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Car Fleet Renewal Schemes: Environmental and Safety Impacts France, Germany and the United States

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FOREWORD

This report was prepared by Dutch research and consultancy organisation TNO (Lead author Filipe Fraga) with research and input from the International Transport Forum (ITF). Safety impact analysis and annexes 1-3 were prepared by the Dutch Institute for Road Safety Research, SWOV.

The project was initiated by the International Transport Forum and the FIA Foundation under the aegis of the Global Fuel Economy Initiative (GFEI – www.globalfueleconomy.org) and started by looking at impacts of selected car fleet renewal schemes on CO_2 emissions and traffic safety. The OECD Environment Directorate joined the project and extended the scope to also include NO_x emission impacts and a qualitative assessment of impacts on emissions of particulate matter.

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EXECUTIVE SUMMARY

Background

Fleet renewal schemes are often introduced as a way of stimulating consumer spending and/or assisting car manufacturers and dealers in times of economic duress. During the economic crisis of 2008-2009, many countries implemented such schemes claiming that not only were they important in terms of economic stimulus, but that they also deliver significant CO_2 and pollution reduction benefits. Following on from work undertaken in 1999 by the ECMT, the Global Fuel Economy Initiative[1] sought to revisit the latter claims and evaluate the safety impacts of these schemes. This study does not look at employment or stimulus-related benefits but seeks to assess how fleet renewal might best be designed to maximise CO_2, NO_x, particulate matter and safety outcomes.

This study assesses three qualitatively different schemes: the French Prime à la Casse, the German Umweltprämie and the US Cars program. It assesses their cost-effectiveness in relation to reducing CO_2 and NO_x emissions and improving road safety.

Accelerated vehicle replacement schemes have been implemented in many countries around the world in recent years. These schemes are meant to have a number of different effects. These can include:

- Support for the automobile industry (not just manufacturers, but also the dealers and other related businesses) to decrease the likelihood of mass lay-offs and increase consumer spending;
- Improving air quality;
- Reducing dependence on imported oil;
- Reducing CO_2 emissions;
- Improving road safety;

This report does not address the employment or stimulus-related impacts of fleet renewal schemes which are arguably their primary objective. However, it does assess how well representative schemes have reduced CO_2 and pollutant emissions and improved safety. It also provides guidance on how such schemes introduced again in the future, can best be used to improve CO_2, NO_x, particulate matter and safety outcomes.

The study examines the effectiveness of fleet renewal schemes in reducing CO_2 and NO_x emissions, and improving road safety. It assesses the overall cost-effectiveness (benefit/cost) for society of such schemes.

The study investigates the fleet renewal schemes implemented in the **United States (CARS program), Germany (Umweltprämie)** and in **France (Prime à la Casse)** in 2009. These three schemes were selected because they each display different designs and have collected detailed enough data to undertake disaggregated analysis. The impacts of the schemes are monetised, providing an approximate evaluation of their **societal cost**

1. www.globalfueleconomy.org

effectiveness in reducing CO_2 and NO_x emissions and improving traffic safety (and *excluding* any stimulus-related impact such as job creation/preservation). To be clear, the present study only evaluates how well fleet renewal schemes deliver benefits *beyond* what they may or may not deliver in terms of benefits/disbenefits related to automobile industry support.

The key messages from this study can be summarised as follows:

- **Insights on scheme design:** For the monetized benefits in terms of CO_2, NO_x or safety to exceed the costs associated with vehicle replacement, *scheme design should ensure that larger and older "dirty" vehicles are traded in for lighter, cleaner ones*. If anything else is allowed by the scheme, then CO_2, NO_x and safety benefits are eroded. The schemes should ideally *target older vehicles that are still being driven*. In Europe, for example, this means covering pre-1992 cars that predate Euro standards and Euro-1 cars produced from 1992 to 1996. The US scheme saw positive results from *targeted incentives* based on fuel economy, even if these were imperfectly aligned with fuel consumption or pollutant emissions. The German scheme involved a larger number of vehicles, but the class shift actually reduced the total impacts (on average more lighter and smaller vehicles were traded in for medium-sized vehicles than *vice versa*). The French scheme benefited from imposing a type-approval CO_2 limit for new cars and retiring very old gross-emitters, but that may have led to a very high share of new diesel vehicles, which strongly limits lifetime NO_x benefits. Increased awareness of the monetised societal benefits of avoided NO_x, in addition to CO_2, might have helped to improve the overall cost-effectiveness of the scheme. For example, the analysis in this report suggests that there may have been a case for differentiated incentives for petrol and diesel vehicles due to the monetised NO_x impacts of diesels.
- **Cost-effectiveness[2]:** Figure 1 summarises this study's findings regarding the cost-effectiveness of the fleet renewal schemes analysed from the perspective of CO_2 and NO_x reduction and increased safety. From a *societal perspective*, the US scheme cost nearly 1 billion Euro in destroyed assets (scrapped vehicles). The largest monetised benefit comes from avoided NO_x emissions (~500 M€), followed by avoided casualties (~150 M€), leading to a total quantified *recovery of approximately 80% of the societal cost[3]*. Given that other possible benefits of the scheme were not quantified or given, and accounting for the uncertainty associated with some of the numbers (e.g. the average value of the scrapped cars), *the US scheme may have had benefits in line with its costs.*

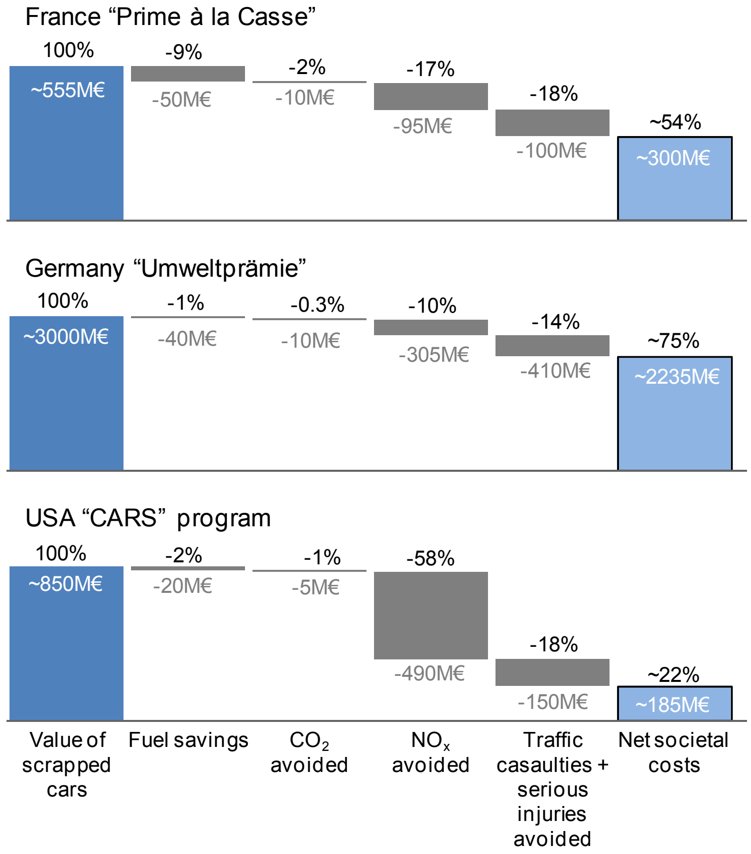
  On a per-vehicle basis, the *German scheme achieved lower CO_2, NO_x and safety impacts throughout.* As a result, *it was less cost-effective in delivering beneficial CO_2, NO_x and safety outcomes with the benefits quantified here representing only around 25% of the estimated costs*.

  In France the *scheme succeeded in targeting the right vehicles for scrapping and resulted in an estimated recovery of around 45%, but a much higher societal value could have been reached through a more ambitious NO_x reduction* (which is the effect with the largest potential for delivering societal benefit).

2. Considering cumulative but undiscounted impacts over the lifetime of the new car. Due to uncertainties involved, all cost-estimates are rounded to the nearest 5M€.

3. Represented here by the value of the scrapped vehicle.

Figure 1. **Cost-effectiveness of the French, German and US Fleet Renewal Schemes**



Notes: See Box 1 for assumptions and values used in cost-effectiveness calculations

- **Impacts on CO_2:** The 3 schemes reduced CO_2 emissions, not only in 2010, but also cumulatively to 2030 (~100, ~200 and ~265 thousand tonnes cumulatively from 2010 to 2025 for the US, Germany and France respectively). However, the monetised value of that impact seems quite small (<5 million Euro in the US, <10 MEuro in Germany and France[4]) and the overall results suggest CO_2 abatement should not be the main rationale for putting a fleet renewal scheme in place. The contributions towards CO_2 reduction vary with the class and age of the scrapped vehicles, but unfortunately the analysis does not clarify which age of vehicles to target – replacing younger vehicles delivers more CO_2 reductions, but at higher societal economic cost.

- **Impacts on NO_x:** The monetised NO_x impact seems to be *1-2 orders of magnitude higher* than the CO_2 impact *(~500 million euro in the US, ~300 MEuro in Germany, ~100 MEuro in France*), and it *does* suggest which vehicles such a scheme ought to target: in general, vehicles older than ~15 years. The French scheme shows that a large share of diesels among replacement vehicles erodes the NO_x impact, and should thus be accounted for.

- **Impacts on traffic safety:** In the long run, the US scheme is estimated to avoid *~2800 serious injuries*, of which *~40 fatalities*. Electronic Stability Control and the effect of general improvements in vehicle safety account for 70% of the impact. In Germany, it is estimated that *~6100 injuries* and *~60 fatalities* will be avoided. Also

4. External cost of ~25 €/tonne in 2010, ~40 €/tonne in 2020 as per IMPACT Handbook (Internalisation Measures and Policies for All external Cost of Transport), for EC DG TREN, 2008.

here, the conclusion seems to be that "older cars should be retired". The French scheme is estimated to have had a much more limited impact: only *~330 serious injuries* avoided, of which *~20 fatalities*.

Figure 2. **Overview and Insights into Fleet Renewal Scheme Design Parameters**

Design parameter	**Choice for desired target impact/objective**			
	CO_2	**NO_x**	**Safety**	**Cost effectiveness**
Age of targeted vehicles	Newer	Older	Older	Older
Class of targeted vehicles	Heavier/ medium	Heavier medium	Unclear	Heavier/ medium
Transaction conditions or at least 'incentives'	New car: lower fuel consumption	New car: lower emission limits	New car: should have 'proven' safety features (e.g. ESC?)	Retired car: should still be in active use

Figure 2 summarises some of this study's main findings regarding the design of fleet renewal schemes so as to maximise societal benefits.

One of the key findings of this work is the necessity to put in place targeted incentives and sufficient differentiation so as to capture not only CO_2 or fuel economy benefits but, more importantly, NO_x and safety benefits since these tend to outweigh the former for the fleet of cars targeted by fleet renewal schemes. Another finding is the need to design schemes that target older vehicles that are still in use – retiring vehicles that travel little provides minimal benefits.

Finally, the figure highlights the complexity of trade-offs that may be involved in developing effective fleet renewal schemes in terms of environmental and safety benefits. Schemes seeking principally to reduce CO_2 emissions or improve fleetwide fuel economy should, perhaps counter intuitively, target more recent vehicles since their higher vehicle kilometre travel outweighs the per-kilometre emissions of older, less-used vehicles. It also underscores the need to control for the type of replacement vehicle chosen in the fleet renewal scheme – lower CO_2-emitting diesels helped the CO_2 profile of the French scheme but also eroded the lifetime benefits of the scheme due to an increase in relatively costly NO_x emissions.

INTRODUCTION

Background

Accelerated vehicle replacement schemes have been implemented in many countries around the world in recent years. These schemes are meant to have a number of different effects. These can include:

- Support for the automobile industry (not just manufacturers, but also dealers and other related businesses) to decrease the likelihood of mass lay-offs and increase consumer spending;
- Improve air quality;
- Reduce dependence on foreign oil;
- Reduce CO_2 emissions;
- Improve road safety;

The real-world impact of these schemes on CO_2 and pollutant emissions from road transport is not really clear *a priori*. Nor is it clear what the impact of these schemes on road safety may be. The Research Centre of the International Transport Forum at the OECD, the OECD Environment Directorate and the FIA Foundation commissioned Dutch research and consultancy organisation TNO to provide additional insight into the effect of early vehicle replacement schemes in order to aid policy-makers intending to design and introduce such schemes in the future.

Aim and approach

This study seeks to provide concrete guidance on the effectiveness and cost-effectiveness of fleet renewal schemes with respect to CO_2 and pollutant emissions reductions and increased safety due to early fleet renewal.

The target audience for this study are national and sub-national policy-makers contemplating implementing early vehicle retirement programmes. The study seeks in particular to provide guidance on the environmental and safety impacts of these schemes in the future. Secondary beneficiaries include staff of these policy-makers and researchers seeking to evaluate the impacts of these schemes.

The study focused on three main topics:

1. The effectiveness of fleet renewal schemes in reducing fuel consumption and total CO_2 emissions;

2. The effectiveness of fleet renewal schemes in reducing total NO_x emissions;

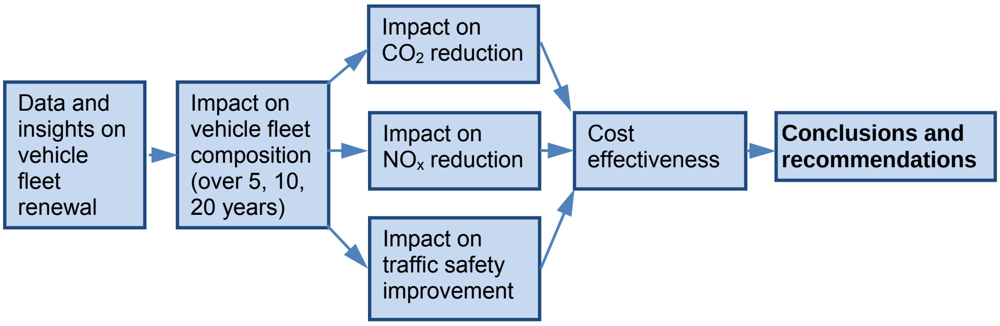
3. An analysis of the traffic safety impacts of the schemes, so that the corresponding reduction in casualties/injuries can be estimated. This is based on the changes in fleet penetration of certain road safety related vehicle features brought about by the schemes.

To that effect, the study investigates the fleet renewal schemes implemented in the United States (CARS program), Germany (Umweltprämie) and in France (Prime à la Casse) in 2009. These three schemes were selected because they each display different designs and have collected detailed enough data to undertake disaggregated analysis. The impacts of the schemes are monetised, providing an approximate evaluation of their societal cost effectiveness in reducing CO_2 and NO_x emissions and improving traffic safety (and *excluding* any stimulus-related impact such as any value attached to job creation/preservation). To be clear, the present study only evaluates how well fleet renewal schemes deliver benefits *beyon*d what they may or may not deliver in terms of benefits/disbenefits related to automobile industry support.

What did we do?

The study consisted of collecting detailed disaggregate data on scheme transactions, projecting impacts on vehicle fleet composition into the future, evaluating CO_2, NO_x and safety impacts and monetising these (Figure 3):

Figure 3. **Task Flow Chart for this Study**



The impact of the different schemes was estimated for each of the 3 analysed vectors (CO_2, NO_x and traffic safety). The associated monetised impacts were compared to the societal costs of early vehicle retirement to assess the overall cost-effectiveness of the fleet renewal schemes.

How did we do it?

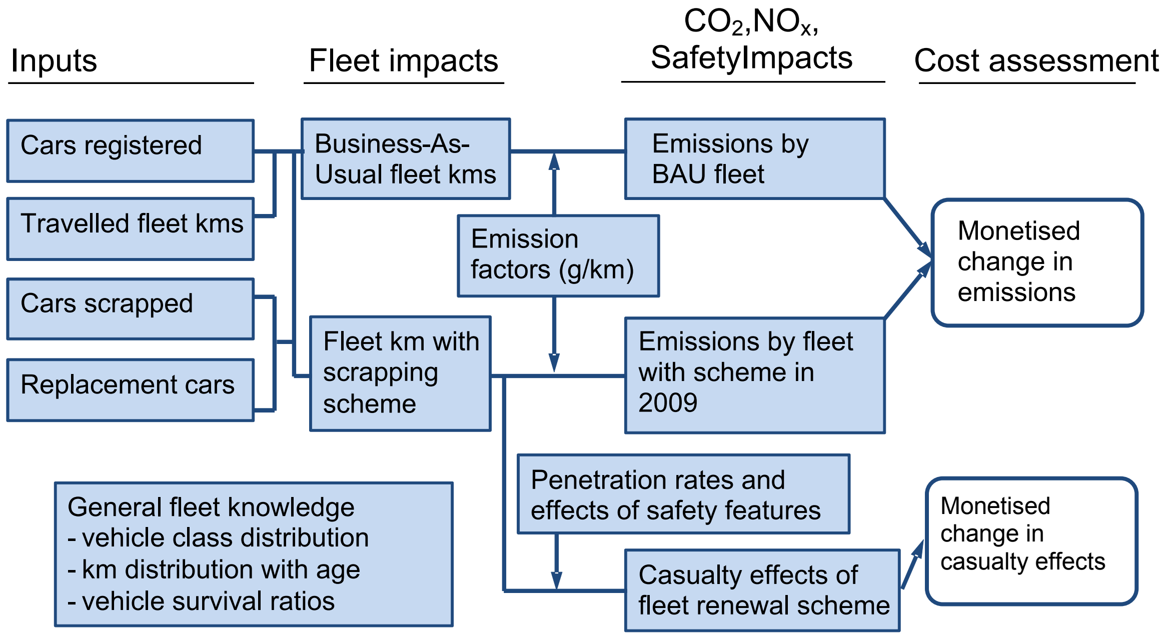
Each of the 6 tasks outlined above entails the collection and calculation of relevant data. Figure 4 describes the general workflow used in this study as described in more detail below.

Task 1: Brief literature review and fleet renewal scheme descriptions

At the start of the study, available literature on the effects of accelerated vehicle replacement schemes was reviewed. Also in task one, a comparative description of the fleet renewal schemes was constructed. That description consists of at least:

- The conditions that apply for *a pair* of vehicles to be eligible for the incentive;
- The size of the incentive and possibly available alternatives, if they exist;
- The total budget available for the scheme;
- The number of vehicles retired under the scheme;
- A description of the vehicles that were retired (divided into vehicle classes);
- The number of new vehicles bought under the scheme;
- A description of the vehicles that were bought (divided into vehicle classes).

Figure 4. **General methodology to assess fleet renewal schemes**



TNO and OECD then collected detailed data from the national governments concerned covering:

- The number of vehicles already retired under the schemes;
- A description of the vehicles that were retired;
- The number of new vehicles bought under the schemes;
- A description of the vehicles that were bought under the schemes;
- The average age composition of the vehicle fleet in the considered countries
- The average age at which vehicles were scrapped in the considered countries before the schemes were in place.

The main source of data for the US CARS program was the National Highway Traffic Safety Administration's (US Department of Transportation) official website for the scheme, available at http://www.cars.gov/carsreport/ and accessed last in March 2010. At that moment, roughly 677 000 correct transactions had been recorded, although the final programme figures report 678 000 transactions[5].

For Germany, the source for transaction information was the "Umweltprämie – Statistik" interim release from the Bundesamt für Wirtschaft und Ausfuhrkontrolle, available at www.bafa.de. The figures used in the analysis were the latest available as of April 2010, which referred to 3/11/2009. For the ensuing calculations, the latest aggregate age figures from the Kraftfahrt-Bundesamt were used (which referred to 5/1/2010 and added up to 1 658 000 transactions). As such, the vehicle class distributions were kept according to the interim publication, but the aggregate results, and their age split, were proportionally expanded to account for the larger confirmed transaction number.

5. Given the inefficiency of repeating the analysis, and the relatively marginal impact that the last roughly 1000 vehicles could have in comparison with the overall ~670 thousand transactions, the former were not included in the calculations described in this report.

The analysis of the French scheme was based on a transaction database supplied by the *Service de l'Observation et des Statistiques* (SOeS) of the Ministry of Ecology, Energy, Sustainable Development and the Sea in July 2010. This dataset was adjusted to account only for the vehicles covered by the 2009 fleet renewal scheme (e.g. by excluding records for vehicles and other motorised equipment that should not have qualified for the scheme and those records for insufficiently identified scrapped or replacement vehicles). A core dataset of 470 000 plausible transactions was used as the basis for calculations and the results were then extrapolated to cover another 80 000 insufficiently identified transactions (but not those transactions that involved non-qualifying vehicles or machinery). Thus the analysis of the French scheme in this report covered 550 000 transactions.

Since the motor vehicle markets and domestic classifications are quite different for the US, Germany and France, a simple class system had to be devised to fit the data for all three countries. This class system was not exhaustively systematic as that would have demanded a model-by-model vehicle data inspection, but coherence was kept through expert knowledge of the models and the fleet classes in each of the countries, and the corresponding emissions. In practice, the "heavier" class contains the largest light duty vehicles, such as campervans, category 3 pick-up trucks in the US, and the largest light commercial vehicles. The "medium" class contains very large passenger cars (*e.g.* Ford Crown Victoria, Mercedes S-Class), the largest (7-seater) mini-vans, category 2 pick-up trucks, SUVs and other commercial vehicles. The "lighter" class contains everything else – mostly regular passenger cars.

Task 2: Impact on fleet composition

We analysed the influence of the three fleet renewal schemes on fleet composition and compared this to a "business as usual" scenario (e.g. without the scheme). We also assessed the impact of the schemes on the fleet composition and vehicle travel distance per age group. The differences between the two scenarios were used to assess the final effect on CO_2 and NO_x emissions and road safety. The calculations also took into account the observed shift in fuel mix (only between petrol and diesel; the influence of other fuels, like LPG, CNG and high-blend biofuels, was not included in this study as their market share is marginal and/or no data is available), since this also influences the total fleet emissions.

