Vehicle Fuel Economy or CO_2 Standards

Introduction

This record of evidence forms part of the work undertaken by UKERC's Technology and Policy Assessment team relating to its project on policy strategy for carbon emissions reduction in the passenger transport sector. The material was produced alongside the project's main report and since it supports that report, it was judged appropriate to make this material available to a wider audience. The main report itself '*What Policies are Effective at Reducing Carbon Emissions from Surface Passenger Transport*?', and the supporting evidence can be found at:

http://www.ukerc.ac.uk/ResearchProgrammes/TechnologyandPolicyAssessment/TPAProjects.aspx

Explanation of Content

Evidence on this policy measure has been collected by the TPA team on the basis that it has, or may have, the potential to result in carbon dioxide emissions reductions in the passenger transport sector. This evidence document begins with a summarised description of the policy measure. The evidence itself follows the summary and is presented in table form.

Each piece of evidence has been assigned a separate row and tabulated using four columns:

- Year of publication, arranged chronologically, beginning with the most recent year
- Name of author, including where applicable additional cited authors (and year); and a Reference ID number.
- Type of evidence:
  - Evidence containing quantitative information is denoted by the letter 'Q'
  - Qualitative evidence is denoted by the letter 'C' for 'comment'
- The evidence itself

The evidence was originally gathered and assessed using several sub-headings. The purpose of this was primarily internal i.e. to facilitate the handling of evidence and the production of the main report. These sub-headings have been retained here as follows:

- Policy Measures and Carbon Savings
- Other potential CO_2 Impacts i.e. outside of the immediate policy influence
- Other Benefits e.g. air quality improvement or traffic congestion reduction
- Policy Costs and/or Revenues i.e. to local or national government
- Business and Consumer Costs
- Unintended Consequences e.g. rebound effect
- Reasons/Arguments for Carbon Savings Achievement or Failure
- Policy Suitability for the UK

A list of references follows the evidence tables. Note that the Reference ID numbers are allocated by Reference Manager, the referencing software used by the TPA team.

Any charts, figures and tables referenced in the evidence are not reproduced here but can be found in the original publication or evidence material.

Where no relevant evidence was found for a particular sub-heading, this has been noted.

Policy Description

The evidence recorded here covers vehicle fuel economy standards (also known as vehicle fuel efficiency standards) which require that automobile manufacturers ensure their vehicles meet defined levels of fuel consumption or CO_2 emissions. Standards can be voluntary agreements or legal instruments, applied at state, national or international level.

Evidence Tables

Carbon Savings and Policy Measures

Year	Author	Type	Evidence
2007	Gallagher (ref 11461)	C	The US CAFE program has not even done what is was designed to do -- prevent ever increasing dependence on foreign oil. Overall fuel economy of passenger cars in the United States is no better than it was twenty-five years ago (see graph in Gallagher, 2007) and U.S. oil-import dependence has increased in both absolute and percentage terms. The fuel economy standard for passenger vehicles is currently set at 27.5 miles per gallon (mpg) and has been at this level since 1985.
2007	Gallagher **(**ref 11461**)**	Q	The fleet average efficiency of passenger cars and light duty trucks is shown in Chart 1 of Gallagher (2007).
2007	Fontaras (ref 11382)	C	Fontaras (2007) uses quantitative data and modelling to show that CO_2 emissions of individual European vehicles have not changed much since 1995, but that the extra weight and power of today's vehicles has been offset by technological improvements to energy efficiency and, to a larger degree, increased market penetration of diesel vehicles.
2007	CEC (ref 11258)	Q	The EU Voluntary Agreement was initially successful in delivering efficiency improvements, as shown in Figure 1. However, the analysis identifies that the targets are unlikely to be met and that legislative alternatives will be pursued.
2007	CEC (ref 11259)	Q	A major analysis of potential successors to the EU VA estimates that each additional reduction by 5 g CO2/km leads to a cumulated Well-to-Wheel CO2 equivalent reduction of circa 100 Mt over the period 2010-2020.
2007	DEFRA (ref 11255)	Q	DEFRA (2007) assumed a new policy measure would begin in 2009 and run until 2020 and would deliver an improvement in average UK new car fuel economy of 1.5% per annum. This means that, by 2020 average new cars would be 17% more fuel-efficient than they would have been in the absence of the new agreement – i.e. 135g of CO_2 per km. The measure appears to be very cost effective for consumers due to lower fuel costs, but there is a cost to industry and to Government.
2007	Schipper (ref 11492)	Q	Japanese sales-weighted average new car CO_2 emissions fell by approximately 18% between 1995 and 2005 (11492 Schipper 2007). The scheme is primarily voluntary but has achieved a greater level of compliance than the EU VA.
2006	DfT (ref 11266)	Q	UK Government modelling of the VA forecast that targets beyond 140g/km after 2008 "might deliver carbon savings

