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Driving Down CO_2 Emissions:

Using mandatory targets to improve vehicle efficiency

by Jenny Bird

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Contents

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List of abbreviations

ACEA	European Automobile Manufacturers Association
AT ZEV	Advanced technology zero emission vehicle
CAFE	Corporate Average Fuel Economy
CfIT	Confederation of Integrated Transport
CO_2	Carbon dioxide
DfT	Department for Transport
EEA	European Environment Agency
EIAG	Environmental Innovations Advisory Group
ERTRAC	European Road Transport Research Advisory Council
EU	European Union
EU-15	The 15 countries of the European Union before the expansion on 1 May 2004: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK
EU-27	Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK
g CO_2/km	Gramme of carbon dioxide per kilometre
JAMA	Japan Automobile Manufacturers Association
KAMA	Korea Automobile Manufacturers Association
MJ	Megajoule
km	Kilometre
MtC	Megatonne of carbon
NOx	Nitrogen oxides (nitric oxide, NO and nitrogen dioxide, NO_2)
PZEV	Partial zero emission vehicle
SULEV	Super ultra low emission vehicle
SUV	Sports utility vehicle
VED	Vehicle excise duty
ZEV	Zero emission vehicle

Executive summary

Emissions of carbon dioxide (CO_2) from passenger cars make up around 12 per cent of Europe's total emissions. Substantial reductions in tailpipe emissions will be necessary if the sector is to meet its share of responsibility for achieving targets for combating climate change.

Reducing the tailpipe emissions from cars will require a package of policies focused across four contributory factors: fuel carbon intensity, vehicle efficiency, driving technique and distance driven. The focus of this paper is on the second of these, **increasing vehicle efficiency**, and the role that mandatory targets can play in bringing forward improvements in this area.

How can carbon dioxide emissions from vehicles be reduced?

There are a number of technologies, currently at differing stages of development, that could help to bring improvements in vehicle efficiency, and hence cut emissions.

In the *short term*, a reduction in carbon emissions is likely to come mostly from incremental improvements to existing technologies, such as improved engine efficiency, regenerative braking (whereby energy is captured that would otherwise be lost as heat) and improved aerodynamics.

In the *medium term*, hybrid technologies could play a greater role in reducing emissions. Some hybrid vehicles are already on the market – the Toyota Prius and Honda Civic are two examples – and a greater uptake by consumers in the future would decrease total emissions.

Looking to the *long term*, radical new technologies, such as full electric vehicles and hydrogen-powered vehicles, could reduce tailpipe emissions of CO_2 to zero.

Ensuring that these potential technological improvements become a reality will therefore form an important strand of reducing CO_2 emissions from passenger cars. Following the publication in December 2007 of the European Commission's proposed regulation for reducing CO_2 emissions from new cars, it seems likely that mandatory targets will be introduced in Europe to achieve this. Mandatory targets have already been used successfully in cutting other types of emissions from road vehicles included in the European EURO Standards programme. And in the United States, the Corporate Average Fuel Economy (CAFE) standards effectively drove improvements in vehicle efficiency during the 1980s.

Mandatory targets can also be used to drive innovation and accelerate the pace of technological change by increasing confidence in long-term markets for low-carbon vehicles. For example, the California Zero Emission Vehicle Program is considered to have driven innovation in battery electric vehicle and fuel cell technologies and the US Light Duty Emissions Standards have led to a 1000-fold reduction in certain emissions from road vehicles since their introduction in the 1970s. Targets can be specifically designed so that they effectively stimulate innovation. To do this, they should be stretching (going beyond what is achievable using current technology), have long lead times before they must be met, and be technology-neutral (that is, they should not favour one particular technology over another).

The European Commission originally proposed the idea of introducing some form of mandatory target for 2012 in February 2007. This was followed by a proposed regulation in December 2007 for a target to reduce average emissions of new cars to 130g CO_2/km by 2012. Although there is broad agreement that a mandatory target should be introduced, debate about how it should be implemented is ongoing.

Four principles should underpin any such strategy:

1. Policy interventions should be targeted at those who can deliver

2. Short-term targets should be used to drive the uptake of existing technologies

3. Long-term targets should be used to drive innovation for new technologies

4. Targets should be technology-neutral.

Recommendations

We recommend that the UK government should push for the following measures to be taken up by the European Council and Parliament:

Separate out targets

A criticism of the European Commission's original proposals was that the overall objective of achieving 120g CO_2/km was 'integrated', that is, made of a component relating to vehicle technologies and a number of 'supplementary measures'. The inclusion of the use of biofuels as a supplementary measure has received particular criticism because vehicle manufacturers have no control over what motorists put into their tanks. We recommend that separating out the components into a number of targets would apportion responsibility more rationally and transparently.

Penalties for non-compliance

If the aim of the policy is to genuinely achieve reductions in emissions from passenger cars, then penalties for non-compliance should align to this. This means that fines or buy-out-prices must be higher than the cost of compliance.

Set medium- and long-term targets

Looking beyond the 2012 target, there is a need to consider medium- and long-term targets that will be necessary to drive innovation in new technologies. The priority is a target for 2020 because the production cycle of passenger cars is around 7-12 years, so legislation must be passed in the next few years in order to allow sufficient lead time for industry to develop the necessary technology and integrate it into the production process.

For a 2020 target to stimulate innovation, it must be a stretch target (see above). Based on extrapolations of studies looking at the technological feasibility of reducing emissions, we conclude that a 2020 target should be set at 95g CO_2/km or lower. This means that the average emissions of carbon dioxide per kilometre driven for all new cars sold in Europe in 2020 should be 95g.

Consideration should also be given to setting longer-term targets, for example for 2030.

1. Introduction

Passenger cars are a significant source of carbon dioxide (CO_2) emissions and are therefore an important contributor to climate change. The European Commission has adopted a three-strand strategy to reduce these emissions within the European Union. This involves establishing voluntary agreements with vehicle manufacturers to reduce the emissions of new cars, a labelling scheme, and the use of fiscal measures to influence motorists' choices in the showroom.

