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Hydrogen and fuel cell technology in EU LDV transport: Potential contribution to environmental goals

by

Anders Christian, Hansen

The Department of Environmental, Social and Spatial Change
ENSPAC
Roskilde University

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Abstract

Hydrogen in fuel cell (HFC) technology offers a fuel and powertrain solution for a.o. Light Duty Vehicles (LDVs) that is free of tail pipe emissions. This analysis aims at quantifying the potential contribution of this technology to the reduction of air pollution from the European LDV stock. The study shows that HFC technology can contribute to a reduction of local pollutants, but in a very modest scale compared to other measures adopted in European air pollution abatement policy. It also shows that green house gas (GHG) emissions from LDV transport can be reduced to a modest degree even if the hydrogen is produced from natural gas. HFC can, however, contribute to a considerable reduction of GHG emissions to the extent it is based on carbon free energy sources ("2nd generation hydrogen"). The results are obtained using the Sustainable Mobility Project (SMP) Model.

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Valuable comments from the project partners are gratefully acknowledged.

Academic disciplines involved:

Energy economics, environmental economics

Keywords:

Emissions, air pollutants, light duty vehicle (LDV) transport in Europe, scenario analysis, hydrogen, fuel cells

Address for correspondence:

Anders Chr. Hansen,

Department of Environmental, Social and Spatial Change (ENSPAC),

Roskilde University, P.O. Box 260, DK-4000 Roskilde, DENMARK

Phone:	+45 4674 2000
Direct Phone:	+45 4674 2860
Cell Phone:	+45 6167 0592
E-mail:	anders@ruc.dk

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HFC technology - a zero tail pipe emission solution

The attractive potentials of the hydrogen and fuel cell (HFC) technology in automotive use include superior fuel efficiency, pleasant and silent electromotor propulsion, and zero tailpipe emissions. Depending on the production technology used for hydrogen production, the energy can also be with little or no emissions of greenhouse gasses (GHG) and of local pollutants such as nitrogen oxides (NOx), particle matter (PM), and volatile organic compounds (VOC), and carbon monoxide (CO). These local pollutants contributes to smog formation, overload of plant nutriants (eutrophication), and acidification in large parts of Europe.

These properties give rise to the question of how much we can expect the use of HFC technology to contribute to the future reduction of environmental pressure from motorised transport. In this paper, we report some preliminary results from model scenarios produced with the *IEA/SMP Transportation Model* (World Business Council on Sustainable Development (WBCSD) (2004a)). The model was developed by the World Business Council for Sustainable Development (WBCSD) and the International Energy Agency (IEA) and is documented in Fulton and Eads (2004). It was used for developing scenarios of future global developments in transport based on a higher degree of mobility and sustainability (see World Business Council on Sustainable Development (WBCSD) (2004b)).

The scenarios

The model calculates the effects of changes in the vehicle stock on GHG emissions and a number of local air pollutants: Particulate matter, NO_X, VOC, and CO. The scenario results reported in this paper are:

A reference scenario

A scenario where the introduction of HFC technology in the light duty vehicle (LDV) market is advanced and where hydrogen is based on natural gas A scenario like scenario 2), but where hydrogen is produced with GHG emission free or light methods (second generation technology).

The reference scenario is included in the model. With what has become known now (2007) since the development of the model (2004) it would be desirable to revise some of the assumptions included in reference scenario, notably the assumptions of future oil prices. However, as long as we are only interested in quantifying the changes the initial levels of the reference scenario is of less importance.

In the reference scenario, HFC technology is not introduced in large scale, hybrid electric vehicles only have a market share of few percent, and the dynamics of the environmental pressure from LDVs come from continuingly improved fuel, efficiency, and exhaust standards and a growing market share of vehicles with diesel engines to 50% in Europe in the 2020s.

The model produces results for "OECD Europe" which includes the EU15 and the Czech Republic, Hungary, Iceland, Norway, Poland, Slovak Republic, Switzerland, Turkey.

The results are shown for the transport sector as a whole (left) and for the LDV sector alone (right). It is important to note that the model includes total Well-to-Wheel (WtW) – i.e., Well-to-Tank (WtT) plus Tank-to-Wheel (TtW) - emissions as far as GHG emissions are concerned, but not for local pollutants.

Second Scenario: Natural gas based HFC in LDVs

This scenario replaces gasoline fuelled vehicles by fuel cell vehicles, fuelled by hydrogen made from natural gas.

The HFC market share of new LDVs in Europe is increased from 3% in 2020 to 43% in 2050. This increase in market share is exclusively at the "cost" of the standard gasoline ICEV (internal combustion engine vehicle) market share.

