The Centre For Business Relationships, Accountability, Sustainability and Society

Car CO2 Reduction Feasibility Assessment; Is 130g/km Possible?

BRASS
The Centre for Business Relationships Accountability, Sustainability & Society

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"…the struggle to reduce and, where possible, eliminate emissions of the greenhouse gases may ultimately have greater repercussions on the motor industry than any efforts made to cut down the amount of toxic gases in the atmosphere."

(Nieuwenhuis, Cope and Armstrong, *The Green Car Guide*, 1992, p37)

1. Introduction – the CO2 issue and the car industry

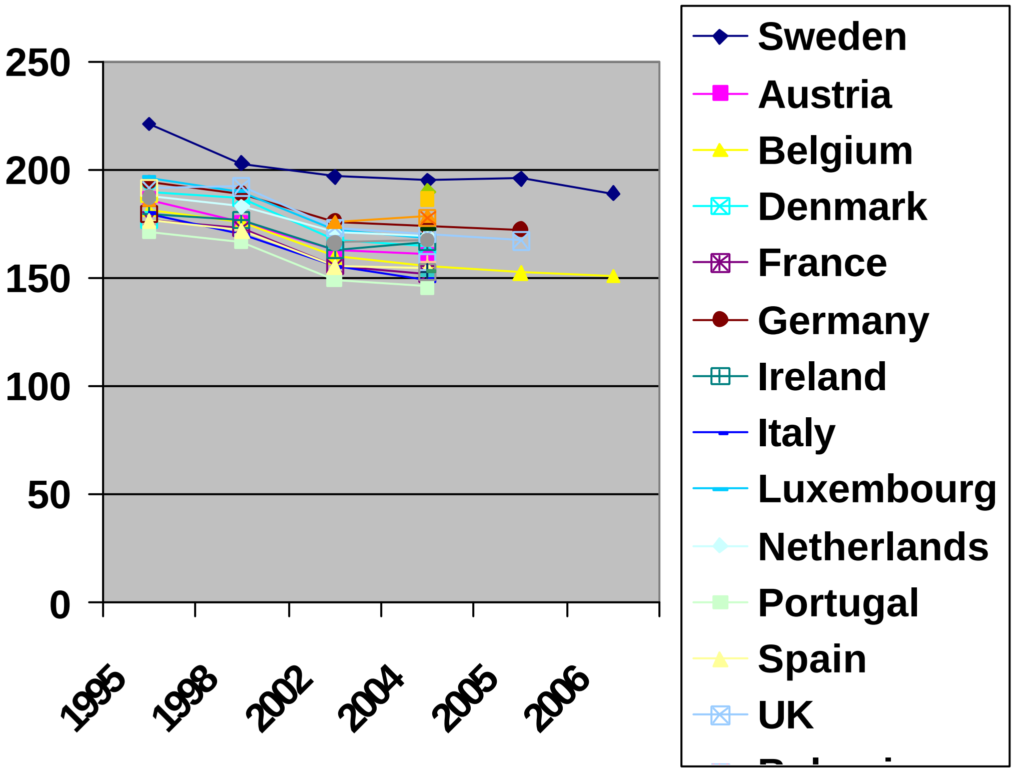
In the EU car industry, the year 2007 has been dominated by a debate around the need and feasibility of reducing CO2 emissions from cars. BRASS and CAIR have been tracking this debate throughout the year and we have in fact kept an eye on this issue for many years, acting as advisors to several of the parties on a number of occasions. This report summarises our current assessment of the situation and serves as our contribution to the debate.

European vehicle manufacturers' association ACEA has been struggling to come up with a common position in the face of Commissioner Dimas' proposal for a mandatory directive to reduce the average CO2 emissions of new cars registered in the EU to 130 g/km by 2012. The announcement was a response to the industry's apparent inability to meet the voluntary target set in the late 1990s of 140 g/km by 2008. The fact that some manufacturers (Renault, PSA) were on track to meet the target, and particularly the fact that the company of current ACEA chairman Marchionne, Fiat Auto, is already meeting that target naturally caused problems within ACEA. Essentially the split pitches the French and Italian manufacturers with their track record of smaller more fuel efficient cars, against the Germans and North Europeans (Ford-PAG members Volvo, Jaguar and Land Rover and GM brand Saab). German car makers enjoyed support from their own government at an early stage. One wonders to what extent such collective agreements and commitments are in fact compatible with genuine competition in any case, as shareholders of the firms on track to meet the standard wondering why their assets should be compromised in order to help non-compliant competitors.

1.1 History

It is clear from developments over the past decade that the measures currently in place have had some impact. Figure 1 shows the average new car fleet emissions of CO2 in g/km in the different member states. Availability of data is still variable by member state. However, it is clear that despite the marked reductions of the average figure, we are still some way off achieving the agreed limit of 140 g/km by 2008.

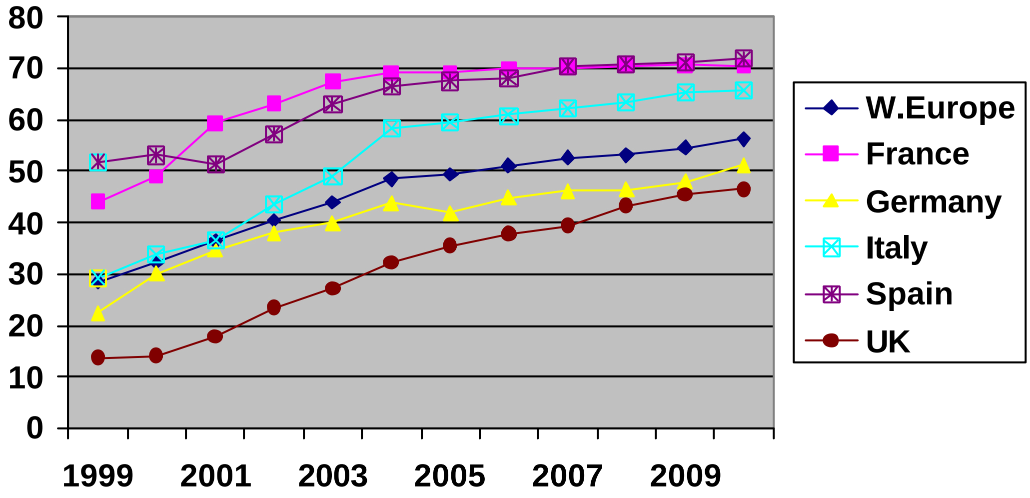
Fig. 1: Average car CO2 emissions reductions in key EU member states



(source: compiled by Greenpeace Austria, 2007)

Much of this reduction in overall fleet CO2 output has been achieved by a greater reliance on diesel engines. The overall greater thermal efficiency (ability to turn energy into power) of the diesel engine more than offsets the slightly higher carbon content of diesel fuel as compared with petrol. Despite the fact that there are a number of health risks associated with diesel emissions, which have been well documented, there is little doubt that any further reduction in CO2 emissions will be achieved at least initially through a further increase in diesel penetration. For this reason, a further rise in sales of diesel cars is forecast (see Fig. 2).

Figure 2: Diesel Car Penetration in Largest Markets



(source: adapted from J D Power, 2005, 89)

It is also for this reason that one of the ACEA stipulations at the time of the original agreement on CO2 was that no further measures would be introduced to reduce the use of diesel. The rise in diesel cars is due not only to government incentives, such as fiscal measures (e.g. excise duty on fuel), but also to the increasing sophistication of diesel cars, which has made them increasingly competitive with petrol powered equivalents.

1.2 The events of 2007

The apparent inability of the industry to reach the agreed limit of a fleet average of 140g/km by 2008 prompted the EU Commission to commission a number of studies in order to assess different policy options of how to deal with the issue (e.g. Ten Brink et al. 2005). These informed the decision by Commissioner Dimas to announce in February 2007 the proposal for a new limit of 120g/km (previously mooted and frequently discussed) but broken down as 130g/km through technical measures and the remainder through other measures such as increasing use of lower carbon, or more carbon-neutral fuels, such as biofuels.

