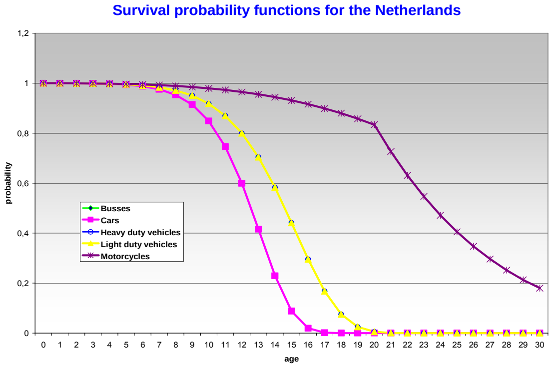
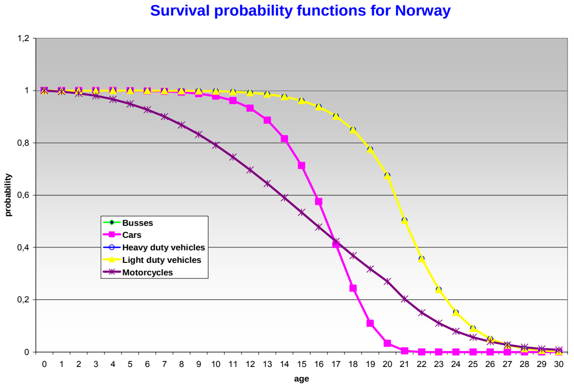


Figure 3.2.6



3.3 Other model inputs

As shown in Appendix 5, quite a lot of input data are required for COPERT. Most of the input parameters have been directly taken from TREMOVE database and held constant for all HyWays time frame, as there is no reason for instance to change the monthly temperature or stuff like this. Also for the fuel specifications no relevant changes have been considered in addition to what was already provided in COPERT. In fact, COPERT has already the possibility to consider the new fuel specification for year 2005, which have been used for the calculations related to 2010 and beyond.
The main change that has been adopted from ENEA is the implementation of the new requirements for SO_2 content in the conventional vehicle fuels. This has been activated from 2010, according with what has been indicated in the specific EC Directive. This has required some care, in order to build the COPERT input data set for the years from 2010 to 2050.

Important inputs are the annual mileage traveled by the different vehicles and the speed and share they are traveling in the different domains considered in the model (urban, rural, highway). For the first kind of information the MARKAL indications [8] have been taken as reference, distributing them among the different technologies in an uneven way, but trying to have an average mileage similar to the MARKAL one. The main criterion that has been adopted is to reduce the mileage for the old vehicles and to increase it for the new ones. Some adjusting of the mileages has been required in order to fit the overall national fuel consumptions. For the vehicle travel share in the different domains MARKAL data have been taken for passenger cars, while specific considerations have been followed for the other vehicle categories (for instance trucks are mostly traveling in highways, while LDVs are more used in urban areas, etc.). Vehicle speed has been provided, looking to passenger cars, whose speed has been set to 20, 60 and 110 km/h respectively in urban, extra-urban and highways and then adjusting the speed for the other vehicles (i.e. urban buses, due to stops have a lower speed of 18 km/h and so on).

One important input is related to the fuel quantities that have been really consumed in each country. In fact, these data can be used as reference to calibrate COPERT, as the model provides among its outputs also an estimation of the consumed fuels. Comparing the real and the estimated fuel consumptions and acting on some parameters it is possible to have a complete equivalence between them and, whenever this condition is satisfied, this makes more realistic the results on the pollutant emissions. It is clear that this check has been performed only for 2000, where statistics are available. All the adjusted parameters have been held constant for all the other years for which the forecasts are required.

The reference fuel consumption data have been taken from IEA [5], but some work has been required in order to determine the fuel consumed in road transport, as not always such information is explicitly available. In the Table 3.1 the statistical data for road transport fuel consumptions related to 2000 are shown.

Table. 3.1. Reference fuel consumptions for HyWays Member States (10^3 tons)

Transport, Motor Gasoline, DATA FOR YEAR 2000	MS	transport, Gas/Diesel Oil, DATA FOR YEAR 2000
28581	DE	25805
13894	FR	27539
3230	GR	1890
16678	IT	17137
4031	NL	4721
1598	NO	1308

Source Table 1 from “OIL INFORMATION 2002” [5]

3.4. Main assumption/positions for COPERT inputs

At the end, for the use of the model, the following assumptions/positions have been made for COPERT analysis:

- The main model outputs considered for the environmental analysis are based on the regulated pollutants, together with the fuel consumption and the pollutants which are contributing to greenhouse effects (CH_4, N_2O).
- For the reference year (2000) COPERT has been made consistent with country statistics related to road transport fuel consumption and vehicle fleets

- COPERT total population of the different vehicle categories is forced to fit the results provided by MARKAL outputs for the years from 2010 to 2050, while for 2000 MS statistics are used (from TREMOVE DB) as starting data
- Two new EURO legislations (V and VI) have been considered in the model (through direct modification of the ACCESS database), with changes on pollutant limits (EURO V) and in fuel consumption for both of them (i.e. as result of Voluntary Agreements between car manufacturers and EC, Kyoto protocol and other possible future initiatives to counteract climate changes). The two new legislations will be enacted respectively on 2010 and 2015.
- The effect on CO_2 specific emissions for new passenger cars, considering the above fuel consumption reductions, is leading to average emission values respectively of 145 g/km and 120 g/km from an initial level of 172 g/km. Such data should be representative of the real circulation cycles, while presently the vehicle performance indicators are determined looking at reference cycles, where the resulting fuel consumption is considerably lower.
- For hydrogen, due to lack of information on specific emissions (i.e. NO_x for ICE vehicles), no pollutant emission has been considered; this assumption is not very critical, considering that for road transport most of the share is taken by fuel cell vehicles, whose emissions are zero. In case specific emissions are available the calculation of the hydrogen contribution is easy and fast.
- New limits on fuel content of SO_2 have been introduced starting from 2010

4. Results

The outcome of each COPERT run provides a lot of information on emissions, but they need to be processed in some way before the analysis activity can be started. In fact, even if COPERT has its own structures to document the results of the calculation, it is not very efficient and safe to use these facilities due to the special HyWays needs. It can be easily understood that the problem is not the consequence of a bad design of COPERT documenting characteristics. In fact, COPERT documentation features have the aim to address different targets,. i.e. mainly to evaluate the yearly emission inventory through single runs of the model, and they were developed accordingly, To this end COPERT shows only the data of its internal ACCESS database which are belonging to the vehicle categories effectively present in the vehicle population. This leads to documents whose structure can be very different in dependence of which categories of vehicles that are present at that time in the database. In our case, due to the long timeframe and the different starting conditions of the countries, it is quite obvious that the COPERT output reports could be very different during the entire HyWays time frame. This would make almost impossible to create some procedures for documentation that can:

- Fit the need to provide automatically tables and figures, saving in this way a lot of time, especially if more and more scenarios have to be analyzed. It is useful to give a rough idea of how many cases have to be run. Considering that there are at least six COPERT calculations per each scenario, at minimum 3 scenarios per MS, six MS involved just in the first phase and more than one application run per MS, it is clear that hundreds of runs are expected. This implies that without any automatic procedure the environmental task would become very hard.
- Give the chance to reach some optimized and similar structure for all the resulting documents,
- Make easier the analysis process, as a huge documentation requires more time to find sound and effective conclusions
- Create a documentation scheme able to fit the needs of the different MS and to allow easy comparisons among both the different scenarios and the their integration where required

Therefore some additional work has been required, in order to select which tables of COPERT ACCESS file have to be exported at the end of each run as EXCEL. As under the ACCESS file all the vehicle technologies declared in COPERT are considered (even if there is no vehicle for some of them), in this way all the resulting EXCEL files have the same size and can be processed automatically. The only drawback is that the export phase is to be made manually, but this allows to have a first check on the results. In any case, such procedure allows each MS to be analyzed in a similar way and with a full integrability of the specific results. In this way there is also the chance to evaluate the relative environmental impact among the different countries.

The present document will just cover the results achieved during the second HyWays run, as they are of course replacing the ones of the first run [6] and addressing most of the issues that have been identified during the discussions of them. For each MS the scenarios to be analyzed are the reference scenario and the specific hydrogen scenarios (the high and low hydrogen penetration scenarios). In particular, looking at the sources of information most of the input data are provided by MARKAL run 6.4 and TREMOVE Version 2.32b [4].

The reference scenario is shown looking at the absolute values for the selected indicators, while for the hydrogen scenarios a relative comparison with the reference scenario is provided to make easier the understanding of the potential benefits of the hydrogen deployment.

At the end of the chapter a comparative analysis among the outcomes of all the MS is also made. For the SO_2, due to the already very low emission level, in dependence of the improvement of the conventional fuels, the comparison with the hydrogen scenario is not provided, as the emission level achieved in the reference scenario is already very low and no additional need of reduction is required. Besides, as the resulting SO_2 value is just proportional to the conventional fuel consumed, the calculation is quite straightforward and immediate.

4.1 MARKAL outputs

The 6.4 MARKAL results for road transport fuel consumption are shown in the following figures related to the basecase, the High Hydrogen penetration (H2H) and Low hydrogen penetration (H2L) scenarios. They show the fuel consumption for the MS participating to the first phase of the HyWays Project and are a reference for comparisons with COPERT outputs.

4.1.1 Baseline

MARKAL outputs show that the trend of fuel consumption in all the MS is increasing, even if there are upper bounds for passenger cars, because the other vehicles are in any case increasing, together with the transport demand. The trend of the six MS is shown in the following figures (from Fig. 4.1.1.1 to 4.1.1.6)

Fig. 4.1.1.1 France fuel consumption

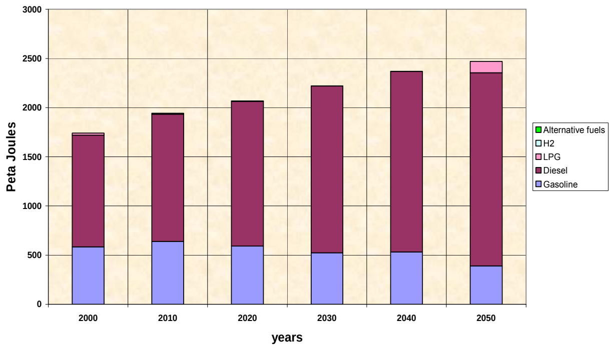


Fig. 4.1.1.2 Germany fuel consumption

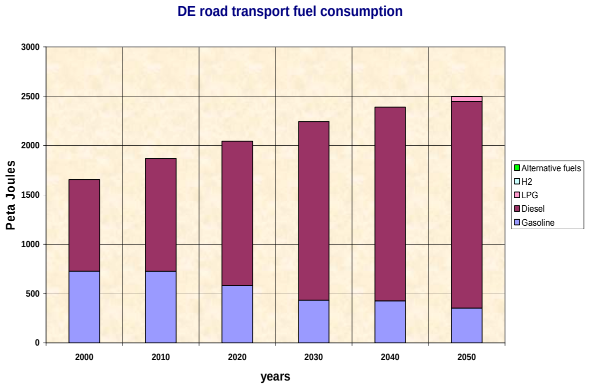


Fig. 4.1.1.3 Greece fuel consumption

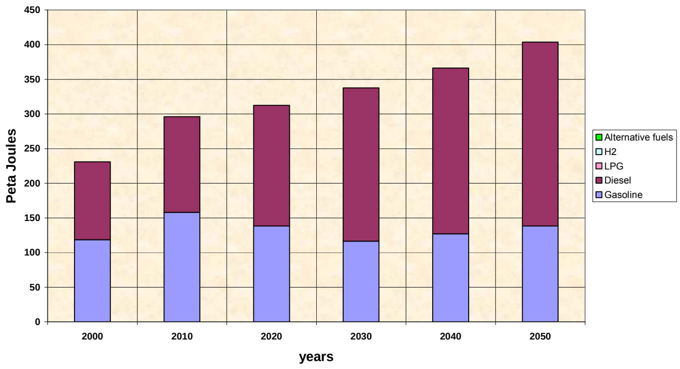


Fig. 4.1.1.4 Italy fuel consumption

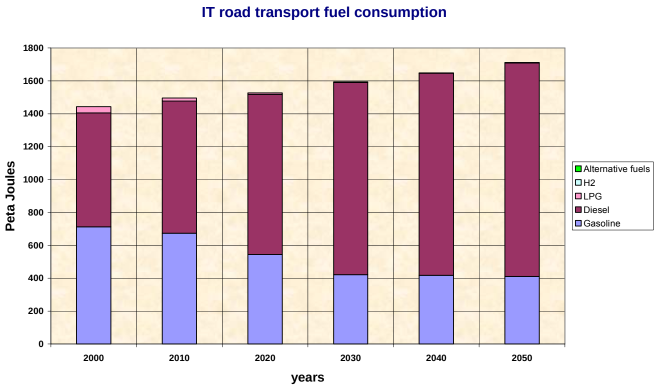


Fig. 4.1.1.5 The Netherlands fuel consumption

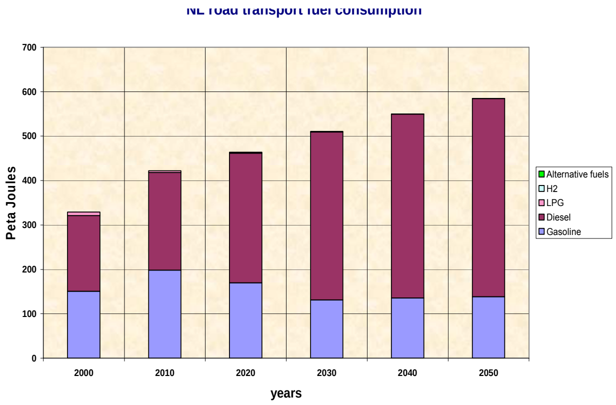
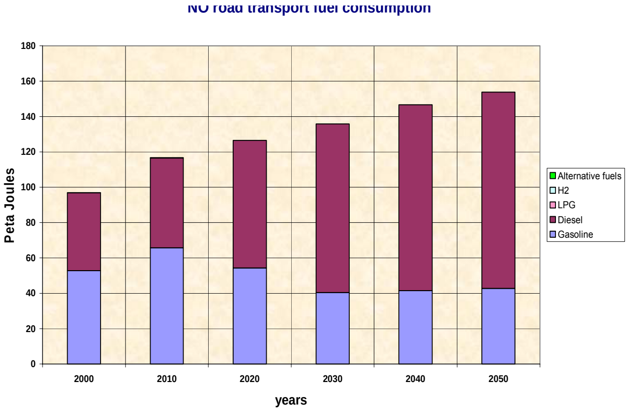


Fig. 4.1.1.6 Norway fuel consumption



4.1.2 Hydrogen High penetration scenario

The hydrogen introduction in the road transport, even if limited to a few categories of vehicles, has some significant effects in reducing the energy consumed in this specific sector, as can be seen in the following figures (from Fig. 4.1.2.1 to 4.1.2.6). The effect is more evident in the countries where there is higher share of hydrogen vehicles, but can be estimated as an average of about 20%. It is important to underline that these figures are to be considered just covering the Tank to Wheel portion of the complete energy chain and therefore do not assure an overall energy saving looking at the full chains, although such figures can give a reasonable possibility to achieve real energy savings. Another interesting consideration is that the consumption of conventional fuels is about 50% of the reference scenario. As conventional fuels are directly tied to fossil resources, while hydrogen can be produced by any source and in particular from renewables, this could imply a considerable reduction of the fossil fuels in the transport, potentially increasing the life expectancy of fossil fuel reserves.

Fig. 4.1.2.1 France fuel consumption

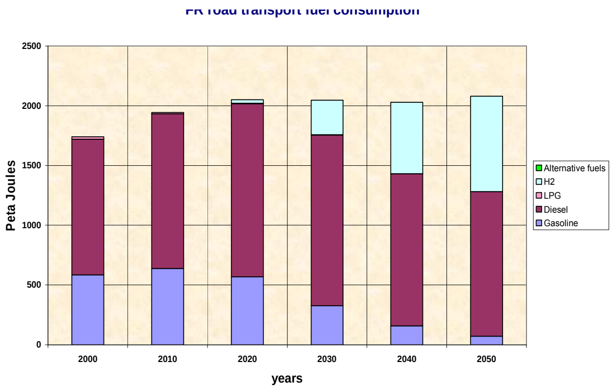


Fig. 4.1.2.3 Greece fuel consumption

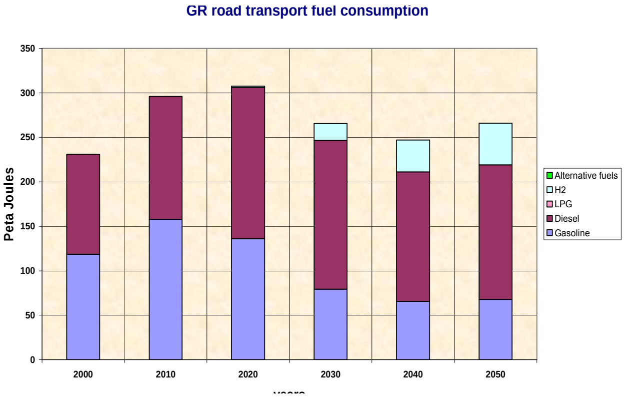


Fig. 4.1.2.2 Germany fuel consumption

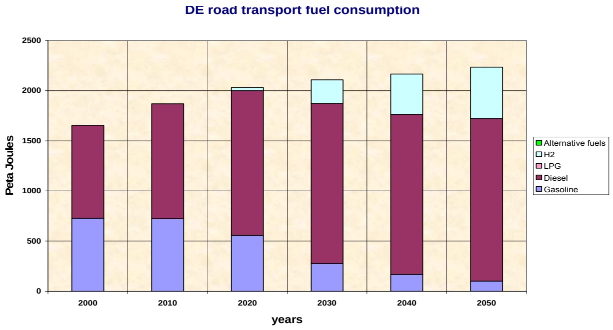


Fig. 4.1.2.4 Italy fuel consumption

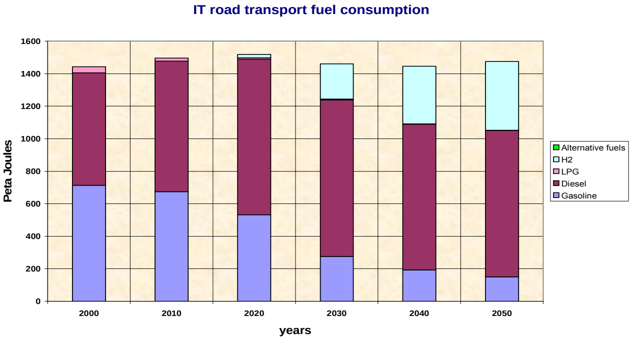


Fig. 4.1.2.5 The Netherlands fuel consumption

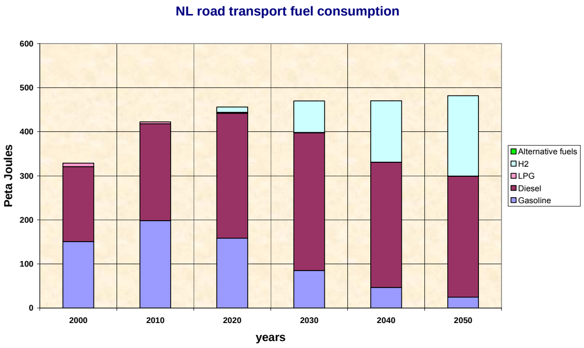
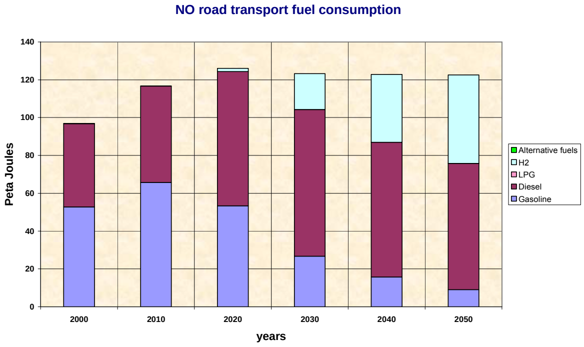


Fig. 4.1.2.6 The Norway fuel consumption



4.1.3 Hydrogen Low penetration scenario

The hydrogen introduction in the road transport, looking at the low penetration scenario, has less significant effects in reducing the energy consumed in such sector, as can be seen in the following figures (from Fig. 4.1.3.1 to 4.1.3.6). There is higher spread in the share of hydrogen consumption among the different MS, probably due to less integration of the markets, as there is a significant delay respect to the high penetration scenario.

Fig. 4.1.3.1 France fuel consumption

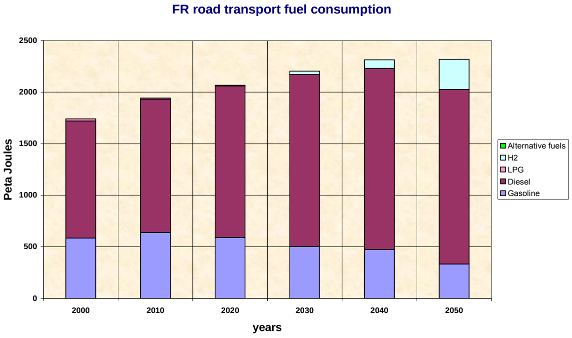


Fig. 4.1.3.4 Italy fuel consumption

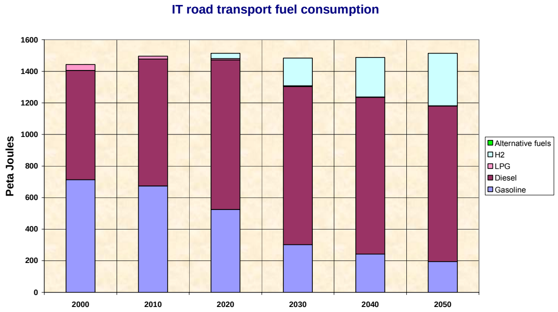


Fig. 4.1.3.2 Germany fuel consumption

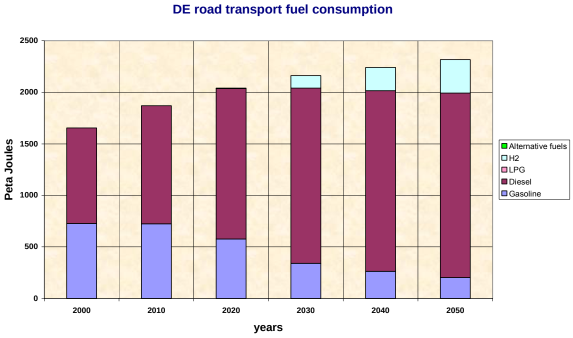


Fig. 4.1.3.5 The Netherlands fuel consumption

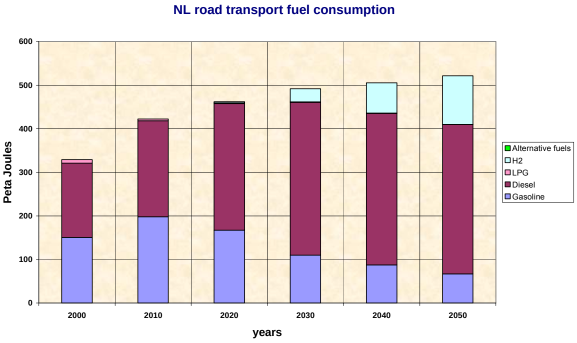


Fig. 4.1.3.3 Greece fuel consumption

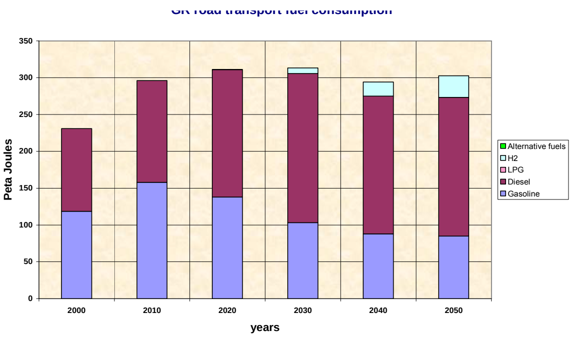
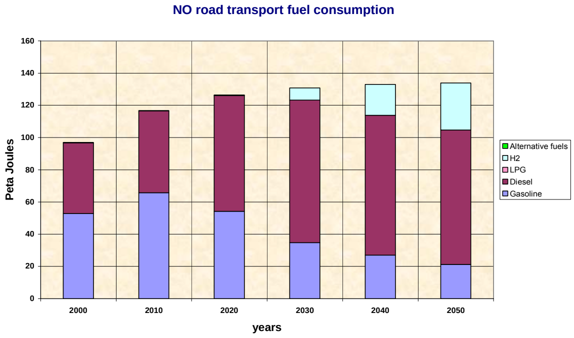


Fig. 4.1.3.6 Norway fuel consumption



4.2 France

4.2.1 Baseline

Running COPERT on the baseline provides a lot of interesting results. Looking at the MARKAL vehicle distribution, it can be seen that the conventional passenger cars are growing in the first portion of the time scale up to a level of about 35 millions of vehicles, while at the end the trend becomes decreasing, probably as result of an upper bound on the MS motorization level (fig. 4.2.1.1). This doesn't interest the other categories of vehicles whose trend is always increasing, especially for two wheels which at 2050 more than double their original number. The fuel consumption (fig. 4.2.1.2) is always increasing, mainly in dependence of the concurrence of two reasons, i.e. the transport demand increases and also the other vehicle categories (mainly the Heavy Duty Vehicles) have a growing trend. In any case, after 2020, the growth of the fuel consumption is reduced, with the CO_2 and N_2O following similar trends. It is to be underlined that nearly one half of the fuel is consumed in the urban domain.

Due to the effect of the new legislations, which reduce the exhaust emission limits of the new vehicles, for important regulated pollutants such as CO (fig. 4.2.1.4) and NO_x (fig 4.2.1.5), there is a decreasing emission trend in the first period followed by a stabilization, as after 2015 no additional improvement in the legislation is assumed and then the positive effect provided by the scrapping of the old dirty vehicles is no more present. Similar trend interests also PM (fig 4.2.1.7), even if the share of diesel fuel consumption is increasing, mainly in dependence of the HDVs, buses, etc.. In fact such vehicles have longer lifetime and, due to the additional time for their complete substitution, the new vehicles will replace very dirty vehicles, giving higher positive effects.. Therefore the larger consumption of diesel fuel doesn't increase the PM emissions. On the other end, due to the large share of diesel cars in the urban areas, PM emissions remain quite high and this create risks for the health of the inhabitants. In any case for almost all the pollutants there is a halving of the 2000 emissions, with the most consistent effects that are detected in urban areas. A behavior similar to CO and NO_x interests also VOCs (fig 4.2.1.6) and CH_4 (fig 4.2.1.10). For such pollutants the most important contribution is due to the motorcycles. The SO_2 emissions (fig 4.2.1.8) reach also very low levels, in dependence of the constraints that a SO_2 concentration of no more than 10 ppm is allowed in future fuels.

Fig. 4.2.1.1

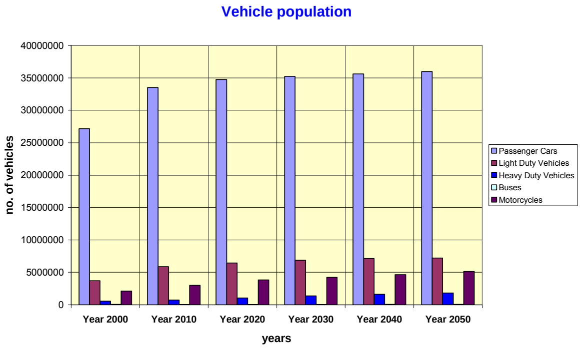


Fig. 4.2.1.2

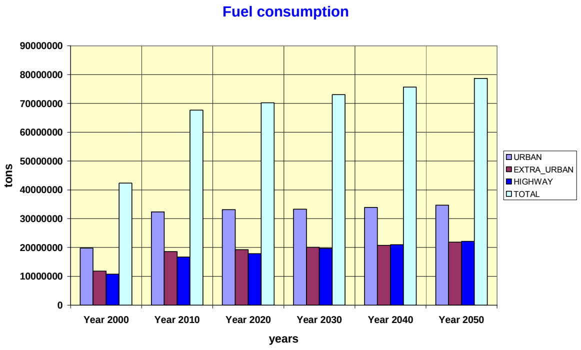


Fig. 4.2.1.3

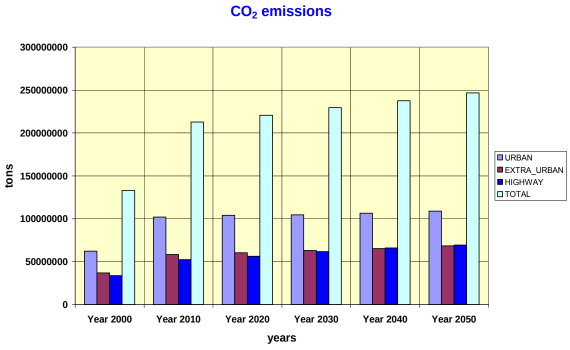


Fig. 4.2.1.4

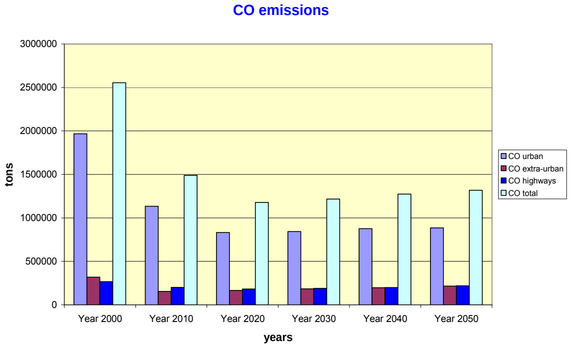


Fig. 4.2.1.5

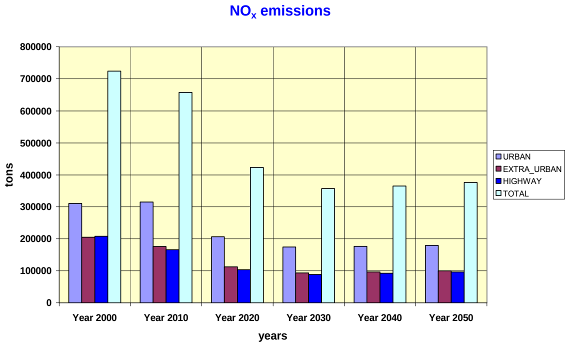


Fig. 4.2.1.6

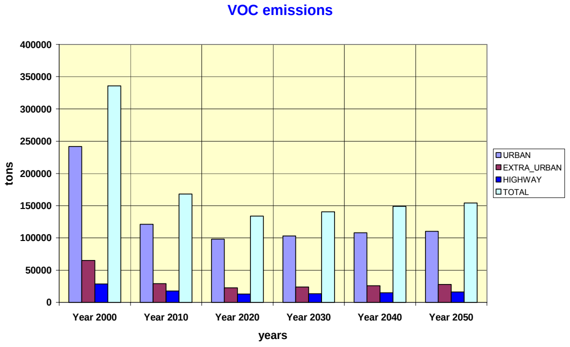
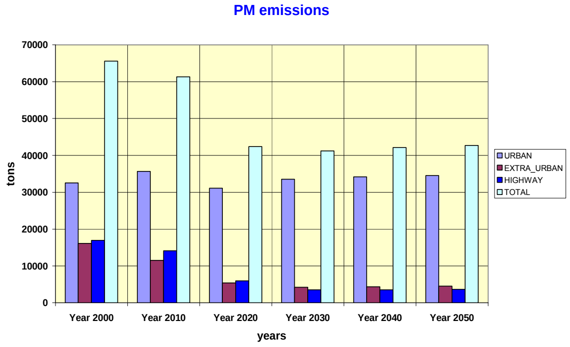


Fig. 4.2.1.7



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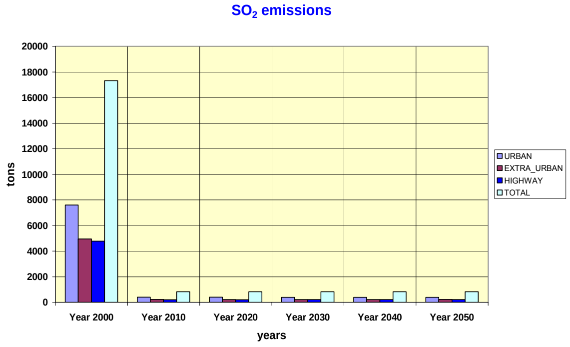

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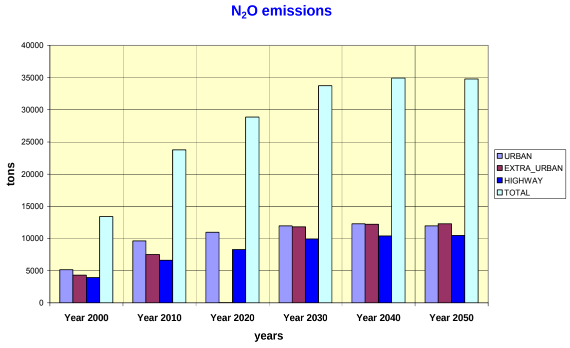

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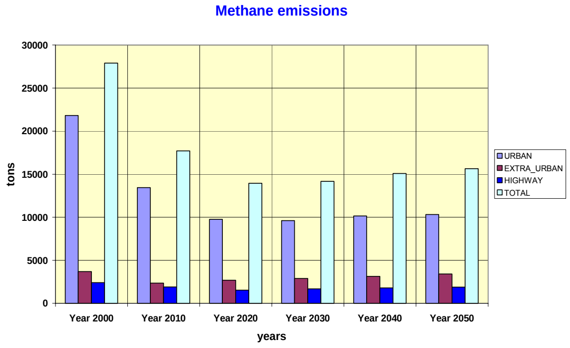


4.2.2 Hydrogen high penetration scenario

Looking at the results of the high hydrogen penetration scenario in terms of vehicles, only the categories of passenger cars, buses and light duty vehicles are interested to the hydrogen switch. Most of the conventional passenger cars are removed after 2030 (fig. 4.2.2.1). At 2050 the shares of conventional vehicles are 15% for passenger cars, 9% for buses and 13% for LDVs. Due to this consistent reduction of the above categories of vehicles, it is quite easy to understand that there is a large reduction of the pollutant emissions, in particular in the urban domains, where the hydrogen vehicles are particularly used. Therefore such vehicles become very effective in cutting atmospheric pollution. Some lower reduction is shown for VOCs (fig. 4.2.2.6) and CH_4 (fig. 4.2.2.9), as for such pollutants the effect of motorcycles is particularly relevant. It is to be underlined that, for fuel consumption (fig. 4.2.2.2), the shown figure indicates just the conventional fuels, while for CO_2 (fig. 4.2.2.3) the reduction effect is to be considered just at the point of use. This doesn't give any information on the CO_2 cumulative effects, which should also include the hydrogen contribution. In particular, the type of primary energy source, the processes used to produce hydrogen, the adoption of CO_2 capture and sequestration processes during the hydrogen production phase, etc. should be considered to have a real indication of CO_2 behavior. There are also some differences with fuel consumption MARKAL results that need some specific investigation, but are probably related to different specific consumption factors used in the two models.

Fig. 4.2.2.1

Conventional vehicle population

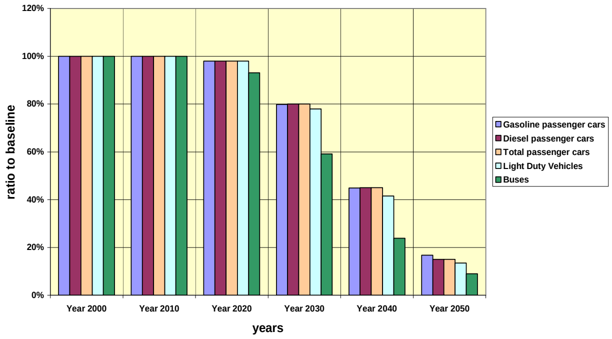


Fig. 4.2.2.2

High hydrogen penetration/ reference scenario relative CO_2 emissions

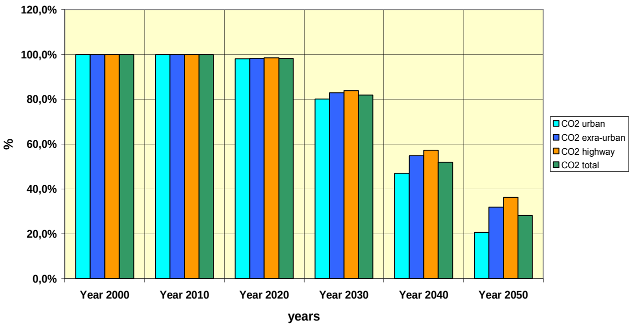


Fig. 4.2.2.2

High hydrogen penetration/ reference scenario relative conventional vehicle fuel consumption

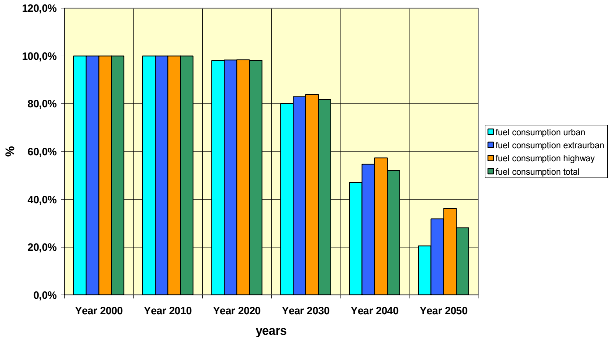


Fig. 4.2.2.4

High hydrogen penetration/ reference scenario relative CO emissions

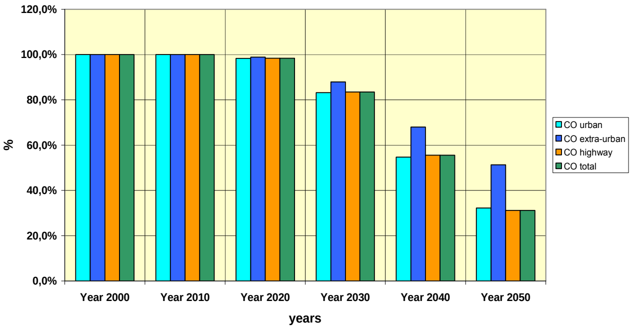


Fig. 4.2.2.5

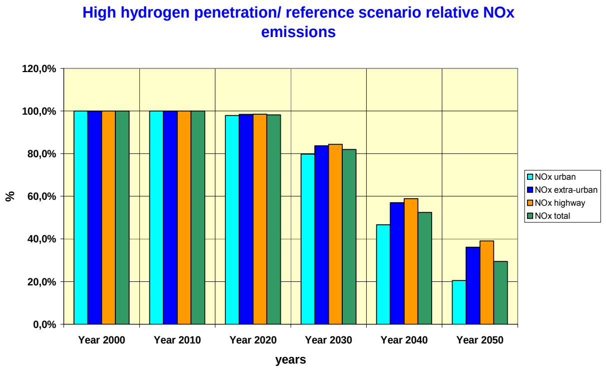

High hydrogen penetration/ reference scenario relative NOx emissions

Fig. 4.2.2.6

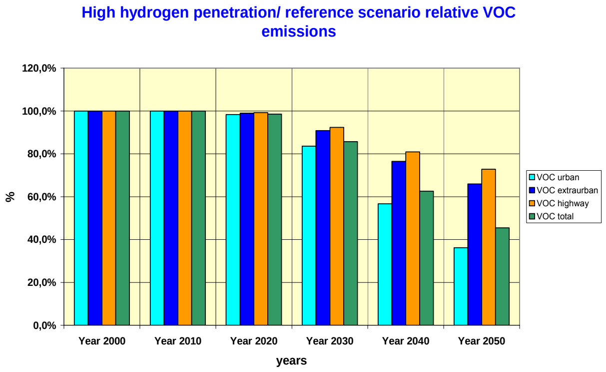

High hydrogen penetration/ reference scenario relative VOC emissions

Fig. 4.2.2.7

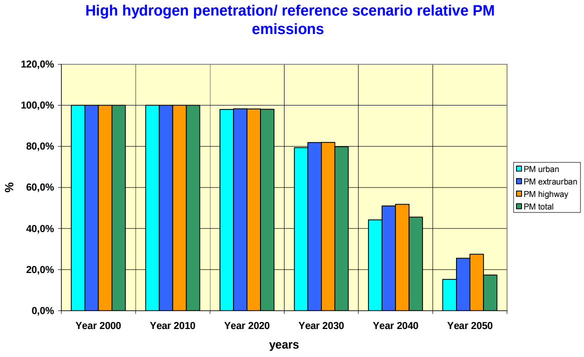

High hydrogen penetration/ reference scenario relative PM emissions

Fig. 4.2.2.8

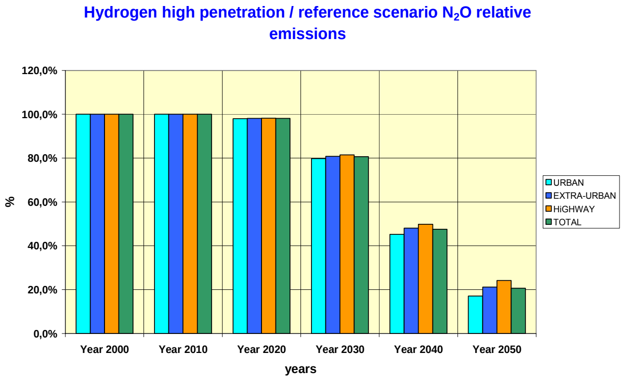

Hydrogen high penetration / reference scenario N_2O relative emissions

Fig. 4.2.2.9

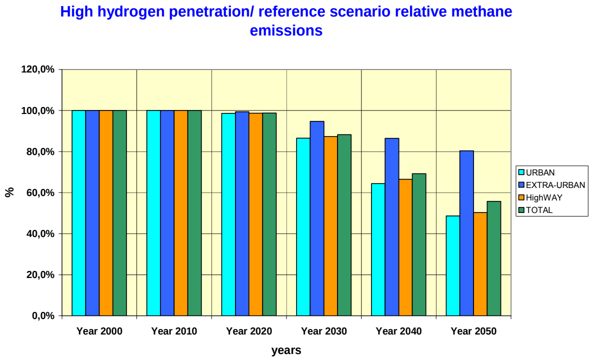
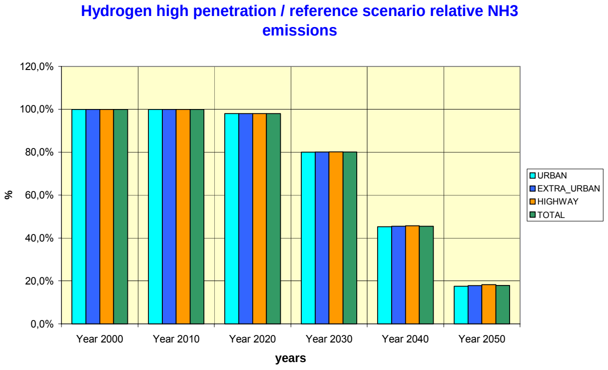

High hydrogen penetration/ reference scenario relative methane emissions

Fig. 4.2.2.10


Hydrogen high penetration / reference scenario relative NH3 emissions

4.2.3 Hydrogen low penetration scenario

For the low hydrogen penetration scenario it can be seen a quite different behavior respect to the high one, with a consistent delay in the vehicle introduction as it can be shown in fig. 4.2.3.1. From the figure it seems evident that a consistent market uptake of passenger cars starts from 2050. There is an exception for buses which are deployed in a consistent share, probably thanks to the investments in public transport. The reduction of conventional passenger cars, respect to the baseline, is quite limited (about 20% at 2050), while the conventional buses and LDVs have a share respectively of 58% and 80% against 9% and 13% of the high hydrogen penetration scenario.