The need for a mandatory emissions reduction target

Although there have been some reductions in average carbon dioxide emissions from cars, it seems likely that the targets set in voluntary agreements will be missed. In addition, the gains that have been achieved must be offset against increasing sales of bigger and more powerful vehicles, and increasing car usage. As a result, the Commission has now proposed introducing a mandatory reduction target for vehicle manufacturers. This represents the most significant policy measure proposed for reducing emissions from cars.

The UK Government's own Energy White Paper lists only two measures to reduce emissions from road transport: a successor to EU voluntary agreements on new car fuel efficiency and the Renewable Transport Fuel Obligation (RTFO). Of these two measures, the successor to the agreements is expected to result in much greater reduction of carbon emissions, with an estimate of 1.8-4.1 megatonnes of carbon (MtC) abated compared with 0.0-1.0 MtC from the RTFO (Department of Trade and Industry 2007).

Structure of the report

Sections 2 and 3 examine this approach to cutting CO_2 emissions, first by considering the options for reducing emissions, including possible advances in vehicle technology, and second by investigating the role mandatory targets can play in ensuring the uptake of low-carbon technologies by vehicle manufacturers.

Section 4 outlines the current strategy for reducing emissions from new cars in Europe as well as the proposals for a new 2012 target. The principle of setting a mandatory reduction target for 2012 has received support in principle from environmental campaigners and vehicle manufacturers alike, but many questions about the form of the target remain. The decision to set medium- and long-term targets is even less clear-cut.

Section 5 summarises some of the key debates around the proposed target and goes on to look at the rationale for setting additional, longer-term targets. **Section 6** provides a summary and list of recommendations.

2. Carbon dioxide emissions from transport

Transport is a significant contributor of carbon dioxide emissions in Europe. In 2005, the transport sector – including road transportation, national civil aviation, railways, national navigation and 'other' transportation (but not international aviation or maritime transport) – was responsible for 21 per cent of the EU-15's total greenhouse gas emissions (consisting mostly of CO_2 emissions). Of these emissions, the vast majority (93 per cent) came from road transport (EEA 2007a).

Emissions from the transport sector have grown over the last few decades. The main factors responsible for this growth have been increases in the distance driven by passenger cars and road freight and in the proportion of trucks in road freight, and, to a lesser extent, a greater proportion of private cars on the road (ibid). These factors have outweighed technological advancements that have reduced the average CO_2 emissions of new passenger cars.

Car use (in terms of passenger transport volumes) for road transport is predicted to continue to increase. The European Environment Agency (EEA) reported that levels are estimated to grow by 36 per cent between 2000 and 2020 (EEA 2007b). If this does happen, it is clear that significant reductions in tailpipe emissions of CO_2 (that is, emissions arising from vehicle use, excluding those generated in manufacturing the vehicle) will be required in order for the transport sector to meet its share of responsibility for achieving overall emissions reduction targets.

Reducing CO_2 emissions from road transport

The *King Review of Low Carbon Cars Part I* (King Review 2007) shows that the total tailpipe emissions arising from the use of passenger cars and other road vehicles are a product of four contributory factors:

1. The carbon intensity of fuel relative to its energy content (which depends on the fuel type)
2. The efficiency of the vehicle (which depends, among other things, on the engine, the weight and aerodynamics of the vehicle)
3. How efficiently the car is driven (which depends on factors such as the speed at which it is driven, tyre pressures and how heavily loaded the vehicle is)
4. The distance driven.

This clarification helps to understand how different policy measures can contribute to reducing total emissions.

Policy interventions are already in place at each level. For example:

1. The Renewable Transport Fuel Obligation in the UK requiring 5 per cent of fuels sold to come from biofuels by 2010 and the EU's target for 10 per cent of fuels sold in Europe to come from biofuels by 2020 both aim to lower the carbon intensity of fuels by replacing fossil fuels with renewable biofuels.
2. The current European voluntary agreement with vehicle manufacturers aims to improve vehicle efficiency.
3. The UK Government's 'Act On CO_2' campaign encourages drivers to pump up tyres and minimise loading.
4. The UK Government's ambition for all schools to have a school travel plan in place by 2010 aims to encourage means of transport other than cars for travelling to school.

It seems clear that any strategic attempt to reduce carbon dioxide emissions from passenger cars should contain measures that target all four factors. It will not be possible to achieve emission reductions through any one measure alone. For example, the 'rebound effect' whereby motorists have been shown to increase the distance they drive in response to improved vehicle efficiency (Sorrel 2007), shows that tackling vehicle efficiency alone will not solve the problem.

This paper focuses on the second of these factors, vehicle efficiency, and the role that mandatory targets can play in improving this. It should be understood that we envisage that any policies adopted in this area would not be implemented in isolation but be complemented by policies aimed at reducing emissions in the other three areas.

Improving vehicle efficiency: low-carbon cars of the future

No amount of crystal-ball-gazing can predict with absolute certainty which technologies will be used in the cars of the future. However, it is possible to make some educated guesses, based on the technology that exists today. There are a number of studies aiming to do just this, most recently, the *King Review of Low-Carbon Cars Part I* (King Review 2007).

This section outlines some of the likely candidates for reducing emissions of $CO2_2$ from passenger cars through vehicle technology before going on to consider the level of CO_2 savings they may be able to provide. It is worth noting that the technologies involved fall broadly into two categories:

- Those that offer improvements in the short term by making incremental improvements to existing technologies; and
- Radical new technologies that could provide long-term, zero-carbon solutions.

Hybrids could represent an additional, transitional phase in the medium term.

Short-term: incremental improvements to existing technologies

Technologies offering benefits in the short term include measures that increase the efficiency of the engine, 'mild' hybrids (which stop the engine when the car is stationary and use a regenerative braking mechanism to capture energy that would otherwise be lost as heat through friction) and technologies that are not directly related to the propulsion of the car, such as the use of lightweight materials, low rolling resistance tyres and improved aerodynamics, which can also bring reductions in emissions.

Medium-term: hybrid technologies

King envisages hybridisation as a stepping stone towards the very low emission cars of the future. Full hybrids can run on stored electricity as well as a small conventional internal combustion engine (examples already on the market include the Toyota Prius and Honda Civic). Plug-in hybrids can be charged from the electricity grid and have larger batteries, allowing them to travel longer distances in electric mode.