Year	Author	Type	Evidence
			of 0.1 MtC in 2010, potentially increasing to 0.7MtC by 2015, depending on the form it took.”
2006	Smokers (ref 11268)	C	Modelling points to the importance of ancillary loads other than powertrain, with mobile air conditioning systems potentially offering more cost effective savings than powertrains.
2004	Michalek et al (ref 3061)	C	Modelling results indicate that leveraging CO2 taxes on producers for expected life cycle emissions yields diminishing returns on fuel efficiency improvement per regulatory dollar as the taxes increase, while CAFÉ standards achieve higher average fuel efficiency per regulatory dollar.
2002	NRC (ref 11375)	C	From 1984 - 1986 fuel economy continued to rise as the CAFE standard tightened and from 1986 - 1988 the fuel economy rose even as the price of fuel fell, all adding weight to the view that CAFÉ was broadly effective. Although the standard’s level has remained almost flat since then “CAFE standards have played a leading role in preventing fuel economy levels from dropping as fuel prices declined in the 1990s.”
2002	NRC (ref 11375)	Q	It is estimated that, accounting for the rebound effect of greater fuel economy resulting in more passenger miles travelled, fuel economy improvements in U.S. passenger cars and light trucks resulted in a saving of 43 billion (US) gallons of gasoline annually, between 1975 and 2000. NRC estimates this to have resulted in the saving of over 100 million metric tonnes of CO2.
2002	US DoT (ref 11430)	Q	The Alternative Motor Fuels Act has provided CAFE incentives since 1999 for the manufacture of vehicles that use ethanol, methanol, or natural gas fuels, either exclusively or as an alternate fuel in conjunction with gasoline or diesel fuel. The primary purpose of AMFA was to encourage the widespread use of these fuels and to promote the production of alternative fuel vehicles by manufacturers. US DoT (2002) concludes that the AMFA CAFE credit program was successful in stimulating a significant increase in the availability of flex fuel vehicles that can run on gasoline or E85, with about 1.2 million of these vehicles on the road. However, the ‘vast majority’ of the vehicles rarely operate on alternative fuel, as a result of lack of fuel provision, and higher costs than gasoline. Even though use of E85 increased greatly in as a result, no GHG savings will be made “If it is assumed that vehicle manufacturers took advantage of the incentive to relax the effect of the CAFE standard on the rest of their fleet, then the credit incentive has resulted in an increase in alternative fuel use (almost all E85), and some slight increase in petroleum consumption (about one percent) and greenhouse gas emissions (well less than one percent). Unless the availability and use of alternative fuels is significantly expanded, the CAFE credit incentive program will not result in any reduced petroleum consumption or greenhouse gas emissions in the future.”

Year	Author	Type	Evidence
			However, the paper notes that having vehicles with the ability to use E85 could lead to potential future savings. Linking the CAFÉ credits to actual alternative fuel used, or coupling with policies for alternative fuel use would increase chances of success.
2001	Plotkin (ref 3140)	Q	The Japanese 'top runner' scheme for vehicle fuel efficiency ratchets up efficiency within a vehicle class by using the current year's 'best in class' vehicle emissions as the next year's target for 'average' new vehicles. Plotkin (2001) forecasts a 22.8 percent improvement in gasoline passenger vehicle fuel economy (15.1km/l in 2010 vs 12.3km/l in 1995); diesel: 14% improvement (11.6km/l in 2010 vs 10km/l in 1995).
1984	Whitford (ref 11069)	C	Up until 1982 US passenger vehicle fuel economy rose as the price of fuel rose. This extensive analysis calculates that this is reflects investment by manufacturers that is over and above the expected level, reflecting the success of CAFÉ.