Due to the limited penetration of hydrogen in the market, also the reduction of the pollutant emissions is limited. Almost all the pollutants show reduction to the basecase that is no more than 20%, as it can be seen in the following figures.

Fig. 4.2.3.1

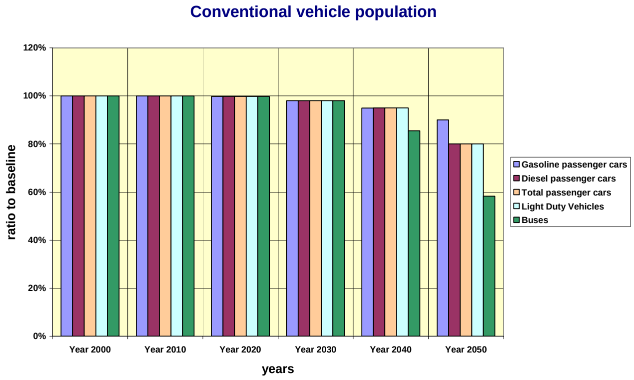


Fig.4.2.3.2

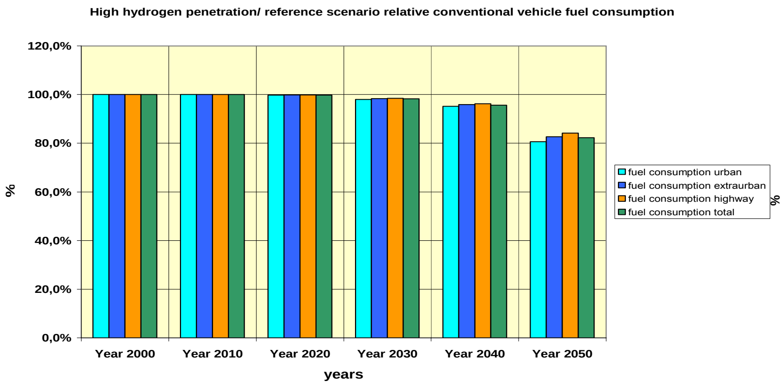


Fig. 4.2.3.3

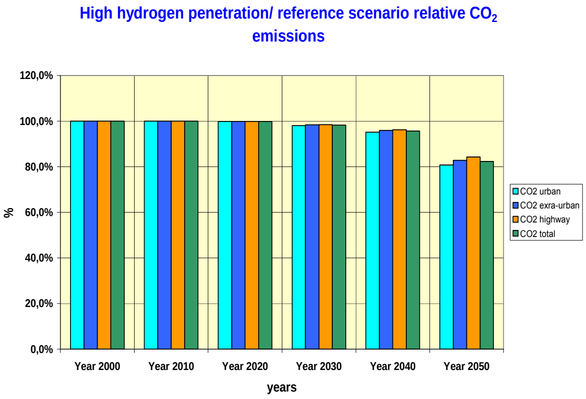


Fig. 4.2.3.4

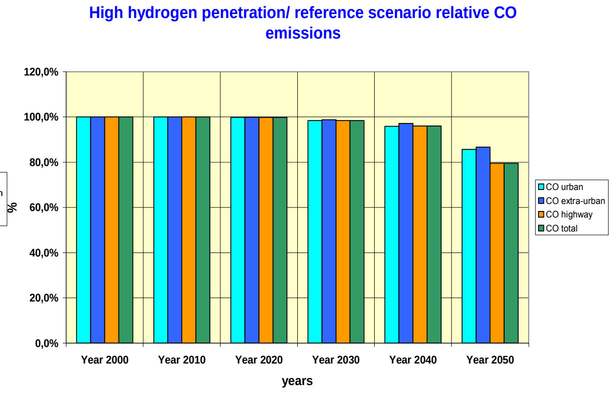


Fig. 4.2.3.5

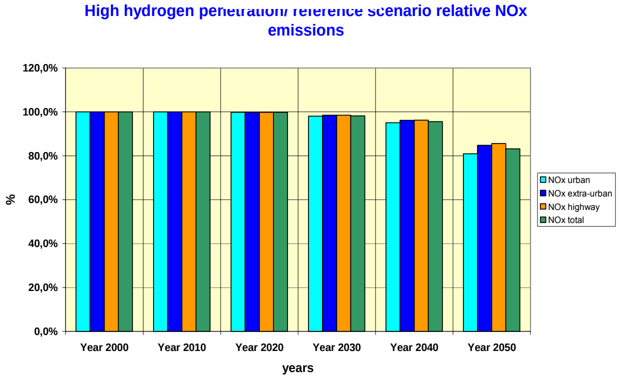


Fig. 4.2.3.8

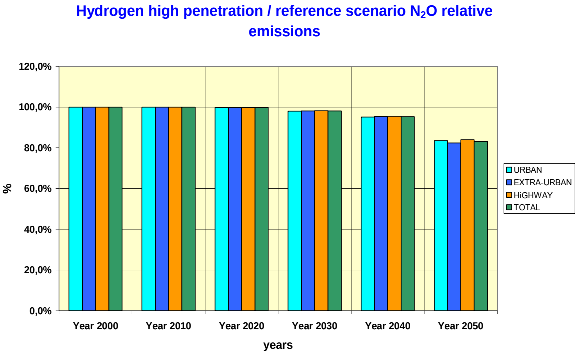


Fig. 4.2.3.6

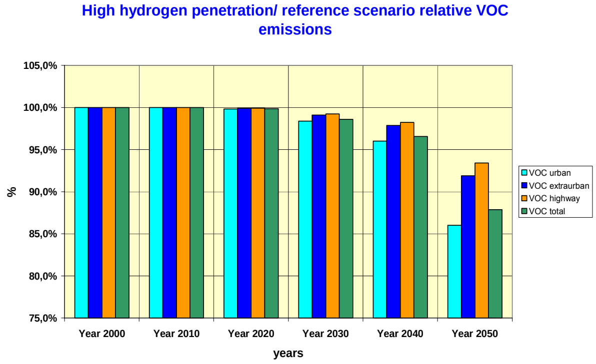


Fig. 4.2.3.9

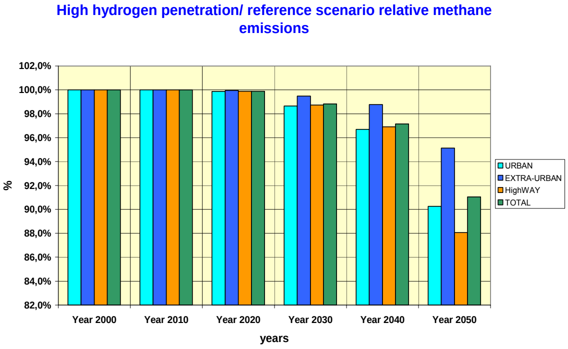


Fig. 4.2.3.7

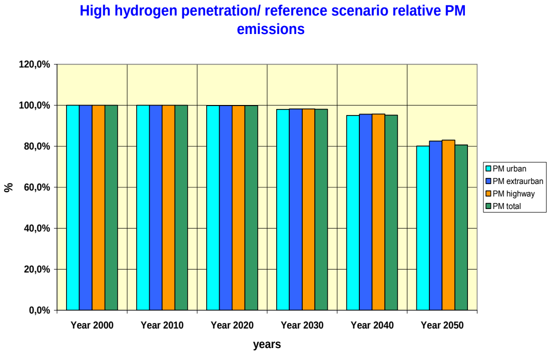
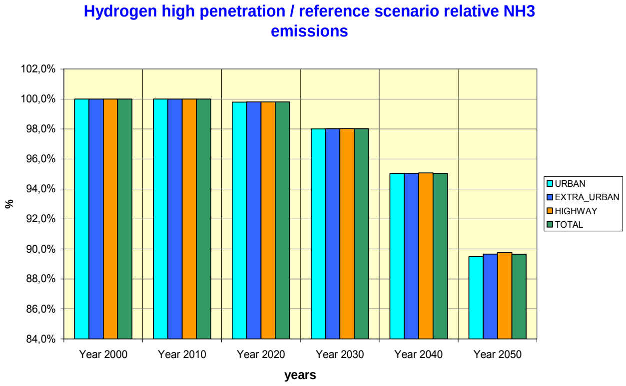


Fig. 4.2.3.10



4.3 Germany

4.3.1 Baseline

Running COPERT on the baseline provides a lot of interesting results. Looking at the vehicle distribution resulting from MARKAL, it can be seen that the conventional passenger cars are growing in the first portion of the time scale up to a level of about 45 millions of vehicles, while at the end the trend becomes decreasing, probably as result of an upper bound on the MS motorization level (fig. 4.3.1.1). This doesn't interest the other categories of vehicles whose trend is always increasing, except for two wheel vehicles which are almost constants. The fuel consumption (fig. 4.3.1.2) stabilizes at the end of the interval, mainly in dependence of the concurrence of two reasons, i.e. the passenger cars are decreasing, while for the other vehicle categories (mainly the Heavy Duty Vehicles) there is a growing trend both for the transport demand and the number of vehicles. The CO_2 and N_2O are following similar trends and it is to be underlined that almost one half of such emissions is interesting the urban domain, in dependence that also the same share of the fuel consumption happens in such domain.

Due to the effect of the new legislations, which reduce the exhaust emission limits of the new vehicles, for important regulated pollutants such as CO (fig. 4.3.1.4) and NO_x (fig 4.3.1.5), there is a decreasing emission trend in the first period followed by a stabilization, as after 2015 no additional improvement in the legislation is assumed and then the positive effect provided by the scrapping of the old dirty vehicles is no more present. A behavior similar to CO and NO_x interests also VOCs (fig 4.3.1.6) and CH_4 (fig 4.3.1.10). Similar trend interests also PM (fig 4.3.1.7), even if the share of diesel fuel consumption is increasing, mainly in dependence of the HDVs, buses, etc.. In fact such vehicles have longer lifetime and, due to the additional time for their complete substitution, the new vehicles will replace very dirty vehicles, giving higher positive effects.. Therefore the larger consumption of diesel fuel doesn't increase the PM emissions. On the other end due to the large share of diesel cars in the urban areas PM emissions (fig 4.3.1.7) remain high and this create risks for the health of the inhabitants. In any case for almost all the pollutants there is a halving of the 2000 emissions, with the most consistent effects that are detected in urban areas. A behavior similar to CO and NO_x interests also VOCs (fig 4.3.1.6) and CH_4 (fig 4.3.1.10). For such pollutants the most important contribution is due to the motorcycles. The SO_2 emissions (fig 4.3.1.8) also reach very low levels, in dependence of the constraints that no more than 10 ppm is allowed in future fuels.

Fig. 4.3.1.1

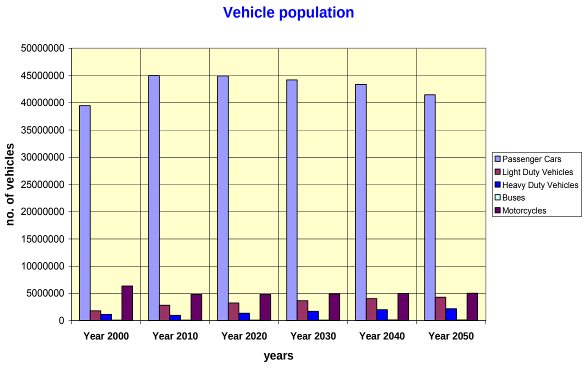


Fig. 4.3.1.2

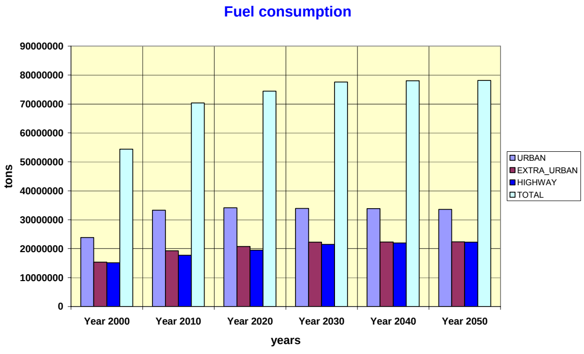


Fig. 4.3.1.3

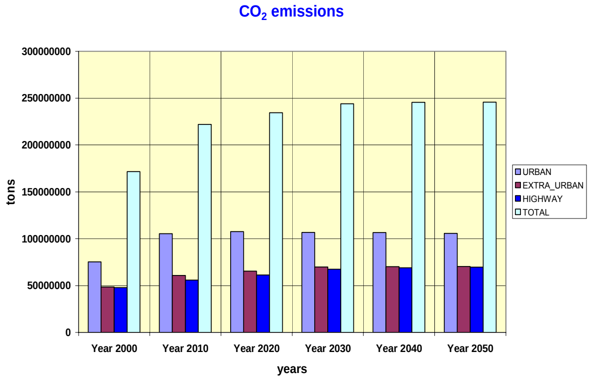


Fig. 4.3.1.4

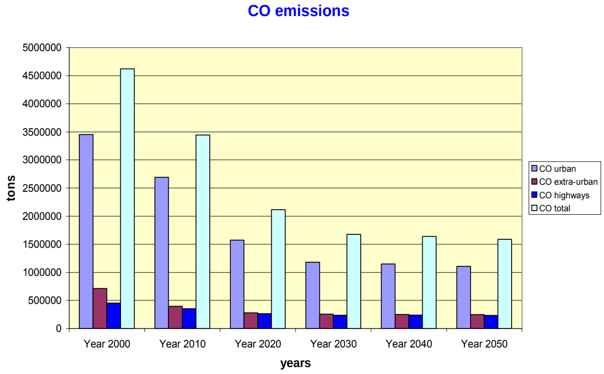


Fig. 4.3.1.5

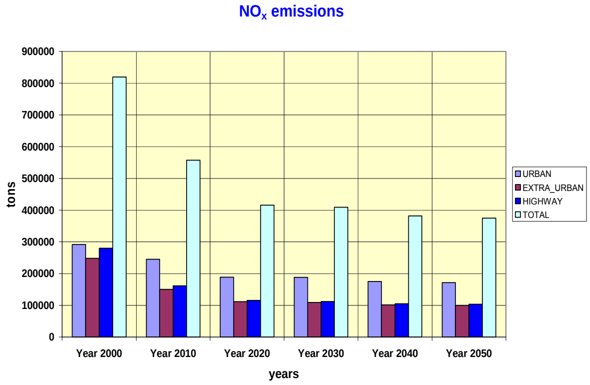


Fig. 4.3.1.6

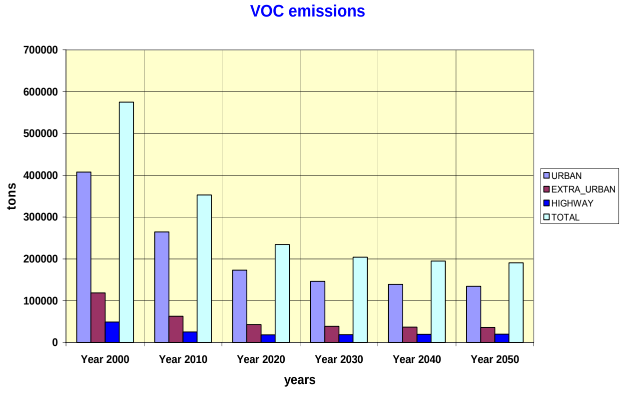


Fig. 4.3.1.7

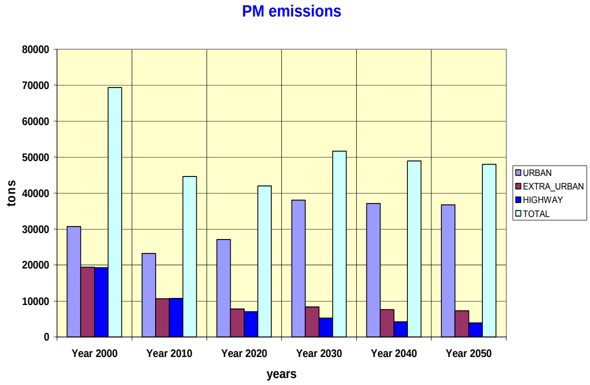


Fig. 4.3.1.8

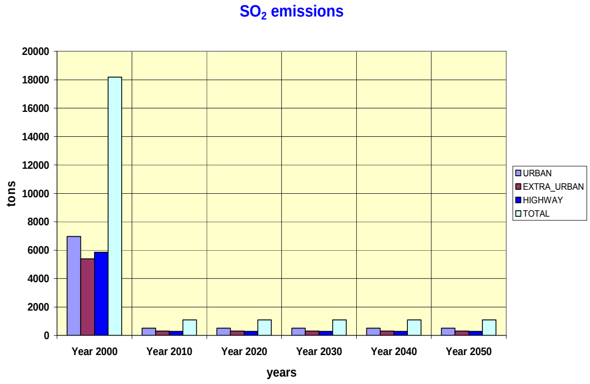


Fig. 4.3.1.9

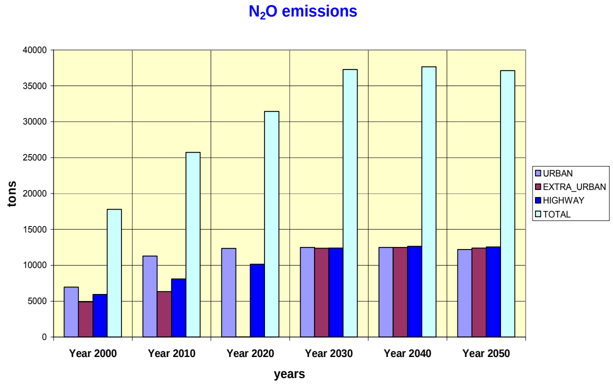
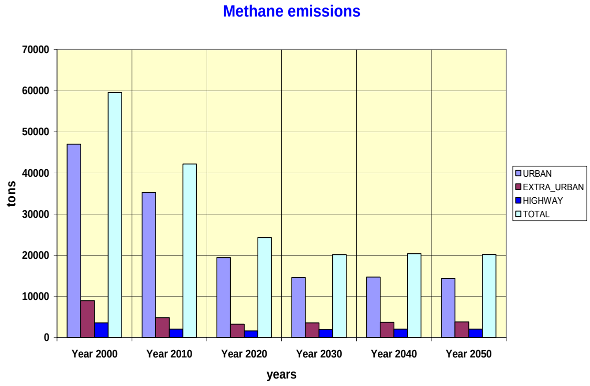


Fig. 4.3.1.10



4.3.2 Hydrogen high penetration scenario

Looking at the results of the high hydrogen penetration scenario in terms of vehicles, only the categories of passenger cars, buses and light duty vehicles are interested to the hydrogen switch. Most of the conventional passenger cars are removed after 2030 (fig. 4.3.2.1). At 2050 the shares of conventional vehicles are 25% for passenger cars, 12% for buses and 23% for LDVs. Due to this consistent reduction of the above categories of vehicles, it is quite easy to understand that there is a large reduction of the pollutant emissions, in particular in the urban domains, where the hydrogen vehicles are particularly used and therefore become very effective in reducing atmospheric pollution. Some lower reduction is shown for VOCs (fig. 4.3.2.6) and CH_4 (fig. 4.3.2.9), as for such pollutants the motorcycle contribution is particularly relevant. It is to be underlined that, for fuel consumption (fig. 4.3.2.2), the reduction shown interests interest just the conventional fuels, while for CO_2 (fig. 4.3.2.3) the reduction effect is to be considered just at the point of use. This doesn't give any information on the CO_2 cumulative effects, which should also include the hydrogen contribution. In particular, the type of primary energy source, the processes used to produce hydrogen, the adoption of CO_2 capture and sequestration processes during the hydrogen production phase, etc. should be considered to have a real indication of CO_2 behavior. There are also some differences with fuel consumption MARKAL results, that need some specific investigation, but are probably related to different specific consumption factors used in the two models.

Fig. 4.3.2.1

Conventional vehicle population

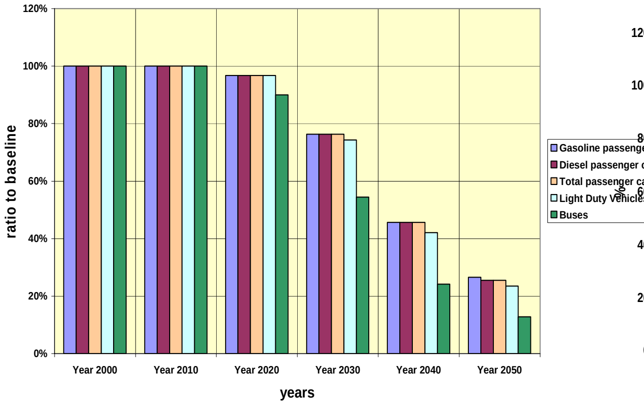


Fig. 4.3.2.2

High hydrogen penetration/ reference scenario relative conventional vehicle fuel consumption

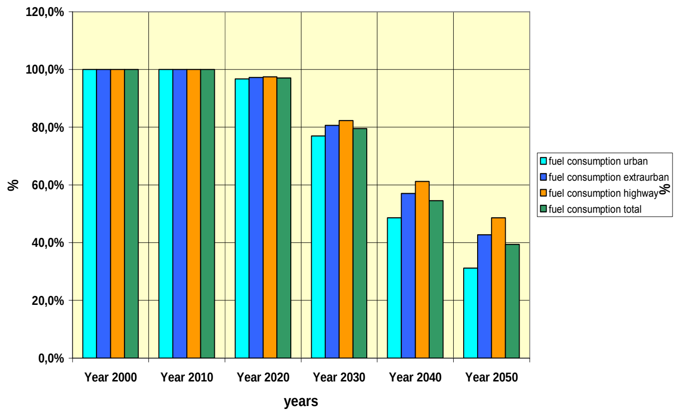


Fig. 4.3.2.3

High hydrogen penetration/ reference scenario relative CO_2 emissions

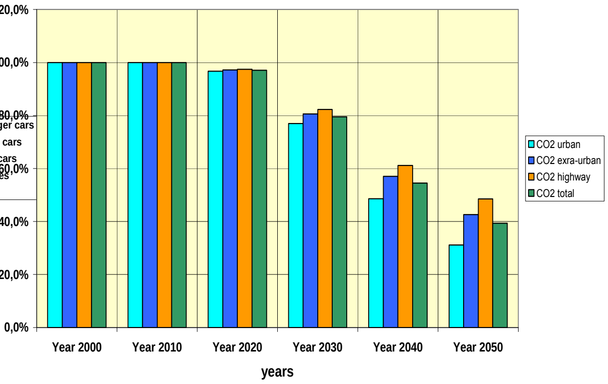


Fig. 4.3.2.4

High hydrogen penetration/ reference scenario relative CO emissions

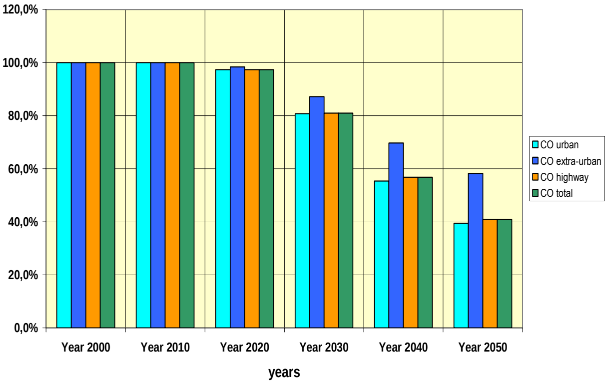


Fig. 4.3.2.5

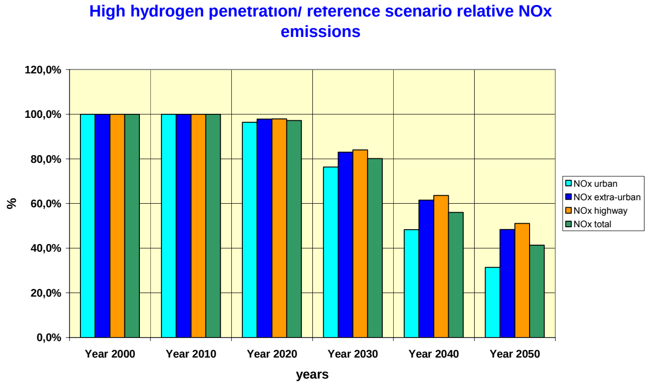


Fig. 4.3.2.8

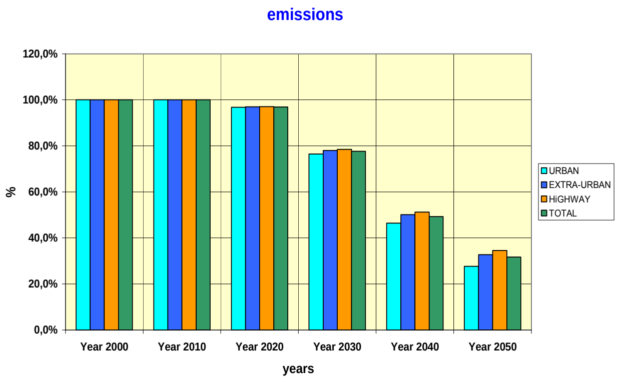


Fig. 4.3.2.6

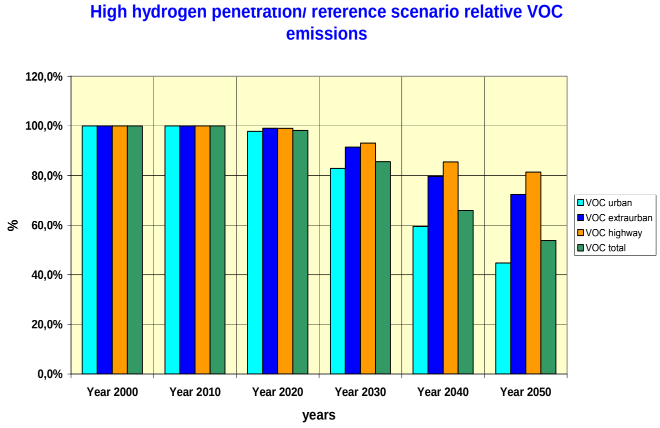


Fig. 4.3.2.9

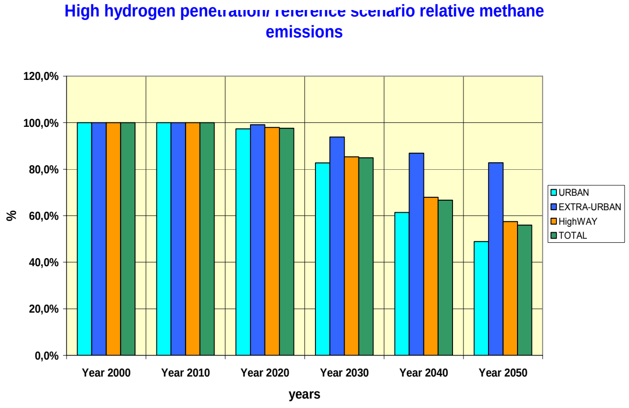


Fig. 4.3.2.7

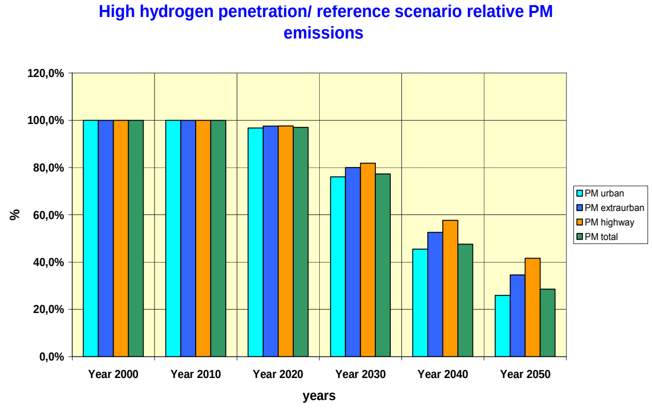
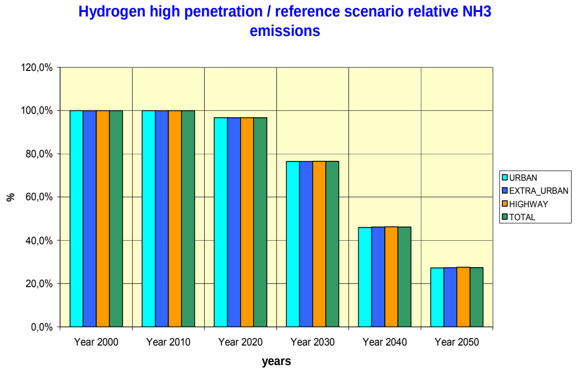


Fig. 4.3.2.10



4.3.3 Hydrogen low penetration scenario

For the low hydrogen penetration scenario it can be seen a quite different behavior respect to the high one, with a consistent delay in the vehicle introduction as it can be shown in fig. 4.3.3.1. From the figure it seems quite evident that a consistent market uptake of passenger cars starts from 2040. There is an exception for buses which are deployed earlier in a consistent share, thanks to the investments in public transport. The conventional passenger cars, respect to the baseline, have the major share of the fleet at 2050 (about 60%), while the conventional buses and LDVs have a share respectively of 36% and 57% against 12% and 23% of the high scenario.

Due to the limited penetration of hydrogen in the market, also the reduction of the pollutant emissions is limited. Almost all the pollutants show reduction to the basecase that is about 40%, as it can be seen in the following figures. Some less reduction is shown by VOCs and methane emissions, due to the high incidence of motorcycles.

Fig. 4.3.3.1

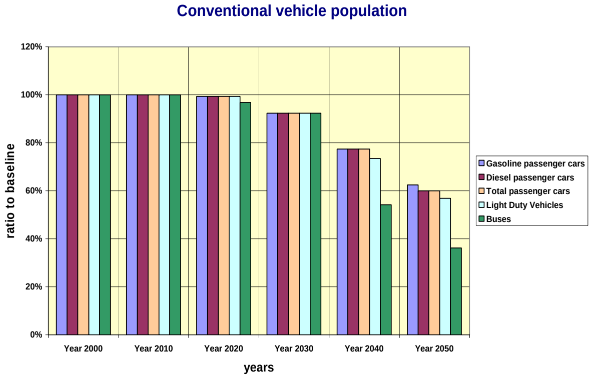


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Fig. 4.3.3.2

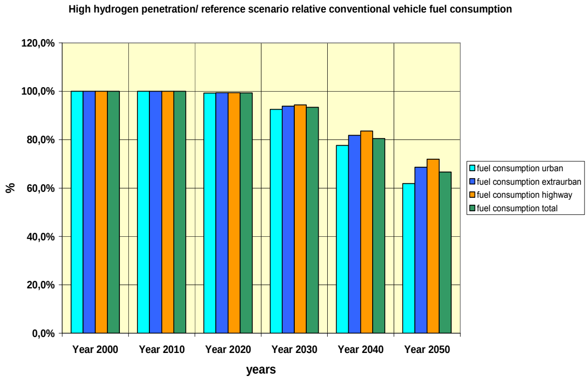


Fig. 4.3.1.3

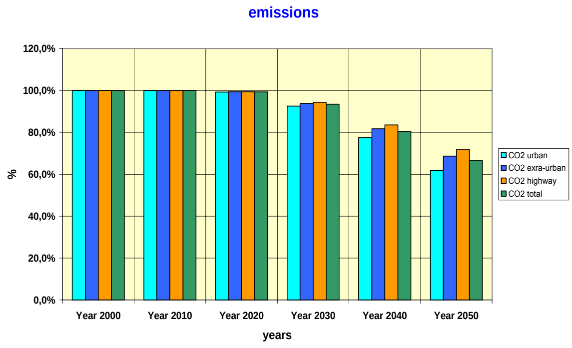


Fig. 4.3.3.4

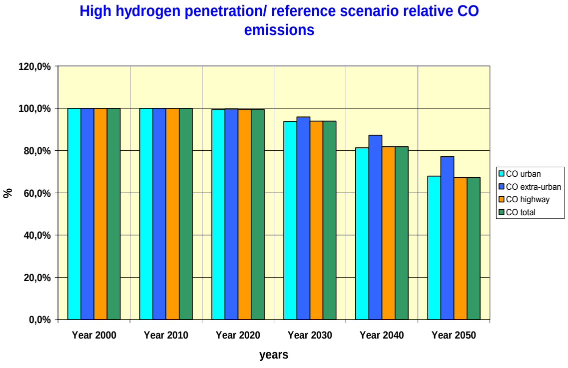


Fig. 4.3.3.5

High hydrogen penetration/ reference scenario relative NOx emissions

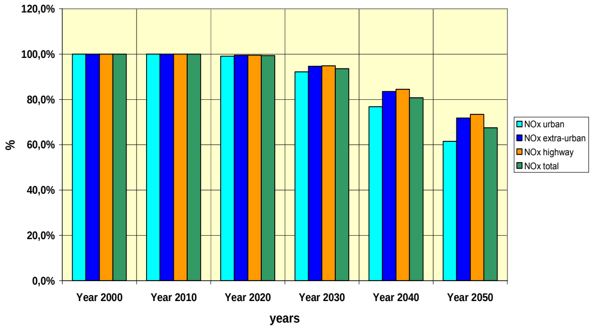


Fig. 4.3.3.6

High hydrogen penetration/ reference scenario relative VOC emissions

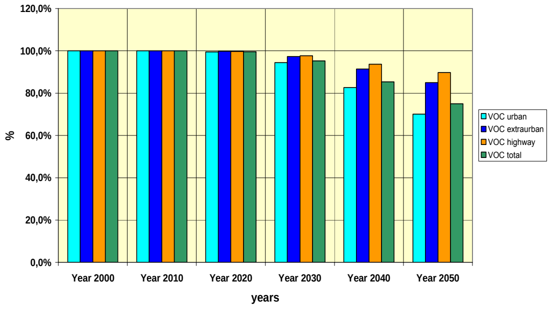


Fig. 4.3.3.7

High hydrogen penetration/ reference scenario relative PM emissions

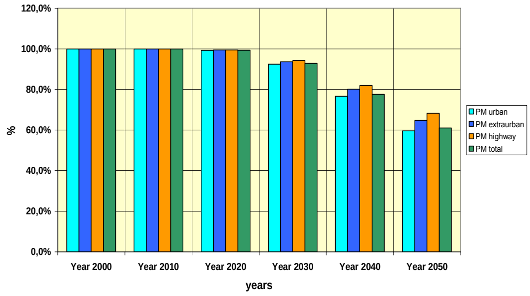


Fig. 4.3.3.8

Hydrogen high penetration / reference scenario N_2O relative emissions

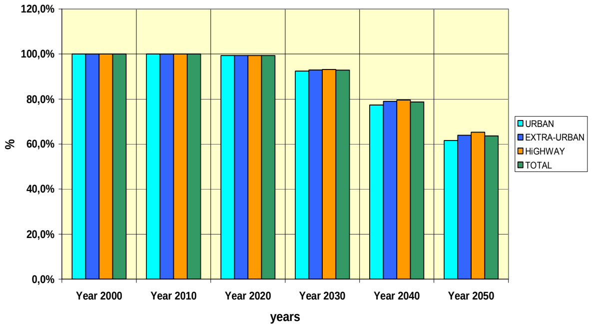


Fig. 4.3.3.9

High hydrogen penetration/ reference scenario relative methane emissions

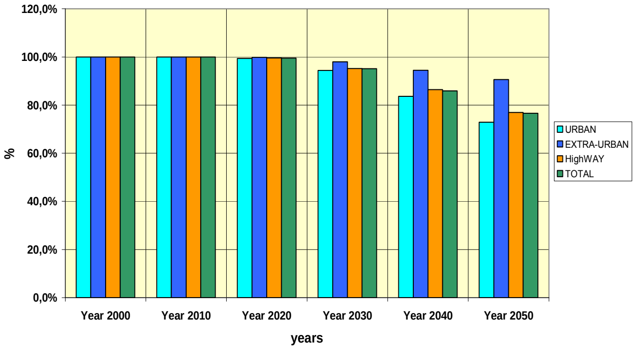
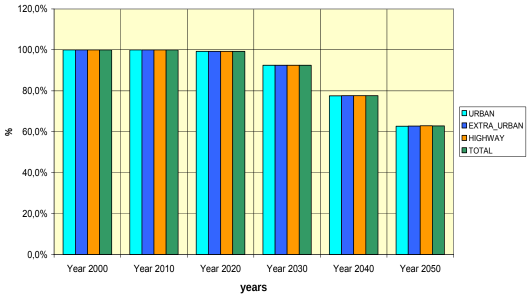


Fig. 4.3.3.10

Hydrogen high penetration / reference scenario relative NH3 emissions



4.4 Greece

4.4.1 Baseline

Running COPERT on the baseline provides a lot of interesting results. Looking at the vehicle distribution provided by MARKAL, it can be seen that the conventional passenger cars are growing in the first portion of the time scale up to a level of about 6 millions of vehicles, while at the end the trend becomes decreasing (fig. 4.4.1.1), probably as result of the very large increase of two wheel vehicles, which reach about 7 millions at 2050, starting from one million at 2000. Some increase applies also to the other categories of vehicles but in a more understandable and limited way. The fuel consumption (fig. 4.4.1.2) is increasing, mainly in dependence of the concurrence of some reasons, i.e. the transport demand increases and also the other vehicle categories (mainly the Heavy Duty Vehicles) have a growing trend. In any case, at the end of the period, the fuel consumption stabilizes, with the CO_2 and N_2O following similar trends; it is to be underlined that about one half of the fuel is consumed in the urban domain.

Due to the effect of the new legislations, which reduce the exhaust emission limits of the new vehicles, for important regulated pollutants such as NO_x (fig 4.4.1.5), there is a decreasing emission trend in the first period, followed by a stabilization, as after 2015 no additional improvement in the legislation is assumed and then the positive effect provided by the scrapping of the old dirty vehicles is no more present. Instead for CO (fig. 4.4.1.4) there is a trend where after an initial decrease there is a new increase, due to the large motorcycle fleet. For PM (fig 4.4.1.7) there is also an increasing trend, mainly driven from the diesel passenger cars whose share is increasing. A negative behavior is shown also by VOCs (fig 4.4.1.6) and CH_4 (fig 4.4.1.10), whose emissions are consequence of the increase of motorcycles. The SO_2 emissions (fig 4.4.1.8) reach very low levels, in dependence of the constraints that no more than 10 ppm is allowed in future fuels.

