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Feebate and scrappage policy instruments

Environmental and economic impacts for the EU27

Françoise Nemry, Kris Vanherle, Wiebke Zimmer, Andreas Uihlein, Aurélien Genty, José-Manuel Rueda-Cantuche, Ignazio Mongelli, Frederik Neuwahl, Luis Delgado, Florian Hacker, Stefan Seum, Matthias Buchert, Wolfgang Schade

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European Commission
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Contact information
Address: Edificio Expo. c/ Inca Garcilaso, 3. E-41092 Seville (Spain)
E-mail: jrc-ipts-secretariat@ec.europa.eu
Tel.: +34 954488318
Fax: +34 954488300

http://ipts.jrc.ec.europa.eu
http://www.jrc.ec.europa.eu

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Preface

This report presents the results and conclusions of research carried out by the JRC/IPTS analysing two demand-side policy instruments that can help improve the environmental performance of cars: the first instrument, the feebate system, is a way to adjust the registration taxes according to the CO_2 car emissions; the second instrument, the scrappage policy, is intended to encourage the owners of old cars to scrap their cars sooner.

The potential for and the consequences of technical options for reducing car weight are also analysed.

This report develops a comprehensive assessment of these policy options at the EU level, covering all major environmental life-cycle impacts and the different economic impacts. The report builds upon IPTS research, supported by a study subcontracted to research consortium led by Transport&Mobility Leuven (TML) and involving Öko-Institut and ISI-Fraunhofer.

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Abbreviations

AD: Abiotic depletion

AP: Acidification potential

BW: Bulk waste

CW: Curb weight

ELV: End-of-life vehicle

EOL: End-of-Life

EP: Eutrophication potential

I/M: Inspection/Maintenance Programme

PCDS: Small diesel passenger car

PCDM: Medium diesel passenger car

PCDB: Big diesel passenger car

PCGS: Small gasoline passenger car

PCGM: Medium gasoline passenger car

PCGB: Big gasoline passenger car

PGM: Platinum Group of Metals

PM: Particulate matters

POCP: Photochemical Pollution

PP: Pivot point in feebate

pkm: passenger-kilometre

TTW: Tank-to-wheel

vkm: vehicle-kilometre

VOC: Volatile organic compound

WTW: Well-to-wheel

WTT: Well-to-tank

Executive Summary

Introduction

Over the last years, efforts have been made and new policy instruments have been introduced to improve the environmental performance of cars. The Euro5 and Euro6 emission standards will lead to substantial improvement of air quality as a result of lower exhaust gas emissions from cars, especially concerning nitrogen oxide (NO_X) and particulates. With the new EU regulation on carbon dioxide (CO_2) emissions from cars, car manufacturers are committed to reducing car emissions. In addition to these supply-side policies, consumer-side measures are also considered, including the labelling of CO_2 car emissions and the inclusion of CO_2 elements in road taxes.

This report presents the results and conclusions of research carried out by the JRC/IPTS analysing such demand-side measures, with a focus on two cases. The first instrument, the **feebate system**, is a way to differentiate the registration taxes according to CO_2 car emissions. The second instrument, the **scrappage policy,** is intended to encourage the owners of old cars to scrap their car sooner.

The potential and the impacts of technical options for reducing car weight are also analysed.

This report develops a comprehensive assessment of these policy options at the EU level, covering all major environmental life-cycle impacts and the different economic impacts, including impacts on the consumer, on public finance, and on the industry sectors. The report builds upon IPTS research, supported by a study subcontracted to research consortium led by Transport&Mobility Leuven (TML) and involving Öko-Institut and ISI-Fraunhofer.

Methodology

The methodological approach combines different analytical tools:

1. The TREMOVE model which is a policy assessment model designed to study the effects of different transport policies.
2. A new database and a new TREMOVE module containing information about the composition of new and End-of-Life Vehicles (ELVs) and of spare car parts in the EU27, and a life-cycle assessment calculation module.
3. The EU27 Input-Output tables fed with TREMOVE outputs are used to analyse the impacts of policy options on the overall economy.

The environmental and economic impacts have been analysed against baseline assumptions and scenario common to these three tools.

Regarding transport, the assumptions were consistent with the latest modelling with TREMOVE. The assumptions about CO_2 emissions from cars have been aligned with those made in the impact assessment of the regulation on CO_2 from cars, namely assuming a constant average CO_2 emission level of new cars from 2006 onwards (160 g CO_2/km). Euro5 and Euro6 emission standards are included in the baseline.

Lightweight case

The potential of lightweight car options was assessed as an alternative baseline based on assumptions on car compositions. The literature reviewed suggests that a weight reduction of up to 25-30% is technically achievable in the medium term by means of an intensive use of lightweight materials (e.g. aluminium, high-strength steels, and/or magnesium). However, a broad market penetration of such light cars appears much less realistic. Therefore, the quantified scenario variant was limited to a 15% reduction by the year 2030, and was assumed to be primarily based on an increased use of high-strength steels and aluminium.

As a result of the fuel savings from the gradual car weight reduction, it is estimated that 246 Mt CO_2-eq could be avoided over the period 2010 to 2020. Although the regulation on CO_2 emissions from cars focuses on new engine technologies, car lightweighting thus represents a significant potential for reducing CO_2 emission from cars.

Feebate

The consumer preference for greater efficiency cars can be enhanced by introducing CO_2 elements in registration and circulation taxes. One particular case is the feebate (or bonus/malus) system, as introduced recently in several EU countries. A feebate system combines elements of both a fee and a rebate, thus providing a price incentive towards cars with lower CO_2 emission levels. The idea is that the rebate granted for cleaner vehicles is financed by the fees imposed on vehicles that are less clean.

The so-called pivot point is the CO_2 emission level below which a rebate (bonus) is granted and above-which a fee (malus) is applied. This pivot-point (PP) can be set in accordance with CO_2 emission targets as defined by the new regulation on CO_2 emissions from cars (e.g. 130 g/km by 2012 and 95 g/km by 2020). In the case of a discontinuous system, it could be coupled with the labelling of CO_2 car emissions, especially when both systems are using a common CO_2 emissions classification (e.g. classes A, B,..., G). The system may also be designed in accordance with public budget constraints.

Several feebate cases were subjected to assessment, covering different pivot points (120 g CO_2/km or 140 g CO_2/km), different rebate and/or fee levels and function shapes. The instrument is assumed to be in place over the period 2010-2015.

The assessment of the environmental and economic effects of this scheme was based on the modeling of the reaction of the car purchaser to the new taxation regime, and response in terms of new preferred car fuel efficiency, making use of available information about the car purchase preferences in terms of CO_2 emission performance, and abatement costs.

There is obvious room for improvement of the modeling approach and the data used. Nevertheless, some key conclusions can be drawn from this assessment.

In general, a feebate system is almost neutral in terms of total new car sales but there is a clear shift to smaller cars and, given the incentive to shift the purchase decisions to lower CO_2 emitting cars, the policy instrument results in reductions of GHG car emissions. This holds true both in the short term (by 2015) and in the long term (by 2020). Positive effects on air pollution, though of less importance, are also expected. These conclusions are also valid when considering the life-cycle impacts.

In total, households would spend more money on cars because the higher cost is not fully compensated by the fuel savings. Budget neutrality for the government is shown to be achievable, especially in the short term, but may be more difficult to guarantee in the longer term.

In general, the real-life outcome may vary depending on the initial purchase patterns and the initial taxation regime which both depend on the situation of each country.

At a macro-economic level, the sectors directly concerned (the automotive sector and the supply sectors, metal sector) would gain both in terms of value added and employment. Depending on the feebate scheme, the net effects on other sectors would be either neutral or negative. In total a small net creation of employment is expected in most cases.

In conclusion, the feebate instrument would benefit both the environment and the economy.

Cash for replacement policy

Old cars have a disproportionate contribution to total air emissions from the European car fleet because they are equipped with inefficient air emission abatement technologies. The decommissioning of these high-polluting cars can be accelerated if an incentive is granted to car owners who scrap their old cars. Generally, two types of scrappage schemes exist:

- A cash-for-scrappage policy option, under which the incentives available *disregard the subsequent replacement car-owner decision* (e.g. no replacement and/or purchase of a public transport pass).
- A cash-for-replacement option, under which the incentive payment is *conditional* upon a specific kind of replacement vehicle being chosen (e.g. a new-model car).

The possible types of scrappage schemes can differ in terms of duration, eligibility criteria to the subsidy (e.g. age of the old car, characteristics of the new cars), and subsidy level, all of which may be adjusted to fit with the primary aim of the policy (i.e. improvement of air quality vs. supporting the car industry).

This report focuses on the assessment of the cash-for-replacement policy, covering a series of illustrative cases where the key parameters chosen were the age of the old car (8 to 10 years) and the subsidy level (1000€ to 2500€, with possible changes throughout the policy period). The policy is assumed to be in place over the period 2010-2015.

Further developments in TREMOVE have been made to model the policy, which consisted of converting the initially exogenous scrappage function into an endogenous function. This conversion was built upon available data on accidents, and on the relevant costs factors (e.g. repair and maintenance cost, costs of new cars, and second-hand market price).

The method could, in the future, be refined and enriched with more accurate data. Nevertheless, some key conclusions can be drawn from this assessment.

The scrappage policy leads to a quick car fleet renewal. Most of the effects are observed within the first two years of the scheme, unless the subsidy starts with low levels and then gradually increases. The strength of the effects is predominantly determined by the subsidy level. Dramatic sales increases are projected with subsidies as high as 2000€.

The rapid renewal of the car fleet is accompanied by acceleration in the expected decline of air emissions. The conclusions regarding CO_2 emissions are more ambiguous. In any case, the effects would disappear after phasing out the scheme.

The expected leap in energy efficiency from the old scrapped cars to the new ones during the operation of the policy (2010-2015) would not be sufficient to enable real gains in energy and CO_2 emissions. In case of a delayed scheme, the gain would be higher because it would operate under a more radical decline of new car emissions (130 g/km by 2015, 95 g/km by 2020).

Also, given the fact that the scrappage policy instrument would, in the short term, pull up sales of slightly more efficient cars, the car fleet renewal would later be reduced, when car emissions are substantially declining. This means that the scrappage policy could potentially reduce the effects of the policy target.

Thus, from an environmental perspective, it can thus be concluded that the scrappage policy (applied alone) would come late with regard to air pollution and too early with regard to greenhouse gas emissions.

The impacts from car manufacturing, which would substantially increase, partly compensate for well-to-wheel emission reductions.

Overall, the household expenditures for cars would increase alongside the tax revenues from passenger cars. The policy would clearly benefit employment in the automotive sector and other related sectors. However, this would be accompanied by employment losses in other sectors. In total, provided that fast adjustments occur, the scrappage policy would result in a small net creation of employment.

Compared strengths and weaknesses

The results for the two policy instruments are summarized and compared in Table 1.

The feebate system offers clear, significant and long term benefits with regard to energy savings and CO_2 emission reductions. Thus, it would help to reach the goal of the EU strategy to reduce CO_2 car emissions. The emission reductions (about 236 Mt CO_2-eq, over the period 2010-2020) would indeed complement the expected effects of the supply-side element of the strategy, namely, the regulation on CO_2 car emissions.

The effects of the scrappage policy on CO_2 emissions are not as clear. On the other hand, it has rapid and important effects in terms of air pollutant emissions, even though they mainly consist of bringing forward baseline improvements by two to four years.

Moderate and high increases in car expenditures for the consumers are expected under the feebate and the scrappage policy, respectively. The short term revenue for the governments is expected to increase in both cases although specific feebate schemes might result in net losses.

Both instruments are expected to result in a comparable small net creation of employment at EU27 level. However, the sector distribution of benefits would differ: the scrappage policy would the most benefit the automotive and related sectors. It would however entail employment losses in most other sectors, whereas, the feebate instrument offers options to limit such negative consequences.

This report shows that the combination of both instruments would represent an advantage for the environment. The respective environmental benefits would indeed be cumulated, thus ensuring long-term reductions in greenhouse gas emissions and, also accelerating the already expected improvement for air quality.

Other options to secure the environmental benefits were not analysed in the study. This would for instance consist in applying CO2-based criteria on the new car replacing the scrapped one.

Regarding effects on the economy, the coupling would enhance the positive effects on employment in the automotive-related sectors. The accumulation effect would however also prevail for the negative effects on the other sectors.

