An Overview of the IEA Transportation Energy Outlook with a detailed impact evaluation of fuel efficiency policies for passenger vehicles

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Synopsis: A Scenario for the OECD transport energy demand from transportation until 2020 is given with a more detailed analysis of the enacted fuel efficiency policies in passenger vehicles in Europe and Japan.

Abstract:
A bottom-up modelling approach based on modally disaggregated energy efficiency and use indicators is applied for projecting and analysing energy demand patterns in transportation. The model covers different OECD regions for a time frame to 2020. Results are presented for a reference case that includes major energy and CO_2 policy measures enacted. As a second step, a set of possible, additional policies is determined, which attempts to reflect the current policy discussions in the different regions. The effect of these policy bundles on energy demand projections is estimated. The results imply that with the additional policies assumed a stabilisation of energy demand and CO_2-emissions after 2010 is in reach. The most prominent measure type currently enacted in the CO_2 context and possibly strengthened in the future is aimed at fuel efficiency improvements in passenger vehicles i.e. the European Voluntary agreement of ACEA on car fuel efficiency and the Japanese 'top-runner' legislation for cars and light trucks. The article gives details of the impact assessment assuming a successful ACEA agreement and a successful toprunner programme in Europe and Japan respectively.

Introduction

The IEA's World Energy Outlook (WEO 2000) (IEA 2000b) analyses the energy demand of the transportation sector in the OECD in more detail than in previous editions with the help of a bottom-up accounting model, distinguishing different passenger modes (cars and light trucks, bus, rail, domestic aviation and international aviation) and freight modes (light and heavy trucks, rail, inland waterways and freight aviation). In each mode, projections are made for activity and fuel intensity based on time series of these indicators (1970 to 1997) with different techniques allowing to simulate the impact of different policy measures. Econometric relationships to GDP, GDP per capita and fuel prices are used for the activity projections. Fuel intensity projections use different elements depending on the mode, ranging from simple trend projections, to fuel price dependance or explicit turnover modelling – or a combination of these. Three main regions are distinguished. OECD North America includes the United States and Canada. OECD Europe consists of two areas modelled separately: Western Europe (the EU-15, plus Switzerland, Norway and Iceland) and Eastern Europe (Poland, Czech Republic, Hungary and Turkey). OECD Pacific includes Australia, New Zealand and Japan, which is modelled separately.

Two cases are defined in the scenario approach of WEO 2000. A "reference scenario" which includes the impact of the most prominent policy measures that were enacted in 1998, notably fuel efficiency measures for cars (see below). And, an "Alternative Policy Case" that assumes further policies to be enacted in the coming years. The choice of these policies is made on the basis of measures that are evoked by different government plans and papers as the next step in the response to further CO_2 increases from transportation and the need for their reduction. Of course, the choice and definition of such measures is somewhat arbitrary. It was made in the spirit of reflecting the currently slow and cautious policy intervention in this area. The first part of the papers reviews briefly the policy measures taken into account and the results for the "reference scenario" and the "alternative policy case" of the WEO 2000. More detail is given in WEO 2000, whereas the focus lies here on the main findings.

Across all the policies analysed, fuel efficiency measures for passenger vehicles appear to be the most important ones in terms of CO_2 reduction. The prolongation and tightening of the measures beyond 2010 would allow to achieve approximately a zero growth in energy demand from passenger vehicles in Western Europe and Japan. All other transport modes will have net increases in energy consumption over 1997 partly due to the lack of measures analysed, partly due to limited impact of the measures. In the second part of the paper, the impact evaluation of the ACEA Voluntary Agreement (Europe) and the toprunner programme (Japan) is therefore be discussed in more detail – as they are included in the reference scenario. With the limited space, this focus allows to document the unpublished, more detailed policy impact assessment in the case of the fuel efficiency measures.