Although the industry's – or at least ACEA's – rhetoric might suggest meeting the 130 g/km limit is somehow a major challenge, we should point out that the industry currently offers in the market a whole range of vehicles that already meet this standard – it is therefore far from impossible (see table 1).

Table 1: < 140g/km cars currently available in the EU

Make	Models < 120g/km	Models 120-130g/km	Models 130-140g/km
BMW	MINI 1.4d	118d, 120d	118i, MINI 1.4, 1.6
Chevrolet		Matiz 0.8	Matiz 1.0, 0.8auto
Citroën	C1, C2 diesel, C3 diesel	C4 1.6d	C2 1.4 stopstart
Daihatsu	Charade, Sirion 1.0		Sirion 1.3
Fiat	Panda 1.3 Multijet; Grande Punto 1.3 Multijet 75	Grande Punto Multijet 90	Panda 1.1,1.2, Punto 1.2; Stilo 1.9 Multijet 90 3d
Ford	Fiesta 1.4 tdci, 1.6tdci	Focus 1.6 tdci; C-Max1.6tdci	Focus 1.8tdci
Honda	Civic 1.3 hybrid	Jazz 1.2dsi-s	Jazz 1.4dsi; Civic 1.4, 2.2cdti
Hyundai		Amica 1.1gsi; Getz 1.1, 1.5d	Amica 1.1cdx
Kia		Picanto 1.0, 1.1; Rio 1.5d; Cerato 1.5d	
Mazda		2 1.4d; 3 1.6d	
Mercedes-Benz		A160 cdi	A180 cdi
MINI			Cooper 1.6
Mitsubishi		Colt 1.1, 1.5d	
Nissan		Micra 1.5d	Note 1.5d
Perodua		Kelisa1.0	Myvi 1.3sxi; Kenari 1.0
Peugeot	107 1.0 urban; 206 1.4hdi	1007 1.4hdi; 207 1.4hdi, 1.6hdi; 206 1.6hdi; 206cc 1.6hdi; 307 1.6hdi 3d	307 1.6 hdi 5d
Proton			Savvy 1.2 street
Renault	Clio Campus 1.5dci; Clio 1.5 dci 86	Modus 1.5dci; Clio 1.5dci; Megane 1.5dci 86 & 106	Scenic 1.5dci 86 & 106; Grand Scenic 1.5dci 106 Privilege
SEAT		Ibiza 1.4tdi	Ibiza 1.9tdi 100; Leon 1.9tdi
Škoda		Fabia 1.4tdi pd	Fabia 1.9tdi; Roomster 1.4tdi pd
Smart	ForTwo Pure; all For Two diesels	ForTwo Pulse & Brabus; ForFour 1.0, 1.5cdi; Roadster, Roadster Brabus	
Suzuki		Swift 1.3d	
Toyota	Aygo; Prius	Yaris 1.0, 1.4d	Auris 1.4d
Vauxhall		Corsa 1.3 cdti; Tigra 1.3cdti	Agila 1.0; Corsa 1.0, 1.2 (some); Meriva 1.3 cdti; Astra 1.7cdti
Volkswagen		Polo 1.4tdi	Polo 1.9tdi
Volvo		C30 1.6d; S40 1.6d	C30

(source: various; table does not show all models that comply)

Significant here are vehicles such as the BMWs, and the Volvo S40 1.6 diesel, at 129 g/km – highly credible cars and clear evidence that making specialist cars that comply is not impossible, nor so expensive that they become uncompetitive. All these cars currently compete in the market. In addition, there is already the Smart ForTwo diesel, which emits around 90 g/km (but note that the previous generation was nearer 85 g/km). The Honda

Insight hybrid emitted similar levels, but has now been discontinued in favour of more conventional Honda hybrids using mainstream bodyshells. There are also a number of cars just above the 140g/km limit, which with some simple reprogramming of the engine management system could be made to comply with the lower limit. In fact, informal conversations with engineers within the industry suggest that many cars currently in the range of 140-160 g/km can be made to meet the standard by such simple measures. More complex is the contribution of alternative fuel vehicles (AFVs), particularly those powered by biofuel. Saab gives a figure of 50 grammes of fossil CO2/km for the 95 BioPower when run on Brazilian bioethanol. The remainder of its 214 grammes of CO2 being renewable and absorbed by growing sugarcane in Brazil. The impact of shipping bioethanol from Brazil is not unsimilar to shipping oil from the Gulf and may in fact be lower in view of the shorter distance from Brazil to Europe as compared with Gulf to Europe via the Cape, the usual route as supertankers do not fit through the Suez Canal and pipelines to the Eastern Mediterranean have limited capacity .

It is also worth emphasizing that certain manufacturers are in fact on track to meet the standard of 140g/km agreed under the voluntary agreement. In fact, Fiat was already close to complying with the 140g/km target in 2005, while both Citroen and Renault were on track to meet that limit (T&E 2006). Some manufacturers have already started to use their CO2 performance in advertising and press releases, notably Citroen. Citroen UK now advertises the fact that it: *"…produces many of the most fuel efficient and environmentally friendly vehicles available, last year selling almost 15% of all low CO2 emitting cars (120g/km or less) registered in the UK* "(Citroen 2007).

2. Emerging carbon reduction technologies and their state of play

It is useful to review a number of current fuel and powertrain technologies and assess their likely introduction scenarios. Many regulators and politicians appear to have expectations of some of these technologies which are perhaps too high. Essentially internal combustion (IC) will be the dominant technology for many years to come and even hybrids still use this technology, after all. The EU Commission proposal for 130g/km will create a split in the market whereby an increasing number of cars that currently emit up to about 170g/km can be brought down to 130 g/km with reprogrammed ECUs and relatively low cost powertrain improvements (e.g. stop-start). It is for this reason that the car industry is keen to introduce some form of segmentation in the regulation – this clearly dilutes the impact of the measures and can penalise those manufacturers that already produce lower-emitting vehicles.

Larger cars will need more esoteric – i.e. much more expensive – technologies in order to bring them down to a level where they will not distort the industry average too much. This is where the challenge will be. The result may well, therefore be a split in the market, whereby small to medium cars will continue to be available at price levels similar to today's, while larger cars will become significantly more expensive. This may in itself have the effect of depressing demand for larger cars, thereby helping to bring down the average CO2 emissions anyway. Although this may unduly affect certain manufacturers (e.g. Jaguar, Land Rover, Mercedes, BMW), they could use this opportunity to adopt new technologies more suited to lower volume, higher margin products, but it must be remembered such a change will take many years to achieve – i.e. not by 2012. These manufacturers could also try and introduce smaller cars but these would still need to be premium priced in order for those manufacturers to survive. BMW's MINI, Mercedes A-Class and B-Class and Audi A2 are examples of how this might be done. Again, such a change in strategy would take some years to implement.

2.1 Biofuels

Biofuels are expected to play a role in bringing overall CO2 emissions down to 120 g/km. The biofuels issue is becoming increasingly controversial. While it is possible to make a positive case for Brazilian bioethanol (von Blottnitz and Curran 2007) and the still largely experimental second-generation biofuels (e.g. those derived from wood products and biomass from agricultural waste, etc.), the current worldwide rush into biofuels brings with it many issues regarding sustainability, actual net CO2 reduction, biodiversity loss, agriculture intensification (including increasing use of pesticides and other agrochemicals, as well as GM crops) and north-south equity. Any carbon reduction policy is therefore advised to tread warily in this area until the dust setlles. Biofuels will have a contribution to make, but they will not be the main solution. In any case, EU Member States will have to comply with the existing EU Biofuels Directive, which virtually guarantees a biofuels content of 5.75% by 2010 and sets various targets beyond this. In addition, the EU is making real efforts to stop imports of unsustainable biofuels. At present this does not appear to be 100% effective.