Fig. 4.4.1.1

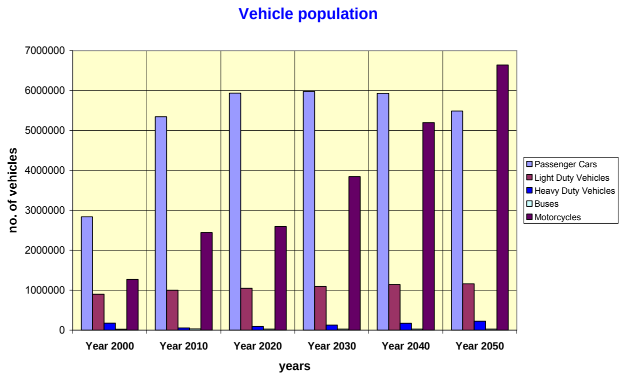

Vehicle population

Fig. 4.4.1.2

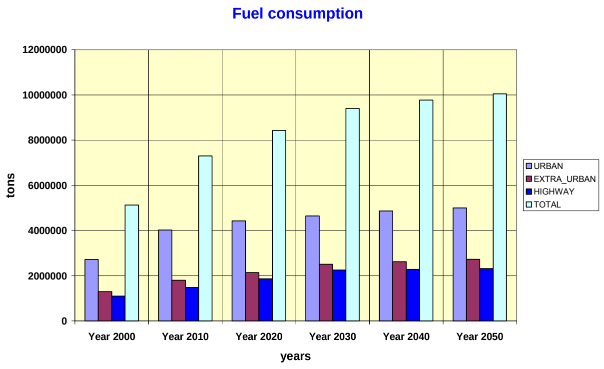

Fuel consumption

Fig. 4.4.1.3

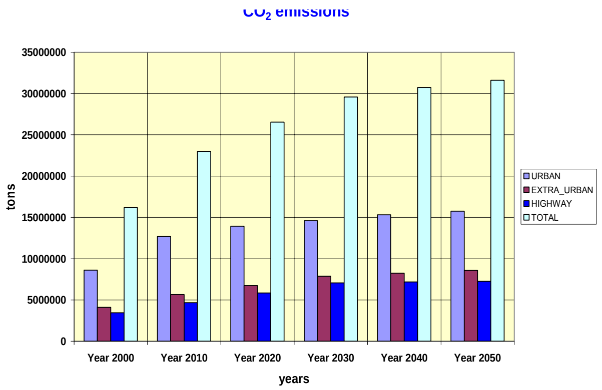


Fig. 4.4.1.4

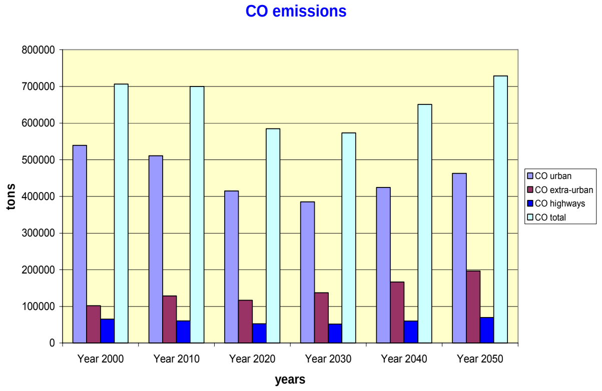


Fig. 4.4.1.5

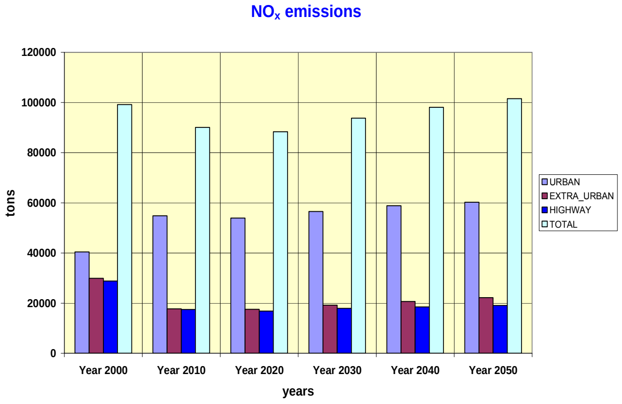


Fig. 4.4.1.6

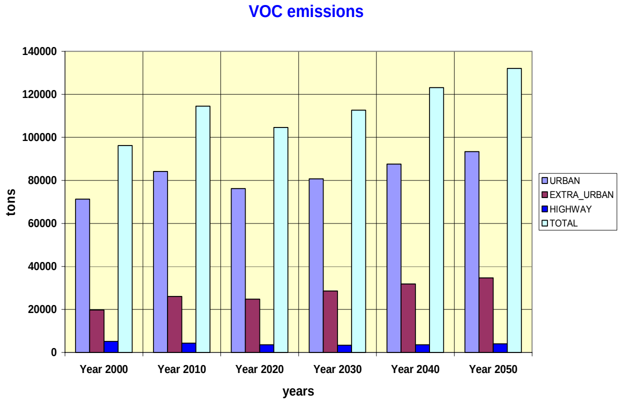


Fig. 4.4.1.7

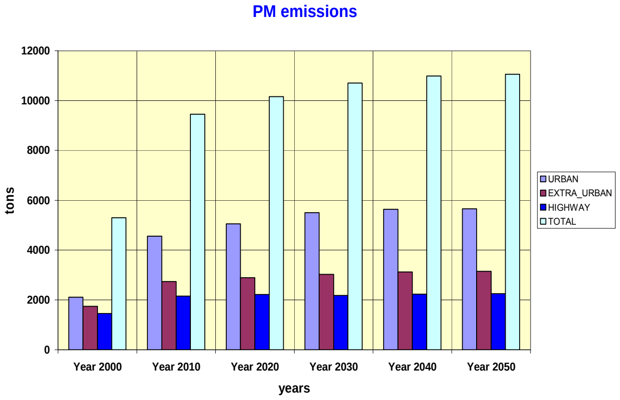


Fig. 4.4.1.8

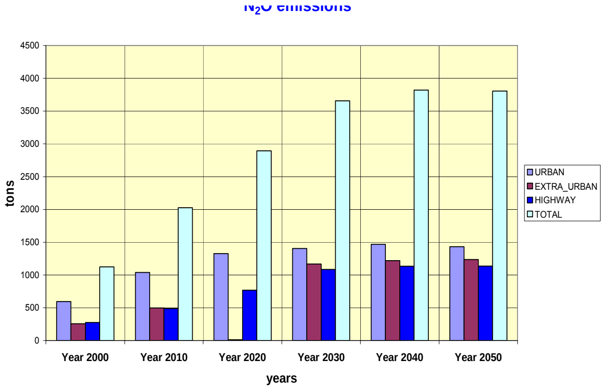


Fig. 4.4.1.9

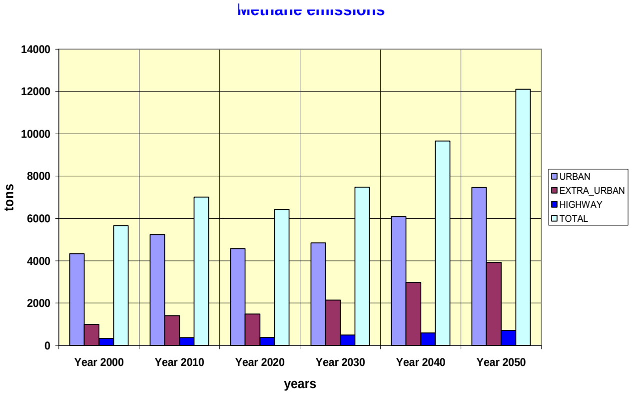
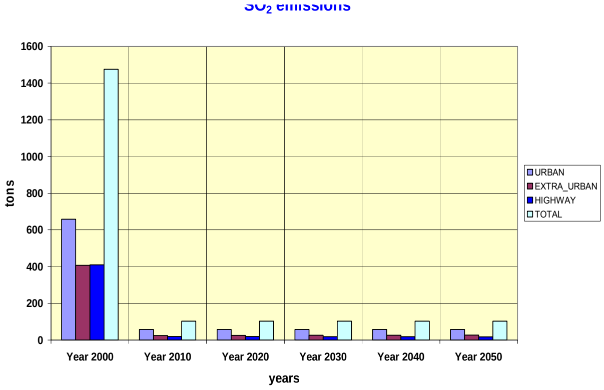


Fig. 4.4.1.10



4.4.2 Hydrogen high penetration scenario

Looking at the results of the high hydrogen penetration scenario, in terms of vehicles only the categories of passenger cars, buses and light duty vehicles are interested to the hydrogen switch. It is quite surprising that most of the conventional passenger cars are removed just in the period 2030-2040 (fig. 4.4.2.1), going from 75% to 45%, while for buses the switch is made earlier. At 2050 the share of conventional vehicles are 25% for passenger cars, 13% for buses and 24% for LDVs. Due to this consistent reduction of the above categories of vehicles, it is quite easy to understand that there is a large reduction of the pollutant emissions, in particular in the urban domains, where the hydrogen vehicles are particularly used and therefore become effective in reducing atmospheric pollution. Important exceptions are shown for CO (fig. 4.4.2.4), VOCs (fig. 4.4.2.6) and CH_4 (fig. 4.4.2.9), as for such pollutants the motorcycle contribution is particularly relevant, also in dependence of the growth of such vehicles. It is to be underlined that, for fuel consumption (fig. 4.4.2.2), the reduction which is shown interests just the conventional fuels, while for CO_2 (fig. 4.4.2.3) the reduction effect is to be considered just at the point of use. This doesn't give any information on the CO_2 cumulative effects, which should also include the hydrogen contribution. In particular, the type of primary energy source, the processes used to produce hydrogen, the adoption of CO_2 capture and sequestration processes during the hydrogen production phase, etc. should be considered to have a real indication of CO_2 behavior.

Fig. 4.4.2.1

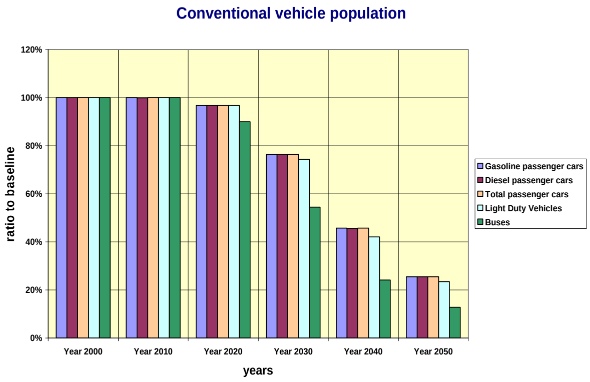


Fig. 4.4.2.3

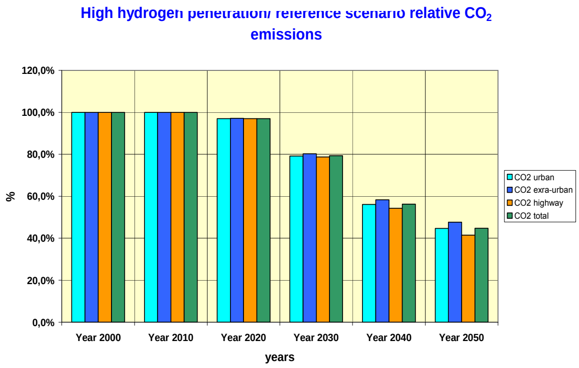


Fig. 4.4.2.2

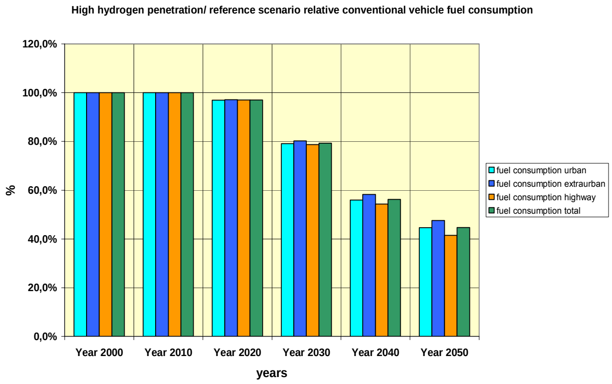


Fig. 4.4.2.4

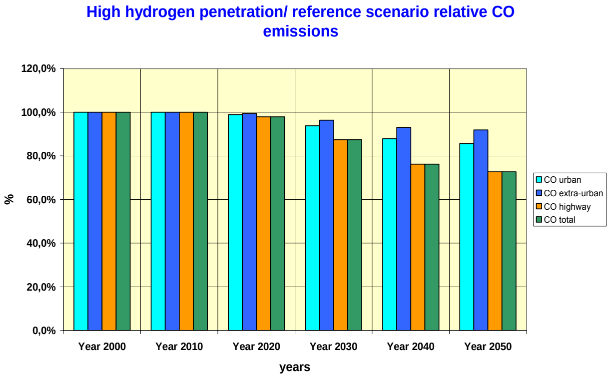


Fig. 4.4.2.5

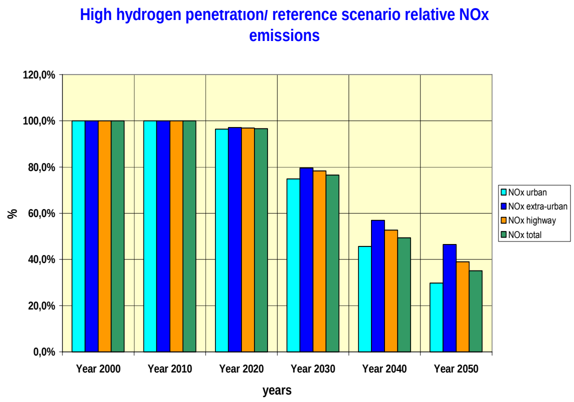


Fig. 4.4.2.8

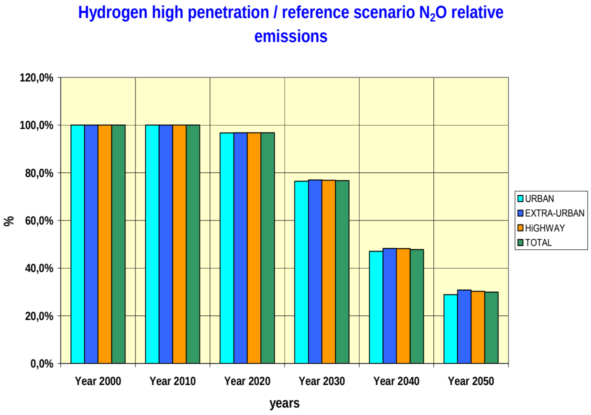


Fig. 4.4.2.6

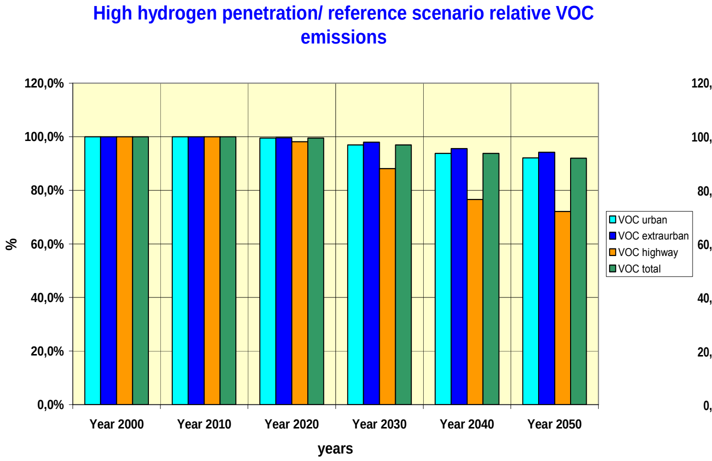


Fig. 4.4.2.9

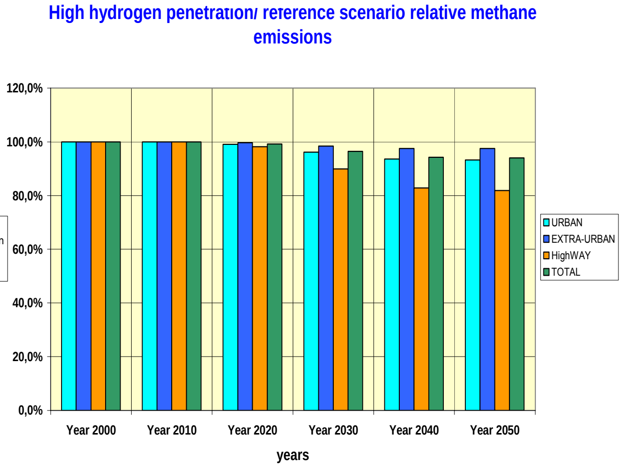


Fig. 4.4.2.7

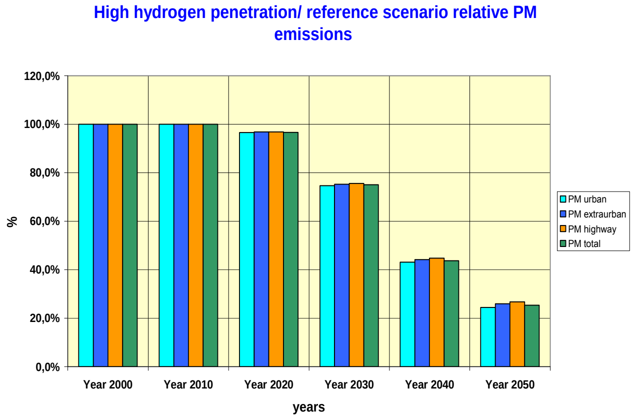
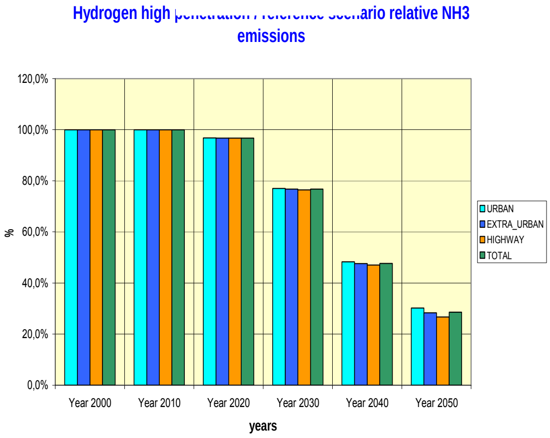


Fig. 4.4.2.10



4.4.3 Hydrogen low penetration scenario

For the low hydrogen penetration scenario it can be seen a quite different behavior respect to the high one, with a consistent delay in the vehicle introduction (fig. 4.4.3.1). From the figure it seems quite evident that a consistent market uptake of passenger cars starts from 2040. There is an exception for buses which are deployed earlier in a consistent share, thanks to the investments in public transport. The conventional passenger cars, respect to the baseline, have the major share of the fleet at 2050 (about 60%), while the conventional buses and LDVs have a share respectively of 36% and 58% against 12% and 23% of the high scenario.

Due to the limited penetration of hydrogen in the market, also the reduction of the pollutant emissions is limited. In addition the presence of a relevant number of motorcycles acts negatively in cutting the pollutant emissions. This effect mainly interests CO, VOC and CH_4 as can be seen respectively in (fig. 4.4.3.4), (fig. 4.4.3.6) and (fig. 4.4.3.9). .For the other pollutants the emission is reduced at a level of about 60%.

Fig. 4.4.3.1

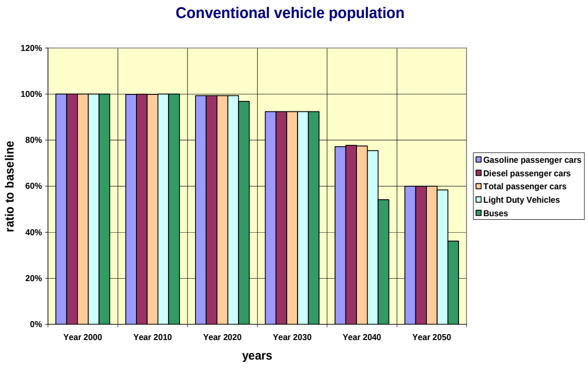


Fig. 4.4.3.2

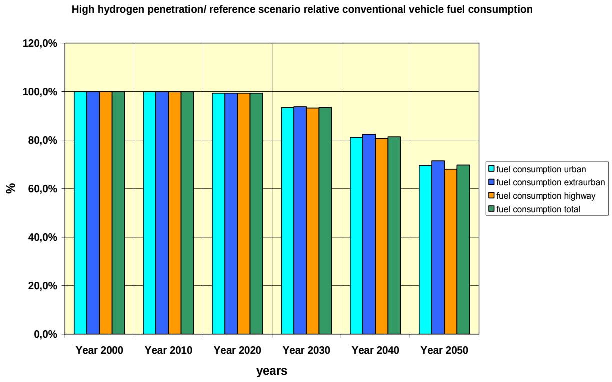


Fig. 4.4.3.3

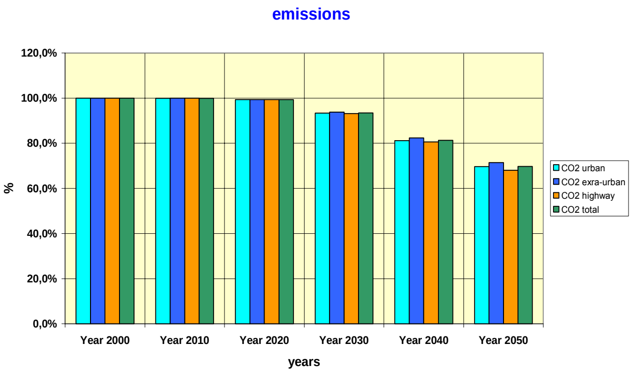


Fig. 4.4.3.4

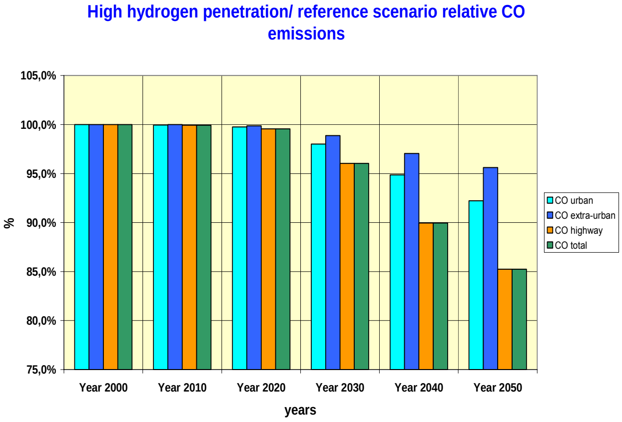


Fig. 4.4.3.5

High hydrogen penetration/ reference scenario relative NOx emissions

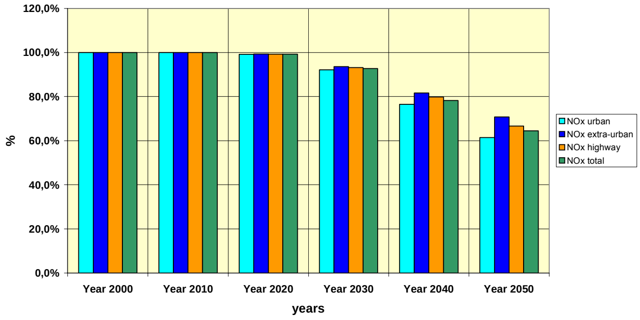


Fig. 4.4.3.6

High hydrogen penetration/ reference scenario relative VOC emissions

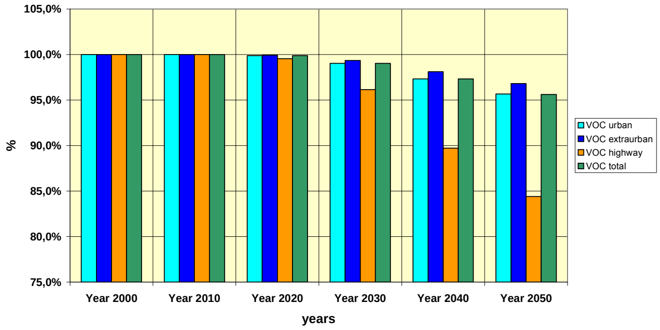


Fig. 4.4.3.7

High hydrogen penetration/ reference scenario relative PM emissions

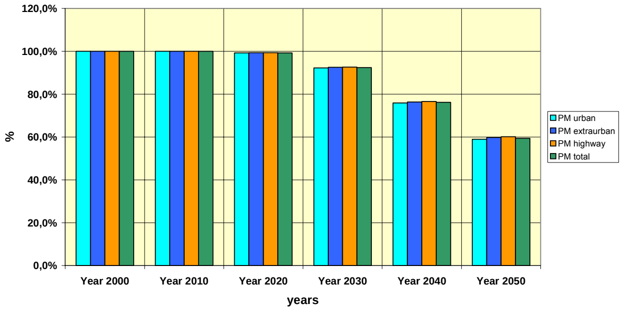


Fig. 4.4.3.8

Hydrogen high penetration / reference scenario N_2O relative emissions

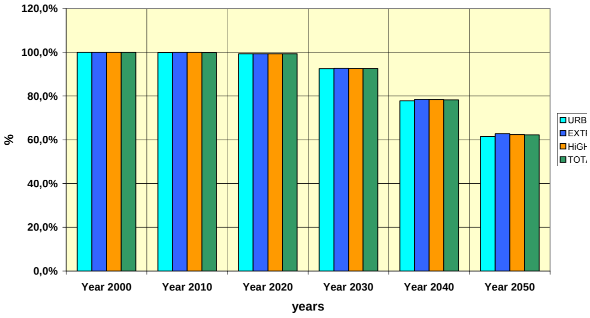


Fig. 4.4.3.9

High hydrogen penetration/ reference scenario relative methane emissions

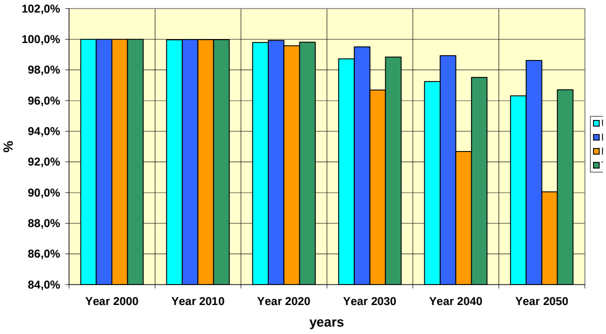
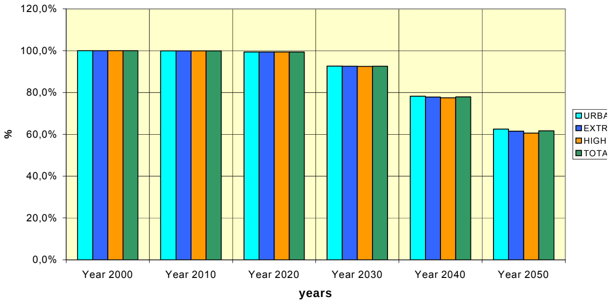


Fig. 4.4.3.10

Hydrogen high penetration / reference scenario relative NH3 emissions



4.5 Italy

4.5.1 Baseline

Running COPERT on the baseline provides a lot of interesting results. Looking at the vehicle distribution provided by MARKAL, it can be seen that the conventional passenger cars are always reducing in the timeframe (fig. 4.5.1.1) as consequence of the upper bound on the car-population ratio from a level of about 32 millions of vehicles to about 26 millions of vehicle at the end of the time interval. This doesn't interest the other categories of vehicles whose trend is always increasing, especially for two wheel vehicles which at 2050 almost double their original number. The fuel consumption (fig. 4.5.1.2) is quite constant, mainly in dependence of the concurrence of two reasons, i.e. the decrease of both number and transport demand for passenger cars, which is compensate by the opposite trend of the other vehicles (mainly the Heavy Duty Vehicles). The CO_2 is following trends similar to the fuel consumption, of which about one half is consumed in the urban domain. For N_2O (fig 4.5.1.9) instead an increasing trend is resulting in the first portion of the time interval, probably in dependence of the increase of the diesel share, while at the end a decrease is detected.

Due to the effect of the new legislations, which reduce the exhaust emission limits of the new vehicles, for important regulated pollutants such as CO (fig. 4.5.1.4) and NO_x (fig 4.5.1.5), there is a decreasing emission trend in the first period followed by a stabilization, as after 2015 no additional improvement in the legislation is assumed and then the positive effect provided by the scrapping of the old dirty vehicles is no more present. For PM (fig 4.5.1.7) there is also a decreasing trend, driven both by the reduction of passenger car fleet size and the very stringent legislations on PM, which overrides the possible negative effects resulting from the increasing number of diesel cars. In any case for almost all the pollutants there is a halving of the 2000 emissions, with the most consistent effects that are detected in urban areas. Similar behavior interests also VOCs (fig 4.5.1.6) and CH_4 (fig 4.5.1.10), for which the most important contribution is related to the motorcycles. The SO_2 emissions (fig 4.5.1.8) also reach very low levels, in dependence of the constraints that no more than 10 ppm is allowed in future fuels.

Fig. 4.5.1.1

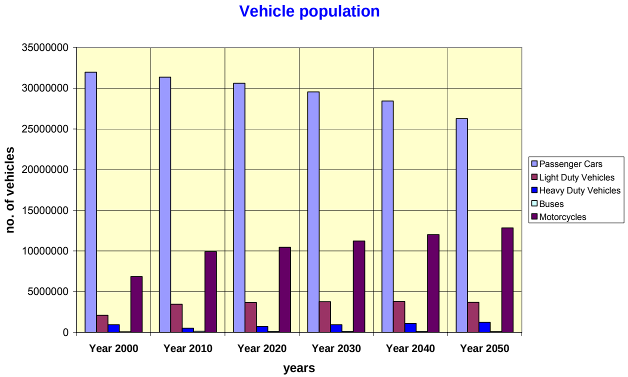


Fig. 4.5.1.3

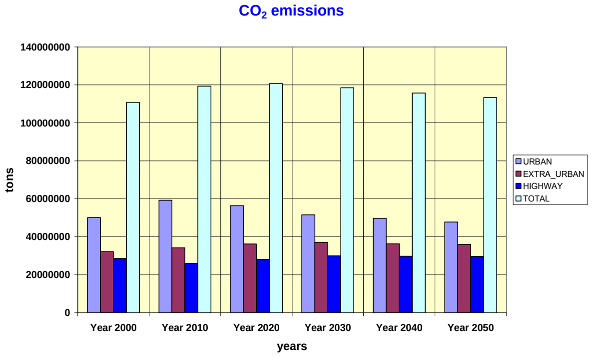


Fig. 4.5.1.2

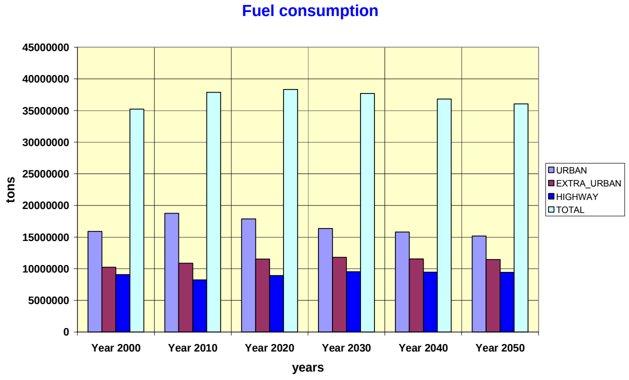


Fig. 4.5.1.4

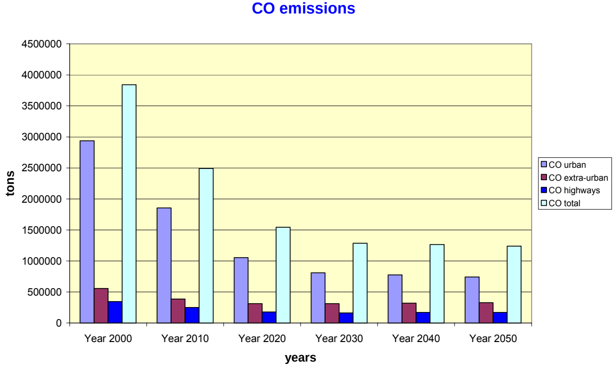


Fig. 4.5.1.5

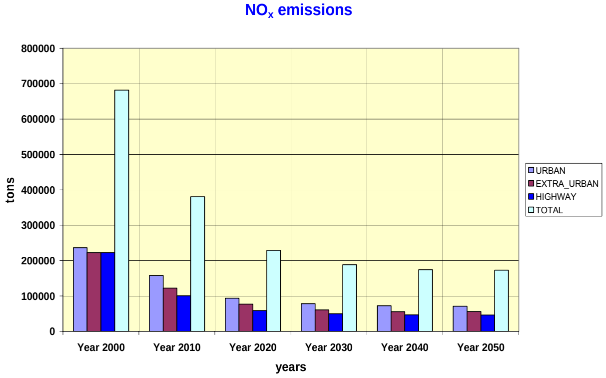


Fig. 4.5.1.8

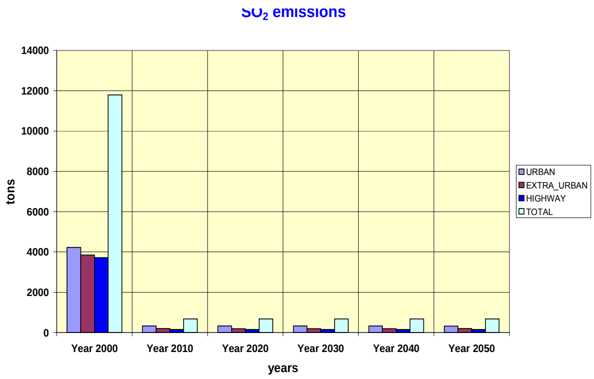


Fig. 4.5.1.6

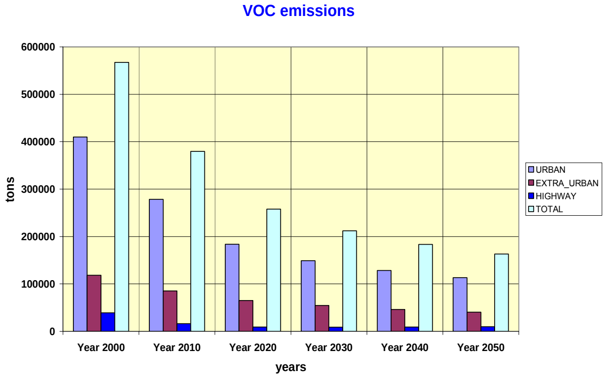


Fig. 4.5.1.9

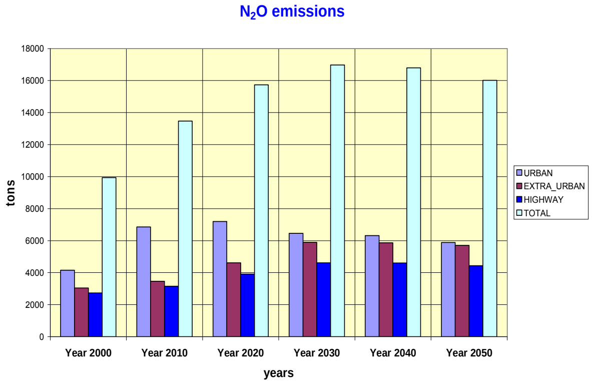


Fig. 4.5.1.7

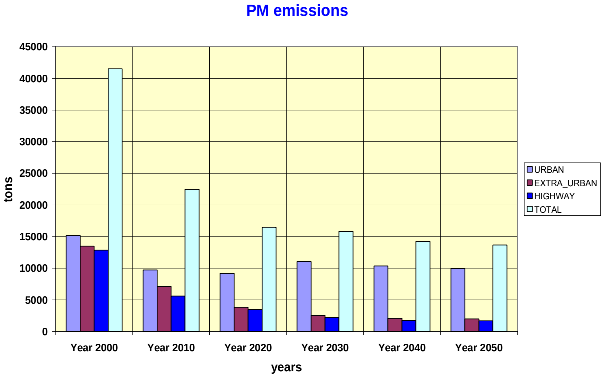
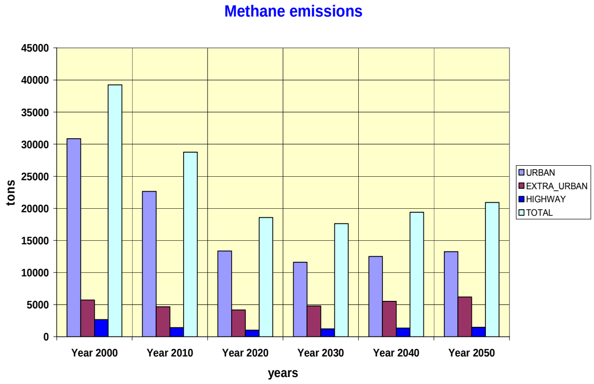


Fig. 4.5.1.10



4.5.2 Hydrogen high penetration scenario

Looking at the results of the high hydrogen penetration scenario in terms of vehicles, only the categories of passenger cars, buses and light duty vehicles are interested to the hydrogen switch. Most of the conventional passenger cars are removed after 2020 (fig. 4.5.2.1), while for buses the switch is faster. At 2050 the share of conventional vehicles are 25.5% for passenger cars, 12.8% for buses and 23.5% for LDVs. Due to this consistent reduction of the above categories of vehicles, it is quite easy to understand that there is a large reduction of the pollutant emissions, in particular in the urban domains, where the hydrogen vehicles are particularly used and therefore become very effective in reducing atmospheric pollution. An exception can be seen for VOCs (fig. 4.5.2.6) and CH_4 (fig. 4.5.2.9), as for such pollutants the effect of motorcycles becomes particularly relevant and overrides the positive contribution of the hydrogen vehicles.. It is to be underlined that, for fuel consumption (fig. 4.5.2.2), the reduction which is shown interests just the conventional fuels, while for CO_2 (fig. 4.5.2.3) the reduction effect is to be considered just at the point of use. This doesn't give any information on the CO_2 cumulative effects, which should also include the hydrogen contribution. In particular, the type of primary energy source, the processes used to produce hydrogen, the adoption of CO_2 capture and sequestration processes during the hydrogen production phase, etc. should be considered to have a real indication of CO_2 behavior.

Fig. 4.5.2.1

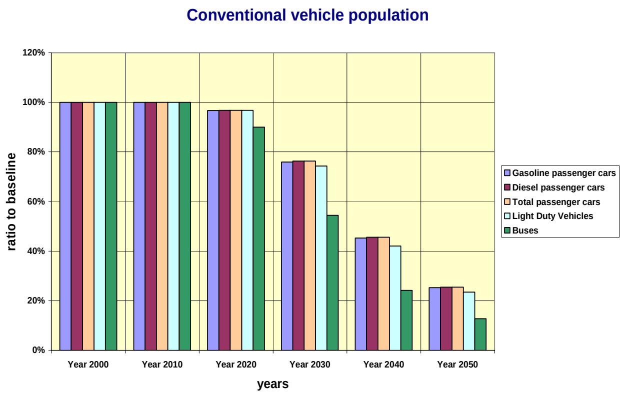


Fig. 4.5.2.2

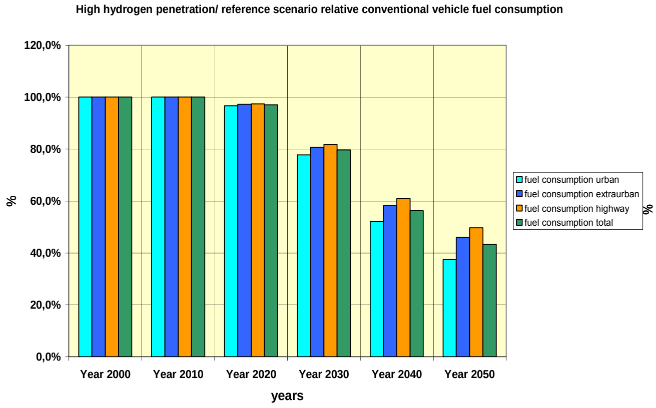


Fig. 4.5.2.3

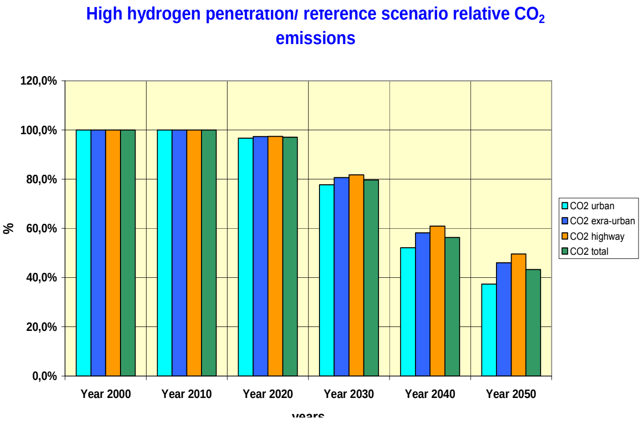


Fig. 4.5.2.4

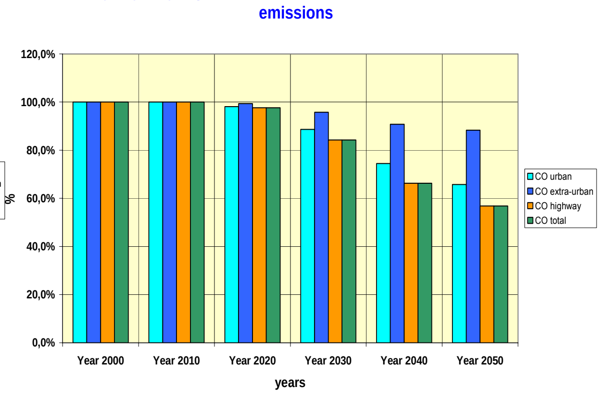


Fig. 4.5.2.5

High hydrogen penetration/ reference scenario relative NOx emissions

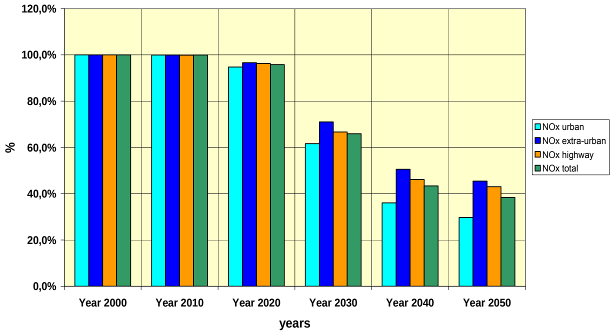


Fig. 4.5.2.6

High hydrogen penetration/ reference scenario relative VOC emissions

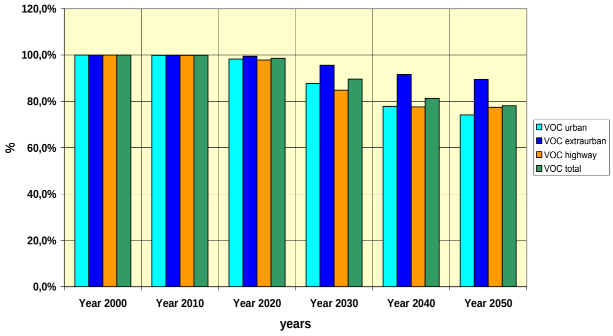


Fig. 4.5.2.7

High hydrogen penetration/ reference scenario relative PM emissions

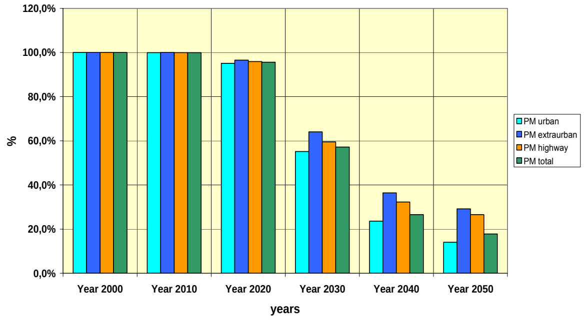


Fig. 4.5.2.8

Hydrogen high penetration / reference scenario N_2O relative emissions

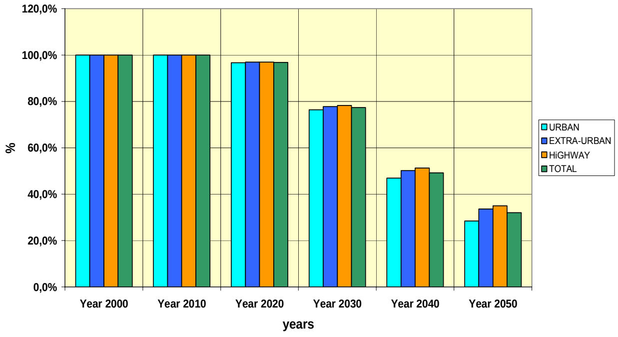


Fig. 4.5.2.9

High hydrogen penetration/ reference scenario relative methane emissions

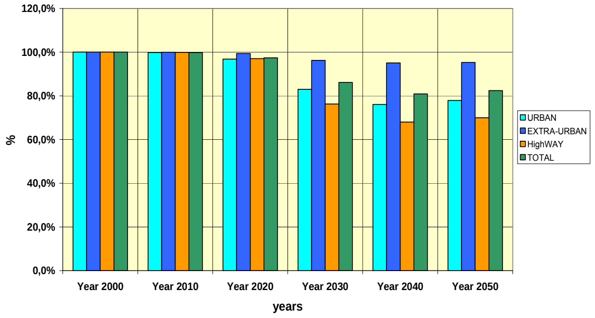
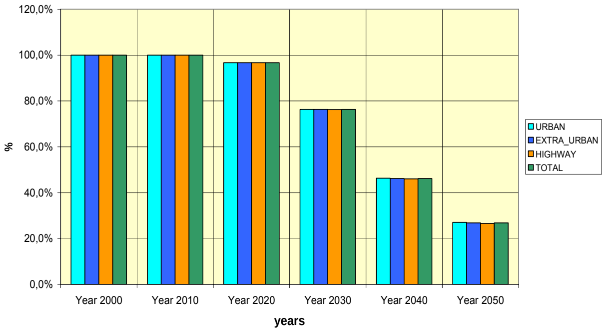


Fig. 4.5.2.10

Hydrogen high penetration / reference scenario relative NH3 emissions



4.5.3 Hydrogen low penetration scenario

For the low hydrogen penetration scenario it can be seen a quite different behavior respect to the high one, whose interpretation is not very easy (fig. 4.5.3.1). In fact, even if at 2050 the shares of the hydrogen vehicles are lower than the corresponding ones of the high penetration scenario, at the beginning of the deployment it can be seen the opposite situation. Looking at passenger cars, buses and LVDs the shares at 2020 are respectively 94.8%, 85.3% and 96.7% against 94.8%, 90.0% and 96.7% of the high penetration scenario. At the end of the period the conventional cars, buses and LDVs have a share which is respectively 49.2%, 27.2% and 46.6% against 25,5%, 12.8% and 23.5% of the high penetration scenario.