A Brief Overview of the WEO 2000 Transportation Case

In the 1997 OECD transport energy demand of 1082 Mtoe, OECD Europe, Pacific and North America accounted for 31%, 11% and 58% respectively. Table 1 gives an overview of the Reference scenario to 2020 compared to the past trends (1970 to 1997). They result from the macroeconomic assumptions (population, GDP), fuel price assumptions (WEO 2000 assumes for crude oil a flat price until 2010 at 21 US$2000 and a slow, continuous increase afterwards to 28 $US2000 until 2020) and model specifications describing certain modal trends departing from the past. For passenger transport, some saturation effects of car ownership and stagnation in public transport modes and a strong expansion of aviation modes are the most important features. In freight, further expansion of the market shares of road freight and the emergence of air freight as distinct transport mode takes place in all regions. Overall, growth in total passenger km is projected somewhat lower in all regions than in the past, also freight tkm growth slackens markedly, except in Europe. This shows also on the level of energy

Table 1: Reference Scenario Summary

	OECD Europe		**OECD Pacific**		**OECD North**	
Annual growth rate (% per annum)	***1970-1997***	***1997-2020***	***1970-1997***	***1997-2020***	***1970-1997***	***1997-2020***
Population	0.6	0.2	0.8	0.2	1.0	0.7
GDP	2.5	2.1	1.7	1.7	2.6	2.1
Passenger-km	2.3	2.0	1.5	1.5	1.8	1.5
Tonne-km	2.0	2.1	1.0	1.0	2.0	1.6
Passenger energy demand	2.5	1.1	4.0	1.1	1.3	1.4
Freight energy demand	3.1	2.1	2.7	1.4	2.6	1.8
Total energy demand	2.8	1.5	3.5	1.2	1.6	1.6
	1997-2010	***1997-2020****	***1997-2010***	***1997-2020****	***1997-2010***	***1997-2020****
Energy demand increases Mtoe	+90	+141	+25	+39	+165	+268
Relative change (% over 1997)	+27	+42	+20	+32	+27	+45
	1990-2010	***1990-2020***	***1990-2010***	***1990-2020***	***1990-2010***	***1990-2020***
CO_2 Emissions - Increases over 1990 levels						
$MtCO_2$	+381	+523	+139	+180	+695	+990
Relative change (% over 1990)	+44	+61	+48	+62	+44	+63

*see Figure 1 a-c (centre bars) for breakdowns by mode

Box 1: Policies considered

Policies included in the Reference case

North America:
- none

Western Europe:
- Voluntary Agreement by European Car manufacturers Association (ACEA) to reach 140g CO2/km by 2008 as sales weighted average of new cars.

Japan:
- the Top-Runner Regulation prescribing a fuel economy performance for cars and small trucks (average across all classes) by 2010;

Additional policies in the Alternative Policy case

All regions:
- Fuel tax increases equivalent to US$95 per ton of carbon for all fuels.

North America:
- Stricter CAFE standards for cars and light trucks after 2005 (level in 2020: 40 mpg for cars and 28 mpg for trucks);

Western Europe:
- Further increased commitment until 2020 under Voluntary Agreement of Car Manufacturers (100 g CO2/km in 2020);
- Demand-restraint and demand-shift policies: urban car restraint; expansion of urban public transport; high-speed rail expansion; electronic charging of trucks per ton-km.

Japan:
- Sharpened requirements for car and small truck fuel efficiency under the Top-Runner Programme until 2020 (17 km/l in 2020);
- Demand-restraint and demand-shift policies: urban road pricing and other car restraint measures; improvement of public modes; mandatory city logistic schemes for small commercial vans and trucks; expansion of high-speed rail service.

Table 2: Summary of Results for the Combined Policies (Alternative Case)

	Europe		**Pacific**		**N. America**	
	1997-2010	***1997-2020****	***1997-2010***	***1997-2020****	***1997-2010***	***1997-2020****
Energy Demand – increases over 1997						
Mtoe	+74	+102	+17	+23	+117	+169
Relative change	22%	30%	13%	19%	+19%	+27%
	1990-2010	***1990-2020***	***1990-2010***	***1990-2020***	***1990-2010***	***1990-2020***
CO_2 Emissions – increases over 1990						
Mt CO_2	+347	+410	+119	+135	+574	+693
Relative change	+40%	+48%	+41%	+46%	+36%	+44%

Note: *See Figure 1a-c (right bar) for energy increase breakdown by mode.

