Department of Energy & Climate Change

A review of data and methods to calculate greenhouse gas emissions from alternative fuel transport

Final report

emisia MISSION FOR ENVIRONMENT

Aether

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Final Report to the Department of Energy and Climate Change

NAEI/GHG emissions from alternative fuel transport

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Table of Contents

Executive Summary

Alternative fuelled vehicles (AFVs) are increasing in number in the UK and therefore it is important that this source is considered for inclusion in the National Atmospheric Emissions Inventory. The aims of this project were to:

1. Identify sources of information on the numbers and activity of the different Alternative Fuel Vehicles (AFVs) both historically and projected to 2030.
2. Review the fuel consumption and emission factors available for AFVs (primarily the basket of GHGs but other regulated air quality pollutants such as NO_X and PM_{10} where possible).
3. Combine activity and emission factor data to estimate fuel consumption and emissions from the different classes of AFVs.
4. Review how other Member States estimate emissions from AFVs, and make recommendations as to whether the UK could benefit from following similar approaches.

The following vehicle fuel and technology types have been included in the project:

AFV type	Emission factors available and included?	Historic numbers available from DfT / DVLA?	Projections of these AFVs available?
LPG	Y	Y	Y
CNG	Y	Y	Y
Hybrid electric vehicles (petrol)	Y	Y	Y
Hybrid electric vehicles (diesel)	Y	Y	Y
Plug-in hybrid electric vehicles (petrol)	Y	Y	Y
Plug-in hybrid electric vehicles (diesel)	Y	N	Y
Range extender electric vehicles	Y	N	Y
Battery electric vehicles	Y	Y	Y
Hydrogen fuel cell vehicles	Y	Y	Y
Biofuels (B100, B85 and biomethane)	Y	N	N

This project estimates emissions on a “by source” basis, which is consistent with international inventory reporting. Therefore, emissions from battery electric vehicles and hydrogen fuel cell vehicles are zero in this regard.

The key findings of the project were:

1. Little work is being undertaken across Europe on the emissions arising from AFVs and only a few countries reviewed included these vehicle types in their inventories.
2. There is uncertainty in the emission factor data available for AFVs – In some cases few measurements have been undertaken and there can also be large variations in the engineering design for the same technology.
3. Accounting for AFVs is likely to have little impact on the UK’s total greenhouse gas emissions for the historic inventory.
4. Whilst there is uncertainty in the emission factor and historic activity data available, this project has shown that it is possible to include the historic emissions arising from AFVs in the UK inventory and that it would be valuable to do so.

5. Going forward the emission estimates from this sector will become more important as a result of potentially large increases in numbers of AFVs. However, future estimates of AFV uptake are highly variable.
6. Estimates for CO_2 are based on the quantity of fuels consumed and therefore significant alterations to methods will not be required. Methods and emission factors for CH_4 and N_2O, which depend on engine load and speed as well as types of energy management processes, will need careful consideration and analysis to take account of different drive cycles. CH_4 and N_2O however make up a small fraction of total transport GHG emissions.

Recommend inclusion in the inventory

The following recommendations are made to improve the emission estimates presented in this project:

1. Improve transport statistics - There is currently some uncertainty regarding the historical numbers of AFVs. It is therefore recommended that improvements are made to the data collection processes for transport statistics so that more reliable emission estimates can be made and different types of AFVs can be identified.
2. CNG consumed by vehicles in the UK is currently included elsewhere in the inventory. Although there is some uncertainty regarding how many of the gas powered vehicles registered run solely on CNG, it is recommended that consideration is given to making estimates of this fuel type for the road transport sector.
3. Use odometer data (once available) - Due to no other data being available, it has been assumed that AFVs travel similar annual distances to conventional vehicles. With odometer data becoming available from MOT test data, it is recommended that data is collected for AFVs (if this is possible).
4. The review has found that there is a lack of good emission factor data available for AFVs. It is recommended that emission test work on these vehicle types is supported and that the UK pools resources with other EU countries to build up a database of reliable emission factors.

Introduction

In 2011, greenhouse gas (GHG) emissions from the transport sector, of which road transport is the dominant source, were estimated to contribute approximately 22% of total UK GHG emissions[1]. There are increasing demands to reduce the emissions arising from this sector as the UK has set legally binding carbon targets, which aim to reduce carbon emissions by 80% by 2050 (relative to 1990 levels)[2]. The Committee on Climate Change, which advises the UK government on setting and meeting carbon budgets, in their fourth budget report described how emissions from the transport sector could be reduced by 2030[3] and alternative fuels and technologies were an important component.

The UK's National Atmospheric Emissions Inventory (NAEI) does not currently estimate the greenhouse gas emissions arising from alternative fuels and technologies used in the road transport sector. This is primarily due to little information being available on the levels of use and the associated emission factors. Emission estimates in the current NAEI are therefore likely to be higher than in reality. The aims of the project were to:

1. Identify sources of information on the numbers and activity (mainly vehicle kilometres travelled) for the different Alternative Fuel Vehicles (AFVs) both historically and projected to 2030.
2. Review the fuel consumption and emission factors available for AFVs (primarily the basket of GHGs but other regulated air quality pollutants such as NO_X and PM_{10} have also been included where possible).
3. Combine activity and emission factor data to estimate fuel consumption and emissions from the different classes of AFVs.
4. Review how other Member States estimate emissions from AFVs, and make recommendations as to whether the UK could benefit from following similar approaches.

The review only covers emissions arising from the tailpipe (i.e. at point of use); life-cycle emissions are outside the scope of the report and would require a much more detailed study. This is in accordance with the reporting in the NAEI, which reports emissions 'by source'[4] for international submissions.

A spreadsheet model has been developed that allows GHG, NO_x and PM_{10} emissions to be estimated over the time period 1990 to 2012 and under different projection scenarios. Further detail is provided in the following sections, and the emission factors in an appendix to this report.

Alternative fuel vehicles

An alternative fuel vehicle is a generic term that covers vehicles that are powered by fuels other than traditional petrol or diesel, or that utilise new technologies. The following fuel and technology types have been covered in this project. Emission factors are provided for all of the AFVs described below, but historic vehicle numbers and projected numbers are not available for all of these vehicle technology and fuel types.

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1 DECC GHG Inventory Summary Factsheet – Transport. July 2013. https://www.gov.uk/government/publications/uk-greenhouse-gas-inventory-summary-factsheets

2 https://www.gov.uk/government/policies/reducing-the-uk-s-greenhouse-gas-emissions-by-80-by-2050/supporting-pages/carbon-budgets

3 http://downloads.theccc.org.uk.s3.amazonaws.com/4th%20Budget/4th-Budget_Chapter4.pdf

4 'By source' refers to emissions being attributed to the sector that emits them directly. The opposite is 'end user' which refers to emissions being reallocated from the fuel producers to the fuel users.

Gas

This covers both vehicles running on Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG).

Currently there are few vehicles in the UK that run on LPG and according to the NAEI there are no reliable figures available on the total number of vehicles or types of vehicles running on this fuel. It is believed that many vehicles running on LPG are cars and vans converted by their owners and that these conversions are not necessarily reported to vehicle licensing agencies. Figures from the Digest of UK Energy Statistics (DUKES)[5] suggest that the consumption of LPG is around 0.3% of the total amount of petrol and diesel consumed by road transport and vehicle licensing data suggested less than 0.4% of all light duty vehicles (LDV[6]) ran on LPG in 2011. Currently the NAEI includes the emissions arising from LPG consumption in the transport sector and assumes that it is all consumed by light goods vehicles (LGVs) [7].

The UK inventory does not currently estimate emissions from vehicles running on compressed natural gas as the number of such vehicles in the UK is extremely small, with most believed to be running in captive fleets on a trial basis in a few areas. Estimates are not made as there are no separate figures from DECC on the amount of natural gas used by road transport, nor according to the NAEI is there useable data on the total numbers and types of vehicles equipped to run on natural gas from vehicle licensing sources[7]. However, this project has found that some information on the numbers of gas powered vehicles is available. The small amount of gas that is used in the road transport sector is currently allocated to other sources in DUKES and therefore allocated to other sectors in the NAEI. Vehicles running on CNG are not thought to be an important component in the drive to reduce carbon emissions from the road transport sector going forward as none of the road transport scenarios obtained for this report included such vehicles.

Hybrids

Hybrid Electric Vehicles (HEVs) are powered by a combination of a conventional internal combustion engine and an electric motor; the engine can run on petrol or diesel. Cars are the most common form of hybrid, with over 120,000 hybrid petrol cars in operation in the UK, and over 1,000 hybrid diesel cars in 2012[8]. Hybrid buses (diesel-electric) are increasing in popularity in cities in a bid to reduce air pollution and comply with Low Emission Zones. There are currently over 800 hybrid buses[9], which usually utilise regenerative braking, where electric energy is generated and stored when the brakes are applied. Currently, hybrids are not specifically taken into account in the NAEI, apart from hybrid buses in London for which Transport for London provide data. However, a watching brief is kept by the NAEI team and including new emission factors and fleet data for hybrids have been identified as a potential improvement[7].

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5 https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

6 Light Duty Vehicles (LDVs) refer to cars and vans. Vans can also be referred to as Light Goods Vehicles (LGVs).

7 UK Informative Inventory Report (1980 to 2011). Annual report for submission under LRTAP. Report available for download from: http://naei.defra.gov.uk/reports/

8 Personal communication with Jeremy Grove and Alex Rubin at DfT in November 2013.

9 Figure estimated by Aether, based on a literature review of the number of hybrid buses in operation in cities across the UK.

Plug-in hybrids
Plug-in Hybrid Electric Vehicles (PHEVs) are hybrid electric vehicles which contain batteries that can be recharged by plugging them in to an electric power source. They are typically driven in electric mode over short-medium ranges, with the combustion engine working as a back-up once the batteries are depleted or when more power is required – for example when accelerating or driving at high speeds. There are currently around 1,000 plug-in hybrid cars running on petrol in the UK[8], with diesel plug-in hybrids and petrol LDV plug-in hybrids predicted to increase in number in some of the future scenarios presented. Currently, plug-in hybrids are not specifically taken into account in the NAEI.

Range-extended electric vehicles (REEVs) are also included in this report. These vehicles are equipped with conventional internal combustion engines coupled to a generator, which supply the battery with electricity or directly power the electric motor, facilitating driving ranges similar to conventional vehicles. Currently, REEVs are not specifically taken into account in the NAEI.

Electric
Battery electric vehicles (BEVs) run on electricity stored in rechargeable batteries, using electric motors for power rather than an internal combustion engine. Thus, they have no tail-pipe emissions and have the potential to greatly reduce emissions from road transport. There are currently over 4,000 pure electric cars and over 3,000 pure electric LGVs[10]. There are several obstacles that need to be overcome for large scale rollout however: the big upfront cost to purchase them, the large size and mass of the battery, the still relatively low range between charges, long charging times, and the uncertainty that owners have about the availability of charging points. There is also the issue of consumer familiarity with the technology which needs to be overcome. When reporting 'by source', emissions from this technology are zero.

Hydrogen fuel cell electric vehicles
Vehicles powered by hydrogen fuel cells work on the same principles as a battery, producing electricity to run an electric motor, but instead of needing recharging with electricity, the fuel cell is refilled with hydrogen. Currently there are very few vehicles running on hydrogen fuel cells, but several manufacturers have recently confirmed commercial launch dates for this technology over the time period 2015 - 2016[10], and demonstration fleets are being released. For example, Transport for London is currently trialling a few hydrogen fuel cell buses[11]. If the hydrogen is produced without using fossil fuels the vehicles would have minimal emissions, but significant investment is needed to develop the infrastructure to produce hydrogen fuel cell vehicles. The UK H2 mobility project is a partnership of UK industry leaders and government, who are working to support the introduction of hydrogen as a transport fuel[12]. When reporting 'by source', emissions from this technology are zero.

Biofuels
This covers bioethanol, an alcohol made most commonly from sugar cane and cereals, biodiesel, which is produced by the esterification of crops such as oil seed rape, and biomethane, a pure methane produced from biogas. They are attractive for reducing emissions as theoretically the carbon emitted during vehicle use are balanced by the carbon sink of the fuel crop's growth. However, a complete balance is unlikely to be a reality as fossil fuel consumption is significant in the agriculture sector for

10 See for example: http://www.gizmag.com/toyota-new-fuel-cell-vehicle-fcv-ces/30474/
11 http://www.tfl.gov.uk/corporate/projectsandschemes/8444.aspx
12 http://www.ukh2mobility.co.uk

fertilisers, harvesting, processing, and distribution. There are no reliable figures on the number of vehicles running solely on biofuels in the UK, and the future biofuel industry greatly depends on competing demands for food, water scarcity, and efficiency and cost improvements. Emissions from B100 (pure biodiesel) and E85 (85% ethanol and 15% petrol by volume) are provided.