Some manufacturers have put considerable investments into the biofuels area, notably Ford and Saab. The reasons for this are much to do with incentives in certain key markets for these manufacturers, notably Sweden and Germany. In addition, Saab and Sweden are hoping to transfer from current imports of Brazilian bioethanol to future domestic supplies of second-generation bioethanol from wood by-products in Sweden. While biofuels may have some role to play in reducing carbon, in reality their role is likely to remain small. Demand will be driven for some time by the EU Directive and the growing public momentum. However, it is likely to settle at a level determined by the regulation and mixed with fossil fuels (max. 10%-15%) for use in mainstream IC engines.

2.2. Gaseous fuels and GTL

Two gaseous fuels are currently widely used in road vehicles worldwide, LPG and CNG. Both have lower carbon content and even though fuel consumption tends to be slightly higher, a net reduction in carbon can be achieved by both fuels compared with petrol or diesel. However, it must be remembered that LPG is a by-product of the oil refining process and production is therefore closely linked with the production of petrol and diesel. It can also be derived from natural gas as part of the exploitation and processing of CNG. Natural gas, however, is largely methane, which is itself a greenhouse gas that is considered many times more damaging than CO2. It therefore needs to be handled in carefully closed systems in order to limit any escape to air. Natural gas can also be liquefied to LNG, but this has to be kept at low temperatures and the systems needed for this are best suited to heavier commercial vehicles. Also, supplies are limited and closely linked with longer-term gas reserves.

Another option is turning natural gas into a liquid fuel that can be handled at normal temperatures. This GTL (gas-to-liquid) technology produces a very pure form of diesel using the Fischer-Tropsch process. This technology can make diesel much cleaner in future, allows the careful engineering of vehicle fuels and draws on much greater reserves than oil. In addition, it has a lower carbon content. The product is currently available in its pure form in a number of countries and is blended with conventional diesel in Shell's premium Pura fuel. Provided suitable incentives are available, oil firms can introduce the fuel using the existing forecourt infrastructure. A Shell GTL refinery is coming on stream in Qatar during 2007, which will greatly increase global capacity for this fuel.

2.3 Hybrids

Toyota has made a considerable impact with its Prius petrol-electric hybrid, particularly in California and in the London Congestion Charge Zone. In typical urban stop-start driving, such powertrains do generally give a CO2 emissions advantage that is not necessarily evident from the EU test cycle. Several other manufacturers are also introducing or preparing hybrid vehicles. Honda was another pioneer with its ultra lightweight Insight two-seater, a vehicle which achieved around 85 g/km of CO2, but which is no longer offered. Instead, Honda now offers a version of the Civic (IMA), while its hybrid technology package (IMA – integrated motor assist) is being introduced on other Hondas as well. In addition, Honda is set to introduce another dedicated hybrid electric vehicle in one of the popular small car segments by 2010.

European manufacturers are following two development trajectories in response to this Japanese initiative. The first involves stop-start systems. These switch off the engine when the car is stationary and start it immediately when the car needs to move off. The system can be introduced on many cars currently in production and evidence from suppliers of these systems suggests they will be seen in considerable numbers on EU roads in the near future. These systems give many of the advantages of a hybrid – particularly in urban driving – at considerably lower cost both to the manufacturer and the consumer. It may even be possible to retrofit some of these systems to existing cars. They are said to give a CO_2 saving on the test cycle of 10-15%.

Another development is the diesel hybrid. This is thought to provide significant savings in fuel consumption as well as CO_2 emissions compared even with a petrol-electric hybrid, although its integration in a car with acceptable NVH (noise, vibration and harshness…a measure of comfort within the vehicle) performance is challenging and costly. Diesel-electric hybrid technology is currently used on trains, heavy earth-moving equipment and some light and medium trucks, as well as buses. It is therefore a proven technology, but the problem is its integration in a car, where expectations of low noise and vibration levels are greater than in commercial vehicles. Various prototypes have been shown, such as that developed by Valeo and Ricardo. PSA Peugeot Citroen has announced it will have a diesel-electric hybrid car available from 2010, although 2012 seems more likely.

2.4 Battery Electric

Battery electric cars have been among the beneficiaries of the London Congestion Charge and have long been popular among environmentalists worldwide. Products in this niche have traditionally combined both electric conversions form mainstream producers (e.g. Peugeot) and dedicated vehicles by specialist niche producers (e.g. Th!nk). More recently, in Europe, electric conversions of Quadricycles have also been added to the mix. The battery electric vehicle (BEV) received a boost in the 1990s from the California ZEV mandate, which led to the development of the landmark GM EV-1 electric sportscar. More recently this niche has seen the gradual roll out of the Lotus-engineered and California-financed Tesla electric sportscar. Improved battery and controller technology have just about made the BEV viable, especially in urban environments and further improvements in battery technology driven by both developments in hybrids and in other products (laptops) may well enhance the competitiveness of BEVs still further.

The mainstream car industry has always had reservations about BEVs as these change the rules of the game by undermining one of the industry's core technologies – internal combustion engines. However, ironically, the growing electrification of cars in the context of hybridisation and weight-reduction (leading to electric steering racks, braking systems, etc.) will push the development of technologies that will also make BEVs more viable. Smaller players can use these enhanced technologies to develop more credible BEVs over the next few years. However, mainstream car makers are unlikely to enter this area in significant numbers. Even Toyota has reluctantly given in to activists in the US by announcing a 'plug-in' (mains rechargeable) version of some of its hybrid cars, due for launch in 2008. GM's Volt prototype is a further step in this direction as it is proposed as a mains rechargeable series-hybrid, thus taking hybridisation one step beyond the Prius which uses a parallel/series hybrid powertrain. These developments will also make fuel cell cars more viable as many of the technologies needed are very similar, or even identical in some cases. BEVs will therefore remain a marginal technology, but will see growth in certain benign environments where they have certain benefits (zero emissions) or incentives (e.g. exemption from congestion charge).

2.5 Fuel Cells

Fuel cell cars are regarded by many as the answer to all our environmental concerns – the Holy Grail of sustainable automobility, but all we have seen so far are a few prototypes and a few buses here and there. The achievements of the fuel cell industry – Ballard in particular – has been impressive; the ratio of Kw/£ has improved dramatically over the past fifteen years or so. In fact, in many respects the fuel cell car is competitive with the internal combustion engined car even today. The problems appear to be in these areas: vehicle integration, materials cost, fuel supply and production, manufacturability and infrastructure (see Nieuwenhuis at al. 2006 for a more detailed assessment):

- ***Vehicle Integration:*** Fuel cell vehicles have come a long way. Not too many years ago, a panel van was the smallest possible fuel cell vehicle, as the system took up so much room. During the 1990s we saw a rapid reduction in size and today's experimental fuel cell vehicles look, in terms of packaging and presentation, uncannily like conventional internal combustion powered vehicles. Toyota's Highlander-based FCV and Ford's Focus FCV are good examples. In practice, the system is still taking up much space, usually for example the rear storage area is used to provide for fuel supply or other parts of the system. In addition, the complexity of the 'plumbing' of these systems is great, and much work needs to be done to improve this aspect of the technology.

- ***Material cost and availability***: One issue that has been flagged up as an outstanding problem is the fuel cells' need for platinum. This precious metal is also used in catalytic converters, so the car industry is no stranger to tracking its value in the market. It is unfortunately relatively rare and reserves could even be stretched by the projected production volumes of cars if they were just petrol-powered and catalyst-equipped. However, a fuel cell system for a car needs at least twice as much of this metal. In view of this, the fuel cell industry and its suppliers are looking at ways of reducing the fuel cell's platinum-dependency. If they fail, we have a problem as the required volumes can then not be achieved; in fact there may not be enough even to supply catalytic converters to all the world's IC cars for much more than 15 years (Cohen 2007). The industry has already achieved a significant reduction in the platinum requirement of fuel cells, and experimented with some alternatives, but fuel cells are still very much an experimental technology.