demand, where demand increases in the future are projected to be significantly lower than in the past – except for North America. The absence of significant fuel economy improvements in passenger vehicles over the projection period – in contrast to the strong impact of CAFÉ standards on passenger vehicles in the past - leads to a relatively strong future fuel demand increase in this region (see Fig 1c first and second bar). Overall, this results in an energy demand increase (virtually all of which is petroleum products) from transportation of about 448 Mtoe across the OECD from 1997 to 2020 (+41%). In the context of the WEO 2000 projections, transport accounts therefore for more than 50% of energy demand increases in end-use in the OECD. The additional demand is broken down by region and transport mode in Figure 1 (left and middle column). In terms of CO_2 and compared to 1990, this implies transport sector emission increases in the order of 60% from 1990 to 2020. Since no significant fuel substitution occurs in contrast to other end-use sectors, transportation CO_2

emission growth is almost exclusively responsible for net CO_2 emission from energy end-use. The additional policies in the Alternative policy case (box 1) consist of additional taxation of fuels according to their carbon content at a level of 95$/tC in 2010 (corresponding to 0,031 Euro/l gasoline and 0,035 Euro/l diesel). This carbon price was determined in an emission trading simulation among Annex B countries with the hypothesis of compliance with the kyot targets (WEO 2000). Secondly, the policy engagements which are under the reference case until 2010, are further tightened after 2010 at a similar pace as before. For North America, a continuous CAFÉ standard tightening is assumed starting in 2005. Finally, certain demand restraint and shift measure bundles are considered in Western Europe and Japan.

Total transport levels in tonne-km and passenger-km are only marginally affected by this policy package. The impact of these measure bundles is given in table 2. The growth of energy demand and CO_2 emissions after 2010 is significantly reduced. Still, CO_2 emissions will have increased until 2020 about 44-48%. The transport modes that contributes most to the reduction over the reference case are passenger vehicles, the other sectors contribute to a much lesser extent. With the additional policy case measures, the remaining fuel demand increases stem to the largest part from road freight and aviation.

Evaluating the potential CO2- impact of the ACEA Voluntary Agreement and the Japanese 'Toprunner' Programme

This part of the paper focuses on different steps of the CO_2-impact evaluation of the ACEA Voluntary agreement in Europe and the top-runner fuel efficiency regulation for cars in Japan. The quantitative evaluation given applies to the currently enacted measures i.e. a strengthening of these measures beyond 2010 as foreseen in the additional policy case is not shown. It is assumed that the test fuel consumption per km (fuel intensity) of new vehicles will reach the respective targets set in Europe and Japan.[1] The ACEA Voluntary Agreement and the Japanese 'top-runner' programme are thus considered as successfully achieved. The assumptions made to convert the policy targets into average fuel intensities of the new vehicle which are needed as model input are briefly discussed. The focus lies on fleet turnover modelling and calibration to actual on-road fuel intensity estimates. And finally it looks at the possible response in vehicle use that could result from a long-term reduction in fuel cost per driving ('rebound'-effect).

[1] For a discussion of whether and how the targets can be achieved see IEA 2000a

Figure 1: Modal Allocation of Growth in Transportation Energy Demand in the Past, the Reference Scenario and the Alternative Policy Case (For legend see 1b)