It is worth noting that hybrids do not offer emissions savings under some driving conditions. Hybrids are more efficient than conventional cars when used for short-distance journeys made at low average speed and in stop-start driving conditions, such as those made in urban environments. If they are used mainly for long-distance trips and driven at high speeds, their CO_2 emissions will be comparable to a car with an efficient traditional internal combustion engine. In these environments, hybrids may not be a suitable route to transition to a truly low-carbon option.

Long-term: full electric and hydrogen-powered vehicles

In the long term, radical new technologies could drastically change the way cars work. The two main contenders for zero-emission cars are full electric vehicles and hydrogen-powered vehicles.

Full electric vehicles are able to run entirely on stored electricity for all journeys. The G-Wiz is an example of a full electric vehicle that is already available. The main technological challenge for this technology is developing powerful enough batteries that also have acceptable size, weight, performance, charging times and durability.

Hydrogen can be used as a fuel in two ways. First, it can be burnt in an internal combustion engine. The BMW Hydrogen 7 is an example of a vehicle that does this (Tempko 2007). However, such models retain much of the inefficiency of a conventional vehicle, so they are unlikely to represent more than a transitional stage in the technology. Second, hydrogen can be used in a fuel cell to produce electricity. The ENV motorbike is an example of a vehicle that uses this technology (Intelligent Energy 2007).

Barriers to the mass use of hydrogen-fuelled cars include insufficient storage and transportation infrastructure for the fuel, difficulties surrounding the storing of hydrogen on board vehicles, high cost and the absence of low-CO_2 sources of hydrogen.

Carbon savings

The King Review provides some estimates of the efficiency gains that can be achieved through different technological improvements. In the short term, King suggests that improvements to engine and non-propulsion technologies could result in a 30 per cent emissions reduction for the average new car within a timescale of five to 10 years (King Review 2007). The average emissions from a new car sold in the UK in 2006 was 167.2g CO_2/km (SMMT 2007a). Taking this as a baseline, a 30 per cent reduction would yield average emissions for all new cars of 117g CO_2/km. Using the European average for 2006 (160g CO_2/km) gives 112g CO_2/km.

King goes on to suggest that cars emitting half the average current level of CO_2 could be available by 2030, in the form of battery-powered vehicles and those using hybrid technologies and lightweight materials (King Review 2007). In the long term, full electric or hydrogen-powered vehicles would have zero tank-to-wheel emissions (that is, emissions produced from driving the car) but the well-to-wheels emissions (that is, the emissions associated with producing the fuel and transporting it to the filling station) would only be zero if the electricity and hydrogen were produced using zero-carbon fuels.

The rate at which low- and zero-carbon technologies become commercial depends critically on the process of innovation. This process does not exist in a vacuum but is driven by external influences, including consumer demand and government regulation. The key question for policymakers is whether policy interventions can ensure that lower carbon technologies are brought to market in time to meet wider CO_2 reduction targets and whether this process might be accelerated.

3. The case for mandatory emissions reduction targets

Mandatory targets have been proposed as one option available for policymakers wishing to drive improvements in vehicle technology. This section sets out two important arguments for introducing them: their high level of effectiveness and their importance in driving innovation.

Making targets mandatory is effective

An important part of the case for introducing mandatory standards is that they can be an effective method of reducing emissions from new vehicles. There are a number of examples of where the vehicle manufacturing industry has responded well to mandatory targets and where these policies have effectively reduced vehicle emissions, and we discuss these below.

EURO Standards

The so-called 'EURO Standards' are a set of emissions standards covering a range of pollutants (but not CO_2) from road vehicles sold in Europe. These standards were introduced in the early 1990s and have subsequently been tightened over time. Emissions of all air pollutants covered by the regulations have declined since the introduction of the standards. For example, between 1990 and 2001, emissions of Nitrogen Oxides (NOx) from road transport in Europe *fell* by 31.4 per cent. In contrast, emissions of CO_2 – which are not covered by the EURO Standards – *rose* by 28 per cent (EEA 2003).

Research by the European Environment Agency showed that regulations on passenger cars have had by far the greatest impact on emissions of NOx – much more than national programmes (EEA 2003). The standards achieved success by driving the introduction of three-way catalytic converters in cars, a technology that was already available in the United States but had not yet been taken up in cars sold in Europe.

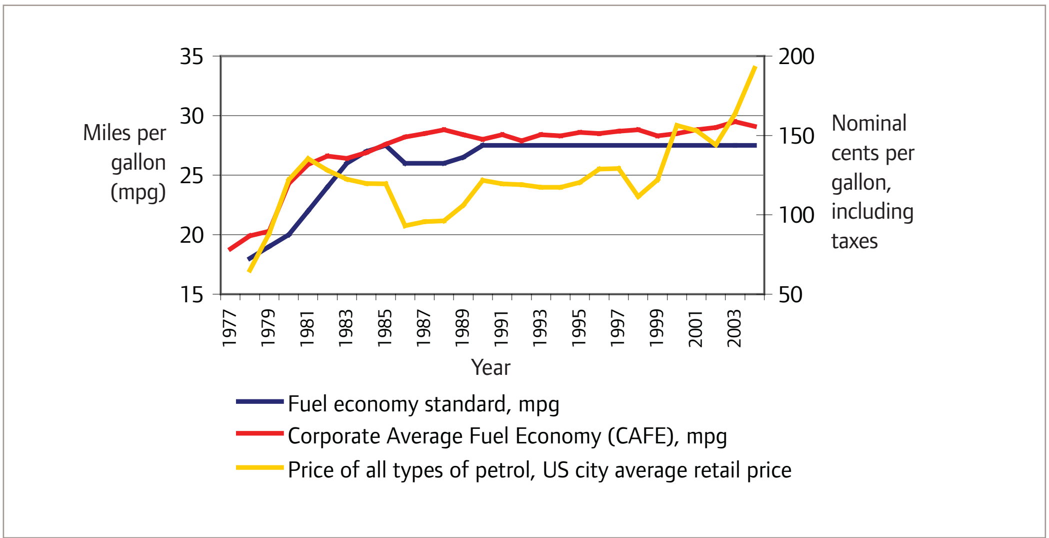
US CAFE Standards

The Corporate Average Fuel Economy (CAFE) standards in the United States also show how mandatory targets can drive improvements. The CAFE standards were initially established in response to the 1973 oil crisis. They are now set by the National Highway Traffic Safety Administration (NHTSA) each year and specify the average fuel economy (measured in miles per gallon) that must be achieved by manufacturers for all passenger cars and light trucks that they sell in the US.