- **Fuel supply**; is another issue to be resolved. Most current automotive fuel cells run on pure hydrogen. This is a substance that does not occur in this form on our planet. On earth it only occurs bound with oxygen in the form of water, or bound with carbon in a range of hydrocarbons. In each case, some process is needed to separate the hydrogen from these other elements and this requires energy, in some cases a lot of energy, with attendant carbon emissions if fossil sources are used, such that the total lifecycle impact of hydrogen does not always make it the most environmentally optimal fuel. On-board reforming of hydrogen from hydrocarbon fuels such as methanol or even petrol has also been suggested. This would obviously add weight and complexity to the vehicle and would also use energy. It would however remove the need for large hydrogen production facilities and for a hydrogen distribution infrastructure. Recent experiments with compressed hydrogen have at least shown that by using very high pressures a sufficient amount of fuel can be carried in a car to give it an acceptable range of around 300 miles. This has also been an issue that has been causing concern over the years. This does show that the industry is achieving improvements in the move towards practical fuel cell cars at a steady rate. If this continues, we are certainly likely to see practical hydrogen fuel cell vehicles in small numbers within the next five years or so and certainly by the much forecast 2012-2015 period.

- ***Manufacturability:*** Ballard is now in the early phases of setting up a manufacturing process for automotive fuel cells. This envisages a gradual, incremental increase in annual production to reach a peak of around 500,000 a year by about 2012-2015 in a single factory. So, if all goes according to plan, Ballard will be able to produce some half a million automotive fuel cell stacks each year. If we assume that the Japanese – led by Toyota – add a similar annual number, we have an annual production capacity of automotive fuel cells of around one million by 2015. It is worth noting that by then total vehicle production (cars and commercial vehicles) will exceed 75 million units per annum and the global vehicle population will be well over 1 billion.

- ***Infrastructure:*** Much has also been made of the need to replace or replicate the existing fuel supply infrastructure with a hydrogen version. The building of a dedicated infrastructure is very expensive; it has been estimated at $5000 per car by Keith and Ferrell (2003). There is also a chicken-and-egg situation in that few fuel cell vehicles would be sold without a fuelling infrastructure, while no commercial organisation would build an infrastructure without some guarantee of demand. Various automotive fuels are currently offered in markets around the world. Petrol is almost universally available, closely followed by diesel, used by trucks worldwide and by cars in Europe as well. In addition, many individual markets offer LPG, CNG, biodiesel, ethanol, methanol-based M85 and other fuels. Adding hydrogen as an additional fuel is often difficult on a crowded forecourt with a fixed number of storage tanks. With only five percent of new car sales being hydrogen powered, this is indeed difficult to justify. However, in British Columbia and California there have been proposals for ‘hydrogen highways’ – corridors where hydrogen availability would be guaranteed at regular intervals. Clearly some government support would be required to encourage such a development and in California governor Schwarzenegger himself has been a keen supporter of this concept. In the EU, hydrogen supply infrastructures are currently very rare with the Europort area of Rotterdam an often-cited example. However, it has also been suggested that hydrogen itself does not actually need to be distributed in the way petrol or diesel are today. In fact, rather than on-board reforming outlined earlier, some are now suggesting this reforming – extracting hydrogen from a feedstock – can be done by larger units set up alongside fuel stations and linked to one or more pumps on the forecourt for the supply of pure hydrogen to fuel cell cars. In this way, no significant change in the fuel distribution system would be needed.

The total number of vehicles produced worldwide today is around sixty million. It is safe to assume that with China, India, Indonesia and others all in the fray by 2015, this number will have grown to nearer eighty million, if not more. The market share of newly registered fuel cell vehicles by then will therefore be a maximum of one eightieth of the annual global market. As they have businesses to run, neither the Canadians at Ballard, nor the Japanese are likely to dramatically increase fuel cell production capacity before there is a clear sign of demand. Once this is apparent – if indeed it materialises – the lead-time for another half million capacity facility will be at least a year, if not more.

Let us assume therefore, that by 2020 we will have a global automotive fuel cell production capacity of four million stacks. If we keep to our global vehicle production figure of eighty million by then we find that five percent of vehicles made can be fitted with a fuel cell. That is one in twenty. At this rate it will obviously take a while to have the majority of the parc running on fuel cells. In practice, these fuel cell vehicles would probably not be equally distributed among world markets. Instead there are likely to be pockets of higher fuel cell car densities. One can imagine areas such as the state of California, Iceland, and the Canadian province of British Columbia – home of Ballard – enjoying a significantly higher density than Texas, or Romania, for example.

Obstacles to the introduction of hydrogen fuel cell vehicles are one by one being dismantled by technological and conceptual solutions. If this trend continues, we can have commercial fuel cell cars appearing on the roads of at least some parts of the world in the next decade. To that extent, the assessment by Ogden et a. (2001) could be correct. They forecast an 'optimistic scenario' whereby 10,000 fuel cell cars would be produced between 2005 and 2008 and by 2010 this figure would be up to 300,000. One million a year would be reached before 2020 by which stage the technology would be cost competitive with conventional cars. Beyond 2020 10 new factories would be built each year (Nieuwenhuis et al. 2006).

On the fuel supply issue, many proponents of fuel cells now suggest we should move to fuel cells urgently; initially using so-called 'black' hydrogen from fossil sources. At the same time we should then build up the capacity to produce hydrogen from renewable sources and thus gradually power the now growing parc of fuel cell vehicles with this 'green' hydrogen. The demand for this will be driven by the vehicles in use. This scenario could in the first instance lead to a net increase in carbon emissions, although toxic emissions in urban areas would be reduced (hence its popularity with regulators in California), while in the long run, when sufficient 'green' hydrogen is available, there would be a benefit for all.

It is clear from this assessment that this issue has no role to play in any carbon reduction strategy whether the target date is 2012 or 2015. This discussion is included to inform various parties who have raised the hydrogen and fuel cell issue in this context.

2.6 Improving Internal Combustion (IC) and Conventional Powertrain

Conventional petrol and diesel fuels and conventional petrol and diesel powertrain will continue to dominate. At the same time, oil-derived fuels are likely to increase in cost. Supply of oil is now estimated to peak around 2010-15, while demand – from newly motorising nations such as China, India, Indonesia and Russia – will continue to increase (Hirsch et al. 2007). This will increase the demand for alternative powertrain technologies such as the hydrogen fuel cell. Alternatively, the car industry will – in a bid to preserve the tried and trusted internal combustion engine – go for enhanced conventional IC powertrain technologies such as petrol- or diesel-hybrid solutions instead. These hybrids still use petrol or diesel fuel, after all, unlike electric powertrain, such as battery-electrics, or fuel cells, which have the potential to make IC obsolete. As outlined earlier, IC fuels can also be derived from natural gas (GTL), coal (CTL) or biomass even when oil itself becomes too costly. This perpetuation of internal combustion could well be used to postpone the inevitable moment when internal combustion will no longer be viable. In that case the hydrogen fuel cell could well continue to be the best future powertrain solution for several more decades.