The time horizon of the scenarios used in our analysis was 20 years – reference years 2010 (year 0), 2015, 2020, 2025 and 2030. This makes it possible to draw conclusions on the short (<5 years), medium (5-10 years) and long (>10 years) term effects of the schemes.

To calculate the impact on fleet composition, we estimated the distance that would have been travelled by each age-class pair (e.g. 10 year old small cars) in the absence of the fleet renewal scheme. We also estimated the lifetime distances travelled by the new vehicles as well as the remaining fleet in comparison with a business-as-usual scenario. In the short-run (2010) we assumed that that vehicle users will not change their usage patterns and thus the fleet covered the same distance in both scenarios (with and without the fleet renewal scheme in place). However, since the new vehicles have a longer lifetime than the scrapped ones, the new fleet covers more distance in the long-run. The scrapped vehicles would have kept getting older and thus would have travelled progressively less. The new vehicles would display a similar erosion of travel distance with age but would start from much higher annual levels of travel. In short, there is more total "lifetime" in the new fleet versus the scrapped fleet. As a consequence, it could be argued that this approach leads to somewhat conservative estimates for the impacts of the schemes - since the replacement fleet is estimated to travel more than the one it replaces, some of the emissions and safety benefit is eroded. Maximum potential impacts would have been estimated in case it had been assumed that the new vehicles would travel exactly as much as the scrapped ones,

In this study, the official national fleet stock, travelled distance and emission inventory figures were used for each respective case: MOVES for the US, obtained through the Environmental Protection Agency; TREMOVE (which covers EU countries and was commissioned by the EC) for Germany and France, obtained through Transport and Mobility Leuven (TML) in Belgium. Vehicle survival ratios over time, which are necessary to properly describe the fleet as vehicles become older, were also extracted from MOVES and TREMOVE.

Task 3: Impact on Tank to Wheel (TTW) CO_2 emissions

Using the fleet impacts from task 2, we estimated the effect on total fleet CO_2 emissions. This calculation took into account the vehicle distance driven per vehicle age class and the observed shift in fuel mix. Only diesel and petrol fuels were included – the marginal number of vehicles powered by other fuels were associated with characteristics of comparable petrol or diesel vehicles on a per-case basis.

The evaluation focused on Tank-To-Wheel CO_2 emissions – the emissions that are directly caused by usage during the operational life of the vehicle. Indirect (Well-To-Tank) CO_2 emissions were not included in this study, nor did it take into account the CO_2 emissions related to the production and disposal of the vehicles since research has shown that for passenger cars, GHG emissions from vehicle use account for approximately 85% of total life-cycle emissions.

The key emission estimates for this calculation (the “g/km emission factors”) were based on estimates of real-world CO_2 emissions (*i.e.*, not just emissions according to type approval testing). Once again, these were based on the official national inventories (MOVES and TREMOVE) and checked from the perspective of TNO’s knowledge and experience with the Dutch fleet, having been considered appropriate. It should be mentioned that for the emission forecasts (2015-2030) the TREMOVE data reflects the estimated effect of the 130 and 95 g/km European targets, while the US data from MOVES does **not** include the latest car and light truck greenhouse gas emissions standards for model years 2012-and-later, since the resulting data was not made available in time. While it was not possible to assess the impact these standards would have had on the results, it could be argued that more stringent future targets generally tend to reduce travel and hence emissions from older vehicles, possibly leading to slightly lower CO_2 emission reduction than estimated in this study.

Since the vehicle classes, in particular the “lighter” one, still include a somewhat broad spectrum of vehicles types and corresponding emission factors, we adjusted our findings using expert judgement and some sampling in the scrapped and new fleets to balance the emission factors towards the *actual* transactions recorded within each scheme.

Using the above approach, we derive emissions from the concerned fleets in both a business-as-usual scenario and our modelled fleet renewal scheme scenario for the years 2010, 2015, 2020 and 2030. We then estimated the total emission impact over the 2010-2030 period by interpolating and integrating the yearly estimates and by contrasting the results from both scenarios.

Task 4: Impact on TTW NO_x emissions and semi-quantitative PM emissions

We used the same approach as that described in the previous section for estimating the real-world NO_x emission impacts from the schemes. This involved modelling and contrasting the total NO_x emissions for both the business-as-usual fleet and the fleet renewal scheme fleet, accounting for vehicle travel by age class and real-world emission factors derived from MOVES and TREMOVE.

In addition, we performed an orders-of-magnitude assessment for impacts of the fleet renewal schemes on exhaust-related Particle Matter (PM) emissions. This estimate, expressed in relative terms, was based on evaluating the relationships between the following parameters:

- the estimated average emission limits (NO_x and PM) applicable to the scrapped and the replacing fleets;
- the relationship between diesel and petrol vehicles within the scrapped and the replacing fleets;
- the reduction of the polluting component NO_x, as a consequence of fleet renewal scheme application.

Through this approach, the underlying assumption is that the emission reduction potential approximately follows the evolution of emission limits over time. This estimate was thus not corrected for the relationship between emission limits and real world emission behaviour. That correction, had it been performed, might have led to a weaker reduction in real world PM emissions with time and thus to a lower estimated impact.

Task 5: Impact on traffic safety

The work on traffic safety impacts was conducted in co-operation with the Dutch Institute for Road Safety research (SWOV). Our assessment of the impacts of the fleet renewal schemes on traffic / road safety is based on how the schemes affected the penetration of selected road-safety-related vehicle features / characteristics in the French, German and US fleets. The initial list of considered features was:

- Antilock brakes;
- Electronic Stability Control (ESC);
- Airbag driver;
- Airbag passenger;
- Airbag side impact;
- Seatbelt pre-tensioners.

The final list of road-safety-related vehicle features to be included in the study was chosen after expert-opinion-based discussions between TNO, SWOV, NHTSA, the OECD and the FIA Foundation. The main criterion was the potential to significantly impact the safety of the fleet involved (i.e., features which are “effective” and for which the fleet penetration increased significantly in the last 15 years). Those features were deemed to be ESC and Side Airbags (SABs), deployed in the head region and the thorax region.

SWOV and other road safety experts consider that in addition to these specific safety features, a general safety improvement effect resulting from improvements in the construction of vehicles and roads (e.g. structure, visibility, lighting) also contribute to reduce the number of seriously injured car occupants – this effect is usually expressed as a % reduction per year. Our analysis therefore combines both feature-specific safety impacts as well as the general safety effect.

We calculated the impact that fleet renewal schemes had on fleet penetration of the chosen features, accounted for the general safety effect and then estimated the number of traffic-related casualties that were avoided by the schemes under consideration. Only the first order (direct) effects of the road safety related vehicle features was included.[6]The final safety impact was the result of comparing the former analysis for the fleet renewal scenarios and the business as usual scenarios.

Task 6: Societal cost effectiveness in relation to CO_2, NO_x and safety.

Task 6 provides an estimate of the approximate benefit to society generated by the impacts of the fleet renewal schemes in relation to:

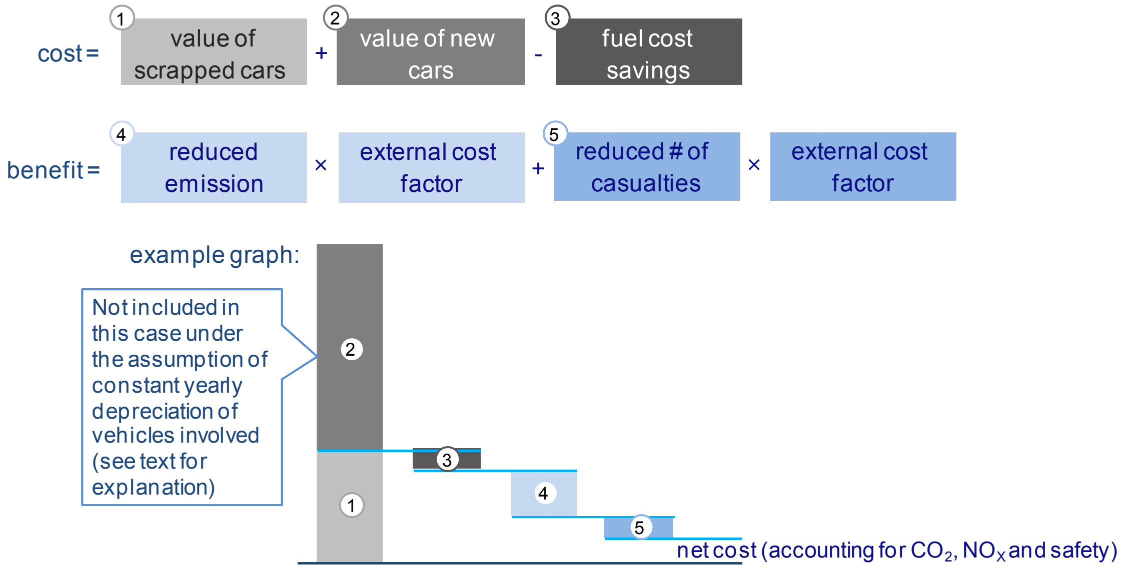
- Total fleet CO_2 emissions;
- Total fleet NO_x emissions;
- Expected traffic safety related casualties.

We use this information to estimate an expected net monetary value to society of the schemes in relation to CO_2, NO_x and safety. External costs were evaluated using guidelines from the handbook published within the IMPACT (Internalisation Measures and Policies for All external Cost of Transport) project of the European Commission's DG TREN. Cost effectiveness of the schemes was assessed by comparing the avoided external costs with the direct societal costs associated with early retirement of vehicles. As noted earlier, our estimates do not include the stimulus or employment impacts of the schemes.

In the calculation of societal costs and benefits, taxes are not taken into account, since these are just a transfer and do not represent a net societal cost (except for the cost of administering tax collection).

6. Drivers may develop a more dangerous driving style when they drive a vehicle fitted with more safety related systems. This effect was not included in this study as it is considered to be a second order effect.

Figure 5. **Cost-effectiveness of fleet renewal schemes from a *societal perspective***



Costs and benefits used in this study are outlined in Figure 5.

The costs of the schemes are calculated as the estimated value of the scrapped asset (the old car) minus the tax-free fuel cost savings generated by the use of the new car in comparison with the old one.

The estimated average value of the scrapped cars is accounted as a pure loss to society because the residual value of the vehicles on secondary markets is largely eliminated. In general the main salvage value of scrapped cars lies in the engine, which - given that these schemes were meant to really remove the vehicles from the road - was not expected to be made available again in the used parts market after scrapping. The rest of the vehicle is usually of very limited value, to the point that in all analysed countries there were reports of salvage yards refusing to join the scheme because they couldn't fully recover their costs through parts sales. This is partly a consequence of current guidelines for recycling, which implies that everything salvagers could not sell would need to be properly disposed of, which is a costly process.

On the other hand, the value of new cars was not included in this study under the assumption of constant yearly depreciation of the vehicles involved. In fact, the value of the new cars is not created by the scheme, and the service they provide to society is not fundamentally different than that of the vehicles they replace - except for the emissions and safety impacts which the study attempts to estimate on the benefits side. Hence, in economic terms the new vehicles represent value to the consumer that is just brought forward in time and depreciates at the same rate as if it had been purchased later in the absence of the scheme.

Benefits are calculated as the quantitative estimate of reduced CO_2 and NO_x emissions multiplied by appropriate external cost factors as well as the quantitative estimate of reduced mortality and morbidity multiplied by appropriate values of statistical life. The latter are different between the 3 countries because this study followed the available published figures of the respective authorities: NHTSA (2002, price level 2000) for the US, BASt (2010, price level 2008) for Germany and Ministère de l'Ecologie (2009, price level 2008) for France. The benefits of reductions in CO_2 and NO_x resort to different external cost factors, effectively leading to 2 separate and additive contributions towards overall society benefit. Total benefits might be marginally underestimated, as we do not include a quantified benefit related to reduced emissions of particulate matter

Boundaries of the study

This study only includes selected effects from the "one shot" fleet renewal schemes active in 2009 and 2010 in the United States, Germany and France. Continuous fleet renewal schemes have a very different influence on vehicle fleet composition and were not evaluated.

We assume that the transactions directly associated with each fleet renewal scheme to be the latter's effect on the fleet. Therefore, we made no attempt to include or remove effects of the schemes in car sales before or after the scheme's duration.

Possible "lowered km price" behavioural rebound effects on total vehicle distance travelled were not included. This means that it was assumed that the fleet covered the same distance in both scenarios (with and without the fleet renewal scheme in place).

Indirect (Well-To-Tank) CO_2 and NO_x emissions were not included in this study, nor did it take into account the CO_2 emissions related to the production and disposal of the vehicles.

With regards to the safety impact of vehicle fleet renewal schemes, only the first order effects of the accelerated market penetration of the chosen safety-related vehicle features were assessed. For example, drivers may develop a more dangerous driving style when they drive a vehicle fitted with more safety related systems. Such effects were not included in this study as they were considered to be second-order effects.

All estimated economic impacts are bounded within one country (hence it was not considered that scrapped cars could be placed on the road again in another country). Further, in line with statements made by the scrapping industry during the schemes, it was also assumed that the recycling value of a scrapped car is much lower than its economic value to its last owners, and hence this amount was not included in the societal cost or benefit.

It could be argued that some of the purchases made under the scheme might have taken place in any case, which would imply that not all the benefits related to the new vehicles would be "credited" to the scheme. On the other hand, some of the related older vehicles might be scrapped and some might not, which would also change the accounting of the societal cost. This issue does not lie within the project's scope and as such was not included.

The rough estimates for the fuel costs assume an oil price of US$ 75 per barrel. Extreme increases in oil price (as seen during 2008) can have a marked effect on the vehicle buying behaviour of consumers. This effect was not considered in this study.

All relevant cost calculations were made in Euros. The exchange rate at 1 October 2009 (0.69 Euro/US$) was used to convert US dollars to Euros.

RESULTS AND DISCUSSION

Task 1: Literature review and fleet renewal scheme descriptions

We analysed relevant literature regarding fleet renewal schemes in general and the schemes of France, Germany and the USA in particular. The main results of our literature survey can be summarised according to CO_2, safety and economic impacts:

CO_2 impact

- In general, temporary schemes essentially simply accelerate the scrapping of vehicles. In this case, the key to success is to preferentially retire high-emitters (which typically offer a disproportionately large contribution to the potential impact) by applying appropriate criteria for eligibility of the vehicles for which fleet renewal subsidies are given.

- A minimum age requirement for scrapping inadvertently excludes some newer but still markedly fuel inefficient vehicles.

Safety impact

- Safety improvements are generally introduced more continuously and gradually over time than emission abatement technology (which occurs in response to discrete steps in emission limits) over vehicles' build years - this goal is less sensitive to scheme design as long as older vehicles are scrapped.

Incentives / Economics

- Maximum cost-effectiveness implies selectively eliminating the worst performing vehicles in the fleet and stimulating replacement by the best performing vehicles.

- Cash-for-replacement schemes may ignore old large emitters if the purchase of a new car is required. Even with the subsidies, many owners of particularly old vehicles which still see relatively elevated levels of use may not be able to purchase new cars. Thus some potential impact of the scheme will not be captured.

- Retiring high emitters is only as useful as the amount of kilometres they would still travel if they had not been scrapped.

From the perspective of the reviewed literature, and therefore before the present analyses were even started, the following suggestions for appropriate scheme design could be drawn out:

- Vehicle eligibility and the monetary size of the incentive could be based on the reduction of fuel consumption resulting from the transaction (e.g. with a sliding scale fuel consumption requirement)

- Purchase of used vehicles could be allowed when that brings a large "fail-safe" reduction in fuel consumption – less affluent consumers cannot always afford new cars. Another alternative would be to offer public transportation passes or other mobility assistance in instances where scrapped vehicles are not replaced by a new one.

- Collecting odometer readings of the retired vehicles would provide some indication of the usefulness of the incentive in scrapping a high-emitting car that is still being used regularly. Performing roadworthiness inspections to check the emission state of cars offered for fleet renewal could be an even more effective criterion, but the cost of that is difficult to justify for these vehicles.

- Schemes could be timed with the introduction of more stringent legislation on vehicle emissions and/or safety, so as to ensure that the new vehicles represent an improvement.

Figure 6 outlines the major features of the fleet renewal schemes selected for this study. The selected schemes each display different levels of incentives and design characteristics. The US scheme used differentiated payments based on fuel economy to incentivise the purchase of more fuel efficient new vehicles and had a maximum age limit which would help ensure that traded vehicles were still in use. Germany allowed some used vehicles but the only requirement on the new car was that it met emission levels that in any case are met by all new cars sold in Germany. France used CO_2 emissions to guide new vehicle purchase but while the 160g per kilometre value might constrain the choice of certain gasoline-driven vehicles, it essentially allows for all but the largest diesel cars to qualify (which, as we discuss later, has an incidence on NO_x emissions and overall cost effectiveness)

Figure 6. **General features of fleet renewal schemes analysed in the study**

Scheme (stated goal)	**Maximum incentive**	**Vehicle age require-ment**	**Emission require-ment**	**Alternatives to new vehicle**	**Cost to government (million €)**
US CARS (fuel econ.)	$4500 (~3100 €)	<25 years	> Fuel efficiency[1]		~2000
German Umweltprämie (pollutant)	2500 €	>9 years	> Euro 4	Used <1 y.o.	~5000
French Prime à la Casse (CO_2)	1000 €[2]	>10 years	New car emits < 160 g CO_2/km		~550-600

[1]A relative fuel efficiency requirement was in place ($3500 for 4<ΔMPG<10, $4500 for ΔMPG>10)

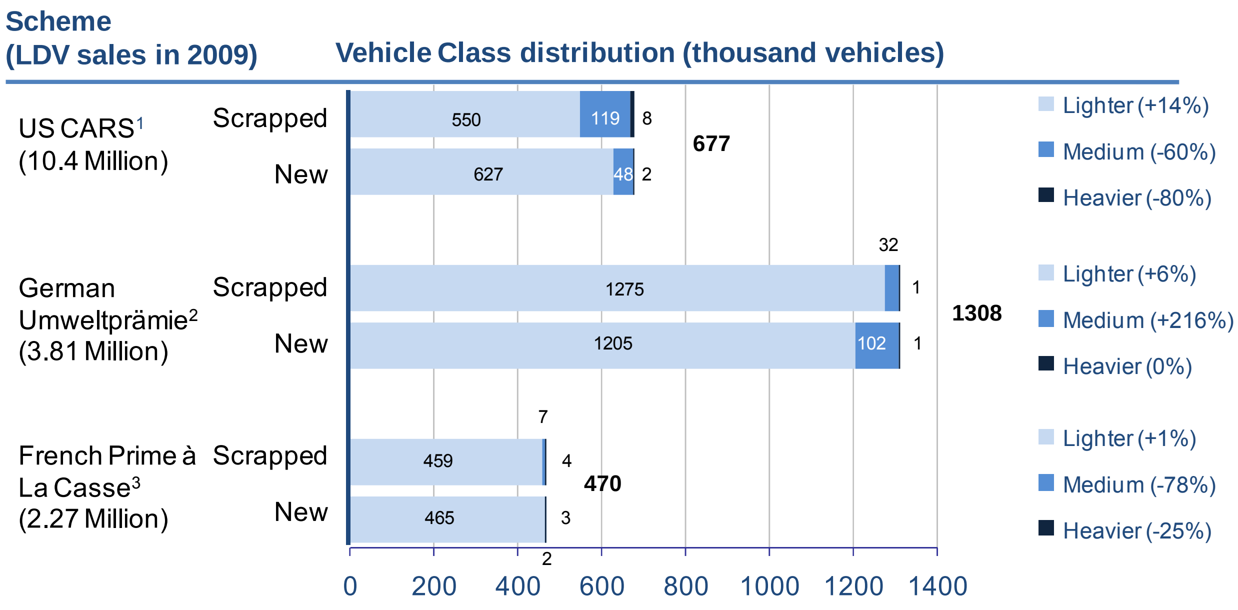
[2]Dealers were invited to contribute further to the incentive

Task 2: Impact on fleet composition

According to our estimates, the CARS program (US) impacted 0.3% of light duty vehicles on the road and roughly 0.2% of the corresponding vehicle-kms-travelled (VKTs). In Germany, the figures were 3.6% and 2.0% respectively - more vehicles were involved, and the total vehicle fleet at the outset was smaller. In France, these figures were 1.5% and 0.75% respectively, so the ratio between the volume of the scheme and the existing fleet lies somewhere between that of the US and Germany.

Figure 7 provides an overview of the vehicle transactions (including class shifts) resulting from the fleet renewal schemes. In the US and French schemes, consumers generally traded larger old cars for smaller new cars (or small old cars for new small cars as in France). In Germany, however, there was a significant shift from lighter to heavier cars classes.

Figure 7. **Vehicle class shift effects of studied fleet renewal schemes**



LDV=Light-duty vehicle

[1] Figures available as of March 2010. Final program figures report 678 thousand vehicles, but the calculations used here were not corrected to account for this since the difference was minimal.

[2] Latest available class figures as of April 2010 - refers to 3/11/2009. For the ensuing calculations the latest aggregate figures were used (refers to 5/1/2010): 1658 thousand vehicles. Maximum budgeted capacity: 2 million vehicles.