When using these results and conclusions, it is important to bear in mind that the research was initiated and conducted within a favorable economic context. An interpretation of these results in light of the current economic crisis and low oil prices needs to be made with caution.

Table 1: Overview of results for the feebate and for the scrappage policies

Numbers give the percentage changes relative to the corresponding total baseline quantities (first, average value; second, range of values in italic)

	Feebate policy		Scrappage policy	
Car sales				
2010 - 2015				
Total	-0.1%	*-0.3% to 0.1%*	25.4%	*4.7% to 41.5%*
Fuel	Shift from diesel to petrol		Diesel cars share slightly increased in the fleet	
Size	Possible shift from medium to small		Big/medium cars share slightly increased in the fleet	
2010 - 2020	-0.3%	*-0.5% to -0.2%*	6.0%	*1.1%* to *13.7%*
Environmental impacts				
Well-to-wheel emissions				
2010 - 2015				
GHG	-1.6%	*-2.6% to -0.7%*	-1.3%	*-2.6% to -0.4%* *(Most probably overestimated reductions)*
CO	-0.1%	*-0.1% to -0.1%*	-18.4%	*-29.9% to -7.0%*
NO_x	-0.4%	*-0.7% to -0.2%*	-3.8%	*-6.7% to -1.4%*
SO_x	-1.7%	*-2.7% to -0.7%*	-1.9%	*-3.8% to -0.6%*
VOC	-0.4%	*-0.7% to -0.2%*	-8.8%	*-13.0% to -3.8%*
PM	-0.9%	*-1.5% to -0.4%*	-2.6%	*-5.6% to -0.7%*
2010 - 2020				
GHG	-1.8%	*-2.9% to -0.8%*	-0.8%	*-1.3% to -0.3%* *(Most probably overestimated reductions)*
NO_x, PM	Effects declining slowly up to 2020		Baseline emission reductions expected over 2010-2020 brought forward by 2 years	
CO, VOC	Effects declining slowly up to 2020		Baseline emission reductions expected over 2010-2020 brought forward by 4 years	
Life cycle impacts (2010-2015)	Of the same order of impacts on Well-to-wheel emissions		Well-to-wheel emissions reductions partly compensated for by the increased impacts from production of cars and spare parts	
Economic impacts				
2010-2015				
Total costs for the consumer	0.9%	*0.5% to 1.2%*	4.4%	*1.0% to 9.0%*
Total tax revenue	1.2%	*-0.4% to 2.6%*	2.9%	*0.5% to 6.4%*
Total employment	0.04%	*-0.01% to 0.08%*	0.02%	*0.00% to 0.06%*

1 Introduction

This report presents the results and conclusions of research carried out by the JRC/IPTS analysing two policy instruments aimed at reducing the environmental impacts of passenger cars. The research was conducted on the request of DGENV and complements the IMPRO-car report (Nemry et al., 2008)[1] which reviewed and assessed the environmental impacts and costs of technological improvements for reducing the life-cycle impacts from cars. That study primarily addressed the question on the extent to which supply-side policy instruments, additional to those already in place or in preparation, could help improve the environmental performance of cars.

The main focus of this report is on consumer-side policies, analysing more specifically two main policy instruments:

- Policy options to encourage consumers to buy low CO_2 emitting cars.
- Policy options to encourage the earlier car retirement with a view to accelerate the market penetration of cleaner technologies.

The potential and the consequences of technical options for reducing car weight while keeping the same utility level were also assessed.

This report builds upon JRC/IPTS research and a study subcontracted to research consortium led by Transport&Mobility Leuven (TML) and involving Oko-Institut and ISI-Fraunhofer.

Over the past recent years, efforts and regulatory instruments have been put in place, with a view to improving the environmental performance of cars. Major examples are the tightening of Euro standards, towards Euro5 and Euro6 which will lead to substantial improvement in air quality as a result of lower exhaust gas emissions from cars (especially NO_x, particulates).

Very recently, the EU has adopted a new regulation to reduce CO_2 car emissions. This new regulation is part of a more comprehensive strategy to reduce the CO_2 emissions from cars, in which demand-side measures are also envisaged (raising awareness and taking fiscal measures).

This policy framework was taken into account when specifying the policy options considered in this study. Both policy instruments should indeed be designed in such a way as to enable synergies. Also, the literature was reviewed where the policy options are described and assessed in terms of their respective strengths and weaknesses. This helped further specifying the project scope in terms of considered policy cases.

Finally, a methodology was set up and implemented in order to perform an ex ante assessment of the policy cases, including the environmental and economic impacts for the EU27.

Chapter 2 and Chapter 3 describe the policy background and the main findings from literature regarding the two possible options considered in the project, respectively.

Chapter 4 describes the overall methodology for the assessment, including the TREMOVE modeling, life-cycle assessments, and the Input-Output table approach and how these tools have been combined to provide a comprehensive analysis.

Chapter 5 presents the main assumptions regarding the baseline scenario built with the TREMOVE model which served as the reference to subsequently assess the two policy options. An alternative baseline is also presented where more ambitious assumptions are made in terms of reducing the weight of cars.

Chapter 6 and Chapter 7 present the approach and results regarding the analysis of the feebate and the scrappage policy cases. Chapter 8 provides the results for the combination of those policy options.

Conclusions are then presented in chapter 9.

2 Policy background

2.1 Strategy to reduce CO_2 emissions from cars

In 2007, the European Commission proposed a new strategy to reduce CO_2 emissions from cars up to 120 g CO_2/km by 2012 (EC, 2007)[2], based on a set of measures for influencing both the supply and demand sides of the EU market for cars and vans.

The strategy was formerly based upon voluntary commitments by the European, Japanese and Korean car industries to reduce CO_2 emissions from their new cars sold in the EU to an average of 140g/km by 2008/2009. However, in light of the average CO_2 emissions over the period (from 186 g CO_2/km to 163 g CO_2/km between 1995 and 2004 – see most up-to-date values in (EC, 2006)[3] -, a revised strategy was proposed in order to achieve faster and stronger emission reductions.

One of the main measures of the revised strategy consists of supply-side measures and especially the EU regulation to reduce CO_2 emissions from new cars and vans (see Section 2.2) aimed of reducing the emissions of the new car fleet to 130 g CO_2/km by 2015, by means of improvement in vehicle motor technology. Additional measures are aimed at further reducing the emissions by 10 g CO_2/km, which include other technological improvements and an increase of the use of biofuels.

Consumer-side measures are also envisaged, including an amendment to the car labelling directive and the encouragement of Member States to base road taxes on car CO_2 emissions.

2.2 Regulatory CO_2 emission reduction target

The regulation on CO_2 from cars[4] sets the average CO_2 emissions for new passenger cars at 130 g CO_2/km in 2015. The proposal is based on the monitoring of **specific emissions of CO_2** of passenger cars which is given by the so-called **limit value curve**.

For each calendar year, the specific emission target will be calculated as the average of the specific emissions of CO_2 of each manufactured car.

In 2012, 65% of each manufacturer's newly registered cars must comply on average with the limit value curve set by the legislation. This will be raised to 75% in 2013, 80% in 2014, and 100% from 2015 onwards.

For the period 2012-2015, the limit value curve is as follows:

$$\textit{Specific emissions of } CO_2 \textit{ (g/km)} = 130 \textit{ g/km} + a \times (M - M_0)$$

$$\textit{where: } M = \textit{mass in kg}, M_0 = 1372 \textit{ kg}, a = 0.0457 \textit{ (1000 km)}^{-1}$$

That curve is set in such a way that heavier cars will have to improve more than lighter cars. However, manufacturers will still be able to make cars with emissions above the limit value curve provided that these are balanced by cars which are below the curve. The progress of manufacturers will be monitored each year by the Member States on the basis of new car registration data.

From 2016 onwards, the coefficient M_0 will be updated.

In case car manufacturers do not comply with these emission limits, they will have to pay penalty which is set to increase over time.

A **longer target of 95 g CO_2/km** is specified for the year 2020 and associated modalities will have to be defined in a review to be completed before 2013.

2.3 Raising consumer awareness

As part of the new Community strategy on CO_2 emissions from cars, the Labelling Directive (Directive 1999/94/EC) is being revised. The adoption of a proposal is foreseen for 2009. The purpose of the existing directive is to ensure that information relating to the fuel economy and CO_2 emissions of new passenger cars offered for sale or lease in the Community is made available to consumers in order to enable consumers to make an informed choice (Article 1).
To this end, a label on fuel efficiency and CO_2 emissions has to be displayed near each passenger car model at the point of sale (Art.3 and Annex I). The harmonisation and specification of the format of the label fall under the revision process. Several options are open, especially the choice between an "absolute" and a "relative" labelling: an isolated figure on fuel consumption or CO_2 emissions does not mean much to the consumer and it is important to put this information into context by using, for instance, efficiency classes (i.e. A (best) to G (worst) classes). There are two ways of providing this comparison:

- **Absolute labelling**: the A-G classes relate to the absolute emission level of the car. A car with very low emissions would get an "A" label, whereas one with very high emissions would get a "G" regardless of their size or type.
- **Relative labelling**: the A-G classes relate to the emission levels of cars in the same category in terms of size or type. Thus, a large car can still have an "A" label if it is among the best-performing cars in that category. Likewise, a small car can have a "G" label if other cars from the same category have even lower emissions.

A combination of elements of absolute and relative labels is also conceivable.

A point worth noting is that this updated instrument would provide the consumer with key information regarding the environmental performance of cars, thus, to a large extent meeting the goal of the eco-label system.

3 Demand-side policy options for the analysis

3.1 CO_2 elements in registration taxes and feebate systems

The energy efficiency and CO_2 emission levels of cars will gradually improve as a result of the new regulation on CO_2 emissions from cars (see section 2.2). The consumer preference to higher efficiency cars may also be enhanced through fiscal measures. This is actually part of the EU strategy to reduce CO_2 emissions from cars (section 2.1).

Fiscal measures may consist of introducing CO_2 elements in registration and circulation taxes. This is actually already in place in some EU Member States (Table 2).

A review of the structure of registration taxes in the different Member States reveals many different implemented options but a common feature is that they consist of increasing the relative price of the least environmentally-friendly cars in order to stimulate their substitution with more efficient ones. The differentiation can be made according to different criteria. In most cases, this is applied to new cars only. However, the system could also be applied to second-hand cars. In that case, criteria may have to be set per age segment.

These systems and their environmental efficiency are discussed in the literature (e.g. Covec, 2005)[5]. The advantages of such instruments on energy efficiency and CO_2 emissions are generally acknowledged. Some perverse effects have also to be considered.

As regards a **differentiation of registration taxes** according to the car energy efficiency or CO_2 emission levels, the possible perverse effect is linked to the fact that new larger vehicles would, in practice, be made more expensive. This means that people who would anyway keep driving such big cars would tend to shift to the second-hand car market. This would also result in longer big car life (e.g. SUV), and consequently a lower fuel-efficiency big cars fleet.
Furthermore, the evidence is weak in terms of a correlation between car purchases and taxation costs in European countries.

In addition, a higher registration tax tends to be compensated by car retailers with lower purchase car prices (e.g. Denmark). This effect is enhanced by the lack of harmonization of registration taxes across EU because the lower purchase price in one country can be compensated for another country with a higher purchase price so that at the EU level the car manufacturers balance their profit margin.