Figure 1a: **OECD Europe:**

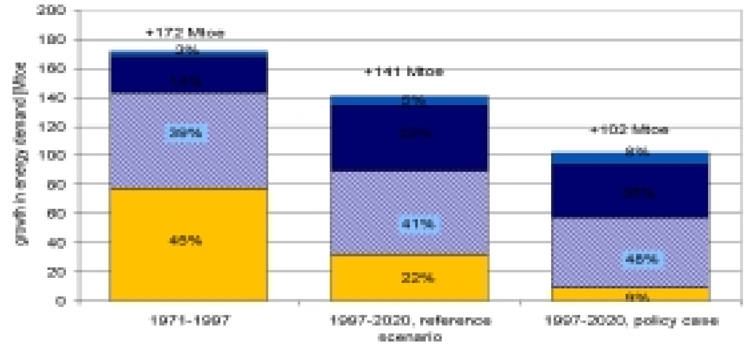


Figure 1b: **OECD Pacific**

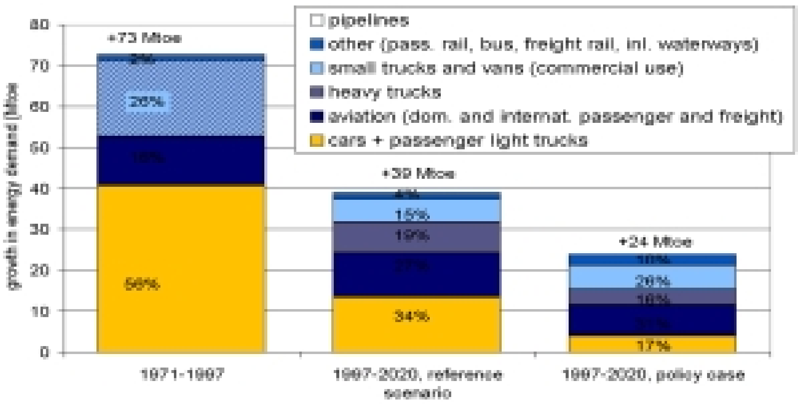


Figure 1c: **OECD North America**

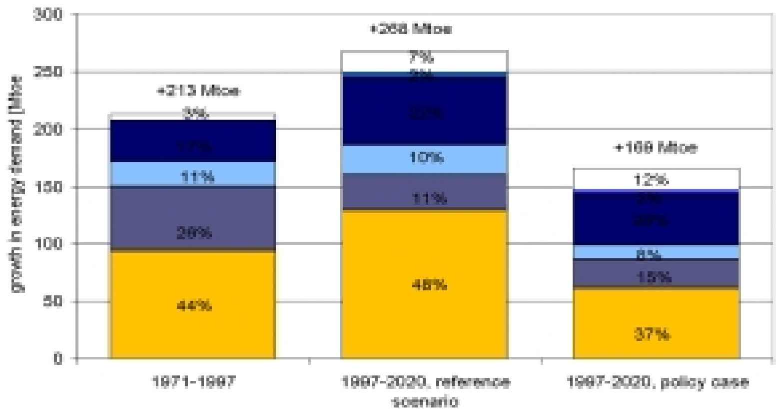
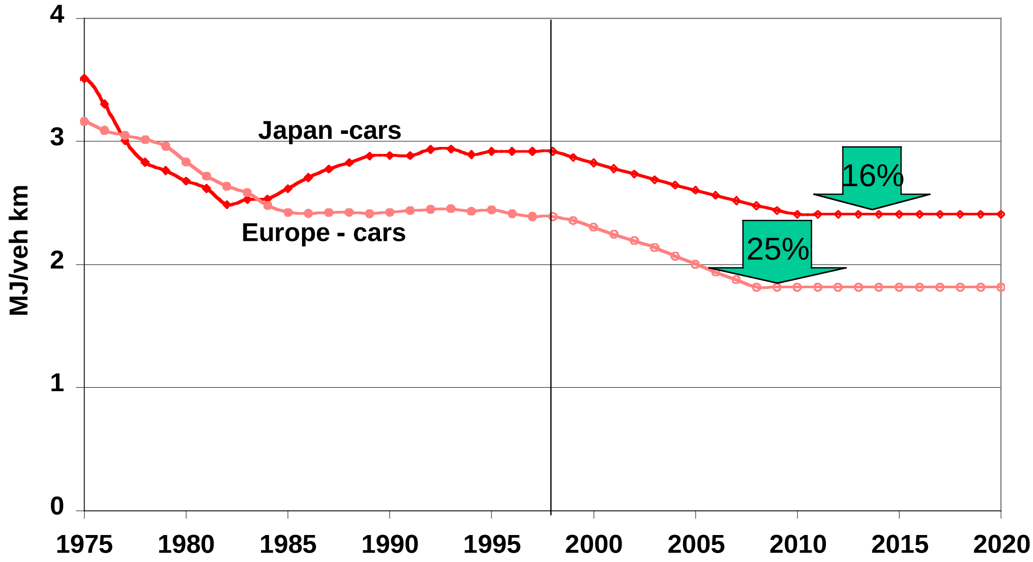


Figure 2: Average sales weighted fuel intensity of new cars in Japan and Western Europe



Note: Japan/Europe data not directly comparable due to different fuel efficiency test cycles.