[3] Transactions with usable data. For the ensuing calculations estimated global figures were used: circa 550 thousand vehicles

In the US, the CARS program brought about a 35% improvement in weighted fuel consumption for the new fleet in comparison with the scrapped vehicles. This is not translated directly to a similar reduction in emissions, but it does provide an indication regarding the effectiveness of the scheme design. In fact, CARS saw positive results from targeted incentives, even if these were imperfectly aligned with the most effective scheme objectives (the criteria to award the transactions were based on fuel economy rather than fuel consumption or, more importantly, pollutant emissions like NO_x as discussed further on). On the other hand, the Umweltprämie in Germany involved a larger number of vehicles, but the class shift actually reduced the total emission impacts (on average, more lighter sized vehicles were traded in for medium sized ones, with this class increasing more than 200% in terms of vehicle numbers). The purchase subsidy was not associated with fuel consumption, and the only requirement was that the pollutant emission class of the new vehicles should be at least Euro 4 – which in principle should be the case for any new light duty vehicle sold from 2005 onwards. In France, the new vehicles were required to have a type-approval CO_2 emission value of 160 g per km or less, which may have contributed to the observed (slight) class shift from medium sized vehicles towards lighter vehicles.

It should be noted that a key parameter to consider when assessing the impacts of fleet renewal schemes is the assumed distance travelled by vehicles involved in the transactions. Hence shifts between classes should not be evaluated on the basis of vehicles, but should rather be weighted with the distances travelled by age and class of the replaced vehicles. Table 1 illustrates this relationship by displaying VKT by vehicle class for the three schemes.

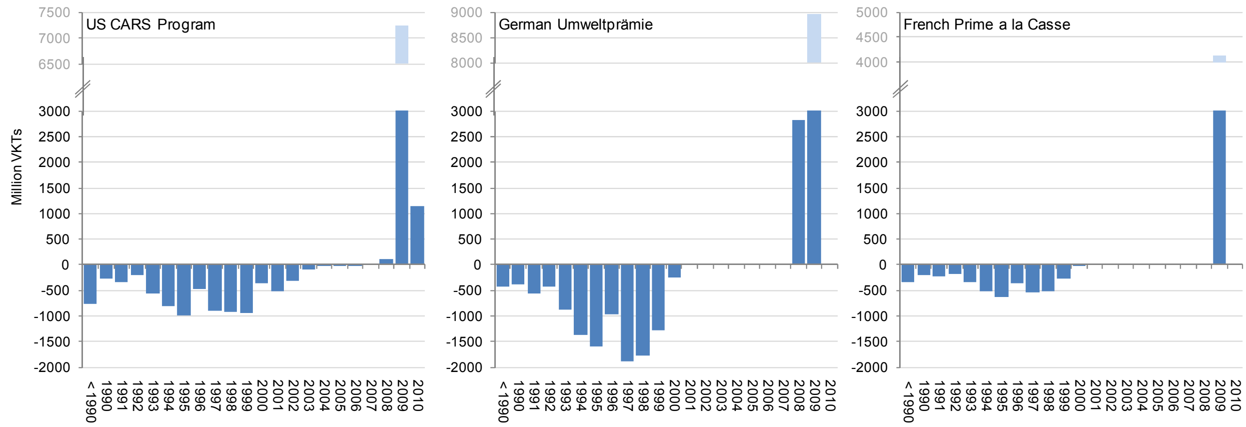
Table 1. **Vehicle KilometresTravelled Impact (millions) by Vehicle Class**

	2010	2020	2030
US Cars			
Light	1157	3	-3
Medium	-1081	31	3
Heavy	-76	0	0
German Umweltprämie			
Light	-636	-55	0
Medium	634	55	0
Heavy	2	0	0
French Prime à la Casse			
Light	68	4	0
Medium	-65	-5	0
Heavy	-3	0	0

In the US, where a clear trend towards lighter (typically more fuel-efficient) vehicles can be observed, the vehicle-kms-travelled (VKTs) driven by lighter-sized vehicles increased at the expense of medium- and heavier-sized. A shift towards lighter vehicles is also visible in France, although the number of transactions is much lower than the other 2 schemes so the absolute impacts are smaller. In Germany, a weaker (but visible) trend towards medium-sized cars (including SUVs), which are typically less fuel-efficient, led to a corresponding VKT shift away from light vehicles to medium-sized vehicles.

Looking at the transactions from the perspective of vehicle age (Figure 8), a similar profile emerges from all schemes, although the larger scale of the Umweltprämie is clear. In this figure we only show the initial impact of the scheme for clarity. The data on VKT per vehicle build year shows a sharply declining effect over time – in other words, as time goes on, each of the vehicles involved in the scheme (scrapped and new) is driven progressively less, and hence their contribution to fleet mileage tends to zero. A noteworthy difference is the substantial distance still covered by the oldest (>20 years old) vehicles which were retired in the US, while that is not the case in Germany and practically also not in France, although in principle there was no age limit to the scrapped vehicles. This <1990 "spike" in the US is due to the substantial number of vehicles of this age that were retired, coupled with the higher assumed annual mileage for these older vehicles in comparison with Europe. On the other hand, the aggregate distances driven by the newer vehicles (<10 years old), which were allowed in the US but not in Europe, do not show a substantial contribution to the total VKT impact of the scheme.

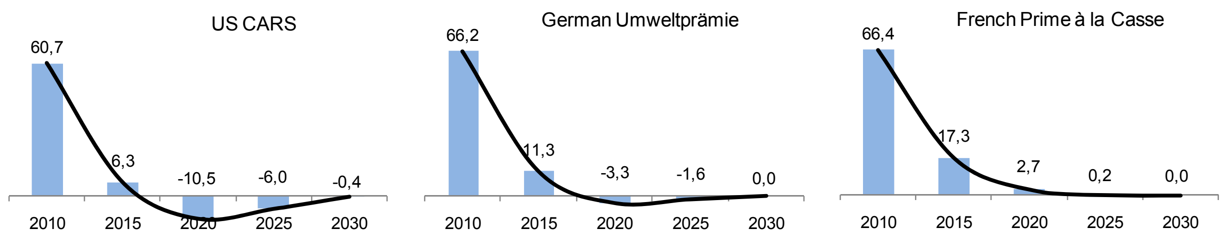
Figure 8. **Vehicle Kilometres Travelled (VKT) impact per vehicle build year in 2010 compared to BAU (Million VKTs)**



Task 3: Impact on Tank to Wheel (TTW) CO_2 emissions

The CARS program achieved a 0.005% reduction of total CO_2 emissions from light-duty vehicles in 2010. The figures for the German and French schemes are an order of magnitude higher, 0.05% and 0.06% (Figure 9). In all cases, CO_2 reduction seems to have occurred. However, in general the benefits last little more than 5 years after the introduction of the scheme.

Figure 9. **CO_2 avoided from studied fleet renewal schemes (KTonnes, in-use phase only)**



0.005% reduction of CO_2 from light duty vehicle travel in 2010, **~100 kTonnes** of avoided CO_2 accumulated from 2010 to 2030

0.05% reduction of CO_2 from light duty vehicle travel in 2010, **~200 kTonnes** of avoided CO_2 accumulated from 2010 to 2030

0.06% reduction of CO_2 from light duty vehicle travel in 2010, **~265 kTonnes** of avoided CO_2 accumulated from 2010 to 2030

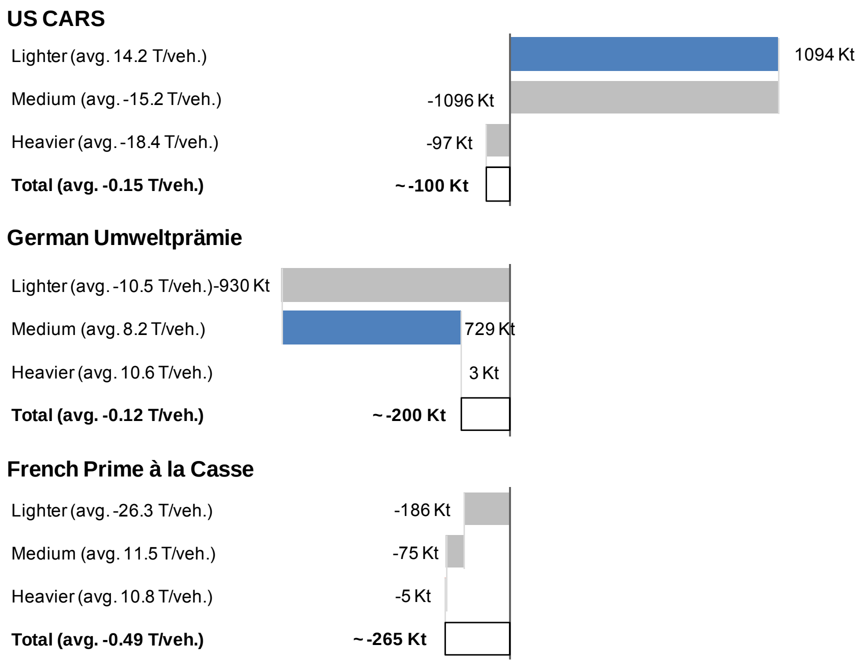
Note: the "rebound effect" (increased CO2 emissions after 2015) results from this being an analysis in comparison with a BAU scenario. Although the new vehicles are assumed to cover the same yearly distances as the ones they replace, the fleet turnover introduced by the schemes increases the total distance travelled by the combination of the 2 vehicles – there is more total "lifetime" than with a single vehicle.

The accumulated impact of the German and French schemes is far more significant than the US case, both in absolute terms and in comparison with the total emissions from light-duty personal transport. In the case of Germany this was driven by the higher number of vehicles involved, while in France the effect stems from a very large share of diesel vehicles in the new fleet (~65%), with markedly lower fuel consumption than the retired fleet – these contribute to reduced CO_2 emissions up to 2025 and generate a large accumulated effect.

It should be noted that the "rebound effect" (increased CO_2 emissions after 2015) results from this being an analysis in comparison with a BAU scenario. Although the new vehicles are initially (in 2010) assumed to cover the same yearly distances as the ones they replace, the fleet turnover introduced by the schemes increases the total distance travelled by the combination of the 2 vehicles – since the scrapped vehicles would keep getting older and thus travel progressively less, and the new vehicles carry on being driven with a usage decrease in line with their age (rather than the older ones), there is more total "lifetime" in the new fleet versus the scrapped one. In all cases, the CO_2 effects phase out completely between 2025 and 2030 as might be expected due to fleet renewal.

When analysing scheme CO_2 impacts by vehicle class, interesting insights emerge (Figure 10). In the US, the reduction in total CO_2 emissions from medium-sized vehicles is almost cancelled out by an increase in total CO_2 emissions from light-sized vehicles. Although that is unavoidable when a class shift towards smaller vehicles is successful, it suggests that an even larger global impact could have been achieved if, hypothetically speaking, some of the medium-sized vehicles had been traded for public transportation passes in the areas where that makes sense (large urban centres). The heavier vehicles, although of limited practical relevance because of their small numbers, were traded in the right direction.

Figure 10**. Cumulative and average per-vehicle CO_2 impact 2010 to 2030 by vehicle class***



* negative implies CO_2 avoided

In Germany, the class shift was in the opposite direction – medium sized vehicles saw an increase in their total CO_2 emissions, as a consequence of their numbers increasing to the detriment of lighter vehicles. The latter saw their emissions decrease because of this shift and partly because their share of the market decreased. Had this light-to-medium shift not occurred, the German scheme would have resulted in a greater CO_2 reduction.

In France, all vehicle classes contribute to avoiding CO_2 emissions. This is due to a class shift where heavier and medium-sized vehicles were replaced with lighter ones in line with the requirement that new vehicles emit less than 160g CO_2 per kilometre. The new light vehicles include a very large share of modern diesel cars with very low fuel consumption.

The lifetime average per vehicle CO_2 emissions relate to the net number of vehicles in each class – i.e., this "per vehicle" average represents the emissions divided by the number of vehicles added to the fleet (in this class) minus the ones which were scrapped (in this class).

The average emissions avoided per vehicle across all size classes was approximately 0.15 Tonnes, 0.12 Tonnes and 0.49 Tonnes, respectively for the US, German and French schemes. In the US we note that scrapping heavier and medium sized vehicles was quite effective. In Germany, however, we observe that the scheme did not provide strong incentives for CO_2 reduction as average emissions per vehicle increased for the heavier and medium-sized vehicles by more than the amount they were reduced for lighter vehicles. This also implies that replacing an old medium size vehicle with a new medium size vehicle does not yield an average net benefit in terms of reduced CO_2 emissions. France succeeded in designing its scheme to deliver CO_2 reductions and lighter vehicle transactions in the *Prime à la Casse* show an average CO_2 reduction for all classes of 0.49 Tonnes -- 3 to 4 times more than the other 2 countries.

For clarity, the "average per car" figures in Figure 10 represent the average avoided emissions, within each class, per scheme transaction in Tonnes per vehicle. The effect of the travelled distances is thus included, *i.e.* these figures estimate the difference between the emissions that the scrapped cars would have caused and the emissions that the new cars are expected to cause taking into account their (age-dependent) usage profile.

As such, the results do not imply that newer vehicles perform worse than older ones, but they do assume that the additional fleet turnover introduced by the fleet renewal schemes implies more kilometres driven over the course of full vehicle lifetimes. Therefore, since the emission gains from individual vehicle replacement are not that large (except for France, at least for CO_2), most of the strong CO_2 avoidance potential during the period of the scheme is eroded in the long run. For that reason, the analysis focused on the positive (or negative) effect of the observed class shifts rather than "in-class" efficiency improvements.

The next Figures 11 through 13 display the estimated gross CO_2 reduction contributions of different build year cohorts of scrapped vehicles compared to business as usual without the fleet renewal schemes. The vertical axis expresses the gross CO_2 reduction contribution of each build year cohort in relation to the total accumulated CO_2 reduction of the respective fleet renewal schemes. Thus most years show a substantial CO_2 reduction due to the retirement of scrapped vehicles. This is counterbalanced by the increased CO_2 emissions (shown as a negative contribution in the figures) of the new vehicles for build years 2009 and 2010.

As mentioned in the methodology section, the underlying emission factors were sourced from MOVES, obtained through the Environmental Protection Agency (EPA) of the US, and TREMOVE from Transport and Mobility Leuven (Belgium).

Figure 11. **Cumulative CO_2 impact compared to BAU by vehicle build year cohort (Kt CO_2) -- US CARS Program**

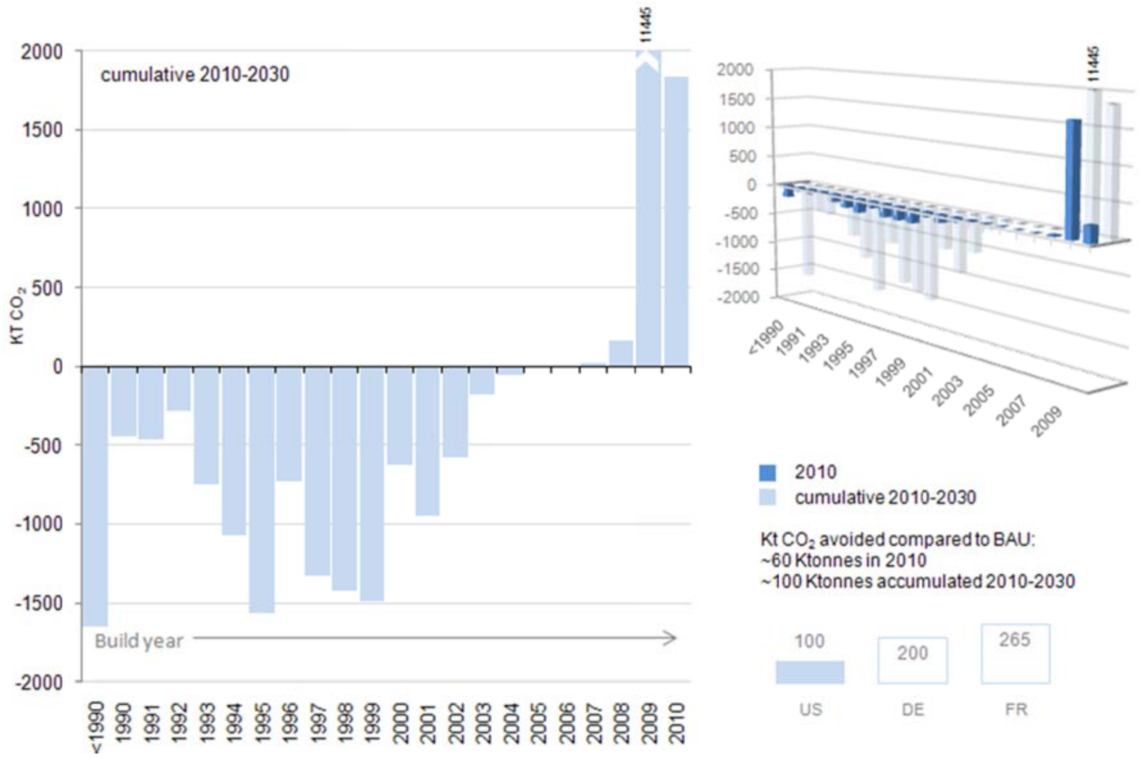


Figure 12. **Cumulative CO_2 impact compared to BAU by vehicle build year cohort (Kt CO_2) –German Umweltprämie**

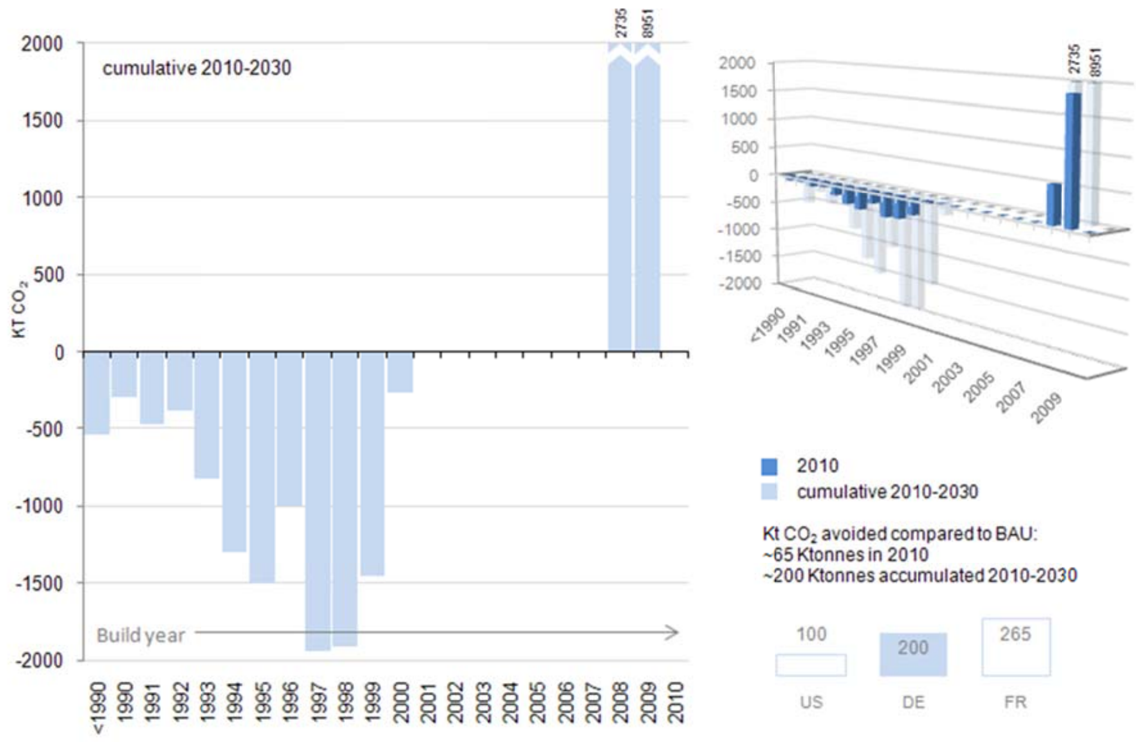
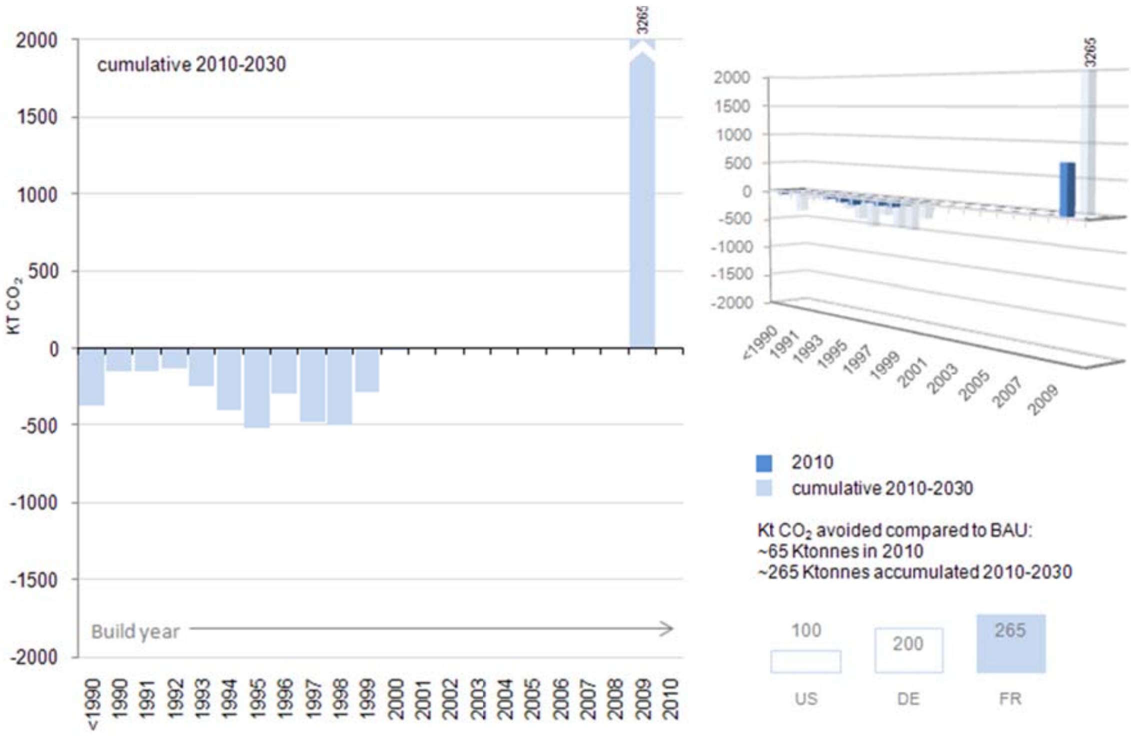


Figure 13. **Cumulative CO_2 impact compared to BAU by vehicle build year cohort (Kt CO_2) –French Prime à la Casse**



For all countries, the distribution of the CO_2 impact across vehicle build year cohorts suggests a roughly even contribution from build years 1994 to 1999 (11 to 16 year old vehicles). These build year cohorts figure heavily in overall scrapped vehicles across schemes (~55% in the US and France, ~70% in Germany). This indicates that the impact on CO_2 emissions is achieved more through a reduction in vehicle numbers more than via reductions in emissions per vehicle - in fact, the more recent scrapped vehicles are characterised by substantial CO_2 reduction impacts (see per-vehicle graphs in figures 14-16). In France, the overall distribution of CO_2 reduction impacts is flatter than in either Germany or the US since the scrapped vehicles had generally lower fuel consumption as did the new vehicles (dominated by small diesels).