Figure 3.1 shows how tough fuel economy standards in the 1980s drove a significant improvement in vehicle efficiency, even when petrol prices were falling in the mid to late 1980s. However, as soon as the standards stopped being progressively tightened, the rate of improvement also virtually levelled off, even as petrol prices rose during the late 1990s.

Figure 3.1: Average fuel economy of new passenger cars, by model year (United States)

Sources: NHTSA 2007, EIA 2008



Innovation for low- and zero-carbon vehicles

It has been argued that mandatory targets can play a vital role in stimulating the innovation process to deliver low-carbon vehicles.

The process of turning a bright idea into a fully commercial product consists of a number of important stages. Very generally, these phases can be described as:

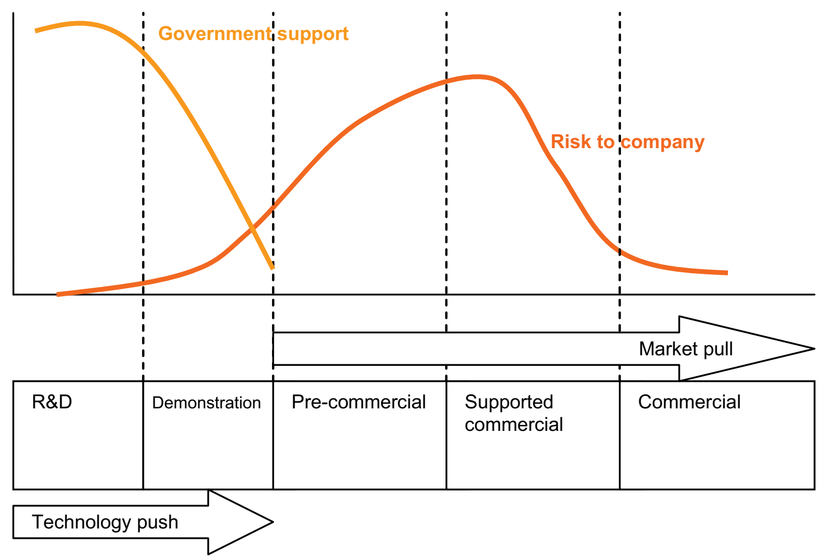
1. Research
2. Demonstration
3. Market entry (pre-commercial and supported commercial)
4. Commercial.

Of course, in reality the process is more complex, and rarely a straightforward linear progression from one step to the next, but it is useful to consider this simplified model when identifying drivers for the process.

The two main drivers of the innovation process can be described as 'technology push' – arising from new inventions – and 'market pull', but many experts argue that the 'pull' is more important than the 'push'. The UK Government's Environmental Innovations Advisory Group (EIAG) suggested in its First Report that the process of innovation works best when there is a clearly articulated demand for a product, rather than when markets are sought for new inventions. This is because the greatest risk to companies occurs not at the research stage of the innovation process – where government support tends to be greatest – but at the point of demonstration and pre-commercial deployment of products (EIAG 2006). The risk profile to investors across the innovation process is illustrated in Figure 3.2.

Figure 3.2: Company risk in the innovation process

Adapted from EIAG 2006 and Department for Transport 2007



However, the consumer-driven 'market pull' for low-carbon vehicles is currently limited. In fact there is a considerable demand in the opposite direction for larger, more powerful cars. There is therefore a key role for government to play in providing a credible framework of incentives to encourage the development and commercialisation of low-carbon vehicle technologies. Such long-term policies can increase investor confidence in future markets for low-carbon vehicles and hence lessen the risk they face in the demonstration and market entry phases (EIAG 2006). (For a more detailed discussion of innovation policy see Lockwood *et al* 2007.)

The lack of such strong regulatory incentives has been identified as a key barrier to innovation for low-carbon road transport technologies in the UK, according to business consultancy E4tech (E4tech 2007). E4tech argues that strong policy signals are needed to drive both incremental improvements in the short term and to encourage investment in developing technologies that are currently further from market (such as plug-in hybrid and fuel cell vehicles) for longer-term gains (ibid). This view is supported by others, for example, Lockwood *et al* (2007) and Watkiss *et al* (2004).

The industry itself also maintains that planning certainty and predictability are vital because of the long lead-times involved in the innovation process. For example, see European Automobile Manufacturers Association (ACEA) and Japanese Automobile Manufacturers Association (JAMA) responses to the European Commission's *CARS 21 Final Report* (European Commission 2006a). Manufacturers claim that the full production cycle of a car can take up to 12 years; the development phase – from concept to production logistics – takes around five years, and the production phase – during which it is essentially not possible to make major changes to the vehicle – lasts approximately seven years (ACEA 2007a).

There seems to be a clear role for targets in driving innovation for low-carbon vehicles and there are examples of where the vehicle manufacturing industry has responded well to this type of approach. Two from the United States that have been successful in advancing zero emission technologies are described below.

Zero Emission Vehicle Program, California

California's Zero Emissions Vehicle (ZEV) Program is often cited as an example of long-term targets successfully driving innovation. The programme, initiated in 1990, initially placed a requirement on large-volume car manufacturers to ensure that 2 per cent of their cars produced for sale in California should be ZEVs in 1998, rising to 5 per cent in 2001 and 10 per cent in 2003. The regulations have subsequently been altered and now include Partial Zero Emission Vehicles (PZEVs) – vehicles that have near-zero tailpipe emissions, such as hybrid-electric vehicles and alternatively fuelled vehicles – and Advanced Technology ZEVs (AT ZEVs), which incorporate cutting-edge technologies that reduce emissions, such as electric drive systems. In 2007, all manufacturers were in compliance with the regulations (CARB 2007).