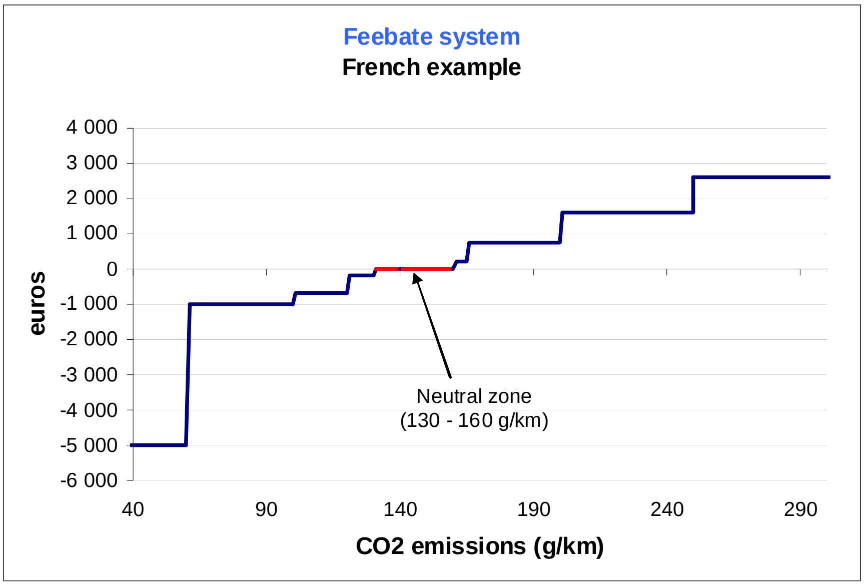
Amongst the various differentiated registration tax schemes, one case was recently introduced in several countries (e.g. France, Belgium), which is the **Feebate system** (or "bonus-malus" system). This system combines elements of both a fee (malus) and a rebate (bonus). The system is intended to be designed in such a way that the rebate which is granted for cleaner vehicles is financed by the fees imposed on less clean vehicles.

Table 2: Differentiated registration systems in place in several EU countries, including feebate systems (source: ACEA, 2008)

	Austria	Belgium	Cyprus	Finland	France	Ireland	Portugal	Spain	Sweden
Feebate system	yes	'- Federal state tax: bonus for low emitting cars - Additional Feebate system applicable in Walloon Region	yes	no	yes	only malus component	only malus component	yes (0€ tax below pivot-point)	yes
Possible link with CO2 labelling	no	yes (Feebate - Wallonia)	yes	no	yes	yes	not straightforward	yes	no
Pivot point / neutral zone	120-180 g CO2/km	Federal state: 115 g CO2/km Walloon region: neutral zone 145 to 195 g CO2/km	200 g CO2/km	NR	130-160 g CO2/km	NR	NR	120 g CO2/km	120 g CO2/km (diesel, petrol, electric hybrid cars) RK : cars driven with biofuels or electricity with consumption below certain levels also eligible
Character of tax function	-300 € below 120 g/km +25€ per g/km in excess to 180 g/km	Federal state bonus: % of purchase price Feebate system in Wallonia: discountinuous	discountinuous with malus levels as % of registration tax as defined by car cylinder classes	continuous function giving the % tax as a linear function of CO2 emissions (10% minimum, 40% maximum)	discountinuous with fix bonus/malus levels	discountinuous	continuous functions defined for each CO2 emission class, specific for diesel and petrol cars	discountinuous	one unique fix bonus
Absolute / Relative	absolute	absolute			absolute	absolute		absolute	absolute
Link with other pollutant	additional tax for particles (diesel cars)				no	no		no	diesel cars must have a particle filter or emit less than 0.005 g particles/km
Specific treatments	hybrid cars, E85, CNG, LPG, hydrogen, DPF						hybrid and electric cars diesel cars with PM emissions < 0.005 g/km		

One element of the system is the so-called pivot point (or neutral zone) which is the CO_2 emission level (or emission range) below which a bonus is granted and above-which a malus is applied. As an example, the system in place in France is displayed in Figure 1.

Figure 1: Illustration of a feebate system (French case)



Several possibilities exist, even amongst the different feebate systems, covering the following features:

- bonus/malus set as a continuous versus a discontinuous function of CO_2 emissions
- fixed levels versus levels proportionate to car parameters (e.g. car engine cylinder)
- absolute / relative system
- link with other pollutants (e.g. particles from diesel cars)
- coexisting versus substituting pre-existing registration taxes
- special cases (e.g. hybrid cars)
- fleet coverage: new cars versus new cars and second hand cars

Compared to the more traditional differentiated registration tax schemes, one may expect an enhancement of the price incentive to the most energy efficient cars with a **feebate system.** The pivot point can be set in accordance with the CO_2 emission targets defined by the new regulation on CO_2 emissions from cars (e.g. 130 g/km target). A discontinuous system could be coupled with the CO_2 car labelling, especially when both systems are using a common CO_2 emissions classification (e.g. classes A, B, …, G.). In addition, the system may, in theory, be designed in such a way as to offer budget neutrality. However, existing examples show that this is uneasy to ex ante assess. Financial imbalance can not be excluded if the effects of the systems are not well anticipated. This was the unexpected experience in the US (Arizona) as described by Covec[5].

Simulations have also shown that feebates can deliver important emission reductions (BenDor et al., 2004)[6].

Given the potential synergy between the revised labelling of CO_2 emissions of cars, the project concentrated on feebate systems. Feebate systems considered in this report have been extended to cases where the bonus part is removed.

3.2 Early car retirement policy options

In 2005, about 32% of the EU-25 car fleet was composed of cars older than 10 years[a]. These cars contribute disproportionately high to the total emissions from the European car fleet because, unlike new cars, they are equipped with obsolete air emissions abatement technologies and also because, over time, exhaust gas cleaning systems deteriorate.

The decommissioning of these high-polluting cars can be accelerated if an incentive is granted to car owners who scrap their old car. This is the essence of the scrappage policy instrument. The instrument has already been implemented in several countries in the past, especially since the 1990s (see Table 3). In the EU, scrappage schemes were introduced in Greece, Hungary, Denmark, Spain, France, Ireland and Italy (ECMT, 1999)[7].

In many cases, the aim was to improve air quality. Further goals were the support of national car industry[8]. The recent initiatives in e.g France ("prime a la casse"), Spain (VIVA plan replacing the PREVIA plan) and Germany are, to a large extent, meant to meet the second objective.

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[a] Based on TREMOVE data

Generally, two types of scrappage schemes exist:

- A cash-for-scrappage policy option, under which the incentives available *disregard the subsequent replacement car owner decision* (thus including no replacement and/or buying a public transport pass).
- A cash-for-replacement option, under which the incentive payment is *conditional* upon a specific kind of replacement vehicle being chosen (e.g. a new-model car).

The possible types of scrappage schemes can differ in terms of duration (temporary or permanent scrappage schemes), eligibility criteria (e.g. old car age, characteristics of the new car), and subsidy level.

These criteria might be set differently depending on the primary aim of the policy (improvement of air quality vs. support for the car industry, etc.).

Table 3: Scrappage schemes implemented in Europe in the 1990s

Country	Period	Requirement on the old car	Cash for replacement	Remarks
Greece	01/1991 - 03/1993	>10 years		First Athens then whole country
Hungary	09/1993 - …	2-stroke engine	Yes	First Budapest then whole country.
Denmark	01/1994 - 06/1995	>10 years		
France	02/1994 - 06/1995	>10 years	Yes	
	10/1995 - 09/1996	>8 years	Yes	
Spain	04/1994 - 06/1995	>10 years	Yes	Permanent since 04/1997
Ireland	06/1995 - 12/1997	>10 years	Yes	
Norway	01/1996	>10 years		
Italy	01/1997 - 12/1997	>10 years	Yes	
	02/1998 - 09/1998	>10 years	Yes	
	10/1997 - …	>10 years	Yes (new car fuelled with LPG, natural gas or electricity)	

The environmental and economic impacts of the scrappage schemes are assessed in various literature sources. Indirect effects (environmental effects from car production and car disposal) are often neglected. Nevertheless, some interesting conclusions can be drawn:

- Scrappage schemes are successful only **if future cars emit considerably less** than the old models, so that additional emissions from car manufacturing and End of Life are offset. This holds only partly true in the case of cash-for-scrappage (when a new car is bought from the incentive).
- Unless the policy is permanent, the effects are temporary; car sales increase during the policy period. After the end of the period, car sales drop because the natural renewal rate of the fleet would replace the same old vehicles some years later. This is also reflected in the car fleet emission pathways. The observed emission reductions during the policy implementation period rapidly disappear after it is no longer in place.
- As an age limit is generally introduced, some people tend to **delay** the envisaged scrappage. This may result in a **drop in car sales and car scrappage,** just before the start of the scrappage program.
- Some people tend to buy a bigger car than the car they had before. They may also travel more with the new car (e.g. due to enhanced reliability, higher energy efficiency).

Regarding the environmental impacts, the effects differ between air quality and GHG emissions. Consensus emerges regarding the benefits with regards to **air pollution**. For **GHG emissions**, the actual effects are highly dependent on the detailed design of the scheme and of possible off-setting side effects (e.g. rebound effects). The effects reported consist in either slight decrease or increase of CO_2 emissions. The expected energy efficiency leap between the old car scrapped and the new one and the timing of the policy instrument largely influences the outcome (ECMT, 1999)[7]. The effects of the additional manufactured cars (life-cycle impacts)[9,10], may also be significant and entail an increase of the life-cycle emissions.

Other effects reported consist in higher road safety and impacts on car manufacturing industries (boosts of car sales).

Equity concerns are often raised as the cash-for-replacement schemes might exclude people who can not afford to buy a new car, despite the incentive. This also means that the system would fail to cover a significant share of old cars.

Early car retirement may also be achieved through alternative policy options, including car taxation (higher taxes on older/higher emitting cars) and Inspection/Maintenance (I/M) programmes. These alternatives can also be combined with scrappage policies (I/M programme and scrappage schemes are often mentioned).

The design of a policy scheme (either a cash-for-replacement or a cash-for-scrappage) should imply to specify several criteria, including the duration of the instrument, the characteristics of the old cars (car age, air abatement standard, mileage) and the granted subsidy. These aspects are taken into account in this project (see section 7.2).

Other criteria might be considered. One of them is the public concerned: the subsidy could be applicable to anybody who disposes an old car or, alternatively, based on some criteria, for instance income. Such options were not assessed in this project.

3.3 Feebate system combined with scrappage schemes

The above discussion about the strengths and possible limitations of the feebate and the early car retirement policy options suggest that these limitations may be reduced if they are combined together:

- The perverse effect of differentiated registration (or circulation) taxes and of feebate systems on the second-hand car market could be reduced if the scheme is coupled with an incentive to an earlier old car retirement.
- On the other hand, the expected effects of the early car retirement policy in terms of accelerated clean technology penetration would be greater – especially regarding CO_2 emission reductions and fuel economy, if there is a reinforced incentive to buy the cleanest cars.

The combined schemes analyzed in this study link a feebate system (bonus-malus) with a car-for replacement policy.

4 Methodology

4.1 General approach

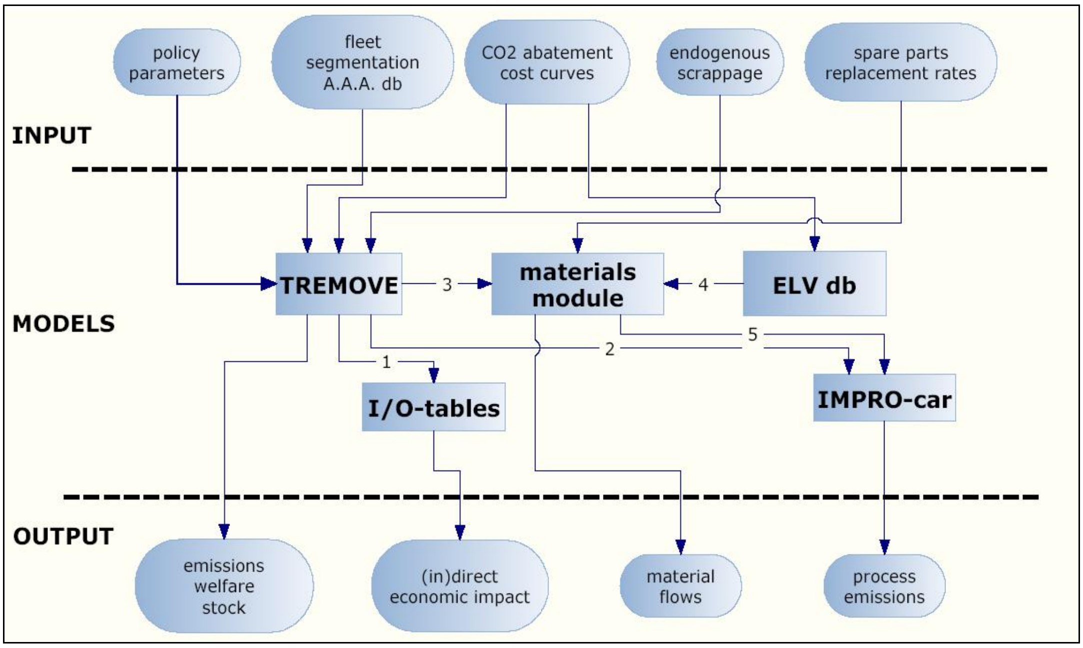
This report analyses the environmental and economic impacts of the selected policy options and also the potentials of car lightweighting. To this end, a methodology was designed combining and applying different analytical tools with a view to developing a comprehensive assessment of the policy options, i.e. considering the EU27 car fleet. Comprehensiveness also meant including all direct and indirect impacts:

- Regarding the environmental impacts, all major impacts had to be covered, especially those associated with the fuel cycle (so-called Well-to-wheel impacts) and those from the production of the materials involved in the car and spare parts manufacturing. The car disposal is also considered.
- Regarding the economic impacts, both impacts on the consumer and on the industry (automotive sector and supplying sectors) are analysed.