Figures 14 through 16 display average tonnes of CO_2 avoided by vehicle by build year cohort compared to the “business as usual” scenarios without the fleet renewal schemes. Figure 14 shows that on an individual basis, retired vehicles from build year cohorts 2001 to 2006 (4 to 9 years old) had the highest per vehicle CO_2 reduction impact in the US. This is because of the higher vehicle kilometres remaining in their lifetimes – older vehicles would be driven less before they would be retired anyway, therefore limiting the total impact of their replacement. This effect is stronger than the trend towards more fuel efficient replacement vehicles[7].

7. A noticeable feature of these figures is the “dips” in years 1992, 1996, 2000 and 2005 which result from a change in the underlying emission factors for those years as applied in both the MOVES and TREMOVE models.

Figure 14. **Average per vehicle CO_2 impact (tonnes per vehicle) by build year cohort compared to BAU– US CARS Program**

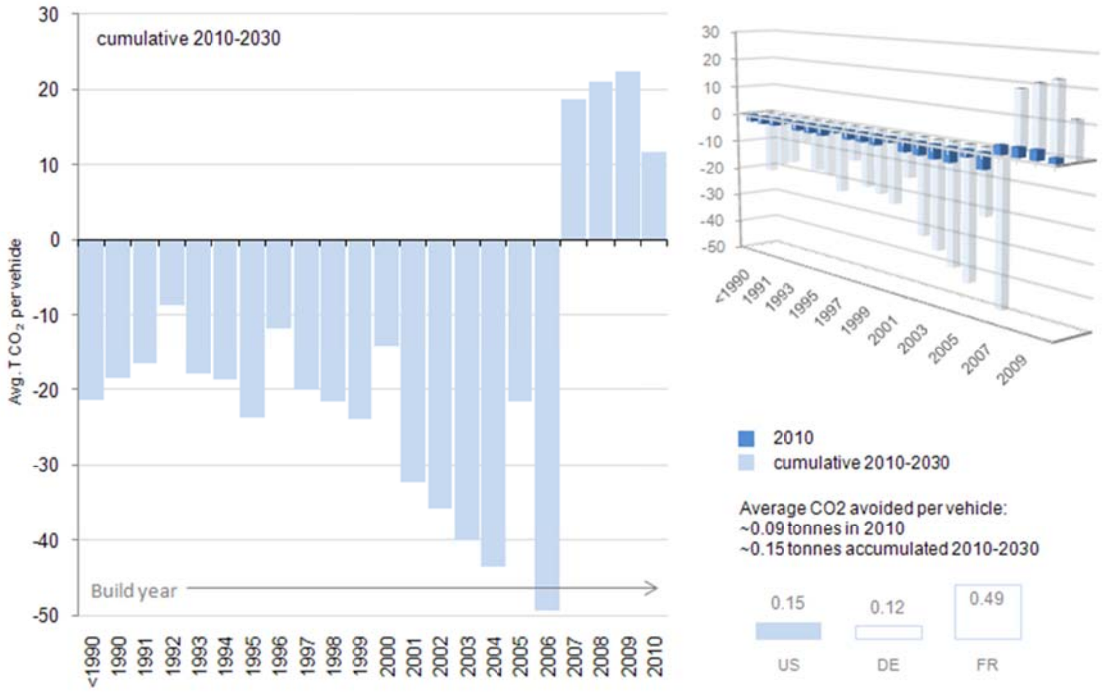


Figure 15. **Average per vehicle CO_2 impact (tonnes per vehicle) by build year cohort compared to BAU – German Umweltprämie**

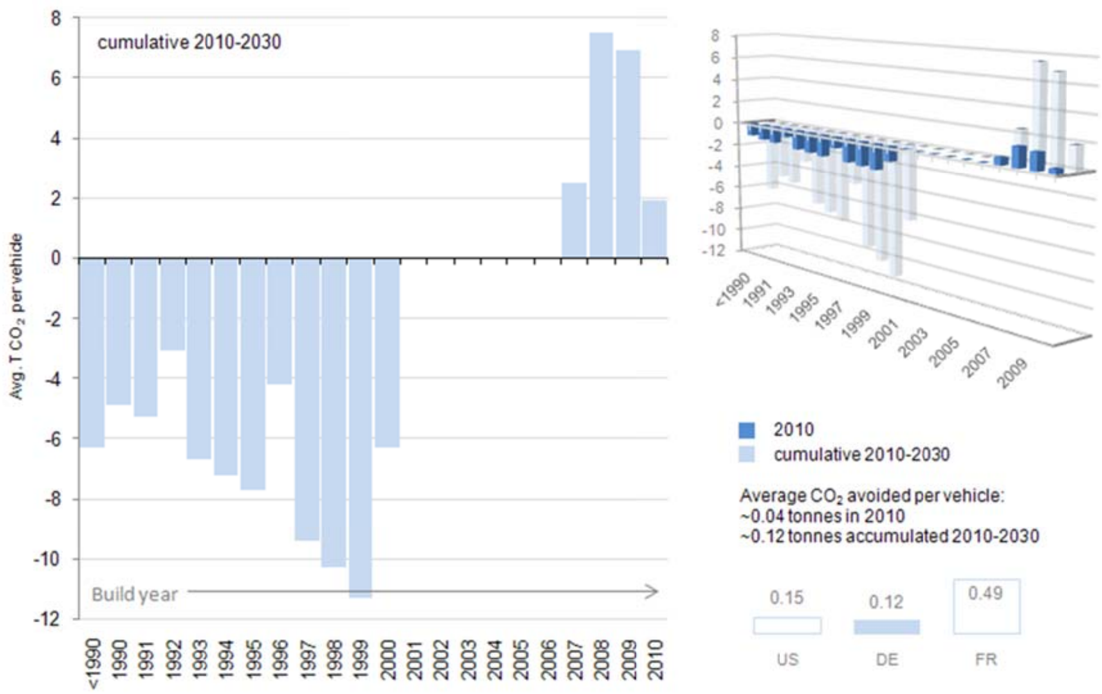
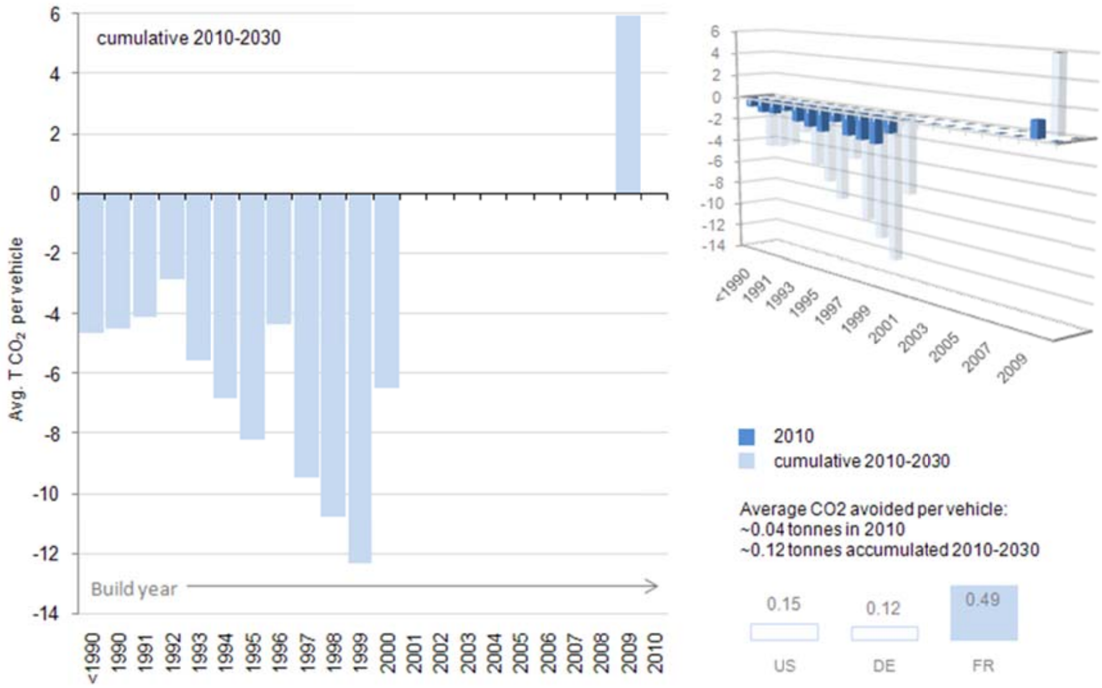


Figure 16. **Average per vehicle CO_2 impact (tonnes per vehicle) by build year cohort compared to BAU – French Prime à la Casse**



The maximum per-vehicle impacts in Germany and France were much lower. For older vehicles, the main reason is that in Europe, these were already much more fuel efficient than their US counterparts. In addition, only vehicles built before 2001were eligible in the German and French schemes, whereas this was not the case in the US where newer vehicles contribute to the largest impacts CO_2 reduction impacts. The 2001 cut-off in Germany and France reduces the expected number of kilometres that would have been driven by the retired vehicles. On the other hand, there are good reasons not to include young vehicles in fleet renewal schemes: their usefulness is in principle far from exhausted and so at least to some extent, replacing them represents a waste of resources for society.

In terms of new vehicles, the key difference between the German and the French schemes is that the added vehicles in France are expected to produce much less lifetime CO_2 emissions as a consequence of the very high share of diesel cars and the elevated number of relatively small and light vehicles. As discussed earlier, this fleet composition effect leads to a larger CO_2 emission avoidance impact than in the German case.

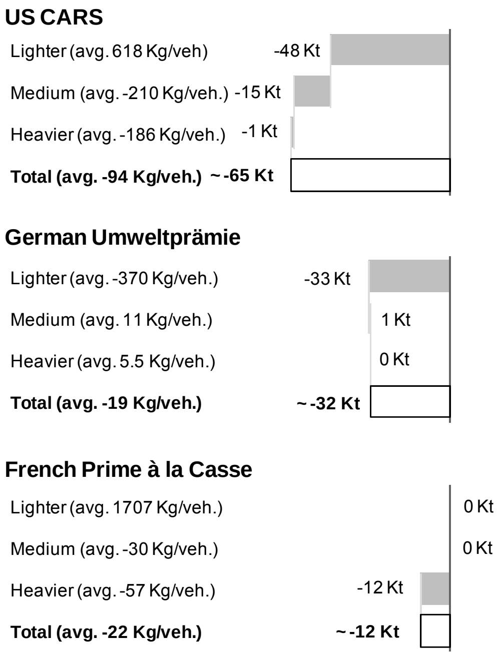
In any case, this analysis does not really clarify which age of vehicles to target – the more recent ones deliver more CO_2 reduction per vehicle, but at a higher economic cost to society.

Task 4: Impact on Tank-to-Wheel (TTW) NO_x emissions and semi-quantitative PM emissions

Essentially the same analyses as described above were carried out for the emissions of nitrogen oxides. The total avoided emissions are less meaningful than for CO_2 (their effect does not accumulate in the same sense as CO_2, and certainly not irrespective of location as is the case for CO_2). The estimation of NO_x emissions is also more prone to inaccuracy than for CO_2.

Nonetheless, our analysis indicates that all three schemes reduced NO_x emissions. The impact in 2010 is estimated at 9 thousand tonnes for the US, 7 thousand tonnes for Germany and 3 thousand tonnes for France. This initial emission reduction impact is expected to more rapidly reduce over time than for CO_2, but would still accumulate by 2020-2025 to around 65 thousand tonnes for the US, 32 thousand tonnes for Germany and 12 thousand tonnes for France.

Figure 17. **Cumulative NO_x impact 2010 to ~2025 compared to BAU by vehicle class**



* negative implies avoided NO_x

In the US, both medium- and light-sized vehicles contribute to the total NO_x impact. This is a consequence of generally improved real-world emissions per vehicle, which have decreased substantially since 2000.

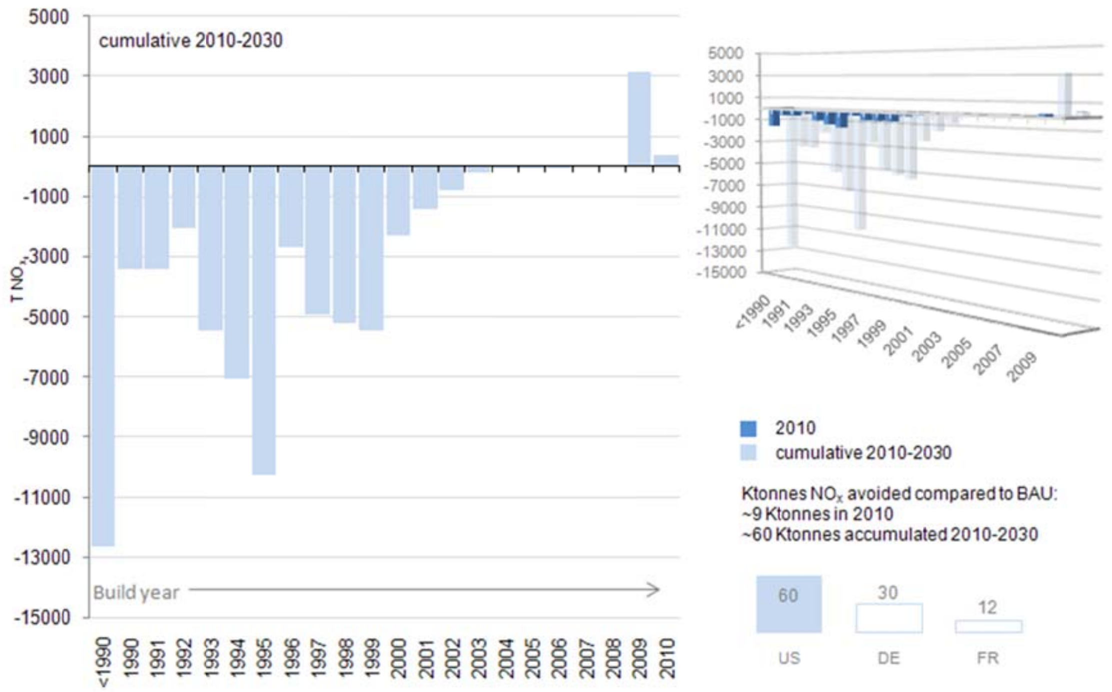
In Germany, once again it is clear that there is missed potential, probably because the scheme incentives were not designed to reduce emissions: the increased share of medium-sized vehicles in the fleet contributed to a higher level of NO_x emissions.

In France, only light vehicles had a (slightly positive) impact. The number of medium-sized decreased but this was balanced by the fact that their individual NO_x emissions increased on a per-vehicle basis.

In the US, our analysis indicates that the average scrapped vehicle transaction avoided 94 kg of NO_x emissions versus 19 kg in Germany and 22 kg in France. This is caused by the very high real world NO_x emissions of older US vehicles, especially medium and larger sized, which were still being driven at the time of scrapping. Within the lighter US vehicles class, the average NO_x emissions per vehicle actually increased, which is a curious effect resulting from the vehicles involved and their age/usage profiles. Still, the fact that many medium-sized vehicles were traded in for lighter sized, in transactions with clear emissions benefit, more than compensated for this and led to an overall reduction for the lighter class. In Germany the increase in the number of medium-sized vehicles eroded the NO_x outcome of the scheme. Lastly, in France, one can clearly observe the elevated average lifetime per-vehicle NO_x emissions (+1707 Kgs) for transactions involving only light vehicles, resulting from the large share of new diesel vehicles. This effect could still be compensated by the fact that a substantial number of additional transactions took place from medium sized to light sized vehicles (with a net emissions benefit), resulting in an approximately null net contribution from the lighter class.

Figures 18 through 20 look at cumulative NO_x emission reductions by vehicle build year cohort as compared to BAU without the fleet renewal schemes. In the US, the distribution of avoided NO_x emissions shows that the impact comes mostly from very old (pre-1990) and 14-18 year old (1992 to 1996) vehicles. These are vehicles with NO_x emissions equivalent to pre-Euro and Euro 1 in terms of the European emission standards.

Figure 18. **Cumulative NO_x impact (Tonnes NO_x) by build year cohort compared to BAU – US CARS Program**



In Germany, a similar conclusion is reached, although the really old vehicles (built before 1990) deliver less impact – the number of scrapped cars of this age was much lower than in the US. Furthermore, although the total number of scrapped vehicles was much higher than in the US, the fact that the scrapped German fleet did not include large numbers of high-emitters leads to a lower overall NO_x impact than in the US.

The French scheme had a high share of NO_x reduction from the oldest vehicles (indeed, France had the highest number of really old, pre-1992 vehicles among the scrapped fleets) but unfortunately that positive impact was almost cancelled out by the fact that it had the highest share of diesels amongst the new vehicles. Had the scheme controlled for NO_x amongst the new vehicles, overall NO_x emission reductions would have been much greater.

Figure 19. **Cumulative NO_x impact (Tonnes NO_x) by build year cohort compared to BAU – German Umweltprämie**