Other CO2 Impacts

Year	Author	Type	Evidence
			No specific evidence found.

Other Benefits

Year	Author	Type	Evidence
2007	CEC (ref 11259)	C	There are several other benefits from vehicle emission standards: better fuel economy gives reduced exposure to oil prices for the consumer, it encourages innovation and technological development in environmental technologies, it creates export markets for environmental technologies, and it promotes highly qualified jobs in Europe
2002	NRC (ref 11375)	Q	CAFÉ reduced dependence on oil imports for U.S. (greater energy security) – the NRC estimates that US oil consumption in 2002 would be approximately 1/3 higher than if CAFE had not been enacted in 1975.

Policy Costs and/or Revenues

Year	Author	Type	Evidence
2007	Barker (ref 11428)	C	Barker (2007) analysed a policy package (comprising the VA on reduced CO2 from vehicles; company car tax; and graduated VED) compared with fuel taxes. The results show that the VAs yield positive macroeconomic effects, with small increases in GDP and employment and small reductions in general inflation, alongside significant reductions in final energy demand and CO2 emissions.
2005	ten Brink (ref 11249)	Q	Examined societal costs of different approaches to fuel economy standards, ten Brink (2005) found that the net

Year	Author	Type	Evidence
			societal costs per car to meet 120g/km are of the order of 1-2% of the cost of a car with an average cost of as low as 126€/car or 252€/car depending on the discount rate used (0% and 5% respectively).
2003	Harmsen (ref 11449) citing ACEA, 2001	C	VA does not cost national governments anything and a part of manufacturers' R&D cost burden is supported by the EU.
2002	DfT (ref 11324)	Q	One UK study provides an estimate of the lost tax revenue from achievement of different levels of low carbon vehicle sales. A moderately ambitious target of 10% of new cars emitting <100gCO2/km by 2012 costs £16m in lost VED and £300m in lost fuel duty (using 2000 rates).

Business and Consumer Costs

Year	Author	Type	Evidence
2007	Stans (ref 11359)	Q	The increased capital costs of vehicles may be offset by fuel efficiency savings, though consumers may not value these sufficiently at the time of purchase. Using April 2007 fuel costs in a 120g/km vehicle a lifetime vehicle fuel cost saving of €2171 is calculated making the purchase roughly cost neutral.
2006	Smokers (ref 11268)	Q	Smokers (2006) estimates an additional retail price compared with 2002 of €1200 per vehicle for reaching an average CO2 emission of new vehicles of 140g/km in 2008 and a further €2450 per vehicle for 120 g/km in 2012.
2005	ten Brink (ref 11249)	Q	ten Brink calculates a rise in average new car price of 1200€ over 2002 for achievement of the 120g/km target. This contrasts with Smokers (2006) above.
2005	ten Brink (ref 11249)	Q	ten Brink (2005) examines a wide range of burden sharing mechanisms for a standard reaching 120g/km by 2012, concluding that the uniform 120g/km target applied per car or manufacturer is politically unviable without trading, though useful as a reference point to highlight the relative benefits of the alternatives. Considering all alternatives the final decision is narrowed to one of whether to have a % reduction target for manufacturers (perhaps changing the reference year) or a trading scheme linked to a utility curve(such as CO2/vehicle weight) or possibly fixed targets. The decision as to which of these is appropriate is a policy decision as it requires a weighting of different factors – costs, equity and impacts on consumers primarily and also, though to a lesser extent, degree of benefit to the environment.
2005	Kampman (ref 11466) citing IEEP/TNO, 2005	Q	Overall, the CO2 abatement cost of vehicle technical measures to meet the EU target of 120 g CO2/km in 2012 is calculated by one major study (IEEP/TNO, 2005) to be at best in the range 34 and 71 €/tonne. Note that this is based on the average oil price of 2002, making the costs