Basic assumptions

In order to model fleet turnover on a region-wide level[2], input data need to be sufficiently aggregated, otherwise the lack of data impedes the analysis. In each region, sales weighted diesel and gasoline fuel consumption per km ('fuel intensity') of new vehicles are aggregated for each year using the energy contents of the fuel and expressed in MJ/km. Japanese and European data cannot directly be compared because they are derived from different fuel consumption test standards. The relative changes in test fuel intensity assumed are –16% in Japan (1998-2010) and –25% in Europe (1995-2008). Figure 2 shows the past trends and future projection of the aggregate fuel intensity in Europe and Japan.

Table 3 gives some more detail on the fuel intensity targets for gasoline and diesel vehicles in the two regions. The translation of the respective target definition (in g CO_2/km in Europe and km/l for different weight classes in Japan) into an aggregate fuel intensity includes some assumptions. For Europe, notably the diesel share in new car sales is an important assumption. In Japan, the future mix of weight classes is needed for an aggregation. In the Japanese case we follow the evaluation given by Minato 1999, that includes some limited class shift towards heavier vehicles compared to today[3].

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[2] The vintage model used is calibrated to reflect the average fleet turnover in each region and to reflect the fact that new vehicles have a higher annual usage. IEA 2001 (forthcoming) will detail the model features.

[3] Note, that - in Japan - the average diesel vehicle sold is less efficient than the average gasoline vehicles due to the fact that diesel vehicles are mostly represented in the upper weight classes.

Table 3: target values of the ACEA Voluntary Agreement (Europe) and the Top-runner regulation (Japan) and equivalent fuel intensity values

	Europe		Japan	
Target value [1]	140g CO2/km by 2008 (new ECE test cycle)		Target value in km/l differentiated according to diesel and gasoline for 7 different weight classes.	
	l/100km (MJ/km)		*km/l (MJ/km)*	
	1997	*2008*	*1997*	*2010*
gasoline	7.3	5.7	12.3	15.1
diesel	6.2	4.6	10.1	11.6
Ø (gasol. equ.)	7.0 (2.39)	5.4 (1.83)	12.2 (2.97)	14.8 (2.46)
dies. share	22%	36%	7%	7%

[1](see e.g. ECMT 2000 for detailed definitions)

Modelling fleet turnover

The average (test) fuel intensity of the fleet can be calculated from these data from vehicle sales data and vehicle stocks. It shows the typical time lag with which the fleet follows the changes in fuel intensities that occurred between 1975 and 1984 in new vehicles. Since 1985, sales weighted fuel intensity data of average new car did not change any more in Europe, implying that shift to heavier, higher powered cars and pollution control measures compensated for technological progress that otherwise would have resulted in fuel intensity reductions. The modelled fleet average converges to this level during the mid 90s. Comparing it to estimates of on-road fleet fuel intensity (derived from traffic volume estimates and fuel consumption data[4]) reveals a gap of about 10 to 15%. The test/on-road gap calculated by this procedure is probably underestimating the real discrepancy between test bench measurement and real life fuel consumption per km – often estimated around 20% (Schipper/Tax 1995). The change of the on-road fleet fuel intensity thus depends, apart from stock turnover, on how the magnitude of the on-road gap changes in the future. There are different methodological and empirical influences that define this gap as summarised in box 2.

A past increase in the test/on-road gap is often evoked, while quantification is difficult (Sorel 1992m Schipper/Tax 1994, Bosseboeuf 1988 and 1991). For Europe, the comparison of the simulated fleet fuel intensity based on test values and fleet on-road fuel intensity values from statistics allows to calculate an increase in the gap between 1985 and 1997 - equivalent to about 0.15l /100km additional consumption. This value should not be over-interpreted, since the estimation procedure and input data is fraught with uncertainties. Yet, an increasing trend appears plausible (and is observed elsewhere)

Box 2: Factors influencing the test/on-road fuel intensity gap.