The methodological approach combined different analytical tools (see Figure 2):

1. The TREMOVE model which is a policy assessment model, designed to study the effects of different transport and environment policies on the European transport sector (see section 4.2).
2. A database containing information about the car composition of ELVs and spare car parts in the EU27. This was built into the framework of the project.
3. The Input-Output tables that are being developed by IPTS for the EU27 have been used to analyse the impacts of policy options on the overall economy (see section 4.5).
4. A life-cycle assessment calculation module built upon the IMPRO-car project[1], especially where the environmental impacts associated with material extraction and processing were concerned.

Figure 2: General methodology



The TREMOVE model was the core of the project, producing the outputs needed for the other modeling components (Input-Output tables and life-cycle assessment module). The materials module was constructed as a new TREMOVE module, receiving input from the existing TREMOVE modules, especially on total vehicle stock by age, technology and mileages. The new materials module was fed by the ELVs database to include detailed material composition.

The following section details each of the components.

4.2 TREMOVE model

TREMOVE is a policy assessment model for studying the effects of different transport and environmental policies on the emissions of the transport sector. The model estimates the transport demand, the modal shifts, the vehicle stock renewal, the emissions of air pollutants and the welfare level. The model can be applied for environmental and economic analysis of different policies such as road pricing, public transport pricing, emission standards, subsidies for cleaner cars etc. TREMOVE models both passenger and freight transport, and covers the period 1995 - 2030.

The model consists of 31 parallel country models, each of them consisting of three inter-linked modules: a transport demand module, a vehicle turnover module and an emission and fuel consumption module. This study used the EU27 country models.

The **transport demand module** describes transport flows and the users' decision-making process in terms of modal choice. Starting from the baseline level of demand for passengers and freight transport per mode, period, region etc., the module describes how the implementation of a policy measure will affect the choice of the users and of the companies between the different transport modes. The key assumption is that the choices are made based on the generalized price for each mode: cost, taxes or subsidy and time cost per kilometre travelled. The output of the demand module consists of passenger kilometres (pkm) and ton kilometres (tkm) that are demanded per transport type for a given policy environment. The pkm and tkm are then converted into vehicle kilometres (vkm).

The **vehicle stock turnover module** describes how changes in demand for transport or changes in vehicle price structure influence the share in the stock by age and vehicle type. The output of the vehicle stock module is twofold: total fleet and the number of km for each year according to vehicle type and age.

The fuel consumption and **emissions module** calculates fuel consumption and emissions, based on the structure of the vehicle stock, the number of kms driven by each vehicle type, and the driving conditions.

Outputs from the vehicle stock and fuel consumptions and emissions modules are fed back into the **demand module**. As fuel consumption, stock structure and usage influence usage costs, they are important determinants of transport demand and modal split.

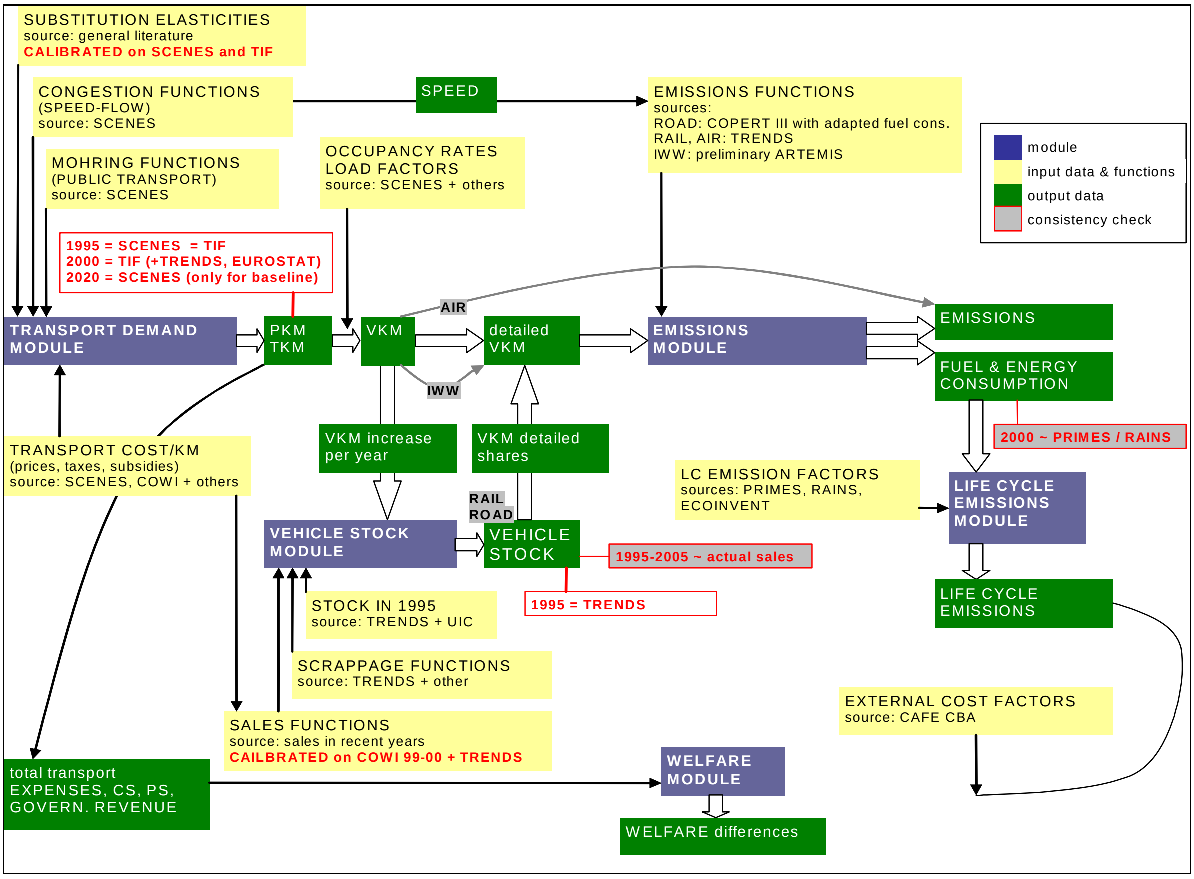
In addition to the three core modules, the TREMOVE model includes a well-to-tank emissions and a welfare cost module. The well-to-tank emissions module calculates the emissions during the production of fuels and electricity.

The welfare cost module enables a calculation of the cost to society associated with emission reduction scenarios in European urban and non-urban areas. The welfare effect of a policy change is calculated as the discounted sum of changes in utility of households, production costs, external costs of congestion and pollution and benefits of tax recycling. These benefits of tax recycling represent the welfare effect of avoiding public funds being collected from other sectors, when the transport sector generates more revenues.

An overview map can be found in Figure 3. More details are given by De Ceuster et al. (2007)[11]

The TREMOVE model baseline considered in this project is described in chapter 5.

Figure 3: TREMOVE model structure



4.3 Material flows

Developing a comprehensive picture of the environmental implications of the policy options (e.g. considering consequences on the car production, spare parts and car disposal) implies to estimating the flows of material involved. As TREMOVE did not incorporate such information, the project built an additional module to the model, incorporating total material volumes per material type associated with:

- The passenger vehicle production, per material type.
- The passenger vehicle usage phase, including spare parts per material type.
- The end-of-life vehicles (ELV).

Relevant information was collected from the literature and available databases, and then combined into a new database. A new output module was created for TREMOVE, linking both to the initial output database (see section 4.2) and the new materials database. In particular, the TREMOVE primary output delivers data on car sales and car scrappage (as given by year and mileage) which have been linked to the average material composition of corresponding cars. These outputs are also linked to the composition and usage rate (e.g. number of tyres per km driven). Specificities of vehicle features (e.g. age, size) influencing the material composition were taken into account. The new materials module[a] enables a calculation of the different material flows and can subsequently be used to calculate the associated environmental impacts (see section 4.4).

The key development stages for the material flow database were to:

- Determine the average weight and material composition of average cars for three engine size categories differentiated by emission standard and engine type (technical progress).
- Quantify material flows generated by the disposal of ELVs.
- Identify the relevant spare parts and their average weight, material composition, average lifetime, and quantify the material flows generated by their dismantling and disposal.

4.3.1 Car composition

4.3.1.1 Materials and vehicle categories

The characterization of car composition started with a material list taken from the IMPRO car project and further extended with new materials known to be involved in innovative car technologies (e.g. advanced lightweight materials).

The database includes ferrous metals (iron, steel, high-strength steel), non-ferrous metals (aluminum, copper, lead, zinc, magnesium, platinum, palladium, rhodium), plastics (PP, PE, PA, PVC, ABS, PUR, PET), oil, refrigerant, glass, textiles, rubber and composite materials.
The vehicle categories represented in TREMOVE have been considered, thus including a differentiation with respect to fuels (diesel and petrol), engine size (small, medium and large), emission standards (Euro1 to Euro6 and pre-Euro1). The differentiation also included four energy efficiency levels for Euro5 and Euro6.

[a] The additional module is conceived as pure post-processing of a TREMOVE run. This gives considerable advantages with respect to runtime and flexibility.

4.3.1.2 Vehicle weight

The literature indicates a steady increase in curb weight (CW) over recent decades. As an example, over the period 1976 to 2002, the CW of the VW Golf has increased from from 885 kg to 1343 kg. ACEA reports an average weight increase of 1.5%/yr (in (Perlo 2008)[12]).

This figure was used to assign weight values for the pre-Euro to Euro 4 passenger cars. The weight for Euro 5 and Euro 6 cars was assumed to be equal to the Euro 4 cars (see Table 4).

Table 4: Curb weight of pre-Euro to Euro 6 passenger cars (kg)

	Petrol			Diesel		
	small	**medium**	**large**	**small**	**medium**	**large**
Pre-Euro 1	780	1 014	1 182	872	1 100	1 385
Euro 1	828	1 076	1 255	925	1 168	1 470
Euro 2	879	1 142	1 332	982	1 239	1 560
Euro 3	933	1 213	1 413	1 042	1 315	1 655
Euro 4 to Euro6	990	1 287	1 500	1 106	1 396	1 757

4.3.1.3 Reference vehicle (Euro 4)

The Euro 4 cars (current new car) have been used as a first reference vehicle for which the material composition was derived from an analysis of:

- Available information on recent passenger cars of different European car manufacturers which cover the respective vehicle categories. For instance, product declarations published by the automotive industry have been considered.
- Other relevant studies providing data on the share of materials: An overview is given in Figure 4 for petrol cars of three car sizes.

The literature suggests a shift from steel to aluminium when moving from small to larger vehicles. However, the share of glass and fluids increases as vehicle size increases.
In general, diesel cars tend to show a higher share of iron and aluminium because of the higher average weight of the diesel engine. The vastt majority of the remaining materials vary little or remain at a constant level (in terms of relative shares, within the vehicle size categories).

Data collected amongst the literature were comparable only at a certain level of material aggregation, namely, for the following groups of materials: ferrous and non-ferrous metals, light metals, lead, plastics, rubber, glass/ceramic and fluids. For key material categories a further breakdown was carried out using selected data in greater detail so that information about each material could be incorporated into the car database. An example of the final material composition for the reference vehicles is shown in Table 5.