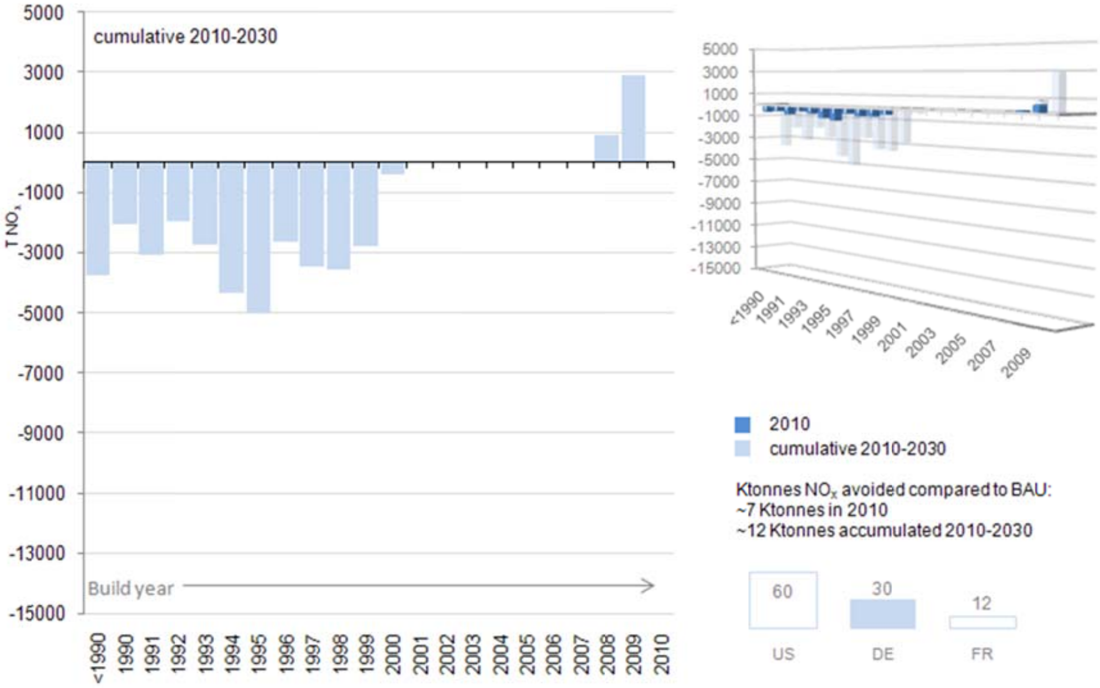
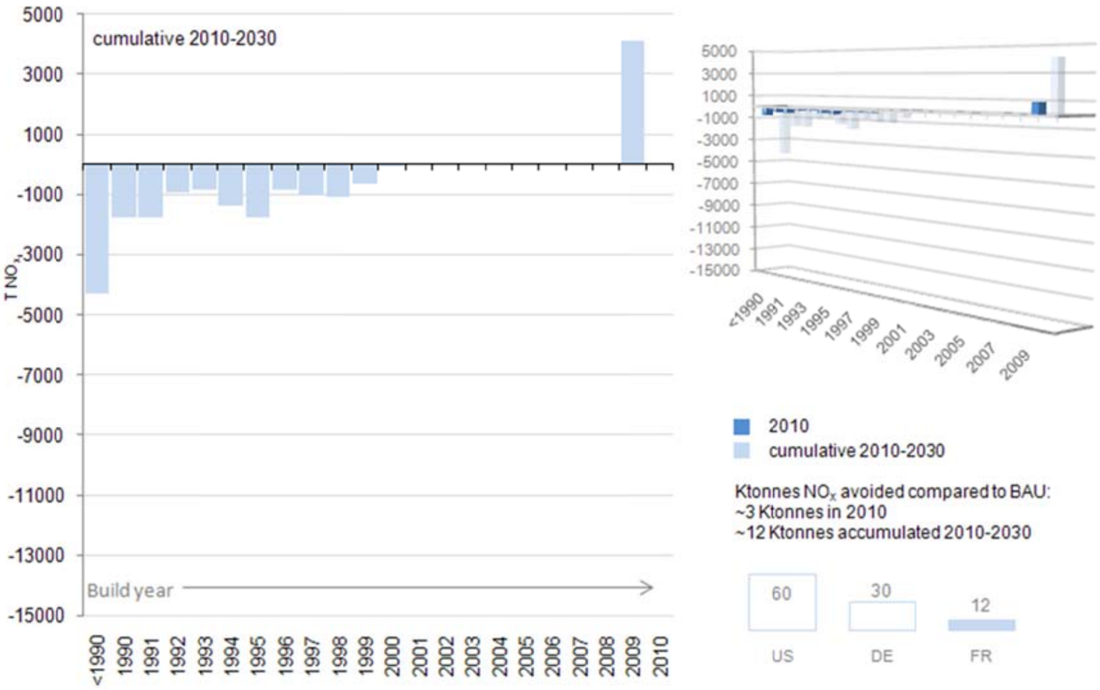
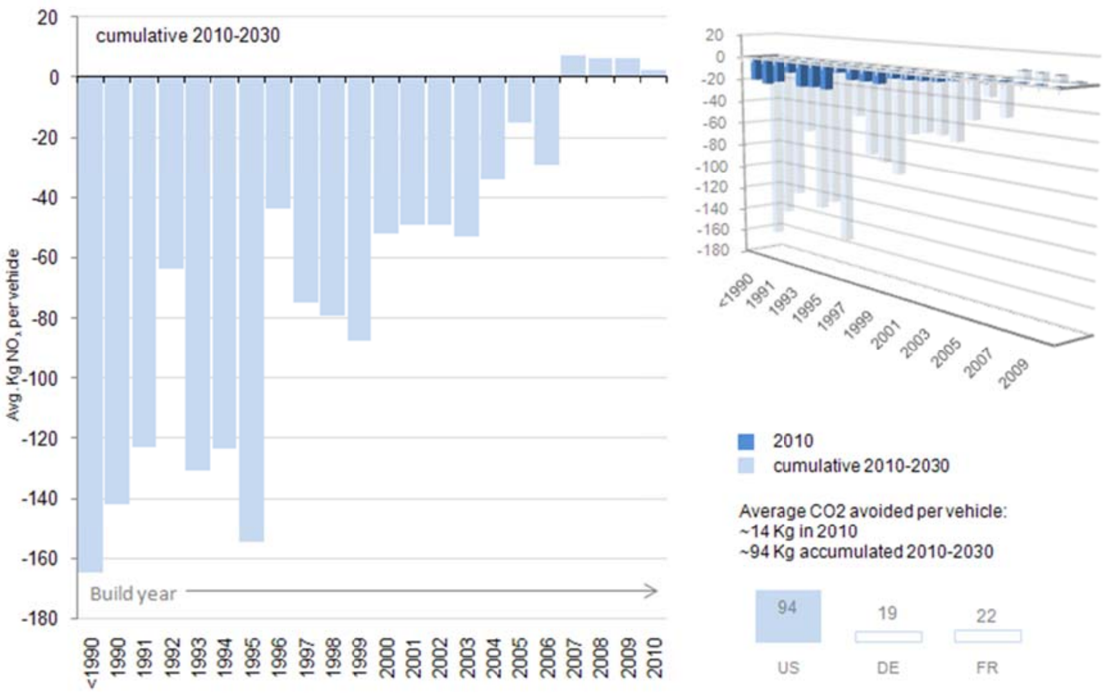


Figure 20. **Cumulative NO_x impact (Tonnes NO_x) by build year cohort compared to BAU – French Prime à la Casse**



The high average NO_x impact of older vehicles can be seen in Figures 21 through 23 that show the per-vehicle distribution over build year cohorts as compared to BAU without the fleet renewal schemes. It is critical to note that these impacts occur despite the fact that the older vehicles would have travelled lower distances in their remaining lifetime than more recent ones.

Figure 21. **Average per vehicle NO_x impact (Kgs per vehicle) by build year cohort compared to BAU – US CARS Program**



These figures highlight the fact that targeting pre-1992 vehicles and vehicles built between 1992 and 1996 (e.g. pre-Euro and Euro 1 vehicles in Europe) have the greatest per-vehicle NO_x emission reduction impact despite the fact that these vehicles would have been driven less in their remaining lifetimes than the new cars.

The per-vehicle impact was much lower in Germany and France than the US, mainly because the real-world emissions of older cars were already much better in these two countries than in the US (especially for Euro 1 cars built from 1992 to 1996). The German case also highlights the importance of regulatory pollutant (e.g. Euro class) thresholds on NO_x emissions for the older build-year cohorts. Although Germany scrapped only a limited number of pre-1992 (e.g. pre-Euro standards) vehicles (5% of the total, vs 11% in the US), and despite the fact that the distance these vehicles would have travelled during their remaining lifetime was necessarily low, their contribution on a per-vehicle basis was higher than more recent, higher travelling cars. This pollutant standard-effect is even stronger in France where the scheme produced even higher per-vehicle NO_x emission reductions from pre-1992 vehicles (e.g. pre-Euro) and where the absolute share of these vehicles was higher than in Germany or the US (27% of scrapped vehicles were pre-1992). As noted earlier, this NO_x emission reduction from scrapped older vehicles in the French scheme was counterbalanced by increased NO_x emissions from new diesels.

Figure 22. **Average per vehicle NO_x impact (Kgs per vehicle) by build year cohort compared to BAU – German Umweltprämie**

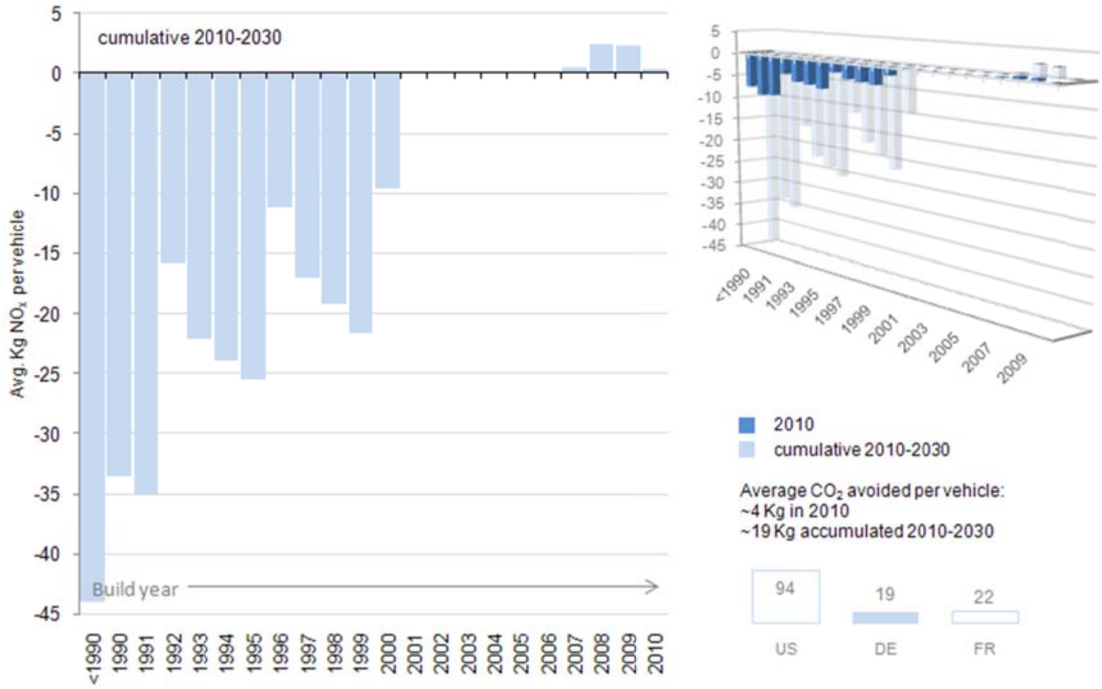
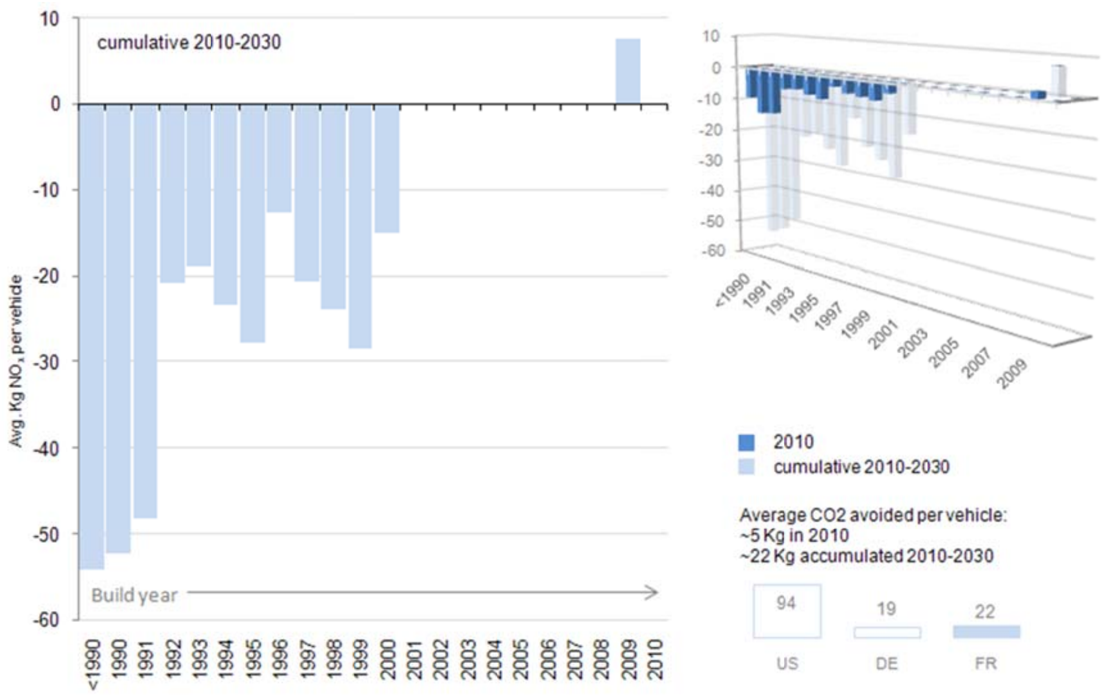


Figure 23. **Average per vehicle NO_x impact (Kgs per vehicle) by build year cohort compared to BAU – French Prime à la Casse**



Semi-quantitative assessment of the reduction potential for Particulate Matter emissions

The approach laid out in the methodology section (2.2, Task 4) was followed for the semi-quantitative assessment of the impact from reduced particulate matter emissions. For the German and French fleets, we observe an approximate exhaust-related NO_x emission reduction potential of 90% and 80% respectively in relation to the BAU scenario, which is based on the ratios between emission limits for the scrapped and new fleets, and takes into account the fuel mix of each country. This induces an estimated actual fleet NO_x emission reduction of around 3% in Germany and 1% in France.

We then assumed that the relation between limits and actual reductions is comparable between NO_x and particulate matter. Therefore an approximate exhaust-related PM emission reduction potential of 75% (derived from the emission limits) in relation to the BAU scenario would lead to an approximate reduction of PM emissions of 2.4% and 0.9% for the German and French fleet renewal schemes, respectively.

For the US fleet, this evaluation shows an approximate NO_x emission reduction potential (derived from the emission limits) of 90% and the schemes induced an estimated fleet NO_x emission reduction of around 0.5%. Therefore, an approximate (emission-limit-derived) PM emission reduction potential of 15% would lead to an approximate particulate emission reduction of 0.1% for the fleet renewal scheme in the US.

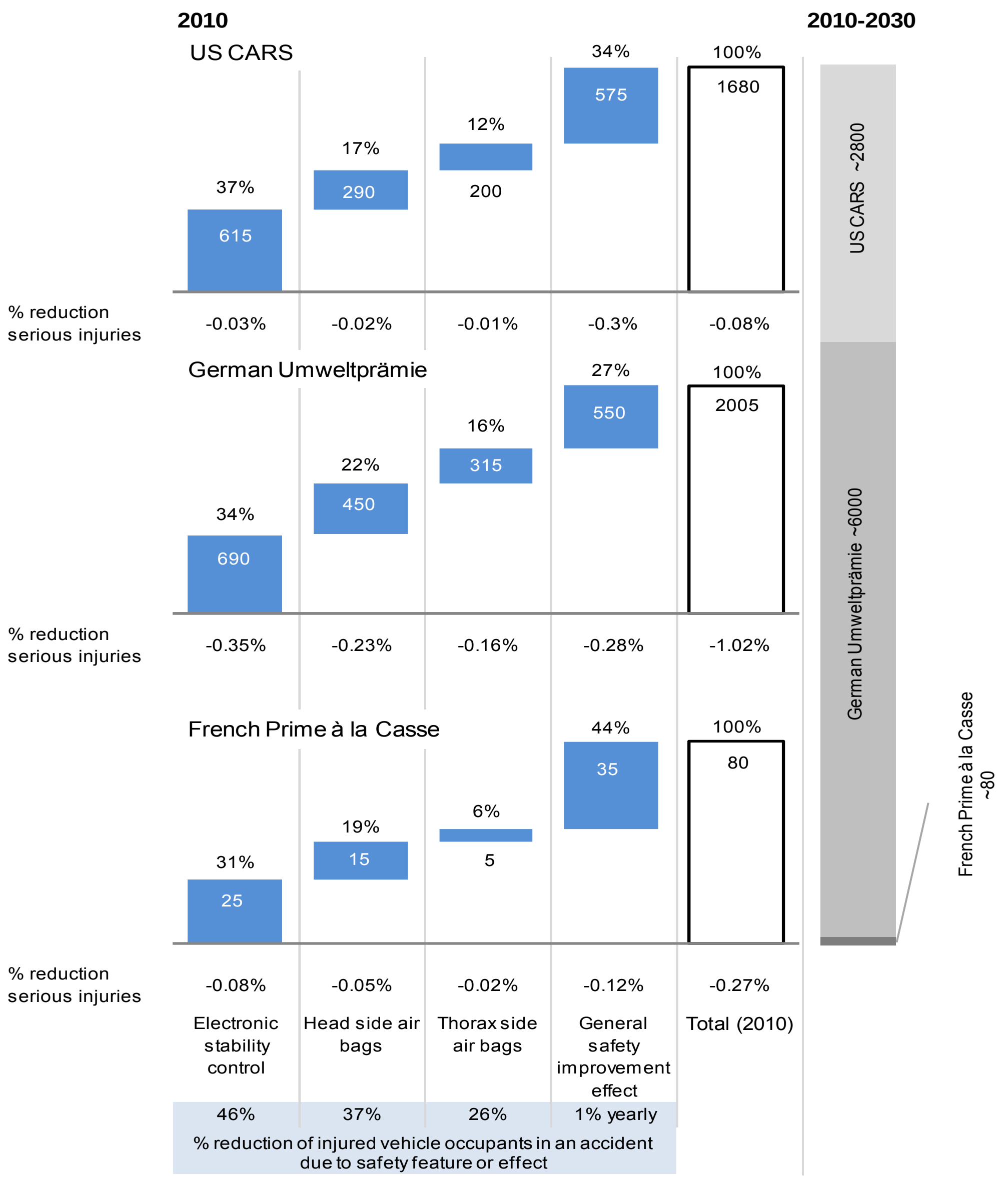
Three key reasons exist for these differences: the scrapped fleet in the US included relatively fewer diesel vehicles (which cause the highest PM emissions), thus lowering the potential for strong reductions through the scrapped fleet, and the CARS program had a proportionally lower impact on the total NO_x emissions of the fleet (in comparison to the German Umweltprämie). For France, the fact that the Prime à la Casse had a 3 times lower PM impact than the German Umweltprämie is due to an increasing share of diesel vehicles (which are the main source of PM) from the scrapped to new fleet, thus implying that even newer and cleaner diesels still erode the PM emissions avoided through scrapping their older petrol counterparts.

Task 5: Impact on traffic safety

Our analysis assumes that that the percentage improvements in safety as a result of the selected safety features are the same for both casualties and serious injuries. It’s also useful to note that the underlying estimates for the percentage reduction in injured occupants in an accident as a consequence of the presence of safety features are 46% for ESC, 37% for Head Side Air Bags, 26% for Thorax SABs and a 1% global yearly reduction in injured crash occupants for the general safety improvement effect

Our analysis suggests that the road safety impact of the US CARS program over the period 2010-2030 could reach ~2800 serious injuries avoided, of which ~40 avoided fatalities. These cumulative impacts are based on the interpolation and integration of yearly estimates for 2010, 2015, 2020, 2025 and 2030. In Germany, we estimate the cumulative road safety impacts of the Umweltprämie to be ~6000 serious injuries avoided, of which ~60 fatalities avoided. In France, we estimate that the Prime à la Casse results in only ~330 serious injuries avoided, of which ~20 avoided fatalities. The 2010 impact, broken down in terms of serious injuries, is illustrated in Figure 24.

Figure 24. **Reduction of serious injuries due to safety features of new vehicles for US, German and French fleet renewal schemes in 2010 and cumulatively from 2010-2030 (% of 2010 total and number of serious injuries avoided)***



*Our analysis assumes that that the percentage improvements in safety as a result of the selected safety features are the same for both casualties and serious injuries

In the US, we observe that ESC (Electronic Stability Control) and the general vehicle safety improvement effect (incremental improvement of vehicle and infrastructure safety technology over time) account for 70% of the expected 2010-2030 impact.

In Germany, higher percentage reduction in BAU injuries is expected from each safety feature – since the penetration of these features in the scrapped vehicles was lower than in the US, their introduction *en masse* through the scheme is estimated to bring a stronger reduction in relation to the BAU injury levels. However, lower global injury figures, as well as lower levels of vehicle travel, lead to only slightly higher improvements in avoided injuries in comparison with the US.

In France the estimated safety impacts are very limited, because of the smaller scale of the scheme (e.g. in comparison to Germany), the lower expected remaining vehicle kilometres of travel of the scrapped fleet (higher share of very old cars) and the lower penetration rate of the safety features in the new cars in comparison with the other countries. Our analysis assumes that percentage improvements in safety due to the safety features identified are the same for both casualties and serious injuries

More details on the safety analysis (conducted by SWOV) can be found in Annexes 1 through 3 for the US, Germany and France), including estimated quantitative impacts on road safety for each individual safety feature.

Task 6: Societal cost effectiveness in relation to CO_2, NO_x and safety

The final part of our analysis comprised the calculation of the societal cost-effectiveness of the schemes based on the results of the previous stages of the study. The cost-effectiveness calculation we undertook only looked at first order effects of the schemes (with the exception of safety impacts which include some second-order effects in the calculation of the monetised general safety effect) and our estimates are not discounted. We also only assessed the cost-effectiveness of the scheme in relation to CO_2, NO_x and safety benefits – our calculations do not account for economic stimulus effects such as job creation (or retention) and other industrial economic impacts on vehicle manufacturers and dealers. Box 1 outlines all of the assumptions and prices used in our calculations. Because of some of the inherent uncertainties involved in our calculations, our results are rounded to the nearest 5 million Euros and are meant to give an indication of the general order of magnitude of the monetised effects of the US, German and French fleet renewal schemes. Finally, our analysis uses as much as possible national values for the monetisation of external effects. In some cases where values were missing, adjustments were made on the basis of expert judgement.

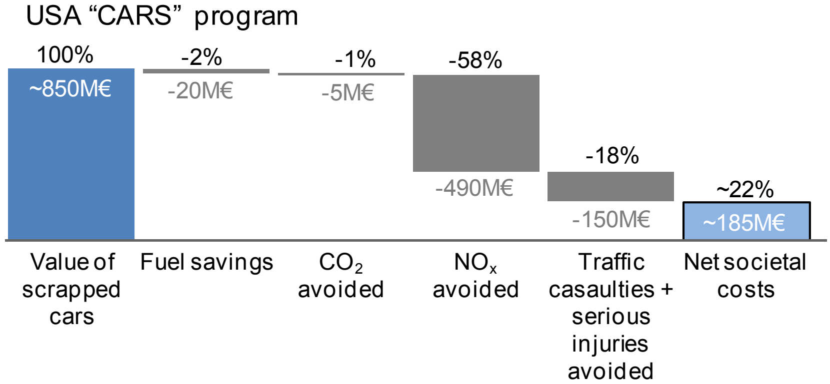
Available monetised NO_x values for the US were incompatible (and incomparable) to monetised NO_x values for Europe since the two are based on different estimation metrics and principles. In order to use comparable values derived from consistent methodologies, we selected a plausible proxy value for the US from the IMPACT Handbook which only covers the EU. France were selected because it seemed to be the best proxy regarding population density distribution, type of cities and GDP per capita, which are the main drivers of the estimates for the NO_x cost factor. France also represents a middle-of-the-road figure among the larger and higher GDP countries.