- The definition of the driving cycle, from which test fuel intensity is termined;
- the difficulties in estimating on-road fuel intensity (Schipper et al 1993);
- the way that sales weighted data on test fuel consumption are established (often using model specifications which are not representative for the average model sold) and others;
- real driving conditions are different from the test cycle (urban/non-urban mix, average speed, max speed, congestion etc.);
- depending on the driver, the fuel consumption a vehicle varies;
- additional loading and traction needed (other passengers and luggage, ski and bicycle racks, etc.)
- energy consumption by on-board devices (air conditioning); and others

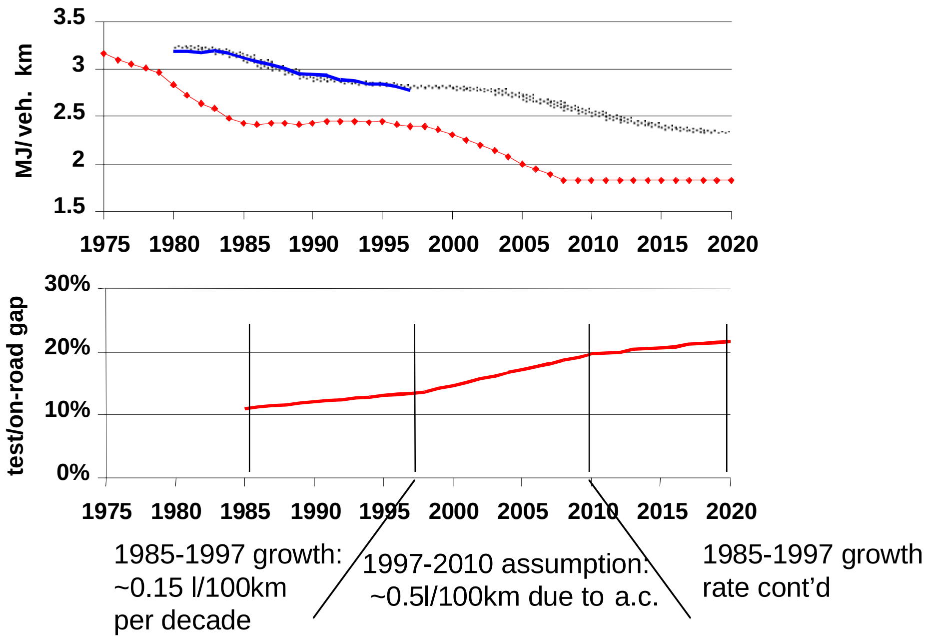
[4] These data have significant caveats with regards to (sometimes circular) estimation techniques quality for many countries (Schipper/Tax 1995). Yet, the trend over time appears to be consistent after 1980.

and the order of magnitude appears rather small compared to what e.g. the ever increasing equipment of cars with additional features or past changes in travel conditions would suggest. Estimating the gap for the Japanese fleet in the same way results in much greater gap growth between 85 and 95 equivalent to about 0.6 l/100km over a decade.

While the role of different factors in the growth of the gap cannot be easily elucidated without significant research, one item has been identified to contribute significantly to a gap between test results on actual real life fuel consumptions: the increased penetration of air conditioning (AC) in cars. Its impact has been estimated in the order of magnitude of 0.5l/100km[5] for the average on-road fuel consumption. While significant increases in AC penetration are observed only since 1995 in Europe, the Japanese new car market was penetrated with this feature during the 80s. It appears therefore reasonable to conclude a gap increase in Europe significantly higher than in the past for the next decade (+0.5 l/100km per decade). After 2010 we assume again a low growth rates similar to the past trend in Europe. For Japan, assume a third of the past gap growth rate, implying that the strong past gap growth was partly triggered by AC penetration. Considering that more electricity consuming devices will be increasingly added to the vehicles in the future (telecommunication devices (ITS) and consumer electronics, refrigerators) these assumptions can be considered conservative.

As a result, future, long-term improvements in the on-road fleet fuel intensity should be estimated lower than the relative changes in new car test performance. The European case is shown in Figure 3.