Figure 4: Overview of relevant studies on (petrol) passenger cars and the reference petrol vehicles for three size categories

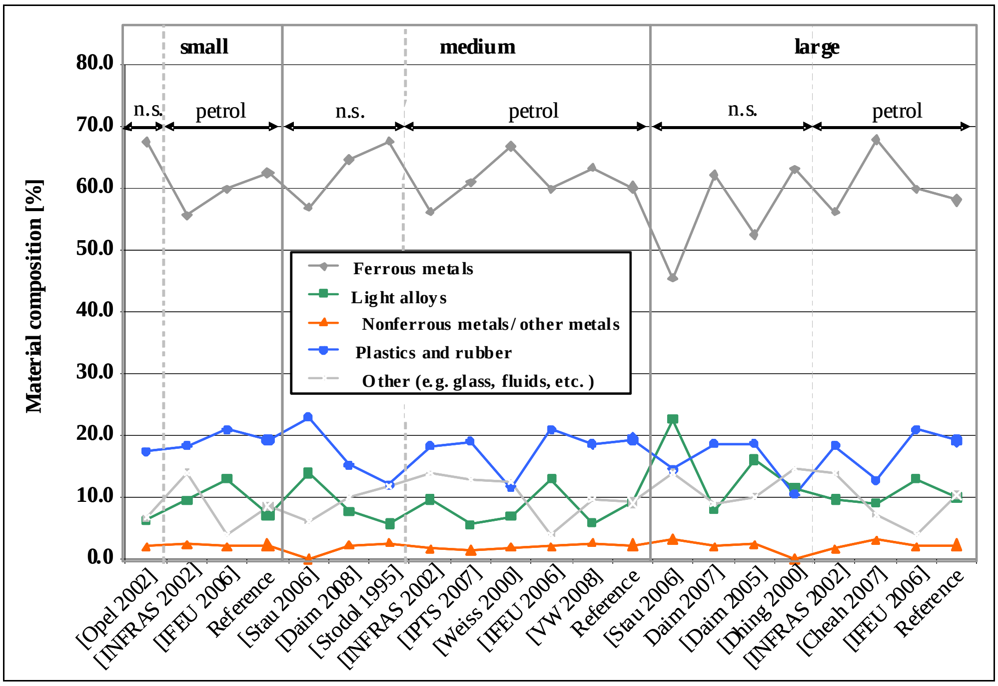


Table 5: Material composition (%) of average small, medium and big Euro 4 petrol and diesel cars

Vehicle size	Small		Medium		Big	
Engine	petrol	diesel	petrol	diesel	petrol	diesel
Materials						
Iron	9.6	10.5	9.5	10.4	9.4	10.3
Steel	43.2	43.1	40.9	40.8	39.2	39.3
High-strength steels	9.8	9.5	9.8	9.5	9.6	9.3
Copper	0.9	0.9	0.9	0.9	0.9	0.9
Zinc	0.2	0.2	0.2	0.2	0.2	0.2
PGM Pt	0.00006	0.00019	0.00005	0.00034	0.00003	0.00049
PGM Pd	0.00010	0.00000	0.00022	0.00000	0.00032	0.00000
PGM Rh	0.00003	0.00000	0.00004	0.00000	0.00004	0.00000
Lead	0.7	0.7	0.7	0.7	0.7	0.7
Aluminium	7.1	7.5	9.0	9.3	9.8	10.1
Magnesium	0.2	0.2	0.2	0.2	0.2	0.2
Other metals	0.4	0.4	0.4	0.4	0.4	0.4
PP	9.1	8.9	9.0	8.8	8.8	8.5
PE	2.5	2.4	2.4	2.4	2.4	2.3
PA	0.4	0.4	0.4	0.4	0.4	0.4
PVC	0.0	0.0	0.0	0.0	0.0	0.0
ABS	0.8	0.8	0.8	0.8	0.8	0.8
PUR	2.1	2.1	2.3	2.3	2.6	2.5
PET	0.1	0.1	0.1	0.1	0.1	0.1
Other plastics	2.0	2.0	2.0	2.0	2.0	2.0
Rubber/ Elastomer	2.2	2.1	2.1	2.1	2.1	2.0
Oil	0.6	0.6	0.6	0.6	0.6	0.6
Refrigerant	0.05	0.05	0.05	0.05	0.05	0.05
Other fluids	1.7	2.1	2.6	1.7	2.0	2.5
Glass	2.2	2.2	2.4	2.3	2.4	2.4
Textile	1.0	1.0	1.0	1.0	1.0	1.0
Other	2.8	2.7	3.0	2.9	3.5	3.4

4.3.1.4 Pre-Euro4 vehicles

The material composition of average (pre Euro 1, Euro 1 to Euro 3) passenger cars was derived from additional analysis. The composition was evaluated for the year in which the corresponding emission standard was introduced, starting with Euro 1 in 1992. The pre-Euro1 vehicles were evaluated in 1988. On the basis of the Euro 4 reference vehicles, the material composition and vehicle weight of pre-Euro 4 cars have been calculated, taking into account the trends of the previous time period (see section 4.3.1.1).

The material composition of pre-Euro 4 cars is mainly derived from the key materials of petrol and diesel passenger cars assumed in INFRA (2002)[13]. The resulting shares have been compared to the composition of the reference Euro 4 vehicles (petrol and diesel). The relative deviation was then used to determine the final material composition of pre-Euro 4 vehicles for each size category. In accordance with the approach used for Euro 4 vehicles, the material composition of pre-Euro 4 vehicles is also differentiated by fuel type (petrol and diesel). As INFRA did consider the same material differentiation, further assumptions have been made:

- the increasing use of magnesium and HSS is correlated to the changing share of aluminium;
- the shares of other fluids, glass and textiles are kept constant over time. An exception is made for refrigerants which are assumed to increase over time with the increasing penetration rate of mobile air conditioning systems;
- the use of PET is correlated to that of PE;
- the use of lead is related to the slight decrease of the battery weight over time;
- the platinum group of metals (PGM) loading is derived from (Umicore 2008)[14], for each vehicle type but small diesel cars. In this case, the data for medium diesel cars was used and rescaled according to the specific vehicle curb weight.

Overall, the following key trends can be stated when moving from pre-Euro 1 to Euro 4 cars:

- the shares of conventional steel and iron slightly decrease;
- the share of lightweight materials such as aluminium, magnesium and HSS increases;
- the share of plastics increases globally; while the share of PP, PE and ABS increases, PVC and PA decreases and the share of PUR and PET remains almost constant,
- the share of all other materials does not show any significant changes compared to the Euro 4 reference vehicle.

4.3.1.5 Post Euro 4 vehicles

The car database was expanded to Euro 5 and Euro 6 cars. The baseline configuration (curb weight, material composition) of Euro 5 and 6 passenger cars is similar to the Euro 4 vehicles. Only the PGM load of the catalytic converter and the amount of refrigerant are adapted individually for each vehicle type (diesel/petrol cars, small, medium, big, Euro 5/Euro 6) based on data taken from (Umicore 2008)[14] and based on the estimated penetration rate of air-conditioning systems assumed in TREMOVE.

Because the Euro 5 and Euro 6 baseline vehicles in the different policy scenarios involve additional fuel efficiency enhancement technology packages, the impact of **future fuel-efficiency technologies** on the material composition was evaluated and, where relevant, these impacts have been quantified for future Euro 5 and 6 passenger cars. As a result, their original material composition was modified accordingly.

Four different fuel efficiency levels have been determined for diesel and petrol cars, in accordance with the analysis which had been used as a background for the impact assessment of the regulation on CO_2 emissions from cars (TNO/IEEP/LAT, 2006)[15]. For diesel cars, this includes the baseline stage and 10%, 20%, 30% reduction (compared to baseline). For petrol cars, baseline stage and 15%, 30%, 40% reductions (compared to baseline). This takes into account of the fact that the fuel efficiency improvement potential is the greater for petrol cars. For these four CO_2 emission levels, technology packages have been defined and the respective material changes have been included in the database. The approach includes an interpolation between these efficiency levels so that the model can reflect the material changes entailed by the efficiency progress.

This approach is based on the statistical approach used in TNO et al. (2006). A rough estimate determined the technologies which are most likely to be used in the future to improve efficiency and which will affect the material composition. This was based on the combinations of technologies specified in the IMPRO-car study.

In light of the regulation about CO_2 emissions from cars, the modified technology packages do not include vehicle weight reduction. The following provides that main changes that the most representative technology improvements would entail:

- Engine downsizing is expected to induce a decrease of material demand of the engine.
- Improved aerodynamics (modified vehicle's shape and height) does not have a relevant impact on the material demand. Further measures such as the installation of fairings and spoilers would however require a modified material demand.
- The hybrid propulsion system leads to a considerable modification in major car components such as the integration of a more powerful energy storage system, an electric motor and related electronics as well as a downsizing of the conventional combustion engine. The main material impact is induced by the energy storage system; in the car database the NiMH battery technology is assumed to be generally applied in the case of mild and full hybrid cars.

4.3.2 Spare parts

The key car components that are usually replaced during the vehicle's life have been documented separately in the car database (material composition and replacement rate for every vehicle category). Spare parts identified to have a relevant impact on the material demand during the life-cycle of passenger cars include tyres, starter batteries, catalytic converters, refrigerants and engine oil. While the replacement rate depends on the spare part and on the average driving pattern, the weight of the materials was adjusted to the curb weight of the specific vehicle category (in terms of their absolute weight) without changing the share of materials. The key information with regard to automotive spare parts was based on a literature review and expanded through a survey of practising experts from several car repair garages who reported on their current practice.

4.3.3 End-of-life vehicles

The development of the treatment of ELVs in the EU27 is shaped by regulatory, economical and technological aspects. In order to forecast the material flows of ELVs in Europe, all three aspects have been qualitatively assessed and a set of assumptions was elaborated.

The regulatory aspects relate to the implementation of the ELV Directive (2000/53/EC) including the 80% and 85% recycling rates for 2006 and 2015 respectively, restrictions regarding landfill waste deposition, and the somewhat delayed implementation of EU law in new Member States. In terms of the economic aspects, ELV exports outside of Europe, increasing costs for landfills and the increased values for particular recycling streams (e.g. copper, advanced materials) have been considered.

Technologically, ELVs are treated in a tiered process, including de-pollution (removal of hazardous materials, as required by the ELV Directive), dismantling, and shredding. The the shredder process output include an iron-fraction, a heavy fraction (mainly non-ferrous metals) and automotive shredder residue (ASR). Advanced post shredder technologies are currently being developed and implemented in response to the current and forthcoming restrictions regarding landfilling ASR and the increasing share of high value materials in the ASR.

The following assumptions constitute the basis for the elaboration of a 'best-case' and 'pessimistic case' scenarios:

- **2008-2012**, the pressure to further treat shredder residue is low (although it is increasing). Consigning shredder residue to landfilsl remains the most common and the cheapest option. Approximately 90% of the ASR is deposited in landfills.
- **By 2016** a larger share of ELV vehicles will remain in the countries of origin. More large-scale shredders will be operating inside the EU 27, creating a critical mass to more deeply treat shredder residue. Furthermore, landfills in Eastern Europe will have become more expensive. However, newly created treatment capacities will have to cope with increasing the total amounts of ELV, limiting the extent of their treatment.
    - In the <u>best case</u> nearly 40% of the ASR will be mechanically treated and the output fractions will be used materially and energetically. The dismantling and material recycling of plastics will be temporarily expanded.
    - In the <u>pessimistic case</u> 20% of ASR will be mechanically treated.
- **By 2025** the increased use of high-strength steel (HSS), aluminum and plastics will have reached the ELV vehicles. The higher values of materials and material scarcity will create more incentives for recovering materials. A larger share of ELV remains in the countries of origin; newly created treatment capacity will have to cope with increasing total amounts of ELV, limiting the depth of treatment.
    - In the <u>best case</u> 80% of the ASR will be mechanically separated with further recycling of individual fractions.
    - In the <u>pessimistic case</u> 40% of the shredder residues will be mechanically separated with further recycling of individual fractions.
- **By 2030** the trends will have continued while the overall recovery rate for vehicles will further increase.
    - In the <u>best case</u> about 85% of the shredder residues will be mechanically separated with further recycling of individual fractions. 15% of ASR will still be landfilled.
    - In the <u>pessimistic case</u> 50% of the shredder residues will be mechanically separated and 50% landfilled.

In the best-case scenario, the recovery and recycling requirements of the ELV Directive will only be met across the EU27 by 2025. A third scenario was created that follows the ELV Directive in the EU27 as a precondition. As a result, this scenario requires much deeper dismantling rates followed by the recycling of plastics and ferrous metals until 2020.