Due to the above conventional passenger car reduction, there is a marginal reduction of the pollutant emissions respect to the one shown by the high penetration scenario. The emission reduction is even lower for VOCs (fig. 4.5.3.6) and CH4 (fig. 4.5.3.9) as for such pollutants the effect of motorcycles is prevailing. For fuel consumption (fig. 4.5.3.2), the final share of the conventional fuels reaches 60% respect to the baseline. A similar figure is achieved for CO_2 (fig. 4.5.3.3), with the same care to use this figure, as indicated for the high penetration scenario. This is in fact what is the CO_2 emission at the point of use, but it doesn't necessarily imply that the same reduction is achieved if the entire hydrogen chains are considered in the analysis.

Fig. 4.5.3.1

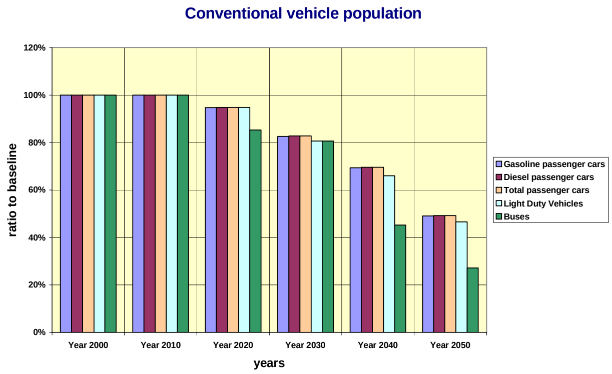


Fig. 4.5.3.3

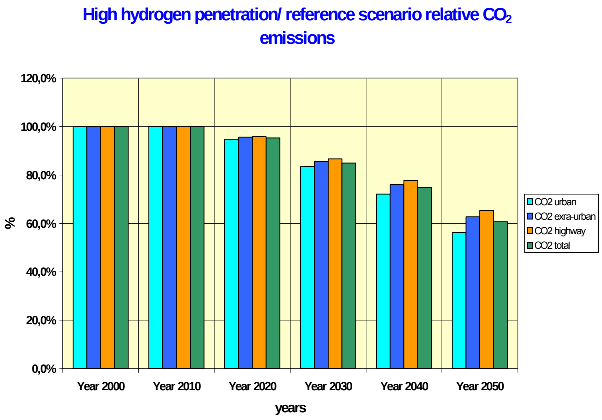


Fig. 4.5.3.2

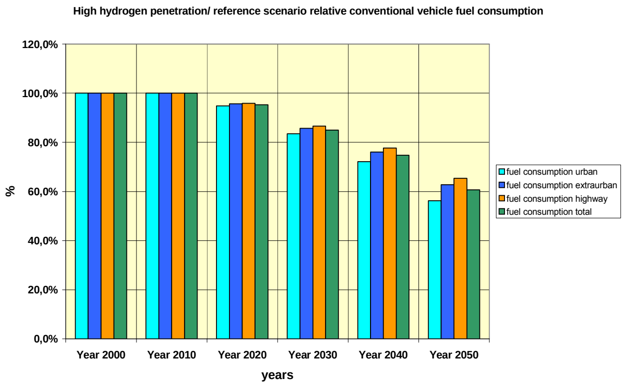


Fig. 4.5.3.4

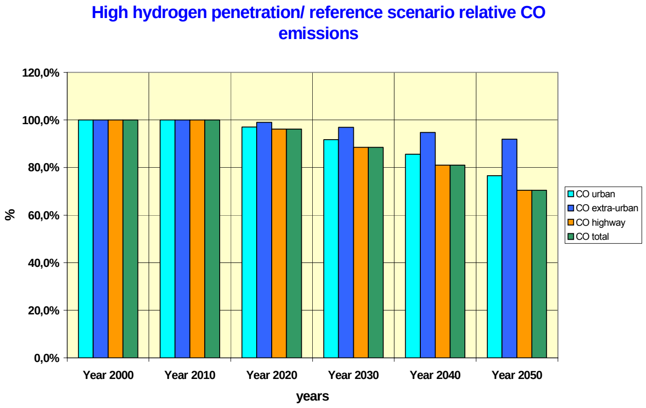


Fig. 4.5.3.5

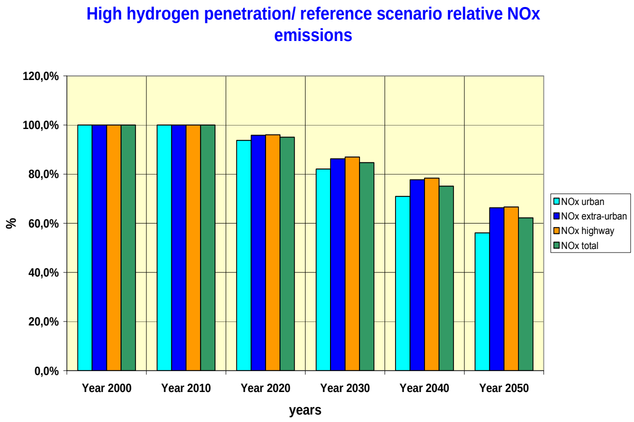


Fig. 4.5.3.6

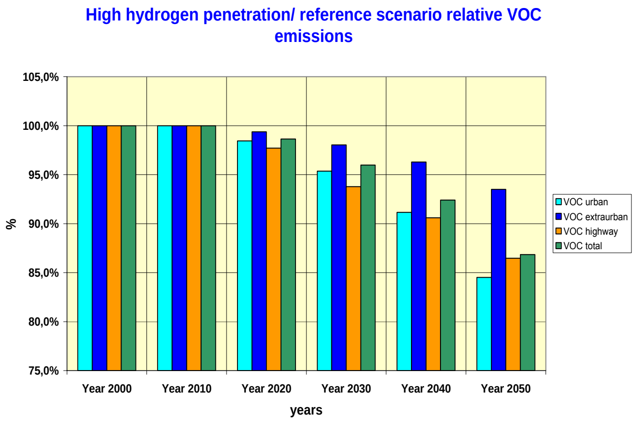


Fig. 4.5.3.7

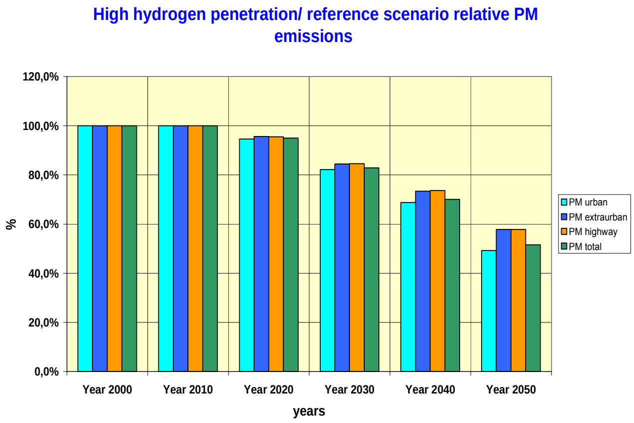


Fig. 4.5.3.8

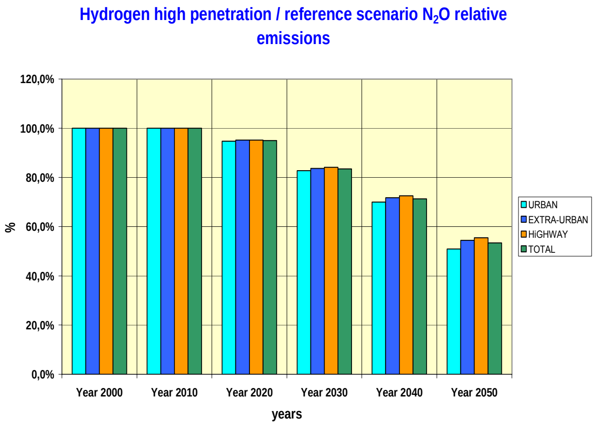


Fig. 4.5.3.9

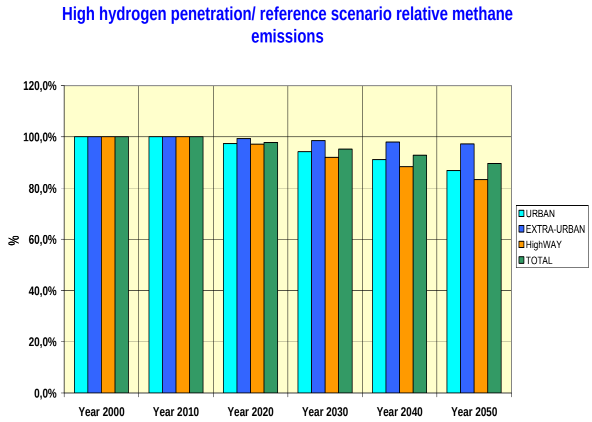
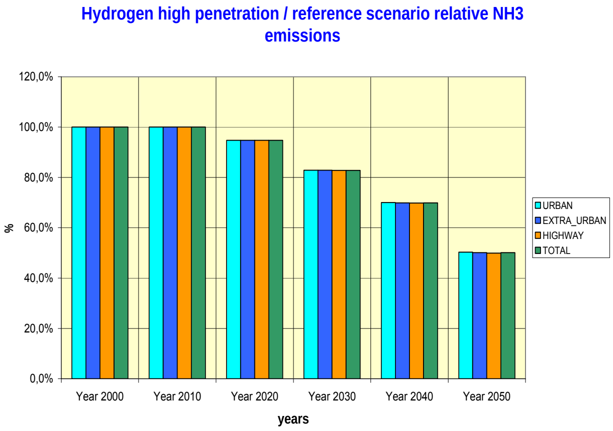


Fig. 4.5.3.10



4.6 The Netherlands

4.6.1 Baseline

Running COPERT on the baseline provides a lot of interesting results. Looking at the vehicle distribution provided by MARKAL, it can be seen that the conventional passenger cars are growing in the first portion of the time scale up to a level of about 10 millions of vehicles, which then stabilizes (fig. 4.6.1.1). Also for the other categories of vehicles the trend is increasing, especially for two wheels which at 2050 more than double their original number. The main result is that the fuel consumption (fig. 4.6.1.2) is also increasing. In any case, at the end of the period, the fuel consumption seems to go into saturation, with the CO_2 following similar trends. For N_2O instead the trend is increasing in the period, probably as consequence of the large share of diesel cars. It is to be underlined that about one half of the fuel is consumed in the urban domain.

Due to the effect of the new legislations, which reduce the exhaust emission limits of the new vehicles, for important regulated pollutants such as CO (fig. 4.6.1.4) and NO_x (fig 4.6.1.5), there is a decreasing emission trend in the first period followed by a stabilization, as after 2015 no additional improvement in the legislation is assumed and then the positive effect provided by the scrapping of the old dirty vehicles is no more present. For PM (fig 4.6.1.7) instead, due to the larger importance of diesel vehicles in the overall fleet, there is an increasing trend. In any case for almost of the pollutants there is a halving of the 2000 emissions, with the most consistent effects that are detected in urban areas. A behavior similar to CO and NO_x interests also VOCs (fig 4.6.1.6) and CH_4 (fig 4.6.1.10. The SO_2 emissions (fig 4.6.1.8) also reach very low levels, in dependence of the constraints that no more than 10 ppm is allowed in future fuels.

Fig. 4.6.1.1

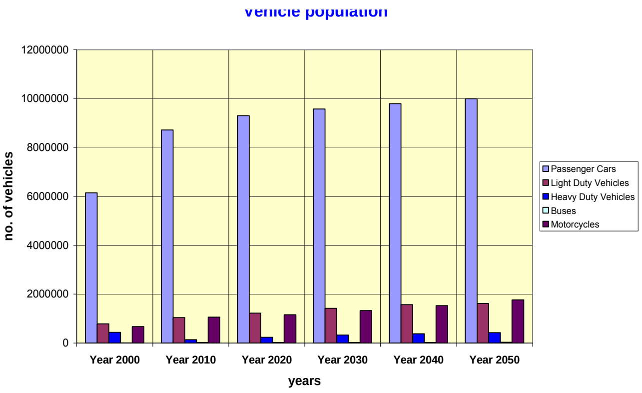


Fig. 4.6.1.3

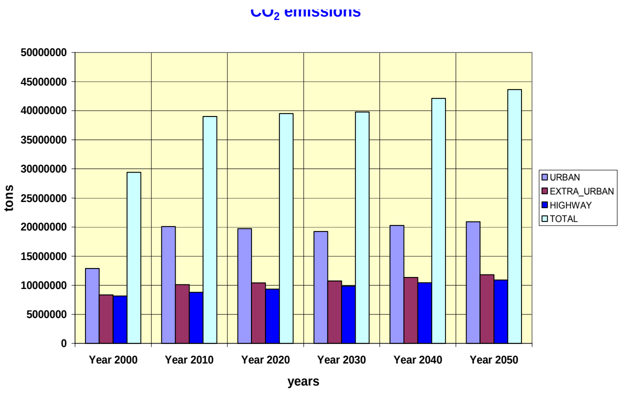


Fig. 4.6.1.2

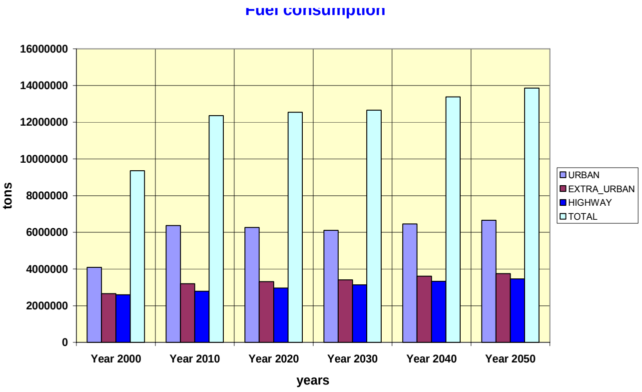


Fig. 4.6.1.4

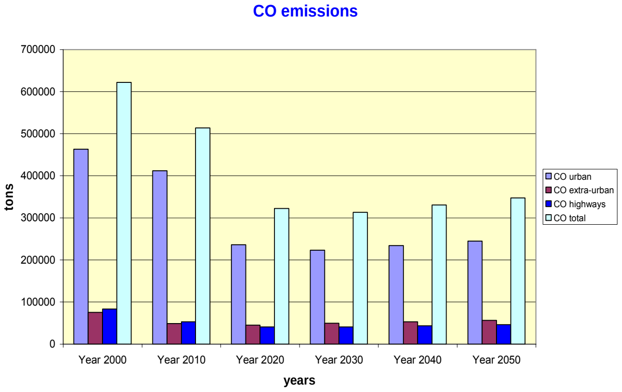


Fig. 4.6.1.5

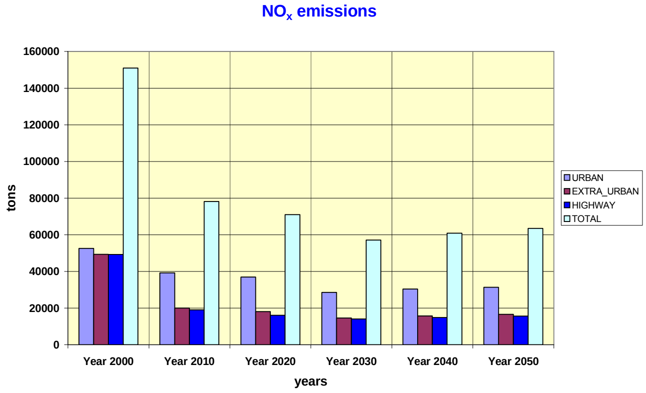


Fig. 4.6.1.8

Fig. 4.6.1.6

ig. 4.6.1.9

4.6.1.8

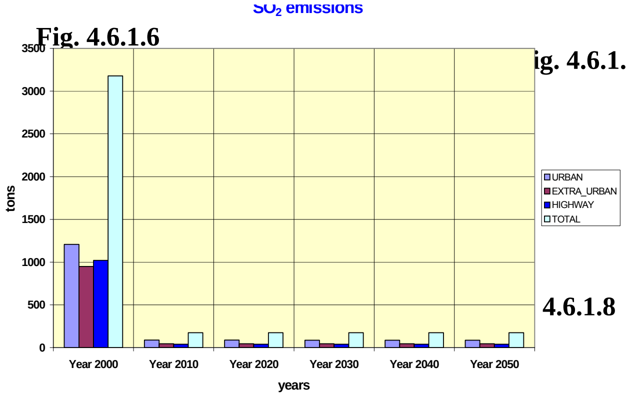


Fig. 4.6.1.6

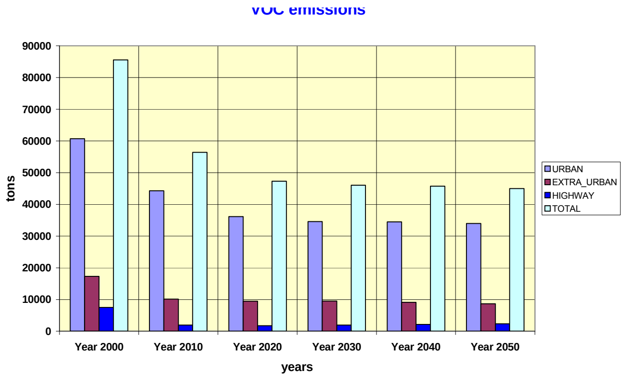


Fig. 4.6.1.9

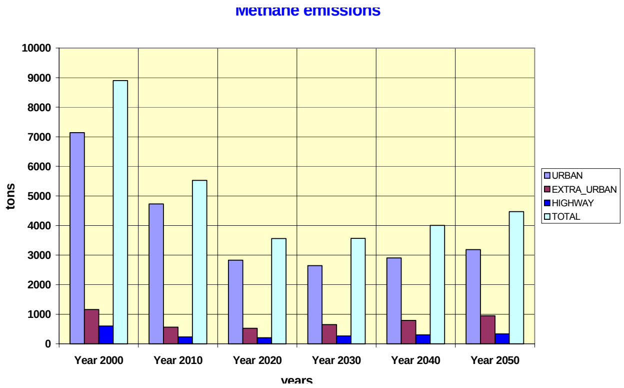


Fig. 4.6.1.7

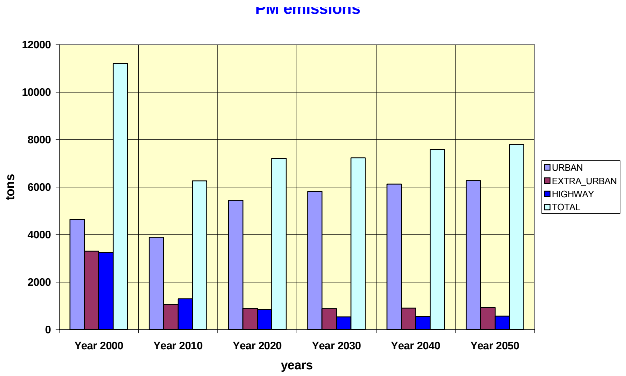
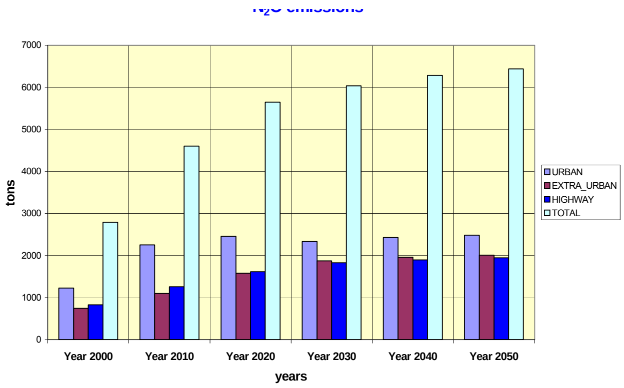


Fig. 4.6.1.10



4.6.2 Hydrogen high penetration scenario

Looking at the results of the high hydrogen penetration scenario, in terms of vehicles only the categories of passenger cars, buses and light duty vehicles are interested to the hydrogen switch. Most of the conventional passenger cars are removed just in the period 2020-2040 (fig. 4.6.2.1), going from 97% to 25%, with also the buses having quite similar behavior; in particular the buses are faster converted to hydrogen technologies than passenger cars, as it is normally expected. At 2050 the shares of conventional vehicles are 25.5% for passenger cars, 12.8% for buses and 23.5% for LDVs. Due to this consistent reduction of the above categories of vehicles, it is quite easy to understand that there is a large reduction of the pollutant emissions, in particular in the urban domains, where the hydrogen vehicles are particularly used and therefore become very effective in reducing atmospheric pollution. Some exception is shown for VOCs (fig. 4.6.2.6) and CH_4 (fig. 4.6.2.9), as for such pollutants the effect of motorcycles is particularly relevant and therefore the resulting positive effect of the hydrogen vehicles is considerably lower. It is to be underlined that, for fuel consumption (fig. 4.6.2.2), the reduction interests just the conventional fuels, while for CO_2 (fig. 4.6.2.3) the reduction effect is to be considered just at the point of use. This doesn't give any information on the CO_2 cumulative effects, which should also include the hydrogen contribution. In particular, the type of primary energy source, the processes used to produce hydrogen, the adoption of CO_2 capture and sequestration processes during the hydrogen production phase, etc. should be considered to have a real indication of CO_2 behavior.

Fig. 4.6.2.1

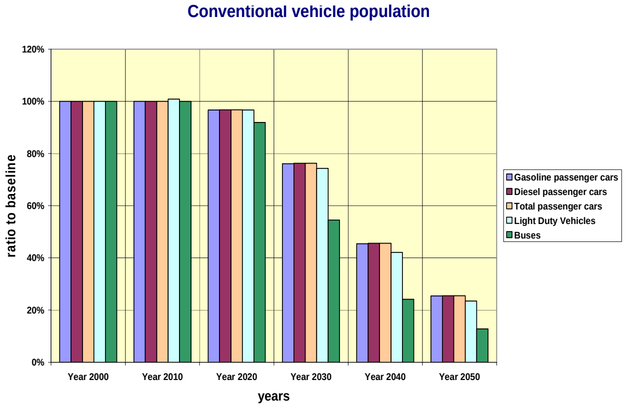


Fig. 4.6.2.3

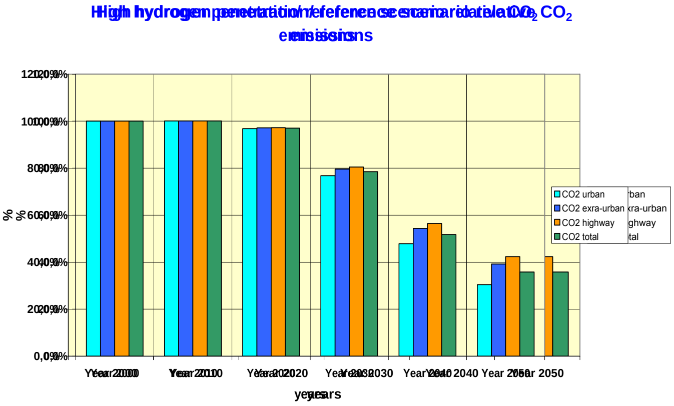


Fig. 4.6.2.2

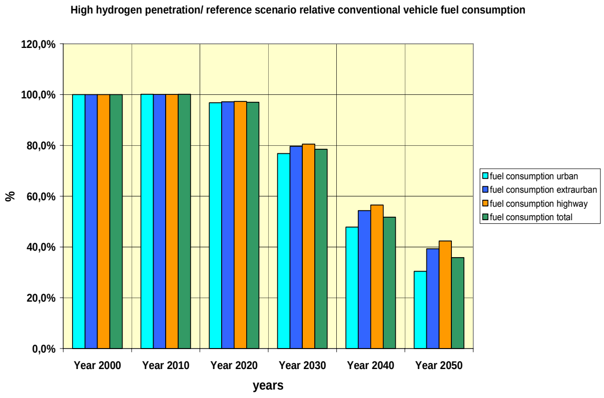


Fig. 4.6.2.4

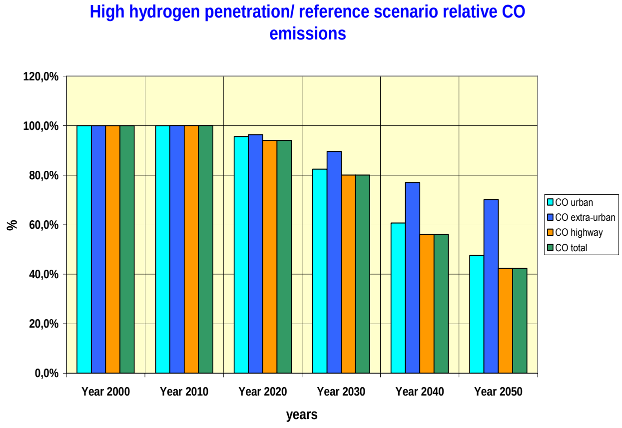


Fig. 4.6.2.5

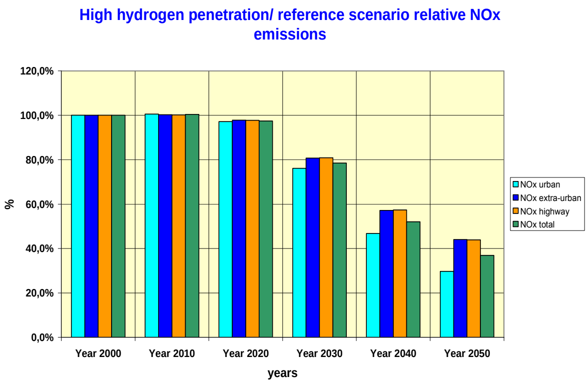


Fig. 4.6.2.6

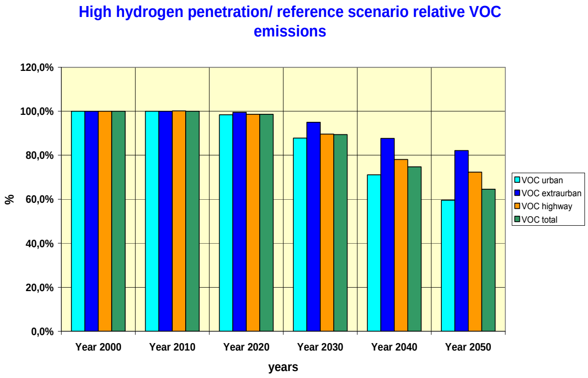


Fig. 4.6.2.7

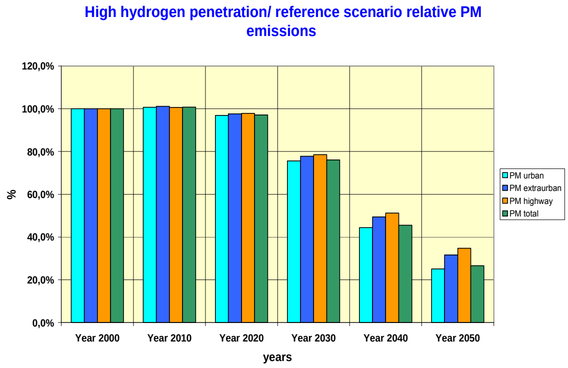


Fig. 4.6.2.8

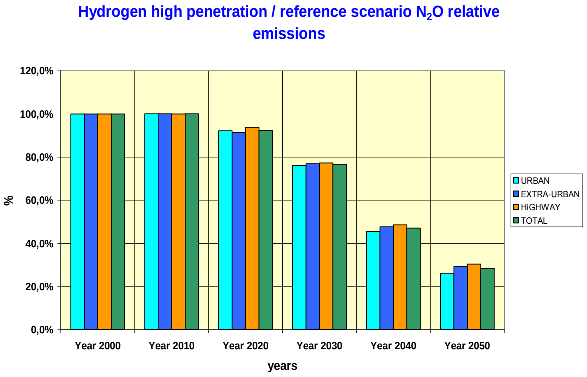


Fig. 4.6.2.9

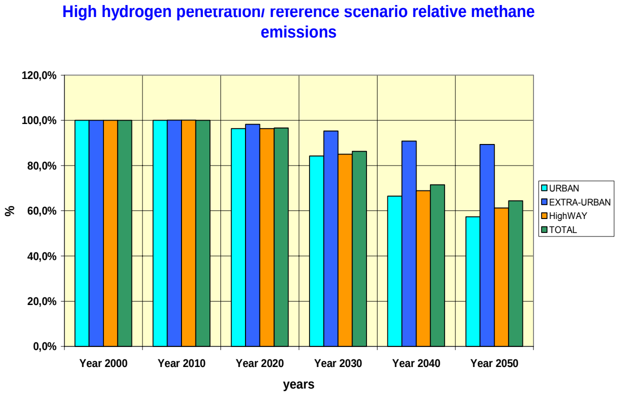
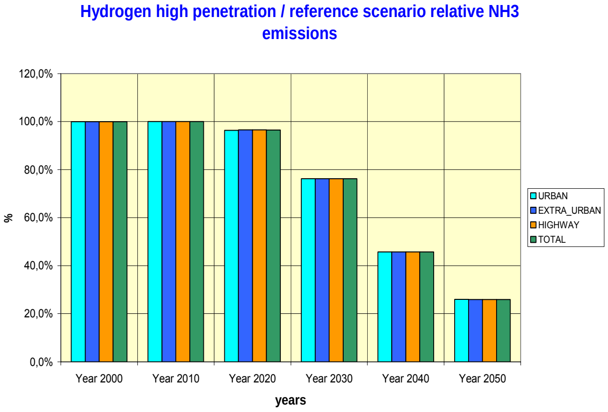


Fig. 4.6.2.10



4.6.3 Hydrogen low penetration scenario

For the low hydrogen penetration scenario it can be seen a quite different behavior respect to the high one (fig. 4.6.3.1) and also in this case the hydrogen buses are the vehicles which are faster introduced in the country market. The change of conventional passenger cars respect to the baseline is mainly carried out from 2030 to 2050 and this leads to a conventional vehicle share at 2050 is about 60% of the reference scenario. As said before buses and LDVs are less interested and their share at 2050 is respectively 36.2% and 58.4% against 12.8% and 23.5% of the high scenario.
Due to the above conventional passenger car reduction, the reduction of the pollutant emissions is marginal respect to the high penetration scenario. The trends are then delayed respect to the previous scenario; even less effects are shown for VOCs (fig. 4.6.3.6) and CH4 (fig. 4.6.3.9) as for such pollutants the contribution of motorcycles is prevailing. For fuel consumption (fig. 4.6.3.2), the final share of the conventional fuels reaches 65%. A similar figure is achieved for CO_2 (fig. 4.6.3.3), with the same care to use this figure as indicated for the high penetration scenario. This is in fact what is the CO_2 emission at the point of use, but it doesn't necessarily imply that the same reduction is achieved if the entire hydrogen chains are considered in the analysis.

Fig. 4.6.3.1

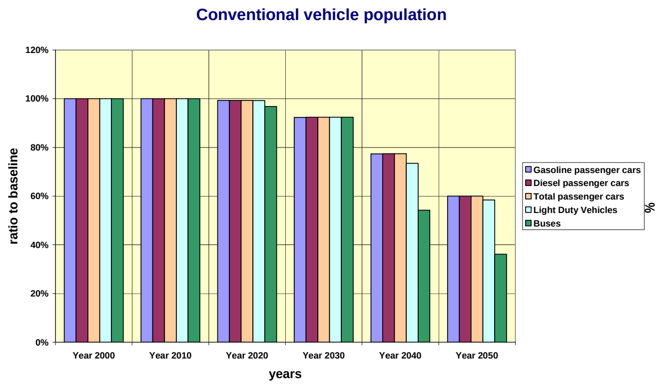


Fig. 4.6.3.3

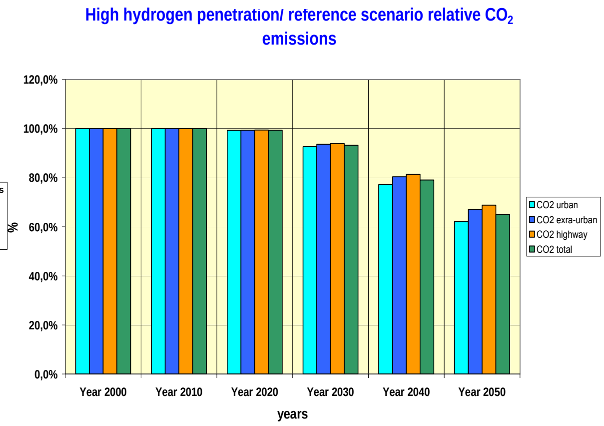


Fig. 4.6.3.2

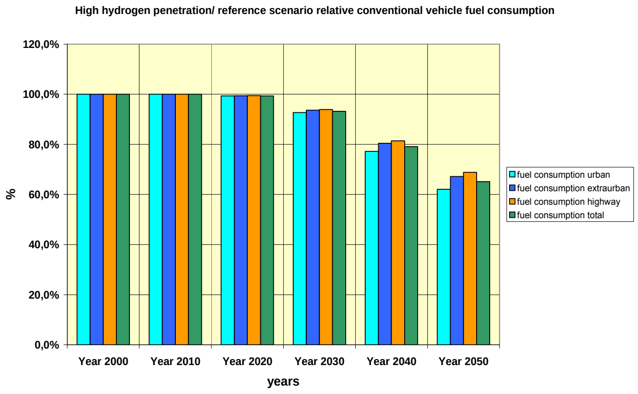


Fig. 4.6.3.4

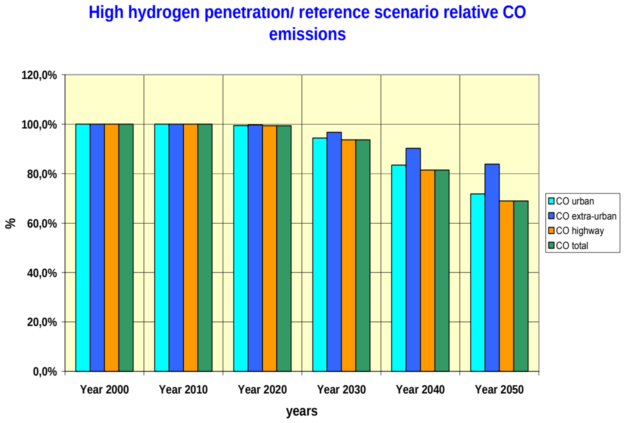


Fig. 4.6.3.5

High hydrogen penetration/ reference scenario relative NOx emissions

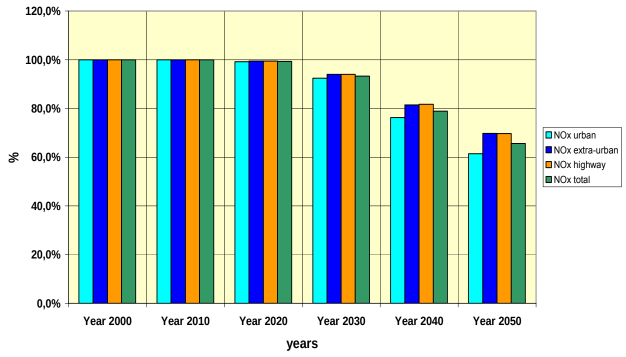


Fig. 4.6.3.6

High hydrogen penetration/ reference scenario relative VOC emissions

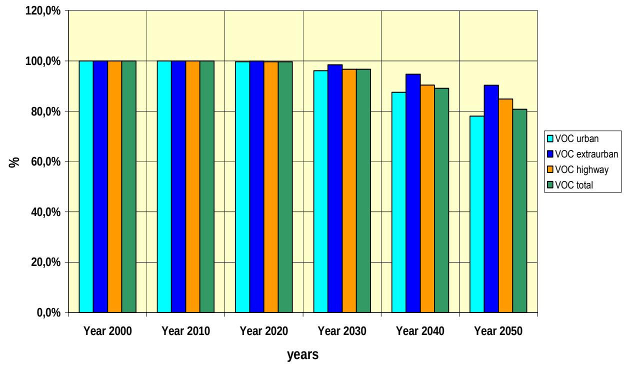


Fig. 4.6.3.7

High hydrogen penetration/ reference scenario relative PM emissions

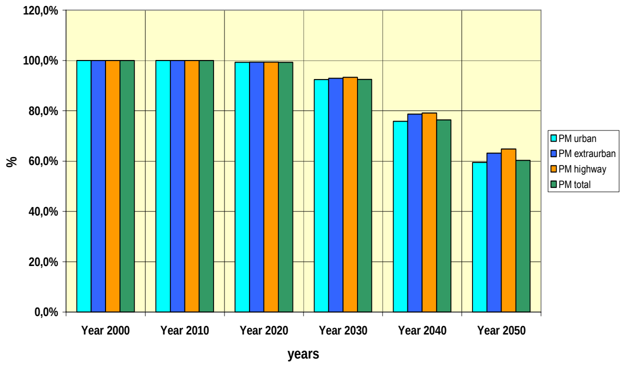


Fig. 4.6.3.8

Hydrogen high penetration / reference scenario N_2O relative emissions

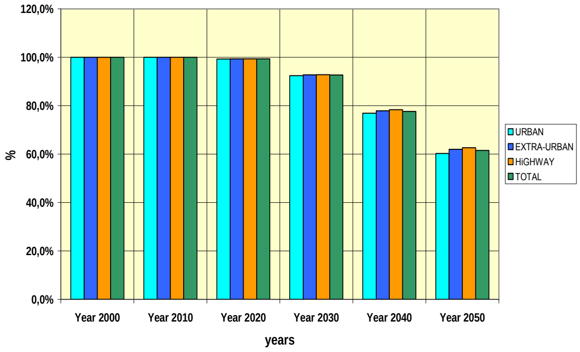


Fig. 4.6.3.9

High hydrogen penetration/ reference scenario relative methane emissions

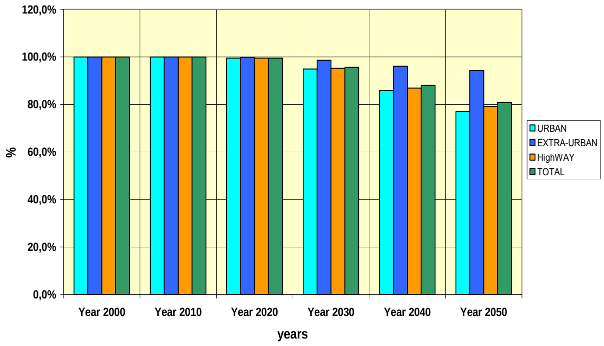
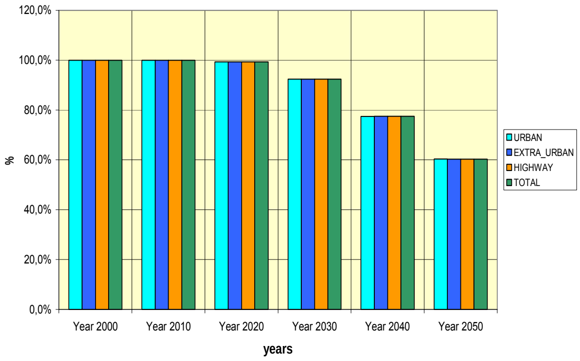


Fig. 4.6.3.10

Hydrogen high penetration / reference scenario relative NH3 emissions



4.7 Norway

4.7.1 Baseline

Running COPERT on the baseline provides a lot of interesting results. Looking at the vehicle distribution provided by MARKAL, it can be seen that the conventional passenger cars are growing in the first portion of the time scale up to a level of about 2.7 millions of vehicles and then stabilizes, even if at the end the trend becomes decreasing(fig. 4.7.1.1). This doesn't interest the other categories of vehicles whose trend is slowly increasing. The fuel consumption (fig. 4.7.1.2) shows a trend that follows the passenger car behavior, as these vehicle represent the most portion of the overall fleet and therefore, at the end of the period, stabilizes, with the CO_2 and N_2O following similar trends. It is to be underlined that about a half of the fuel is consumed in the urban domain.
Due to the effect of the new legislations, which reduce the exhaust emission limits of the new vehicles, for important regulated pollutants such as CO (fig. 4.7.1.4) and NO_x (fig 4.7.1.5), there is a decreasing emission trend in the first period followed by a stabilization, as after 2015 no additional improvement in the legislation is assumed and then the positive effect provided by the scrapping of the old dirty vehicles is no more present. For PM (fig 4.7.1.7) instead, there is a large increase after the reduction, which cannot be justified with larger importance of diesel vehicles in the overall fleet and need to be specifically investigated, although it is understandable that an increasing trend for these emissions could happen. In any case for all the other pollutants there is a halving of the 2000 emissions, whose most consistent effects are detected in urban areas. A behavior similar to CO and NO_x interests also VOCs (fig 4.7.1.6) and CH_4 (fig 4.7.1.10. The SO_2 emissions (fig 4.7.1.8) also reach very low levels, in dependence of the constraints that no more than 10 ppm is allowed in future fuels.