Figure 3: Projection of new vehicle test fuel intensity and on-road fleet fuel intensity, including gap growth assumption (lower graph)



[5] ADEME 1999 estimates that the penetration of air conditioning in the French car market will increase from 16% in 1995 to 87% in 2005 and 90% in 2010 and beyond. Annual additional fuel consumption is estimated at 7% today, 5% after 2001 and 3% after 2010 due to technical progress. Which amounts to about 0,5l/100km, 0.35l/100km and 0.2 l/100km additional consumption of new cars in 1995, 2001 and 2010 respectively. Of course, these estimates only consider fuel consumption effects and no GHG emissions from leakage of refrigerant.

Rebound in vehicle use

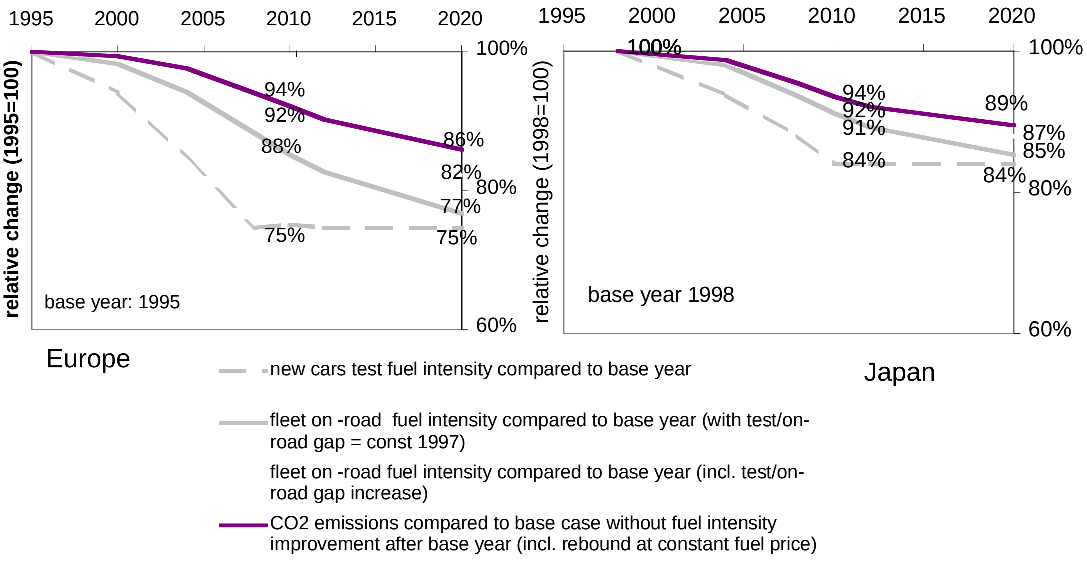
Statistically, the number of vehicle-km travelled is related to the cost of driving, including fuel cost (fuel consumption per km multiplied by the price of the fuel). This effect is particularly visible over longer periods[6]. There is debate about how big this effect is, whether it is symmetric (absolute change in veh-km identical for cost increases and decreases) etc. and a wide range of values given. Conservative estimates place this elasticity at values around -0.1 to –0.3, i.e. a reduction in fuel cost per km of -10% leads to an increase in driving of +1 to +3% ("rebound", Greening et al. 2000, Oum et al. 1990, Dahl 1995)[7]. Such an effect should be expected with improved fuel efficiency of the vehicles as triggered by the ACEA Agreement or the top-runner legislation. Obviously, high(er) fuel prices would counter a reduction of fuel cost per km resulting from fuel intensity improvements. In the European case, two effects could be compounded and increase the 'rebound effect'. A shift to diesel, as assumed over the course of the Voluntary Agreement, leads to lower (volumetric) fuel consumption (l/100km) *and* the use of a fuel, which is significantly cheaper than gasoline in many countries. The resulting fuel cost per km is significantly lower than that of the substituted gasoline car (Schipper et al. 2000) and a possible rebound therefore higher. Fuel intensity improvements compounded with fuel switching towards a cheaper fuel therefore is likely to entail a higher rebound.