The percentage distribution of each vehicle material in terms of the different waste treatment was defined for ELV for 2008, 2012, 2016, 2020, 2025 and 2030. The percentage distribution linked with the ELV input results in the ELV material flows.

4.4 Indirect environmental impacts

The TREMOVE model calculates the well-to-wheel (WTW) emissions. In order to build a more complete picture of the major life-cycle impacts of the car fleet, the environmental impacts from the production of cars and of spare parts have been calculated by using the output results from TREMOVE on material flows which were subjected to life-cycle analysis.

The calculation was based on the tool built and the data used in the IMPRO-car project, implementing the well established life-cycle approach. All industrial or economic activities directly or indirectly linked to the production of cars and spare parts were included. The environmental impacts were expressed in terms of aggregated midpoint indicators (e.g. t CO_2-equivalents for climate change), using the CML 2001 methodology (CML, 2001)[16]. The following impact categories (midpoint indicators) have been considered:

- Abiotic depletion (excluding primary energy depletion)(AD)
- Global warming potential (GHG)
- Photochemical ozone creation potential (POCP)
- Acidification potential (AP)
- Eutrophication potential (EP)
- Bulk waste (BW)

The life-cycle data for the extraction and processing of raw materials, and material production have been mainly taken from the Ecoinvent database (Frischknecht et al., 2004)[17], selecting Western Europe representative processes. Table 5 shows the material considered.

4.5 Input-output tables

This report quantifies the macroeconomic effects on employment and value added of different policy scenarios at EU27 level. The methodology is described in the following sections.

4.5.1 Input-output methodology

An input-output matrix of technical coefficients, $A = (a_{ij})$ where $i, j = 1, \ldots, n$ (where n is the number of commodities), represents the direct requirements of commodity i needed to produce a physical unit of commodity j. For instance, if industry 1 corresponds to agriculture and industry 2 corresponds to chemicals, then a_{21} will be the amount of chemical products consumed by agriculture per physical unit of peaches, apples and so on (ten Raa and Rueda-Cantuche, 2003)[18]. In more general terms, the standard reference is Leontief (1986)[19].
The matrix of technical coefficients A has been used for economic analysis by means of the so-called quantity equation or material balance: $x = Ax + y$. Vector x denotes total output of commodities while vector Ax reflects the requirements for intermediates and vector y represents the exogenous aggregate final demand. This equality makes total supply to match with total use of commodities.

The quantity equation is used for national or regional economic planning; for instance, the output requirements to satisfy a certain final demand level could be analysed. Thus, there will be a direct effect over the output levels, which will depend on the final demand variations (y) and additional indirect effects that will be determined by the A-matrix, in accordance with the material balance equation (ten Raa and Rueda-Cantuche, 2003)[18].

Input-output analysis has frequently been used to analyse impact of final demand on total output. Furthermore, the input-output system allows also evaluating the direct and indirect impact of economic policies on other economic variables such as labour, capital, energy and emissions, by using the appropriate extensions (Eurostat, 2008)[20]. Most of these policies have to be analysed with macroeconomic models which provide a minimum of sectoral disaggregation. From the quantity equation, we could derive that $x = (I - A)^{-1}y$ and subsequently, the following extension will offer multiple approaches for analysis: $z = B(I - A)^{-1}y$ (central input-output equation system).

Matrix B includes the input coefficients of the selected variables for the analysis (e.g. intermediates, labour, capital, energy, emissions) and vector z shows the direct and indirect requirements (e.g. energy, labour, capital) or joint products (emissions) for the produced goods and services (Eurostat, 2008)[20]. Within this framework, the use of input-output systems is generally and often applied in the literature to evaluate environmental and employment policies, to productivity analysis, to energy issues, and so on.

On the other hand, the main limitations of the standard input-output methodology are in its lack of micro-economic foundations and in being used as a purely top-down model. However, the IO study presented in this technical report establishes a link to TREMOVE. Under the policy scenarios considered in this report, TREMOVE-based outputs have been used as input parameters for the macroeconomic assessment, including the demand for new cars and spare parts, the demand for fuels, the demand for insurance and repair services as well as the tax revenues gained by the public sector (e.g. purchase taxes, fuel tax, VAT on servicing). These specific outcomes allow to account for the policy-related changes caused in households' consumption and therefore, in final demand. Eventually, the quantity equation and the central input-output equation system (including a technical coefficients matrix) provide the output multipliers and the employment and value added effects.

4.5.2 Data availability

Since some of the environmental policy scenarios considered in this report refers to the future (mainly 2010-2015), we constructed a matrix of technical coefficients for the year 2015. With this purpose, we took as a starting point the consolidated EU27 symmetric input-output table (SIOT) of the year 2000 (Rueda-Cantuche et al., 2009)[21], which was compiled by IPTS.

This SIOT consists of 59 industries and 59 commodities (NACE-2 digits), to which two additional rows and columns were added, i.e. automotive fuel and manufacturing of passenger cars, which were disaggregated from the petroleum refining sector (NACE-23) and the manufacturing of motor vehicles, trailers and semi-trailers (NACE-34), respectively. For the disaggregation of the former, we used the standard EU27 SIOT which includes a matrix of imports (Rueda-Cantuche et al., 2009)[21], data from the GTAP database[a] and existing information from a biofuels study (Neuwahl et al., 2008)[22]. For the splitting of the latter, we used the so-called 'Intermediate consolidated sector tables (104 sectors)' published by the Japanese Statistics Bureau[b] (which includes a disaggregated sector of passenger motor car production) together with TREMOVE results on household consumption of passenger cars and the already mentioned EU27 SIOT. Since the motor vehicles purchased by industries are recorded as capital formation and not as intermediate inputs, the total output of passenger cars

[a] See: https://www.gtap.agecon.purdue.edu/

[b] See: http://www.stat.go.jp/english/data/io/2000/zuhyou/sec104.xls

was assumed to be consumed only by final demand agents (households, government and gross fixed capital formation) rather than as intermediate use.

Once the new SIOT was constructed with 61 industries and 61 commodities, we used a refined version of the Euro method (Eurostat, 2008)[20] to update the current EU27 SIOT up to 2015. The Euro method pivots on three types of data inputs to be effectively implemented, i.e. growth rates of value added by sector; growth rates of import uses by sector; and growth rates of final demand by sector.

a) *Value added growth rates*: for the sake of consistency, they have been aligned with the background economic growth in TREMOVE which were based on the PRIMES model[a] and detailed in (EC, 2005)[23]. The breakdown of these rates was not detailed enough and the augmented EU27 SIOT had to be aggregated accordingly to 19 industries and 19 commodities.

b) *Import growth rates*: the Euro method was refined by identifying individual import growth rates by sector (and not a single growth rate for all) using econometric time series analysis (Gujarati, 2003)[24] to forecast both volumes and prices of import commodities (goods and services separately) in 2015. Data on external trade of goods (in monetary and volume values) came from the Eurostat database ComExt[b] while the EU27 Balance of Payments[c] provided external trade on services though only in monetary values. For goods, we disposed of monthly data from 1999 to 2008 and for services, of quarterly data from 2004 to 2008.

c) *Final demand growth rates*: first, the Ghosh price model (Dietzenbacher, 1997)[25] was used to estimate the new total output values, which must be consistent with the already estimated import and value added growth rates. Next, final demand values were obtained by keeping constant the shares of intermediate consumption over total use of commodities.

4.5.3 Link to TREMOVE and modelling

Once we have projected the EU27 SIOT for 2015 (and therefore, a technical coefficients matrix for the same year), we mapped the TREMOVE expected changes in households' demand for each one of the policy scenarios considered into the NACE categories of the final demand vector of the EU27 SIOT for 2015. In addition, the EUKLEMS[d] data on labour were used to address employment impact analysis through the central input-output equation system and finally, we assumed that tax revenues obtained from each of the policy options are re-distributed again to households in order to keep the government budget unchanged. Otherwise, that would result in undesirable distorted welfare effects.

[a] The 3.0 TREMOVE version is calibrated in consistency with macro-economic projections used in the PRIMES model. This doesn't include any assumption about growth annual rates of sectoral final demand nor growth annual rates of total imports. Only growth annual rates of total final consumption of households and of GDP (market prices) are available
[b] See: http://epp.eurostat.ec.europa.eu/
[c] See: http://epp.eurostat.ec.europa.eu/
[d] See: www.euklems.net

5 Basecase scenario and lightweight variant

5.1 Central Basecase

This chapter describes the TREMOVE baseline applied for the scenario policy simulations. It describes the most important assumptions relevant for the specific simulations. Also, some TREMOVE input data was revised and, where needed, were updated.

5.1.1 Assumptions and data update

The TREMOVE version 3.1 was used. This version is based on the version constructed in the FP6 I-TREN project[a]. The most important features of the baseline are as follows:

- **CO_2-emissions**: the assumptions about the evolution of car emissions have been aligned to those used in the impact assessment of the regulation on CO_2 emissions from cars (EC, 2007)[26], namely assuming a CO_2 emission level of 160 g/km in 2006 and no further decrease for future years and no autonomous mass increase.
- **Abatement technologies**: EURO5 & 6 are included in the baseline.

Some tax data have been updated. Both policy simulations would indeed (directly or indirectly) relate to registration. Research by (Kunert, 2007)[27] and the ACEA tax guide (ACEA, 2007)[28] provide recent data about **registration taxes**. Where inconsistencies were detected in TREMOVE, data were updated. This was mainly the case for New Member States. It is worth noting that registration tax values differ significantly between countries, e.g. DK has a registration tax which is, on average, almost equal to the purchase cost while others have no registration tax at all (e.g. DE, FR). The tax structure can also vary significantly: some countries apply a registration tax flat rate whereas others apply a differentiated registration tax (e.g. a function of vehicle cost or engine size). Some countries partly use differentiated CO_2-registration tax (like NL, see also section 3.1). In these cases, an average was set as input. Ownership taxes were also updated for some countries.

5.1.2 Stock

This section describes the projection on car stock: penetration of new technologies, i.e. Euro-standard compliant vehicles, trends in diesel/gasoline, share and stock breakdown by vehicle size class. Differences between countries are also discussed.

Figure 5 shows the continuous increase of the total passenger vehicle stock over time, due to increasing demand. In the period 1995-2010 emission standards are imposed on new sold vehicles. With a gradual fleet renewal, these new environmentally friendly vehicles become more common in the vehicle fleet. Note that, even without policy, in 2025 almost all vehicles in EU27 will be at least Euro5 compliant.

Figure 6 shows the evolution of the diesel share in the EU27 fleet. The diesel share has been increasing since the nineties and continues to increase until about 2015. Later, the share remains stable (40%). This increase is due to the substantial improvements in terms of performance of diesel cars that will become more attractive for consumers. The increasing

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[a] http://www.isi.fraunhofer.de/projects/itren-2030/

diesel share is mostly visible for medium-sized diesel cars, at the cost of medium petrol cars. Overall for EU27, a shift from small to medium engine-size is expected.

