

PENETRATION OF HYDROGEN TECHNOLOGIES: STUDY ON THE ENVIRONMENTAL IMPACT OF ROAD TRANSPORT IN PORTUGAL

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ABSTRACT

Road traffic is one of the transportation sectors with faster growth and also one of the most important emitters of greenhouse gases (GHGs). In this work, an analysis of the environmental benefits resulting from the introduction of hydrogen on road transport in Portugal is made. Impact is analyzed mainly looking at the pollutant emissions provided by road transport at the point of use. Emissions associated to road transport have been estimated using the software COPERT (version 4), since it provides a detailed methodology for each specific pollutant related to the vehicle fleet of a region or country, as well as the driving conditions and fuel consumption. Passenger cars, light duty vehicles and public transport buses are the vehicles categories in which the hydrogen technology is foreseen. The hydrogen penetration rates (moderate and high) are extracted from the European Project HYWAYS. Two trends are then considered, which give penetration rates of 40.0 % and 74.5 % in 2050 for the moderate and high scenarios respectively.

Keywords: Road transport, pollutant emissions, COPERT 4, Hydrogen technologies, Portugal.

RESUMEN

El tráfico rodoviario es uno de los sectores del transporte con más rápido crecimiento y también uno de los más importantes emisores de gases tipo invernadero. En el presente trabajo se presenta un análisis de los beneficios medioambientales que podrían resultar de la introducción de hidrógeno en el sector de transporte rodoviario en Portugal. Tal impacto, es analizado tomando en consideración las emisiones en el punto de uso. Las emisiones asociadas al transporte rodoviario fueron estimadas utilizando el software COPERT (versión 4), este incluye una metodología detallada para cada emisión relacionada con la flota de vehículos de una región o país, así como también relativamente a las condiciones de conducción y consumo de combustible. Los carros de pasajeros, vehículos ligeros y buses para transporte público, son las categorías de vehículos en los cuales la penetración de la tecnología del hidrógeno fue prevista. Las tasas de penetración (moderadas y altas) fueron extraídas del Proyecto Europeo HYWAYS. Dos tendencias fueron consideradas, penetraciones de 40% y 74.5%, para los escenarios moderado y alto respectivamente.

Palabras llave: Transporte rodoviario, emisiones, COPERT 4; Hidrógeno, Portugal.

1. INTRODUCTION

Road transportation is one of the most important emitters sectors of greenhouse gases (GHGs) such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). It is also a significant emission source of pollutants such as (SO_x), (NO_x), (CO) and non-methane volatile organic compounds (NMVOC),

indirectly responsible for the formation of ozone (O₃) in the lower troposphere. Substantial emissions of ammonia, particulate matter and heavy metals, result also from transportation activity while exhaust emissions result from the combustion.

A reduction of the reported pollutant is foreseen with the introduction of clean fuels, such as renewable hydrogen.

In this work, different scenarios for road transport (with and without hydrogen) are developed from 2005 to 2050 and the correspondent pollutant emissions are calculated.

It is considered that the hydrogen technology is driven to the market in 2020 and will be the dominant technology in 2050 for the most optimistic trend.

Passenger cars, light duty vehicles and public transport buses are the vehicles categories in which the hydrogen technology is foreseen. Two trends are considered, which give moderate and high penetration rates for respective scenarios.

The software and methodology chosen to calculate the emissions from the road transportation sector is associated to the COPERT program.

2. PROCEDURE

The software COPERT v.4 (COmputer Programme to calculate Emissions from Road Transport) is used in this work. It is the fourth update of the initial version COPERT 85 (1989) [1].

The software estimates emissions of all regulated air pollutants (CO, NO_x, VOC, PM) produced by different vehicle categories (passenger cars, light duty vehicles, heavy duty vehicles, including buses and coaches, mopeds and motorcycles) as well as CO₂ emissions on the basis of fuel consumption.

Emissions are also calculated for an extended list of non-regulated pollutants, including CH₄, N₂O, NH₃ and SO₂.

COPERT calculates the pollution produced by one (or more) vehicles on a yearly base. The methodology is based on the calculations of the so called *Emission Factors*, which quantifies how much of a pollutant is produced by a vehicle per Km.

In the first instance, COPERT 4 was used for the calculation of the pollution generated by the vehicle fleet in Portugal in the year 2005, taken as a baseline scenario.

The input data is reported to different parameters, related to the country’s fleet configuration, such as vehicles categories and vehicle classes as well as legislation according to built year.