Fig. 4.7.1.1

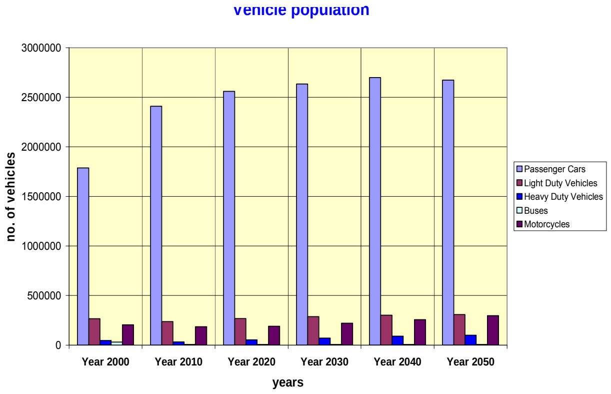


Fig. 4.7.1.3

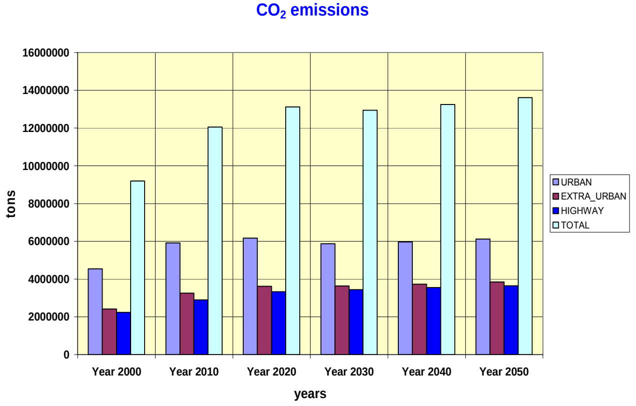


Fig. 4.7.1.2

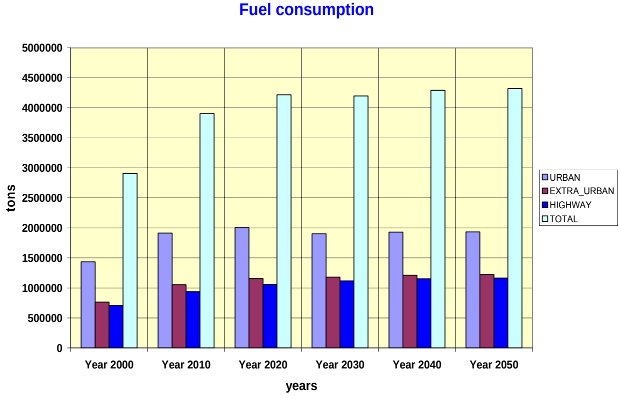


Fig. 4.7.1.4

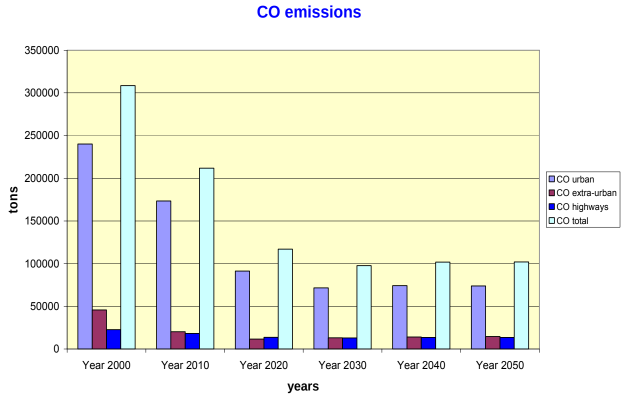


Fig. 4.7.1.5

NO_x emissions

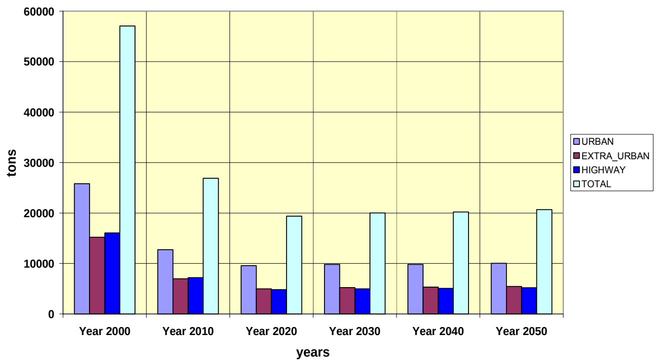


Fig. 4.7.1.6

VOC emissions

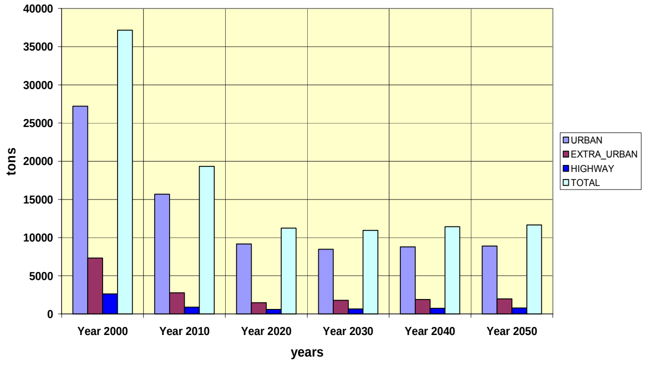


Fig. 4.7.1.7

PM emissions

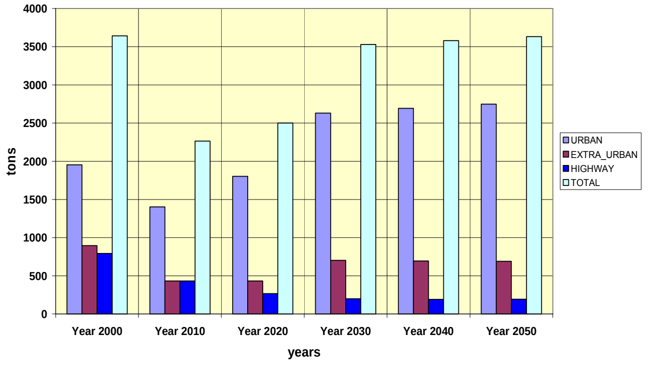


Fig. 4.7.1.8

SO_2 emissions

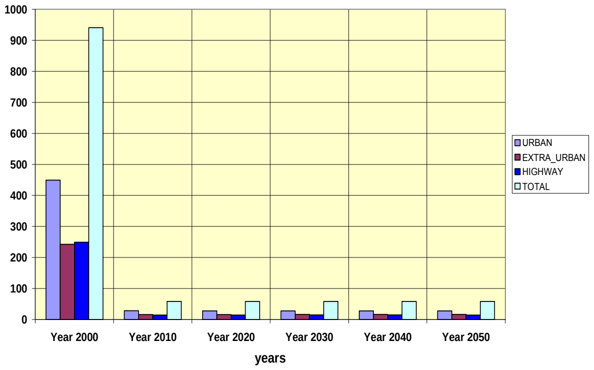


Fig. 4.7.1.9

N_2O emissions

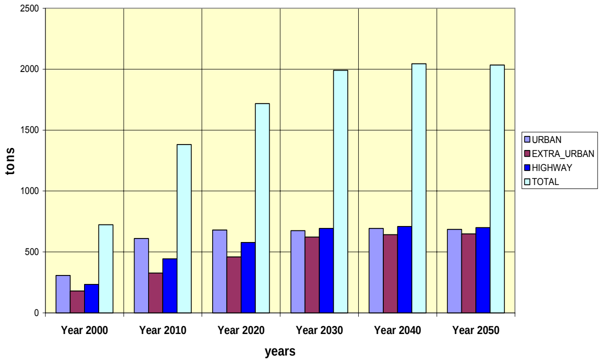
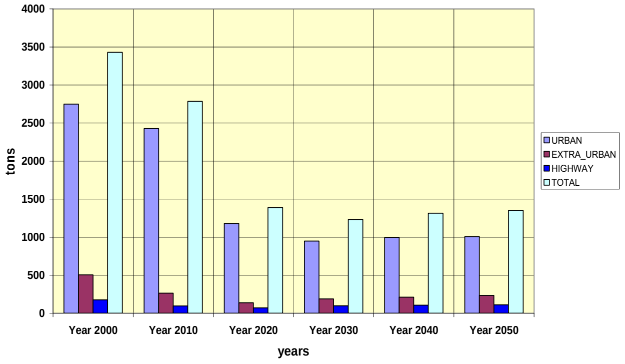


Fig. 4.7.1.10

Methane emissions



4.7.2 Hydrogen high penetration scenario

Looking at the results of the high hydrogen penetration scenario, in terms of vehicles only the categories of passenger cars, buses and light duty vehicles are interested to the hydrogen switch. Most of the conventional passenger cars are removed just in the period 2020-2040 (fig. 4.6.2.1), going from 95% to 45%, with also the buses and LDVs having quite similar behavior; in particular the buses are faster converted to hydrogen technologies than passenger cars, as it is normally expected during the time interval and at the end of the period their share is a little bit lower. At 2050 the share of conventional vehicles are 25% for passenger cars, 12.8% for buses and 22.8% for LDVs. Due to this consistent reduction of the above categories of vehicles, it is quite easy to understand that there is a large reduction of the pollutant emissions, in particular in the urban domains, where the hydrogen vehicles are particularly used and therefore become very effective in reducing atmospheric pollution. Some lower impact is shown for VOCs (fig. 4.7.2.6) and CH_4 (fig. 4.7.2.9), as for such pollutants the effect of motorcycles is particularly relevant. It is to be underlined that, for fuel consumption (fig. 4.7.2.2), the reduction which is shown interests just the conventional fuels, while for CO_2 (fig. 4.7.2.3) the reduction effect is to be considered just at the point of use. This doesn't give any information on the CO_2 cumulative effects, which should also include the hydrogen contribution. In particular, the type of primary energy source, the processes used to produce hydrogen, the adoption of CO_2 capture and sequestration processes during the hydrogen production phase, etc. should be considered to have a real indication of CO_2 behavior.

Fig. 4.7.2.1

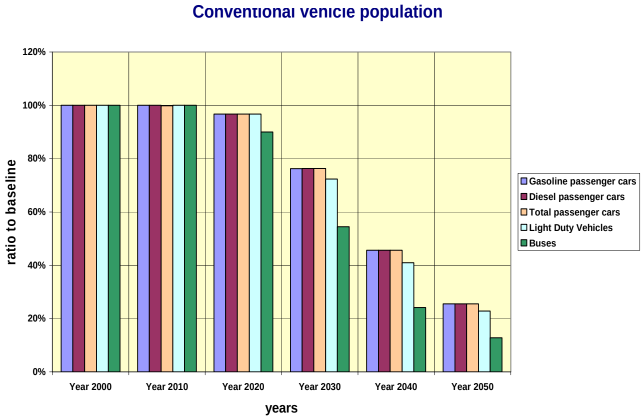


Fig. 4.7.2.3

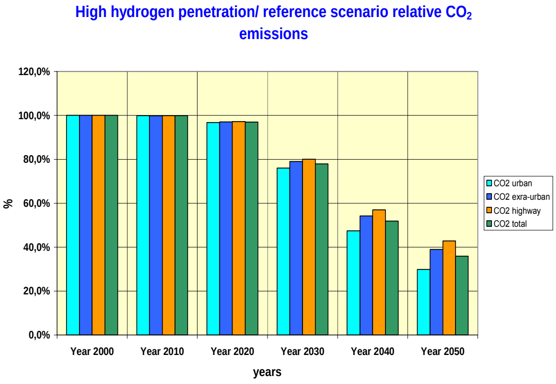


Fig. 4.7.2.2

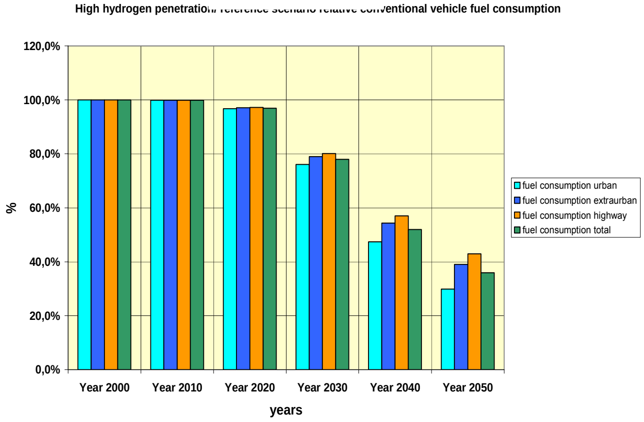


Fig. 4.7.2.4

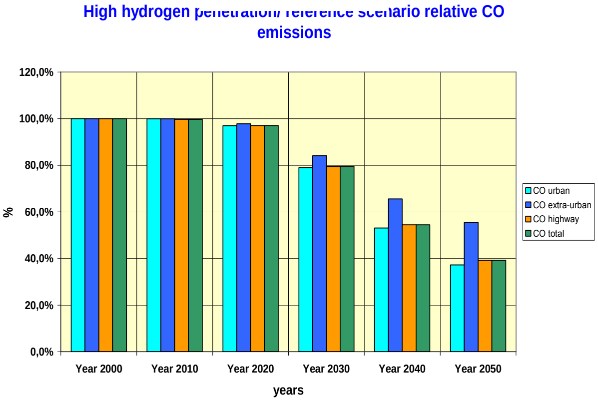


Fig. 4.7.2.5

High hydrogen penetration/ reference scenario relative NOx emissions

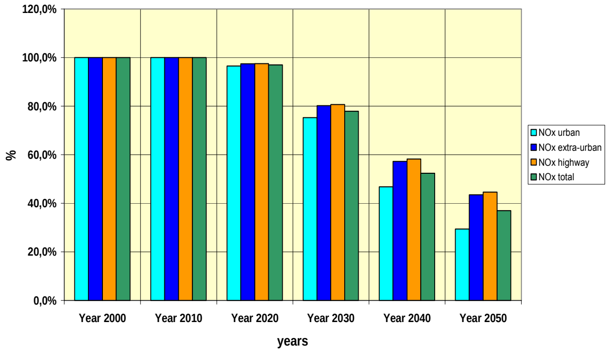


Fig. 4.7.2.6

High hydrogen penetration/ reference scenario relative VOC emissions

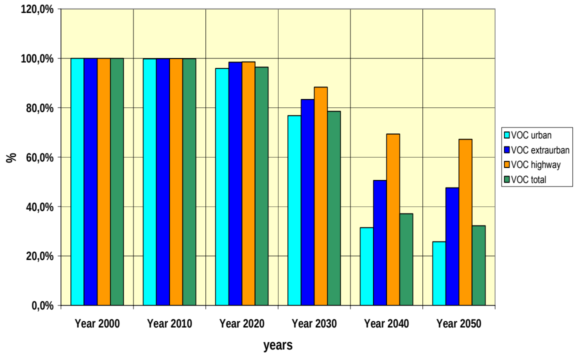


Fig. 4.7.2.7

High hydrogen penetration/ reference scenario relative PM emissions

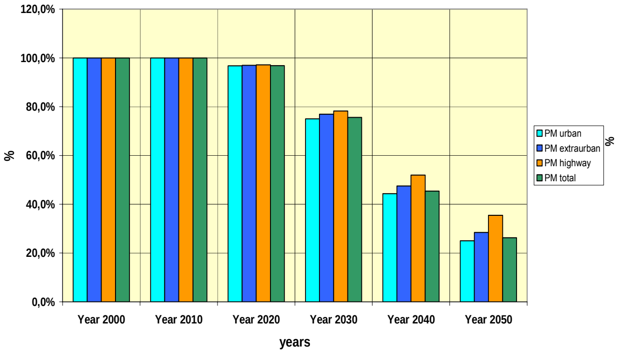


Fig. 4.7.2.8

Hydrogen high penetration / reference scenario N_2O relative emissions

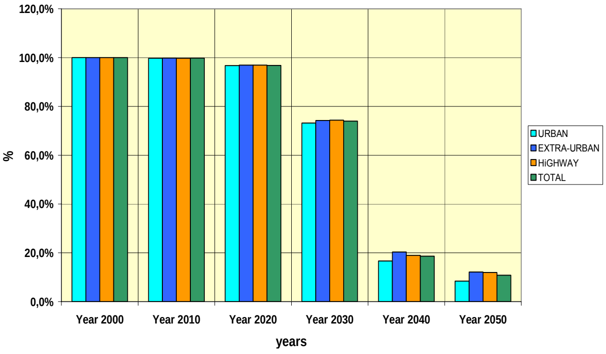


Fig. 4.7.2.9

High hydrogen penetration/ reference scenario relative methane emissions

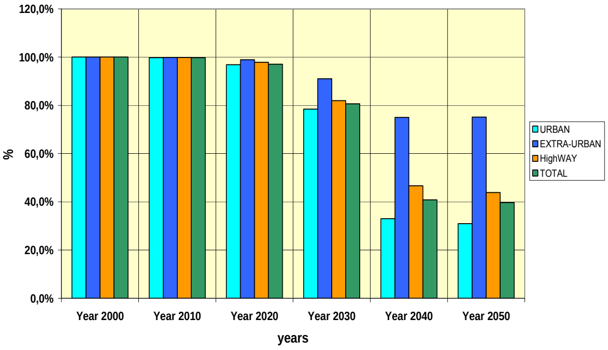
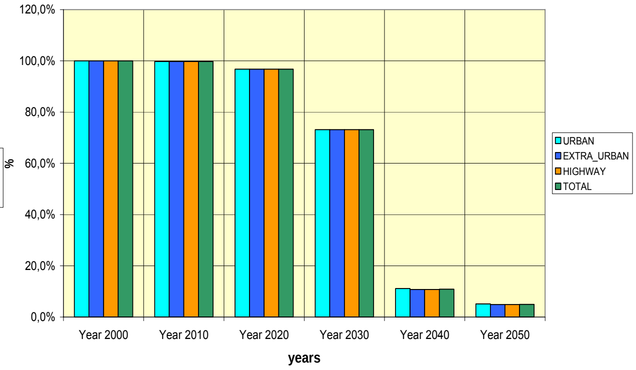


Fig. 4.7.2.10

Hydrogen high penetration / reference scenario relative NH3 emissions



4.7.3 Hydrogen low penetration scenario

For the low hydrogen penetration scenario it can be seen a quite different behavior respect to the high one (fig. 4.7.3.1) and also in this case the hydrogen buses are the vehicles which are faster introduced in the country market. The change of conventional passenger cars respect to the baseline is mainly carried out from 2030 to 2050 and this leads to a conventional vehicle share at 2050 is about 60% of the reference scenario. As said before buses and LDVs are less interested and their share at 2050 is respectively 36.2% and 56.8% against 12.8% and 23.5% of the high scenario.

Due to the above conventional passenger car reduction, the reduction of the pollutant emissions is marginal respect to the high penetration scenario. The trends are then delayed respect to the previous scenario; even less effects are shown for VOCs (fig. 4.7.3.6) and CH4 (fig. 4.7.3.9) as for such pollutants the contribution of motorcycles is prevailing. For fuel consumption (fig. 4.6.3.2), the final share of the conventional fuels reaches 65%. A similar figure is achieved for CO_2 (fig. 4.7.3.3), with the same care to use this figure as indicated for the high penetration scenario. This is in fact what is the CO_2 emission at the point of use, but it doesn't necessarily imply that the same reduction is achieved if the entire hydrogen chains are considered in the analysis.

Fig. 4.7.3.1

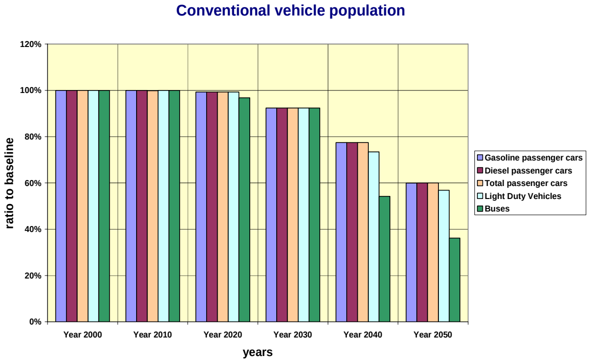


Fig. 4.7.3.3

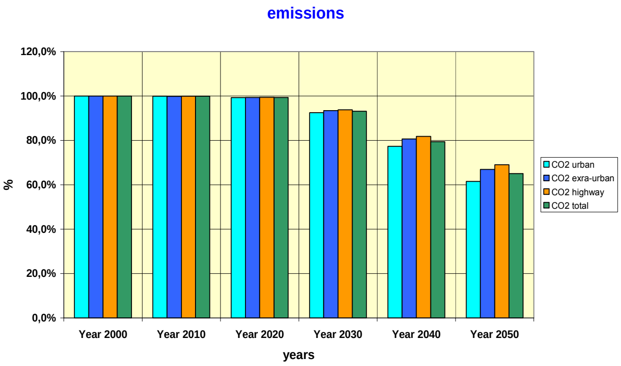


Fig. 4.7.3.2

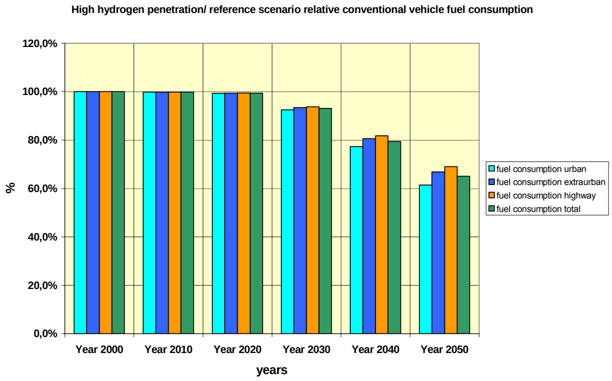


Fig. 4.7.3.4

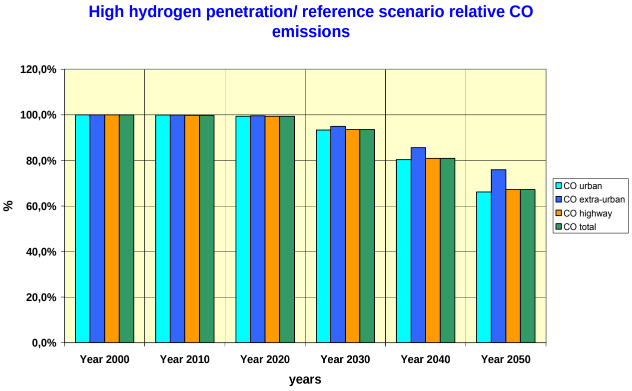


Fig. 4.7.3.5

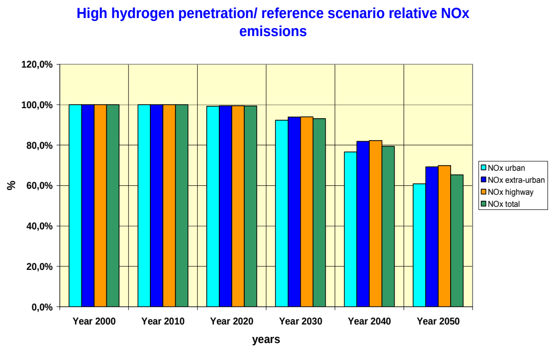

High hydrogen penetration/ reference scenario relative NOx emissions

Fig. 4.7.3.6

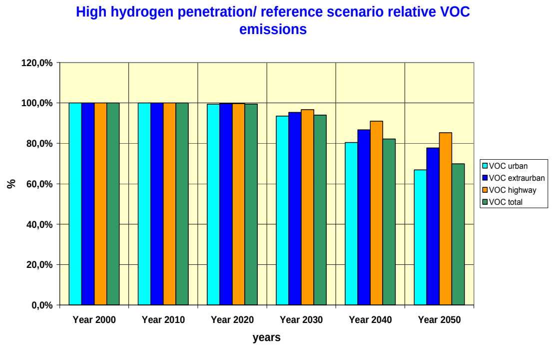

High hydrogen penetration/ reference scenario relative VOC emissions

Fig. 4.7.3.7

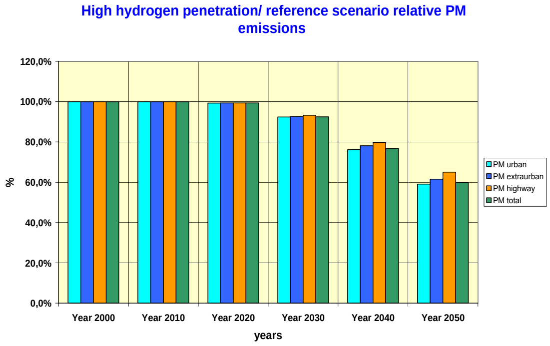

High hydrogen penetration/ reference scenario relative PM emissions

Fig. 4.7.3.8

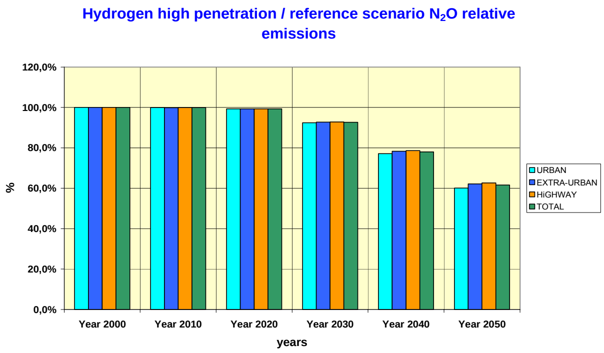

Hydrogen high penetration / reference scenario N_2O relative emissions

Fig. 4.7.3.9

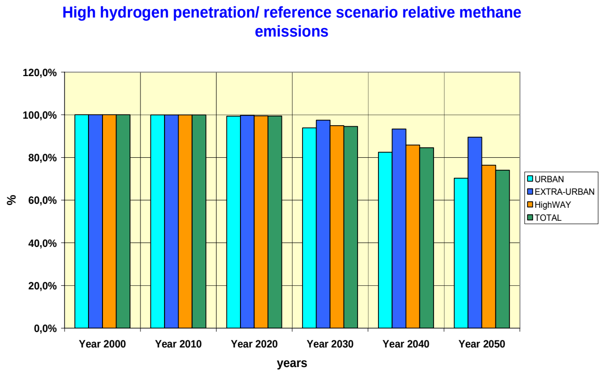
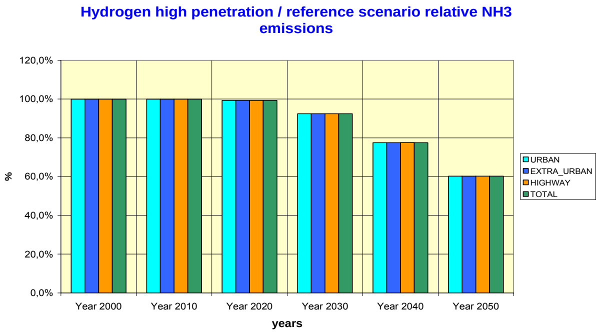

High hydrogen penetration/ reference scenario relative methane emissions

Fig. 4.7.3.10


Hydrogen high penetration / reference scenario relative NH3 emissions

4.8 Cumulative MS analysis

The environmental effects of the hydrogen scenarios of the Member States considered in the first phase of HyWays Project, normalized to the reference scenario, are then analyzed together, in order to get an idea at the first glance of the potential advantages related to the hydrogen deployment and where the benefits are more or less relevant. In the following paragraphs the high and low penetration scenarios will be shown, considering as indicators the following relative COPERT results: conventional fuel consumption, CO_2, CO NO_x, VOC, PM, N_2O, CH_4 and NH_3 emissions.

It is to be underlined that the fuel figures are related to conventional fuels only, while for the CO_2 the emissions are just estimated to the point of use. Of course, if also the hydrogen is added the fuel consumption would assume different values and the reduction respect to the basecase is lower but in any case not minimal, as can be seen in the fig. 4.1.1.1-4.1.1.6 for the basecase and the fig. 4.1.2.1-4.1.2.6 for the high penetration scenario. In other terms, due to the higher efficiency of fuel cell vehicles and being equal the transport demand, the overall fuel consumption in road transport, considering just the Tank to Wheel portion of the fuel chain, is certainly lower for the hydrogen scenarios.

Looking instead at CO_2, if the entire chain is considered, the level of reduction indicated in the following graphs could be achieved only if the hydrogen production is provided by renewable sources or there is the sequestration where fossil sources are used. The main indication is that the CO_2 reduction figures are to be considered as an upper bound of the hydrogen benefits and therefore this could be the maximum target achievable from road transport.

Another important consideration is that, due to the uneven penetration of hydrogen fuel into the different vehicle categories, the resulting effects are negatively biased by the presence of vehicles which are not involved in the transition. In particular the lack of introduction of hydrogen vehicles especially in the category of the Heavy Duty Vehicles doesn't allow to reach better environmental targets.

In any case from the graphs it is easy to see that all the MS get relevant benefits from the hydrogen deployment, even if the effects are not of the same level for all of them and for all the indicators.

4.8.1 *Cumulative hydrogen high penetration scenario analysis*

Fig. 4.8.1.1

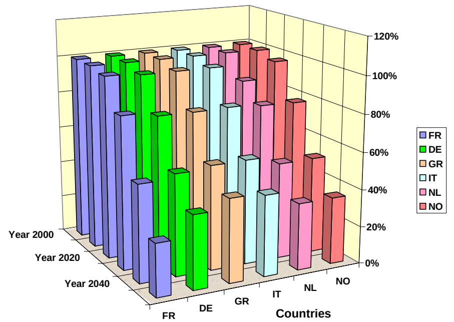


Fig. 4.8.1.2

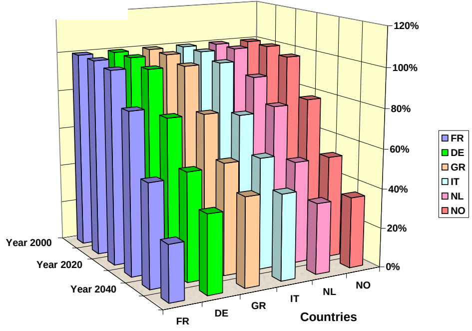


Fig. 4.8.1.3

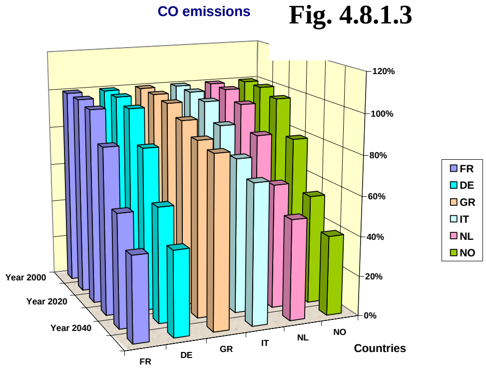
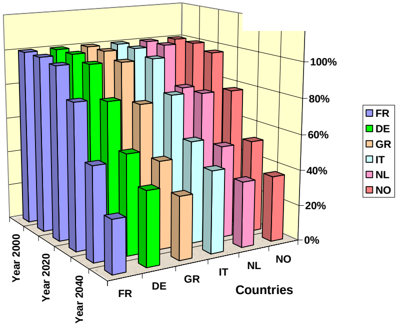


Fig. 4.8.1.4



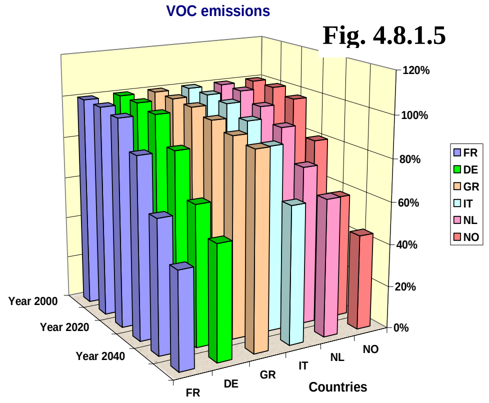


Fig. 4.8.1.5

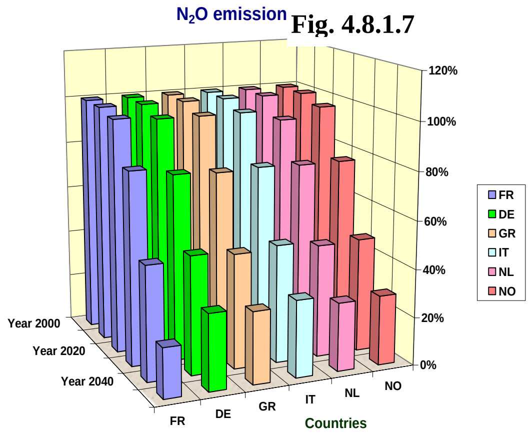


Fig. 4.8.1.7

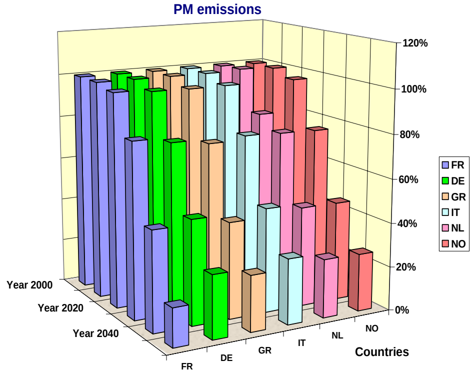


Fig. 4.8.1.6

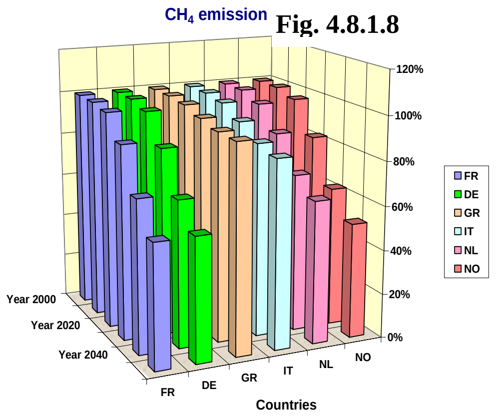


Fig. 4.8.1.8

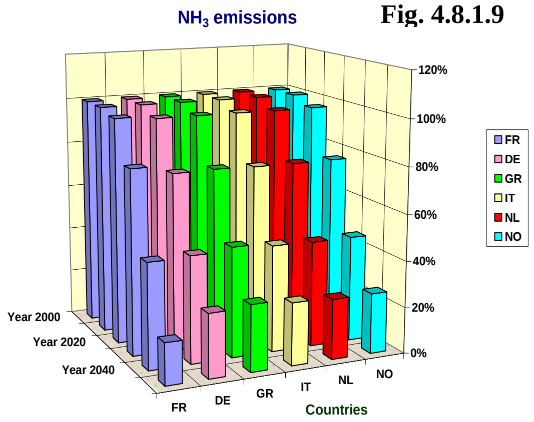


Fig. 4.8.1.9

Looking at the different indicators, for fuel consumption and CO_2 emissions, the most relevant reductions are associated to France and Norway, which have for conventional fuels figures close to 20% of the reference scenarios, while the countries where the effects are less consistent are Greece and Italy, where the level is about 40%. Some important differences respect to the other MS are shown by CO, VOCs and CH_4 for Greece and Italy, where the final share of these pollutants is quite higher that the other countries. These high pollutant levels are mainly the consequence of the very high number of two wheel vehicles that are circulating in these MS and this fact masks most of the potential benefits provided by the hydrogen deployment.

4.8.2 Cumulative hydrogen low penetration scenario analysis

Looking at the low hydrogen penetration cumulative results, it can be seen that at 2050 the differences are quite large respect to the corresponding high hydrogen penetration scenarios as the hydrogen deployment in the road transport is not very large. Therefore, as already described for the single MS the effects in terms of reduction of the pollutant emissions are quite limited. Of course a discussion can be started if the scenario, which imply a very long period of time to reach relevant targets in terms of market shares for the hydrogen is viable or not. In fact the low hydrogen penetration scenario differs from the high one as the starting of hydrogen vehicle market penetration is delayed on time respect to it, and this implies that the process of hydrogen deployment is not yet completed. Of course it is quite obvious to consider if it is possible to have a so long process in the reality.

Looking at the scenario outcomes, it is important to detect that, in any case, the high and low penetration scenarios shows results that are coherent between them, in the sense that no evident discrepancy can be detected at least for the environmental impact.