Figure 5: Evolution of passenger vehicle stock by emission standard (1995-2030 – EU27)

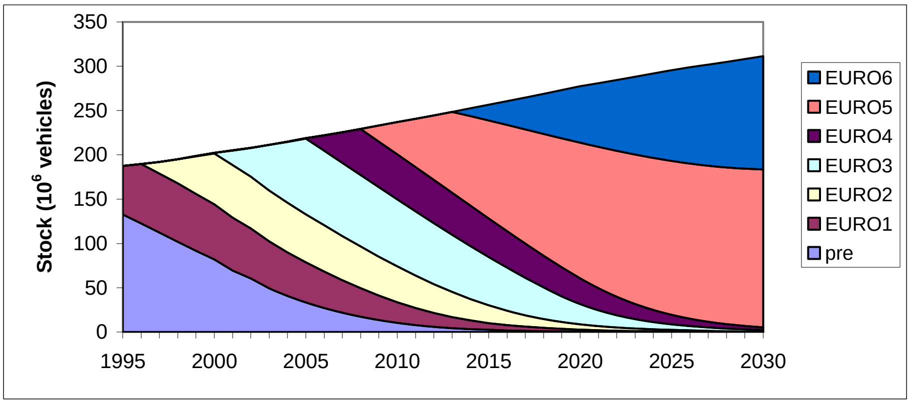
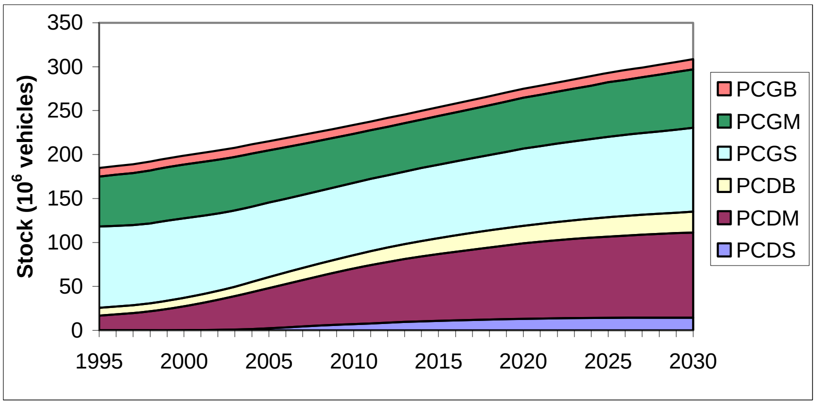
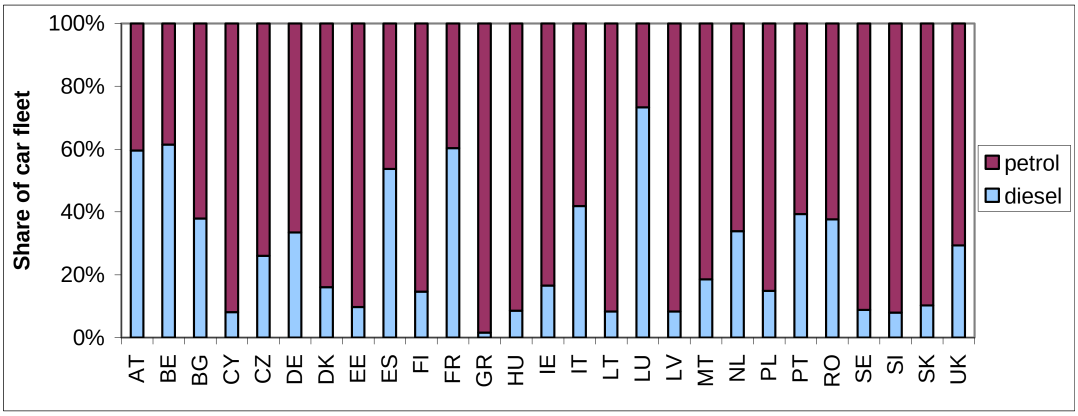


Figure 6: Evolution of passenger vehicle type share, CNG & LPG excluded (1995 - 2030 – EU27)



The variation of stock composition between countries is important. Figure 7 shows the diesel-gasoline share expected in 2010 for each country. Large variations are observed; e.g. BE and LU hold large diesel shares over 50%, while others such as GR, SE, EE have diesel shares lower then 10%. This shows that the policy impact can differ significantly between countries.

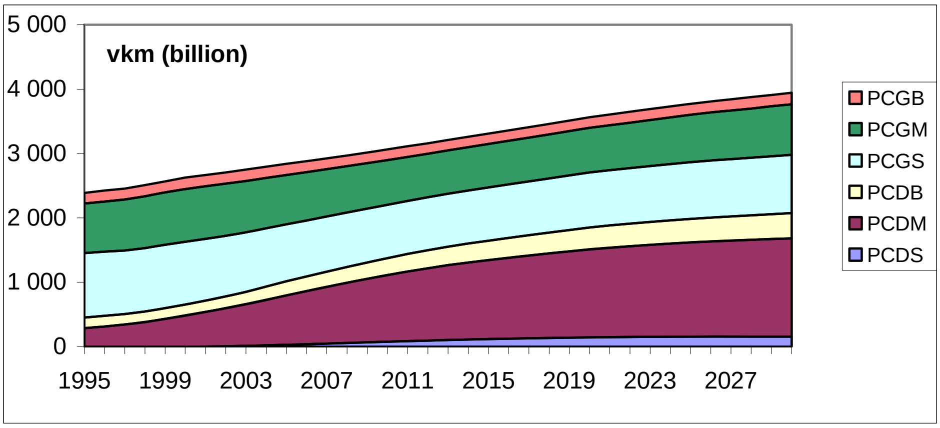
Figure 7: Passenger vehicle stock diesel (blue) – petrol (purple) share in EU27 countries in 2010



5.1.3 Demand

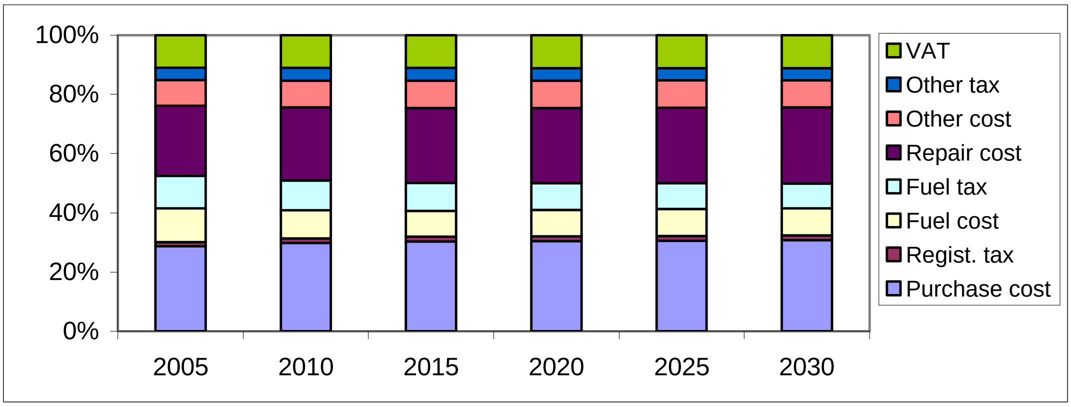
Passenger vehicle transport demand has been increasing and is expected to keep increasing. This is also reflected in the TREMOVE baseline (Figure 8). The breakdown of demand per vehicle type is similar to the vehicle stock composition.

Figure 8: Evolution of passenger vehicle transport demand, by vehicle type (1995 - 2030 – EU27)



The generalized price of passenger transport is determined by various cost components. Figure 9 gives the overview of cost components. Purchase cost and repair cost are the most important cost components and take half of the total cost. Registration tax holds only a small share in the basecase (1.5%). Total fuel cost (half resource cost half tax), holds a share of about 20%. Note that the share remains stable over time. The only (small) shift is from total fuel cost to purchase cost. This reflects a shift from running cost to investment cost, trading fuel cost for abatement cost.

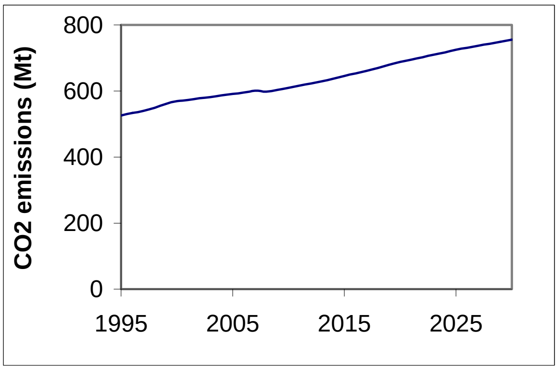
Figure 9: Share of passenger vehicle costs for the consumer by cost component (2005-2030 – EU27)

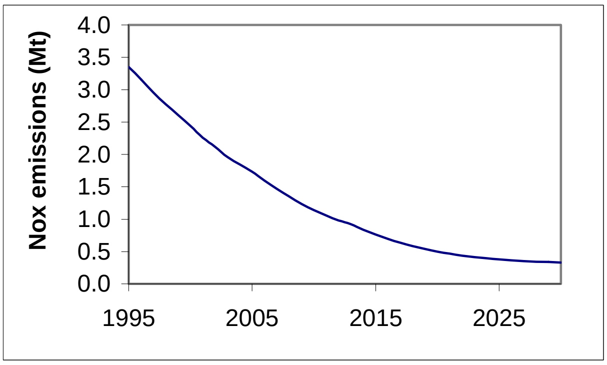


5.1.4 Well-to-Wheel Emissions

CO_2 emissions increase over time due to increasing demand and despite the continuous fuel efficiency improvements. In contrast, NOx emissions strongly decrease, due to Euro emission standards introduced since the nineties which are increasingly more stringent. NOx emissions are a good illustration for other regulated pollutants like particulate matters (PM) and volatile organic compounds (VOC). The reduction levels can vary depending on the emission gap between pre-Euro and Euro standards.

Figure 10: Evolution of CO_2 and NOx emissions of passenger vehicles in EU27 (1995 - 2030)





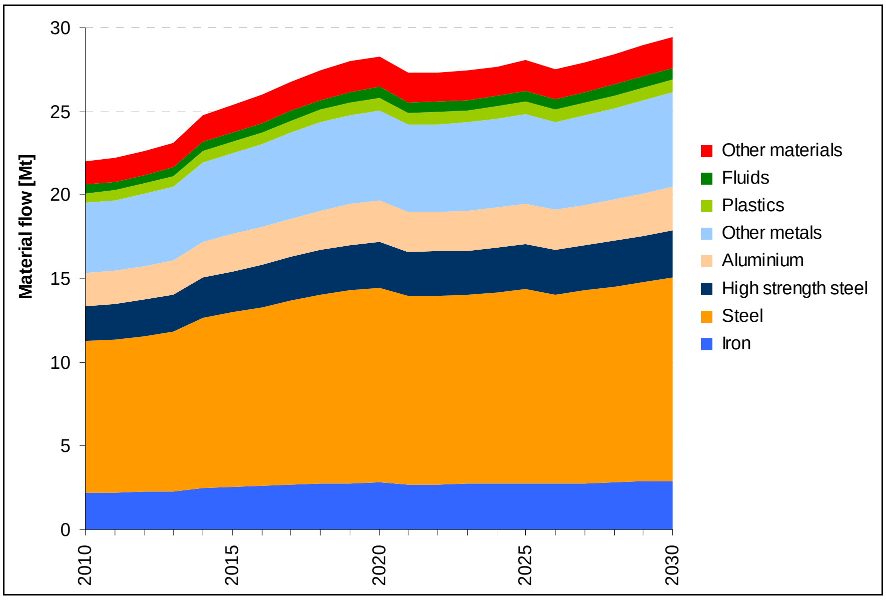
5.1.5 Material flows and associated impacts

The following section presents the material flows estimated by the new TREMOVE material module (see Section 4.3). Then, the life-cycle impacts are presented.

5.1.5.1 Material flows due to the production and EOL of cars

The total material flows due to the production of cars for the basecase are shown in Figure 11 for the years 2010 to 2030. The materials included in the analysis (Table 5) have been in part regrouped for the sake of clarity. Material flows show an increase of about 34% between 2010 and 2030. This increase follows the trend in transport demand (see section 5.1.3) and vehicle stock (see section 5.1.2). The total material flows do not show a constant increase over the years due to the shift to other car categories or fuel type (Figure 6), but also new technologies (Euro standards).