Year	Author	Type	Evidence
			lower for current oil prices. Kampman (2005) notes that these are societal costs presented as average costs to meet the targets (not marginal costs). Costs for manufacturers are even higher according to the authors. This leads them to conclude that if automobile industry were to be included in ETS (CO2-emission trading scheme), they would probably be net buyers of rights instead of applying measures to their engines.
2006 2005 2005	IEEP (ref 11521) Lane (ref 11520) ten Brink (ref 11249)	C	Consumers often do not fully evaluate or value long term savings at the time of purchase. This pattern of behaviour is often described as high 'personal discount rates', and there is considerable evidence that car purchasers (indeed most private consumer purchase decisions) exhibit a strong preference for short term savings over long term cost effectiveness
2005	Ricardo (ref 11558)	Q	(11558 Ricardo 2005) explored the cost of technology improvements deployed in an effort to meet the European voluntary agreement range, and these are shown in the table below. The costs are those faced by the vehicle manufacturer – they are not necessarily the additional cost to the consumer, and they do not take into account the reduced fuel cost to the consumer:

Costs of reducing car CO_2 emissions

Car type	**CO_2 reduction achieved between 1995 and 2004**	**Cost of CO_2 reduction vehicle manufacture (£ vehicle**
Diesel cars		
Small car	18.3%	567
Medium car	9.2%	319
Large car	8.3%	288
Gasoline cars		
Small car	3.5%	140
Medium car	4.7%	207
Large car	4.5%	198

1997	Greene (ref 11225)	C	In addition, consumers do not fully evaluate fuel efficiency savings at the time of purchase due to insufficient information.

Unintended Consequences

Year	Author	Type	Evidence
2007	Sorrell (ref 11510)	Q	An effect of the order of 0.2 - 0.4% rebound for every 1% increase in efficiency is supported by several studies . See Sorrell (2007) for a comprehensive discussion of the

Year	Author	Type	Evidence
			rebound effect and the related literature).
2007	Buchan **(**ref 11452**)**	Q	Increasing the rate of manufacture, in order to replace existing cars with more efficient models, would cause a serious increase in carbon produced. About 15-20% of the total carbon emitted during a car's lifetime is from its manufacture.
2005	Litman (ref 3344)	C	Increased vehicle travel increases mileage-related costs such as traffic congestion, facility costs, crashes and sprawl. Higher fuel economy may reduce per km emission rates of some pollutants, such as VOCs, but not others, such as NOx and particulates (fuel efficiency often involves a trade-off with these emissions), and increased mileage increases emissions per vehicle-year. Increased fuel economy tends to reduce operating costs but often increases vehicle production costs, resulting in little change in affordability. The increased vehicle mileage increases mobility benefits, but reduces consumers' vehicle purchase options
2003	Kageson (ref 11175); and citing Färnlund et al, 2001	C	Kageson (2003) highlights the increased NOx from a shift to diesel vehicles, and increased particulates from diesel and from direct injection gasoline. "Direct injected gasoline cars, however, have been shown to give rise to nearly as many small particles as the cleanest diesel cars" (citing Färnlund et al, 2001). A growing share of diesel and direct injected gasoline cars may make it difficult for some European cities to comply with the Community's air quality standard for PM10.
2002	NRC (ref 11375)	C	CAFE is believed to have resulted in an additional 1,300 to 2,600 traffic fatalities in 1993 due to downsizing of vehicles, though two of thirteen CAFÉ committee members did not agree with this finding.
2002	NRC (ref 11375)	C	There is a positive relationship between fuel standards and new vehicle cost reducing consumer utility.
1997	Greene (ref 11225)	Q	The above relationship reduces the rate at which vehicles are scrapped and therefore the speed at which the fleet average CO2 emissions improve. Greene (1997) estimates a reduction of 1mpg resulting from increased vehicle lifetimes, though other factors such as quality improvements also play a role.

Reasons/Arguments for Carbon Saving Achievement or Failure

Year	Author	Type	Evidence
			Lack of obligation
2007	Anable and Bristow (ref 11297) citing Michaelis and Zerle (2006)	C	The VA also does not include any specific incentive for the consumer to encourage uptake of more efficient vehicles.