However, the Renewable Transport Fuel Obligation (RTFO) requires fossil fuel suppliers to produce evidence showing that a percentage of fuels for road transport supplied in the UK come from renewable sources and are sustainable, or that a substitute amount of money is paid. All fuel suppliers who supply at least 450,000 litres of fuel a year are obligated. By April 2013, 4.75% of total road transport fuel supplied by volume needed to be biofuels[13]. According to HMRC, 0.52 million tonnes of bioethanol and 0.82 million tonnes of biodiesel were consumed in the UK in 2011[14]. On a volume basis, this represents about 3.3% of all petrol and 3.6% of all diesel sold in the UK respectively.

The NAEI currently assumes that all biofuels are consumed as weak blends (typically 5%) with fossil fuels. The carbon dioxide (CO_2) emissions associated with biofuel combustion are estimated and reported as memo items but not included in national totals in line with international reporting requirements. Methane (CH_4) and nitrous oxide (N_2O) emissions are however included.

The availability of AFV activity data

A review was undertaken of the historic activity data (for 1990 – 2012, with the latter being the latest year available) that was available for road vehicles using alternative fuels and technologies. In addition, various road transport scenarios were obtained to provide an indication on the possible uptake rates in the future.

Historic

Licensed stock

The UK Department for Transport (DfT) provided data on the numbers of registered vehicles by propulsion type (including AFVs) from 1994 onwards[8]. Other departments and organisations were also contacted but this was the best and most comprehensive data source as it was derived from data provided by the Driver and Vehicle Licensing Agency and approved by DfT. In order to cover the period of reporting for the UK's Greenhouse Gas Inventory, data was required from 1990 onwards; therefore data was extrapolated linearly prior to 1994. Some of the data provided by DfT differs slightly from their published data due to improvements being made to the data by them since the time of publication.

There are however a number of issues with the data:

1. As identified above, data was only available from 1994 onwards and therefore a complete and accurate dataset is currently unavailable.
2. From 2010 onwards the data includes Northern Ireland registrations, whereas prior to this year data is for Great Britain only. Therefore, there is data missing from the time series prior to 2010.
3. Bi-fuel vehicles that consume gas are classified as 'gas' and therefore it is unknown whether some of these vehicles run on conventional fuels for a large amount of the time.

13 https://www.gov.uk/renewable-transport-fuels-obligation

14 HM Revenue & Customs Hydrocarbon Oils Bulletin, Summary of Quantities Released for Consumption (2011) https://www.uktradeinfo.com/Statistics/StatisticalBulletins/Pages/BulletinArchive.aspx?viewname=Hydrocarbon Oils Duties Archive

4. The data shows there to be no hybrid diesel cars in operation. Data from the Society of Motor Manufacturers and Traders suggests that were approximately 4,500 such vehicles during the time period 2011 to 2013[15].
5. The data shows there to be very few hybrid buses in operation and none post 2005. However, data from Transport for London shows however that there were 691 hybrid buses in London in 2013[16]. The DfT dataset has been supplemented for this project with figures collated by Aether on the number of hybrid buses in operation in the UK. However, there is some uncertainty surrounding the figures and therefore further work is required in this aspect.
6. The data does not include vehicles running on dedicated biofuels (such as B100, E85 or biomethane). Whilst this is thought to be small in number, there are some vehicles in the UK that have been manufactured or converted to run on this fuel type[17].

There is therefore uncertainty over the numbers of AFVs in operation in the UK during the time period 1990 to 2012. Table 1 shows the estimated number of conventional vehicles and AFVs in the UK in 2012. The data relates to licensed stock at the end of the calendar year. The data shows that currently, vehicles using alternative fuels and technologies only make up a small proportion of the UK road transport fleet. For example, petrol hybrids made up less than 0.5% of the car fleet and electric cars only 0.01% in 2012.

Table 1: UK 2012 vehicle numbers by propulsion type[18]

Vehicle	Fuel	Licensed stock	Percentage of vehicle type
Car	Petrol	19,158,800	66.7
	Diesel	9,385,100	32.7
	Hybrid Petrol	124,145	0.4
	Hybrid Diesel	1,310	0.004
	Gas	49,311	0.2
	Electric	4,103	0.01
	Plug-In Hybrid Petrol	1,009	0.004
	Hydrogen Fuel Cell	11	0.00004
Bus	Diesel	107,995	98.9
	Hybrid Diesel	837	0.7
	Gas	230	0.2
	Electric	108	0.1
HGV	Diesel	378,775	99.8
	Gas	591	0.2
LGV	Diesel	3,116,748	95
	Petrol	148,165	4.5
	Gas	11,416	0.3
	Electric	3,822	0.1
	Hybrid Petrol	28	0.0009

*Note: for the percentage of vehicle type column, the sum of the components may not exactly equal 100% due to rounding

15 http://www.smmt.co.uk/2014/02/fuel-efficient-motoring-drives-solid-start-2014-new-car-registrations/
16 Personal communication with Claire Cheriyan at TfL in November 2013 and Finn Coyle at TfL in January 2014.
17 http://www.mepc.com/parklife/miltonpark/News/NewDoubleDeckerforMiltonPark.aspx?r=miltonpark/News.aspx
18 Data provided by Jeremy Grove at DfT but with hybrid bus data added from other literature sources collated through a review undertaken by Aether.

Annual distance travelled

No information is available specifically on the average annual distance travelled by AFVs in total or the split between urban roads, rural roads and motorways. It has therefore been assumed for this project that the distance travelled will be the same as an equivalent conventional vehicle for the year of concern. The exception to this would be for electric and hydrogen fuel cell cars, for which half the distance would be assumed[19]. The annual distance travelled by conventional vehicles has been calculated by dividing the total number of billion vehicle kilometres by vehicle type undertaken on each road type in Great Britain[20] by the total number of licensed vehicles in Great Britain each year[21]. It is recognised that this is a simplified approach; in order for more accurate data to be obtained, a vehicle stock turnover and mileage model would need to be developed. Due to the low numbers of AFVs, this will only have a small impact on the results.

Whilst a consistent approach with the NAEI has been followed where possible in this project, it is worth noting that a new possible future data source on the average annual distance travelled by cars, other light duty vehicles (including light goods vehicles), private buses and motorcycles became available in June 2013 in the form of DfT experimental statistics[22]. One of the items of information recorded by the Nominated Tester during an MOT test is the vehicle odometer reading. Although it is not currently mandatory[23], it is recorded in around 95% of cases. The MOT database therefore contains mileage information for a very large proportion of GB registered vehicles that are subject to an annual test. This might eventually provide more accurate information on the total annual mileage travelled for vehicles of different ages. Heavy goods vehicles (over 3.5 tonnes) and large buses and coaches are subject to a separate testing regime and would therefore not be covered by this dataset.

Projections

Scenarios of the numbers of AFVs travelling on UK roads in future years were obtained from various sources. For some vehicle technologies there is a considerable range in the predicted number of future vehicles, particularly if the technology is currently in its very early stages. The different scenarios also focus on different specific vehicle technology types and do not present a complete coverage of vehicle types and technologies going forward. Government policies, infrastructure investment, consumer behaviour, the economic climate, and conflicting pressures will all affect the future numbers of AFVs, and the scenarios all assume different priorities. These are described below.

1. **UK Department for Transport[8].** These projections cover the time period from 2013 to 2030 for Great Britain and cover electric cars, electric vans, plug-in hybrid cars and plug-in hybrid vans. Northern Ireland is therefore not covered in the dataset. There are therefore only selected vehicle and fuel /technology types covered in this set of projections. The projections are based on the Office of Low Emission Vehicles' strategy, which outlines the central projection up to 2020 and the uncertainty surrounding it. The technical and technology cost assumptions come from work undertaken by Element Energy and Ricardo-AEA, the fuel costs are published by DECC and it

19 This assumption was made following discussions with the Low Carbon Vehicle Partnership and Emisia. However, as this report only compiles estimates on a 'by source' basis, emission estimates are zero for both electric and fuel cell vehicles and therefore this assumption is not actually used.

20 Billion vehicle kilometre data in GB by road type for 1990 to 2012 was provided by Ricardo-AEA by extracting data from the 2012 NAEI.

21 The number of licensed vehicles in GB was obtained from DfT Transport Statistics. https://www.gov.uk/government/statistical-data-sets/tsgb09-vehicles

22 https://www.gov.uk/government/publications/experimental-statistics-analysis-of-vehicle-odometer-readings-recorded-at-mot-tests

23 Whilst not currently mandatory, it soon will be under Directive 2010/48/EU.

assumes that the current policy continues beyond 2015. The underlying data is confidential and therefore cannot be made publically available.

2. **The Committee on Climate Change's fourth carbon budget**[24] report included low, medium and high scenarios for transport covering both technology and behaviour change. The majority of these measures are either negative cost (i.e. cost saving) or cost effective compared to the UK's carbon price over that period. The scenarios have been informed by the need to meet the required emission reductions by 2050 and how they can be met cost effectively. The projections cover:
    - Electric cars and the different scenarios reflect different assumptions with regard to battery cost and range. For the low scenario, no increase in market share of electric vehicles beyond 2020 is assumed and they account for around 16% of new cars and around 15% of the fleet in 2030. Under the medium scenario, the take up of electric cars reaches 60% of new vehicles (31% of the fleet) in 2030, of which 30% are battery electric and the remaining 70% are plug-in hybrid cars. Under the high scenario, take up of electric cars reaches 85% of new vehicles (37% of the fleet) in 2030. Of these 70% are battery electric and the remaining 30% are plug-in hybrid cars. The approach for electric vans is similar.
    - The use of hydrogen in transport. Three scenarios for the deployment of hydrogen fuel cell vehicles in the 2020s were developed reflecting different assumptions on the extent to which current barriers are addressed and uptake in niche markets versus more widespread deployment. Under the low scenario, take up of fuel cell vehicles is limited to a small number of demonstration projects and these vehicles do not achieve a significant market share for any mode. Under the medium scenario, low carbon hydrogen production and the availability of vehicles at reasonable cost such that fleets capable of depot-fuelling can deploy fuel cell vehicles, but without the development of a national distribution network. In this scenario uptake is limited to buses, which come in around 2021 and account for a market share of 50% of new buses in 2030. In the high scenario, challenges in production, storage and distribution are addressed, such that there is a national fuelling network in place supporting uptake in cars, vans, HGVs and buses.

Whilst the CCC projections include an 8% penetration by energy of biofuels in 2020 in line with the Gallagher review[25], no breakdown by vehicle type is included and it is assumed to be consumed as a blend[26]. Therefore this aspect is not covered in the low, medium and high scenarios presented in this report.

3. **The Committee on Climate Change** has also produced some revised projection scenarios as part of their Fourth Carbon Budget Review (Part 2) in December 2013[27] and the new central scenario is included in this project. Changes from the previous scenarios include: new emission projections produced by the DfT, updated projections for the costs of all vehicle types and analysis that the CCC commissioned on consumer barriers to the take-up of electric vehicles. The updated scenario results in slightly greater reductions in emissions in the fourth carbon budget

24 http://www.theccc.org.uk/publication/the-fourth-carbon-budget-reducing-emissions-through-the-2020s-2/

25http://webarchive.nationalarchives.gov.uk/20110407094507/renewablefuelsagency.gov.uk/reportsandpublications/reviewoftheindirecteffectsofbiofuels

26 Personal communication with Nina Meddings at the Committee on Climate Change in January 2014.

27 http://www.theccc.org.uk/wp-content/uploads/2013/12/1785b-CCC_TechRep_Singles_Chap5_1.pdf

period. According to the CCC it remains appropriate to aim for a significant penetration (for example 60% of new car purchases) of plug-in hybrid vehicles, battery electric vehicles and hydrogen cell vehicles by 2030. The new analysis predicts a slightly slower trajectory relative to the previous assessment, reflecting projected production capacity. The review notes that there is some scope for biofuels in surface transport but given continued uncertainty over sustainability issues and technologies for advanced biofuels, the uptake of biofuels in the 2020s is limited to a level indicated by the Gallagher Review[25] of between 5-8% in energy in 2020.

4. **Emisia projections**

The vehicle stock structure is obtained from the baseline included in SIBYL[28]. This baseline is initially based on the output of the TRACCS project[29]. TRACCS is able to provide road transport country-specific data (stock, activity and economic data) for each of the EU28 Member States, as well as for Norway, Switzerland, Iceland, FYROM, and Turkey in the period 2005-2010. Thus, the vehicle stock structure and activity (combined mileage) for year 2010 are directly provided by TRACCS, while future projections have been formulated upon the following set of assumptions:

i. For years 2011-2012, the new registrations are in agreement with historic data obtained from ACEA.
ii. Stock development is compatible with the PRIMES[30] 2012 Reference scenario. PRIMES provides the demand at a higher-tier to calculate technology penetration, consumption, and emissions,
iii. Activity is consistent with the output of the LIFE EC4MACS project[31].

In addition, a certain degree of expert judgment was required to fill in the details – for example, vehicle category allocation and market segment to capacity-based classification.

The alternative fuels vehicle stock development is based on the following guidelines:

i. LPG and CNG vehicle categories are included in TRACCS, therefore, projections are similar to the other conventional technologies,
ii. No dedicated biofuel vehicles are reported for the UK in TRACSS; thus, the baseline scenario does not include flex-fuel vehicles.
iii. The “electrified” vehicle stock development is calculated on the basis of the projected conventional passenger car stock, i.e. as a percentage of gasoline and diesel passenger car stock development.