The monetisation associated with a fatality in this study followed the available published figures of the respective authorities: NHTSA (2002, price level 2000) for the US, BASt (2010, price level 2008) for Germany and Ministère de l'Ecologie (2009, price level 2008) for France.

Also important to note is that we assumed a perspective of utility for society regarding the intrinsic value of the vehicles involved for our cost effectiveness calculation. Hence the scrapped vehicles were considered to correspond to a societal cost, since their usage is no longer possible. On the other hand, under this assumption the new vehicles provide the same intrinsic value as the ones they replace (*i.e.* average annual depreciation would be constant over cars' lifetimes and between cars) and thus the value of the new cars was not included.

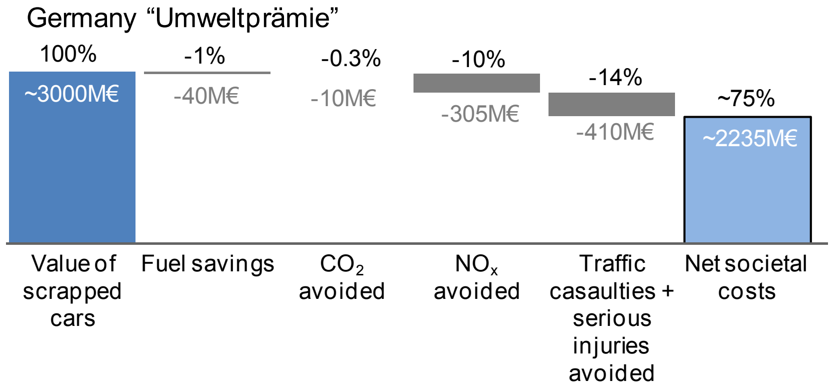
Figures 25 through 27 illustrate the cost-effectiveness of the schemes in relation to CO_2, NO_x and safety.

Figure 25. **Cost-effectiveness of US CARS Program 2010-2030 (cumulative costs from societal perspective, nearest 5M€, undiscounted)**



Our analysis suggests that the US CARS program recovered nearly 80% of the value of the scrapped vehicles and among the three schemes studied is the one that closest comes to full cost recovery when considering CO_2, NO_x and safety outcomes..

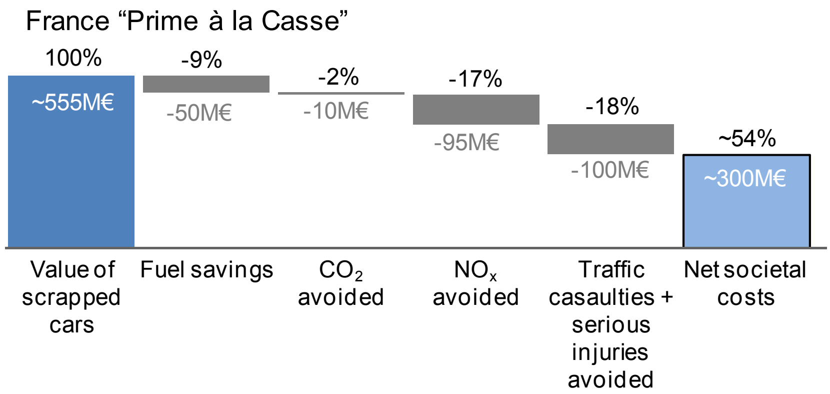
Figure 26. **Cost-effectiveness of the German Umweltprämie 2010-2030 (cumulative costs from societal perspective, nearest 5M€, undiscounted)**



For Germany, the net value to society of the quantified CO_2, NO_x and safety impacts of the scheme is far from a clear case – our analysis indicates that the scheme only recovered approximately 25% of the value of the scrapped cars.

In France, the scheme's cost effectiveness lies between the estimates for the other 2 countries: we estimate the scheme recovered approximately 50% of the value of the scrapped cars.

Figure 27. **Cost-effectiveness of the French Prime à la Casse 2010-2030 (cumulative costs from societal perspective, nearest 5M€, undiscounted)**



Box 1: Assumptions and values for cost-effectiveness calculations:

1. Value of scrapped cars
2. Fuel savings
3. CO_2 avoided
4. NO_x avoided
5. Traffic casaulties + serious injuries avoided

US CARS Program

1. ~680 thousand cars at an average value of 1250€ - based on a brief search of prices for used cars that were representative of the scrapped fleet in the US
2. 100 kTonnes of CO_2 emissions avoided, 1 tonne CO_2= ~120 gallons of petrol, 1 gallon= ~ 1.7€ (2.5USD) excl. tax
3. 60 kTonnes of CO_2 emissions avoided in 2010 and the remaining 40 kTonnes in the 2011-2030 period monetised using an external cost of ~25 €/tonne in 2010 and ~40 €/tonne as an average in the 2011-2030 period as per IMPACT Handbook (Internalisation Measures and Policies for All external Cost of Transport), for EC DG TREN, 2008
4. 64 kTonnes of NOx emissions avoided mostly accumulated in the 2010-2020 period, monetised using an external cost factor considered similar to the French situation (deemed the closest proxy to the US case for density, exposure and levels): 7700 €/tonne[8] in 2010 as per IMPACT Handbook (Internalisation Measures and Policies for All external Cost of Transport), for EC DG TREN, 2008
5. ~40 avoided fatalities from 2010-2030, external cost of 3.8 million € (5.5 million USD) per fatality. Excluding human costs (NHTSA 2002, price level 2000*. Also accounts for costs saved by non-fatal injuries avoided through the corresponding safety improvement.

German "Umweltprämie"

1. 2 million cars at an average value of 1500€ - based on a brief search of prices for used cars that were representative of the scrapped fleet in Germany
2. 200 kTonnes CO_2 emissions avoided, 1 tonne CO_2= ~400 liters of fuel, 1 liter= ~ 0.5€ excl. tax
3. 65 kTonnes CO_2 emissions avoided in 2010 and the remaining 135 kTonnes in the 2011-2030 period monetised using an external cost of ~25 €/tonne in 2010 and ~40 €/tonne as an average in the 2011-2030 period as per IMPACT Handbook (Internalisation Measures and Policies for All external Cost of Transport), for EC DG TREN, 2008
4. 32 kTonnes NO_x emissions avoided mostly accumulated in the 2010-2020 period, monetised using an external cost factor of 9600 €/tonne in 2010 as per IMPACT Handbook (Internalisation Measures and Policies for All external Cost of Transport), for EC DG TREN, 2008
5. ~60 avoided fatalities from 2010-2030. External cost of 6.9 million € per fatality (Excluding human costs; including compensations which in general are much lower than actual human costs (Hoehnscheid & Straube 2010, price level 2008). Also accounts for costs saved by non-fatal injuries avoided through the corresponding safety improvement.

French "Prime à la casse"

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8. Also for the US, other (much lower) estimates exist for the value of NO_x emissions – e.g. 1000 USD per tonne, based on permit prices in the NO_x trading scheme. For the purpose of this study however, it was more relevant to use a number based on estimated social costs.

1.	550 thousand cars at an average value of 1000€ - based on a brief search of prices for used cars that were representative of the scrapped fleet in France
2.	265 kTonnes CO_2 emissions avoided, 1 tonne CO_2= ~400 liters of fuel, 1 liter= ~ 0.5€ excl. tax
3.	65 kTonnes CO_2 emissions avoided in 2010 and the remaining 200 kTonnes in the 2011-2030 period monetised using an external cost of ~25 €/tonne in 2010 and ~40 €/tonne as an average in the 2011-2030 period as per IMPACT Handbook (Internalisation Measures and Policies for All external Cost of Transport), for EC DG TREN, 2008
4.	12 kTonnes NO_x emissions avoided mostly accumulated in the 2010-2020 period, monetised using an external cost factor of 7700 €/tonne in 2010 as per IMPACT Handbook (Internalisation Measures and Policies for All External Cost of Transport), for EC DG TREN, 2008
5.	~18 avoided fatalities from 2010-2030. External cost of 5.6 million € per fatality (Includes direct and indirect economic costs (e.g. medical costs, property damage and production loss) as well as human costs. Ministère de l'Ecologie, 2009: 18 and Ministère de l'Ecologie, 2009: 11. Price level 2008). Also accounts for costs saved by non-fatal injuries avoided through the corresponding safety improvement.
*	*If the NHTSA 2002 estimate had been inflated to 2009 level, the quantified net loss of the scheme would have been in the order of 5 percentage points lower*

Discussion

It can be observed that the quantified impacts of the CARS program leads to a total recovery of almost 80% of the societal costs when considering CO_2, NO_x and safety outcomes. Given that other possible benefits of the scheme were not quantified, and the uncertainty associated with some of the numbers (e.g. the average value of the scrapped cars), the US scheme may all in all have had benefits in line with the costs.

On a per-vehicle basis, the German scheme achieved generally lower impacts and cost more. As a result, it was less cost-effective and the quantified CO_2, NO_x and safety benefits represent only around 25% of costs.

In France, with quantified CO_2, NO_x and safety benefits estimated to represent around 46% of the costs, the scheme did succeed in efficiently targeting the right vehicles for scrapping but a much higher societal value could have been reached through stronger incentives for NO_x reduction.

Table 2. **Cost effectiveness - Sensitivity to harmonised values of statistical life**

National Value of Statistical Life (VSL)				
	Avoided fatalities	VSL (M€)	Monetised impact (M€)	Total cost recovery (%)
US CARS	40	3.8	150	~78%
German Umweltprämie	60	6.9	410	~25%
French Prime à la Casse	18	5.6	100	~46%
Common Value of Statistical Life (VSL) M€				
US CARS	40	6	240	~89%
German Umweltprämie	60	6	360	~24%
French Prime à la Casse	18	6	110	~50%

As noted in the methodology section, we chose to use nationally-specific values of statistical life (VSL) to monetise the safety impacts of the schemes. However, as noted in Box 1 and seen in Table 2 above, the official VSL figure for the US is considerably lower than that used by France and Germany (3.8 M€, 5.6 M€ and 6.9 M€, respectively). Our choice to use official national VSL figures is consistent with national cost-benefit exercises but had we chosen to use a harmonised VSL, our findings on the overall cost-recovery of the schemes might not have been very different except in the case of the United States where the scheme might have recovered nearly 90% of the lost asset value in the end.

CONCLUSIONS AND RECOMMENDATIONS

This study seeks to inform policy-making on the CO_2, NO_x and safety impacts of car fleet renewal programmes. It examines true cost effectiveness of scrapping and renewal schemes in delivering environmental and safety improvements and provides guidance on maximising true benefits. It is one of the first studies to attempt a quantification of the safety and NO_x impacts of such programmes. The key conclusions and recommendations from this study are as follows.

Impacts on the fleet: The CARS program impacted **0.3%** of light duty vehicles and roughly **0.2%** of the corresponding vehicle-kms-travelled. In Germany, the figures were **3.6%** and **2.0%** respectively, since more vehicles were involved and the total fleet is smaller than in the US. In France, the figures were **1.5%** and **0.75%**. Germany expended more than double the total subsidy of the US and almost 10 times that of France (almost 3 billion USD in the US, 5 billion Euro in Germany and 0.6 billion Euro in France).

Impacts on CO_2: The three schemes were formed to reduce CO_2 emissions, not only in 2010, but also cumulatively to 2030 (~100, ~200 and ~265 thousand tonnes cumulatively from 2010 to 2025 for the US, Germany and France respectively). However, the monetised value of that impact is quite small (<5 million Euro in the US, <10 million Euro in Germany and France[9]) and the overall results suggest CO_2 abatement should not be the main rationale for putting a fleet renewal scheme in place. The contributions towards CO_2 reduction vary with the class and age of the scrapped vehicles. The analysis is not unequivocal as to which age of vehicles to target – replacing younger vehicles delivers more CO_2 reductions, but at higher societal economic cost.

Impacts on NO_x: The monetised NO_x impact seems to be *1-2 orders of magnitude higher* than the CO_2 impact *(~500 million euro in the US, ~300 million Euro in Germany, ~100 million Euro in France*). The analysis ***does*** suggest which vehicles such a scheme ought to target: in general, vehicles older than ~15 years. The French scheme shows that a large share of diesels among replacement vehicles erodes the NO_x benefit substantially.

Impacts on traffic safety: In the long run, the US scheme is estimated to avoid *~2800 serious injuries*, of which *~40 fatalities*. Electronic Stability Control and the effect of general improvements in vehicle safety account for 70% of the impact. In Germany, it is estimated that *~6100 injuries* and *~60 fatalities* will be avoided. Also here, the conclusion seems to be that older cars should be targeted. The French scheme is estimated to have had a more limited impact: only *~330 serious injuries* avoided, of which *~20 fatalities*.

Cost-effectiveness[10]: Figure 26 summarises this study's findings regarding the cost-effectiveness of the fleet renewal schemes analysed from the perspective of CO_2, NO_x and safety. From a *societal perspective*, the US scheme cost nearly 1 billion Euro in destroyed assets (scrapped vehicles). The largest monetised benefit examined here comes from avoided NO_x emissions (~500 M€), followed by avoided casualties (~150 M€), leading to a total quantified *recovery of approximately 80% of the societal cost[11]*. Given that other possible benefits of the scheme were not quantified and accounting for the uncertainty

9. External cost of ~25 €/tonne in 2010, ~40 €/tonne in 2020 as per IMPACT Handbook (Internalisation Measures and Policies for All external Cost of Transport), for EC DG TREN, 2008.

10. Considering cumulative but undiscounted impacts over the lifetime of the new car. Considering uncertainties involved, all cost-estimates are rounded to the nearest 5M€.

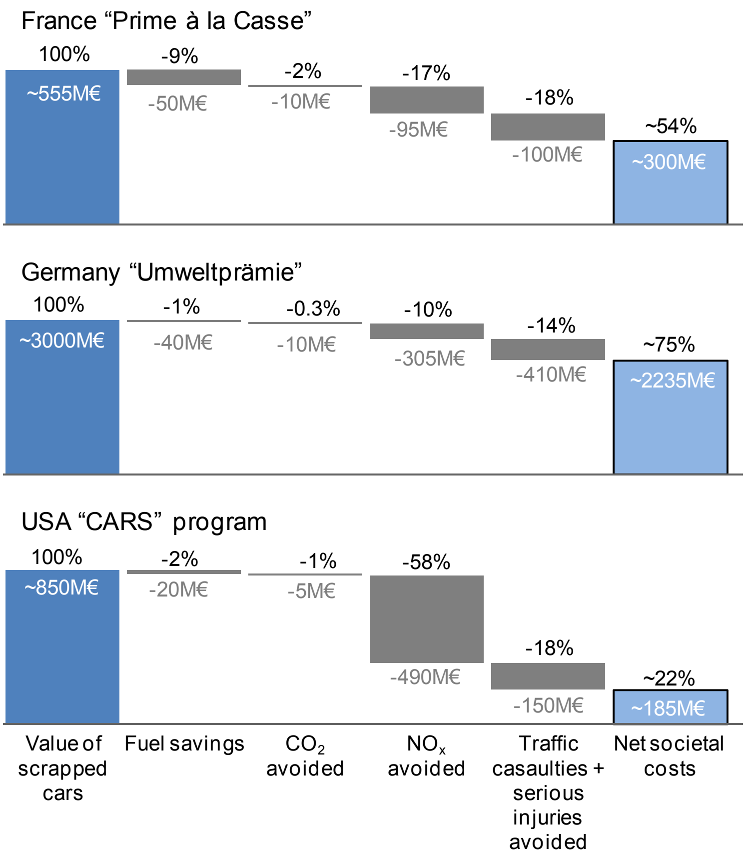
11. Represented by the value of the scrapped asset.

associated with some of the numbers (e.g. the average value of the scrapped cars), *the US scheme may have had benefits in line with its costs.*

On a per-vehicle basis, the *German scheme achieved lower CO_2, NO_x and safety impacts throughout.* As a result, it was less cost-effective and the *CO_2, NO_x and safety benefits quantified here represent only around 25% of the estimated costs*.

In France the *scheme succeeded in targeting the right vehicles for scrapping and resulted in an estimated recovery of around 45%, but a much higher social value could have been reached through a more ambitious NO_x reduction* (which is the effect with the largest potential for delivering benefits).

Figure 26. **Cost-effectiveness of the French, German and US Car Fleet renewal Schemes**



Notes: See Box 1 for assumptions and values used in cost-effectiveness calculations

Insights on scheme design: For the monetized benefits in terms of CO_2, NO_x or safety to exceed the costs associated with vehicle replacement, *scheme design should ensure that larger and older "dirty" vehicles are traded in for lighter, cleaner ones equipped to higher safety standards*. If anything else is allowed by the scheme, then CO_2, NO_x and safety benefits are eroded. The schemes should ideally *target older vehicles that are still being driven*. In Europe, for example, this means covering pre-1992 cars that predate Euro standards and Euro-1 cars produced from 1992 to 1996. The US scheme saw positive results from *targeted incentives* based on fuel economy, even if these were imperfectly aligned with on-road fuel consumption or pollutant emissions. The German scheme involved a larger number of vehicles, but a class shift reduced the total impacts (more lighter and smaller vehicles were traded in for medium-sized vehicles than vice versa). The French scheme benefited from imposing a type-approval CO_2 limit for the new cars and retiring very old gross-emitters, but that may have led to a very high share of new diesel vehicles, which strongly limits NO_x benefits. Increased awareness of the monetised societal benefits of avoided NO_x, as well as CO_2 emissions might have helped to improve the design of the scheme's transaction conditions. The analysis in this report suggests that there may have been a case for differentiated incentives between petrol and diesel vehicles due to the monetised NO_x impacts.

Table 3. **Overview and Insights into Fleet renewal Scheme Design Parameters**

Design parameter	**Choice for maximizing benefits**			
	CO_2	**NO_x**	**Safety**	**Cost effectiveness**
Age of targeted vehicles	Newer	Older	Older	Older
Class of targeted vehicles	Heavier/ medium	Heavier medium	Unclear	Heavier/ medium
Transaction conditions ,	New car: lower fuel consumption	New car: lower emission limits	New car: should have 'proven' safety features (e.g. ESC?)	Retired car: should still be in active use

Table 3 summarises some of this study's main findings regarding the design of fleet renewal schemes so as to maximise social benefits.

One of the key findings of this work is the necessity to put in place targeted incentives and sufficient differentiation so as to capture not only CO_2 or fuel economy benefits but also and more importantly, NO_x and safety benefits since these tend to outweigh the other benefits for the cars targeted by fleet renewal schemes.

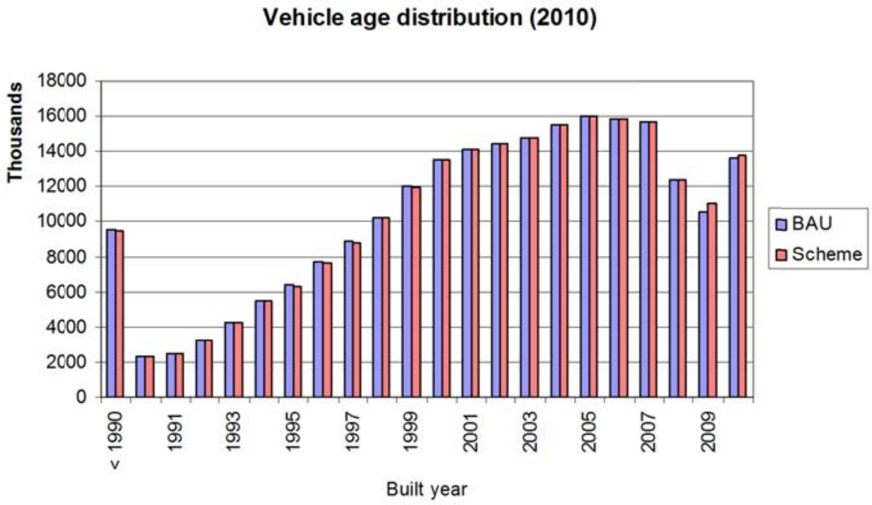
Another finding is the need to design schemes that target older vehicles that are still in use – retiring vehicles that are not used provides nil benefit.

The table highlights the complexity of trade-offs that may be involved in developing effective fleet renewal schemes in terms of environmental and safety benefits. Schemes seeking principally to reduce CO_2 emissions or improve fleetwide fuel economy should, perhaps counter intuitively, target more recent vehicles. This is because newer cars would accumulate much higher mileage over their remaining life if they were not scrapped than older vehicles and this factor outweighs the per-kilometre emissions of older vehicles. The table also underscores the need to control for the type of replacement vehicle chosen in the fleet renewal scheme – lower CO_2-emitting diesels helped the CO_2 profile of the French scheme but also eroded the lifetime benefits of the scheme overall due to an increase in relatively costly NO_x emissions.

ANNEX 1 (SWOV) – SAFETY IMPACT OF THE CARS PROGRAM FLEET RENEWAL SCHEME IN THE UNITED STATES

Step 1:

1.1 Change in vehicle age distribution as a result of the fleet renewal scheme (including passenger cars, light and heavy vans)



*BAU: Business as usual (i.e. without fleet renewal scheme)

Table 1. **Estimated number of vehicles in 2010 distributed over their built year (including passenger cars, light and heavy vans)**

Build Year	# vehicles BAU	# vehicles Scheme	Change relative to BAU
< 1990	9515403	9438560	-0.81%
1990	2342343	2318350	-1.02%
1991	2528066	2500030	-1.11%
1992	3234641	3202393	-1.00%
1993	4246650	4204998	-0.98%
1994	5509740	5452595	-1.04%
1995	6389618	6323255	-1.04%
1996	7675966	7614536	-0.80%
1997	8871919	8805964	-0.74%
1998	10227886	10162010	-0.64%
1999	12047989	11985548	-0.52%
2000	13561441	13517683	-0.32%
2001	14115306	14086123	-0.21%
2002	14455240	14439126	-0.11%
2003	14736233	14731761	-0.03%
2004	15517431	15516205	-0.01%

Build Year	# vehicles BAU	# vehicles Scheme	Change relative to BAU
2005	16008398	16008144	0.00%
2006	15861282	15861230	0.00%
2007	15694495	15695491	0.01%
2008	12341662	12349591	0.06%
2009	10509164	11018738	4.85%
2010	13622079	13780621	1.16%

1.2 Change in penetration rate of safety features due to the fleet renewal scheme

Safety feature: Electronic Stability Control (ESC)

Table 2 presents the penetration rates of Electronic Stability Control (ESC) for the 'BAU scenario'[12] and for the "with fleet renewal scheme scenario". The latter was obtained as shown in the Appendix.