The activity data comprise values from the vehicle fleet (population), mileage, fuel injection and evaporation control. The speed values in different driving modes and different vehicles type are also consider.

The vehicle fleets (passenger cars, light duty vehicles and buses), in which penetration of hydrogen technology is foreseen, were projected since 2020 until 2050. The hydrogen penetration rates (moderate and high) were extracted from HYWAYS [2]. Two trends are then considered, which give penetration rates of 40.0 % and 74.5 % in 2050 for the moderate and high scenarios respectively (see table1).

Table 1. Penetration rates for hydrogen technology on road transport.

Share car fleet	2020	2030	2040	2050
High	3.3%	23.7%	54.4%	74.5%
Moderate	0.7%	7.6%	22.6%	40.0%

3. RESULTS AND DISCUSSION

3.1 CO₂ emissions

For the considered baseline scenario, 2005, carbon dioxide emissions are shown in figure 1, by vehicles type and driving mode.

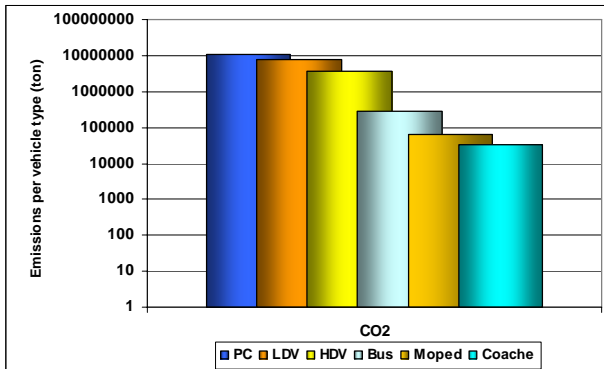
The passenger cars are shown to be the vehicle type responsible for the most of the gas emissions followed by LDV and HDV.

Urban driving mode is found to be the greatest CO₂ contributor, in comparison with rural and highway modes.

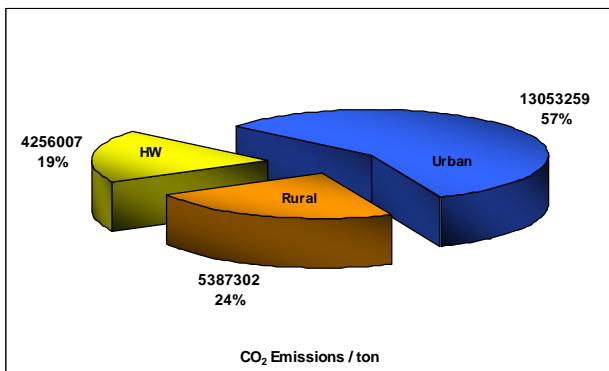
For the year of 2020 the differences of data for gas emissions, in the scenario with hydrogen technology penetration and otherwise in absence of this technology, give small decrease since the penetration rate is a reduced percentage.

From 2030 until 2050 the penetration of hydrogen in the road transport has a more significant increase (see also table 1) and consequently a decrease in the gas emissions; in addition, in a scenario in the absence of hydrogen technology penetration, emissions are reported to increase.

Figure 2 reveals an increase in the emissions from 2005 up to 2050 in the absence of penetration of hydrogen technology for CO₂.



(a)



(b)

Fig. 1. CO₂, CH₄ and N₂O emissions, in ton (a); and their relationship with vehicles type (b).

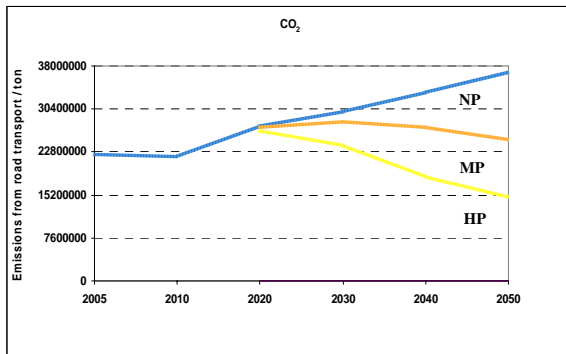


Fig. 2. CO₂ emissions, in ton, from 2005 up to 2050, in presence (MP and HP) and absence (NP) of hydrogen penetration.

3.2 Non-CO₂ emissions

The influence of catalyst converters and the application of Euro I and Euro II technology [NIR] allowed a decrease of NO_x. Recently, more severe legislation has contributed to diminish pollutants such as NO_x, nevertheless, an increase of N₂O has been reported.

The introduction of catalytic converters is thought to promote, during the reduction process of NO to N₂, the formation of N₂O as an intermediate.