The initial electrified fleet in 2010 comprises solely of hybrid petrol vehicles. The projected market vehicle penetration rates are based on the moderately decarbonised scenario presented by Pasaoglou, Honselaar and Thiel[32].

28 SIBYL is a vehicle stock projection and scenario evaluation software package, developed, and updated by Emisia.
29 Project funded by DG Climate Action. More info available at traccs.emisia.com
30 As a partial equilibrium model for the European Union energy markets, PRIMES is used for forecasting, scenario construction and policy impact analysis up to the year 2030.
31 European Consortium for Modelling of Air Pollution and Climate Strategies. A project funded by the EU-LIFE program, http://www.ec4macs.eu.
32 Guzay Pasaoglu, Michel Honselaar, Christian Thiel, "Potential vehicle fleet CO2 reductions and cost implications for various vehicle technology deployment scenarios in Europe", Energy Policy, vol. 40, p. 404-421, 2012

5. **The European Commission impact analysis**[33] for the uptake electric vehicles provided three scenarios for battery electric cars, plug-in hybrids, and range extender electric cars:
    i. Scenario 1 was intended to provide the 'most realistic' projections of electric vehicles, and assumes government incentives continuing roughly as they are currently, high consumer reluctance to switch to electric vehicles, and production capacity and charging opportunities to limit market uptake until 2025.
    ii. Scenario 2 predicts the continuing dominance of internal combustion engine vehicles, with relatively limited technological progress in electric batteries, significant CO_2 efficiency improvements for combustion engines at reasonable cost, government incentives for electric vehicles reduce over time and are insufficient to compensate for the relative high cost of ownership, and consumer interest remains limited.
    iii. Scenario 3 is the most optimistic, assuming research and development leads to a rapid decrease in the cost of electric batteries and increase in their lifetime after 2015, government incentives are high at first and then rapidly reduced as costs come down, fast charging is offered throughout the EU after 2025, and no significant breakthroughs in internal combustion engine technology.

6. **E4Tech's Biofuel Roadmap**[34] assesses the potential contribution of biofuels in road transport to 2030 and includes four scenarios covering regulatory pressure on industries and economic capacity of industries to change. The roadmap only considers blends of biofuels; they do not foresee increasing the biodiesel blend beyond 7% as worthwhile because of the engineering challenge associated with making engines that use biodiesel blends higher than B7[35] compatible with Euro 4/IV air quality requirements. In terms of gasoline, the recommendation is to continue to aim for maximal E10 roll-out by 2020, followed by the introduction of E20 in 2025. Therefore, the scenarios do not cover vehicles which are using high blends of biofuels. The scenarios do include however electric, plug-in hybrids, hydrogen fuel celled vehicles and vehicles running on LPG and CNG.
    i. Scenario A predicts minimal change at least cost, due to low regulatory pressure and limited economic resources.
    ii. Scenario B assumes low regulatory pressure but high economic capacity, resulting in a focus on attributes other than environmental protection, such as luxury and comfort. Low export capacity to the EU.
    iii. Scenario C foresees an economically constrained world but with high regulatory pressure to deliver energy secure environmental improvements. Medium technology efficiency improvements.
    iv. Scenario D, with high regulatory pressure and economic capacity, sees greater long-term investment in new technologies with higher initial costs but a more transformational long-term impact for environment and security targets. High environmental conservation, large technological cumulative installed capacity.

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33 Impacts of electric vehicles – Delivery 5. Impact analysis for market uptake scenarios and policy implications. April 2011. http://ec.europa.eu/clima/policies/transport/vehicles/docs/d5_en.pdf

34 A harmonised auto fuel biofuels road map for the EU to 2030. November 2013. http://www.e4tech.com/PDF/EU_Auto-Fuel-report.pdf

35 B7 refers to a fuel which contains 7% biodiesel in fossil fuel diesel. E10/E20 refers to a fuel which contains 10%/20% bioethanol in fossil fuel petrol.

7. **TfL** provided projections of the uptake of hybrid and electric buses in London[16]. There are currently 691 hybrid buses in London and this is expected to increase to 2,115 in 2020 and to 3,053 in 2030. Electric buses are anticipated to number approximately 100 in 2020, an increase of 98 from present. Overall there are currently around 8,700 buses in London. They do not expect hydrogen fuel cell buses to feature in London in the near future.

No projection scenarios were available for high blends of biofuel or biomethane use. This is thought to be due primarily to the uncertainty surrounding the sustainability of biofuels and the availability of fuels going forward. There is however work being undertaken on the role of biomethane in heavy goods vehicles[36] so this fuel type may increase in popularity in the future but no projection scenarios were available at the current time. In addition, none of the scenarios obtained covered alternative fuel motorcycles or hybrid light goods vehicles.

Overall it was found that the projection scenarios tended to focus on different vehicle types and technologies and therefore it was not possible to estimate total GHG emissions arising from all AFVs in future years or to make a comparison between different datasets, other than on a vehicle and technology basis. However, the different projections provide an indication of the likely range of uptake of the different AFVs and therefore their importance in the future.

Annual distance travelled

In terms of the annual distance travelled, it has been assumed that the average annual mileage undertaken in future years is the same as in 2012. This is a short research project to scope out the information available on AFVs and this was deemed to be appropriate at this stage. Further work in the form of a vehicle stock and mileage model would need to be developed for more accurate results to be obtained.

Fuel consumption and emission factors

Fuel consumption factors and carbon, methane and nitrous oxide emission factors have been sourced for each alternative fuel and technology where available. In addition, emission factors for nitrogen oxides and PM_{10} have also been included in the calculations where possible. The emission factors for each AFV are provided for different road types; urban, rural, and motorway, apart from buses which are solely urban.

In the first instance, UK data has been sourced where possible and then gap filling has been undertaken using European data. Emission factors were available either in the form of scaling factors relative to the equivalent conventional vehicle or in absolute terms (grams per kilometre). In only a few cases UK specific data was actually available, for example emission factors for hybrid buses which was provided by Transport for London from the emission tests that Millbrook have undertaken**Error! Bookmark not defined.**. Even in UK projects and research reports, the emission factors referred to tend to be based on research programmes carried out at JRC Ispra, TNO in the Netherlands and the USA and others, for which the results are reported in the EMEP / EEA Guidebook[37] and used in COPERT.

36 For example see: http://www.lowcvp.org.uk/events,uk-biomethane-and-gas-vehicle-conference_1163.htm

37 http://www.eea.europa.eu//publications/emep-eea-guidebook-2013

Uncertainties

In many cases, there is lots of uncertainty in the emission factors. This is primarily due to:

1. Few measurements having been undertaken on alternative fuelled vehicles, which therefore leads to a high uncertainty in the emission factors.
2. In some cases the emission factors have been obtained from studies in which little information is available on the exact vehicle type and drive cycle the emissions were measured over. This therefore makes it difficult to undertake a meaningful analysis compared to a conventional vehicle.
3. There can be a large variation in the engineering design for the same technology, which can lead to a large deviation in emissions. An example of this is hybrid technology for which there are different types; these include parallel and series hybrids as well as mild and full hybrids. These technologies may offer similar benefits in terms of fuel consumption and therefore carbon emissions, but may have very different emissions of other gases and pollutants, making it difficult to draw general conclusions.
4. The uncertainty in activity levels, in particular for electric vehicles. The fraction of the total mileage driven in electric or internal combustion engine (ICE) mode depends on the daily trip patterns, for which very little information is available. As an example, a plug-in hybrid or REEV with a fully-loaded battery driven for 30-40 kilometers primarily operates in electric mode and hence emission factors (in g/km) are extremely low (close to zero). Emission factors increase considerably when the ICE is used – for example, for driving over longer distances.
5. Over time there will be technology improvements. For example, there is now a second generation of hybrid buses in London. However, no specific emission factor data is available for the different types of hybrid and therefore one set of emission factors has been assumed for all hybrid buses.

It is recommended that the emission factors presented in this project are reviewed regularly as new data emerges to ensure that the best information is always being used. At the present time it is unknown when new improved data may become available. For example, a new version of the European COPERT model will be made available in summer 2014 but no new AFV emission factors will be provided in that version.

Dealing with uncertainties in the inventory

Greenhouse gas and air quality pollutant emission estimates will always have an element of uncertainty associated with them. The UK reports the uncertainty of its emission estimates alongside the inventory when it is published. This is calculated by quantifying uncertainties on emission factors and activity data, which therefore provides an overall uncertainty in the emission estimates.

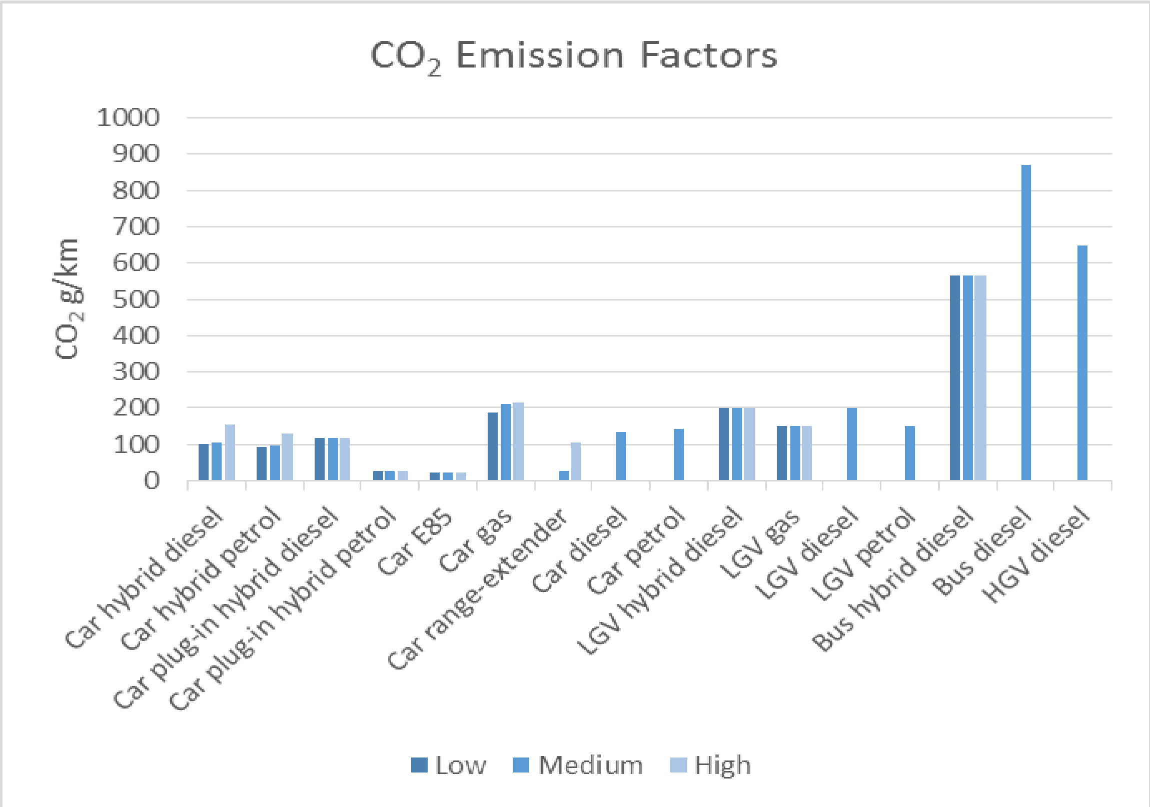
Carbon emissions are calculated from the fuel consumed and the carbon content of the fuel. Methane, nitrous oxide and air quality pollutant emissions are however more difficult to estimate since there is not a direct link between fuel and emissions. Emissions of these gases and pollutants are dependent on a number of factors including vehicle type, age, whether the vehicle has a catalyst and operating characteristics.

For conventional vehicles, the uncertainty associated with CO_2 emissions is low since the carbon content of the fuel is well known. For other greenhouse gases the uncertainty is high, but the contribution to the total GHG emissions from road transport is small (<1%). Overall GHG emissions uncertainty in 2011 from the road transport sector was ±3% with a 95% confidence interval[1].

For AFVs, there is much uncertainty surrounding the emission factor data and therefore where possible low, medium and high values have been provided. The uncertainty of the emission factors originates from the variability of the underlying experimental data, i.e. the variability in the emission level of each individual vehicle, which has been included in the sample of vehicles used to derive the emission factors.

The spread in values may also reflect the variation of emission factors extracted from different literature sources. The graphs below show the low, medium, and high emission factors across different vehicles and fuels / technologies for Euro 5/V standard vehicles on urban roads, for CO_2, N_2O, and CH_4. In some cases, in the absence of more than one emission factor being available for a particular fuel and technology, the same emission factor has been assumed for the low, medium and high case. In addition, for some vehicle and technology combinations, emission factors were not available and therefore the data has been gap filled using emission factors for conventional vehicles.

Figure 1: CO_2 Emission Factors



Note: In some cases, emission factor data was not available and therefore the data has been gap filled using emission factor data for conventional vehicles. For example, LGV gas emissions were assumed to be the same as for LGV petrol and LGV hybrid diesel were assumed to be the same as LGV diesel.

