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# Greenhouse gas emissions from Spanish motorway transport: Key aspects and mitigation solutions

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HIGHLIGHTS

- Three model stretches, representative of Spanish motorway conditions, were evaluated.
- Three environmental improvement scenarios were proposed.
- Speed limit seemed the easiest measure to implement in a near future.
- Afforestation showed limited effectiveness per unit of land surface.
- A drastic technological improvement is required to obtain significant reductions.

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ABSTRACT

The current increasing importance of road transport in the overall greenhouse gas (GHG) emissions has led to the adoption of diverse policies for the mitigation of global warming. These policies focus in two directions, depending on whether they involve the reduction of emissions or the mitigation through carbon dioxide ($CO_2$) sequestration. In this paper, the Tier 3 methodology from the European Monitoring and Evaluation Programme and the Environment Agency (EMEP/EEA) was applied to determine the evolution of Spanish motorway GHG emissions in the period 2005–2010. According to the results, though the average daily traffic (ADT) is the major parameter, the average fleet age and vehicle size also affect the level of emissions. Data analysis also revealed a clear connection between the decrease in European trade volume during the financial crisis and the GHG release, despite its temporary character. Among the three improvement scenarios evaluated, reduced speed limit seems the most direct measure while the consequences of afforestation strongly depend on the traffic density of the stretch of the motorway considered. Finally, technological improvement requires a drastic change in the fleet to obtain substantial decrease. The combination of different policies would allow a more robust strategy with lower GHG emissions.



## 1. Introduction

Recent scientific observations reveal that greenhouse gas (GHG) emissions from anthropogenic activities have modified their natural variability, causing an increase in their concentration levels (Crowley, 2000; Doney et al., 2006; García et al., 2010). The alteration of the energy balance has led to the environmental impact of climate change with adverse effects in ecosystem and society, evidenced even in short and medium terms (IPCC, 2007; Lindner et al., 2010; Walther et al., 2002). In order to prevent hazardous consequences and stabilize GHG concentration at an acceptable level, governments are adopting policies to slow down climate change. More than 100 countries have agreed to set a global warming limit of 2 °C, which requires a decrease in global emissions of at least half 1990 levels (Meinshausen et al., 2009; UNFCCC, 1998). However, world emissions are increasing faster than at the beginning of the 1990s, especially in developing countries (Baiocchi and Minx, 2010). Even more, according to the International Energy Agency (IEA, 2011), global energy-related emissions of carbon dioxide ($CO_2$), the main GHG, reached a record of 30.4 Gt in 2010.

Energy sector is one of the main sources of GHG emissions derived from anthropogenic activities. Particularly, transport accounts for approximately 15% of overall emissions and is still

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increasing in most countries (Li, 2011; OECD/ITF, 2010). In fact, this sector experienced the largest growth (+24%) in EU-27 GHG emissions between 1990 and 2008, with more than 90% coming from road transport; whereas total emissions were reduced to 11.1% below their 1990 level (EEA, 2011a). In the case of Spain, energy-related sources in 1990 included 74.2% of the total of 283.2 Mt $CO_2$ eq emitted, with 19.5% of total emissions derived from transport. Almost two decades later, total emissions had increased 26.9% in 2009 while specific transport emissions had grown by 52.6% from the corresponding level in 1990, representing a final percentage of 25.7% (Spanish Ministry of the Environment and Rural and Marine Affairs, 2011).

According to Spanish Ministry of Development (2009), GHG emissions from road transport account for about 90% of total GHGs from national transport sector. Light vehicles, including passenger cars, motorcycles and light freight vehicles, contribute with 66% to the total emissions, whereas heavy-duty vehicles and coaches account for 34%. With regard to driving conditions, 49.6% of road transport emissions in 2006 were generated in high-speed ways, specifically in intercity routes. In the same base year, highways and motorways represented 48.1% of the total travelled kilometers in Spain, so that the contribution per travelled kilometer is higher than in other types of road (Spanish Ministry of Development, 2012). During the last years, travelled kilometers in highways and motorways have increased, reaching 51.5% of the total road transport in 2010.

Due to the importance of transport sector, there is an urgent need to adopt improvement measures in order to limit GHG emissions. These improvements can be achieved by applying transport policies focused in two directions: (i) reduction of emissions or (ii) mitigation through $CO_2$ capture or sequestration processes (Smith, 2004). Moreover, the reduction of emissions from road transport can be addressed by promoting an updating of technologies or by forcing a change in the operation of the existing vehicles. In this study, three main strategies were selected, according to the suitability of the above-mentioned policies in the Spanish context. These scenarios include forestry activities that compensate $CO_2$ release, technological improvement of vehicles and changes in driving patterns (Barkenbus, 2010; EMEP/EEA Emission Inventory Guidebook, 2009; Hansen et al., 1995; McCarl and Sands, 2007). Regarding the involved stakeholders, the first option would be the only feasible one for the motorway operator, whereas the change in driving patterns through speed limitation would require the government intervention and a technological updating would constitute a more widespread measure, affecting international vehicle manufacturers and policy-makers.