The ZEV programme is widely considered to have driven innovation in emission-reducing technology. Following the introduction of the programme in 1990, there was a peak in patenting for battery electric vehicle-related technologies (Wells Bedsworth and Taylor 2007). The programme is also recognised as having driven the development of fuel cell technology and the introduction of 'super clean vehicles', which have significantly lower tailpipe emissions than average cars (EIAG 2006). The success has been mainly attributed to the fact that the targets were stretching for industry: they looked beyond what was achievable using the technology that existed at the time the targets were set.

It is worth noting, however, that the original regulations have come in for some criticism by those claiming that mandating the sale of zero tailpipe emissions vehicles was equivalent to forcing the sale of battery electric vehicles – since this was the only viable technology available at the time – rather than providing a technology-neutral approach (Wells Bedsworth and Taylor 2007).

Light Duty Emissions Standards, United States

The US Light Duty Emissions Standards have led to major reductions in emissions of air pollutants. Since their introduction in the 1970s, development of new technologies has led to 1000-fold reductions in emissions. Importantly, the standards represented stretching targets for the vehicle industry. For example, when California's Super-Ultra Low Emission Vehicle (SULEV) target was set, the technology did not exist to meet the target. However, by the time the SULEV target had come into force, the industry had been able to develop new technology to meet the target.

A policy framework for low-carbon innovation

The examples above share a number of common features:

- They set stretching targets
- They provided sufficient time for industry to adapt
- They were technology-neutral, in that they did not specify how the targets should be met but left it to the market to deliver the best solution.

These features are very similar to those in recommendations made by the UK's Environmental Innovations Advisory Group (EIAG) for a successful policy framework for stimulating innovation. EIAG proposes such a framework should contain the following three features:

- **Progressive regulations with 'stretch' targets** (i.e. deliberately set beyond the current best available technology) to give business the incentive to look at new solutions rather than incremental developments
- **Long lead times** (including timely planning for the implementation of EU legislation), backed by the certainty of legislative enforcement, which give business the time and confidence to invest in finding new solutions
- **Clear objectives and a focus on outcomes**, rather than prescriptive approaches, to give business the freedom to innovate and avoid locking-in current technologies. (EIAG 2006: 23)

The vehicle manufacturing industry is highly competitive and highly innovative. The examples in this section show that it has responded well to this type of approach in the past and been able to deliver new technologies to meet stretching targets, provided it has been given enough time in which to do so.

Summary

Mandatory targets are not only more effective than voluntary agreements in achieving emissions reductions, but they can also stimulate the uptake of best available technologies in the short term, and in the longer term drive the process of innovation that is needed to deliver the low- and zero-carbon vehicles of the future to market.

4. Overview of Europe's strategy for reducing emissions from light-duty vehicles

The European Commission has a long-standing objective to reduce average CO_2 emissions from new passenger cars to 120g CO_2/km. The target date has been extended several times and is now set for 2012.

The strategy for meeting the objective consists of three strands:

1. **A commitment from the automobile industry to improve fuel economy.** In 1998, the European Automobile Manufacturers Association (ACEA) reached a voluntary agreement with the European Commission to reduce CO_2 emissions from new passenger cars over a 10-year period, to 140g CO_2/km by 2008. The Korean Automobile Manufacturers Association (KAMA) and the Japanese Automobile Manufacturers Association (JAMA) reached similar agreements in 1999, with their target year being 2009 (EU 2007). The agreements state that if ACEA, KAMA and JAMA fail to achieve the CO_2 emission targets, the Commission will present a legislative proposal (European Commission 1999, 2000a, 2000b).
2. **A fuel economy labelling system for new cars.** EU Directive 1999/94/EC requires a label to be displayed on each new car that shows fuel consumption and CO_2 emissions, as well as publication of fuel efficiency in a variety of formats.
3. **The promotion of fuel efficiency through fiscal measures to influence motorists' choices.** The Commission has issued a proposal to move towards CO_2-related taxes, but this has met with some opposition among Member States. (European Commission 2007a, European Union 2007)

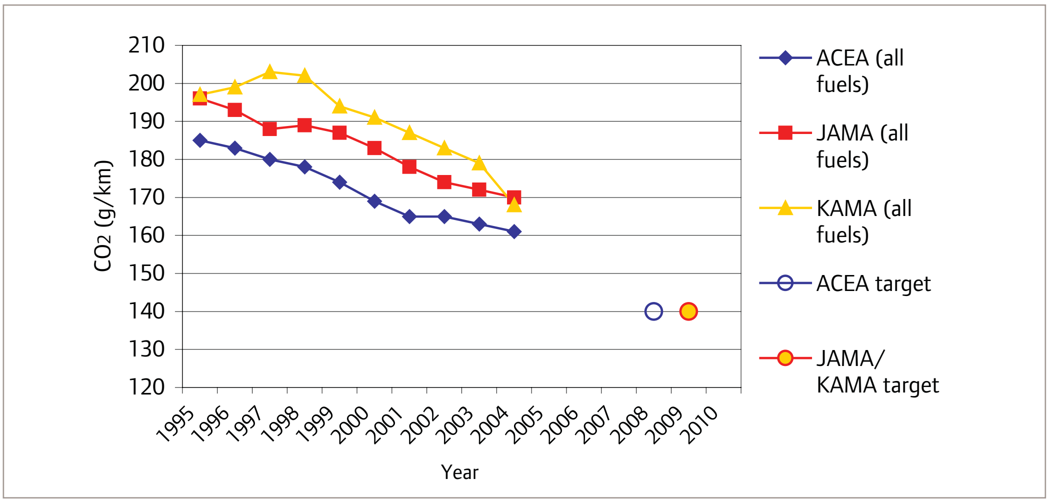
Vehicle efficiency improvements

Improving vehicle fuel economy is an important leg of the European strategy but success in achieving this has so far been limited. Technological improvements have decreased the average tailpipe CO_2 emissions by improving the fuel efficiency of new cars sold in Europe in recent years. For example, average emissions for all new cars across the EU-15 fell from 186g CO_2/km in 1995 to 163g CO_2/km in 2004 (European Commission 2006). However, the technical improvements made by vehicle manufacturers have not occurred at a rate sufficient to meet the levels set out in the voluntary agreements and it is now widely accepted that these targets will not be met. Between 2004 and 2005 the rate of progress across all three associations was just a one per cent reduction in CO_2 (T&E 2007b).