Figure 2: N_2O Emission Factors

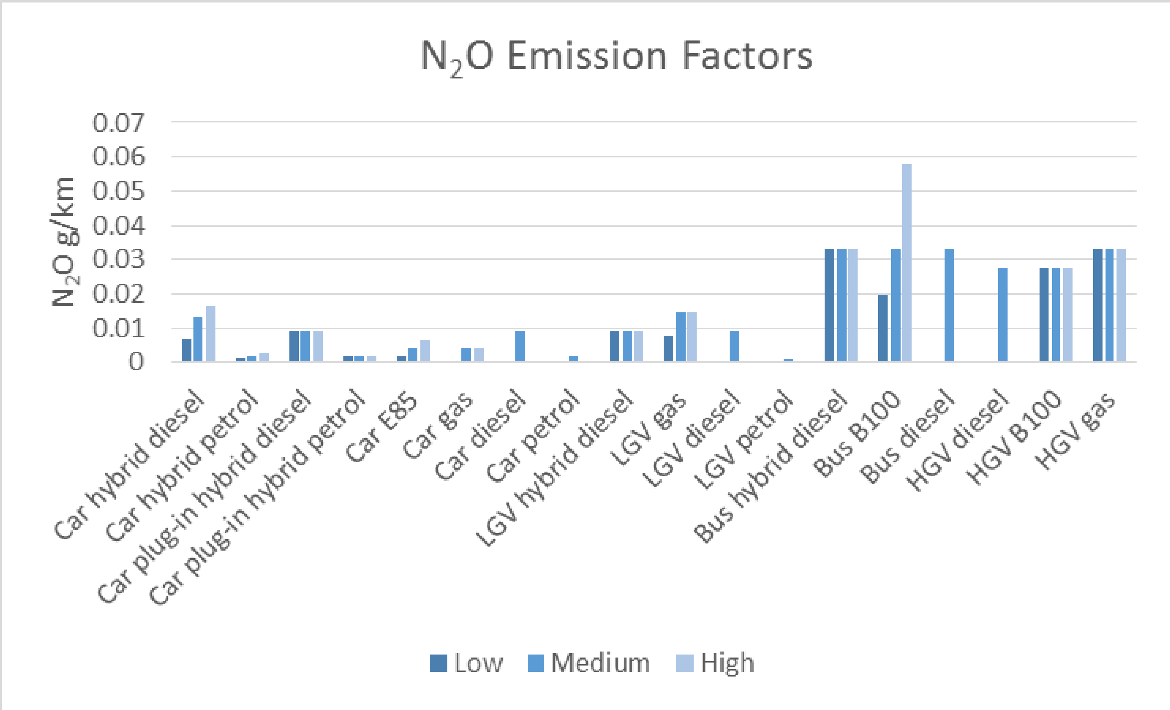
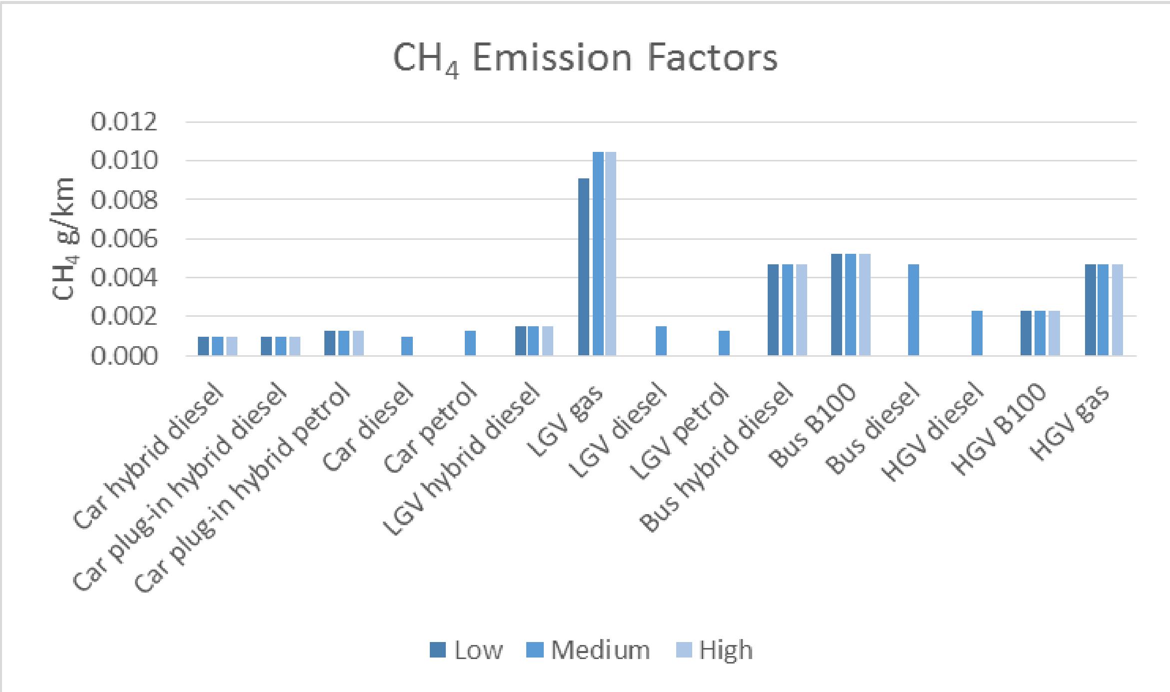


Figure 3: CH_4 Emission Factors



Gas – LPG and CNG

Emission factors for cars running on LPG and CNG have been calculated with COPERT 4 v10[38]. COPERT is the most recognized and widely used tool for road transport emission inventories. It is supported by the European Environment Agency and the Joint Research Centre, while it has been developed, maintained and updated by Emisia researchers. The emission factors included in COPERT are in line with the 2013 update to the EMEP / EEA Emission Inventory Guidebook[37] and the 2006 IPCC Guidelines.

For the assessment of uncertainty the relevant Tier 1 ranges included in the Emission Inventory Guidebook have been used and presented as low, medium and high emission factors.

Hybrids

Similarly to LPG and CNG, emission factors from COPERT have been used for petrol hybrids. For diesel hybrid cars, which are currently not included in COPERT and for which no experimental data exists, reasonable assumptions on their emissions level were made using Emisia's expert judgement. These assumptions are based on the differences between the conventional petrol and the diesel vehicles applying simple scaling factors over the emissions of hybrid petrol.

Similar assumptions were also made for estimating the uncertainty in the emission factors of hybrid vehicles.

For hybrid buses, emission factor data has been obtained from Transport for London[16].

Plug-in hybrids and electric vehicles with range extender

For these advanced powertrain technologies, which are not included in COPERT, emission factors have been obtained from SIBYL. The related fuel/energy consumption factors and resulting CO_2 emission factors have been based on extensive simulations, employing custom-designed models and powertrain system level simulation tools, as well as reasonable modelling assumptions. For other greenhouse gases and air pollutants, conventional model emission factors have been assumed in the absence of any relevant experimental data.

Electric vehicles

The emissions inventory reports emissions at point of use and therefore emissions are deemed to be zero from this vehicle type. However, for the 'end user' inventory, emissions from this category would be required.

Hydrogen fuel celled vehicles

The emissions inventory reports emissions at point of use and therefore emissions are deemed to be zero from this vehicle type.

Biofuels

As discussed earlier, most biofuels are currently consumed in the form of a weak blend in vehicles with conventional petrol and diesel engines. This has been driven by the RTFO. The effect of weak biofuels blends on CH_4, N_2O and air quality pollutant emissions is already accounted for in the NAEI via a set of

38 http://www.emisia.com/copert/General.html

scaling factors that are applied to the base factor. This is the best approach as it is the combined effect of both the biofuel and the conventional fuel that determines the emissions[39].

Whilst there is no historic data on the numbers of dedicated biofuels vehicles and given the sustainability issues surrounding its expansion, emission factors are included in the AFV emissions calculations for completeness. When reporting carbon emissions, only the fossil fuel consumption element should be taken into account in the calculation. This is consistent with the 1996 and 2006 IPCC Guidelines, which states that ‘the emissions associated with the production of biofuels should be attributed to the Land Use, Land Use Change and Forestry sector under IPCC. Although carbon emissions from biogenic carbon are not included in national totals, the combustion of biofuels in mobile sources generates methane, nitrous oxide and air quality pollutant emissions and these should be calculated and reported in the emission estimates’.

Emission factors are provided for B100 (pure biodiesel) and E85 (85% ethanol and 15% petrol by volume). B100 may contain 10% fossil carbon from the methanol (made from natural gas) used in the esterification process; however due to the uncertainty surrounding the manufacture of this fuel type in the UK, carbon emissions are assumed to be zero. In contrast, the biogenic portion of pure ethanol is 100%.

The emission factors provided for E85 and B100 have been obtained from the 2013 update to the EMEP/EEA Emissions Inventory Guidebook[37].

Compatibility with the 2006 IPCC Guidelines

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories provides an update to the 1996 Guidelines and associated Good Practice Guidance, which provides internationally agreed methodologies for use by countries to estimate greenhouse gas emission inventories for reporting to the United Framework Convention on Climate Change.
The fundamental methodology for estimating GHG emissions from road vehicles has not been modified since the publication of the 1996 IPCC Guidelines and the 2000 Good Practice Guidance, except that the emission factors now assume full oxidation of the fuel so as to be consistent with emission estimates for stationary combustion[40]. The method for estimating carbon emissions from catalytic converters using urea is also included for the first time.

The Chapter contains information on estimating emissions from biofuels. The majority of the text relates to the issue of avoiding double counting carbon emissions in your estimates. Most alternative fuelled vehicles are sufficiently covered, with the exception of hybrids, plug-in hybrids and REEVs, for which there is no information provided. Electric and hydrogen fuel cell vehicles are also not included, but these are not relevant for the road transport sector in the GHG inventory as they have zero emissions at point of use.

Results

Historic (1990 – 2012)

As outlined previously, alternative fuel vehicles still comprise a small proportion of the total road vehicle fleet. There were approximately 28.5 million cars registered in the UK in 2012. Petrol hybrid cars are the most prevalent AFV with approximately 124,000 licensed in 2012, a 100-fold increase in the last 10

39 NAEI emission factors for alternative vehicle technologies. February 2013.
40 2006 IPCC Guidelines. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf

years. Electric cars on the other hand have only increased in number from approximately 135 in the early 1990s to around 4,000 in 2012.

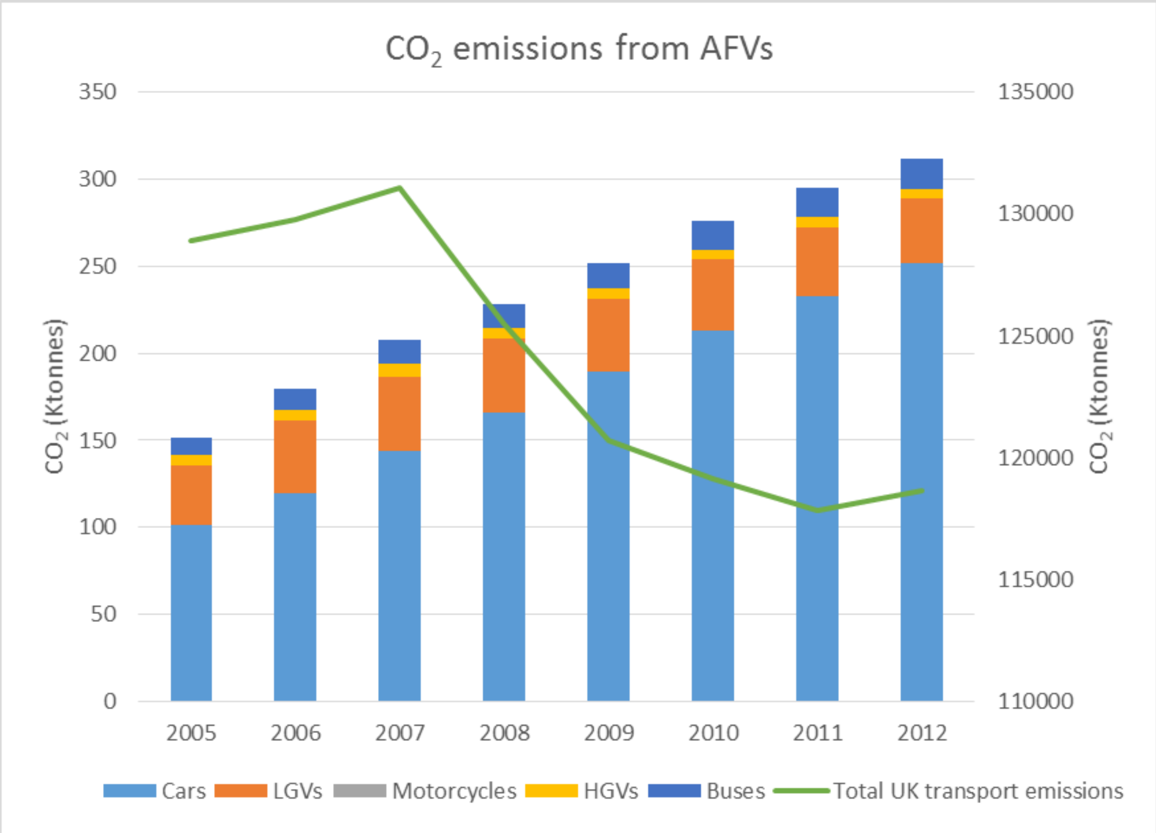
Tables 2a to 2c shows the estimated CO_2, CH_4 and N_2O emissions from AFVs from 2005 to 2012 based on DfT data on the number of registered vehicles and using the central ('medium') emission factors.