Year	Author	Type	Evidence
2006	Michaelis (ref 5648)	C	In general industry-developed agreements are unlikely to be accepted by one or more participants if they are seen to have disproportionate impacts – an association does not have the power to obligate. As a result targets do not diverge significantly from business as usual, which is what has happened with the EU VA.
			Design of standards
2007	CEC (ref 11523)	Q	The EU voluntary agreements are in the process of being superseded by a regulatory target, announced in 2007. The legislation, which includes fines for non-compliance, will set a vehicle tailpipe target of 130g/km for the EU new car vehicle fleet by 2012. Additional measures are intended to bring the effective level down to 120g/km. The target is a sales-weighted average, and applies to each manufacturer. A limit value curve is used to define the vehicle-specific target, depending on the vehicle mass. There is a voluntary pooling mechanism to facilitate burden sharing between manufacturers and an exception for low-volume and specialist vehicles.
2007	US GAO (ref 11191)	C	Failure to comply with a standard needs to be met with penalties that are sufficiently high to encourage compliance. This has not been the case for CAFÉ in the view of a recent comprehensive review of the policy (US GAO (2007)).
2007	US GAO (ref 11191)	C	The relatively low level of CAFÉ, combined with the absence of a trading mechanism, means that those manufacturers that do comply are not encouraged to improve further.
2004	LowCVP (ref 11332)	C	The lack of an efficiency standard for buses is noted by LowCVP (2004), though other studies point to the economic imperative for efficiency that ensures that commercial vehicles provide low operating costs.
2002 2002	US DoT (ref 11430) NRC (ref 11375)	C	Major studies note that the provision creating extra credits for multi-fuel vehicles had, if anything, a moderately negative effect on fuel economy, petroleum consumption, greenhouse gas emissions and cost because these vehicles seldom use any fuel other than gasoline, yet enable automakers to increase their production of less fuel efficient vehicles.
			Consumer Preferences
2007	Anable and Bristow (ref 11297) citing T&E, 2006	C	In recent years a large number of additional features have become available in vehicles contributing to weight gain and rising electrical demands i.e. parasitic loads.
2007	Anable and Bristow (ref 11297) citing Ricardo, 2005	Q	Manufacturers have used some of the improvement in powertrain efficiency in recent years to compensate weight gain and additional loads. UK CO2 emissions savings have been offset by up to 50% as a result of weight increases.
2007	Veitch (ref 11317)	C	Vehicle purchase is a complex consumer choice in which a wide range of attributes are weighed up, largely

Year	Author	Type	Evidence
			subjectively, and fuel economy is only one. Depreciation remains the main running cost for most new cars and so factors such as brand choice are key, though fuel economy can play a large role in resale value.
2006	ECMT (ref 11271)	C	Buyers of new cars typically consider fuel costs over a three year horizon, reducing the value of vehicle efficiency in their evaluations. As a result, the additional cost associated with more efficient technology cannot fully be passed on to consumers. Furthermore, it is hard for consumers to make a full evaluation of operating costs at the time of purchase since there is rarely perfect knowledge of duty cycles, annual distances etc.
2005	Lane (ref 11520)	C	As well as applying high discount rates to future fuel savings consumers place value on other vehicle attributes such as safety, image, equipment, comfort, performance, reliability and space.
			Technical Issues
2007	Anable and Bristow (ref 11297)	C	Vehicle safety regulations have significantly increased for manufacturers and this has, in almost all cases, led to an increase in vehicle weight as features are added and strengthened. Anable & Bristow (2007) point to differing views on the necessity of weight gain to increase safety, but it is certainly the case that vehicle makers often cite safety as a key reason for not attaining CO2 reductions.
2007	An (ref 11368)	C	Japan now uses a more representative vehicle emissions test cycle than the U.S.
2004	LowCVP (ref 11332)	C	There is a need for test cycles to take account of the use of air conditioning (which reduces overall efficiency). This is contested by vehicle manufacturers.
2002	NRC (ref 11375)	C	There is some conflict between the requirement for reduced vehicle pollution and CO2 emissions. This is because some of the technical options to reduce CO2 such as lean burn do not meet the pollutant requirements with ease.
2001	Plotkin (ref 3140)	C	Test cycles by which CO2 emissions are measured can influence the type of technologies that are used. Japan is in a more favourable position than Europe and the US to obtain strong increases in fuel economy from available drivetrain technology (due to its less strict emissions standards and test cycle). Europe and the US, on the other hand have higher potential to exploit load reduction technologies such as improved aero design.
			Automotive Industry Response
2007	ECMT (ref 11272)	C	There is limited evidence on the mechanism by which vehicle manufacturers innovate in response to policies on CO2. ECMT, 2007 cites Ricardo engineering's view that a step-wise evolution in technology is "likely to be the only approach compatible with the business-model and corporate philosophies of the car industry".
2006	Kampman **(**ref 11466**)**	C	Kampman (2006) expects innovation to be gradual until the marginal abatement cost becomes too high and then a step will occur. Faced with continued pressure to improve he asserts that new technological solutions are likely to