The use of afforestation and reforestation as compensation options has been long discussed (Bala et al., 2007; Canadell and Raupach, 2008; Kaul et al., 2010; Malmsheimer et al., 2008; Marland and Schlamadinger, 1997). The rationale behind this strategy lies on the photosynthesis process by which plants uptake $CO_2$ from the atmosphere. The Kyoto Protocol explicitly mentions that GHG removal by sinks resulting from direct human-induced forestry activities shall be used to meet the reduction commitments assigned to each country (UNFCCC, 1998). However, several drawbacks in the inclusion of forestry activities in the GHG inventory have been reported. In this sense, European Commission (2008) argues that the adoption of this strategy would require a standard of monitoring and reporting of emissions that is not currently available. In addition, it could delay the development of carbon-efficient technologies and threat local ecosystems due to the potential use of faster growing species. Streck et al. (2009) pointed out the non-permanence of the carbon stored in biomass and soils due to disturbances, such as fires or illegal logging. Furthermore, some authors suggest that global forestation could even lead to warming due to surface albedo changes, specifically in middle and high latitudes (Betts, 2000; Bala et al., 2007). Finally, as the relative potential contribution of forest sinks will decline within the century, forest-carbon absorption should not be considered a long-term solution to global warming but a temporary alternative (Malhi et al., 2002).

Concerning technological measures, policies shall focus on the development of alternative energy sources with lower GHG emissions or the reduction of energy use through the substitution of inefficient vehicles. Nowadays, transport is mainly dependent on non-renewable liquid fuels such as gasoline and diesel, which are linked to 40% of the total energy consumption in the world (Tan et al., 2008). In the Spanish case, these fuels were responsible of 99.8% of total GHG emissions from road transport in 2009 (Spanish Observatory for Sustainability (OSE), 2011). According to several authors, the substitution of these fuels by renewable sources such as ethanol can lead to reductions of 60–80% in GHG emissions while hydrogen fuel cell vehicles may result in an improvement of 60% (González-García et al., 2010; Nguyen et al., 2007; Stephens-Romero et al., 2009). Another possibility is the reduction of fuel consumption through vehicle downsizing, lower power-to-weight ratios or more efficient technologies (Michaelis and Davidson, 1996; Zervas, 2010a). However, new technologies are emerging slowly in Spain, where gasoline and diesel include 99% of national road fleet (Spanish General Directorate of Traffic (DGT), 2012). Thus, the substitution of vehicles shall be encouraged so as to increase the number of low-consumption vehicles. Among the measures to substitute vehicles with high emissions, many studies show the effectiveness of taxing size or gasoline, as well as subsidizing new vehicles (West, 2004).

Nevertheless, fuel consumption and therefore GHG emissions depend not only on vehicle technology, but also on driving patterns. Indeed, a strong dependency between pollutant emissions and speed level has been widely reported (André and Hammarström, 2000; Ntziachristos and Samaras, 2000; Pandian et al., 2009). Regarding this effect, Sjodin et al. (1998) measured a large on-road fleet in a tunnel, showing that there was a minimum in the emissions of carbon monoxide (CO) and $CO_2$ for a speed range between 60 and 80 km/h, which is in agreement with the values reported in other studies (Barth and Boriboonsomsin, 2008; El-Shawarby et al., 2005). As a result, a decrease in speed limit has been proposed as a feasible policy to reduce GHG emissions (Barkenbus, 2010).

Controlling GHG emissions from the transport sector requires an accurate computation of these gases for the evaluation of the strategies related to climate policy (Creutzig et al., 2011). Different alternatives for the quantification of GHG emissions may be used for this purpose. Weigel et al. (2010) distinguish two main categories: registry based calculators and Life Cycle Assessment calculators. Registry based calculators allow a consistent approach to end-use GHG emissions, whereas Life Cycle calculators may enable a holistic assessment of a wider system that includes the emissions associated with the production, use and disposal of fuels and vehicles. Regarding the inventoried gases, current climate policies focus on direct GHGs, whose behavior is relatively well known. However, Fuglestvedt et al. (2008) highlighted the need to take into account other mechanisms by which emissions from transport can also affect climate. Among these mechanisms, direct emissions of aerosols and indirect GHGs such as precursors of tropospheric ozone or related gases which potentially affect the oxidation capacity of the atmosphere should be considered.

The present study aims to develop a detailed assessment of GHG emissions and evaluate feasible improvement scenarios within the Spanish context. As operational emissions have been proven as the dominant contribution to GHG emissions from road transport (Chester and Horvath, 2009), the evaluation will focus on emissions which are directly generated from vehicle circulation.