While there is debate on the precise magnitude of the rebound effect, it should not be ignored. It is a simple way of accounting for consumer reaction to fuel cost changes in absence of a more detailed understanding. For this reason, different governments have suggested a policy towards increased fuel taxation which is oriented to keep the fuel cost per km at least constant. Such an approach would also have implications for the discrepancy in fuel taxation of diesel and gasoline.

Summary of impact on vehicle consumption and CO_2-emissions

The superposition of the different steps of the analysis before allows giving an estimate of the impact on fuel consumption and CO_2-emissions from reaching the fuel efficiency targets. Such an impact

Figure 5: Summary of Impact assessment



[6] This reflects gradual changes such as longer commuting distances to work that become affordable rather than short-term reaction (e.g. renouncing to do a certain trip), where elasticity is much lower.
[7] The values used are –0.2 for Europe and –0.1 for Japan, being conservatively low.

assessment always depends on what would have happened without the change analysed (no-policy base case, for comparison see CEC 1998, CEC 2000). For convenience and in order to be independent from any base case assumptions, 1995 and 1998 levels of fuel intensity are assumed frozen and taken as a reference for Europe and Japan respectively. The result is shown in Figure 5 for each of the analysis steps :

- Modelling fleet turn-over without taking into account any other influence would result in changes of the fleet fuel intensity similar to changes in new car fuel intensity after complete fleet turnover (>15 years) (lower two lines in figure 5). Such an approach corresponds to the calculation of a sales weighted "test" fuel intensity rating of the whole fleet and is not representative for the actual fuel consumption change. In 2010 our estimate is that fleet turnover would only have resulted in –6% and–12% in Japan and Europe respectivly or about 40% and 50% of the ultimate, theoretical gains. In 2020, gains would have almost converged towards the final level equivalent to new cars.
- Our assumptions on the future increases in the test/on-road fuel intensity gap imply that *on-road fleet fuel intensity* improves less – about 4 percentage points in Europe and _ percentage point in Japan in 2010. The influence in Europe is much stronger due to the assumed AC penetration (third line from the bottom in figure 5)
- In order to calculated CO_2 savings, the vehicle-km travelled need to be taken into account. The change in vkm due to changed fuel cost per km (rebound) assuming constant real fuel prices at 1999 levels is estimated to decrease gains by 2.4 percentage points in 2010 in Europe and 1.5% in Japan (3.8 and 2 percentage points respectively in 2020).[8] The resulting change in fuel consumption (and approximatively CO_2 emissions) is shown by the upper curve in figure 5. CO_2 savings below a base case with constant 1995/1998 fuel intensity levels would thus be 6% and 14% in 2010 and 2020 in Europe. The respective values for Japan are 6% and 11%.

Conclusions

While the precise figures given depend on the assumptions given (gap growth, rebound, diesel shares) the following policy relevant issues should be retained from the methodology applied[9]:

(1) Car-km driven in Europe are likely to increase in 2020 by more than 30% compared to 1995

- current targets achieve less than 20% reduction per km by 2020;
- In order to achieve at least zero energy/emission-growth over 1997 for passenger vehicles, targets would need to be further tightened beyond 2010 as proposed under the additional policy case (Figure 1)[10].
- Relative changes in (test)l fuel efficiency do result in similar relative changes of economy wide fuel consumption and CO2-emissions
- 'supportive' (fiscal) policies might be needed to keep 'fuel cost per km' constant;
- additional fuel consumption (from on-board electricity) is substantial and likely to increase;

[8] Two effects intervene: an elasticity of –0.23 for Europe being higher than in Japan (-0.15) and the fact that dieselisation in Europe increases the rebound due to the shift to a cheaper fuel.

[9] It should be recalled that the achievement of the measure target values is assumed in the beginning, so no policy recommendations to actually achieve the target values are made.

[10] Of course, energy consumption and emissions from transportation as a whole are still projected to rise significantly, even in the addional policy case as shown in table 2.

(2) Fuel efficiency standards (test cycles) do not cover all fuel consumption aspects

- Test cycles to determine fuel efficiency could be reconsidered to include ancillary load.
- More efficient electricity production on board is needed.
- Drivers need to know how to use a car efficiently (training, intelligent econometer etc.)!

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