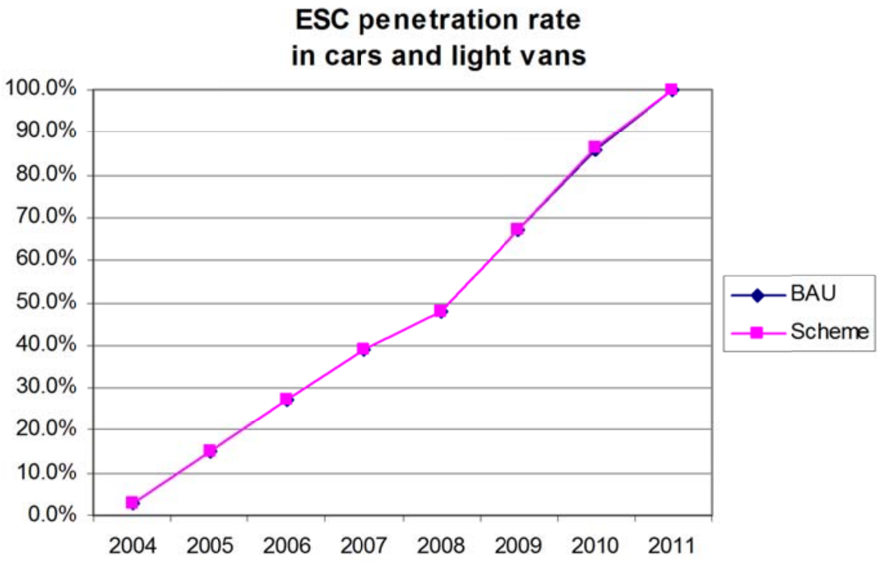
Assumptions:

The penetration rate of the ESC safety feature on heavy vans is assumed to be 75 percent of the lighter vehicles (passenger and light vans).

Table 2. **Penetration rate of ESC**

	Penetration rate in fleet			
	Cars and light vans		Heavy vans	
	BAU	Scheme	BAU	Scheme
2004	3.0%	3.0%	2.3%	2.3%
2005	15.0%	15.0%	11.3%	11.3%
2006	27.0%	27.0%	20.3%	20.3%
2007	39.0%	39.0%	29.3%	29.3%
2008	48.0%	48.0%	36.0%	36.0%
2009	67.0%	67.0%	50.3%	50.3%
2010	**86.0%**	**86.3%**	**64.5%**	**64.5%**
2011	100.0%	100.0%	75.0%	75.0%

12. Estimates for penetration rates for the BAU scenario were provided by NHTSA and obtained through TNO.



<u>Safety feature: Side Airbag (SAB)</u>

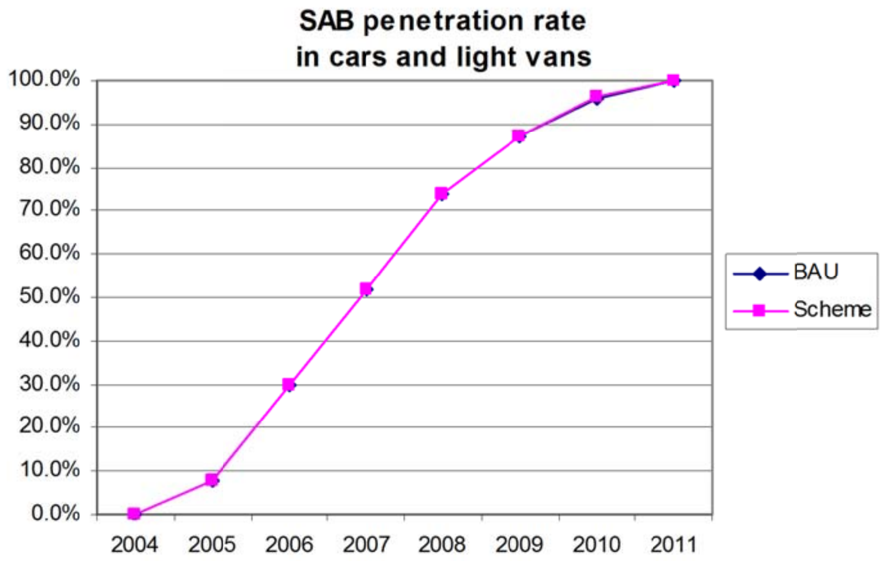
Assumptions:

The penetration rate of the side airbag (SAB) safety feature on heavy vans is assumed to be 75 percent of the lighter vehicles.

The penetration rate of SAB in sold vehicles is assumed to be equal to ESC's penetration rates.

Table 3. **Penetration rate of SAB**

	Penetration rate in fleet			
	Cars and light vans		Heavy vans	
	BAU	Scheme	BAU	Scheme
2004	0.0%	0.0%	0.0%	0.0%
2005	8.0%	8.0%	6.0%	6.0%
2006	30.0%	30.0%	22.5%	22.5%
2007	52.0%	52.0%	39.0%	39.0%
2008	74.0%	74.0%	55.5%	55.5%
2009	87.0%	87.0%	65.3%	65.3%
2010	**96.0%**	**96.3%**	**72.0%**	**72.0%**
2011	100.0%	100.0%	75.0%	75.0%



Note: Given that the numbers of scrapped and added heavy vans are rather low, the penetration rate due to the fleet renewal scheme does not change and therefore, has not been included in the graphs.

Step 2

2.1 Safety impact of specific safety features

Table 4. **Injury and fatality rates**

Year	Injury rate per million VKT[13]	Fatality rate per million VKT
2007	0.5095	0.0085
2008	0.4971	0.0079
2009	*0.4847*	*0.0073*
2010	*0.4722*	*0.0068*

The figures for the years 2009 and 2010 have been obtained through extrapolation. Further assumptions:

1. Proportion of number of injured occupants in crashed passenger cars (based on Dutch accidents)

Single accidents	43%
Multiple accidents	57%

Effects of ESC

Single accidents:	46%	reduction in injured occupants

13. Injury and fatality rates for the United States were obtained from: FARS, GES and FHWA VMT, April 2009 TVT).

2. Proportion of number of injured occupants in crashed passenger cars (based on Dutch accidents)

Side impacts: 25% (assumption)

Effects of SAB

Head airbag	37%	reduction in injured occupants (assuming same percentage as killed occupants as reported by McCartt & Kyrychenko (2007)
Thorax airbag	26%	reduction in injured occupants (assuming same percentage as killed occupants as reported by McCartt & Kyrychenko (2007)

The table below shows the effects on safety that the fleet renewal scheme generates, for three safety features.

Table 5. **Estimates for 2010**

Number of injuries due to specific accident type				
Scenario 1: BAU	Scenario 2: with fleet renewal scheme	Difference	Change (in percentage)	Safety feature
550,876	550,262	614	0.11%	ESC
340,565	340,278	287	0.08%	SAB head
393,594	393,392	202	0.05%	SAB thorax

Note that the column ‘change’ refers to the reduction in injuries caused by certain accident type, not to the total. This means that in the case of ESC, for instance, the change in percentage due to the fleet renewal scheme implies that there is 0.11 percent reduction in injuries due to single accidents.

2.2 Overall effect of vehicle safety

According to Broughton (2003)the effect on safety of vehicle improvement is a reduction of 1% in the number of serious injured car occupants per year, the effect on safety of the fleet renewal scheme is the following:

*Overall effect = 1% * (AVGYadded – AVGYscrapped) * % of fleet scrapped * % AVGVTKscrapped*

Where: AVGY is the average built year of the added or scrapped vehicles

AVGVTK scrapped is the average VKT of scrapped vehicles

		Calculation
Injury reduction	*1%*	
AVGY scrapped	*1995*	
AVGY added	*2009*	*14*
AVG mill VTK scrapped	*0.013*	
AVG mill VTK fleet	*0.019*	*0.65*
% of fleet scrapped		*0.3*
Overall effect		***0.028%***

The overall effect of the fleet renewal scheme is a reduction of 0.028% of the serious injured occupants in crashed vehicles.

2.3 Effect of the fleet renewal scheme in the United States on road safety

Table 6 below shows the percentage of injury reduction due to the existence of the different safety features. The figures shown in the table are relative to the total estimated injuries caused by all types of accidents. Note that the difference with Table 5 is that the latter provides the injury reduction relative to the accident type for which the safety feature in question has an effect, not the total.

Estimated total number of injuries in 2010 :	**2075747**

Table 6. **Injury reduction due to the fleet renewal scheme**

Safety feature	Injury reduction (relative to total)
ESC	0.030%
SAB head	0.030%
SAB thorax	0.010%
Overall effect	0.028%
Total	0.082%

The total reduction in serious injuries can therefore be estimated as:

Total reduction: 0.030 + 0.014 + 0.010 + 0.028 = 0.082 %

By adding up all these effects there is certainly a slight overlap but given the magnitude, it can be neglected.

2.4 Monetised impact of the fleet renewal scheme in the United States

The safety effects of the fleet renewal scheme in terms of saved costs is calculated according to the method known as the '1 million euro test' (introduced by the European Commission in 1995).

Assuming that fatalities are reduced by the safety features in the same proportion as serious injuries, the estimated reduction in fatalities is the following:

	Year 2010
Estimated total number of VKT	4395513 million
Fatality rate (see Table 4)	0.0068 per million VKT
Estimated number of fatalities	29771
Estimated fatality reduction	0.082%*29771 = **24**

Based on figures from US NHTSA, the costs per fatality amount to 10,4 million USD including human costs and 5,5 million USD excluding human costs (price level 2000; see Appendix).

Saved costs due to the fleet renewal scheme	
Including human costs	**250 million USD**
Excluding human costs	**132 million USD**

Calculation of penetration rates

ESC in Year 2010

	BAU				Added			Scheme	
	Fleet	Penetration in the fleet	Fleet with ESC	Fleet without ESC	New fleet	new fleet ESC	new fleet without ESC	Fleet with ESC	Penetration rate
Light vehicles	200658278	0.86	172566119	28092159	674827	535892	138935	**173102011**	0.863
Heavy vans	28354674	0.65	18288765	10065909	2254	1223	1031	**18289988**	0.645
			Pf * Fleet		Σ Fi	Σ Psvi * Fi			

Pf: penetration in fleet

Psvi: penetration of sold vehicles built in year i

Fi: Vehicles sold built in year i

SAB in Year 2010

	BAU				Added			Scheme	
	Fleet	Penetration in the fleet	Fleet with SAB	Fleet without SAB	New fleet	new fleet SAB	new fleet without SAB	Fleet with SAB	Penetration rate
Light vehicles	200658278	0.96	192631947	8026331	674827	535892	138935	**193167838**	0.963
Heavy vans	28354674	0.72	20415365	7939309	2254	1223	1031	**20416588**	0.720

The following penetration rates in sold vehicles (cars and light vans) was used. Note that the penetration of SAB was assumed to be equal to the ESC.

Year	ESC penetration in sold vehicles[14]	SAB penetration in sold vehicles
2004	0	*0*
2005	0	*0*
2006	0.15	*0.15*
2007	0.35	*0.35*
2008	0.55	*0.55*
2009	0.75	*0.75*
2010	0.95	*0.95*
2011	1	*1*

1 million Euro test

To estimate the total benefits of casualties and crashes saved, we firstly calculate the costs per fatality by dividing the total costs of road crashes (including costs of injuries and property damage only (PDO) crashes) by the number of fatalities. The total benefits are then calculated multiplying the number of fatalities saved by the cost per fatality. Note that these benefits also include the benefits of non-fatal crashes saved. This method assumes that the same percentage of (all categories of) injuries and PDO crashes are saved as the percentage of fatalities saved. (This method is known as the '1 million euro test', introduced by the European Commission in 1995.)

Figures from NHTSA (2002) for the year 2000 have been used. Table A4 below summarizes the number of casualties and PDO vehicles per injury severity (MAIS) category, costs per casualty and PDO vehicle, as well as the resulting total costs of road crashes in the US in 2000. The economic costs (e.g. medical costs, lost productivity and property damage) have been separated from the human costs (quality of life loss).

The total economic costs of road crashes in the US amounted to 433 billion USD in 2000, of which 231 billion USD in economic costs and 203 billion USD in human costs. The number of fatalities was 41.821. This means that the costs per fatality amount to 10.4 million USD including human costs and 5,5 million USD excluding human costs.

14. Estimated penetration rates of ESC in sold vehicles was provided by NHTSA and obtained through TNO.

	number casualties and PDO vehicles	costs per casualty and PDO vehicle (USD)			total costs (million USD)		
injury severity		economic costs	quality of life lost	total	economic costs	quality of life lost	total
PDO	23.631.696	2.532	0	2.532	59.838	0	59.838
MAIS 0	2.548.458	1.962	0	1.962	5.000	0	5.000
MAIS 1	4.659.585	10.562	4.455	15.017	49.214	20.758	69.972
MAIS 2	436.007	66.820	91.137	157.957	29.134	39.736	68.870
MAIS 3	125.903	186.097	128.107	314.204	23.430	16.129	39.559
MAIS 4	36.509	348.133	383.446	731.579	12.710	13.999	26.709
MAIS 5	9.463	1.096.161	1.306.836	2.402.997	10.373	12.367	22.740
Fatal	41.821	977.208	2.389.179	3.366.387	40.868	99.918	140.786
Total					**230.568**	**202.908**	**433.475**

References

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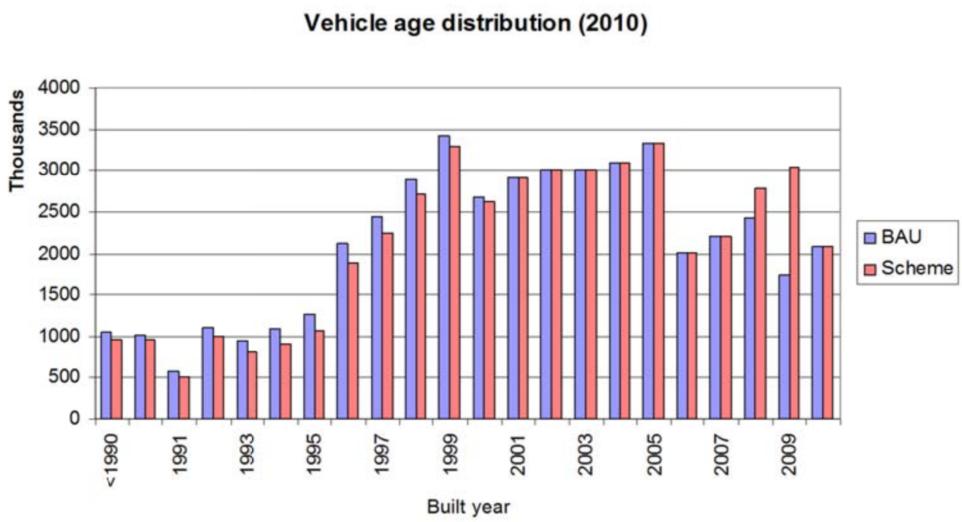
ANNEX 2 (SWOV) – SAFETY IMPACT OF THE UMWELTPRÄMIE FLEET RENEWAL SCHEME IN GERMANY

Step 1

1.1 Change in vehicle age distribution as a result of the fleet renewal scheme (including passenger cars, light and heavy vans)



*BAU: Business as usual (i.e. without fleet renewal scheme)

Table 7. **Estimated number of vehicles in 2010 distributed over their build year (including passenger cars, light and heavy vans)**

Build year	# vehicles BAU	# vehicles Scheme	Change relative to BAU
<1990	1045429	960252	-8.15%
1990	1011850	952007	-5.91%
1991	584598	503074	-13.95%
1992	1112891	988846	-11.15%
1993	936142	812929	-13.16%
1994	1087060	906259	-16.63%
1995	1261504	1065014	-15.58%
1996	2114760	1879062	-11.15%
1997	2449998	2244770	-8.38%
1998	2901615	2716478	-6.38%
1999	3419807	3290553	-3.78%
2000	2671255	2629263	-1.57%
2001	2913998	2913998	0.00%
2002	2997940	2997940	0.00%
2003	2996457	2996457	0.00%

Build year	# vehicles BAU	# vehicles Scheme	Change relative to BAU
2004	3092843	3092843	0.00%
2005	3336167	3336167	0.00%
2006	2007884	2007884	0.00%
2007	2209533	2209533	0.00%
2008	2419754	2786329	15.15%
2009	1743592	3034801	74.05%
2010	2087043	2087043	0.00%

1.2 Change in penetration rate of safety features due to the fleet renewal scheme

Safety feature: Electronic Stability Control (ESC)

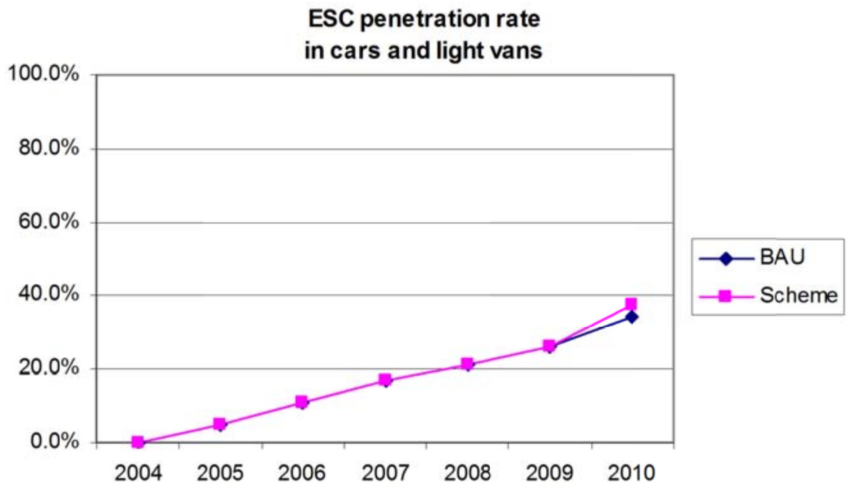
Table 8 presents the penetration rates of Electronic Stability Control (ESC) in light vehicles for the 'BAU scenario' as given by Grošanić & Assenmacher (2007). The penetration rate in 2010 for the "with fleet renewal scheme scenario" was obtained as shown in the Appendix.

Assumptions:

The penetration rates for heavy vans is assumed to be 75 percent of the lighter vehicles (passenger and light vans).

Table 8. **Penetration rate of ESC**

	Penetration rate in fleet			
	Cars and light vans		Heavy vans	
	BAU	Scheme	BAU	Scheme
2004	0.0%	0.0%	0.0%	0.0%
2005	5.0%	5.0%	3.8%	3.8%
2006	11.0%	11.0%	8.3%	8.3%
2007	17.0%	17.0%	12.8%	12.8%
2008	21.0%	21.0%	15.8%	15.8%
2009	26.0%	26.0%	19.5%	19.5%
2010	**34.0%**	**37.4%**	**25.5%**	**25.5%**



Safety feature: Side Airbag (SAB)

Assumptions:

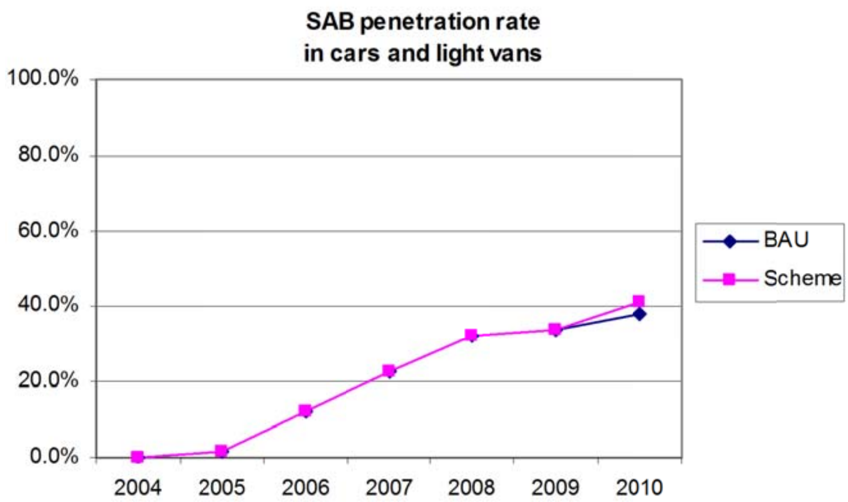
Given the lack of data, the penetration rate of the Side Airbag (SAB) in Germany was estimated by assuming it equal to the penetration rate of SAB in the United States, corrected by the ratio between the ESC figures from Germany and the United States.

SAB(DE) = SAB(US) x ESC(DE)/ESC(US)

The penetration rate of the SAB in heavy vans is assumed to be 75 percent of the lighter vehicles.