The hydrogen used is produced exclusively from natural gas. WtW GHG emissions of natural gas based hydrogen is 3.136 kg CO_2 eq/l gasoline equivalent. This assumption is based on the Joint Research Centre of the EU Commission (2006) accounting of WtW emissions.

The figures below show for each pollutant the emissions from European LDV transport in the reference scenario and in the 2nd scenario. The difference between the two in percent of the reference scenario is shown on the right hand axis.

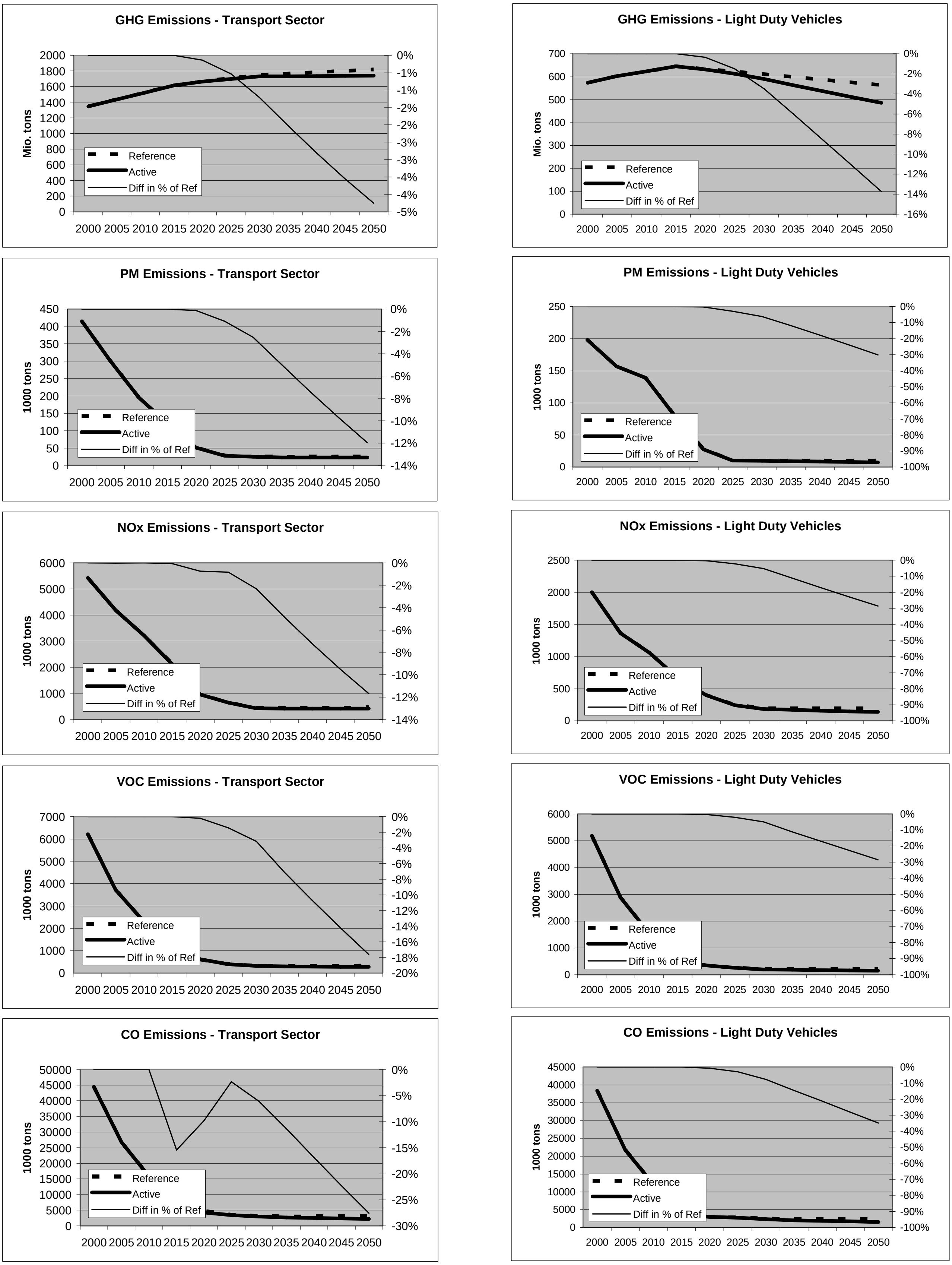

Figure 1. Emissions of air pollutants from European LDV transport in 2nd scenario: Hydrogen based on natural gas

Source: Authors's calculations on the IEA/SMP Transportation Model

In this scenario almost all of the LDV sales of gasoline fuelled standard ICEVs is replaced by sales of hydrogen fuelled FCVs by 2050. Only 6% of the LDVs sold in 2050 are standard gasoline ICEVs whereas 50% are more efficient diesel ICEVs and 41% are hydrogen fuelled FCVs.