Table 2a: Estimated CO_2 emissions from AFVs by vehicle type (Ktonnes)

	2005	2006	2007	2008	2009	2010	2011	2012
Cars	101.5	119.7	143.9	165.9	189.3	213.1	233.1	252
LGVs	33.9	41.7	42.8	42.2	41.9	40.9	39.3	37.2
Motorcycles	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HGVs	6	5.7	7	6.3	5.8	5.5	5.5	5.3
Buses	10	12	13.9	13.6	14.9	16.7	17.2	17
Total	**151.5**	**179.3**	**207.7**	**228.1**	**252.1**	**276.3**	**295.2**	**311.5**
Total UK transport emissions[41]	128,913	129,759	131,084	125,485	120,695	119,116	117,861	118,658
AFV emissions as a proportion of total UK transport emissions	0.12%	0.14%	0.16%	0.18%	0.21%	0.23%	0.25%	0.26%

*Note: the sum of the emissions by vehicle may not exactly equal the total due to rounding

Figure 4: Estimated CO_2 emissions from AFVs by vehicle type (Ktonnes)



There is some uncertainty in the historic activity data, but the estimates show that whilst the CO_2 emissions arising from AFVs are increasing year on year, in 2012 the estimated emissions were only the equivalent of approximately 0.26% of the total transport emissions in the UK. Therefore at present they make up a very small fraction of the UK's emissions.

For methane and nitrous oxide, AFVs are estimated to emit the equivalent of approximately 0.9% and 0.1% respectively of the UK's total transport emissions of these gases in 2012. This is shown in Tables 2b and 2c below.

The noticeable decrease in CH_4 emissions from AFVs in 2008 is mainly due to increasing numbers of gas-fuelled HGVs and buses. In addition, Euro 5 standard vehicles increased in number which have lower emissions than older vehicles. The distance travelled by gas-fuelled buses also began decreasing, explaining the continuing reductions of CH_4 emissions from buses.

Table 2b: Estimated CH_4 emissions from AFVs by vehicle type (Ktonnes)

	2005	2006	2007	2008	2009	2010	2011	2012
Cars	0.014	0.016	0.018	0.024	0.027	0.028	0.033	0.037
LGVs	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.006
Motorcycles	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HGVs	0.006	0.005	0.007	0.003	0.003	0.003	0.002	0.002
Buses	0.009	0.009	0.009	0.004	0.004	0.003	0.003	0.002
Total	**0.035**	**0.038**	**0.041**	**0.038**	**0.040**	**0.041**	**0.045**	**0.047**
Total UK transport emissions[41]	14.5	13.3	11.9	10.4	7.7	6.7	5.9	5.5
AFV emissions as a proportion of total UK transport emissions	0.24%	0.28%	0.35%	0.36%	0.52%	0.62%	0.76%	0.85%

*Note: the sum of the emissions by vehicle may not exactly equal the total due to rounding

Figure 5: Estimated CH_4 emissions from AFVs by vehicle type (Ktonnes)

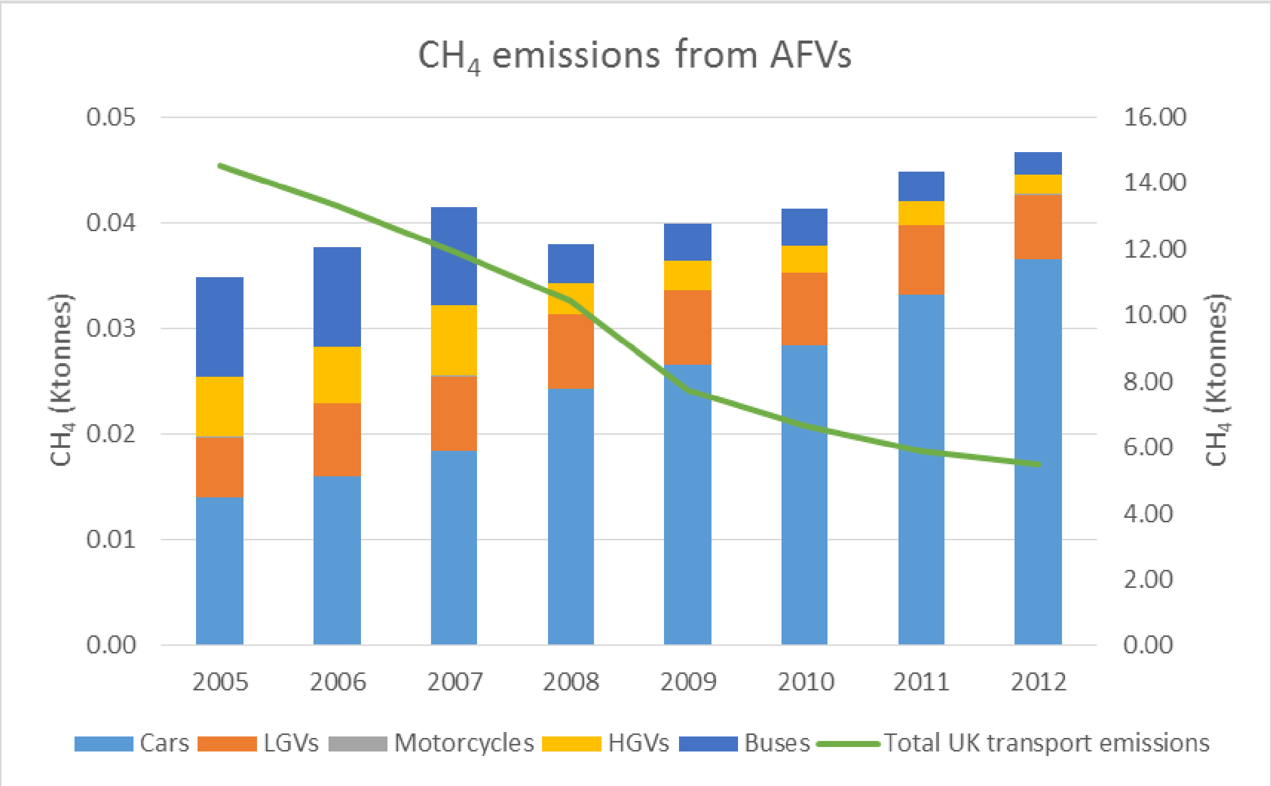
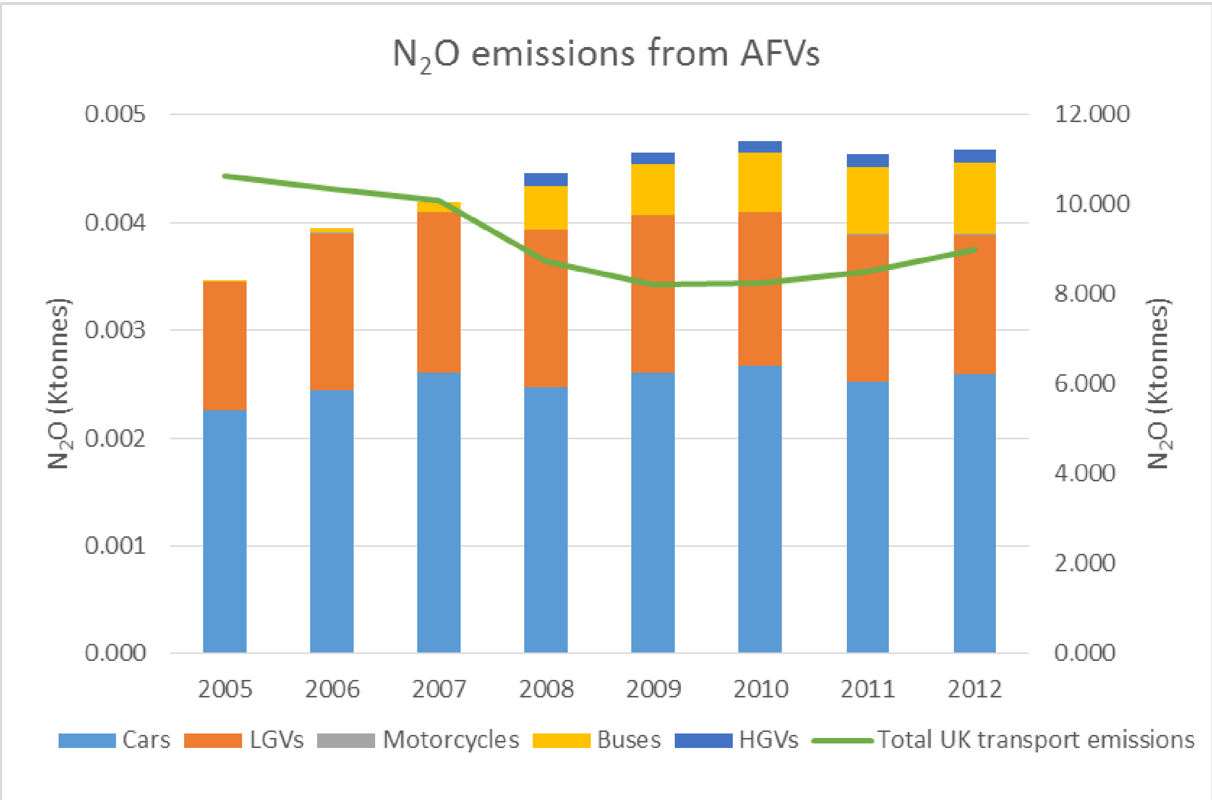


Table 2c: Estimated N_2O emissions from AFVs by vehicle type (Ktonnes)

	2005	2006	2007	2008	2009	2010	2011	2012
Cars	0.002	0.002	0.003	0.002	0.003	0.003	0.003	0.003
LGVs	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Motorcycles	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HGVs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Buses	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Total	**0.003**	**0.004**	**0.004**	**0.004**	**0.005**	**0.005**	**0.005**	**0.005**
Total UK transport emissions[41]	10.6	10.3	10.1	8.7	8.2	8.2	8.5	9.0
AFV emissions as a proportion of total UK transport emissions	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%

*Note: the sum of the emissions by vehicle may not exactly equal the total due to rounding

Figure 6: Estimated N_2O emissions from AFVs by vehicle type (Ktonnes)



Uncertainties

To assess the impact of the uncertainty in the emission factors, the low and high values were also used to compile estimated CO_2, CH_4 and N_2O emissions in 2012 from the alternative fuel car fleet. Cars were chosen as the most comprehensive data set is available for this vehicle type and they comprise the majority of the AFV emissions. The estimates are shown in Tables 3a to 3c below.

Table 3a: **Estimated CO_2 emissions from alternative fuelled cars in 2012 using low, medium and high emission factors (Ktonnes).**

L/M/H estimate	**2012**
Low estimate	237.6
Medium estimate	252.0
High estimate	280.9

Table 3b: Estimated CH_4 emissions from alternative fuelled cars in 2012 using low, medium and high emission factors (Ktonnes).

L/M/H estimate	**2012**
Low estimate	0.033
Medium estimate	0.037
High estimate	0.051

Table 3c: **Estimated N_2O emissions from alternative fuelled cars in 2012 using low, medium and high emission factors (Ktonnes).**

L/M/H estimate	**2012**
Low estimate	0.001
Medium estimate	0.003
High estimate	0.003

The estimates show that there is a discrepancy of approximately 43 Ktonnes between the low and high estimate for CO_2. The uncertainty range for CH_4 and N_2O emissions is greater. For example, the high estimate for CH_4 emissions from LPG cars is approximately twice the low estimate.

Projections

Various projection scenarios have been presented. These include those provided by DfT, which solely covers cars and LGVs, and those such as the E4Tech and Committee on Climate Change fourth budget scenarios, which are the only ones to cover heavy goods vehicles. All the scenarios obtained have tended to focus on particular vehicle or technology types and no source was obtained that covered all the main vehicle technology types. For example, projections of diesel hybrid bus numbers were only available from data provided by Transport for London, and yet this is thought to be an increasingly important AFV going forward.

No scenarios covered the use of high blend biofuels such as B100 or E85. Whilst a decade ago this was expected to be an important element in terms of reducing the UK's greenhouse gas emissions, due to the current sustainability issues, in the near future only consumption in weak blends is likely. In addition, no scenarios obtained covered motorcycles.

By way of example, two of the projection scenario results are presented in this report to provide an indication of the range of CO_2 emissions that may be expected in the future.

DfT projections

The DfT projections cover the following vehicle and technology types:

1. Petrol and diesel hybrid cars
2. Petrol plug-in hybrid cars
3. Electric cars
4. Range extender cars
5. Electric LGVs
6. Plug-in hybrid LGVs.