Table 9. **Penetration rate of SAB**

	Penetration rate in fleet			
	Cars and light vans		Heavy vans	
	BAU	Scheme	BAU	Scheme
2004	0.0%	0.0%	0.0%	0.0%
2005	1.8%	1.8%	1.3%	6.0%
2006	12.2%	12.2%	9.2%	22.5%
2007	22.7%	22.7%	17.0%	39.0%
2008	32.4%	32.4%	24.3%	55.5%
2009	33.8%	33.8%	25.3%	65.3%
2010	**38.0%**	**41.3%**	**28.5%**	**28.5%**



Note: Given that the numbers of scrapped and added heavy vans are low, the penetration rate due to the fleet renewal scheme does not change and therefore, it has not been included in the graphs.

Step 2

2.1 Safety impact of specific safety features

Table 10. **Injury and fatality rates**

Year	Injury rate per million VKT	Fatality rate per million VKT
2010	0.331	0.003

These figures are based on the yearly vehicle-kilometers travelled (VKT)[15] in Germany and on data of the total injured and killed victims until 2008 (obtained from the "CARE - European Road Accident Database,") extrapolated to 2010.

Further assumptions:

1. Proportion of number of injured occupants in crashed passenger cars (based on Dutch accidents)

Single accidents 43%
Multiple accidents 57%

Effects of ESC

Single accidents 46% reduction in injured occupants (Erke, 2008)

2. Proportion of number of injured occupants in crashed passenger cars (based on Dutch accidents)
Side impacts 35%

15. Data on VKT in Germany were provided by TNO.

Effects of SAB

Head airbag	37%	reduction in injured occupants (assuming same percentage as killed occupants as reported by McCartt & Kyrychenko (2007))
Thorax airbag	26%	reduction in injured occupants (assuming same percentage as killed occupants as reported by McCartt & Kyrychenko (2007))

The table below shows the effects on safety that the fleet renewal scheme generates, for three safety features.

Table 11. **Estimates for 2010**

Number of injuries due to specific accident type				
Scenario 1: BAU	Scenario 2: with fleet renewal scheme	Difference	% change	Safety feature
71367	70675	692	0.97%	ESC
59181	58729	452	0.76%	SAB head
62033	61717	315	0.51%	SAB thorax

Note that the column 'change' refers to the reduction in injuries caused by certain accident type, not to the total. This means that in the case of ESC, for instance, the change in percentage due to the fleet renewal scheme implies that there is 0.97 percent reduction in injuries due to single accidents.

2.2 Overall effect of vehicle safety

According to Broughton (2003) the effect on safety of vehicle improvement is a reduction of 1% in the number of serious injured car occupants per year, the effect on safety of the fleet renewal scheme is the following:

*Overall effect = 1% * (AVGYadded – AVGYscrapped) * % of fleet scrapped * % AVGVTKscrapped*

Where: AVGY is the average built year of the added or scrapped vehicles

AVGVTK scrapped is the average VKT of scrapped vehicles

		Calculation
Injury reduction	*1%*	
AVGY scrapped	*1995*	*14*
AVGY added	*2009*	
AVG mill VTK scrapped	*0.007*	*0.55*
AVG mill VTK fleet	*0.013*	
% of fleet scrapped		*3.6*
Overall effect		***0.28%***

The overall effect of the fleet renewal scheme is a reduction of 0.28% of the serious injured occupants in crashed vehicles.

2.3 Effect of the fleet renewal scheme in Germany on road safety

Table 12 below shows the percentage of injury reduction due to the existence of the different safety features. The figures shown in the table are relative to the total estimated injuries caused by all types of accidents. Note that the difference with Table 11 is that the latter provides the injury reduction relative to the accident type for which the safety feature in question has an effect, not the total.

Estimated total number of injuries in 2010 :	**196498**

Table 12**. Injury reduction due to the fleet renewal scheme**

Safety feature	Injury reduction (relative to total)
ESC	0.35%
SAB head	0.23%
SAB thorax	0.16%
Overall effect	0.28%
Total	1.02%

The total reduction in serious injuries can therefore be estimated as:

Total reduction: 0.35 + 0.23 + 0.16 + 0.28 = 1.02 %

By adding up all these effects there is certainly a slight overlap but given the magnitude, it can be neglected.

2.4 Monetised impact of the fleet renewal scheme in Germany

The safety effects of the fleet renewal scheme in terms of saved costs are calculated according to the method known as the '1 million euro test' (introduced by the European Commission in 1995, see Appendix of the US report).

Assuming that fatalities are reduced by the safety features in the same proportion as serious injuries, the estimated reduction in fatalities is the following:

	Year 2010
Estimated total number of VKT	593972 million
Fatality rate (see Table 10)	0.003 per million VKT
Estimated number of fatalities	1962
Estimated fatality reduction	1.02% * 1962 = **20**

To estimate the benefits we use the same method as for the US. According to the Federal Highway Research Institute (BASt) the social cost road crashes in Germany amounted to 31.0 billion euro in 2008. The number of registered fatalities in that year was 4,477 (source: CARE database). The costs per fatality are thus 6.9 million euro per fatality (price level 2008; source: Hoehnscheid & Straube). This figure does not include human costs. It does include however payments to compensate (among others) human losses. These compensation payments are in general much lower than the actual human losses.

The saved costs can be calculated by: 6.9 million euro * 20 (number of estimated fatality reduction) and is:

Saved costs due to the fleet renewal scheme 138 million EURO

Calculation of penetration rates

ESC in Year 2010

	BAU				Added			Scheme	
	Fleet	Penetration in the fleet	Fleet with ESC	Fleet without ESC	New fleet	new fleet ESC	new fleet without ESC	Fleet with ESC	Penetration rate
Light vehicles	44827951	0.340	15241503	29586447	1657395	1506479	150916	**16747983**	0.374
Heavy vans	1574169	0.255	401413	1172756	389	265	124	**401678**	0.255

Pf * Fleet Σ Fi Σ Psvi * Fi

Pf: penetration in fleet

Psvi: penetration of sold vehicles built in year i

Fi: Vehicles sold built in year i

SAB in Year 2010

	BAU				Added			Scheme	
	Fleet	Penetration in the fleet	Fleet with SAB	Fleet without SAB	New fleet	new fleet SAB	new fleet without SAB	Fleet with SAB	Penetration rate
Light vehicles	44827951	0.380	17013771	27814180	1657395	1506479	150916	**18520250**	0.413
Heavy vans	1574169	0.285	448089	1126080	389	265	124	**448354**	0.285

The following penetration rates in sold vehicles (cars and light vans) were used. Note that the penetration of SAB was assumed to be equal to the ESC.

Year	ESC penetration in sold vehicles	SAB penetration in sold vehicles
2004	0.67	*0.67*
2005	0.72	*0.72*
2006	0.77	*0.77*
2007	0.82	*0.82*
2008	0.87	*0.87*
2009	0.92	*0.92*
2010	0.97	*0.97*

Source: eSafety – Implementation Status Survey 2007, Final Report 2008

References

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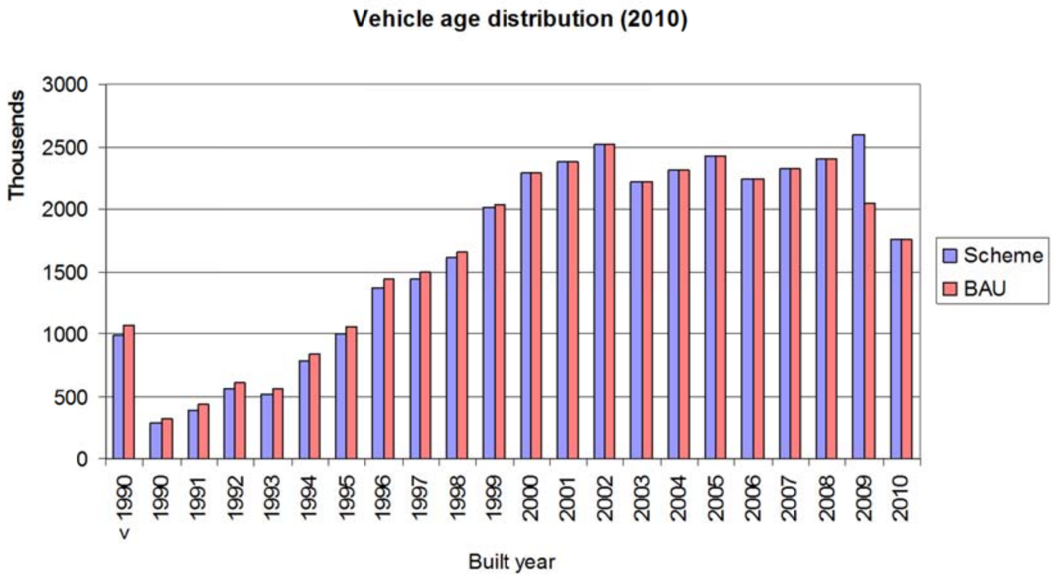
ANNEX 3 (SWOV) – SAFETY IMPACT OF THE PRIME À LA CASSE FLEET RENEWAL SCHEME IN FRANCE

Step 1

1.1 Change in vehicle age distribution as a result of the fleet renewal scheme (including passenger cars, light and heavy vans)



*BAU: Business as usual (i.e. without fleet renewal scheme) (Data source: TNO)

Table 13 **Estimated number of vehicles in 2010 distributed over their build year (including passenger cars, light and heavy vans)**

Build year	# vehicles BAU	# vehicles Scheme	Change relative to BAU
<1990	1066331	986827	-7,46%
1990	326086	292697	-10,24%
1991	432726	396534	-8,36%
1992	606572	560717	-7,56%
1993	564715	520041	-7,91%
1994	843530	784693	-6,98%
1995	1061169	998048	-5,95%
1996	1432299	1364515	-4,73%
1997	1489797	1438897	-3,42%
1998	1654702	1608410	-2,80%
1999	2036134	2012964	-1,14%

Build year	# vehicles BAU	# vehicles Scheme	Change relative to BAU
2000	2283083	2282932	-0,01%
2001	2381337	2381337	0,00%
2002	2516721	2516721	0,00%
2003	2219273	2219273	0,00%
2004	2305801	2305801	0,00%
2005	2421253	2421253	0,00%
2006	2245439	2245439	0,00%
2007	2324131	2324131	0,00%
2008	2407196	2407196	0,00%
2009	2044449	2594318	26,90%
2010	1762742	1762742	0,00%

1.2 Change in penetration rate of safety features due to the fleet renewal scheme

Safety feature: ESC

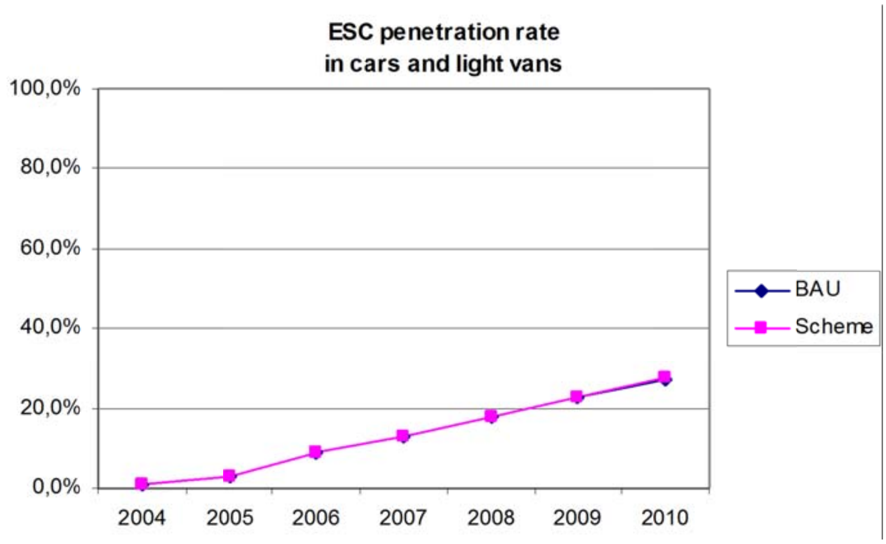
Table 14 presents the penetration rates of Electronic Stability Control (ESC) in light vehicles for the 'BAU scenario' as given by Grošanić & Assenmacher (2007). The penetration rate in 2010 for the "with fleet renewal scheme scenario" was obtained as shown in the Appendix.

Assumptions:

The penetration rates for heavy vans is assumed to be 75 percent of the lighter vehicles (passenger and light vans).

Table 14. **Penetration rate of ESC**

	Penetration rate in fleet			
	Cars and light vans		Heavy vans	
	BAU	Scheme	BAU	Scheme
2004	1,0%	1,0%	0,8%	0,8%
2005	3,0%	3,0%	2,3%	2,3%
2006	9,0%	9,0%	6,8%	6,8%
2007	13,0%	13,0%	9,8%	9,8%
2008	18,0%	18,0%	13,5%	13,5%
2009	23,0%	23,0%	17,3%	17,3%
2010	**27,0%**	**27,7%**	**20,3%**	**20,3%**



Safety feature: SAB

Assumptions:

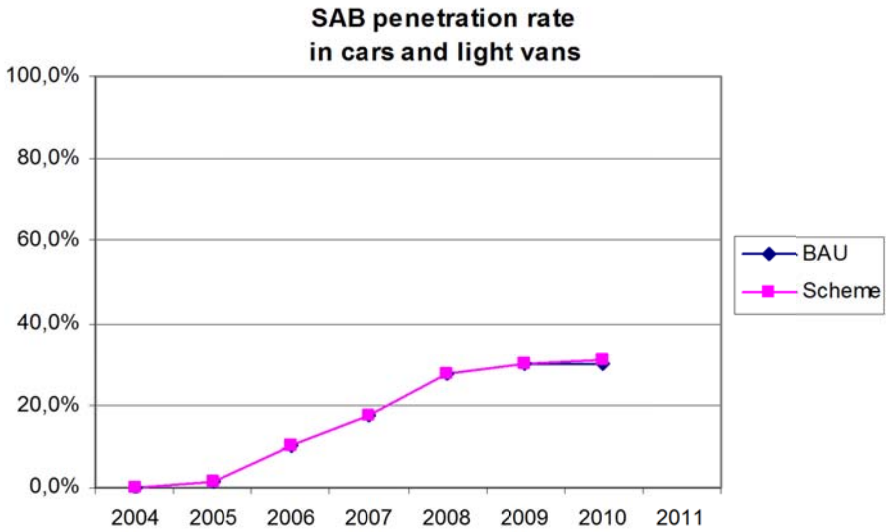
Given the lack of data, the penetration rate of the Side Airbag (SAB) in France was estimated by assuming it equal to the penetration rate of SAB in the United States, corrected by the ratio between the ESC figures from France and the United States.

SAB(FR) = SAB(US) x ESC(FR)/ESC(US)

The penetration rate of the SAB in heavy vans is assumed to be 75 percent of the lighter vehicles.

Table 15. **Penetration rate of SAB**

	Penetration rate in fleet			
	Cars and light vans		Heavy vans	
	BAU	Scheme	BAU	Scheme
2004	0,0%	0,0%	0,0%	0,0%
2005	1,6%	1,6%	1,2%	1,2%
2006	10,0%	10,0%	7,5%	7,5%
2007	17,3%	17,3%	13,0%	13,0%
2008	27,8%	27,8%	20,8%	20,8%
2009	29,9%	29,9%	22,4%	22,4%
2010	**30,1%**	**31,0%**	**22,6%**	**22,7%**



Note: Given that the numbers of scrapped and added heavy vans are low, the penetration rate due to the fleet renewal scheme does not change and therefore, it has not been included in the graphs.

Step 2

2.1 Safety impact of specific safety features

Table 16. **Injury and fatality rates**

Year	Injury rate per million VKT	Fatality rate per million VKT
2010	0.055	0.003

These figures are based on the yearly vehicle-kilometers traveled (VKT)[16] in France and on data of the total injured and killed victims until 2008 (obtained from the *CARE - European Road Accident Database*) extrapolated to 2010.

Further assumptions:

3. Proportion of number of injured occupants in crashed passenger cars (based on Dutch accidents)

Single accidents	43%
Multiple accidents	57%

Effects of ESC

Single accidents	46%	reduction in injured occupants (Erke, 2008)

4. Proportion of number of injured occupants in crashed passenger cars (based on Dutch accidents)

Side impacts	35%

16. Data on VKT in France were provided by TNO.

Effects of SAB

Head airbag	37%	reduction in injured occupants (assuming same percentage as killed occupants as reported by McCartt & Kyrychenko (2007))
Thorax airbag	26%	reduction in injured occupants (assuming same percentage as killed occupants as reported by McCartt & Kyrychenko (2007))

The table below shows the effects on safety that the fleet renewal scheme generates, for three safety features.

Table 17. **Estimates for 2010**

Number of injuries due to specific accident type				
Scenario 1: BAU	Scenario 2: with fleet renewal scheme	Difference	% change	Safety feature
11520	11500	20	0.17%	ESC
9632	9619	13	0.13%	SAB head
9945	9936	9	0.09%	SAB thorax

Note that the column 'change' refers to the reduction in injuries caused by certain accident type, not to the total. This means that in the case of ESC, for instance, the change in percentage due to the fleet renewal scheme implies that there is 0.17 percent reduction in injuries due to single accidents.

2.2 Overall effect of vehicle safety

According to Broughton (2003) the effect on safety of vehicle improvement is a reduction of 1% in the number of serious injured car occupants per year, the effect on safety of the fleet renewal scheme is the following:

*Overall effect = 1% * (AVGYadded – AVGYscrapped) * % of fleet scrapped * % AVGVTKscrapped*

Where: AVGY is the average built year of the added or scrapped vehicles

AVGVTK scrapped is the average VKT of scrapped vehicles

Table 18. **Overall general effect of fleet renewal scheme**

		Calculation
Injury reduction	*1%*	*1%*
AVGY scrapped	*1993*	*16*
AVGY added	*2009*	
AVG mill VTK scrapped	*0.007*	*0.49*
AVG mill VTK fleet	*0.015*	
% of fleet scrapped		*1.5*
Overall effect		***0.12%***

The overall effect of the fleet renewal scheme is a reduction of 0.12% of the serious injured occupants in crashed vehicles.

2.3 Effect of the fleet renewal scheme in France on road safety

Table 19 below shows the percentage of injury reduction due to the existence of the different safety features. The figures shown in the table are relative to the total estimated injuries caused by all types of accidents. Note that the difference with Table 18 is that the latter provides the injury reduction relative to the accident type for which the safety feature in question has an effect, not the total.

Estimated total number of injuries in 2010 :	**Injury rate(**Table 16**) x VKT (**Table 20**)=30,399**

Table 19. **Injury reduction due to the fleet renewal scheme**

Safety feature	Injury reduction (relative to total)
ESC	0.08%
SAB head	0.05%
SAB thorax	0.02%
Overall effect	0.12%
Total	0.27%

The total reduction in serious injuries can therefore be estimated as:

Total reduction: 0.08 + 0.05 + 0.02 + 0.12 = 0.27 %

By adding up all these effects there is certainly a slight overlap but given the magnitude, it can be neglected.

2.4 Monetized impact of the fleet renewal scheme in France

The safety effects of the fleet renewal scheme in terms of saved costs are calculated according to the method known as the '1 million euro test' (introduced by the European Commission in 1995, see Appendix of the US report). This method assumes that injuries (all severities) and crashes with material damage only (MDO) are saved in the same proportion as fatalities.

The social cost of road crashes in France amounted to 24.7 billion euro in 2008 (Ministère de l'Ecologie, 2009: 18). This includes direct and indirect economic costs (e.g. medical costs, property damage and production loss) as well as human costs. The number of registered fatalities in 2008 was 4.443 (Ministère de l'Ecologie, 2009: 11). The costs per fatality, including costs of injuries and MDO crashes, are thus 5.6 million euro per fatality (price level 2008).

The estimated reduction in fatalities is the following:

Table 20. **Estimated fatality reduction due to France fleet renewal scheme**

	Year 2010
a. Estimated total number of VKT	552,707 million (source TNO)
b. Fatality rate (see Table 10)	0.003 per million VKT
c. Estimated number of fatalities (a*b)	1658
d. Estimated fatality reduction (total Table 6 * c)	0.26% * 1658 = **4.5 fatalities**

This means that the monetary benefits of the France fleet renewal scheme for 2010 are estimated at **25 million euro** (4.5 fatalities * 5.6 million euro).

Calculation of penetration rates

ESC in Year 2010

	BAU				Added			Scheme	
	Fleet	Penetration in the fleet	Fleet with ESC	Fleet without ESC	New fleet	new fleet ESC	new fleet without ESC	Fleet with ESC	Penetration rate
Light vehicles	33554208	0,270	9059636	24494572	546231	251266	294965	**9310902**	0,277
Heavy vans	2871281	0,203	581434	2289847	3638	1255	2383	**582690**	0,203
			Pf * Fleet		Σ Fi	Σ Psvi * Fi			

Pf: penetration in fleet

Psvi: penetration of sold vehicles built in year i

Fi: Vehicles sold built in year i

SAB in Year 2010

	BAU				Added			Scheme	
	Fleet	Penetration in the fleet	Fleet with SAB	Fleet without SAB	New fleet	new fleet SAB	new fleet without SAB	Fleet with SAB	Penetration rate
Light vehicles	33554208	0,301	10113082	23441126	546231	273115	273115	**10386197**	0,310
Heavy vans	2871281	0,226	649043	2222238	3638	1819	1819	**650862**	0,227

The following penetration rates in sold vehicles (cars and light vans) were used. Note that the penetration of SAB was assumed to be equal to the ESC.

Year	ESC penetration in sold vehicles	SAB penetration in sold vehicles
2004	0,39	0,39
2005	0,42	0,42
2006	0,43	0,43
2007	0,46	0,46
2008	0,42	0,42
2009	0,46	0,46
2010	0,50	0,50

Source: eSafety – Implementation Status Survey 2007, Final Report 2008 and Robert Bosch GmbH (2009)

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