There are a number of technologies coming onto the market which will have this effect of keeping conventional IC engines more environmentally competitive. Table 1 lists some of the more important of these ('other' includes LPG, CNG, hydrogen internal combustion, etc.). Within the next few years we will see a development whereby petrol engines will become smaller, turbocharged and fitted with technologies for greater efficiency. This will make petrol engines competitive in fuel consumption (and CO_2 emissions) terms with diesel, but with the advantage of cheaper emissions control than future generations of diesel engine. Diesel technology is becoming increasingly expensive as more esoteric technologies are needed for it to meet tightening emissions standards. Yet diesel is a key element of the car makers' strategy for meeting lower CO_2 limits. The focus is now on improved, lean-burn petrol engines, which mimic to some extent the advantages and characteristics of diesel engines. On the other hand, improvements in the diesel combustion process are being developed in order to avoid expensive and complex after-treatment technologies. Both these approaches involve the technologies outlined in table 2 below.

Table 2: Future Powertrain Developments

Technology	Likely EU introduction	Likely CO2 savings (source)
Variable valve actuation	Now	
Electronic valve actuation (no camshaft)	2010	15-20% (Valeo)
Direct injection petrol engines (GDI)	Now	15% (Bosch)
Cylinder switch off (available in US)	2010	
Stop-start	2006	10-15% in urban driving (Citroen); 5% overall (Lotus); 20-25% in urban driving (Fiat)
Starter-generator	Now	
Variable compression	?	
Turbocharging and supercharging combined with downsizing	Now	
Improved transmissions (CVT, DSG, AMT, etc.)	Now	
Low rolling resistance tyres	Now	2-5% (Michelin)
Petrol-electric hybrid	Now	18% (Honda); 22% (Lotus); 25% (Connaught)
Diesel-electric hybrid	2010-2012	35% (PSA)

Transmissions are also subject to rapid development as a whole powertrain approach is now needed; this can often avoid spending on more complex engine technologies. More and more control is being taken away from the driver, who is increasingly regarded as interfering with optimum (emissions) performance. Even automated manual transmissions will therefore become more automated even though at their core there is a conventional gearbox. Automatic transmissions have already enjoyed improvements such as lock-up torque converters which significantly reduce frictional losses, while other novel technologies such as CVT see a new lease of life as a result of improved electronic control systems. CVT is a well established technology in Japan and will increasingly be seen in Europe, especially on small cars, although Audi has been driving its use on larger cars. The UK IVT technology, as developed by Torotrak, may also finally come to market within the next few years.

A relatively simple measure is the fitment of low rolling resistance tyres. The new Peugeot 308 will be fitted as standard with Michelin Energy Saver tyres, which according to the tyre manufacturer will reduce CO2 emissions by almost 4 grammes per kilometre.

3. OEM-supplier relations:

The relationship between vehicle manufacturers (assemblers) and their suppliers is a constantly changing one. The first mass car manufacturing model, as developed by Ford, involved an extremely high level of vertical integration, whereby iron ore was input at one end of the factory and a finished car came out at the other end (see Nieuwenhuis and Wells 2007 for an analysis of this model). At this stage, Ford increased production volumes at such a rate that there was no supply sector that could keep up with the volumes needed. However this model did not last long and soon specialist firms developed which could supply particular items more efficiently and cheaply than the final assemblers could do the same job in-house. Over time there have been various waves of moving activities in-house, then outsourcing them again, but by the 1980s most of the car industry worked with a model whereby a typical assembly plant relied on a network of around 2000 suppliers to support the assembly process. The car manufacturer, or OEM, became a skilled integrator of these components. OEMs typically outsource between 60% and 80% of the ex-works value of a car.

This system became increasingly regarded as inefficient and during the 1980s and 1990s, under the influence of the tiered supply system developed in Japan – whereby each OEM only needs to interface with a limited number of top tier or 'tier 1' suppliers[1] – European and American car makers reduced the number of suppliers to typically around 200. This process was enabled via consolidation within the supply sector. However, the model was soon transformed into one whereby the OEM worked with a limited number, typically around 20, super suppliers who co-developed major sub-assemblies which were then supplied to the OEM for a greatly simplified final assembly process. This extreme model is still very rare. The typical example of this last model is the MCC Smart plant at Hambach in eastern France whereby around 30 suppliers feed into a greatly simplified assembly process. The assembly of a Smart takes only around five hours, compared with a minimum in a more conventional plant of at least fifteen hours, sometimes more like 50 hours.

In this process, the top tier of suppliers not only grew in size, often matching some OEMs, they also grew in capability as the OEMs increasingly relied on these top suppliers to co-develop new car models. This capability was either developed in-house or acquired via takeover of an expert firm (e.g. Bosch' takeover of specialists CVT belt maker VDT). However, in many cases it was also outsourced to the network of contract engineering companies that have developed around the world. Some of these new supersuppliers, often described as 'tier 0.5' have the capability to design, engineer and build cars themselves, thus threatening the position of the very car makers who are their customers. Canadian firm Magna is an example and its recent attempts to take over Chrysler fits this pattern well. This is one of the reasons why some car manufacturers have been more reluctant than others to force such

[1] Although the 'tiering' terminology is now used throughout the industry, in its pure form it only ever applied to the Japanese system with its history in the zaibatsu and subsequent keiretsu systems. In the west, supply systems have always been less structured.

changes on their suppliers. As a result we have a somewhat mixed picture, although the overall trend has been to larger, more competent and capable suppliers which are more global in their reach and have greater in-house product development capabilities.

The result of these developments is that much of the technological expertise relevant to carbon reduction is held not by the OEMs, as represented by ACEA, but by their top suppliers, smaller specialist suppliers in pioneering technology areas, and the various engineering consultancies to whom much of this development work is subcontracted by both OEMs and suppliers. For this reason these players need to be considered in this study. It is understandable that these firms are reluctant in the current climate to speak 'on the record' for fear of upsetting generally workable relationships with their OEM clients. However, many people within these sectors have been willing to speak freely 'off the record' and this has informed much of this assessment.

There have also been relevant developments which are in the public domain and which give some indication of what the industry is doing to reduce CO_2 emissions. It is perhaps surprising that with these genuine efforts taking place – to some extent behind the scenes – the industry as a whole has not been more forthcoming and public, as they could claim a certain amount of credit for efforts currently in the pipeline and likely to enter the market well before 2012. We review a few of these projects below.

3.1 Case studies:

3.1.1.Bosch

Lewin (2007) reports that Bosch expects great things from their GDI technology. Gasoline direct injection, pioneered on aircraft in WW2 and on performance cars such as the Mercedes 300SL of the 1950s was launched into the mainstream by Mitsubishi in the late 1990s. The technology promises diesel-like emissions and consumption combined with much lower particulate emissions. Bosch's automotive head Bernd Bohr is quoted as predicting an increase in penetration of this technology from the current 800,000 to 900,000 units in Western Europe to around two million by 2010. This represents around 28% of the market for petrol engines. During 2007, CSM Worldwide estimates that some 10.2% of new petrol vehicles built in Europe will feature the technology, rising to 21% by 2013. This assessment is based on the firm's knowledge of existing and approved production programmes (Lewin 2007).

It has also been announced (Motoring News 13/6/07) that Bosch is developing a diesel hybrid system not related to the PSA effort with the same technology. The order involves a European OEM and is scheduled for introduction for 2010. What is known is Bosch's involvement in developing a stop-start system for the 1.2 litre Fiat petrol engine, to be used in the new 500. Fiat claims the system would cut CO_2 emissions by 20 to 25% in city driving. Fiat's suppliers for the system are listed as Bosch and Magneti Marelli (ANE 2007c).

3.1.2 Delphi

Lewin (2007) also reports that Delphi has received a large order for GDI technology, supplying 500,000 units a year to a US OEM for use on six and eight cylinder engines. This is a new area for Delphi and the supplier expects a sales potential for this technology of $500-$600 million over the next three to five years – i.e. up to 2012. Their competitors, Siemens VDO and Denso expect similar high demand for this CO2 reducing technology. Siemens spokesman Joachim Töpfer expects a penetration of GDI technology around 25% for the period 2009-2010 (Lewin 2007).