Some alternative fuel technologies such as gas and hydrogen fuel cell cars and gas and hybrid LGVs do not feature in the DfT projections, despite there being historical data for these vehicle types. Therefore the projections are a sub-set of the alternative fuelled car and LGVs.

Table 4 provides the estimated CO_2 emissions from AF car and LGVs under the DfT scenario at 5 yearly intervals out to 2030.

Table 4: Estimated CO_2 emissions from AFVs under the DfT scenario by vehicle and technology type (Ktonnes)

	2015	**2020**	**2025**	**2030**
Car – diesel - hybrid	28.0	440.6	1,317.5	2,044.2
Car – petrol – hybrid	287.6	813.1	1,464.9	1,951.1
Car – petrol – plug in hybrid	1.9	55.7	330.2	980.6
Car – electric	0	0	0	0
Car – REEV	3.3	36.4	229.5	740.8
LGV – electric	0	0	0	0
LGV – petrol - plug-in hybrid	0	30.5	178.7	562.8
Total emissions	**321**	**1,376**	**3,521**	**6,279**
Total UK projected transport emissions	116,812	120,509	123,700	126,483
Equivalent compared to total UK projected transport emissions[41]	0.27%	1.1%	2.8%	5.0%

The DfT car and LGV projections forecast a large increase in the numbers of alternative fuelled vehicles and hence CO_2 emissions from the AFV sector are expected to increase by a large amount by 2030. The increase in numbers and hence emissions is particularly noticeable for petrol plug-in hybrid cars and range extender cars. The DfT projections are however fairly conservative compared to the other scenarios gathered. For example, in terms of plug-in hybrid cars, the DfT projections forecast the least number of this vehicle type in 2030, aside from the Emisia projections.

CCC December 2013 fourth carbon budget review scenario

The CCC fourth budget review scenario provides a more optimistic view of the uptake of alternative fuelled vehicles out to 2030. The scenario covers the following vehicles and technologies:

1. Petrol plug-in hybrid cars
2. Hybrid petrol cars – note that a distinction wasn't made between petrol and diesel hybrid cars and they have all assumed to be petrol in this case.
3. Electric cars
4. Hybrid petrol LGVs- as with cars, a distinction wasn't made between petrol and diesel hybrid cars and they have all assumed to be petrol in this case.
5. Plug-in hybrid petrol LGVs
6. Electric LGVs
7. Hydrogen fuel cell buses.

No information is included on other vehicle types (such as heavy goods vehicles or motorcycles) or other technologies.

Table 5 provides the estimated CO_2 emissions from AF car, LGVs and buses in the 4th carbon budget review CCC scenario at 5 yearly intervals out to 2030.

Table 5: Estimated CO_2 emissions from AFVs in the 4th carbon budget review scenario by vehicle and technology type (Ktonnes)

	2015	2020	2025	2030
Car – petrol – hybrid	1,141	6,369	13,567	17,735
Car – petrol – plug in hybrid	39	393	1,893	5,333
Car – electric	0	0	0	0
LGV – petrol – hybrid	195	1,353	2,749	3,669
LGV – petrol - plug-in hybrid	20	138	883	1,978
LGV – electric	0	0	0	0
Buses – hydrogen fuel cell	0	0	0	0
Total emissions	**1,395**	**8,254**	**19,092**	**28,715**
Total UK projected transport emissions	116,812	120,509	123,700	126,483
Equivalent compared to total UK projected transport emissions[41]	1.2%	6.8%	15.4%	22.7%

In line with the more aggressive uptake of alternative fuelled vehicles and technologies, under the CCC fourth carbon budget review scenario, these vehicle types would comprise a significant part of the road transport emissions post 2020. In line with the DfT projections, petrol hybrid cars are expected to be the largest contributor; however under the CCC forecast, the numbers and hence emissions are expected to be almost 9 times higher.

Sensitivity of uptake rates

As none of the projection scenarios obtained provided a complete coverage of all vehicle types and technologies, a sensitivity analysis has been undertaken using predicted uptake rates of the following vehicle types:

1. Hybrid petrol cars
2. Hybrid diesel cars
3. Plug-in hybrid petrol cars

Table 6: Estimated CO_2 emissions at 5 yearly intervals to 2030 from hybrid petrol cars under the three scenarios that covered this vehicle and technology type (Ktonnes).

	2015	2020	2025	2030
DfT projection	287.6	813.1	1,464.9	1,951.1
CCC 4th budget review	1,141	6,369	13,567	17,735
Emisia projection	108	265.1	503.4	757.8

Table 7: Estimated CO_2 emissions at 5 yearly intervals to 2030 from hybrid diesel cars under the two scenarios that covered this vehicle and technology type (Ktonnes).

	2015	2020	2025	2030
DfT projection	28.0	440.6	1,317.5	2,044.2
Emisia projection	44.1	153.8	429.8	902

Table 8: Estimated CO_2 emissions at 5 yearly intervals to 2030 from plug-in hybrid petrol cars under the four scenarios that covered this vehicle and technology type (Ktonnes).

	2015	2020	2025	2030
DfT projection	1.9	55.7	330.2	980.6
Emisia projection	8.6	49.9	130.4	234.2
CCC 4th budget review	39.3	393.4	1,892.6	5,332.7
E4Tech A	48.7	92.6	995.6	2,030.1

The data in Tables 6, 7 and 8 above show that the projected scenarios differ hugely in their suggested uptake of hybrids and plug-in hybrids out to 2030. The significance of the emissions arising from AFVs is therefore highly uncertain in future years. However, the different projection scenarios provide an indication of the range of possible uptake rates and therefore their possible importance in the future.

Lessons learnt from other countries

The National Inventory Reports (NIRs) of the four member states with the highest number of AFVs based on new registrations in 2011 in the European CO_2 monitoring database[42] were reviewed to assess if and how they include emissions from AFVs. The countries were Germany, Ireland, Italy and Sweden. In addition, Japan and the USA's NIRs were also reviewed to give a perspective outside Europe. In some

42 http://www.eea.europa.eu/data-and-maps/data/co2-cars-emission

cases there was limited information available in the NIRs and so contact was made with the road transport emission inventory compilers to gather further information.

Germany

Germany is in the process of developing its estimates for AFVs, and currently only provides data on biodiesel and bioethanol vehicles. Emission factors for biodiesel are set to the same as conventional diesel fuel, and emission factors for bioethanol are the same as used for conventional petrol. Germany uses the TREMOD model to calculate emissions, which has recently been extensively revised to more accurately calculate LPG and CNG emissions in keeping with Tier 3; previously it was oversimplified and incomplete. Data is provided on the number of cars using CNG, and country-specific emission factors are used for CNG and LPG, but no data is available on vehicle kilometres travelled by AFVs.

Ireland

Despite Ireland having a high number of AFVs according to the CO_2 monitoring database, according to their NIR and communication with their inventory compiler they do not yet estimate emissions as the number of AFVs on the roads is still very small. The COPERT 4v 9.1 model is currently used in Ireland to estimate CH_4 and N_2O emissions using a detailed bottom-up Tier 3 approach, and reports that emissions from AFVs will be included in the COPERT model when the number of AFVs become significant[43].

Italy

Italy estimates CO_2 emissions from biodiesel based on the carbon content of the fuel, but includes non-CO_2 emissions of biodiesel in the diesel fuel category, citing lack of detailed information regarding the type and technology of vehicles and the associated biodiesel consumption as the reason. LPG-fuelled car emissions are calculated using the COPERT 4 model, whereas emissions from CNG cars are estimated using country specific emission factors based on fuel consumption, split by user defined categories of engine size.

Sweden

Almost all petrol sold in Sweden contains 5% ethanol, and emissions of N_2O and CH_4 from this low blend ethanol-petrol mix is included in conventional petrol emissions for all vehicles. Emissions of higher blends, such as E85, are estimated by the SMED model using an implied emission factor derived from petrol consumption and emissions from conventional cars, together with the amount of ethanol used in E85 cars and buses. As of 2012, N_2O and CH_4 emissions from CNG and biogas are calculated in a similar manner; using activity data from national statistics on delivered quantities of CNG and biogas with national emission factors. CO_2 and SO_2 emissions from E85 cars are reported under biomass-fuelled cars. Data is collected on the number of hybrid and electric cars, but estimates of emissions are not currently made as their numbers are not yet thought to be significant.

Japan

Japan previously estimated LPG and LNG CO_2 emissions by including them in the commercial/institutional section of other sectors, reporting them as “IE” in the transport sector. The reason given was that the natural gas consumption by natural gas-powered vehicles was so low and there were no consumption statistics available. Fuel consumption statistics have since been established and activity data made available, so from 2010 onwards, the emissions are reported under gaseous fuels in road transport. However, Japan still reports NO_x, CO, NMVOCs, and SO_2 from natural gas vehicles

43 See the Section on AFVs and the NAEI for further information as to what is currently included in COPERT and new information is likely to be included.

and motorcycles as “NE”. Very few ethanol-powered vehicles exist in Japan, so as activity data is negligible it is assumed emissions are also negligible, and emissions associated with biomass-fuelled vehicles is reported as “NO”.

USA

The United States of America’s NIR, as another significant user of AFVs, was additionally reviewed. The USA was the only country that included a separate section for the methodology for AFVs in the NIR and of their emissions in the Common Reporting Format (CRF) under Other Fuels. They applied a multiplier to conventional vehicle emission factors, and expressed fuel consumption in petrol equivalent terms – how much petrol is equivalent to the amount of energy of the alternative fuel. Since 2003 petrol-electric hybrids are included in the petrol vehicle category. The USA estimates electric, CNG and LPG vehicle fuel consumption based on the Energy Information Administration (EIA) transportation sector energy estimates by fuel type, and uses bottom-up activity data to apportion consumption by mode. In line with IPCC Guidance, the carbon emissions from biofuels are not included in the carbon content of road transport, and are instead accounted for in Land Use, Land-use Change and Forestry.

Summary

Apart from the USA, the other top AFV sales countries do not yet have a methodology to deal with hybrids, plug-in hybrids, electric-powered vehicles, or hydrogen fuel cell-powered vehicles and therefore there is little that can be learnt from these countries with regard to estimating emissions from these vehicle types. The USA however appears to be leading the way in compiling emission estimates for AFVs and therefore the UK could also make estimates for these vehicle types.

Like the UK, some countries estimate the emissions arising from the biogenic content of petrol and diesel and also from LPG vehicles. The UK does not currently estimate the emissions arising from heavy duty vehicles running on CNG, but this could be undertaken going forward.

Many countries do not collect official statistics on the numbers of these AFVs, and some, such as Sweden and Ireland, who have collected data have concluded they were not yet of a significant number to be worth calculating the resulting emissions.

The proportion of Sweden and Ireland’s car fleet that were hybrid and electric in 2012 was similar to the UK’s (approximately 0.5% petrol hybrids and 0.01% electric[44]) and therefore the UK is typical in not including hybrid and electric cars in the inventory. For comparison, hybrid and electric cars comprised of approximately 1% and 0.03% of the USA car fleet respectively[45].

Conclusions and recommendations

The data collected and analysed in this project has shown that alternative fuelled vehicles are becoming an increasingly important sub-sector of road transport in the National Atmospheric Emissions Inventory. Whilst in 2012, CO_2 emissions from this sector are estimated to be only the equivalent of 0.5% of the UK’s total transport emissions, this may increase substantially in the future.

44 Irish Bulletin of Vehicle and Driver Statistics (2012)

45 Alternative Fuels Data Centre, Alternative Fuel Vehicles In Use (2012)

Key findings

1. Little work is being undertaken across Europe - From the small review undertaken to ascertain what other countries are doing with regard to estimating emissions from alternative fuelled vehicles, it appears that little work is currently being done and that the UK is on a par with other countries.
2. There is uncertainty in the emission factor data available for AFVs – In some cases few measurements have been undertaken and there can also be large variations in the engineering design for the same technology, leading to uncertainties in the best emission factors to use.
3. Low impact on emissions estimates for the historic inventory - Accounting for AFVs is likely to have little impact on the UK's total greenhouse gas emissions for the historic inventory; the main impact will be a reallocation of emissions to different vehicle types and sources (for example reporting emissions from gas powered vehicles under the road transport sector rather than in industry). This will however allow for more accurate emissions reporting and therefore actions to reduce GHG emissions can be targeted more appropriately.
4. Whilst there is uncertainty in the emission factors and historic activity data available, this project has shown that it is possible to include the emissions arising from AFVs in the UK inventory and that it would be valuable to do so.
5. Going forward the emission estimates from this sector will become more important as a result of potentially large increases in numbers of AFVs.
6. Limited changes to methods - Estimates for CO_2 are based on the quantity of fuels consumed and therefore significant alterations to methods will not be required (although information on biofuel blends will be important in order to differentiate emissions from fossil and biogenic carbon for reporting). Methods and emission factors for CH_4 and N_2O, which depend on engine load and speed as well as types of energy management processes, will need careful consideration and analysis to take account of different drive cycles. CH_4 and N_2O however make up a small fraction of total transport GHG emissions.