Fig. 4.8.2.1

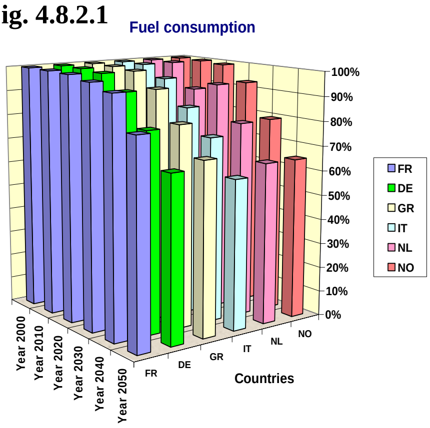


Fig. 4.8.2.3

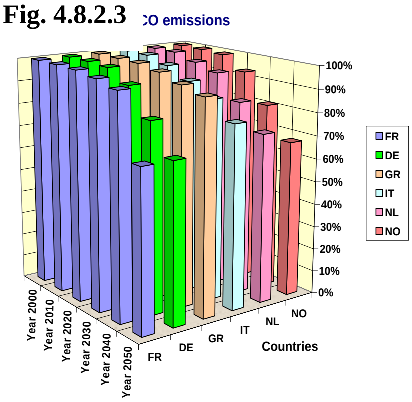


Fig. 4.8.2.4

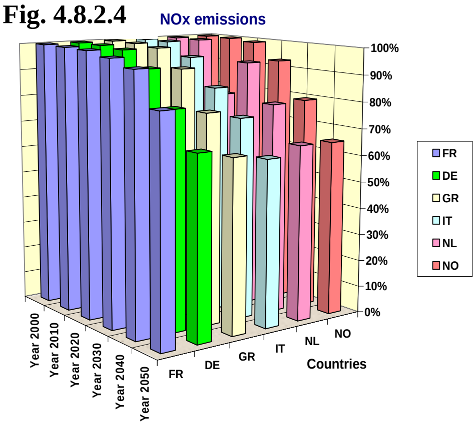


Fig. 4.8.2.2

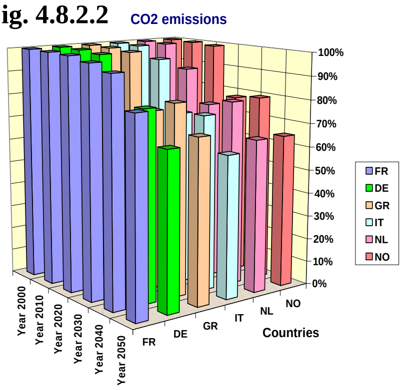


Fig. 4.8.2.5

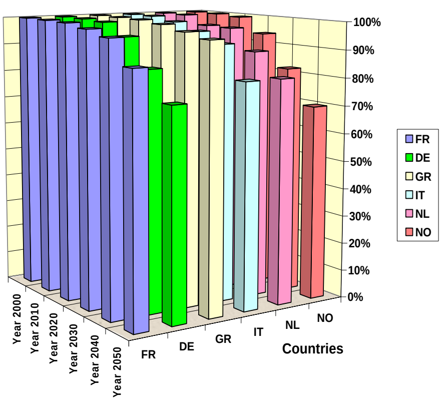


Fig. 4.8.2.7

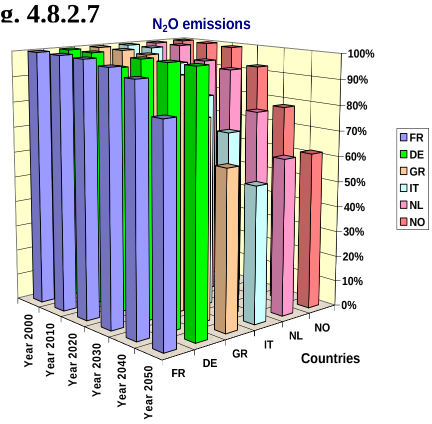
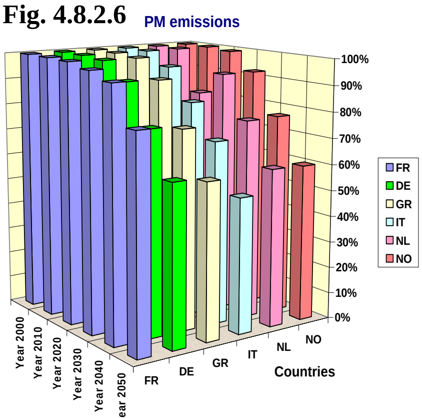


Fig. 4.8.2.6



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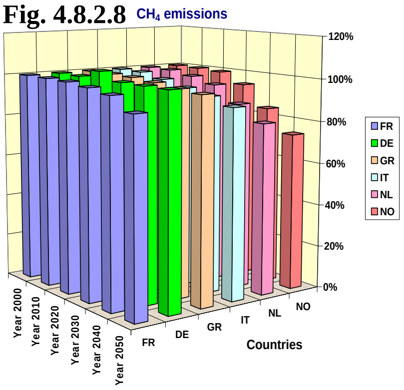
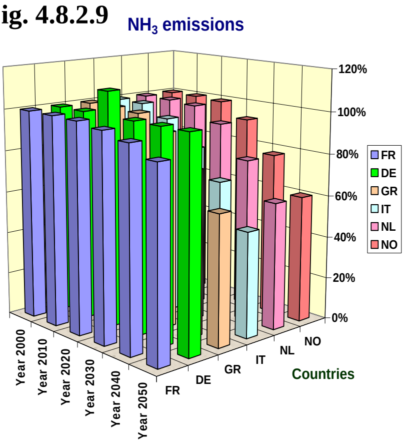


Fig. 4.8.2.9



5. Open questions

In the previous paragraphs the approach and the results related to the environmental analysis have been described. The effort had lead to a consistent procedure that can now be applied for the environmental impact in road transport for all the MS. In particular all the aspects, i.e. the assumptions, the sources of the required data, the procedures to manage all the information, etc. have been defined and this makes possible to analyze quite easily any new hydrogen scenario. This could lead to create a procedure which can be used automatically to generate the results whenever required, but for some reasons it has been decided that it is better at this stage to keep the complete control of each run under the modeler's hands, in order to avoid that some undesirable situation can occur. Whenever some more experience would be available this possibility could be reconsidered.
The results from the COPERT (and the other models) runs show in some cases aspects that need to be more understood, not only in terms of coherence respect to the main assumptions, but if in all the cases the assumptions can be valid or instead they lead to inconsistencies. Of course, these particular situations should be welcome as they give the chance to better understand the hydrogen deployment process and to investigate all the important aspects.

One of such situations is related to the lack of trucks converted to hydrogen fuel. This is quite critical, as looking for instance at 2050 a very large share of cars are converted and, what is more interesting, this share even increases if we consider the cars of bigger size. Under MARKAL and COPERT assumptions these cars are typically the vehicles that annually are traveling more and are therefore used not exclusively in urban areas, but most frequently in the extra-urban domains and for very long trips. This means that such vehicles:

- require to find everywhere in the Europe fuel stations to be refilled
- have onboard storage capabilities not different from the conventional vehicles, this means they can travel for a range of 600-800 km whenever the fuel tank is full (otherwise they would be not competitive respect to the conventional cars of the same size)

The above considerations imply that for the hydrogen cars all the technological problems we had to consider in the early phase of the market deployment have been fully overcome and, if almost all the new cars sold are based on hydrogen fuel, they should have performances and features which are all better or at least not lower than conventional cars of the same size. At that time therefore it is not easily understandable why the freight transport is not switching to hydrogen, at the light that also quite a lot of buses are running with such fuel.

Another important effect that results from the original assumption is related to the choice that trucks and two-wheel vehicles are not using hydrogen as fuel. Due to this, such vehicles are in most cases the main responsible of pollutant emissions and this prevent to reach better environmental figures. It is clear that HyWays Project is focused on hydrogen deployment and cannot analyze all the steps of a comprehensive strategy which has the aim to address the complete set of the energy and environment options in each country. Therefore such limitations could be not very dangerous, provided that they are fully justified and backed whenever criticisms can be shown. If not, the lack of attention to these particular aspects could generate some bad feeling in the stakeholders and at the end impair the success of the hydrogen market without any valid argument.

6. Lesson learnt

The results provided in the report by COPERT runs are based on MARKAL results version 6.4.

Running many times COPERT in dependence of new MARKAL outputs has shown that it is useless to try to follow always such scheme. In fact, there is quite a “weak” dependence of the environmental impact from the hydrogen consumed in the energy sectors.

The reason is to be found in the consideration that, while for economic changes variations of few percentage points can have very important effects and lead to different conclusions, the same changes in the environmental field are not very relevant. This is due to many reasons, i.e. the lack of very accurate detecting systems for the overall pollutant emissions, the different perception of the impact from citizens, the delay between pollution release and health and ecosystem worsening, the sharing of recover costs among different categories of individuals, et.. Therefore, provided that the hydrogen is deployed in the transport sector in a consistent way, the environmental results are not changing so much, the qualitative trend is not affected from modest changes in the hydrogen market shares and the final decisions are not modified by such variations. In some cases the main issue is that, just acting on hydrogen side, this wouldn’t give much help in reducing pollution, because some categories of vehicles are not converted and try to keep high the overall emissions.

This means that for the environmental analysis, under the above assumptions, the results are always usable, even if they are not completely consistent with the latest MARKAL versions, if they provide just refinements of the previous runs and are not radically changing the main assumptions. Therefore in such cases the previous environmental results can give indications valuable for the aim of HyWays Project and they remain effective to check if the hydrogen scenarios can provide environmental tangible benefits.

Of course, this can be accepted just during the execution of the project, in order to avoid that considerable delays are generated for the environmental task, but at the end, whenever all the model results will be stabilized, in the sense that they have been discussed and reached the maximum consensus from all the stakeholders, COPERT needs to be rerun with the final set of data, to become fully consistent with all the HyWays outcomes.

7. Conclusions

In the previous paragraphs the activities to analyze the environmental effects resulting from the hydrogen roadmaps have been fully addressed. This task has been carried out mainly considering the effects under the road transport sector; as this sector is the one where the most consistent share of hydrogen is used. Of course this is a simplification, but it gives in any case important insights on the effectiveness of the hydrogen to be a possible option to counteract in a significant way the negative environmental externalities that come out from the energy sectors. The environmental analysis was carried out using COPERT model with the following assumptions/positions:

- COPERT total population of the different vehicle categories is forced to fit the results provided by MARKAL outputs for the years from 2010 to 2050, while for 2000 MS statistics are used (from TREMOVE DB) as starting data.
- Two new EURO legislations (V and VI) have been considered in COPERT (through direct modification of its ACCESS based database), with changes on pollutant limits (EURO V) and in fuel consumption for both of them (i.e. as result of Voluntary Agreements between car manufacturers and EC). The two legislations are enacted respectively on 2010 and 2015, having as target a reduction on CO_2 specific emissions for new passenger cars, as a consequence of the above fuel consumption reductions, to average emission values respectively of 145 g/km and 120 g/km from an initial level of 172 g/km.
- For hydrogen, due to lack of information on specific emissions (i.e. NO_x for ICE vehicles), no pollutant emission has been considered, but this doesn't provide big effects, as most of the vehicles are fuel cell powered.
- New limits on fuel content of SO_2 have been introduced starting from 2010. For the reference year (2000) COPERT has been made consistent with country statistics related to road transport fuel consumption and vehicle fleets.

The results of COPERT runs allow to achieve the following conclusions, looking primarily at 2050, although most of the considerations can be qualitatively applied to 2030. Where not explicitly indicated the indications are related to the high penetration scenario, which is the one providing as it is easy to understand the most important environmental benefits:

- Looking at fuel consumption and considering both MARKAL and COPERT results, it appears that the share of the hydrogen energy consumed in road transport is lower than the one corresponding to the conventional fuels that have been substituted. This is the direct consequence of the large use of hydrogen fuel cells, whose higher energy efficiency allows to take care of the related transport demand with a lower quantity of energy.
- The reduction of fuel consumption and CO_2 emissions at the point of use doesn't automatically imply that there is a corresponding saving on the entire chain. Such analysis cannot be performed by COPERT. In any case the results shown for CO_2 can be considered as the upper bound of the benefits achievable from the hydrogen introduction in road transport, in both the cases where hydrogen is produced by renewables or from fossil fuel with CO_2 capture and sequestration.
- There is in any case an advantage in terms of total greenhouse gases emissions due to the hydrogen deployment, as other greenhouse gases such as N_2O and CH_4, whose emissions are also imputable to road transport and are specifically generated at the point of use, are considerably lower as the hydrogen introduction reduces the conventional fuel consumption.

- The large market of hydrogen vehicles provides considerable positive environmental effects for all the MS, especially for the high hydrogen penetration scenario. This is particularly true looking at the local pollutants (regulated and non-regulated), whose lower resulting emission is mainly driven by the reduction of the conventional vehicle share, as H_2 vehicles are almost emission free.
- Comparing the pollutant emissions of the high penetration scenario to the baseline, the new emissions often reach levels of 20-30% with respect to the reference at 2050, thanks to the substitution of conventional vehicles with emission free ones.. This means a decisive step in redeveloping the livability of the urban areas, considering that the pollutant emissions of road vehicles will be already low compared to actual levels, as result of the new more restrictive emission legislations.
- The reduction of environmental pollution is almost evenly distributed in all the geographical domains, with some better figures for the urban domains. This implies important improvements in terms of health effects as quite a lot of people can be subjected to less risks of diseases.
- The categories of conventional vehicles, which are not considered to be involved in the hydrogen transition, acts, in any case, negatively and prevent to reach even better environmental effects. Better figures could be achieved if also trucks could be converted to hydrogen use and/or provisions could be identified for conventional vehicles to cut their pollutant emissions.
- The results of the low penetration scenario show a consistent delay with respect to the high penetration scenario and have lower positive effects on the environment. It is quite obvious that effects similar to the ones shown by the high scenario will be probably achieved in longer terms and beyond the HyWays timeframe. Looking specifically to this scenario and its limited environmental effects, it could be not easy to understand if the benefits will be sufficient to foster the hydrogen market take off. Therefore under this case the environmental benefits are not a main driver and any positive decision to proceed in the direction to foster the hydrogen economy will probably rely to other considerations.

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8. References

[1] Leonidas Ntziachristos and Zissis Samaras "COPERT III Computer programme to calculate emissions from road transport Methodology and emission factors (Version 2.1)" ETC/AEM http://vergina.eng.auth.gr/mech/lat/copert/copert.htm

[2] Chariton Kouridis, Leonidas Ntziachristos and Zissis Samaras "COPERT III Computer programme to calculate emissions from road transport User manual (Version 2.1)" ETC/AEM

[3] "TREMOVE 2.30 Model and Baseline Description" FINAL REPORT European Commission, DG ENV Service Contract B4-3040/2003/366851/MAR/C.1, 18 February 2005, http://www.tremove.org/download/TREMOVE%202.30%20v18feb05.pdf

[4] TREMOVE database, http://www.tremove.org/download/index.htm

[5] "OIL INFORMATION – 2002 Edition" International Energy Agency

[6] Antonio Mattucci "HYWAYS PROJECT - Environmental analysis of hydrogen deployment scenarios: The impact in road transport" ENEA

[7] DIRECTIVE 2003/17/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive 98/70/EC relating to the quality of petrol and diesel fuels, 3rd March 2003

[8] G.H. Martinus, K.E.L. Smekens, H. Rosler "Energy system modelling of a hydrogen economy – MARKAL model extensions and results for HYWAYS Phase I" ECN-I—05-000, July 2005

9. Annexes

Appendix 1 COPERT passenger cars types (gasoline)

List of COPERT gasoline passenger cars types

Gasoline <1,4 l	PRE ECE
Gasoline <1,4 l	ECE 15/00-01
Gasoline <1,4 l	ECE 15/02
Gasoline <1,4 l	ECE 15/03
Gasoline <1,4 l	ECE 15/04
Gasoline <1,4 l	Improved Conventional
Gasoline <1,4 l	Open Loop
Gasoline <1,4 l	Euro I - 91/441/EEC
Gasoline <1,4 l	Euro II - 94/12/EC
Gasoline <1,4 l	Euro III - 98/69/EC Stage2000
Gasoline <1,4 l	Euro IV - 98/69/EC Stage2005
Gasoline <1,4 l	Euro V (post 2005)
Gasoline <1,4 l	Euro VI (post 2015)
Gasoline 1,4 - 2,0 l	PRE ECE
Gasoline 1,4 - 2,0 l	ECE 15/00-01
Gasoline 1,4 - 2,0 l	ECE 15/02
Gasoline 1,4 - 2,0 l	ECE 15/03
Gasoline 1,4 - 2,0 l	ECE 15/04
Gasoline 1,4 - 2,0 l	Improved Conventional
Gasoline 1,4 - 2,0 l	Open Loop
Gasoline 1,4 - 2,0 l	Euro I - 91/441/EEC
Gasoline 1,4 - 2,0 l	Euro II - 94/12/EC
Gasoline 1,4 - 2,0 l	Euro III - 98/69/EC Stage2000
Gasoline 1,4 - 2,0 l	Euro IV - 98/69/EC Stage2005
Gasoline 1,4 - 2,0 l	Euro V (post 2005)
Gasoline 1,4 - 2,0 l	Euro VI (post 2015)
Gasoline >2,0 l	PRE ECE
Gasoline >2,0 l	ECE 15/00-01
Gasoline >2,0 l	ECE 15/02
Gasoline >2,0 l	ECE 15/03
Gasoline >2,0 l	ECE 15/04
Gasoline >2,0 l	Euro I - 91/441/EEC
Gasoline >2,0 l	Euro II - 94/12/EC
Gasoline >2,0 l	Euro III - 98/69/EC Stage2000
Gasoline >2,0 l	Euro IV - 98/69/EC Stage2005
Gasoline >2,0 l	Euro V (post 2005)
Gasoline >2,0 l	Euro VI (post 2015)

Appendix 2 MARKAL vehicle categories

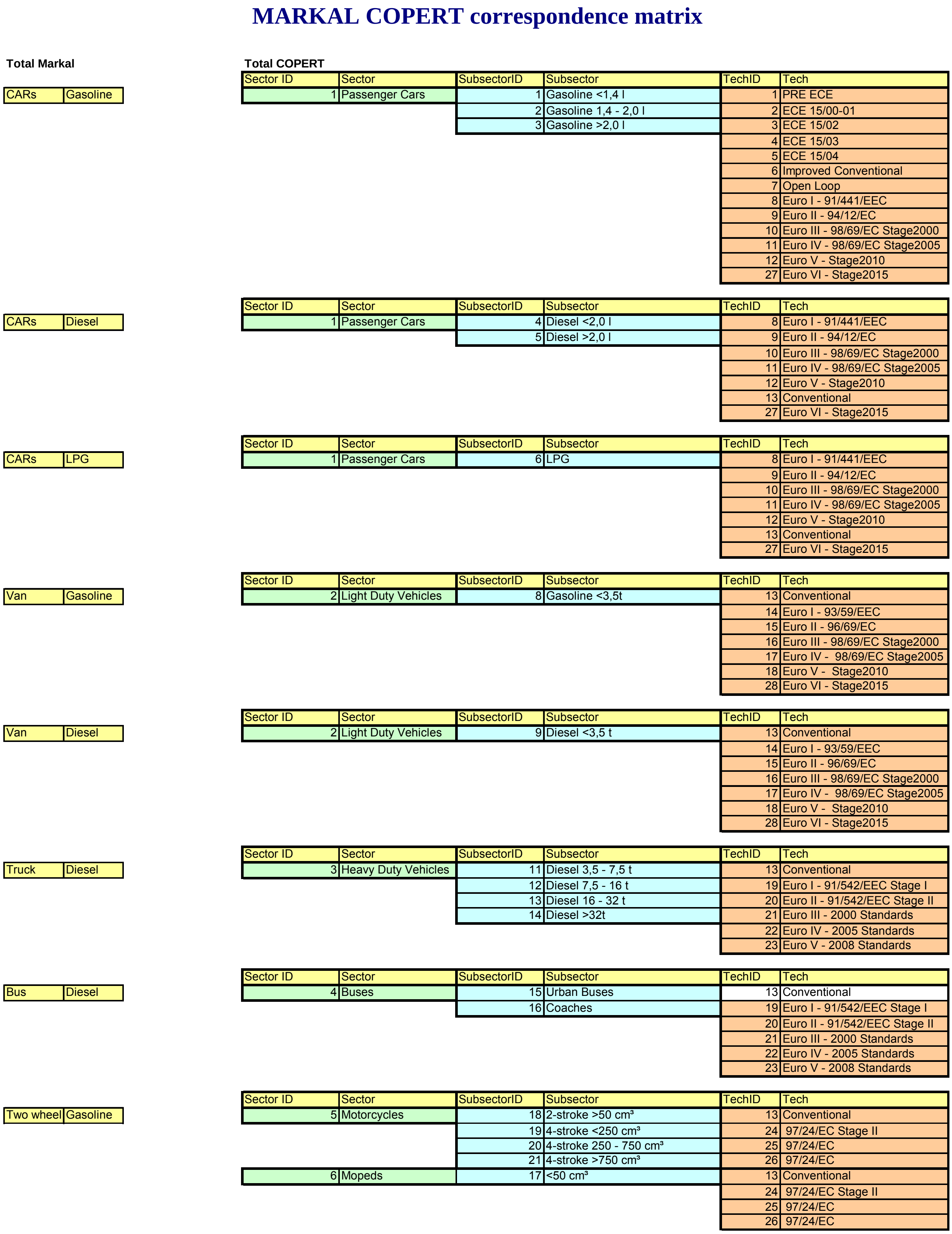
List of MARKAL vehicle categories

CATEGORIES	VEHICLES
PASSENGER CARS	CNG car local
	CNG car hybride local
	Electric accu car city
	LPG car local
	Methanol car fuel cell local
	Diesel car local
	Diesel car hybride local
	Hydrogen car fuel cell local
	Hydrogen liquid fuel cell car city
	Gasoline car fuel cell local
	Gasoline car local
	Gasoline car hybride local
	CNG car international
	CNG car hybride international
	LPG car international
	Methanol car fuel cell international
	Diesel car international
	Diesel car hybride international
	Hydrogen car fuel cell international
	Hydrogen car fuel cell hybride international
	Hydrogen liquid fuel cell car international
	Gasoline car fuel cell international
	Gasoline car international
	Gasoline car hybride international
	Hydrogen ICE car international
	Hydrogen liquid car international
	CNG car regional
	CNG car hybride regional
	Electric car accu regional
	LPG car regional
	Methanol car fuel cell regional
	Diesel car regional
	Diesel car hybride regional
	Hydrogen car fuel cell regional
	Hydrogen car fuel cell hybrid regional
	Hydrogen liquid fuel cell car regional
	Gasoline car fuel cell regional
	Gasoline car regional
	Gasoline car hybride regional
	Hydrogen ICE car regional
	Hydrogen liquid car regional

CATEGORIES	VEHICLES
LIGHT DUTY VEHICLES	Electric van accu
	Electric van high energy accu
	Diesel van local
	Gasoline van local
	Gasoline van hybride
	Hydrogen van fuel cell
	Hydrogen liquid van fuel cell
BUS	CNG bus city
	Electric trolley bus city
	Methanol fuel cell bus city
	CNG bus regional
	Methanol fuel cell bus regional
	Diesel bus city
	Diesel bus hybrid city
	Diesel bus regional
	Diesel bus hybrid regional
	Hydrogen bus fuel cell city
	Hydrogen liquid fuel cell bus city
	Hydrogen bus fuel cell regional
	Hydrogen liquid fuel cell bus regional
	Hydrogen bus city
	Hydrogen liquid bus city
HEAVY DUTY VEHICLES	CNG truck
	Methanol truck fuel cell
	Diesel truck international
	Gasoline truck
	Hydrogen truck fuel cell
	Hydrogen liquid truck
Motorcycles	2 Wheelers

🟦	**vehicle categorie normally existing in MARKAL output baseline**
🟦	**vehicle categorie normally existing in MARKAL output baseline**
🟨	**vehicle categorie normally non existing in MARKAL output baseline**
🟧	**vehicle categorie normally non existing in MARKAL output baseline**

Appendix 3 MARKAL COPERT correspondence matrix



MARKAL COPERT correspondence matrix

Total Markal | **Total COPERT**

		Sector ID	Sector	SubsectorID	Subsector	TechID	Tech
CARs	Gasoline	1	Passenger Cars	1	Gasoline <1,4 l	1	PRE ECE
				2	Gasoline 1,4 - 2,0 l	2	ECE 15/00-01
				3	Gasoline >2,0 l	3	ECE 15/02
						4	ECE 15/03
						5	ECE 15/04
						6	Improved Conventional
						7	Open Loop
						8	Euro I - 91/441/EEC
						9	Euro II - 94/12/EC
						10	Euro III - 98/69/EC Stage2000
						11	Euro IV - 98/69/EC Stage2005
						12	Euro V - Stage2010
						27	Euro VI - Stage2015

		Sector ID	Sector	SubsectorID	Subsector	TechID	Tech
CARs	Diesel	1	Passenger Cars	4	Diesel <2,0 l	8	Euro I - 91/441/EEC
				5	Diesel >2,0 l	9	Euro II - 94/12/EC
						10	Euro III - 98/69/EC Stage2000
						11	Euro IV - 98/69/EC Stage2005
						12	Euro V - Stage2010
						13	Conventional
						27	Euro VI - Stage2015

		Sector ID	Sector	SubsectorID	Subsector	TechID	Tech
CARs	LPG	1	Passenger Cars	6	LPG	8	Euro I - 91/441/EEC
						9	Euro II - 94/12/EC
						10	Euro III - 98/69/EC Stage2000
						11	Euro IV - 98/69/EC Stage2005
						12	Euro V - Stage2010
						13	Conventional
						27	Euro VI - Stage2015

		Sector ID	Sector	SubsectorID	Subsector	TechID	Tech
Van	Gasoline	2	Light Duty Vehicles	8	Gasoline <3,5t	13	Conventional
						14	Euro I - 93/59/EEC
						15	Euro II - 96/69/EC
						16	Euro III - 98/69/EC Stage2000
						17	Euro IV - 98/69/EC Stage2005
						18	Euro V - Stage2010
						28	Euro VI - Stage2015

		Sector ID	Sector	SubsectorID	Subsector	TechID	Tech
Van	Diesel	2	Light Duty Vehicles	9	Diesel <3,5 t	13	Conventional
						14	Euro I - 93/59/EEC
						15	Euro II - 96/69/EC
						16	Euro III - 98/69/EC Stage2000
						17	Euro IV - 98/69/EC Stage2005
						18	Euro V - Stage2010
						28	Euro VI - Stage2015

		Sector ID	Sector	SubsectorID	Subsector	TechID	Tech
Truck	Diesel	3	Heavy Duty Vehicles	11	Diesel 3,5 - 7,5 t	13	Conventional
				12	Diesel 7,5 - 16 t	19	Euro I - 91/542/EEC Stage I
				13	Diesel 16 - 32 t	20	Euro II - 91/542/EEC Stage II
				14	Diesel >32t	21	Euro III - 2000 Standards
						22	Euro IV - 2005 Standards
						23	Euro V - 2008 Standards

		Sector ID	Sector	SubsectorID	Subsector	TechID	Tech
Bus	Diesel	4	Buses	15	Urban Buses	13	Conventional
				16	Coaches	19	Euro I - 91/542/EEC Stage I
						20	Euro II - 91/542/EEC Stage II
						21	Euro III - 2000 Standards
						22	Euro IV - 2005 Standards
						23	Euro V - 2008 Standards

		Sector ID	Sector	SubsectorID	Subsector	TechID	Tech
Two wheel	Gasoline	5	Motorcycles	18	2-stroke >50 cm³	13	Conventional
				19	4-stroke <250 cm³	24	97/24/EC Stage II
				20	4-stroke 250 - 750 cm³	25	97/24/EC
				21	4-stroke >750 cm³	26	97/24/EC
		6	Mopeds	17	<50 cm³	13	Conventional
						24	97/24/EC Stage II
						25	97/24/EC
						26	97/24/EC

Appendix 4 – List of vehicles considered in COPERT III

		Sector	Subsector	Tech
PASSENGER CARS	**1**	Passenger Cars	Gasoline <1,4 l	PRE ECE
	2	Passenger Cars	Gasoline <1,4 l	ECE 15/00-01
	3	Passenger Cars	Gasoline <1,4 l	ECE 15/02
	4	Passenger Cars	Gasoline <1,4 l	ECE 15/03
	5	Passenger Cars	Gasoline <1,4 l	ECE 15/04
	6	Passenger Cars	Gasoline <1,4 l	Improved Conventional
	7	Passenger Cars	Gasoline <1,4 l	Open Loop
	8	Passenger Cars	Gasoline <1,4 l	Euro I - 91/441/EEC
	9	Passenger Cars	Gasoline <1,4 l	Euro II - 94/12/EC
	10	Passenger Cars	Gasoline <1,4 l	Euro III - 98/69/EC Stage2000
	11	Passenger Cars	Gasoline <1,4 l	Euro IV - 98/69/EC Stage2005
	12	Passenger Cars	Gasoline <1,4 l	Euro V (post 2005)
	13	Passenger Cars	Gasoline <1,4 l	Euro VI (post 2015)
	14	Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE
	15	Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01
	16	Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/02
	17	Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/03
	18	Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/04
	19	Passenger Cars	Gasoline 1,4 - 2,0 l	Improved Conventional
	20	Passenger Cars	Gasoline 1,4 - 2,0 l	Open Loop
	21	Passenger Cars	Gasoline 1,4 - 2,0 l	Euro I - 91/441/EEC
	22	Passenger Cars	Gasoline 1,4 - 2,0 l	Euro II - 94/12/EC
	23	Passenger Cars	Gasoline 1,4 - 2,0 l	Euro III - 98/69/EC Stage2000
	24	Passenger Cars	Gasoline 1,4 - 2,0 l	Euro IV - 98/69/EC Stage2005
	25	Passenger Cars	Gasoline 1,4 - 2,0 l	Euro V (post 2005)
	26	Passenger Cars	Gasoline 1,4 - 2,0 l	Euro VI (post 2015)
	27	Passenger Cars	Gasoline >2,0 l	PRE ECE
	28	Passenger Cars	Gasoline >2,0 l	ECE 15/00-01
	29	Passenger Cars	Gasoline >2,0 l	ECE 15/02
	30	Passenger Cars	Gasoline >2,0 l	ECE 15/03
	31	Passenger Cars	Gasoline >2,0 l	ECE 15/04
	32	Passenger Cars	Gasoline >2,0 l	Euro I - 91/441/EEC
	33	Passenger Cars	Gasoline >2,0 l	Euro II - 94/12/EC
	34	Passenger Cars	Gasoline >2,0 l	Euro III - 98/69/EC Stage2000
	35	Passenger Cars	Gasoline >2,0 l	Euro IV - 98/69/EC Stage2005
	36	Passenger Cars	Gasoline >2,0 l	Euro V (post 2005)
	37	Passenger Cars	Gasoline >2,0 l	Euro VI (post 2015)
	38	Passenger Cars	Diesel <2,0 l	Conventional
	39	Passenger Cars	Diesel <2,0 l	Euro I - 91/441/EEC
	40	Passenger Cars	Diesel <2,0 l	Euro II - 94/12/EC
	41	Passenger Cars	Diesel <2,0 l	Euro III - 98/69/EC Stage2000
	42	Passenger Cars	Diesel <2,0 l	Euro IV - 98/69/EC Stage2005
	43	Passenger Cars	Diesel <2,0 l	Euro V (post 2005)
	44	Passenger Cars	Diesel <2,0 l	Euro VI (post 2015)
	45	Passenger Cars	Diesel >2,0 l	Conventional
	46	Passenger Cars	Diesel >2,0 l	Euro I - 91/441/EEC
	47	Passenger Cars	Diesel >2,0 l	Euro II - 94/12/EC
	48	Passenger Cars	Diesel >2,0 l	Euro III - 98/69/EC Stage2000
	49	Passenger Cars	Diesel >2,0 l	Euro IV - 98/69/EC Stage2005
	50	Passenger Cars	Diesel >2,0 l	Euro V (post 2005)
	51	Passenger Cars	Diesel >2,0 l	Euro VI (post 2015)
	52	Passenger Cars	LPG	Conventional
	53	Passenger Cars	LPG	Euro I - 91/441/EEC
	54	Passenger Cars	LPG	Euro II - 94/12/EC
	55	Passenger Cars	LPG	Euro III - 98/69/EC Stage2000
	56	Passenger Cars	LPG	Euro IV - 98/69/EC Stage2005
	57	Passenger Cars	LPG	Euro V (post 2005)
	58	Passenger Cars	LPG	Euro VI (post 2015)
	57	Passenger Cars	2-Stroke	Conventional

LIGHT DUTY VEHICLES	**1**	Light Duty Vehicles	Gasoline <3,5t	Conventional
	2	Light Duty Vehicles	Gasoline <3,5t	Euro I - 93/59/EEC
	3	Light Duty Vehicles	Gasoline <3,5t	Euro II - 96/69/EC
	4	Light Duty Vehicles	Gasoline <3,5t	Euro III - 98/69/EC Stage2000
	5	Light Duty Vehicles	Gasoline <3,5t	Euro IV - 98/69/EC Stage2005
	6	Light Duty Vehicles	Gasoline <3,5t	Euro V (post 2005)
	7	Light Duty Vehicles	Gasoline <3,5t	Euro VI (post 2015)
	8	Light Duty Vehicles	Diesel <3,5 t	Conventional
	9	Light Duty Vehicles	Diesel <3,5 t	Euro I - 93/59/EEC
	10	Light Duty Vehicles	Diesel <3,5 t	Euro II - 96/69/EC
	11	Light Duty Vehicles	Diesel <3,5 t	Euro III - 98/69/EC Stage2000
	12	Light Duty Vehicles	Diesel <3,5 t	Euro IV - 98/69/EC Stage2005
	13	Light Duty Vehicles	Diesel <3,5 t	Euro V (post 2005)
	14	Light Duty Vehicles	Diesel <3,5 t	Euro VI (post 2015)
HEAVY DUTY VEHICLES	**1**	Heavy Duty Vehicles	Gasoline >3,5 t	Conventional
	2	Heavy Duty Vehicles	Diesel 3,5 - 7,5 t	Conventional
	3	Heavy Duty Vehicles	Diesel 3,5 - 7,5 t	Euro I - 91/542/EEC Stage I
	4	Heavy Duty Vehicles	Diesel 3,5 - 7,5 t	Euro II - 91/542/EEC Stage II
	5	Heavy Duty Vehicles	Diesel 3,5 - 7,5 t	Euro III - 2000 Standards
	6	Heavy Duty Vehicles	Diesel 3,5 - 7,5 t	Euro IV - 2005 Standarts
	7	Heavy Duty Vehicles	Diesel 3,5 - 7,5 t	Euro V - 2008 Standarts
	8	Heavy Duty Vehicles	Diesel 7,5 - 16 t	Conventional
	9	Heavy Duty Vehicles	Diesel 7,5 - 16 t	Euro I - 91/542/EEC Stage I
	10	Heavy Duty Vehicles	Diesel 7,5 - 16 t	Euro II - 91/542/EEC Stage II
	11	Heavy Duty Vehicles	Diesel 7,5 - 16 t	Euro III - 2000 Standards
	12	Heavy Duty Vehicles	Diesel 7,5 - 16 t	Euro IV - 2005 Standarts
	13	Heavy Duty Vehicles	Diesel 7,5 - 16 t	Euro V - 2008 Standarts
	14	Heavy Duty Vehicles	Diesel 16 - 32 t	Conventional
	15	Heavy Duty Vehicles	Diesel 16 - 32 t	Euro I - 91/542/EEC Stage I
	16	Heavy Duty Vehicles	Diesel 16 - 32 t	Euro II - 91/542/EEC Stage II
	17	Heavy Duty Vehicles	Diesel 16 - 32 t	Euro III - 2000 Standards
	18	Heavy Duty Vehicles	Diesel 16 - 32 t	Euro IV - 2005 Standarts
	19	Heavy Duty Vehicles	Diesel 16 - 32 t	Euro V - 2008 Standarts
	20	Heavy Duty Vehicles	Diesel >32t	Conventional
	21	Heavy Duty Vehicles	Diesel >32t	Euro I - 91/542/EEC Stage I
	22	Heavy Duty Vehicles	Diesel >32t	Euro II - 91/542/EEC Stage II
	23	Heavy Duty Vehicles	Diesel >32t	Euro III - 2000 Standards
	24	Heavy Duty Vehicles	Diesel >32t	Euro IV - 2005 Standarts
	25	Heavy Duty Vehicles	Diesel >32t	Euro V - 2008 Standarts
BUSES	**1**	Buses	Urban Buses	Conventional
	2	Buses	Urban Buses	Euro I - 91/542/EEC Stage I
	3	Buses	Urban Buses	Euro II - 91/542/EEC Stage II
	4	Buses	Urban Buses	Euro III - 2000 Standards
	5	Buses	Urban Buses	Euro IV - 2005 Standarts
	6	Buses	Urban Buses	Euro V - 2008 Standarts
	7	Buses	Coaches	Conventional
	8	Buses	Coaches	Euro I - 91/542/EEC Stage I
	9	Buses	Coaches	Euro II - 91/542/EEC Stage II
	10	Buses	Coaches	Euro III - 2000 Standards
	11	Buses	Coaches	Euro IV - 2005 Standarts
	12	Buses	Coaches	Euro V - 2008 Standarts
MOPEDS	**1**	Mopeds	<50 cmi	Conventional
	2	Mopeds	<50 cmi	97/24/EC Stage I
	3	Mopeds	<50 cmi	97/24/EC Stage II
MOTORCYCLES	**1**	Motorcycles	2-stroke >50 cmi	Conventional
	2	Motorcycles	2-stroke >50 cmi	97/24/EC
	3	Motorcycles	4-stroke <250 cmi	Conventional
	4	Motorcycles	4-stroke <250 cmi	97/24/EC
	5	Motorcycles	4-stroke 250 - 750 cmi	Conventional
	6	Motorcycles	4-stroke 250 - 750 cmi	97/24/EC
	7	Motorcycles	4-stroke >750 cmi	Conventional
	8	Motorcycles	4-stroke >750 cmi	97/24/EC

Appendix 5 – List of COPERT III input data

A5.1. Annual Fuel Consumption from the ROAD TRANSPORT

FUEL		ANNUAL CONSUMPTION 2000 (tons)
1.1.1.	Gasoline Unleaded	
1.1.2.	Diesel	
1.1.3.	LPG	

A5.2. FUEL SPECIFICATIONS and Date of coming in force of New Emission Rules in the period: 2005 - 2050

Year:	Year:	Year:	Year: ....