3.1.3 Marelli

In an interview for Automotive News Europe (ANE 2007a) Marelli CEO Razelli asserts that his company will benefit from the EU's drive to reduce CO2 emissions*: "…because the fight to reduce emissions pushes one toward smaller, more fuel efficient engines, a traditional strength of Magneti Marelli".*

3.1.4 ZF

Similarly, ZF's CEO Härter explains in the same issue (ANE 2007b) how his firm is set to benefit from tighter CO2 regulation*: "It looks like we will* [benefit]. *We are already involved in hybrids with our strategic partner Continental. We have a lot of products that will help reduce emissions such as our six-speed automatic transmission and, in two years from now[=2009], our eight-speed automatic for passenger cars, We also offer electric power steering systems, which also help reduce fuel consumption".*

3.2 And the OEMs?

More important is what happens when these technologies developed by suppliers end up being used by OEMs in their cars. I review a number of examples – by no means exhaustive – below:

3.2.1 BMW & MINI

OEM BMW has recently shown what can be achieved in terms of CO2 reduction by combining a number of relatively simple and low cost technologies in an existing product range under the Efficient Dynamics label. During 2007, the MINI is enjoying a technology revision consisting of the following elements:

- Brake energy regeneration – combines an intelligent alternator which engages only when required. In addition the system uses energy from the engine on over-run (braking or hill descent) to charge the battery.
- Stop-start – on manual transmission models
- Change point display – indicates to the driver the optimum point at which to change gear

The combination of these technologies allows the MINI Cooper D to return 72.4 mpg with CO_2 emissions of 104g/km – the same as a Toyota Prius. The resulting improvements throughout the MINI range are as set out in Table 3.

Table 3: CO_2 emission improvements MINI range 2007

	One	Cooper D	Cooper	Cooper S
Carbon dioxide from 8/2007	128	104	129	149
Carbon dioxide 11/06-7/07	138	118	139	164
% improvement	-7.2	-11.9	-7.2	-9.1

(source: BMW press release 25/5/07)

This technology push does not come for free. BMW's R&D costs rose by nearly 40% to €835 million in the second quarter of 2007, making its net profit fall 4.3% to €753 million (Ciferri & Franey 2007). This would be of even greater concern to less profitable companies, but will give BMW a competitive advantage, which should stand it in good stead in the long term. By the end of 2007, some 40% of BMW models (including MINI) will have CO_2 emissions below 140g/km. Beyond that, the firm is planning to launch a hybrid version of its forthcoming X6 in 2009 (BMW press release 15/5/07; Holloway 2007). Of course decision makers at BMW also realise that this technology push is essential to keep the company viable in the long term. In 2005, BMWs average CO_2 emissions were 192 g/km according to T&E, so there is some urgency behind these measures.

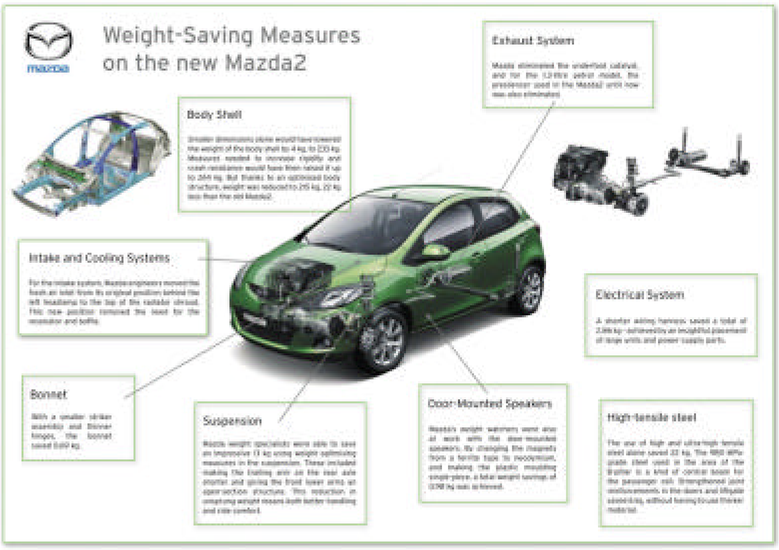
3.2.2 Ferrari

If ever a sign was needed that the car industry is responding to the CO_2 reduction agenda it is the fact that even Ferrari is in on the act. As part of its 60th anniversary celebrations the Italian Fiat-owned sportscar firm showed a new concept car, the Millechili (= 1000 kg), taking the supercar maker right back to its roots in lightweight sportscar design. Compared with the current, and already legendary, Enzo, the new car is 1000mm shorter and 300kg lighter, which means that with a smaller engine (V8 instead of V12, 550hp instead of 800hp) it would nevertheless be faster than the current supercar. CO_2 emissions drop from 400g/km to a mere 250g/km. Ferrari is showing to the world the key to greening the car – weight reduction

3.2.3 Mazda

Mazda is also a leader in thoughtful sportscar design and has taken on board the need to reduce weight, as set out in the illustration below (Fig. 3).

Fig. 3: Mazda diagram



(Source: Mazda)

3.2.4 Mercedes-Benz

BMW's rivals at Mercedes feel they have been left behind a bit by BMW's Efficient Dynamics initiative. Though helped by their share of smaller cars in the A Class and B Class, the company still relies heavily on larger cars, although its large diesel share has helped. Some 38% of the Mercedes new car fleet now emit less than 150 g/km of CO2. It is introducing stop-start technology from late 2007 onwards. Mercedes' CO2 emissions averaged 185 g/km in 2005, according to T&E (Ciferri & Franey 2007).

Fig. 4: Mercedes F700 Concept Car.

(source: Mercedes-Benz)

At the 2007 Frankfurt motor show, Mercedes also showed a concept car which gives an indication of what could be achieved with technologies currently under development (Kable 2007). The F700 is a large luxury saloon, which is nevertheless powered by a small 1.8 litre engine. The engine uses a combination of diesel and Otto (conventional petrol engine) cycles to produce 258bhp, returns only 53mpg. This means CO2 emissions of only 127 g/km for a car of 5.17 metres in length and a weight of around 1700kg (Mercedes-Benz UK press release, 11 September 2007). This performance is achieved by combining the IC engine with a hybrid powertrain, while the engine itself has two-stage turbocharging and optimised IC technology.

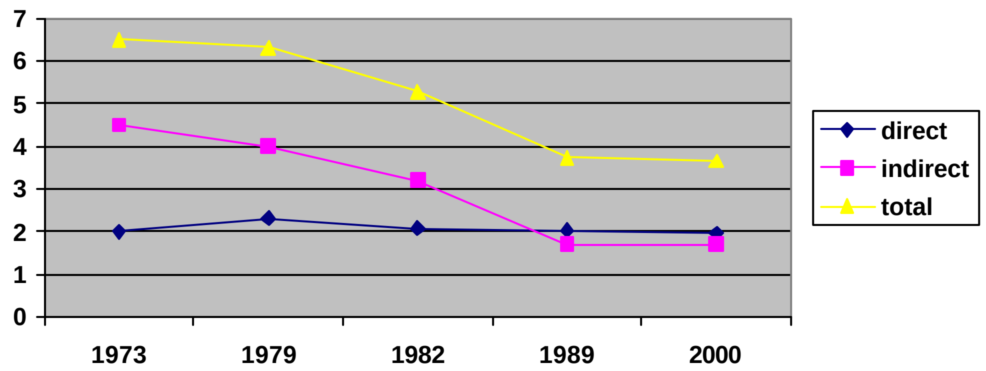
4. Assessing issues raised by ACEA

The industry's first response to the Commissioner's proposals was predictable and initially focussed on the usual issues of loss of jobs, increased costs for consumers, benefits to low cost locations, etc. We will investigate each of these issues in turn.