This pattern of sales will have reduced GHG emissions from LDVs in 2050 by 14% compared to the reference scenario. This reduction does, however, only amount to 5% of the total transport sector emissions.

The impact on emissions of the local air pollutants PM10, NOX, VOC, and CO is much stronger: about 30% of LDV emissions in 2050. However, this is a reduction from emission levels that have already been reduced by 90% - 96% in the LDV sector as well as in the rest of transport sector.

This is primarily due to tighter fuel and emission standards. Moreover, natural gas based hydrogen production involve emissions (WtT) of these pollutants that are not included in the calculations.

These findings are in accordance with what could be expected considering that natural gas based hydrogen in FCVs represent a zero tail pipe solution where the on-board fuel combustion is replaced by natural gas combustion at the hydrogen production plant.

Third Scenario: Carbon neutral HFC in LDVs

The third scenario includes a relatively fast introduction of carbon neutral hydrogen production technologies reaching a market share of 99% in 2025. All other assumptions are identical to the natural gas based scenario described above.

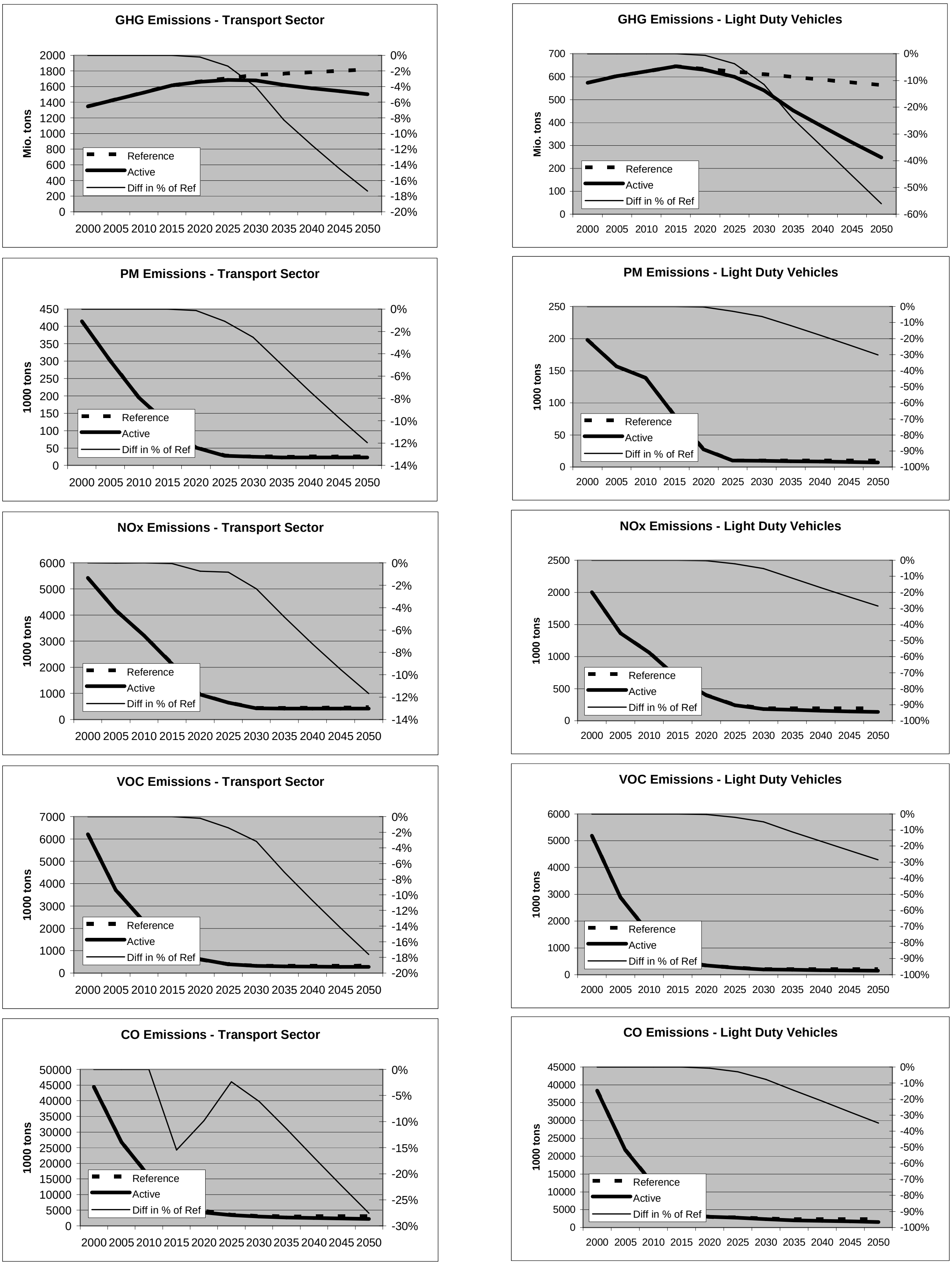

Figure 2. Emissions of air pollutants from European LDV transport in 3rd scenario: Hydrogen based on carbon neutral sources.

Source: Authors's calculations on the IEA/SMP Transportation Model

Replacing natural gas by carbon neutral feedstocks results in a 55% reduction of GHG emissions from LDVs in 2050 and 17% from the transport sector as a whole. These results indicate that second generation hydrogen offers the opportunity of a considerable contribution to eliminating the unsustainable GHG emissions from transport.

The impacts on local pollutants are the same as in the former scenario, but this is partly due to the lack of WtT emissions in the model. Including these emissions would, however, not change the conclusion.

Comparison with the CAFE[1] assessment

The declining emissions of local and regional air pollutants in the reference scenario are due to the ongoing efforts of the European Union and the member states to control air pollution. The regulation already in force (2004) is expected to reduce emissions of NOx, VOC, and PM2.5 in the EU25 by 45-50% from year 2000 to 2020 (Amann, Bertok et al. (2005a)). Transport contributes in varying degrees to the total emissions and the reductions in emissions of these pollutants. Comparing with Amann, Bertok et al. (2005b) shows that transport contributes with 70% of the NOx emission reduction, 55% of the VOC emission reduction, and 36% of the PM2.5 emission reduction.

In the reference scenario the trends in fuel efficiency, fuel and exhaust standards are continued and if this development materialises then the oil based fuel and ICE technology has notable potentials for reduction of emissions of local pollutants. But the realism of the assumption is of cause open to debate.

Conclusions

These preliminary results led to two observations.