Figure 4.1 shows progress towards the targets by different manufacturing associations.

Figure 4.1
Progress towards voluntary targets

Source: European Commission 2006b



Perhaps surprisingly, the slow nature of progress does not appear to be due to a lack of technological know-how but rather to the slow uptake of new technologies. Without strong consumer demand or binding targets on vehicle manufacturers, there is no incentive to use technologies that could deliver greater emissions reductions but that come at a greater cost (E4tech 2007). Some commentators suggest that it is only because mandatory targets look set to become a reality that these technologies are being brought to market. In a recent press release, the European Federation for Transport and the Environment (T&E) quoted the head of DaimlerChrysler's research and development saying that the manufacturer could have launched a more efficient version of its Mercedes A Class three years before it did: 'We had it ready behind the curtains, but no one asked for it…so we held it back…now everything has changed' (T&E 2007c).

The European Automobile Manufacturers Association (ACEA) claims that consumer trends towards buying bigger, more powerful cars and European safety and air quality regulations, which have led to heavier vehicles, have acted as barriers towards reducing vehicle CO_2 emissions (ACEA 2007b).

The average weight of new cars sold in Europe has increased in recent years, as Table 4.1 demonstrates, and consumer preference does appear to be responsible in some part for this. For example, in the UK, the market share of 4x4s and Sports Utility Vehicles (SUVs) rose from 3.8 per cent in 1997 to 7.5 per cent in 2006 and the share for multipurpose vehicles increased from 2 per cent to 5.3 per cent over the same period (SMMT 2007b).

Table 4.1: Average weight of new cars sold in Europe (kg)

Year	Overall average	Cars produced by members of ACEA	Cars produced by members of JAMA	Cars produced by members of KAMA
2004	1347	1355	1310	1298
2005	1356	1365	1340	1340
2006	1374	1382	1317	1384

Source: T&E 2007d
(ACEA= European Automobile Manufacturers Association; JAMA= Japan Automobile Manufacturers Association; KAMA= Korea Automobile Manufacturers Association)

Fuel efficiency does not yet seem to be a very influential factor for consumers buying a new car. The use of labelling and fiscal measures set out in the European Strategy have not yet occurred to a sufficient level to influence consumer purchasing behaviour. The UK has introduced a system of banding Vehicle Excise Duty (VED) according to CO_2 emission ratings. The differentials between bands were initially too small to affect purchasing behaviour. While the differentials were increased in the 2006 and 2007 Budgets, it is too early to say whether this has been a sufficient incentive to change behaviour (Retallack *et al* 2007).

These are not the only influences on purchasing behaviour, however, and a number of critics note that advertising plays a key role in determining motorists' choice of vehicle. The UK Low Carbon Vehicle Partnership is currently carrying out research into whether more polluting cars are advertised more intensely and widely than their cleaner counterparts.

A combination of factors therefore seems responsible for the failure of the voluntary agreements. Consumer demand for more efficient vehicles has not materialised and the nature of the voluntary agreement means it has not had sufficient 'bite' to force manufacturers to improve their performance. The Commission stated that it would consider mandatory targets if voluntary agreements were not reached, and this led to the Commission's communication published early in 2007.

Future regulation

In February 2007 the European Commission adopted a communication to the Council and European Parliament, which set out the Commission's intention of proposing an EU legislative framework to reduce CO_2 emissions from passenger cars and light commercial vehicles (European Commission

2007b). This was followed in December 2007 with a proposal for a regulation setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles (European Commission 2007c). The main elements of this proposal are set out in Box 4.1.

Box 4.1: The European Commission's proposal for a regulation to set emission performances standards for new passenger cars

The proposed legislation would set a mandatory target for vehicle manufacturers to reduce average emissions of CO_2 from new passenger cars sold in Europe to 130g CO_2/km by 2012. (A number of supplementary measures would then make a reduction of a further 10g to 120g CO_2/km – see below.)

The target would be differentiated (by defining a limit value curve of CO_2) according to the mass of the vehicle so that heavier cars would have to make greater improvements proportionally than lighter vehicles but that the average emissions would be 130g CO_2/km across the fleet as a whole.

Manufacturers must ensure that the average emissions across all of their vehicles manufactured and registered in a given year are below the levels set out by the limit value curve.

Manufacturers who fail to meet the target would have to pay a fine based on the amount by which their average fleet emissions exceed the target multiplied by the number of vehicles sold. A premium of EUR20 per g CO_2/km by which the manufacturer exceeds the target has been suggested for the year 2012, rising to EUR35 in 2013, EUR60 in 2014 and EUR95 in 2015.

The Commission envisages that this regulation will contribute towards its overall objective of reducing CO_2 emissions from new cars to 120g CO_2/km by 2012. In addition to the improvements in vehicle motor technology achieved through the regulation, an additional 10 gCO_2/km is to be achieved through 'supplementary measures' including tyre pressure gauges, use of biofuels and improvements to air conditioning units (among others) (European Commission 2007b).

The Commission's proposal is now being discussed by the European Council and European Parliament. It is likely that the Directive will be adopted in 2009.

5. Debates around the proposed European Strategy for reducing emissions

The case for introducing mandatory targets is clear. This section outlines some of the key debates around the development of the legislative framework for a 2012 target and looks further into the future to ask whether targets for 2020 and beyond should be set.

Before looking in more detail at contentious areas, it is useful to outline some basic principles, based on the evidence presented so far in this paper. These principles should underpin the strategy:

1. **Policy interventions should be targeted at those who can deliver.** Targets should only be set for those who have the ability to deliver them. This could mean setting a number of discrete targets rather than one all-encompassing target. For example, targets aimed at vehicle manufacturers should only relate to the materials and technologies used in constructing vehicles and not to the way in which motorists operate them.
2. **Short-term targets should be used to bring forward the uptake of existing carbon-reducing technologies.** Long-term targets should be used to drive radical innovation for new technologies.
3. **Innovation targets should have long lead times** to allow industry sufficient time in which to develop suitable technologies.
4. **Targets should be technology-neutral** and focus on need rather than prescribing solutions.

With these points in mind we now look at some of the key debates around the European Commission's current proposals.