This reaction takes place particularly at lower temperatures, so the urban drive conditions present the higher emission. The emissions of N₂O may increase also as the catalyst ages or at lower speeds circulation of the vehicle [2-3].

The values of NO_x obtained in this work, are compatible with data reported from UNFCCC, fig. 3.

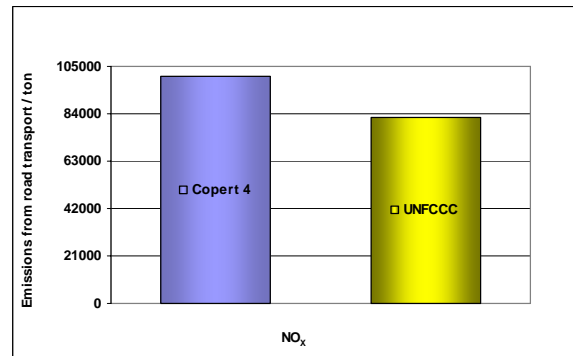


Fig. 3. Baseline scenario (2005): NO_x emissions obtained in this work and data reported by UNFCCC.

Figure 4 shows how increasing hydrogen penetration from MP to HP brings about a decrease in NO_x emissions. A reference curve for the baseline scenario, in the absence of hydrogen penetration (NP) is also represented in the figure.

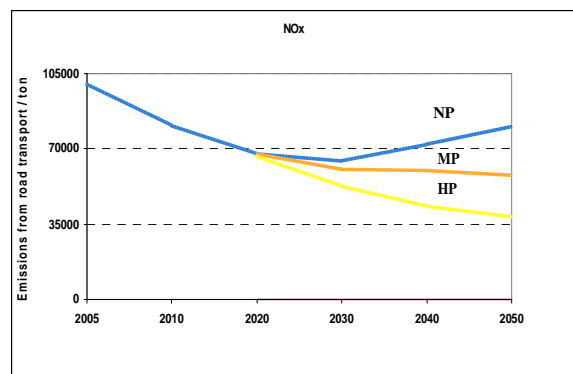


Fig. 4 NO_x, emissions, in ton, from 2005 up to 2050, in presence (MP and HP) and absence (NP) of hydrogen penetration.

4. Final remarks

The implementation of hydrogen technology from 2020 up to 2050, will promote a reduction of gases emissions due the replacement of fossil fuels by a

clean energy source like hydrogen in agreement with the compliance of legislation concerning the pollutants in road transport.

In this work, the values given by COPERT 4, related to CO₂, N₂O and CH₄ emissions, regarding the road transport sector, are reported in comparison with data obtained from sources such as NIR (National Inventory Report, 2007), UNFCCC (United Nations Framework Convention on Climate Change), and PNAC (Programa Nacional para as Alterações Climáticas), with good agreement [4-8].

The vehicle fleets were projected up to 2050, according data from the TIMES model [9].

The scenario business-as-usual, projected for 2050, can be considered extreme since it is based on the growth of road transport without further restrictive emission legislations or other improvement in fuel and motor technology. So, the amount of pollutant emissions foreseen is probably overestimated, nevertheless the scenario is useful to evaluate the decrease of the total pollutant emissions with the introduction of hydrogen technology.

From 2020 to 2050 emissions are found to decrease with the increase hydrogen penetration. The penetration of hydrogen technology is significant for the high penetration scenario (HP). The data for moderate penetrations (MP) are less relevant, although restraining the natural increase of the emissions in a scenario in the absence of hydrogen technology penetration (NP).

The reduction in pollutant emissions achieved by hydrogen technology will be also determinant for the improvement of air quality in urban centres, where emissions are concentrated and consequently more noxious to the urban populations (in addition to the green house effect):

The urban drive mode is mainly accountable for all emissions, followed by rural and highway modes.

Passenger cars (PC) appear more polluting followed by light duty (LDV) and high duty vehicles (HDV).

Regarding CO₂ and CH₄ emissions the higher contributions come from LDV while for N₂O the higher contribution comes from HDV.

In the time period until 2020, the main challenges to the implementation of the intended hydrogen infrastructure were identified as end use applications, hydrogen production, and hydrogen distribution. In terms of transport applications, fuel cell vehicles are seen as a challenge due to the perceived low stage of development of the drive chain technologies, and the consequent high vehicle costs, and lack of refuelling infrastructure.

Acknowledgements

This work was partially funded by ADI (Agência de Inovação) in the framework of the EDEN Project, Portugal.

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