A5.3. ANNUAL MONTHLY MIN AND MAX TEMPERATURES

	Month	Annual Monthly Temperatures, o C	
		MIN	MAX
1	January		
2	February		
3	March		
4	April		
5	May		
6	June		
7	July		
8	August		
9	September		
10	October		
11	November		
12	December		

A5.4. VAPOR PRESSURE

	Month	Fuel Reid Vapor Pressure, kPa	
		example	
1	January	85	
2	February	85	
3	March	75	
4	April	75	
5	May	75	
6	June	75	
7	July	75	
8	August	75	
9	September	75	
10	October	75	
11	November	85	
12	December	85	

A5.5. COLD START PARAMETERS

5.1. Value for average trip length (ltrip): …………. Km

A5.6. VEHICLE CATEGORY SPLIT AND POPULATION UP TO 2050

		Sector	Subsector	Tech	Population of vehicles at the 2000	Forecast for the vehicle population at 2010	Forecast for the vehicle population at 2020	Forecast for the vehicle population at 2030	Forecast for the vehicle population at 2040	Forecast for the vehicle population at 2050
PASSENGER CARS	1	Passenger Cars	Gasoline <1,4 l	PRE ECE						
	2	Passenger Cars	Gasoline <1,4 l	ECE 15/00-01						
	3	Passenger Cars	Gasoline <1,4 l	ECE 15/02						
	4	Passenger Cars	Gasoline <1,4 l	ECE 15/03						
	5	Passenger Cars	Gasoline <1,4 l	ECE 15/04						
	6	Passenger Cars	Gasoline <1,4 l	Improved Conventional						
	7	Passenger Cars	Gasoline <1,4 l	Open Loop						
	8	Passenger Cars	Gasoline <1,4 l	Euro I - 91/441/EEC						
	9	Passenger Cars	Gasoline <1,4 l	Euro II - 94/12/EC						
	10	Passenger Cars	Gasoline <1,4 l	Euro III - 98/69/EC Stage2000						
	11	Passenger Cars	Gasoline <1,4 l	Euro IV - 98/69/EC Stage2005						
	12	Passenger Cars	Gasoline <1,4 l	Euro V (post 2005)						
	13	Passenger Cars	Gasoline 1,4 - 2,0 l	PRE ECE						
	14	Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/00-01						
	15	Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/02						
	16	Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/03						
	17	Passenger Cars	Gasoline 1,4 - 2,0 l	ECE 15/04						
	18	Passenger Cars	Gasoline 1,4 - 2,0 l	Improved Conventional						
	19	Passenger Cars	Gasoline 1,4 - 2,0 l	Open Loop						
	20	Passenger Cars	Gasoline 1,4 - 2,0 l	Euro I - 91/441/EEC						
	21	Passenger Cars	Gasoline 1,4 - 2,0 l	Euro II - 94/12/EC						
	22	Passenger Cars	Gasoline 1,4 - 2,0 l	Euro III - 98/69/EC Stage2000						
	23	Passenger Cars	Gasoline 1,4 - 2,0 l	Euro IV - 98/69/EC Stage2005						
	24	Passenger Cars	Gasoline 1,4 - 2,0 l	Euro V (post 2005)						
	25	Passenger Cars	Gasoline >2,0 l	PRE ECE						
	26	Passenger Cars	Gasoline >2,0 l	ECE 15/00-01						
	27	Passenger Cars	Gasoline >2,0 l	ECE 15/02						
	28	Passenger Cars	Gasoline >2,0 l	ECE 15/03						
	29	Passenger Cars	Gasoline >2,0 l	ECE 15/04						
	30	Passenger Cars	Gasoline >2,0 l	Euro I - 91/441/EEC						
	31	Passenger Cars	Gasoline >2,0 l	Euro II - 94/12/EC						
	32	Passenger Cars	Gasoline >2,0 l	Euro III - 98/69/EC Stage2000						
	33	Passenger Cars	Gasoline >2,0 l	Euro IV - 98/69/EC Stage2005						
	34	Passenger Cars	Gasoline >2,0 l	Euro V (post 2005)						
	35	Passenger Cars	Diesel <2,0 l	Conventional						
	36	Passenger Cars	Diesel <2,0 l	Euro I - 91/441/EEC						
	37	Passenger Cars	Diesel <2,0 l	Euro II - 94/12/EC						
	38	Passenger Cars	Diesel <2,0 l	Euro III - 98/69/EC Stage2000						
	39	Passenger Cars	Diesel <2,0 l	Euro IV - 98/69/EC Stage2005						
	40	Passenger Cars	Diesel <2,0 l	Euro V (post 2005)						
	41	Passenger Cars	Diesel >2,0 l	Conventional						
	42	Passenger Cars	Diesel >2,0 l	Euro I - 91/441/EEC						
	43	Passenger Cars	Diesel >2,0 l	Euro II - 94/12/EC						
	44	Passenger Cars	Diesel >2,0 l	Euro III - 98/69/EC Stage2000						
	45	Passenger Cars	Diesel >2,0 l	Euro IV - 98/69/EC Stage2005						
	46	Passenger Cars	Diesel >2,0 l	Euro V (post 2005)						
	47	Passenger Cars	LPG	Conventional						
	48	Passenger Cars	LPG	Euro I - 91/441/EEC						
	49	Passenger Cars	LPG	Euro II - 94/12/EC						
	50	Passenger Cars	LPG	Euro III - 98/69/EC Stage2000						
	51	Passenger Cars	LPG	Euro IV - 98/69/EC Stage2005						
	52	Passenger Cars	LPG	Euro V (post 2005)						
	53	Passenger Cars	2-Stroke	Conventional						
LIGHT DUTY VEHICLES	1	Light Duty Vehicles	Gasoline <3,5t	Conventional						
	2	Light Duty Vehicles	Gasoline <3,5t	Euro I - 93/59/EEC						
	3	Light Duty Vehicles	Gasoline <3,5t	Euro II - 96/69/EC						
	4	Light Duty Vehicles	Gasoline <3,5t	Euro III - 98/69/EC Stage2000						
	5	Light Duty Vehicles	Gasoline <3,5t	Euro IV - 98/69/EC Stage2005						
	6	Light Duty Vehicles	Gasoline <3,5t	Euro V (post 2005)						
	7	Light Duty Vehicles	Diesel <3,5 t	Conventional						
	8	Light Duty Vehicles	Diesel <3,5 t	Euro I - 93/59/EEC						
	9	Light Duty Vehicles	Diesel <3,5 t	Euro II - 96/69/EC						
	10	Light Duty Vehicles	Diesel <3,5 t	Euro III - 98/69/EC Stage2000						
	11	Light Duty Vehicles	Diesel <3,5 t	Euro IV - 98/69/EC Stage2005						
	12	Light Duty Vehicles	Diesel <3,5 t	Euro V (post 2005)						

		Sector	Subsector	Tech	Population of vehicles at the 2000	Forecast for the vehicle population at 2010	Forecast for the vehicle population at 2020	Forecast for the vehicle population at 2030	Forecast for the vehicle population at 2040	Forecast for the vehicle population at 2050
HEAVY DUTY VEHICLES	1	Heavy Duty Vehicles	Gasoline >3,5 t	Conventional						
	2	Heavy Duty Vehicles	Diesel 3,5 - 7,5 t	Conventional						
	3	Heavy Duty Vehicles	Diesel 3,5 - 7,5 t	Euro I - 91/542/EEC Stage I						
	4	Heavy Duty Vehicles	Diesel 3,5 - 7,5 t	Euro II - 91/542/EEC Stage II						
	5	Heavy Duty Vehicles	Diesel 3,5 - 7,5 t	Euro III - 2000 Standards						
	6	Heavy Duty Vehicles	Diesel 3,5 - 7,5 t	Euro IV - 2005 Standarts						
	7	Heavy Duty Vehicles	Diesel 3,5 - 7,5 t	Euro V - 2008 Standarts						
	8	Heavy Duty Vehicles	Diesel 7,5 - 16 t	Conventional						
	9	Heavy Duty Vehicles	Diesel 7,5 - 16 t	Euro I - 91/542/EEC Stage I						
	10	Heavy Duty Vehicles	Diesel 7,5 - 16 t	Euro II - 91/542/EEC Stage II						
	11	Heavy Duty Vehicles	Diesel 7,5 - 16 t	Euro III - 2000 Standards						
	12	Heavy Duty Vehicles	Diesel 7,5 - 16 t	Euro IV - 2005 Standarts						
	13	Heavy Duty Vehicles	Diesel 7,5 - 16 t	Euro V - 2008 Standarts						
	14	Heavy Duty Vehicles	Diesel 16 - 32 t	Conventional						
	15	Heavy Duty Vehicles	Diesel 16 - 32 t	Euro I - 91/542/EEC Stage I						
	16	Heavy Duty Vehicles	Diesel 16 - 32 t	Euro II - 91/542/EEC Stage II						
	17	Heavy Duty Vehicles	Diesel 16 - 32 t	Euro III - 2000 Standards						
	18	Heavy Duty Vehicles	Diesel 16 - 32 t	Euro IV - 2005 Standarts						
	19	Heavy Duty Vehicles	Diesel 16 - 32 t	Euro V - 2008 Standarts						
	20	Heavy Duty Vehicles	Diesel >32t	Conventional						
	21	Heavy Duty Vehicles	Diesel >32t	Euro I - 91/542/EEC Stage I						
	22	Heavy Duty Vehicles	Diesel >32t	Euro II - 91/542/EEC Stage II						
	23	Heavy Duty Vehicles	Diesel >32t	Euro III - 2000 Standards						
	24	Heavy Duty Vehicles	Diesel >32t	Euro IV - 2005 Standarts						
	25	Heavy Duty Vehicles	Diesel >32t	Euro V - 2008 Standarts						
BUSES	1	Buses	Urban Buses	Conventional						
	2	Buses	Urban Buses	Euro I - 91/542/EEC Stage I						
	3	Buses	Urban Buses	Euro II - 91/542/EEC Stage II						
	4	Buses	Urban Buses	Euro III - 2000 Standards						
	5	Buses	Urban Buses	Euro IV - 2005 Standarts						
	6	Buses	Urban Buses	Euro V - 2008 Standarts						
	7	Buses	Coaches	Conventional						
	8	Buses	Coaches	Euro I - 91/542/EEC Stage I						
	9	Buses	Coaches	Euro II - 91/542/EEC Stage II						
	10	Buses	Coaches	Euro III - 2000 Standards						
	11	Buses	Coaches	Euro IV - 2005 Standarts						
	12	Buses	Coaches	Euro V - 2008 Standarts						
MOPEDS	1	Mopeds	<50 cmi	Conventional						
	2	Mopeds	<50 cmi	97/24/EC Stage I						
	3	Mopeds	<50 cmi	97/24/EC Stage II						
MOTORCYCLES	1	Motorcycles	2-stroke >50 cmi	Conventional						
	2	Motorcycles	2-stroke >50 cmi	97/24/EC						
	3	Motorcycles	4-stroke <250 cmi	Conventional						
	4	Motorcycles	4-stroke <250 cmi	97/24/EC						
	5	Motorcycles	4-stroke 250 - 750 cm	Conventional						
	6	Motorcycles	4-stroke 250 - 750 cm	97/24/EC						
	7	Motorcycles	4-stroke >750 cmi	Conventional						
	8	Motorcycles	4-stroke >750 cmi	97/24/EC						

A5.7. FLEET DATA

		Subsector	Legislation Standart	Population of vehicles at the 2009	Annual Mileage, km	Fuel Injection, %	Evaporation Control, %
PASSENGER CARS	1	Gasoline <1,4 l	PRE ECE				
	2	Gasoline <1,4 l	ECE 15/00-01				
	3	Gasoline <1,4 l	ECE 15/02				
	4	Gasoline <1,4 l	ECE 15/03				
	5	Gasoline <1,4 l	ECE 15/04				
	6	Gasoline <1,4 l	Improved Conventional				
	7	Gasoline <1,4 l	Open Loop				
	8	Gasoline <1,4 l	Euro I - 91/441/EEC				
	9	Gasoline <1,4 l	Euro II - 94/12/EC				
	10	Gasoline <1,4 l	Euro III - 98/69/EC Stage2000				
	11	Gasoline <1,4 l	Euro IV - 98/69/EC Stage2005				
	12	Gasoline <1,4 l	Euro V (post 2005)				
	13	Gasoline 1,4 - 2,0 l	PRE ECE				
	14	Gasoline 1,4 - 2,0 l	ECE 15/00-01				
	15	Gasoline 1,4 - 2,0 l	ECE 15/02				
	16	Gasoline 1,4 - 2,0 l	ECE 15/03				
	17	Gasoline 1,4 - 2,0 l	ECE 15/04				
	18	Gasoline 1,4 - 2,0 l	Improved Conventional				
	19	Gasoline 1,4 - 2,0 l	Open Loop				
	20	Gasoline 1,4 - 2,0 l	Euro I - 91/441/EEC				
	21	Gasoline 1,4 - 2,0 l	Euro II - 94/12/EC				
	22	Gasoline 1,4 - 2,0 l	Euro III - 98/69/EC Stage2000				
	23	Gasoline 1,4 - 2,0 l	Euro IV - 98/69/EC Stage2005				
	24	Gasoline 1,4 - 2,0 l	Euro V (post 2005)				
	25	Gasoline >2,0 l	PRE ECE				
	26	Gasoline >2,0 l	ECE 15/00-01				
	27	Gasoline >2,0 l	ECE 15/02				
	28	Gasoline >2,0 l	ECE 15/03				
	29	Gasoline >2,0 l	ECE 15/04				
	30	Gasoline >2,0 l	Euro I - 91/441/EEC				
	31	Gasoline >2,0 l	Euro II - 94/12/EC				
	32	Gasoline >2,0 l	Euro III - 98/69/EC Stage2000				
	33	Gasoline >2,0 l	Euro IV - 98/69/EC Stage2005				
	34	Gasoline >2,0 l	Euro V (post 2005)				
	35	Diesel <2,0 l	Conventional				
	36	Diesel <2,0 l	Euro I - 91/441/EEC				
	37	Diesel <2,0 l	Euro II - 94/12/EC				
	38	Diesel <2,0 l	Euro III - 98/69/EC Stage2000				
	39	Diesel <2,0 l	Euro IV - 98/69/EC Stage2005				
	40	Diesel <2,0 l	Euro V (post 2005)				
	41	Diesel >2,0 l	Conventional				
	42	Diesel >2,0 l	Euro I - 91/441/EEC				
	43	Diesel >2,0 l	Euro II - 94/12/EC				
	44	Diesel >2,0 l	Euro III - 98/69/EC Stage2000				
	45	Diesel >2,0 l	Euro IV - 98/69/EC Stage2005				
	46	Diesel >2,0 l	Euro V (post 2005)				
	47	LPG	Conventional				
	48	LPG	Euro I - 91/441/EEC				
	49	LPG	Euro II - 94/12/EC				
	50	LPG	Euro III - 98/69/EC Stage2000				
	51	LPG	Euro IV - 98/69/EC Stage2005				
	52	LPG	Euro V (post 2005)				
	53	2-Stroke	Conventional				
LIGHT DUTY VEHICLES	1	Gasoline <3,5t	Conventional				
	2	Gasoline <3,5t	Euro I - 93/59/EEC				
	3	Gasoline <3,5t	Euro II - 96/69/EC				
	4	Gasoline <3,5t	Euro III - 98/69/EC Stage2000				
	5	Gasoline <3,5t	Euro IV - 98/69/EC Stage2005				
	6	Gasoline <3,5t	Euro V (post 2005)				
	7	Diesel <3,5 t	Conventional				
	8	Diesel <3,5 t	Euro I - 93/59/EEC				
	9	Diesel <3,5 t	Euro II - 96/69/EC				
	10	Diesel <3,5 t	Euro III - 98/69/EC Stage2000				
	11	Diesel <3,5 t	Euro IV - 98/69/EC Stage2005				
	12	Diesel <3,5 t	Euro V (post 2005)				

		Subsector	Legislation Standart	Population of vehicles at the 2009	Annual Mileage, km	Fuel Injection, %	Evaporation Control, %
HEAVY DUTY VEHICLES	1	Gasoline >3,5 t	Conventional				
	2	Diesel 3,5 - 7,5 t	Conventional				
	3	Diesel 3,5 - 7,5 t	Euro I - 91/542/EEC Stage I				
	4	Diesel 3,5 - 7,5 t	Euro II - 91/542/EEC Stage II				
	5	Diesel 3,5 - 7,5 t	Euro III - 2000 Standards				
	6	Diesel 3,5 - 7,5 t	Euro IV - 2005 Standarts				
	7	Diesel 3,5 - 7,5 t	Euro V - 2008 Standarts				
	8	Diesel 7,5 - 16 t	Conventional				
	9	Diesel 7,5 - 16 t	Euro I - 91/542/EEC Stage I				
	10	Diesel 7,5 - 16 t	Euro II - 91/542/EEC Stage II				
	11	Diesel 7,5 - 16 t	Euro III - 2000 Standards				
	12	Diesel 7,5 - 16 t	Euro IV - 2005 Standarts				
	13	Diesel 7,5 - 16 t	Euro V - 2008 Standarts				
	14	Diesel 16 - 32 t	Conventional				
	15	Diesel 16 - 32 t	Euro I - 91/542/EEC Stage I				
	16	Diesel 16 - 32 t	Euro II - 91/542/EEC Stage II				
	17	Diesel 16 - 32 t	Euro III - 2000 Standards				
	18	Diesel 16 - 32 t	Euro IV - 2005 Standarts				
	19	Diesel 16 - 32 t	Euro V - 2008 Standarts				
	20	Diesel >32t	Conventional				
	21	Diesel >32t	Euro I - 91/542/EEC Stage I				
	22	Diesel >32t	Euro II - 91/542/EEC Stage II				
	23	Diesel >32t	Euro III - 2000 Standards				
	24	Diesel >32t	Euro IV - 2005 Standarts				
	25	Diesel >32t	Euro V - 2008 Standarts				
BUSES	1	Urban Buses	Conventional				
	2	Urban Buses	Euro I - 91/542/EEC Stage I				
	3	Urban Buses	Euro II - 91/542/EEC Stage II				
	4	Urban Buses	Euro III - 2000 Standards				
	5	Urban Buses	Euro IV - 2005 Standarts				
	6	Urban Buses	Euro V - 2008 Standarts				
	7	Coaches	Conventional				
	8	Coaches	Euro I - 91/542/EEC Stage I				
	9	Coaches	Euro II - 91/542/EEC Stage II				
	10	Coaches	Euro III - 2000 Standards				
	11	Coaches	Euro IV - 2005 Standarts				
	12	Coaches	Euro V - 2008 Standarts				
MOPEDS	1	<50 cmi	Conventional				
	2	<50 cmi	97/24/EC Stage I				
	3	<50 cmi	97/24/EC Stage II				
MOTORCYCLES	1	2-stroke >50 cmi	Conventional				
	2	2-stroke >50 cmi	97/24/EC				
	3	4-stroke <250 cmi	Conventional				
	4	4-stroke <250 cmi	97/24/EC				
	5	4-stroke 250 - 750 cmi	Conventional				
	6	4-stroke 250 - 750 cmi	97/24/EC				
	7	4-stroke >750 cmi	Conventional				
	8	4-stroke >750 cmi	97/24/EC				

A5.8. Circulation Data

sector		Subsector	Legislation Standart	Average Speed, km/h			Driving Share		
				URBAN	RURAL	HIGHWAY	URBAN	RURAL	HIGHWAY
PASSENGER CARS	1	Gasoline <1,4 l	PRE ECE						
	2	Gasoline <1,4 l	ECE 15/00-01						
	3	Gasoline <1,4 l	ECE 15/02						
	4	Gasoline <1,4 l	ECE 15/03						
	5	Gasoline <1,4 l	ECE 15/04						
	6	Gasoline <1,4 l	Improved Conventional						
	7	Gasoline <1,4 l	Open Loop						
	8	Gasoline <1,4 l	Euro I - 91/441/EEC						
	9	Gasoline <1,4 l	Euro II - 94/12/EC						
	10	Gasoline <1,4 l	Euro III - 98/69/EC Stage2000						
	11	Gasoline <1,4 l	Euro IV - 98/69/EC Stage2005						
	12	Gasoline <1,4 l	Euro V (post 2005)						
	13	Gasoline 1,4 - 2,0 l	PRE ECE						
	14	Gasoline 1,4 - 2,0 l	ECE 15/00-01						
	15	Gasoline 1,4 - 2,0 l	ECE 15/02						
	16	Gasoline 1,4 - 2,0 l	ECE 15/03						
	17	Gasoline 1,4 - 2,0 l	ECE 15/04						
	18	Gasoline 1,4 - 2,0 l	Improved Conventional						
	19	Gasoline 1,4 - 2,0 l	Open Loop						
	20	Gasoline 1,4 - 2,0 l	Euro I - 91/441/EEC						
	21	Gasoline 1,4 - 2,0 l	Euro II - 94/12/EC						
	22	Gasoline 1,4 - 2,0 l	Euro III - 98/69/EC Stage2000						
	23	Gasoline 1,4 - 2,0 l	Euro IV - 98/69/EC Stage2005						
	24	Gasoline 1,4 - 2,0 l	Euro V (post 2005)						
	25	Gasoline >2,0 l	PRE ECE						
	26	Gasoline >2,0 l	ECE 15/00-01						
	27	Gasoline >2,0 l	ECE 15/02						
	28	Gasoline >2,0 l	ECE 15/03						
	29	Gasoline >2,0 l	ECE 15/04						
	30	Gasoline >2,0 l	Euro I - 91/441/EEC						
	31	Gasoline >2,0 l	Euro II - 94/12/EC						
	32	Gasoline >2,0 l	Euro III - 98/69/EC Stage2000						
	33	Gasoline >2,0 l	Euro IV - 98/69/EC Stage2005						
	34	Gasoline >2,0 l	Euro V (post 2005)						
	35	Diesel <2,0 l	Conventional						
	36	Diesel <2,0 l	Euro I - 91/441/EEC						
	37	Diesel <2,0 l	Euro II - 94/12/EC						
	38	Diesel <2,0 l	Euro III - 98/69/EC Stage2000						
	39	Diesel <2,0 l	Euro IV - 98/69/EC Stage2005						
	40	Diesel <2,0 l	Euro V (post 2005)						
	41	Diesel >2,0 l	Conventional						
	42	Diesel >2,0 l	Euro I - 91/441/EEC						
	43	Diesel >2,0 l	Euro II - 94/12/EC						
	44	Diesel >2,0 l	Euro III - 98/69/EC Stage2000						
	45	Diesel >2,0 l	Euro IV - 98/69/EC Stage2005						
	46	Diesel >2,0 l	Euro V (post 2005)						
	47	LPG	Conventional						
	48	LPG	Euro I - 91/441/EEC						
	49	LPG	Euro II - 94/12/EC						
	50	LPG	Euro III - 98/69/EC Stage2000						
	51	LPG	Euro IV - 98/69/EC Stage2005						
	52	LPG	Euro V (post 2005)						
	53	2-Stroke	Conventional						
LIGHT DUTY VEHICLES	1	Gasoline <3,5t	Conventional						
	2	Gasoline <3,5t	Euro I - 93/59/EEC						
	3	Gasoline <3,5t	Euro II - 96/69/EC						
	4	Gasoline <3,5t	Euro III - 98/69/EC Stage2000						
	5	Gasoline <3,5t	Euro IV - 98/69/EC Stage2005						
	6	Gasoline <3,5t	Euro V (post 2005)						
	7	Diesel <3,5 t	Conventional						
	8	Diesel <3,5 t	Euro I - 93/59/EEC						
	9	Diesel <3,5 t	Euro II - 96/69/EC						
	10	Diesel <3,5 t	Euro III - 98/69/EC Stage2000						
	11	Diesel <3,5 t	Euro IV - 98/69/EC Stage2005						
	12	Diesel <3,5 t	Euro V (post 2005)						

sector		Subsector	Legislation Standart	Average Speed, km/h			Driving Share		
				URBAN	RURAL	HIGHWAY	URBAN	RURAL	HIGHWAY
HEAVY DUTY VEHICLES	1	Gasoline >3,5 t	Conventional						
	2	Diesel 3,5 - 7,5 t	Conventional						
	3	Diesel 3,5 - 7,5 t	Euro I - 91/542/EEC Stage I						
	4	Diesel 3,5 - 7,5 t	Euro II - 91/542/EEC Stage II						
	5	Diesel 3,5 - 7,5 t	Euro III - 2000 Standards						
	6	Diesel 3,5 - 7,5 t	Euro IV - 2005 Standarts						
	7	Diesel 3,5 - 7,5 t	Euro V - 2008 Standarts						
	8	Diesel 7,5 - 16 t	Conventional						
	9	Diesel 7,5 - 16 t	Euro I - 91/542/EEC Stage I						
	10	Diesel 7,5 - 16 t	Euro II - 91/542/EEC Stage II						
	11	Diesel 7,5 - 16 t	Euro III - 2000 Standards						
	12	Diesel 7,5 - 16 t	Euro IV - 2005 Standarts						
	13	Diesel 7,5 - 16 t	Euro V - 2008 Standarts						
	14	Diesel 16 - 32 t	Conventional						
	15	Diesel 16 - 32 t	Euro I - 91/542/EEC Stage I						
	16	Diesel 16 - 32 t	Euro II - 91/542/EEC Stage II						
	17	Diesel 16 - 32 t	Euro III - 2000 Standards						
	18	Diesel 16 - 32 t	Euro IV - 2005 Standarts						
	19	Diesel 16 - 32 t	Euro V - 2008 Standarts						
	20	Diesel >32t	Conventional						
	21	Diesel >32t	Euro I - 91/542/EEC Stage I						
	22	Diesel >32t	Euro II - 91/542/EEC Stage II						
	23	Diesel >32t	Euro III - 2000 Standards						
	24	Diesel >32t	Euro IV - 2005 Standarts						
	25	Diesel >32t	Euro V - 2008 Standarts						
BUSES	1	Urban Buses	Conventional						
	2	Urban Buses	Euro I - 91/542/EEC Stage I						
	3	Urban Buses	Euro II - 91/542/EEC Stage II						
	4	Urban Buses	Euro III - 2000 Standards						
	5	Urban Buses	Euro IV - 2005 Standarts						
	6	Urban Buses	Euro V - 2008 Standarts						
	7	Coaches	Conventional						
	8	Coaches	Euro I - 91/542/EEC Stage I						
	9	Coaches	Euro II - 91/542/EEC Stage II						
	10	Coaches	Euro III - 2000 Standards						
	11	Coaches	Euro IV - 2005 Standarts						
	12	Coaches	Euro V - 2008 Standarts						
MOPEDS	1	<50 cmi	Conventional						
	2	<50 cmi	97/24/EC Stage I						
	3	<50 cmi	97/24/EC Stage II						
MOTORCYCLES	1	2-stroke >50 cmi	Conventional						
	2	2-stroke >50 cmi	97/24/EC						
	3	4-stroke <250 cmi	Conventional						
	4	4-stroke <250 cmi	97/24/EC						
	5	4-stroke 250 - 750 cmi	Conventional						
	6	4-stroke 250 - 750 cmi	97/24/EC						
	7	4-stroke >750 cmi	Conventional						
	8	4-stroke >750 cmi	97/24/EC						

A5.9. Evaporation Share

sector		Subsector	Legislation Standart	URBAN, %	RURAL, %	HIGHWAY, %
PASSENGER CARS	1	Gasoline <1,4 l	PRE ECE			
	2	Gasoline <1,4 l	ECE 15/00-01			
	3	Gasoline <1,4 l	ECE 15/02			
	4	Gasoline <1,4 l	ECE 15/03			
	5	Gasoline <1,4 l	ECE 15/04			
	6	Gasoline <1,4 l	Improved Conventional			
	7	Gasoline <1,4 l	Open Loop			
	8	Gasoline <1,4 l	Euro I - 91/441/EEC			
	9	Gasoline <1,4 l	Euro II - 94/12/EC			
	10	Gasoline <1,4 l	Euro III - 98/69/EC Stage2000			
	11	Gasoline <1,4 l	Euro IV - 98/69/EC Stage2005			
	12	Gasoline <1,4 l	Euro V (post 2005)			
	13	Gasoline 1,4 - 2,0 l	PRE ECE			
	14	Gasoline 1,4 - 2,0 l	ECE 15/00-01			
	15	Gasoline 1,4 - 2,0 l	ECE 15/02			
	16	Gasoline 1,4 - 2,0 l	ECE 15/03			
	17	Gasoline 1,4 - 2,0 l	ECE 15/04			
	18	Gasoline 1,4 - 2,0 l	Improved Conventional			
	19	Gasoline 1,4 - 2,0 l	Open Loop			
	20	Gasoline 1,4 - 2,0 l	Euro I - 91/441/EEC			
	21	Gasoline 1,4 - 2,0 l	Euro II - 94/12/EC			
	22	Gasoline 1,4 - 2,0 l	Euro III - 98/69/EC Stage2000			
	23	Gasoline 1,4 - 2,0 l	Euro IV - 98/69/EC Stage2005			
	24	Gasoline 1,4 - 2,0 l	Euro V (post 2005)			
	25	Gasoline >2,0 l	PRE ECE			
	26	Gasoline >2,0 l	ECE 15/00-01			
	27	Gasoline >2,0 l	ECE 15/02			
	28	Gasoline >2,0 l	ECE 15/03			
	29	Gasoline >2,0 l	ECE 15/04			
	30	Gasoline >2,0 l	Euro I - 91/441/EEC			
	31	Gasoline >2,0 l	Euro II - 94/12/EC			
	32	Gasoline >2,0 l	Euro III - 98/69/EC Stage2000			
	33	Gasoline >2,0 l	Euro IV - 98/69/EC Stage2005			
	34	Gasoline >2,0 l	Euro V (post 2005)			
LIGHT DUTY VEHICLES	1	Gasoline <3,5t	Conventional			
	2	Gasoline <3,5t	Euro I - 93/59/EEC			
	3	Gasoline <3,5t	Euro II - 96/69/EC			
	4	Gasoline <3,5t	Euro III - 98/69/EC Stage2000			
	5	Gasoline <3,5t	Euro IV - 98/69/EC Stage2005			
	6	Gasoline <3,5t	Euro V (post 2005)			
MOPEDS	1	<50 cmi	Conventional			
	2	<50 cmi	97/24/EC Stage I			
	3	<50 cmi	97/24/EC Stage II			
MOTORCYCLES	1	2-stroke >50 cmi	Conventional			
	2	2-stroke >50 cmi	97/24/EC			
	3	4-stroke <250 cmi	Conventional			
	4	4-stroke <250 cmi	97/24/EC			
	5	4-stroke 250 - 750 cmi	Conventional			
	6	4-stroke 250 - 750 cmi	97/24/EC			
	7	4-stroke >750 cmi	Conventional			
	8	4-stroke >750 cmi	97/24/EC			

Appendix 6 - Creation of COPERT vehicle population input

The software procedure, to be used to make the forecasts of vehicle population up to 2050, requires that specific rules are followed, in order to execute it in the correct way and get reliable results from the run.

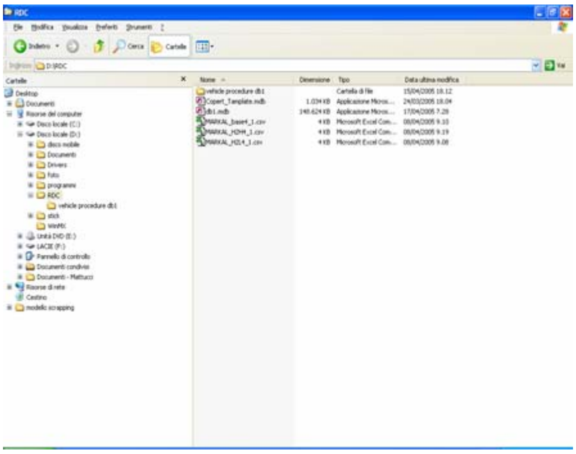
The first rule is that the database and the related software procedures, named "**db1**" is stored in the directory "**RDC**" belonging to disk "**D**" of the computer, as shown in the figure A6.1. below. In case the computer doesn't have disk D, you need to create a virtual unit with such name and, after that, such directory. After having created the above directory, the next step is to transfer inside RDC all the files that are required to run the procedure.

A6.1 Transfer of MARKAL data file

After that the MARKAL results related to transport applications (typically they are named as "MarkalOutputENEA…..") have been provided and transferred in the EXCEL file, where the data are grouped together, in order to determine the total consistence of the different fleets, they need to be input to the ACCESS procedure **db1.**

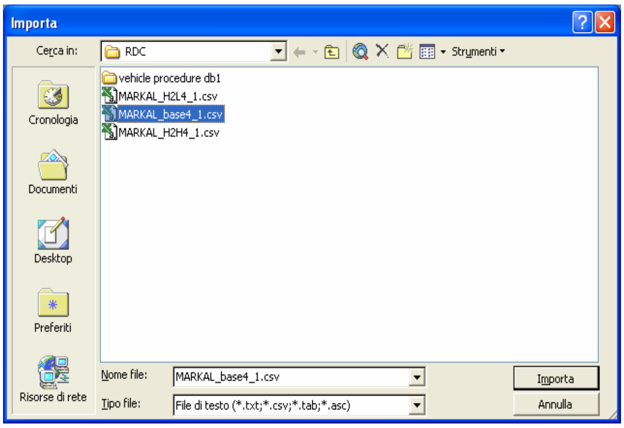
In db1 procedure such data are used as reference to make TREMOVE forecasts consistent with the MARKAL ones. To this end a specific spreadsheet has been built under the EXCEL file, whose name is "**MARKAL-COPERT**", where for all the countries and for each year considered in the forecasts, the total number of the vehicles present in each category is provided. This specific spreadsheet is to be stored in the directory RDC, in a format with extension "**.csv**", as shown in the following figure A6.2., where three such files are provided, as they are representing, in this example, MARKAL forecasts for the baseline (MARKAL_base4_1.csv) and two different hydrogen scenarios.

Figure A66.1. – Computer configuration to use db1



vehicle procedure db1 | Cartella di file
Copert_Template.mdb
db1.mdb
MARKAL_base4_1.csv
MARKAL_H2H4_1.csv
MARKAL_H2L4_1.csv

Figure A6.2. – MARKAL_COPERT correspondence files



Nome file: MARKAL_base4_1.csv
Tipo file: File di testo (*.txt;*.csv;*.tab;*.asc)

According with the type of application to be done, one of such "**.csv**" file is to be selected and imported under the database db1. In particular, after having started the procedure db1, it is possible to select under **File** menu the function to import external data as shown in the following figure A6.3. Then ACCESS asks for the directory from which the data are to be imported and the format of such data. Therefore RDC directory is to be indicated, together with "**.csv**" for the format, before selecting the file of interest as shown in figure A6.4.

Figure A6.3. – Import procedure of external file in db1

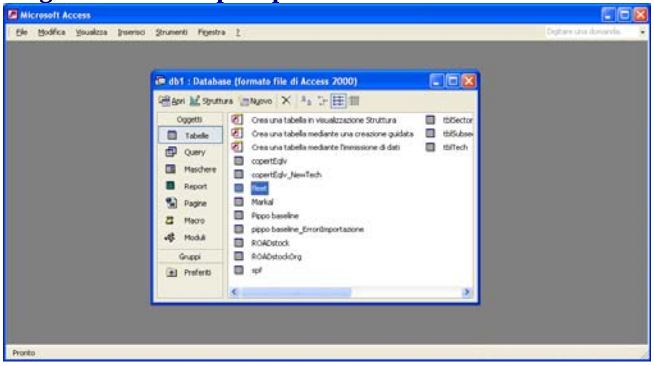
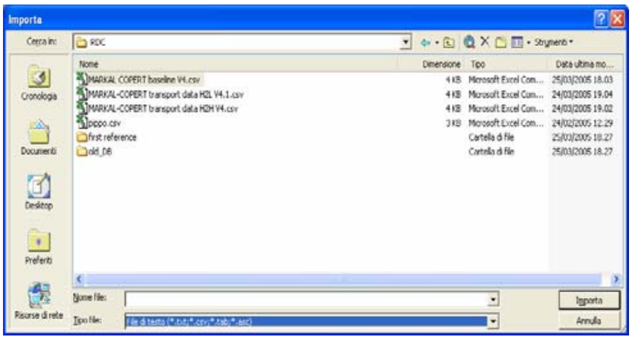


Figure A6.4. – Import procedure of external file in db1



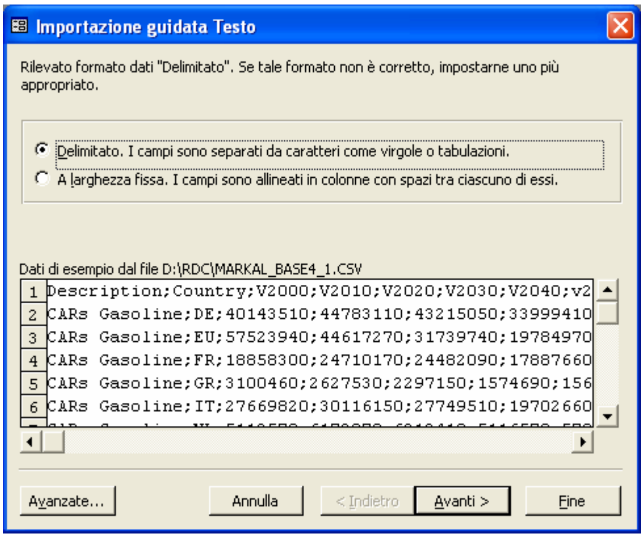
Nome	Dimensione	Tipo	Data ultima mo...
MARKAL COPERT baseline V4.csv	4 KB	Microsoft Excel Com...	25/03/2005 18.03
MARKAL-COPERT transport data H2L V4.1.csv	4 KB	Microsoft Excel Com...	24/03/2005 19.04
MARKAL-COPERT transport data H2H V4.csv	4 KB	Microsoft Excel Com...	24/03/2005 19.02
pippo.csv	3 KB	Microsoft Excel Com...	24/02/2005 12.29
first reference		Cartella di file	25/03/2005 18.27
old_DB		Cartella di file	25/03/2005 18.27

Nome file:
Tipo file: File di testo (*.txt;*.csv;*.tab;*.asc)

The next step is to provide additional information for ACCESS, i.e. how the fields are separated (in this case through semicolons), as shown in the following figure A6.5.

ACCESS asks to know the character used for separation and if there are the indications, which describe the fields in the first row; in case this information is lacking it is required to click in the small square in figure A6.6.

Fig A6.5. – Import procedure of external file in db1



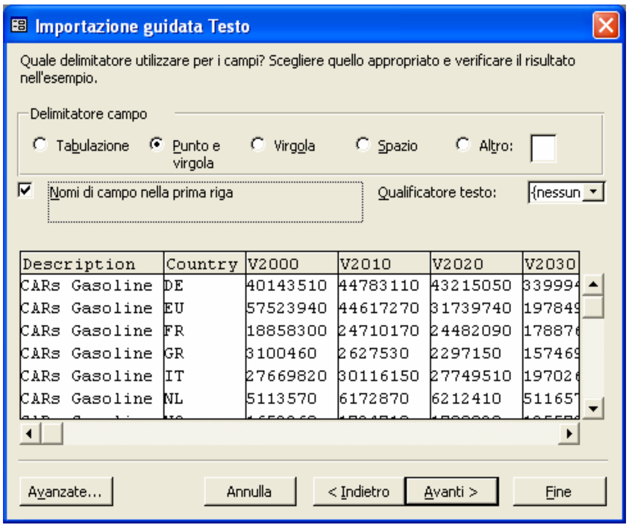
Rilevato formato dati "Delimitato". Se tale formato non è corretto, impostarne uno più appropriato.

● Delimitato. I campi sono separati da caratteri come virgole o tabulazioni.
○ A larghezza fissa. I campi sono allineati in colonne con spazi tra ciascuno di essi.

Dati di esempio dal file D:\RDC\MARKAL_BASE4_1.CSV

```
1 Description;Country;V2000;V2010;V2020;V2030;V2040;v2
2 CARs Gasoline;DE;40143510;44783110;43215050;33999410
3 CARs Gasoline;EU;57523940;44617270;31739740;19784970
4 CARs Gasoline;FR;18858300;24710170;24482090;17887660
5 CARs Gasoline;GR;3100460;2627530;2297150;1574690;156
6 CARs Gasoline;IT;27669820;30116150;27749510;19702660
```

Figure A6.6. – External file import in db1



Quale delimitatore utilizzare per i campi? Scegliere quello appropriato e verificare il risultato nell'esempio.

Delimitatore campo
○ Tabulazione ● Punto e virgola ○ Virgola ○ Spazio ○ Altro: ☐

☑ Nomi di campo nella prima riga

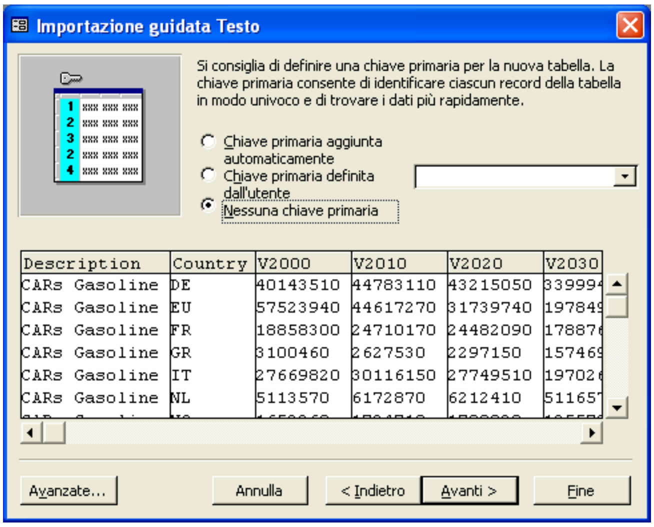
Qualificatore testo: {nessun

Description	Country	V2000	V2010	V2020	V2030
CARs Gasoline	DE	40143510	44783110	43215050	339994
CARs Gasoline	EU	57523940	44617270	31739740	197849
CARs Gasoline	FR	18858300	24710170	24482090	178876
CARs Gasoline	GR	3100460	2627530	2297150	157469
CARs Gasoline	IT	27669820	30116150	27749510	197026
CARs Gasoline	NL	5113570	6172870	6212410	511657

The next windows asks if there is any primary key and it is required to click in the small circle, where no primary key is indicated in figure A6.7.

Next, the name of the table, where data are to be transferred, is required. The name is “**Markal**” as shown in the following figure and then the procedure is completed, clicking the “**End**” button on the right side of the window in the following figure A6.8. In case this table be already existing in the database, it is required **to delete it** before starting the procedure.

Figure A6.7. – Import procedure of external file in db1

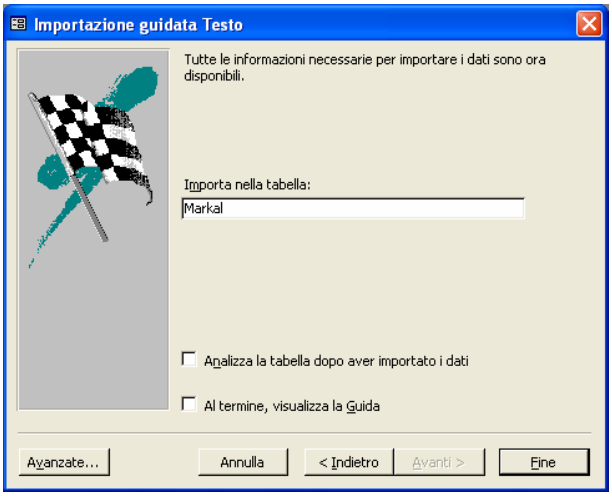


Si consiglia di definire una chiave primaria per la nuova tabella. La chiave primaria consente di identificare ciascun record della tabella in modo univoco e di trovare i dati più rapidamente.

○ Chiave primaria aggiunta automaticamente
○ Chiave primaria definita dall'utente
● Nessuna chiave primaria

Description	Country	V2000	V2010	V2020	V2030
CARs Gasoline	DE	40143510	44783110	43215050	33999
CARs Gasoline	EU	57523940	44617270	31739740	19784
CARs Gasoline	FR	18858300	24710170	24482090	17887
CARs Gasoline	GR	3100460	2627530	2297150	15746
CARs Gasoline	IT	27669820	30116150	27749510	19702
CARs Gasoline	NL	5113570	6172870	6212410	51165

Figure A6.8. – Import procedure of external file in db1



Tutte le informazioni necessarie per importare i dati sono ora disponibili.

Importa nella tabella: Markal

☐ Analizza la tabella dopo aver importato i dati

☐ Al termine, visualizza la Guida

A6.2 Use of COPERT reference file

As the procedure db1 creates the table “**Activity data**” of COPERT database, it is required to start from a reference COPERT database, where db1 procedure can modify the content of the above table, according with the data available under TREMOVE database. Therefore the ACCESS file where COPERT reference data are stored is to be copied under RDC directory and renamed as “**Copert_Tamplate.mdb**” before the updating procedure be started.

A6.3 Forecast of vehicle population

In order to create the data for the vehicle population, some activities have been required, of which some are to be considered off-line, as their aim is to identify the equivalent structures between TREMOVE and COPERT, in order to transfer the data in a very reliable and coherent way, and other on-line, as they are really referring to the run of a software procedure.

A6.3.1 Construction of equivalent vehicle structures between TREMOVE and COPERT

The first step is to create a right overlapping between the vehicle categories, in the way indicated in the following table A6.1. The second step is to make a correspondence between vehicle types considered under the two models, such as in the following table A6.2. The third step is to make a correspondence between vehicle technologies considered under the two models, such as in the following table A6.3.

The process is quite straightforward as TREMOVE is in some way embedding COPERT; nevertheless some new TREMOVE vehicle types have required special attention and they have been merged with existing types; in particular hybrid vehicles are put together with the corresponding ICE vehicle types, as they are not yet covered in COPERT. This has been shown in the following tables A6.4 and A6.5. As it can be seen, a change of fuels has also been required for TREMOVE CNG bus, as there is no CNG fuel available in COPERT model. Therefore, considering that CNG buses are normally used inside the cities and their number is limited they have been merged into Diesel bus type.