First, the local air pollution problems are expected to be reduced considerably even without electric vehicles, primarily though tighter standards for fuels, fuel efficiency, and car exhaust. The zero tailpipe emission quality of HFCVs does make the technology a perfect candidate for technology trends reducing local and regional air pollution, but the measures already adopted in air pollution abatement and those that are in the pipeline can have reduced the air pollution at the time when HFCVs are introduced in large scale on the market to such an extent that the contribution is of very little importance to the problem.

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[1] Clean Air for Europe (CAFE) was launched in March 2001 with a Communication (COM(2001)245)). CAFE is a programme of technical analysis and policy development that underpinned the development of the Thematic Strategy on Air Pollution under the Sixth Environmental Action Programme. More information on the programme is available at http://ec.europa.eu/environment/air/cafe/index.htm.

Second, hydrogen and HFCVs can have a considerable impact on GHG emissions if the hydrogen is produced by 2nd generation technologies such as renewable, nuclear, or fossil with CCS. To the extent hydrogen is produced by natural gas without CCS, it will only contribute moderately to curbing GHG emissions.

The results point to the conclusion that the main environmental benefit of advancing HFC technology in automotive use will be the reduction of GHG emissions, but only to the extent that natural gas based hydrogen is replaced by second generation – carbon neutral - hydrogen.

These conclusions come, however, with several reservations.

First, accounting of the emissions of local pollutants along the entire WtW chain in all dimensions are needed before firm conclusions can be drawn upon the full effects on local and regional pollutant emissions.

Second, it should be noted that HFC technology is not only an LDV solution, but will be used in numerous applications in transport, energy transformation, and energy service activities. Thus, the effects calculated here, must not be interpreted as the full effect of the technology as such.

Third, the reference scenario is based on somewhat obsolete assumptions and it needs to be updated. This would, however, hardly change the magnitude and direction of the effects calculated in the two HFC scenarios.

Fourth, the assumption that HFCVs will only replacing standard gasoline fuelled vehicles is debatable. This type of cars will compete with diesel, natural gas, and biofuel fuelled cars too, with and without hybrid powertrains. Taking this into account would reduce the contribution of introducing the HFC technology in European LDV transport further.

Fifth, the emission reduction due to progress in fuel, efficiency, and exhaust standards and increasing diesel market share assumed in the scenarios can be too optimistic. However, assumptions based on more modest expectations will hardly lead to very different conclusions.

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