The 2012 target

How integrated is the target for 2012?

The Commission's proposal is for an 'integrated approach' to meet the EU's objective of average emissions of 120g CO_2/km for new cars by 2012. As described above, this consists of a mandatory target for vehicle manufacturers to reduce emissions to 130g CO_2/km by 2012 by improving vehicle motor technologies and a number of 'supplementary measures', which will reduce emissions by a further 10g CO_2/km.

This approach has been supported by vehicle manufacturers (see, for example, ACEA 2007b, VDA 2007 and SMMT 2007c), who claim that such an approach would be the quickest and most cost-effective way of reducing CO_2 emissions from passenger cars (SMMT 2007c). However, an integrated objective has been strongly criticised by environmental non-governmental organisations who argue that the full 120g CO_2/km should be achieved by technological improvements and that additional measures should be counted on top of – rather than instead of – the regulation on vehicle manufacturers (T&E 2007a, WWF 2007).

However, it is not clear who the responsibility for achieving the 'supplementary measures' lies with. While manufacturers can control the extent to which equipment such as tyre pressure gauges is installed in new cars, they cannot control whether or not motorists pump up their tyres. Equally, they cannot control what fuel motorists put in their tanks, yet the use of biofuels is included in the list of supplementary measures.

There are also difficulties associated with measuring the impacts of certain types of onboard equipment, such as air conditioning units, on CO_2 emissions from cars. Air conditioning is known to contribute significantly to a car's overall CO_2 emissions, but the impact is not currently measured in the test cycles that are used to determine vehicle emission ratings. It is also difficult to ascertain the extent to which drivers will use their air conditioning units in practice. The same is true for other electrical equipment. Without altering the test cycle to include the use of these facilities, it is hard to account for the benefit more efficient units will bring in terms of reduced CO_2 emissions.

While an integrated approach to reducing car emissions is undoubtedly needed, combining different elements into one objective in this way is confusing. Separate targets should be articulated for different elements of the strategy and aimed at those who are best able to deliver them and responsibility for each aspect should be clearly allocated. Targets for vehicle manufacturers should not include aspects of vehicle use, such as the use of biofuels, over which they have no control. Consideration should be given to how to measure targets for aspects of a car's performance not yet covered by the test cycle, such as the impact of gadgets like air conditioning.

The Commission is likely to put forward proposals in some of these areas – on efficiency requirements for onboard equipment and on the carbon content of road fuels.

Improving vehicle technology

It seems clear that a major aim of the 2012 target is to drive the uptake of low-carbon technologies in new cars sold in Europe. We infer this from the fact that the bulk of the 2012 target is aimed at improving motor technology with 'supplementary measures' accounting for around 25 per cent of the necessary improvements needed.

As discussed above, such a short-term target cannot be used to drive radical innovation since the lead time is too short, but should instead aim to promote the uptake of best available technologies to reduce emissions across the fleet.

Compliance measures should be aligned to this aim. Penalties for manufacturers who fail to meet the targets should be higher than the price of compliance, otherwise there is a risk that manufacturers could fail to deliver the necessary improvements and simply 'buy their way out' of making the necessary improvements.

Level and type of target

A mandatory vehicle technology target could be applied in a number of different ways and there are two choices that must be made.

First, the level at which the target is applied must be considered. There are three options:

- Each individual vehicle must comply with the target; or
- Manufacturers must meet the target on average across their whole fleet; or
- Manufacturers must meet the target on average across their whole fleet, but trading is allowed between manufacturers so that those who exceed their target can sell credits to those who do not meet it.

The latter option would appear to allow the reductions to be made in the most cost-effective way and also to provide an incentive to manufacturers to go beyond the target. However, this proposal is not popular with vehicle manufacturers and there are some concerns regarding the effectiveness of trading and whether, in what is not likely to be a liquid market, trading will actually take place. A more detailed explanation of the different options and combinations is given in ten Brink *et al* (2005).

The second choice relates to the type of target that is set. Again, there are three options:

- Having a single emission value, whereby the sale of cars that emit more than this level of CO_2 would be banned; or
- Making a percentage reduction on a baseline, where all manufacturers would have to make the same fleet-average level of improvement over a defined period of time; or
- Linking the target to a 'utility parameter', that is, some measure of the use or type of vehicle.

The Commission favours the third option above. There are lots of different parameters that could be used, including the power rating and vehicle volume, but two are being considered seriously: weight and footprint (defined as the area of the rectangle delimitedby the four wheels). The idea would be that vehicles of the same weight (or footprint) would have the same emissions target. In general, the heavier (or larger footprint) cars would be expected to make a greater effort in reducing their emissions than lighter (or smaller footprint) models but in absolute terms, the heavier (larger) cars would still have a higher level of emissions.

Those in favour of using weight argue that it is the parameter that correlates most closely with CO_2 emissions and that it is already used in targets set by other countries like Japan. Critics argue that reducing weight is an important method of cutting vehicle emissions but if the target were dependent on the vehicle weight – that is, heavier cars have weaker targets than lighter cars – there would be no incentive to manufacturers to reduce the weight of vehicles (because reducing the weight would result in a more stringent target). In fact, it could actually provide a perverse incentive to increase the weight of cars (in order to obtain a weaker target) and therefore lead to higher total emissions across the fleet (T&E 2007e).

However, this would depend on a number of factors, including the agreed relationship between CO_2 and the utility factor. Vehicle manufacturers point to evidence from Japan, where similar weight-based targets do not appear to have resulted in heavier vehicles (Lücke 2007). One solution would be to impose a ceiling on the target so that vehicles over a certain maximum weight would all have the same target. (Similarly, a floor could be included to ensure that vehicles at the low-CO_2 end of the scale were not unfairly penalised.) (ten Brink *et al* 2005).

The European Federation for Transport and the Environment (T&E) has argued for using footprint instead of weight as the appropriate utility function because it also correlates with emissions intensity but would avoid the problem of creating perverse incentives described above. It also suggests that it is a good proxy for the size and interior space of a car (T&E 2007e). Critics of this idea argue that 'platform sharing' – whereby manufacturers use a single a set of components, including the chassis, as a basic building block for a number of different models – can mean that very different types of car can have the same footprint.