Table A6.1. - TREMOVE – COPERT category correspondence

TREMOVE		COPERT	
Name	Description	SectorID	Sector
B	bus	4	Buses
BC	big cars	1	Passenger Cars
C	coach	4	Buses
HDV	heavy duty vehicle	3	Heavy Duty Vehicles
LDV	light duty vehicle	2	Light Duty Vehicles
MOC	motorcycles	5	Motorcycles
MOP	mopeds	6	Mopeds
SC	small cars	1	Passenger Cars

Table A6.2. - TREMOVE – COPERT vehicle types correspondence

TREMOVE		COPERT	
Name	Description	SubsectorID	Subsector
BUS	buses	15	Urban Buses
BUS_CNG	compressed natural gas buses	15	Urban Buses
COACH	coaches	16	Coaches
HTD1	heavy duty trucks - diesel - <7.5t	11	Diesel 3,5 - 7,5 t
HTD2	heavy duty trucks - diesel - 7.5-16t	12	Diesel 7,5 - 16 t
HTD3	heavy duty trucks - diesel - 16-32t	13	Diesel 16 - 32 t
HTD4	heavy duty trucks - diesel - >32t	14	Diesel >32t
HTG	heavy duty trucks - gasoline	10	Gasoline >3,5 t
LTD	light duty trucks - diesel	9	Diesel <3,5 t
LTG	light duty trucks - gasoline	8	Gasoline <3,5t
MC1	motorcycles - 2-stroke >50cm3	18	2-stroke >50 cm^3
MC2	motorcycles - 4-stroke 50-250cm3	19	4-stroke <250 cm^3
MC3	motorcycles - 4-stroke 250-750cm3	20	4-stroke 250 - 750 cm^3
MC4	motorcycles - 4-stroke >750cm3	21	4-stroke >750 cm^3
MP	mopeds <50cm3	17	<50 cm^3
PCDB	cars - diesel - big >2.0l	5	Diesel >2,0 l
PCDHB	cars big diesel hybrid	5	Diesel >2,0 l
PCDHM	cars medium diesel hybrid	4	Diesel <2,0 l
PCDHS	cars small diesel hybrid	4	Diesel <2,0 l
PCDM	cars - diesel - medium 1.4-2.0l	4	Diesel <2,0 l
PCDS	cars - diesel - small < 1.4l	4	Diesel <2,0 l
PCG2	cars - gasoline - 2strokes	7	2-Stroke
PCGB	cars - gasoline - big >2.0l	3	Gasoline >2,0 l
PCGHB	cars big gasoline hybrid	3	Gasoline >2,0 l
PCGHM	cars medium gasoline hybrid	2	Gasoline 1,4 - 2,0 l
PCGHS	cars small gasoline hybrid	1	Gasoline <1,4 l
PCGM	cars - gasoline - medium 1.4-2.0l	2	Gasoline 1,4 - 2,0 l
PCGS	cars - gasoline - small <1.4l	1	Gasoline <1,4 l
PCL	cars - lpg	6	LPG

Table A6.3. - TREMOVE – COPERT category correspondence

TREMOVE		COPERT	
Name	Description	TechID	Tech
RTCNG	CNG bus technology	23	Euro V - 2008 Standards
RTD1	diesel-LPG-2stroke car technology 1 Conventional	13	Conventional
RTD2	diesel-LPG-2stroke car technology 2 Euro I - 91 441 EEC	8	Euro I - 91/441/EEC
RTD3	diesel-LPG-2stroke car technology 3 Euro II - 94 12 EC	9	Euro II - 94/12/EC
RTD4	diesel-LPG-2stroke car technology 4 Euro III - 98 69 EC Stage20	10	Euro III - 98/69/EC Stage2000
RTD5	diesel-LPG-2stroke car technology 5 Euro IV - 98 69 EC Stage200	11	Euro IV - 98/69/EC Stage2005
RTG1	gasoline car RTechnology 1 PRE ECE	1	PRE ECE
RTG10	gasoline car RTechnology 10 Euro III - 98 69 EC Stage20	10	Euro III - 98/69/EC Stage2000
RTG11	gasoline car RTechnology 11 Euro IV - 98 69 EC Stage200	11	Euro IV - 98/69/EC Stage2005
RTG2	gasoline car RTechnology 2 ECE 15 00-01	2	ECE 15/00-01
RTG3	gasoline car RTechnology 3 ECE 15 02	3	ECE 15/02
RTG4	gasoline car RTechnology 4 ECE 15 03	4	ECE 15/03
RTG5	gasoline car RTechnology 5 ECE 15 04	5	ECE 15/04
RTG6	gasoline car RTechnology 6 Improved Conventional	6	Improved Conventional
RTG7	gasoline car RTechnology 7 Open Loop	7	Open Loop
RTG8	gasoline car RTechnology 8 Euro I - 91 441 EEC	8	Euro I - 91/441/EEC
RTG9	gasoline car RTechnology 9 Euro II - 94 12 EC	9	Euro II - 94/12/EC
RTH1	Gasoline & diesel HDV-bus-coach technology 1 Conventional	13	Conventional
RTH2	Gasoline & diesel HDV-bus-coach technology 2 Euro I - 91 542 EEC Stage I	19	Euro I - 91/542/EEC Stage I
RTH3	Gasoline & diesel HDV-bus-coach technology 3 Euro II - 91 542 EEC Stage	20	Euro II - 91/542/EEC Stage II
RTH4	Gasoline & diesel HDV-bus-coach technology 4 Euro III - 2000 Standards	21	Euro III - 2000 Standards
RTH5	Gasoline & diesel HDV-bus-coach technology 5 Euro IV - 2005 Standards	22	Euro IV - 2005 Standards
RTH6	Gasoline & diesel HDV-bus-coach technology 6 Euro V - 2008 Standards	23	Euro V - 2008 Standards
RTL1	Gasoline & diesel LDV technology 1 Conventional	13	Conventional
RTL2	Gasoline & diesel LDV technology 2 Euro I - 93 59 EEC	14	Euro I - 93/59/EEC
RTL3	Gasoline & diesel LDV technology 3 Euro II - 96 69 EC	15	Euro II - 96/69/EC
RTL4	Gasoline & diesel LDV technology 4 Euro III - 98 69 EC Stage20	16	Euro III - 98/69/EC Stage2000
RTL5	Gasoline & diesel LDV technology 5 Euro IV - 98 69 EC Stage20	17	Euro IV - 98/69/EC Stage2005
RTMC1	Motorcycle technology 1 Conventional	13	Conventional
RTMC2	Motorcycle technology 2 Euro I	24	97/24/EC Stage II
RTMC3	Motorcycle technology 3 Euro II	25	97/24/EC
RTMC4	Motorcycle technology 4 Euro III	25	97/24/EC
RTMP1	Moped technology 1 Conventional	13	Conventional
RTMP2	Moped technology 2 Euro I	26	97/24/EC
RTMP3	Moped technology 3 Euro II	26	97/24/EC
RTMP4	Moped technology 4 Euro III	26	97/24/EC

Table A6.4. - TREMOVE vehicle types

no.	class	fuel
1	PCGS small gasoline car -1,4 l	Gasoline
2	PCGM medium gasoline car 1,4-2,0 l	
3	PCGB big gasoline car +2,0 l	
4	PCGHS small hybrid gasoline car -1,4 l	
5	PCGHM med. hybrid gasoline car 1,4-2,0 l	
6	PCGHB big hybrid gasoline car +2,0 l	
7	PCL medium+big LPG car +1,4 l	LPG
8	PCDS small diesel car -1,4 l	Diesel
9	PCDM medium diesel car 1,4-2,0 l	
10	PCDB big diesel car +2,0 l	
11	PCDHS small hybrid diesel car -1,4 l	
12	PCDHM med. hybrid diesel car 1,4-2,0 l	
13	PCDHB big hybrid diesel car +2,0 l	
14	MC2 motorcycle 50-250cc	Gasoline
15	MC3 motorcycle 250-750cc	
16	MC4 motorcycle +750cc	
17	LTG light duty vehicle gasoline	Gasoline
18	LTD light duty vehicle diesel	Diesel
19	HTD1 heavy duty vehicle 3,5-7,5 ton	Diesel
20	HTD2 heavy duty vehicle 7,5-16 ton	
21	HTD3 heavy duty vehicle 16-32 ton	
22	HTD4 heavy duty vehicle +32 ton	
23	BUS diesel	Diesel
24	BUS CNG	CNG
25	COACH diesel	Diesel

Table A6.5. -Resulting types for COPERT

no.	equivalent COPERT type	fuel
1-4	PCGS eq (ICE & hybrid)	Gasoline
2-5	PCGM eq.	
3-6	PCGB eq.	
8-11	PCDS eq	Diesel
9-12	PCGM eq.	
10-13	PCGB eq.	
7	PCL medium+big LPG car +1,4 l	LPG
14	MC2 motorcycle 50-250cc	Gasoline
15	MC3 motorcycle 250-750cc	
16	MC4 motorcycle +750cc	
17	LTG light duty vehicle gasoline	Gasoline
18	LTD light duty vehicle diesel	Diesel
19	HTD1 heavy duty vehicle 3,5-7,5 ton	Diesel
20	HTD2 heavy duty vehicle 7,5-16 ton	
21	HTD3 heavy duty vehicle 16-32 ton	
22	HTD4 heavy duty vehicle +32 ton	
23 - 24	BUS diesel eq.(diesel & CNG)	Diesel
25	COACH diesel	Diesel

A6.3.2 Software procedure to create the vehicle population for COPERT

The procedure is started clicking “**Mask**” command in the left part of the window and then the “**Test**” function in the other part, as indicated in the following figure A6.9.

Figure A6.9. – Activation of db1 procedure to make vehicle population forecast

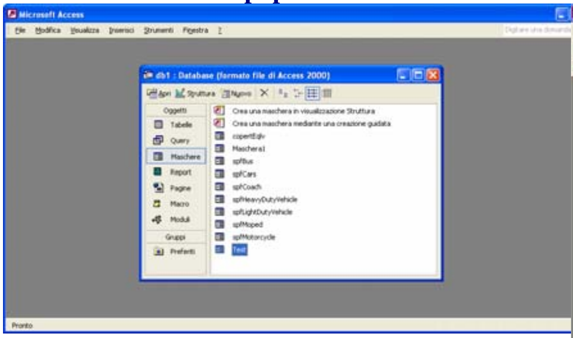
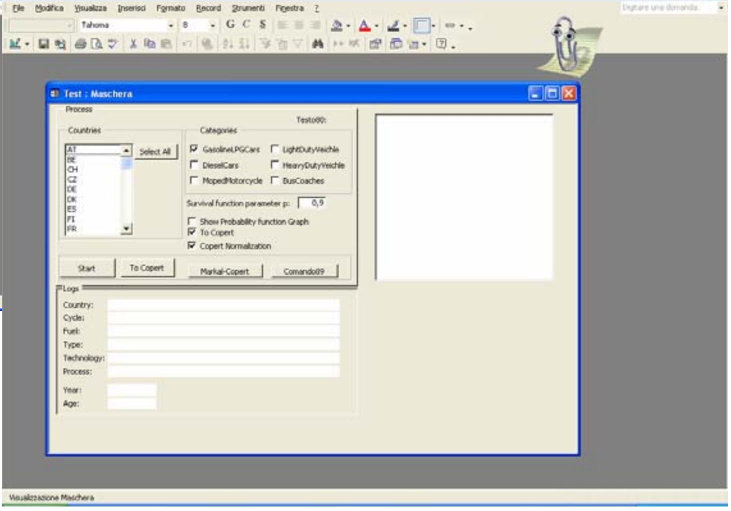


Figure A6.10. – Activation of db1 procedure to make vehicle population forecast



☑ GasolineLPGCars ☐ LightDutyVeichle
☐ DieselCars ☐ HeavyDutyVeichle
☐ MopedMotorcycle ☐ BusCoaches
Survival function parameter p: 0,9
☐ Show Probability function Graph
☑ To Copert
☑ Copert Normalization

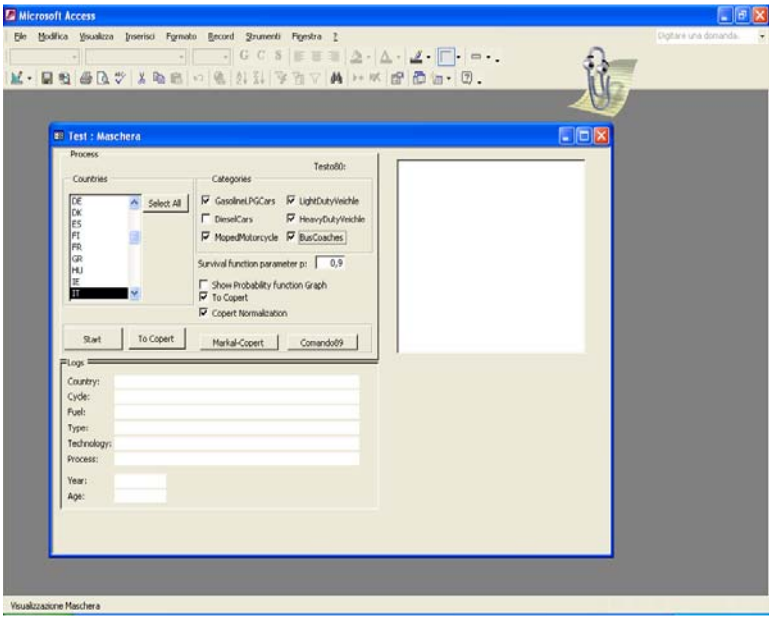
A new window is generated, such as the one in the figure A6.10, where some additional indication is required to complete the set of commands.
In particular the following inputs are required:

1. the Country acronym in the upper left box (default is IT)

2. the vehicle categories to be considered for the forecasts (typically all of them are to be selected, clicking the corresponding small squares, except Diesel cars that are automatically taken if Gasoline Cars are selected)
3. the survival function parameter which is by default put to 0.9, but that can be modified to make faster or slower the disappearance of very old vehicles (more than 20 years old) from the stock; of course the only condition is that the parameter is lower than 1
4. the step of the procedures (respectively clicking the small squares "**to Copert**" and "**Copert normalization**" the six forecast files from 2000 to 2050 one each ten years are provided for COPERT input, extrapolated according with TREMOVE data and normalized respect MARKAL forecasts)
5. Pressing of Start button to activate the procedure

An example of a forecast run for Italy is shown in the following figure A6.11. In any case, according to specific needs, just some of the functions available can be requested.

Figure A6.11. – Activation of db1 procedure to make vehicle population forecast



Countries: DE, DK, ES, FI, FR, GR, HU, IE, IT (selected)

☑ GasolineLPGCars ☑ LightDutyVeichle
☐ DieselCars ☑ HeavyDutyVeichle
☑ MopedMotorcycle ☑ BusCoaches

Survival function parameter p: 0,9

☐ Show Probability function Graph
☑ To Copert
☑ Copert Normalization

Country:
Cycle:
Fuel:
Type:
Technology:
Process:
Year:
Age:

The procedure is normally composed of three steps:

1. The construction of vehicle forecasts up to 2050
2. The generation of the COPERT input files according with the forecasts made under point 1
3. The normalization of vehicle forecasts according with MARKAL forecasts and the generation of the COPERT input files

A6.3.2.1 Construction of vehicle survival probability function

For each category of vehicles it is required to build the function that provides the probability that a new vehicle be working after n years from the year it was sold. This function, which has been named "**Survival probability function**", is necessary to allow to extend the forecasts after the year 2020 up to the year 2050 that is the time target of HyWays Project. As it has been checked that in TREMOVE forecasts this function is the same for all the types of vehicles inside the same category (for instance the passenger cars) independently of the fuel, the calculation has been done for HyWays just considering one of such types.

In order to proceed for the calculation it is required to select a specific type (for instance PCGS small gasoline cars and PCGHS small hybrid gasoline cars, both with engine less than 1.4 L, according with TREMOVE classification); then, starting from year 2000, it is possible to extract from TREMOVE database the number of vehicles that were sold at year 2000 (i.e. the ones having zero year age in such year). For the years after 2000 it is required to build a set of data that are extracted from the database, looking at the number of vehicles that at year 2001 are one year old, at year 2002 two years old, and so on up to 2020. Such set allows to build a curve that gives how many of the 2000 new vehicles are remaining working after n years from 2000.

Due to the fact that in many cases the survival probability is not close to zero at year 2020, there is a need to extend the function for the vehicles having more than 20 years of age; this is carried out imposing that the number of the vehicles older than 20 years be extrapolated using the scheme shown in Appendix 3.

Of course normalizing each of such functions respect to the number of vehicles at year 2000, the resulting curves can be used as an indicator of the survival probability function, which gives the probability that one vehicle is working after n years, as shown in the following figure A6.12 for different categories of vehicles. As it can be seen the trend of curves have a change of slope after the age of 20 years, as the following values are calculated just extrapolating the previous values using the survival function parameter (typically set to 0.9) as it is shown in Appendix 7.

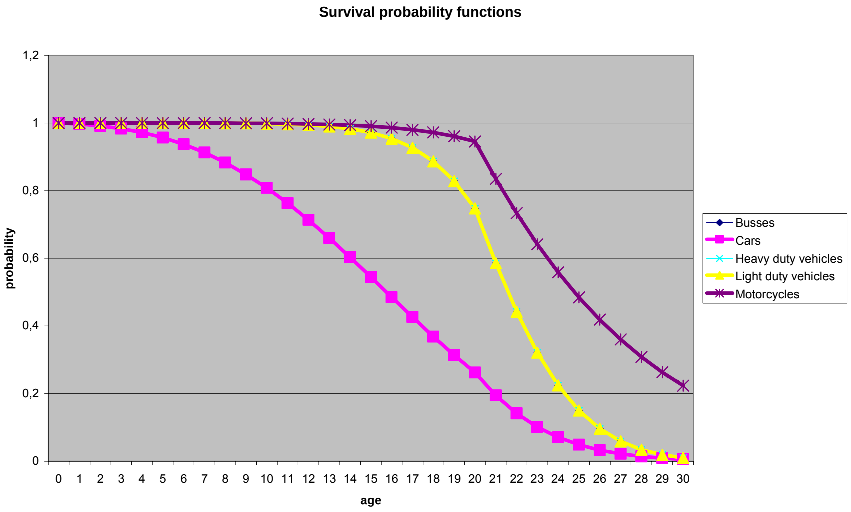
The survival probability trends are different for the different categories of vehicles (passenger cars, LDVs, buses, etc.) and are held constant for all the forecast period and all the technologies belonging to the same vehicle category. Such functions are specific for each Member State and are therefore recalculated for each of them.

Once the curves that give the survival probability have been constructed for each category of vehicles, to calculate the composition of the fleet it is required to have the forecast of the new vehicles sold after 2020. For this task a simple forecast function has also been used, considering the increase of vehicles over a time span of the last five years (from 2015 to 2020), calculating the **yearly increase** (**d_v**) and using it to create the **new vehicle population** (**new_{2020+i}**) with the formula

$$\mathbf{new_{2020+i} = new_{2020+i-1} + d_v} \qquad \mathbf{i = 1,2,\ldots 30} \qquad \mathbf{A6.1}$$

for the entire category of vehicles; in this way the forecasts for the new vehicles can cover the entire required time span.

Figure A6.12.
Example of survival probability functions for different categories of vehicles



As it has been already indicated that in the period of time considered in HyWays there are new legislations enacted for the vehicles (for instance EURO V, EURO VI, etc. for passenger cars), care is to be paid to distribute the values to the legislation in force at the specific year.

With the above positions all the information required to proceed for the forecast is available, with the only additional feature that, in order to avoid to excessively increase the database size, the vehicles older than 20 years are grouped together in one age item (of course if they are belonging to the same subset type).

Then, indicating with $\mathbf{veh(cat,typ,tech)_{y,a}}$ the **number of vehicles** belonging to

category = cat,
type = typ,
technology = tech,
at **year = y**
and of **age = a**,

all the values from 2000 to 2050 can be calculated according to:

$$\mathbf{veh(cat,typ,tech)_{y,a} = veh(cat,typ,tech)_{y-1,a-1} * R_a} \qquad \mathbf{A6.2}$$

where $\mathbf{R_a}$ is the **Survival Probability Ratio** defined in Appendix 7.

At the end of the extrapolation, for each equivalent type of vehicle, a two dimensions matrix related to all the available technologies and the years is available and gives therefore a complete description of the vehicle stock composition.

After the completion of the extrapolation, as COPERT does not distinguish vehicle of different ages belonging to the same technology, a sum of such homogeneous contributions is carried out. Indicating with $\mathbf{Veh(cat,typ,tech)_y}$ the data required by COPERT at year y, it is the result of

$$\mathbf{Veh(cat,typ,tech)_y = \Sigma_a\, veh(cat,typ,tech)_{y,a}} \qquad \mathbf{a = 0,\ldots,21} \qquad \mathbf{A6.3}$$

where, with a is indicated the age of the vehicles (21 is the indication for all the vehicles older than 20 years).

A.6.3.2.2 The generation of the COPERT input files according with the forecasts made under point 1

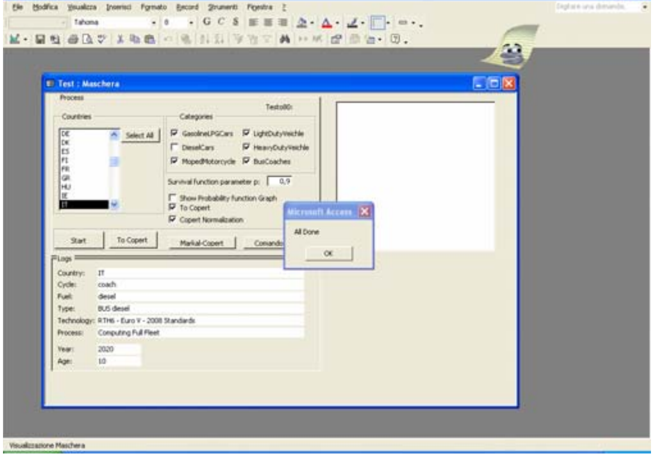
Running the procedure, after the completion of each step a small window is generated and requires to be acknowledged from the user, in order to allow the computer to continue, as shown in the next figure. In particular, at the end of the first step, the window tells that the forecasts of the vehicle categories for the selected Member State have been completed. But, in order to have a real input that fits COPERT requirements some additional work is required to start the transfer the new data in the "**Activity Data**" table. This is carried out by the software procedure after acknowledging the small window, according to the indications provided in par. 3.1., as shown in figure A6.13.

At the end of the step the COPERT input files are provided for each decade from 2000 to 2050, so creating six ACCESS files, which are named as **XXyyyy.mdb**, where

XX stands for the acronym of the Member State and
yyyy for the year

All the above files are stored under RDC directory. In the figure A6.14the completion of such procedure is shown.

Figure A6.13. – Activation of db1 procedure to make vehicle population forecast



☑ GasolineLPGCars
☐ DieselCars
☑ MopedMotorcycle
☑ LightDutyVeichle
☑ HeavyDutyVeichle
☑ BusCoaches

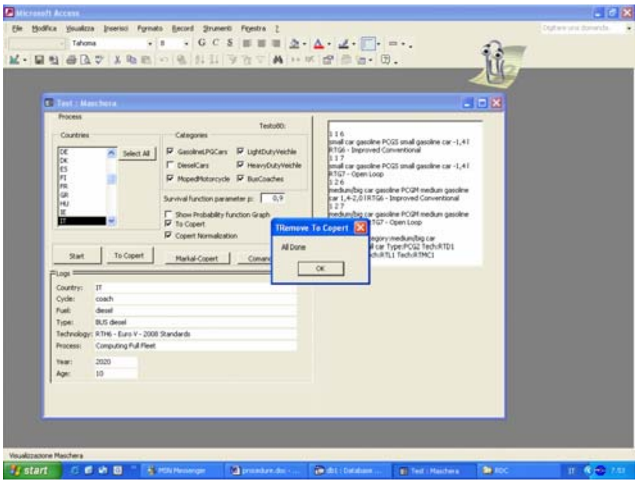
Survival function parameter p: 0,9

☐ Show Probability function Graph
☑ To Copert
☑ Copert Normalization

Country: IT
Cycle: coach
Fuel: diesel
Type: BUS diesel
Technology: RTH6 - Euro V - 2008 Standards
Process: Computing Full Fleet
Year: 2020
Age: 10

All Done

Figure A6.14. – Activation of db1 procedure to make vehicle population forecast



☑ GasolineLPGCars
☐ DieselCars
☑ MopedMotorcycle
☑ LightDutyVeichle
☑ HeavyDutyVeichle
☑ BusCoaches

Survival function parameter p: 0,9

☐ Show Probability function Graph
☑ To Copert
☑ Copert Normalization

Country: IT
Cycle: coach
Fuel: diesel
Type: BUS diesel
Technology: RTH6 - Euro V - 2008 Standards
Process: Computing Full Fleet
Year: 2020
Age: 10

```
1 1 6
small car gasoline PCGS small gasoline car -1,4 l
RTG6 - Improved Conventional
1 1 7
small car gasoline PCGS small gasoline car -1,4 l
RTG7 - Open Loop
1 2 6
medium/big car gasoline PCGM medium gasoline
car 1,4-2,0 l RTG6 - Improved Conventional
1 2 7
medium/big car gasoline PCGM medium gasoline
TG7 - Open Loop
egory:medium/big car
l car Type:PCG2 Tech:RTD1
ch:RTL1 Tech:RTMC1
```

All Done

A.6.3.2.3 The generation of the COPERT input files normalized according with MARKAL forecasts

The last step of the procedure is to make COPERT input data consistent with MARKAL forecasts. This is done starting from the just calculated vehicle forecasts and then comparing and adjusting them to the MARKAL forecasts, but not changing the share for all the technologies considered in each class of vehicles. The task is done for all the COPERT files, with the exception of the one related to 2000, as in this case the data we have used are statistical data from the real vehicle stock and there is no need of any additional adjustment.

The last step is required as the assumptions made under the two models are different; therefore the direct association of MARKAL values to correspondent COPERT structures at level of categories and types (the technologies are not considered under MARKAL) is incorrect as there is neither complete overlapping, nor easy possibility to create general functions to fit COPERT scheme, as no reliable rule can be identified. But this issue can be overcome considering the aggregated structures at level of the single categories and fuels. Therefore the correspondence matrix, shown in figure 3.1, is used to make consistent MARKAL and COPERT data. In this way the sum of all COPERT vehicles, indicated in the right side, are forced to match the MARKAL data, but keeping the same share for all the technologies included in each class of vehicles.

In the figure A6.15 the completion of such procedure is shown.

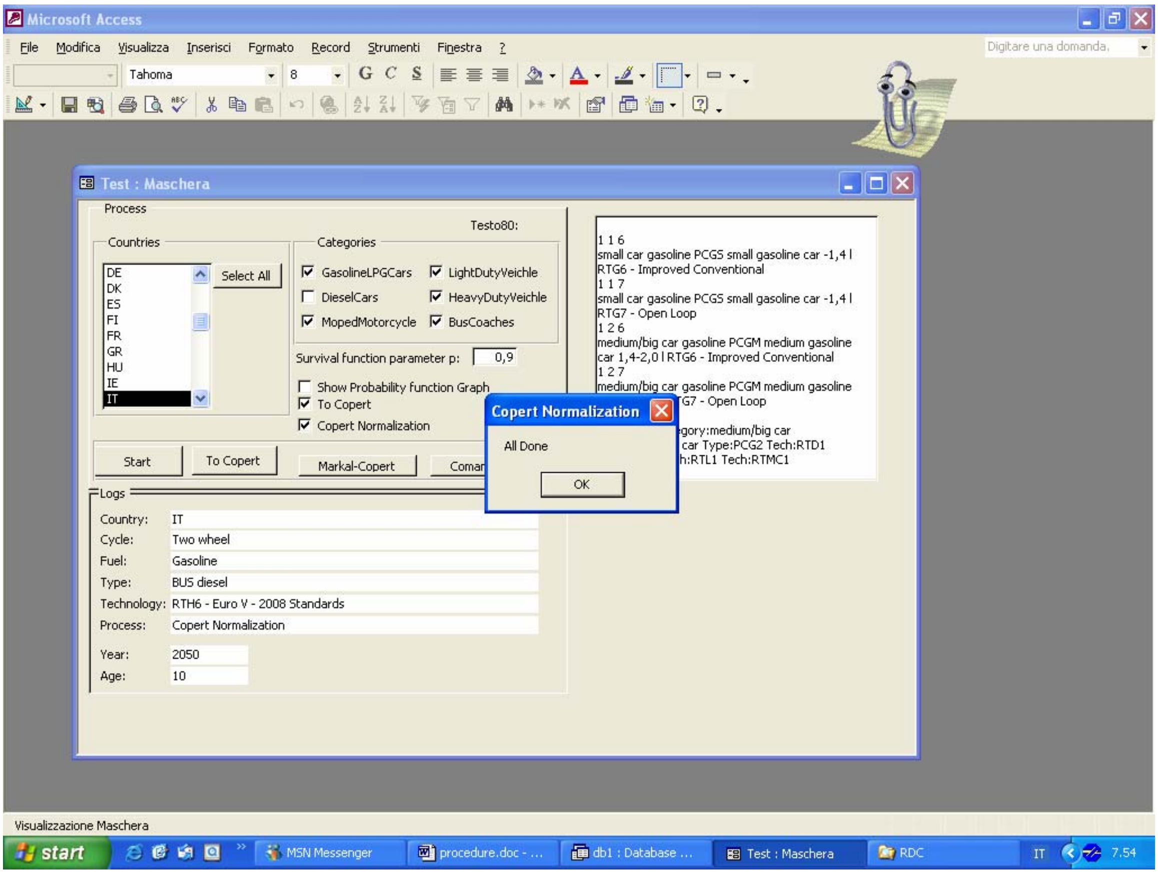
At the end of the step the COPERT input files are provided for each decade from 2000 to 2050, so creating six ACCESS files, which are named as **XXyyyyNorm.mdb**, where

XX stands for the acronym of the Member State and
yyyy for the year

All the above files are stored under RDC directory.

It is important to know that, whenever only the hydrogen scenarios are to be run, it is not necessary to start the entire procedure from the beginning. The only steps to be carried out are the change of **MARKAL** table inside db1 database with the new MARKAL data (see figure 4.2) and to click the Markal-Copert button. Of course it is required that the previously calculated **XXyyyyNorm.mdb** files have been already saved, as otherwise they are overwritten and their content is lost.

Figure A6.15. – Completion of db1 procedure to make vehicle population forecast



Countries: DE, DK, ES, FI, FR, GR, HU, IE, IT (selected)

Categories:
☑ GasolineLPGCars ☑ LightDutyVeichle
☐ DieselCars ☑ HeavyDutyVeichle
☑ MopedMotorcycle ☑ BusCoaches

Survival function parameter p: 0,9

☐ Show Probability function Graph
☑ To Copert
☑ Copert Normalization

Testo80:

```
1 1 6
small car gasoline PCGS small gasoline car -1,4 l
RTG6 - Improved Conventional
1 1 7
small car gasoline PCGS small gasoline car -1,4 l
RTG7 - Open Loop
1 2 6
medium/big car gasoline PCGM medium gasoline
car 1,4-2,0 l RTG6 - Improved Conventional
1 2 7
medium/big car gasoline PCGM medium gasoline
G7 - Open Loop
gory:medium/big car
 car Type:PCG2 Tech:RTD1
h:RTL1 Tech:RTMC1
```

All Done

Country: IT
Cycle: Two wheel
Fuel: Gasoline
Type: BUS diesel
Technology: RTH6 - Euro V - 2008 Standards
Process: Copert Normalization
Year: 2050
Age: 10

A.6.4 Storage of output files

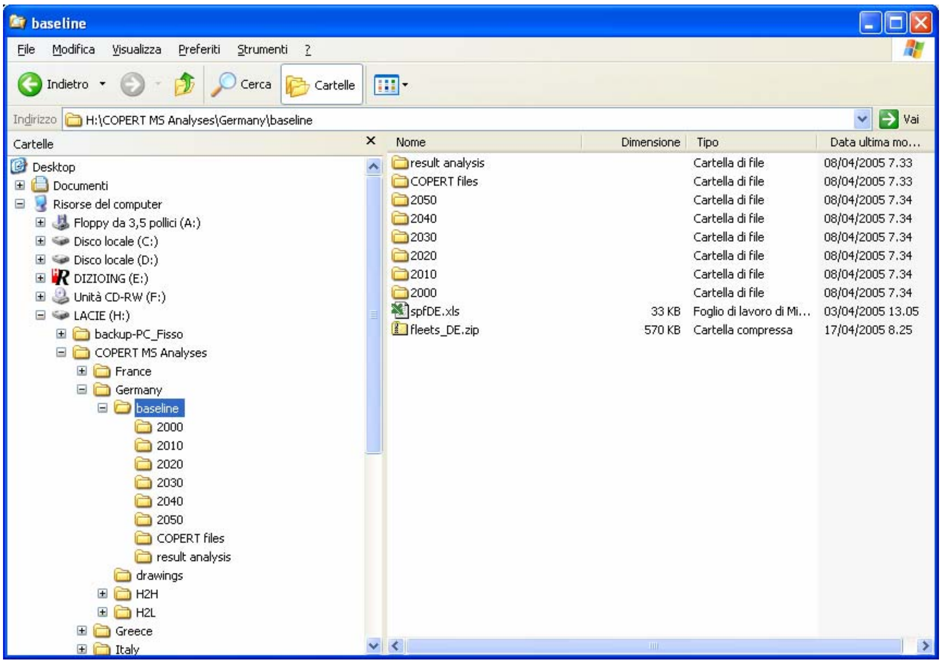
In order to increase the reliability of the overall procedure, some attention is to be also paid on the identification of a suitable structure to save the files just created and the ones that will be created, after running COPERT and processing the hydrogen scenarios. To this end a specific directory, named "**COPERT MS Analyses**" has been created, where all the data are saved. Each MS is characterized by its own directory, named with the country name. Such directory has an internal structure with the following directories:

- **Baseline** that contains all the data of the reference scenario and has the following internal structure of directories
  - **2000** which stores COPERT output results for year 2000
  - **2010** which stores COPERT output results for year 2010
  - **….**
  - **2050** which stores COPERT output results for year 2050
  - **COPERT files** which stores COPERT input files both created to feed the previous procedure and resulting from its run
  - **result analysis** where all the COPERT results for the baseline are handled through EXCEL files in order to allow some analysis of them
- **Drawings** where all the results, belonging to baseline and hydrogen scenarios are compared each other through specific EXCEL files

- **H2H** which has the same structure of baseline directory, but contains the hydrogen high penetration scenario
- **H2L** which has the same structure of baseline directory, but contains the hydrogen low penetration scenario

In the following figure A6.16 the scheme of the directories is shown.

Figure A6.16. – Organization of computer directories for environmental analysis



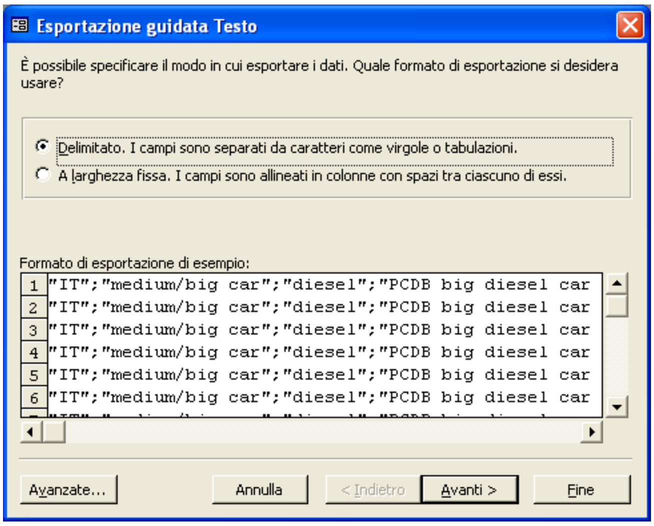
Nome	Dimensione	Tipo	Data ultima mo...
result analysis		Cartella di file	08/04/2005 7.33
COPERT files		Cartella di file	08/04/2005 7.33
2050		Cartella di file	08/04/2005 7.34
2040		Cartella di file	08/04/2005 7.34
2030		Cartella di file	08/04/2005 7.34
2020		Cartella di file	08/04/2005 7.34
2010		Cartella di file	08/04/2005 7.34
2000		Cartella di file	08/04/2005 7.34
spfDE.xls	33 KB	Foglio di lavoro di Mi...	03/04/2005 13.05
fleets_DE.zip	570 KB	Cartella compressa	17/04/2005 8.25

Looking at such figure, in the right side, after the directories, there are two files of which one has been compressed in order to reduce its size:

- **spfDE.xls,** which has been created, exporting **spf** db1 table, containing the survival probability function in EXCEL format for the MS (in this case Germany)
- **fleets_DE.zip** has been created, exporting **fleet** db1 table, containing the vehicle fleet forecasts for the MS in EXCEL format and then compressing it with WINZIP

In the following figures A6.17, A6.18 and A6.19 the way to proceed to the export of **fleet** table is shown. After having selected the **export** function under **File** menu and indicated the format (it is better to use the format **.txt** or **.csv** to save space) the following window appears, where the computer requires the indication about the way the data are separated.

Figure A6.17. – Export of fleet table



Esportazione guidata Testo

È possibile specificare il modo in cui esportare i dati. Quale formato di esportazione si desidera usare?

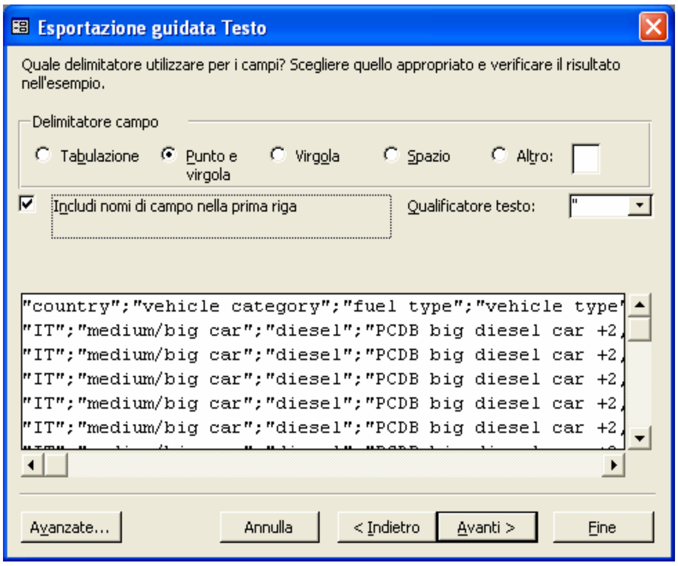
● Delimitato. I campi sono separati da caratteri come virgole o tabulazioni.
○ A larghezza fissa. I campi sono allineati in colonne con spazi tra ciascuno di essi.

Formato di esportazione di esempio:

```
1 "IT";"medium/big car";"diesel";"PCDB big diesel car
2 "IT";"medium/big car";"diesel";"PCDB big diesel car
3 "IT";"medium/big car";"diesel";"PCDB big diesel car
4 "IT";"medium/big car";"diesel";"PCDB big diesel car
5 "IT";"medium/big car";"diesel";"PCDB big diesel car
6 "IT";"medium/big car";"diesel";"PCDB big diesel car
```

Then the type of symbol (in this case semicolon) is to be provided

Figure A6.18. – Export of fleet table



Esportazione guidata Testo

Quale delimitatore utilizzare per i campi? Scegliere quello appropriato e verificare il risultato nell'esempio.

Delimitatore campo
○ Tabulazione ● Punto e virgola ○ Virgola ○ Spazio ○ Altro:

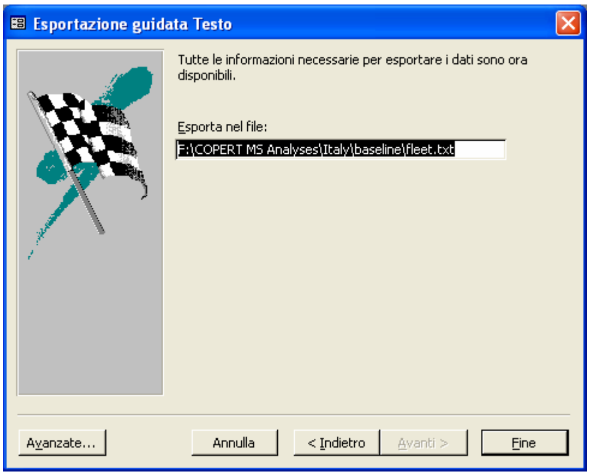
☑ Includi nomi di campo nella prima riga

Qualificatore testo: "

```
"country";"vehicle category";"fuel type";"vehicle type"
"IT";"medium/big car";"diesel";"PCDB big diesel car +2
"IT";"medium/big car";"diesel";"PCDB big diesel car +2
"IT";"medium/big car";"diesel";"PCDB big diesel car +2
"IT";"medium/big car";"diesel";"PCDB big diesel car +2
"IT";"medium/big car";"diesel";"PCDB big diesel car +2
```

At the end the name and the path of the file, where the table is to be stored, are required.

Figure A6.19. – Export of fleet table



Esportazione guidata Testo

Tutte le informazioni necessarie per esportare i dati sono ora disponibili.

Esporta nel file: F:\COPERT MS Analyses\Italy\baseline\fleet.txt

Appendix 7 – Extrapolation of survival probability function

As the vehicle data existing in TREMOVE database covers the time span up to 2020, some processing of them is required to allow that vehicles older than 20 years are considered in the vehicle stock. Therefore a simple algorithm has been created to make possible the extrapolation of the **Survival Probability Function** ($\mathbf{S_n}$).

By definition, having a population of new vehicles $\mathbf{V_0}$, if at year **n** the remaining vehicle of such population are $\mathbf{V_n}$, it follows for Survival Probability Function that

$$\mathbf{S_n = V_n/V_0} \qquad \mathbf{A7.1}$$

It can be also calculated another function, named **Survival Probability Ratio** ($\mathbf{R_n}$)

$$\mathbf{R_n = S_n/S_{n-1}} \qquad \mathbf{A7.2}$$

Of course if S_{n-1} is different from zero (if not R_n is set to zero)

To calculated the values of the above function for

$$\mathbf{n > 20} \qquad \mathbf{A7.3}$$

the **difference** (**d**) of the last 2 R_n, is considered.

$$\mathbf{d = R_{20} - R_{19}} \qquad \mathbf{A7.4}$$

The extrapolation of R_n function is then performed following the rule

$$\mathbf{R_{20+k} = max (R_{20} - k*d, 0)} \qquad \mathbf{k=1, ...} \qquad \mathbf{A7.5}$$

Then it is possible to proceed to the extrapolation of S_n up to at least 30 years, according to:

$$\mathbf{S_{20+k} = S_{20+k-1} * R_{20+k} * p} \qquad \mathbf{k=1, ...} \qquad \mathbf{A7.6}$$

Where with **p** the **survival function parameter** has been indicated. Such parameter, in order to accelerate the process, has to respect the inequality

$$\mathbf{p < 1} \qquad \mathbf{A7.7}$$

and has been set to a default value of 0.9

Acknowledgements

A deep thank is to be given to Costantino Galli, who has been created the software procedure that allows to access TREMOVE database, to select and export the data, to extrapolate the vehicle fleet up to 2050, to check the fleet forecasts according to MARKAL data and, at the end, to build automatically COPERT input.

Additional information

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