4.1 Jobs

ACEA has made much of a possible loss of jobs as a result of the proposals. However, it is not clear how the need for additional technology will lead to a reduction in the number of jobs. It seems more likely to lead to an overall increase in the number of jobs, as new technology will require more engineering input, hence more engineers and then more production staff to make the equipment. In truth, the industry is no longer the large employer it once was, certainly in the old EU member states. The loss of white collar jobs in particular has been quite marked in the past twenty years, as IT has replaced many activities these people were engaged in (Figure 5).

Fig. 5: Labour in Western Europe's Motor Industry 1973-2000 (millions)



(source: adapted from Andera, 2007, table 3.3, p58)

4.2 Moves to the East

The suggestion by industry spokespeople that such regulation would benefit Far East producers, particularly low cost (i.e. Chinese) manufacturers is also hard to justify. It has become quite clear over the years that regulation leads to increased engineering input, more engineers, more IPR and that it therefore benefits the established players and established manufacturing locations with many decades of expertise. At present, China or India are unlikely to be able to meet the engineering challenges created by tighter environmental regulation. In fact they come to European design and engineering consultancies and suppliers to solve such problems, although this will change with time. Even Brazil's innovative FlexFuel systems allowing cars to use any mixture of petrol and bioethanol were developed by EU suppliers Bosch and Magneti Marelli, not indigenous Brazilian firms.

4.3 Cost

As for the cost increase argument, this is also worth exploring. It is true that environmental regulation has added cost to the average car over time. Mondt (2000) estimates that by 1997 this additional cost already amounted to some $2000 per car for the US, which was slightly ahead of the EU. Whilst cheap motoring may well be considered by many to be a good thing, we need to explore perhaps what these costs are and where they go. What is a cost to the consumer and the carmaker, is often a benefit to new or established suppliers. For example, the introduction of catalytic converters, though a cost to car makers and car buyers, was of great benefit to suppliers such as Johnson Matthey and Engelhardt, employing their engineers and production staff. There are therefore broader social and economic benefits to the introduction of such technologies, benefits which in many cases can come to the countries introducing the regulation. Thus, from the point of view of the regulator to favour one group (automotive OEMs) over another (automotive suppliers) would need to be justified in a more robust manner than has hitherto been the case. In general we would expect legislators to take a more macro-economic approach whereby the fact that the cost base shifts slightly and possibly temporarily from one group of players to another within the wider EU economy and with overall benefits to the wider EU economy should not stop play. These benefits arise because of the more advanced nature of the technologies needed, the IPR for which tends to reside with firms within the established car producing countries such as many EU member states.

4.4 Weight and Safety

It has also been argued by the industry that despite their best efforts to reduce CO2 emissions, both customers and legislators have demanded more comfort and more safety and that this has inevitably led to more weight and size and hence higher CO2 emissions. This argument has some merit, but not as much as has been suggested. For a start many such technologies have not been demanded by the market, but have been offered to the market in an effort to boost profitability in an industry that struggles to make money on basic cars.

Also, although many such features do add equipment and thus weight in the first instance, over time the weight of such systems is pared down by the supply industry. Bosch, for example has been able to reduce the weight of its ABS system over time from around five kilograms when first introduced in the 1980s to only 1.4 kg on the latest generation 8.1 system.

4.5 Mixed Messages

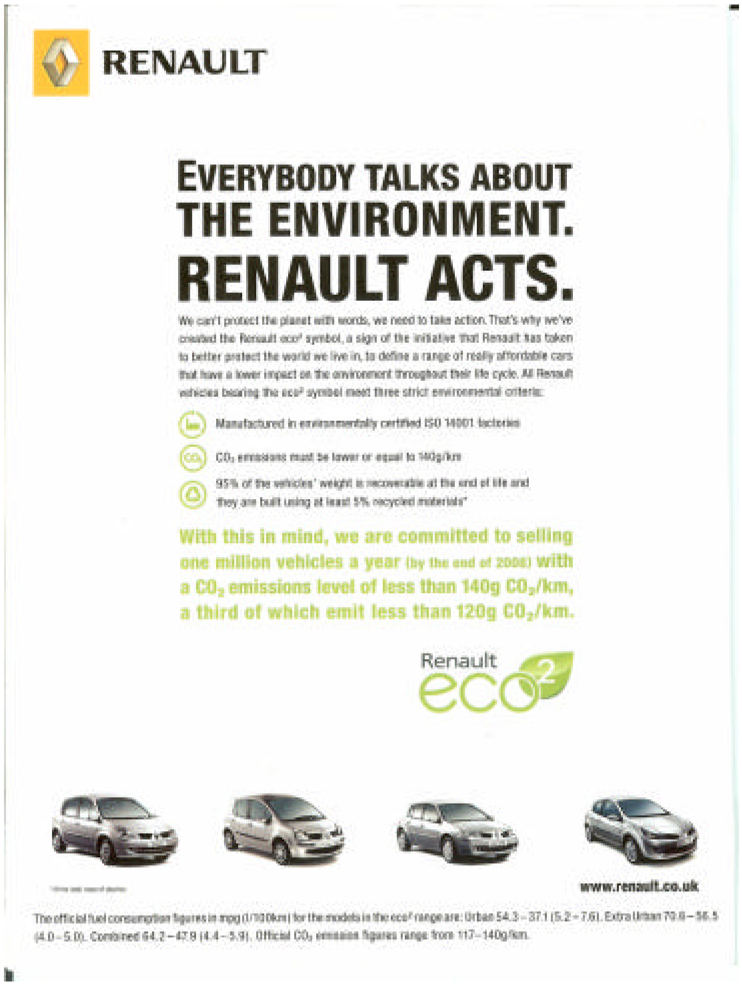
Although ACEA is asking for postponement, some of its members have started to use their CO2 performance in advertising. This is only right and proper in a competitive market, but one cannot but feel that it does help to undermine the ACEA case somewhat.

Figure 6: from Citroen UK advertisement

(Source: The Guardian July 6, 2007, page 9)

Figure 6 shows that Citroen has started to use its CO2 performance in its advertising, highlighting the fact that it offers 22 vehicles with CO2 emissions of 120g/km or less. Renault (Figure 7) goes even further and has introduced a specific Eco range which is defined in part by its CO2 performance of less than 140 g/km – the agreed 2008 limit.

Fig. 7: Renault advertisement



(source: New Scientist, 7 July 2007, back cover)

4.6 Culture Clash

One aspect of this debate that is rarely understood by those participating in it is the fundamental 'culture clash' between different parties to the debate. This problem was perhaps first identified by Herman Daly (1996). Daly is an economist who for some years worked at the World Bank. He identified two quite distinct worldviews among his colleagues on the environmental question. On the one hand there were those who essentially saw the environment as a subset of the economy – environmentalism is a luxury; first we need a decent standard of living. On the other there were those who saw the economy as a subset of the environment – there is no economy without a healthy environment. It is probably safe to assume that the vast majority of people on the environmental NGO side adhere to the latter mindset. This is also true for some MEPs, though by no means all. However, most people on the industry side – and many politicians – probably subscribe to the former view. It is clear that these are incompatible views. Nevertheless, it is important that in order for any dialogue to take place both sides are to some extent conversant with the other's worldview. The arguments in support of one's view on issues such as the CO2 problem need to be put in appropriate terms, therefore. As an example, if you believe the car industry is destroying our very ability to survive on this planet, any arguments based on economics are completely and utterly irrelevant. The same is even true for jobs, as in the second worldview the choice would essentially be between death (even though this may be some time into the future) and employment.