Recommend inclusion in the inventory
The quality of the emission factor estimates are not as high as for conventional vehicles but this is expected to improve with time as more emission tests are undertaken. The European COPERT model currently includes emission factors for some alternative fuel vehicle types (including LPG, CNG, E85, biodiesel buses and petrol hybrid cars) and therefore those countries that use the model (which includes 20 of the 28 EU Member States) are likely to start making estimates of emissions arising from this source if they have activity data available. The next version of the COPERT model is expected in summer 2014, but there are no plans at present to include any new vehicle technologies. However, the SIBYL model includes emissions and energy consumption factors for all the other alternative powertrains (battery electric, plug-in hybrids, electric with range extender and fuel cells).

The emission factors are expected to improve over the coming years, particularly for the more sophisticated and advanced technologies such as plug-in hybrid and range extender vehicles. It is therefore recommended that the UK considers including emission estimates from AFVs explicitly in the UK GHG inventory as emission factor data is available, potentially with the aim of including it for the 2015 submission so that it can be included as part of the UK's CP2 assigned amount.

The following recommendations are made to improve the emission estimates presented in this project:

1. Improve transport statistics - There is currently some uncertainty regarding the historical numbers of AFVs. This includes obtaining data on the numbers of such vehicles prior to 1994, including

Northern Ireland in the dataset in all years, collecting data on the numbers of vehicles running on high biofuel blends, improving the accuracy of the hybrid bus data and understanding the gas data. It is recommended that improvements are made to the data collection processes for transport statistics so that more reliable emission estimates can be made and different types of AFVs can be identified.

2. CNG consumed by vehicles in the UK is currently included elsewhere (notation key IE) in the inventory (Industrial emissions 1A2 or 1A4). Although there is some uncertainty regarding how many of the gas powered vehicles registered run solely on CNG it is recommended that consideration is given to making estimates of this fuel type for the road transport sector.
3. Use odometer data (once available) - Due to no other data being available, it has been assumed that AFVs travel similar annual distances to conventional vehicles. With odometer data becoming available from MOT test data, it is recommended that data is collected for AFVs (if this is possible).
4. The review has found that there is a lack of good emission factor data available for AFVs. It is recommended that emission test work on these vehicle types is supported and that the UK pools resources with other EU countries to build up a database of reliable emission factors. JRC Ispra are particularly active in this area and therefore it would be useful to have discussions with this organisation to discuss co-ordination of research programmes.

Appendix – Emission Factors

The emission factors compiled for the analysis in this report are shown in the table below. Only the medium scenario emission factors are shown. Some of the emission factors are from the literature, some are estimates based on expert judgement, and where no data or estimates were available, gap filling was undertaken and vehicles were assumed to have the same emission factors as conventional vehicles.

Vehicle	Technology	Fuel	Road	Euro standard	CO_2 g/vkm	N_2O g/vkm	CH_4 g/vkm	NO_x g/vkm	PM_{10} g/vkm
bus	conventional	diesel	urban	Euro 4	852.15	0.0128	0.0053	4.2100	0.0340
bus	conventional	diesel	rural	Euro 4	581.26	0.0128	0.0056	3.3500	0.0270
bus	conventional	diesel	motorway	Euro 4	713.91	0.0114	0.0042	3.8500	0.0290
bus	conventional	diesel	urban	Euro 5	869.59	0.0332	0.0047	3.3500	0.0300
bus	conventional	diesel	rural	Euro 5	590.27	0.0332	0.0050	2.1600	0.0230
bus	conventional	diesel	motorway	Euro 5	734.16	0.0336	0.0038	1.9100	0.0200
bus	conventional	diesel	urban	Euro 6	869.59	0.0415	0.0016	0.5390	0.0760
bus	conventional	diesel	rural	Euro 6	590.27	0.0415	0.0017	0.1263	0.0423
bus	conventional	diesel	motorway	Euro 6	734.16	0.0290	0.0013	0.1033	0.0203
bus	electric	electricity	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
bus	electric	electricity	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
bus	electric	electricity	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
bus	electric	electricity	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
bus	electric	electricity	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
bus	electric	electricity	motorway	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
bus	electric	electricity	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
bus	electric	electricity	rural	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
bus	electric	electricity	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
bus	fuel cell	hydrogen	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
bus	fuel cell	hydrogen	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
bus	fuel cell	hydrogen	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
bus	gas	gas	urban	Euro 4	1039.25	0.0000	0.9800	3.6903	0.0825
bus	gas	gas	urban	Euro 5	584.37	0.0332	0.0050	2.1600	0.0230
bus	gas	gas	urban	Euro 6	0.00	0.00	0.00	0.00	0.00
bus	hybrid	diesel	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
bus	hybrid	diesel	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
bus	hybrid	diesel	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
bus	modified conventional	biomethane	urban	Euro 4	0.00	0.02	0.98	7.29	0.19
bus	modified conventional	biomethane	rural	Euro 4	663.61	0.00	0.98	2.03	0.01
bus	modified conventional	biomethane	motorway	Euro 4	639.61	0.00	0.98	1.85	0.01
bus	modified conventional	biomethane	urban	Euro 5	1039.25	0.0000	0.9800	3.6903	0.0225
bus	modified conventional	biomethane	rural	Euro 5	663.61	0.0000	0.9800	2.0303	0.0123
bus	modified conventional	biomethane	motorway	Euro 5	639.61	0.0000	0.9800	1.8513	0.0083
bus	modified conventional	biomethane	urban	Euro 6	1039.25	0.00	0.98	3.69	0.02
bus	modified	biomethane	rural	Euro 6	663.61	0.00	0.98	2.03	0.01

Vehicle	Technology	Fuel	Road	Euro standard	CO_2 g/vkm	N_2O g/vkm	CH_4 g/vkm	NO_x g/vkm	PM_{10} g/vkm
	conventional								
bus	modified conventional	biomethane	motorway	Euro 6	639.61	0.00	0.98	1.85	0.01
bus	modified conventional	B100	urban	Euro 4	0.00	0.0128	0.0053	6.3528	0.1145
bus	modified conventional	B100	rural	Euro 4	0.00	0.0000	0.0000	3.5823	0.0640
bus	modified conventional	B100	motorway	Euro 4	0.00	0.0000	0.0000	3.2833	0.0410
bus	modified conventional	B100	urban	Euro 5	0.00	0.0333	0.0053	7.1540	0.1163
bus	modified conventional	B100	rural	Euro 5	0.00	0.0000	0.0000	2.2007	0.0620
bus	modified conventional	B100	motorway	Euro 5	0.00	0.0000	0.0000	2.0613	0.0353
bus	modified conventional	B100	urban	Euro 6	0.00	0.0415	0.0053	4.5216	0.0962
bus	modified conventional	B100	rural	Euro 6	0.00	0.0000	0.0000	0.1763	0.0423
bus	modified conventional	B100	motorway	Euro 6	0.00	0.0000	0.0000	0.1553	0.0203
car	conventional	diesel	urban	Euro 4	150.94	0.0090	0.0010	0.4800	0.0270
car	conventional	diesel	rural	Euro 4	134.17	0.0040	0.0008	0.4400	0.0240
car	conventional	diesel	motorway	Euro 4	154.10	0.0040	0.0007	0.7200	0.0250
car	conventional	diesel	urban	Euro 5	132.90	0.0090	0.0010	0.3500	0.0010
car	conventional	diesel	rural	Euro 5	116.13	0.0040	0.0008	0.3100	0.0010
car	conventional	diesel	motorway	Euro 5	135.75	0.0040	0.0007	0.5200	0.0010
car	conventional	diesel	urban	Euro 6	117.71	0.0090	0.0010	0.3003	0.0243
car	conventional	diesel	rural	Euro 6	100.88	0.0040	0.0008	0.1877	0.0243
car	conventional	diesel	motorway	Euro 6	120.59	0.0040	0.0007	0.3093	0.0243
car	conventional	petrol	urban	Euro 4	160.75	0.0018	0.0013	0.0500	0.0010
car	conventional	petrol	rural	Euro 4	149.36	0.0006	0.0010	0.0300	0.0010
car	conventional	petrol	motorway	Euro 4	168.98	0.0005	0.0018	0.0200	0.0010
car	conventional	petrol	urban	Euro 5	141.45	0.0018	0.0013	0.0400	0.0010
car	conventional	petrol	rural	Euro 5	130.37	0.0006	0.0010	0.0200	0.0010
car	conventional	petrol	motorway	Euro 5	149.99	0.0005	0.0018	0.0100	0.0010
car	conventional	petrol	urban	Euro 6	125.43	0.0018	0.0013	0.1045	0.0225
car	conventional	petrol	rural	Euro 6	114.14	0.0006	0.0010	0.0200	0.0123
car	conventional	petrol	motorway	Euro 6	133.85	0.0005	0.0018	0.0137	0.0083
car	electric	electricity	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
car	electric	electricity	rural	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
car	electric	electricity	motorway	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
car	electric	electricity	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
car	electric	electricity	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
car	electric	electricity	motorway	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
car	electric	electricity	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
car	electric	electricity	rural	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
car	electric	electricity	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
car	fuel cell	hydrogen	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
car	fuel cell	hydrogen	rural	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000

Vehicle	Technology	Fuel	Road	Euro standard	CO_2 g/vkm	N_2O g/vkm	CH_4 g/vkm	NO_x g/vkm	PM_{10} g/vkm
car	fuel cell	hydrogen	motorway	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
car	fuel cell	hydrogen	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
car	fuel cell	hydrogen	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
car	fuel cell	hydrogen	motorway	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
car	fuel cell	hydrogen	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
car	fuel cell	hydrogen	rural	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
car	fuel cell	hydrogen	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
car	gas	gas	urban	Euro 4	204.24	0.0080	0.0595	0.1203	0.0225
car	gas	gas	rural	Euro 4	139.86	0.0020	0.0020	0.0267	0.0010
car	gas	gas	motorway	Euro 4	187.12	0.0010	0.0000	0.0183	0.0010
car	gas	gas	urban	Euro 5	210.51	0.0040	0.0800	0.0560	0.0010
car	gas	gas	rural	Euro 5	133.16	0.0003	0.0277	0.0200	0.0123
car	gas	gas	motorway	Euro 5	147.26	0.0000	0.0433	0.0137	0.0010
car	gas	gas	urban	Euro 6	204.24	0.0043	0.0595	0.0310	0.0225
car	gas	gas	rural	Euro 6	139.86	0.0003	0.0020	0.0200	0.0123
car	gas	gas	motorway	Euro 6	187.12	0.0000	0.0000	0.0137	0.0083
car	hybrid	petrol	urban	Euro 4	100.40	0.0005	0.0214	0.0250	0.0213
car	hybrid	petrol	rural	Euro 4	104.91	0.0003	0.0013	0.0210	0.0010
car	hybrid	petrol	motorway	Euro 4	135.42	0.0000	0.0025	0.0180	0.0012
car	hybrid	petrol	urban	Euro 5	98.70	0.0018	0.0214	0.0200	0.001
car	hybrid	petrol	rural	Euro 5	98.70	0.0003	0.0013	0.0140	0.0010
car	hybrid	petrol	motorway	Euro 5	98.70	0.0000	0.0025	0.0090	0.0010
car	hybrid	petrol	urban	Euro 6	84.00	0.0005	0.0214	0.0000	0.0000
car	hybrid	petrol	rural	Euro 6	98.70	0.0003	0.0013	0.0210	0.0113
car	hybrid	petrol	motorway	Euro 6	98.70	0.0002	0.0025	0.0180	0.0070
car	hybrid	diesel	urban	Euro 4	150.94	0.01	0.00	0.48	0.03
car	hybrid	diesel	rural	Euro 4	134.17	0.00	0.00	0.44	0.02
car	hybrid	diesel	motorway	Euro 4	154.10	0.00	0.00	0.72	0.03
car	hybrid	diesel	urban	Euro 6	117.71	0.01	0.00	0.30	0.02
car	hybrid	diesel	rural	Euro 6	100.88	0.00	0.00	0.19	0.02
car	hybrid	diesel	motorway	Euro 6	120.59	0.00	0.00	0.31	0.02
car	hybrid	diesel	urban	Euro 5	104.50	0.0135	0.0010	0.7386	0.0305
car	hybrid	diesel	rural	Euro 5	104.50	0.0040	0.0008	0.6658	0.0281
car	hybrid	diesel	motorway	Euro 5	104.50	0.0040	0.0007	0.9225	0.0591
car	modified conventional	E85	urban	Euro 4	0.00	0.0043	0.0428	0.0530	0.0091
car	modified conventional	E85	rural	Euro 4	0.00	0.0003	0.0027	0.0180	0.0091
car	modified conventional	E85	motorway	Euro 4	0.00	0.0000	0.0050	0.0130	0.0010
car	modified conventional	E85	urban	Euro 6	0.00	0.0043	0.0428	0.0530	0.0091
car	modified conventional	E85	rural	Euro 6	0.00	0.0003	0.0027	0.0180	0.0091
car	modified conventional	E85	motorway	Euro 6	0.00	0.0000	0.0050	0.0130	0.0010
car	modified conventional	E85	urban	Euro 5	0.00	0.0043	0.0428	0.0530	0.0091