The Commission's proposal uses mass as the utility function although it also requires data on footprint to be collected 'in order to facilitate longer-term evaluations of the utility-based approach' (European Commission 2007c: 14).

Medium- and long-term targets

The Commission's proposal does not contain proposals for targets beyond 2012 but many actors, including the UK Government, support the idea of setting additional long-term targets.

Medium- and long-term targets should be set with the aim of stimulating radical innovation. This means setting targets that cannot be achieved with today's existing technology but that will require the development of new technologies. As the examples in Section 4 above showed, the vehicle manufacturing industry is very good at delivering innovation provided that a suitable incentive framework is supplied on an adequate time scale.

The priority should be to set a target for 2020. In order to give a sufficient lead time of at least 10 years, this means discussions should start immediately to allow time for the legislative process. The target should also include milestones for progress in the intervening years. Consideration should also be given to targets for the even longer term, for example up to 2030.

A number of suggestions for what a 2020 target should be have been put forward:

- The European Federation for Transport and the Environment (T&E) recommends 80g CO_2/km on the grounds that this is consistent with reducing total European CO_2 emissions by 30 per cent by 2020 in Europe (T&E 2007b).
- The European Parliament passed a non-legislative (non-binding) resolution in October 2007 which invited the Commission to present legislative proposals for achieving average emissions of 95g CO_2/km (European Parliament 2007).
- The Commission for Integrated Transport proposes a 100g CO_2/km target on the basis that such a target would be feasible and cost-effective (CfIT 2007).
- The UK government has announced Britain's intention to press for 100g CO_2/km target by 2020, or no later than 2025 (Brown 2007). This is the most recent suggestion of the four.

However, in order to determine whether these targets are sufficiently stretching, it is necessary to first get an idea of what is technologically feasible. As set out in Section 2 above, with the 30 per cent reductions envisaged by King it should be possible to achieve 112g CO_2/km in Europe in the next five to 10 years – that is, by 2017 at the latest – through incremental improvements to and uptake of existing technologies. In the medium term, King suggests that 'cars that emit 50 per cent less CO_2 than today's equivalent models could be widely available by 2030' (King Review 2007: 41). She also charts a potential future technology pathway, with average emissions halved by 2030. This corresponds to 80g CO_2/km based on the European 2006 average.

At a European level, the European Road Transport Research Advisory Council (ERTRAC) has set a research target of 'Improvements in vehicle efficiency (that) will deliver as much as a 40 per cent reduction in CO_2 emissions for passenger cars in 2020' (ERTRAC 2004: 41). This would correspond to a new fleet average of 95g CO2/km. The target is based on the Future Road Vehicle Research (FURORE) network's R&D technology roadmap, which looks at potential future technologies based on scenarios for 2015-2020 (FURORE 2003) and has been supported by the European Commission (European Commission 2007b).

Table 5.1. Summary of technical feasibility studies and the proposed targets for reducing CO_2 emissions

Year	2012-2017	2020	2030
Technological feasibility			
Extrapolation from King Review	112g CO_2/km		80g CO_2/km
ERTRAC/FURORE		95g CO_2/km	
Proposed targets			
T&E		80g CO_2/km	
European Parliament		95g CO_2/km	
CfIT		100g CO_2/km	
UK Government		100g CO_2/km	

Abbreviations: ERTRAC: European Road Transport Research Advisory Council; FURORE: Future Road Vehicle Research; T&E: European Federation for Transport and Environment; CfIT: Confederation of Integrated Transport

Table 5.1 summarises the technical feasibility studies and the proposed targets. If the 2020 target is to be a stretch target, aimed at stimulating innovation and accelerating the pace of technological change, it needs to be set at a level that is more ambitious than what is considered to be technologically feasible. The rate of technological improvement put forward in the King Review suggests reductions to the fleet average amounting to approximately 101g CO_2/km by 2020 and 91g CO_2/km in 2025. Taking this as our baseline, a target of 100g CO_2/km would not be sufficiently stretching. A target of 95g CO_2/km or lower is needed to drive innovation. This is also in line with what is suggested by ERTRAC.

The discussion above described a graduated 2012 target, varying according to some function of utility. The long-term goal should be to achieve zero CO_2 emissions from all cars, no matter how large or small they are. Therefore, medium- and long-term targets should become less graduated over time and tend towards a long-term goal of zero emissions on a well-to-wheel basis (that is, including all of the associated emissions from producing and transporting fuel to driving the car itself).

6. Summary and recommendations

Passenger cars contribute a significant proportion of Europe's total carbon dioxide emissions. The voluntary agreements with vehicle manufacturers agreed as part of the European strategy to reduce CO_2 emissions from cars have so far failed to deliver the required levels of reduction and are very unlikely to meet the 2008/9 targets.

Mandatory targets have proved to be an effective way of reducing other types of emissions from cars, as the EURO standards programme shows. Mandatory short-term targets can be used in this way to stimulate the uptake of available technologies. Mandatory long-term targets can also be used to drive the innovation of new technologies that will deliver low- and zero-carbon cars in the future.

In order to be effective at driving innovation, long-term targets should be stretching, with long lead times and should be set on a 'needs' basis rather than by prescribing any particular technology.

Recommendations for European targets

- Targets aimed at reducing carbon dioxide emissions through technological improvements to vehicles should be applied as part of a package of measures that also focus on reducing the carbon intensity of fuels and encourage more efficient driving behaviours among motorists.
- Targets should not be integrated but should be rationally applied to those who can deliver them. For example, targets aimed at vehicle manufacturers should only relate to the materials and technologies used in constructing vehicles and not to the way in which motorists operate them.
- Test cycles should be modified to allow measurement of improvements such as more efficient air conditioning units in order to monitor progress towards targets.
- Fines or buy-out prices should be higher than the price of compliance to ensure reductions in emissions are achieved.
- Targets should be technology-neutral.
- Discussions on setting a 2020 target should begin as soon as possible to allow sufficient lead time for industry to deliver technological improvements.
- A 2020 target should be a 'stretch' target to encourage innovation. This means setting it at a level beyond what can be achieved using today's technology. A target of 95g CO_2/km or lower would achieve this.
- Consideration should be given to setting a longer term target, beyond 2020.

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