5. Conclusions – how feasible is it for the industry to meet the 130g/km limits for 2012?

The position of ACEA currently appears to be that 130g/km is possible, but needs an additional three years to achieve and possibly should hit the makers of large cars less severely than those of small cars. The argument appears to be that five years (2007-2012) is not sufficient. However, this is somewhat surprising given that the industry has in fact known that a reduction was expected at least since 1998 when the voluntary agreement was negotiated. Also, the EU Commission has consistently, over the past ten years or so, aired its intention to move to 120g/km by 2012. And as we saw earlier, there are clear signs that though not quite on track to meet the agreed limit of 140g/km by 2008, the industry has made obvious and evident efforts to move in the direction of lower CO2 emissions, while it has many more CO2-reducing technologies in the pipeline. We have to assume therefore that these technologies have been under development since at least 1998 to bring about these achievements. This would therefore give the industry 14 years – i.e. two long model generations to comply by the 2012 deadline. However, the opening quote also shows that this was not a new concern even in 1998, as some of us have been flagging this up as a crucial issue for at least 15 years. The quote was published in 1992 and we were not alone even then, so that would give the car makers 20 years from 1992 until 2012 to prepare. In this context it is unclear what would actually be achieved in the additional three years.

The apparent lack of longer term strategic management thinking in some firms is worrying for an industry as important as the car industry and should certainly not be rewarded by the legislator. Also, some firms have shown clear signs of a strategic approach to this agenda. Fiat's rediscovery of its traditional strengths in small cars under Marchionne's leadership is an example – why should such sound strategic management go unrewarded? Similarly the French firms' development of modern diesel technology with Fiat's common rail technology shows clear commitment and understanding of this agenda. Also product decisions such as rethinking the innovative Espace concept as a compact family hatchback – the Renault Scénic – are examples of downsizing that have been rewarded in the market.

The vehicles in table 1 show that compliance is possible. However, the real issue is with heavier and higher performance vehicles. Here technical measures – some expensive – would be needed to make them anywhere near compliant. These are the vehicles that cause concern to ACEA and some of its members. While some lower cost solutions are still possible here, such as downsizing engines combined with GDI and turbocharging, car makers may have to resort to other solutions. In the upper segments, advanced powertrain (e.g. hybrids), alternative fuels, weight reduction through esoteric materials may all need to be deployed in order to reduce their CO2 emissions and thereby bring down the industry average. For this reason, one could see a split in the market developing between on the one hand vehicles very similar to those available today and outlined in the table above at below 130 g/km, at price levels similar to today's, and on the other hand larger vehicles with significantly increased technology and lightweight material – and cost – content, which would be more expensive than their equivalents today. Even a size-discriminating regulatory approach would not remove this pressure, merely buy some more time.

The net result could be a decline in sales of some of these vehicles within EU markets. Alternatively, we could see a downsizing of specialist cars, luxury cars, SUVs and MPVs. Conventional knowledge dictates that the market is not prepared to pay premium prices for small cars, however, the BMW MINI has shown this not necessarily to be the case. Similarly, Audi has been able to sell its compact A3 (though admittedly the more innovative A2 was less successful), Mercedes has been able to sell its A-class and more recently B-class compact MPVs, BMW does well with its 1-Series, while Volvo has high hopes for its compact C30, which in its 1.6 diesel variant only emits 129 g/km. One could in future imagine compact Jaguars (possibly using the same Focus-S40-C30 platform, subject to Jaguar retaining access to Ford technology – or it might leave ACEA after a sell-off) and lightweight Land Rovers (e.g based on their Land-e concept) as well. The skill is in carrying traditional brand values into more compact cars, i.e. in the marketing, not just in the engineering of such cars. These skills on both the marketing and engineering side are more likely to be available in the established industrialised countries and in established car makers and their suppliers, than in new manufacturing locations and emerging markets. At least for the time being; if EU car makers are not willing to pick up this gauntlet themselves, car makers in newly motorising economies will – given enough time – do it for them.

There would also be clear advantages to such developments. Reduced running costs due to greater fuel efficiency are an obvious benefit, but there are others. Large luxury cars tend to lose value quickly compared with small hatchbacks, for example. The reason is that used car buyers tend to be less affluent thus less able to afford the high running costs – particularly fuel costs – of these heavy cars. If luxury cars were smaller and lighter, their appeal to the used market would rise, thus boosting residual values. This would impact on the overall lifecycle costs of luxury cars, making them generally more competitive in economic lifecycle terms. This would benefit customers, but also manufacturers as higher residual values would boost brand image. This is an area deserving of further analysis.

On the sportscar side, lightweighting has always helped enhance both value and performance. The Lotus Elise and Smart Roadster show what is possible in this respect; the latter emitted less than 130g/km of CO2, even in its high performance Brabus version. Weight reduction is therefore likely to lead to more sophisticated, more enjoyable cars, albeit at a financial cost in some cases and for some segments. Although a market split between normally priced smaller and more expensive larger cars is likely to occur, there is no need for car makers to be unduly harmed by the introduction of a 130g/km limit by 2012. The additional three years currently proposed would not significantly change any of this.

One way some of the industry's concerns could be addressed is by means of a gradual roll-out of the 130g/km limit, as has been suggested. This could also be done on the basis of production volume, for example. In the first phase the limit could apply to vehicles produced in volumes of, say, over 200,000/year. In the next phases this limit could be reduced to 100,000 a year. The logic is that the climate system is affected by total volumes of CO2, not industry averages. This means that in reality – and perhaps counterintuitively – the total impact of a volume producer of small cars is greater than that of a low volume producer of supercars. This approach would also give the producers of heavier, but generally lower volume luxury cars – where the technology input needed is greater, though profit margins are also greater – more time to comply. There would be a cut-off at lower volumes, of say 1000/year, or even 5000/year, as the impact of such low volumes specialist producers – not normally members of ACEA in any case – on the climate system is minimal.

5.1 Role of the Customer

Traditionally, the car industry has blamed the customer for the nature of the products it makes: "we only make what the customer wants". It was therefore refreshing a number of years ago during a visit to one car maker when we were told this was nonsense – the customer is not a car designer or automotive engineer we were told. It is significant that that car maker is also in the forefront of CO2 reduction today. Much less is the customer aware of the implications of his or her decisions; ordinary citizens do not have this information, nor do they have time to track down enough information to make such lifecycle assessments on each and every product they buy or use. The notion of primary customer responsibility was well and truly challenged by Stuart Hart's influential article (Hart 1997) where he put the primary responsibility for greening products firmly in the court of the manufacturers:

"Like it or not, the responsibility for ensuring a sustainable world falls largely on the shoulders of the world's enterprises…corporations can and should lead the way, helping to shape public policy and driving change in consumers' behaviour."

Hart encourages industry to help shape public policy not in its own short term interests but in the longer term social interests that are implied in the sustainability agenda. These will ultimately coincide, of course, a concept that has been recognised by at least some firms. If this partial abdication of customer responsibility seem novel, let us remember that as well as buying today's product offerings, 15 million customers also quite happily bought Ford Model Ts, more than 20 million bought VW Beetles and some even bought BMW Isetta and Messerschmitt Kabinenroller bubble cars. The customer can only choose from what he or she is offered by manufacturers and dealers in the market place.

The consumer of automobility does have a role to play. Ultimately we need to recognise that most motorists – aided and abetted by the car industry – are currently engaged in car abuse – an affliction not unlike drug abuse. As with some such activities, moderate use need not be unduly harmful and needs to become the norm if we do not want to lose our right to automobility, which in truth is a privilege. We must abandon the automotive excess that has led to many modern cars being more akin to mobile boudoirs or mobile offices than true driving machines or even basic means of 'getting from A to B'. We probably need a 'campaign for real motoring' and responsible car use involving real driving machines with a realistic, useable performance envelope. The issues we need to address go far beyond CO2 and need to be seen within the broader context of sustainability. The car of tomorrow will therefore also need to address the issues of resource depletion, waste generation, congestion and quality of life in the broadest sense. It is likely that the products that will meet such requirements are more involving, more likeable and more fun to drive than the often over-specified, over-weight devices of today.

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