Vehicle	Technology	Fuel	Road	Euro standard	CO_2 g/vkm	N_2O g/vkm	CH_4 g/vkm	NO_x g/vkm	PM_{10} g/vkm
car	modified conventional	E85	rural	Euro 5	0.00	0.0003	0.0027	0.0180	0.0091
car	modified conventional	E85	motorway	Euro 5	0.00	0.0000	0.0050	0.0130	0.0010
car	plug-in hybrid	petrol	urban	Euro 4	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	petrol	rural	Euro 4	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	petrol	motorway	Euro 4	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	petrol	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
car	plug-in hybrid	petrol	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
car	plug-in hybrid	petrol	motorway	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
car	plug-in hybrid	petrol	urban	Euro 6	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	petrol	rural	Euro 6	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	petrol	motorway	Euro 6	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	diesel	urban	Euro 4	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	diesel	rural	Euro 4	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	diesel	motorway	Euro 4	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	diesel	urban	Euro 5	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	diesel	rural	Euro 5	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	diesel	motorway	Euro 5	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	diesel	urban	Euro 6	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	diesel	rural	Euro 6	0.00	0.00	0.00	0.00	0.00
car	plug-in hybrid	diesel	motorway	Euro 6	0.00	0.00	0.00	0.00	0.00
car	range extender	electricity	rural	Euro 4	31.8700	0.0002	0.0570	0.0310	0.0225
car	range extender	electricity	rural	Euro 5	31.8700	0.0005	0.0350	0.0290	0.0123
car	range extender	electricity	rural	Euro 6	31.8700	0.0005	0.0000	0.0070	0.0213
car	range extender	electricity	motorway	Euro 4	43.6200	0.0011	0.0350	0.0085	0.0225
car	range extender	electricity	motorway	Euro 5	43.6200	0.0005	0.0350	0.0290	0.0123
car	range extender	electricity	motorway	Euro 6	43.6200	0.0005	0.0000	0.0070	0.0213
car	range extender	electricity	urban	Euro 4	27.7500	0.0005	0.0350	0.0290	0.0123
car	range extender	electricity	urban	Euro 5	27.75	0.0005	0.0000	0.0070	0.0213
car	range extender	electricity	urban	Euro 6	76.30	0.0005	0.0000	0.0070	0.0213
HGV	conventional	diesel	urban	Euro 4	638.34	0.0106	0.0026	3.4700	0.0270
HGV	conventional	diesel	rural	Euro 4	560.66	0.0129	0.0016	3.1900	0.0230
HGV	conventional	diesel	motorway	Euro 4	583.99	0.0106	0.0012	2.8600	0.0240
HGV	conventional	diesel	urban	Euro 5	649.55	0.0276	0.0023	2.7700	0.0250
HGV	conventional	diesel	rural	Euro 5	568.66	0.0371	0.0014	1.3400	0.0200
HGV	conventional	diesel	motorway	Euro 5	592.18	0.0313	0.0011	0.8100	0.0180
HGV	conventional	diesel	urban	Euro 6	649.55	0.0340	0.0008	0.5070	0.0750
HGV	conventional	diesel	rural	Euro 6	568.66	0.0356	0.0005	0.1100	0.0403
HGV	conventional	diesel	motorway	Euro 6	592.18	0.0269	0.0004	0.0840	0.0200
HGV	fuel cell	hydrogen	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
HGV	fuel cell	hydrogen	rural	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000

Vehicle	Technology	Fuel	Road	Euro standard	CO_2 g/vkm	N_2O g/vkm	CH_4 g/vkm	NO_x g/vkm	PM_{10} g/vkm
HGV	fuel cell	hydrogen	motorway	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
HGV	fuel cell	hydrogen	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
HGV	fuel cell	hydrogen	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
HGV	fuel cell	hydrogen	motorway	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
HGV	fuel cell	hydrogen	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
HGV	fuel cell	hydrogen	rural	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
HGV	fuel cell	hydrogen	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
HGV	gas	gas	urban	Euro 4	1039.25	0.0000	0.9800	3.6903	0.0825
HGV	gas	gas	urban	Euro 5	860.89	0.0332	0.0047	3.3500	0.0300
HGV	gas	gas	urban	Euro 6	860.89	0.0332	0.0047	3.3500	0.0300
HGV	modified conventional	B100	urban	Euro 4	0.00	0.0000	0.0000	4.2130	0.0000
HGV	modified conventional	B100	rural	Euro 4	0.00	0.0129	0.0016	3.5090	0.0207
HGV	modified conventional	B100	motorway	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
HGV	modified conventional	B100	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
HGV	modified conventional	B100	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
HGV	modified conventional	B100	motorway	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
HGV	modified conventional	B100	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
HGV	modified conventional	B100	rural	Euro 6	0.00	0.0356	0.0005	0.1210	0.0363
HGV	modified conventional	B100	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
LGV	conventional	diesel	urban	Euro 4	199.99	0.0090	0.0015	0.7100	0.0220
LGV	conventional	diesel	rural	Euro 4	220.87	0.0040	0.0004	0.6800	0.0300
LGV	conventional	diesel	motorway	Euro 4	329.09	0.0040	0.0007	1.0200	0.0490
LGV	conventional	diesel	urban	Euro 5	199.99	0.0090	0.0015	0.5100	0.0010
LGV	conventional	diesel	rural	Euro 5	220.87	0.0040	0.0004	0.4900	0.0020
LGV	conventional	diesel	motorway	Euro 5	329.09	0.0040	0.0007	0.7063	0.0153
LGV	conventional	diesel	urban	Euro 6	329.09	0.0040	0.0007	0.7300	0.0030
LGV	conventional	diesel	rural	Euro 6	199.99	0.0090	0.0015	0.2210	0.0197
LGV	conventional	diesel	motorway	Euro 6	220.87	0.0040	0.0004	0.3173	0.0153
LGV	conventional	petrol	urban	Euro 4	165.49	0.0008	0.0013	0.0400	0.0010
LGV	conventional	petrol	rural	Euro 4	150.94	0.0013	0.0010	0.0400	0.0010
LGV	conventional	petrol	motorway	Euro 4	169.61	0.0013	0.0018	0.0600	0.0010
LGV	conventional	petrol	urban	Euro 5	148.41	0.0008	0.0013	0.0300	0.0010
LGV	conventional	petrol	rural	Euro 5	133.53	0.0013	0.0010	0.0300	0.0010
LGV	conventional	petrol	motorway	Euro 5	152.52	0.0013	0.0018	0.0400	0.0010
LGV	conventional	petrol	urban	Euro 6	133.98	0.0008	0.0013	0.0973	0.0345
LGV	conventional	petrol	rural	Euro 6	118.73	0.0013	0.0010	0.0293	0.0190
LGV	conventional	petrol	motorway	Euro 6	138.00	0.0013	0.0018	0.0973	0.0345
LGV	electric	electricity	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
LGV	electric	electricity	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
LGV	electric	electricity	motorway	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000

Vehicle	Technology	Fuel	Road	Euro standard	CO_2 g/vkm	N_2O g/vkm	CH_4 g/vkm	NO_x g/vkm	PM_{10} g/vkm
LGV	electric	electricity	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
LGV	electric	electricity	rural	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
LGV	electric	electricity	motorway	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
LGV	electric	electricity	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
LGV	electric	electricity	rural	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
LGV	electric	electricity	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
LGV	fuel cell	hydrogen	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
LGV	fuel cell	hydrogen	rural	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
LGV	fuel cell	hydrogen	motorway	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
LGV	fuel cell	hydrogen	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
LGV	fuel cell	hydrogen	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
LGV	fuel cell	hydrogen	motorway	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
LGV	fuel cell	hydrogen	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
LGV	fuel cell	hydrogen	rural	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
LGV	fuel cell	hydrogen	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
LGV	gas	gas	urban	Euro 4	329.09	0.0098	0.0307	0.0000	0.0030
LGV	gas	gas	rural	Euro 4	0.00	0.0037	0.0172	0.0000	0.0000
LGV	gas	gas	motorway	Euro 4	329.09	0.0020	0.0163	0.0000	0.0030
LGV	gas	gas	urban	Euro 5	0.00	0.0148	0.0105	0.0000	0.0000
LGV	gas	gas	rural	Euro 5	199.99	0.0000	0.0000	0.0000	0.0197
LGV	gas	gas	motorway	Euro 5	199.99	0.0000	0.0000	0.0000	0.0197
LGV	gas	gas	urban	Euro 6	220.87	0.0000	0.0000	0.0000	0.0153
LGV	gas	gas	rural	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
LGV	gas	gas	motorway	Euro 6	220.87	0.0000	0.0000	0.0000	0.0153
LGV	hybrid	diesel	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
LGV	hybrid	diesel	rural	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
LGV	hybrid	diesel	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
LGV	hybrid	diesel	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
LGV	hybrid	diesel	rural	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
LGV	hybrid	diesel	motorway	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
LGV	hybrid	diesel	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
LGV	hybrid	diesel	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
LGV	hybrid	diesel	motorway	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
LGV	hybrid	petrol	urban	Euro 4	103.37	0.0005	0.0214	0.0000	0.0213
LGV	hybrid	petrol	rural	Euro 4	106.02	0.0003	0.0013	0.0000	0.0010
LGV	hybrid	petrol	motorway	Euro 4	135.92	0.0000	0.0025	0.0000	0.0012
LGV	hybrid	petrol	urban	Euro 5	103.56	0.0018	0.0214	0.0000	0.0197
LGV	hybrid	petrol	rural	Euro 5	101.10	0.0003	0.0013	0.0000	0.0153
LGV	hybrid	petrol	motorway	Euro 5	98.70	0.0000	0.0025	0.0000	0.0220
LGV	hybrid	petrol	urban	Euro 6	89.72	0.0005	0.0214	0.0000	0.0197
LGV	hybrid	petrol	rural	Euro 6	102.67	0.0003	0.0013	0.0210	0.0113
LGV	hybrid	petrol	motorway	Euro 6	101.76	0.0002	0.0025	0.0180	0.0070
LGV	plug-in hybrid	petrol	urban	Euro 4	199.99	0.0000	0.0000	0.0000	0.0020
LGV	plug-in hybrid	petrol	rural	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000

Vehicle	Technology	Fuel	Road	Euro standard	CO_2 g/vkm	N_2O g/vkm	CH_4 g/vkm	NO_x g/vkm	PM_{10} g/vkm
LGV	plug-in hybrid	petrol	motorway	Euro 4	199.99	0.0000	0.0000	0.0000	0.0177
LGV	plug-in hybrid	petrol	urban	Euro 5	199.99	0.0000	0.0000	0.0000	0.0020
LGV	plug-in hybrid	petrol	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
LGV	plug-in hybrid	petrol	motorway	Euro 5	199.99	0.0000	0.0000	0.0000	0.0177
LGV	plug-in hybrid	petrol	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
LGV	plug-in hybrid	petrol	rural	Euro 6	199.99	0.0000	0.0000	0.0000	0.0020
LGV	plug-in hybrid	petrol	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	conventional	petrol	urban	Euro 5	99.99	0.0020	0.0762	0.0700	0.0040
motorcycle	conventional	petrol	rural	Euro 5	100.94	0.0020	0.0326	0.1600	0.0050
motorcycle	conventional	petrol	motorway	Euro 5	156.00	0.0020	0.0318	0.3400	0.0050
motorcycle	electric	electricity	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	electric	electricity	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	electric	electricity	motorway	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	electric	electricity	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	electric	electricity	rural	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	electric	electricity	motorway	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	electric	electricity	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	electric	electricity	rural	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	electric	electricity	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	fuel cell	hydrogen	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	fuel cell	hydrogen	rural	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	fuel cell	hydrogen	motorway	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	fuel cell	hydrogen	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	fuel cell	hydrogen	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	fuel cell	hydrogen	motorway	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	fuel cell	hydrogen	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	fuel cell	hydrogen	rural	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	fuel cell	hydrogen	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	gas	gas	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	gas	gas	rural	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	gas	gas	motorway	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	gas	gas	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	gas	gas	rural	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	gas	gas	motorway	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	gas	gas	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	gas	gas	rural	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	gas	gas	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	hybrid	petrol	urban	Euro 4	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	hybrid	petrol	rural	Euro 4	0.00	0.0000	0.9800	3.6903	0.0825
motorcycle	hybrid	petrol	motorway	Euro 4	0.00	0.0000	0.9800	3.6903	0.0825
motorcycle	hybrid	petrol	urban	Euro 5	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	hybrid	petrol	rural	Euro 5	0.00	0.0000	0.9800	3.6903	0.0825
motorcycle	hybrid	petrol	motorway	Euro 5	0.00	0.0000	0.9800	3.6903	0.0825
motorcycle	hybrid	petrol	urban	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000

Vehicle	Technology	Fuel	Road	Euro standard	CO_2 g/vkm	N_2O g/vkm	CH_4 g/vkm	NO_x g/vkm	PM_{10} g/vkm
motorcycle	hybrid	petrol	rural	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000
motorcycle	hybrid	petrol	motorway	Euro 6	0.00	0.0000	0.0000	0.0000	0.0000

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