Year	Author	Type	Evidence
			appear that may go through the same cycle of falling costs followed by rising marginal abatement costs in the longer term. This is broadly borne out by recent experience [e.g. hybrids], but pressure for innovations that are beyond reach will be counter-productive e.g. ZEVs
			Vehicle Use
Multi-years	Various	Q	Most studies examined identify some form of rebound, though some do not agree and there are different views over the level of the effect. Although the basis for each study varies Table 1 below summarises some key findings.

Table 1

Study	Basis	Findings
Kageson, 2003 (ref 11175)	Based on review of EU fuel efficiency measures	To counteract the rebound effect requires a 0.2% increase in fuel tax for each 1% increase in vehicle efficiency.
Greening, 2004 (ref 124)	Historic analysis of CAFÉ, examining modal intensity (CO_2 per passenger km) compared with vehicle efficiency (CO_2 per vehicle km)	Modal intensity fell 1.1% per year 1986-91 even when fuel prices were low. CAFÉ was seen to be effective at keeping aggregate emissions growth down in this period. After 1991 this changed and consumers exhibited a preference for less efficient vehicles and lower vehicle load factors.
Litman, 2005 (ref 3344)	Econometric modelling of all impacts from vehicle efficiency change (North American context)	A 15% increase in vehicle efficiency will lead to a 5% increase in vehicle miles and a 10% reduction in net energy demand. However, the additional mileage-related costs (e.g. congestion, accidents) will lead to a net overall increase in economic cost.
Frondel, 2006 **(**ref 11460**)**	Econometric analysis for Germany	The relative reduction in energy use due to a percentage change in efficiency is in the order of 33% to 43% (a rebound effect of 57% to 67%)
Lovins, 1988; Greene (1992); Schipper & Gribb (2000)	Studies cited by Frondel, 2006	The rebound effect is so insignificant that it can be safely ignored
Brookes (1990, Saunders (1992), Wirl (1997)	Studies cited by Frondel, 2006	The rebound effect may be so large as to defeat the purpose of the efficiency improvements
Henscher, 2008 (ref 3523)	Modelling using integrated TRESIS model, for Sydney area	A 25% increase in efficiency across all cars to 2015 will result in a 21.3% reduction in vehicle CO_2 emissions

Policy suitability for UK

Year	Author	Type	Evidence
2006	DTI (ref 11266**)**	C	There are some structural features of the UK vehicle market that mean that the UK may be a challenge for EU-wide standards. UK new vehicles have higher emissions than the EU average (DTI, 2006)
1997	Greene (ref 11225)	Q	The indigenous UK automotive industry is now dominated by makers of higher emission luxury and sporting vehicles. Greene (1997) quotes figures for price elasticity of -5 for choice of vehicle make and model, but significantly lower (around -1) for aggregate demand for all new cars. Inequitable standards, therefore, could spell disaster for individual car manufacturers. As a minimum, economically efficient compliance will be required to prevent some UK manufacturers becoming uncompetitive.

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