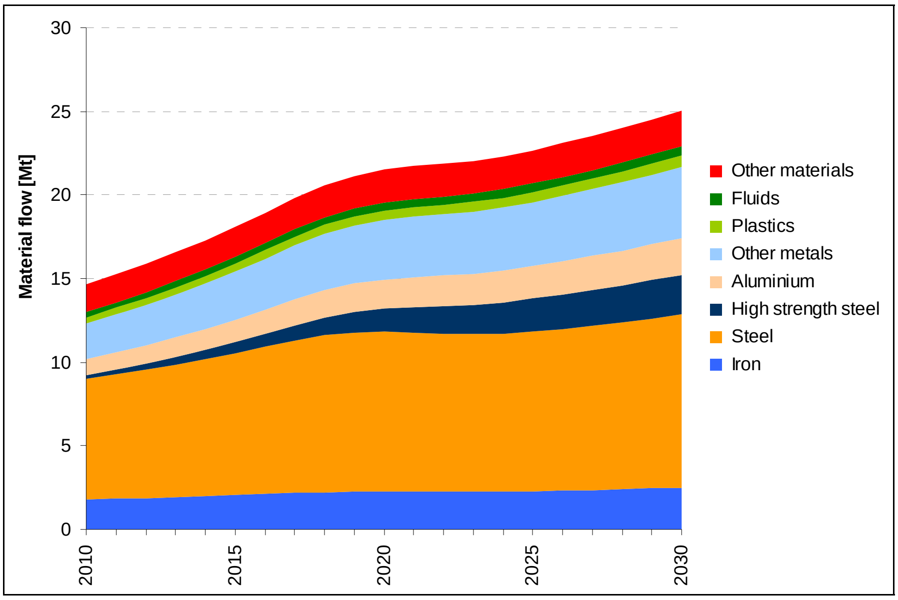
Figure 11: Material flows due to the production of new cars according to materials



Total material flows due to the EOL of cars for the basecase are depicted in Figure 12. Materials have been again regrouped as in the case of new cars production. Material flows due to EOL show a more pronounced increase between 2010 and 2030. This can be explained by increases in the average car weight in the past. This also explains why total material flows due to EOL vehicles are always smaller than those that are due to car production.

The shares of HSS, aluminium and plastics increase over time (from 1.4% to 9.4%, 6.6% to 8.7%, and 16.8% to 19.1%, respectively) while the shares of conventional steel and iron decrease.

Figure 12: Material flows due to the EOL of cars according to materials



5.1.5.2 Material flows due to the production and EOL of spare parts

For the basecase, the material flows due to spare parts production and EOL of spare parts do not differ (every spare part that is disposed of is replaced by a new one).

In Figure 13, the material flows for the different spare parts are shown. Figure 14 depicts the material flows according to materials. Material flows due to spare parts show a steady increase from 2.84 Mt in 2010 to 3.75 Mt in 2030 (34% increase). Compared to the material flows due to the production and EOL of new cars, spare parts are of minor relevance (12% to 13%). Tyres clearly dominate the material flows, followed by batteries and engine oil (about 64%, 19% and 16%, respectively). Refrigerants and catalysts play a minor role.

Regarding the different materials, the main fraction is plastics (about 32%) which include rubbers/elastomer from tyres and plastics from batteries (Figure 14). Other materials (26%) stem from tyres (e.g. carbon black, additives), batteries (e.g. sulphuric acid), and catalysts. Engine oil represents 16% of the material flows and 11% is due to lead from batteries. Textiles and refrigerants are of minor importance.

Figure 13: Material flows due to the production/EOL of spare parts according to spare part

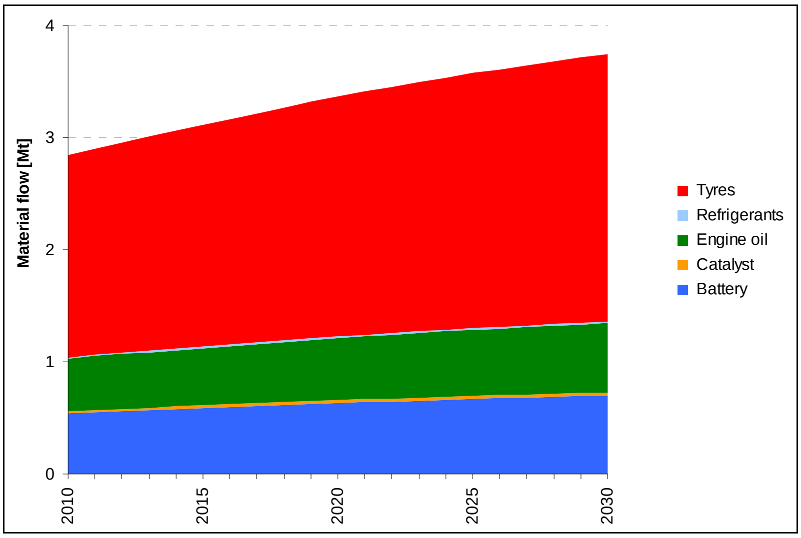
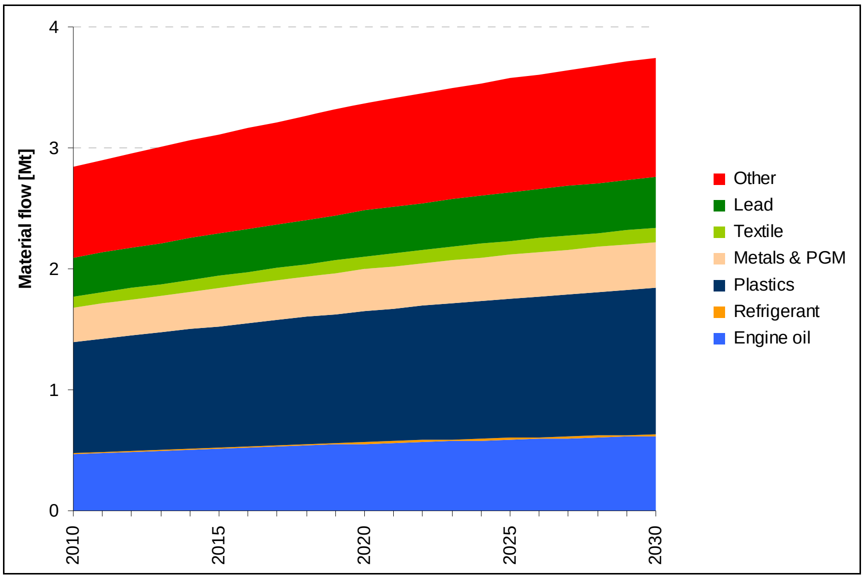


Figure 14: Material flows due to the production/EOL of spare parts according to materials



5.1.5.3 EOL material flows according to waste treatment technology

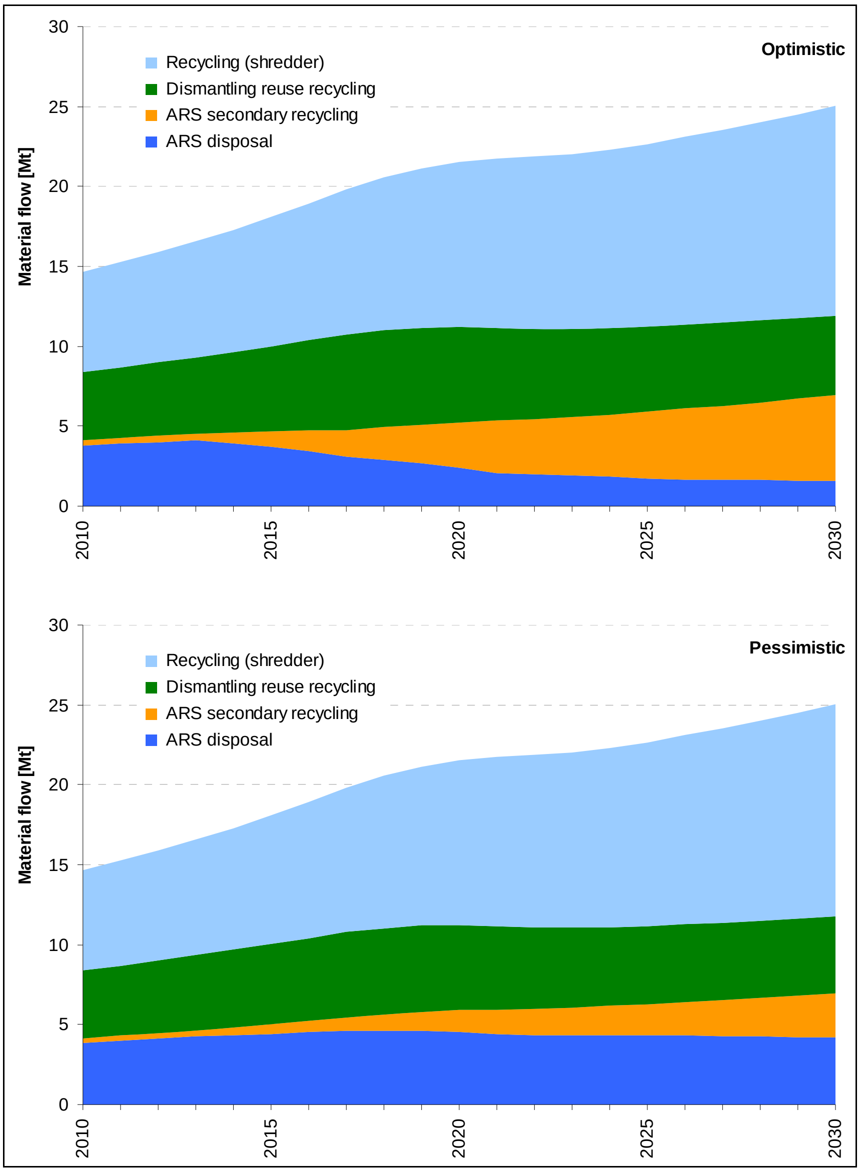
The material module allows for the determination of EOL material flows according to waste treatment technology. For ELVs, the shares of the single treatment technologies have been assumed for the 'optimistic' and 'pessimistic' scenarios (Figure 15) as described in section 4.3.3). The main differences are higher ASR treatment and subsequent material end energy recovery shares (ASR secondary recycling) and less landfilling (ASR disposal) in the 'optimistic' scenario compared to the 'pessimistic' scenario (see Section 4.3.3).

The different treatment technologies for EOL of spare parts are shown in Table 6.

Table 6: Treatment technologies for EOL of spare parts

Spare part	Treatment technology
Battery	Plastic recycling (energy and material recovery) Lead recovery
Tyre	Reuse Refurbishment Energy recovery Material recovery Landfilling Export
Catalyst	Recycling
Engine oil	Refurbishment Energy recovery Hazardous waste incineration
Refrigerant	Refrigerants recycling

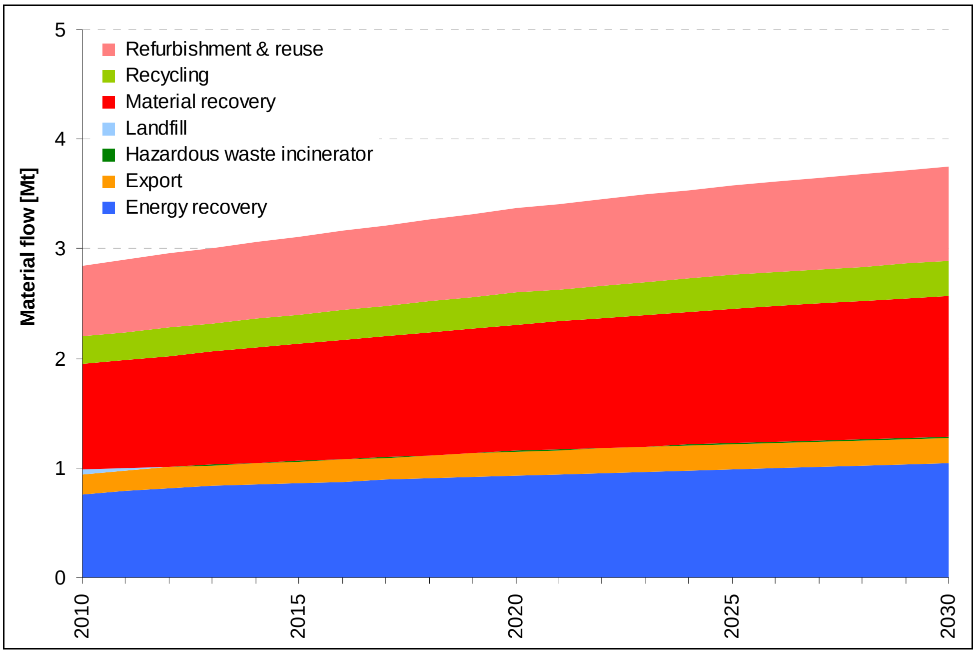
Figure 15: Material flows due to the EOL of cars according to treatment technology



Total material flows according to treatment technologies are shown in Figure 16. Material recovery (of tyres) dominates the treatment technologies. Energy recovery and refurbishment

& reuse (tyres and engine oil) play also a major role. Phasing out of landfilling of old tyres occurs in 2012. Also hazardous waste incineration is of very little importance.

Figure 16: Material flows due to the EOL of spare parts according to treatment technology



5.1.5.4 Life-cycle impacts due to the production of cars and spare parts

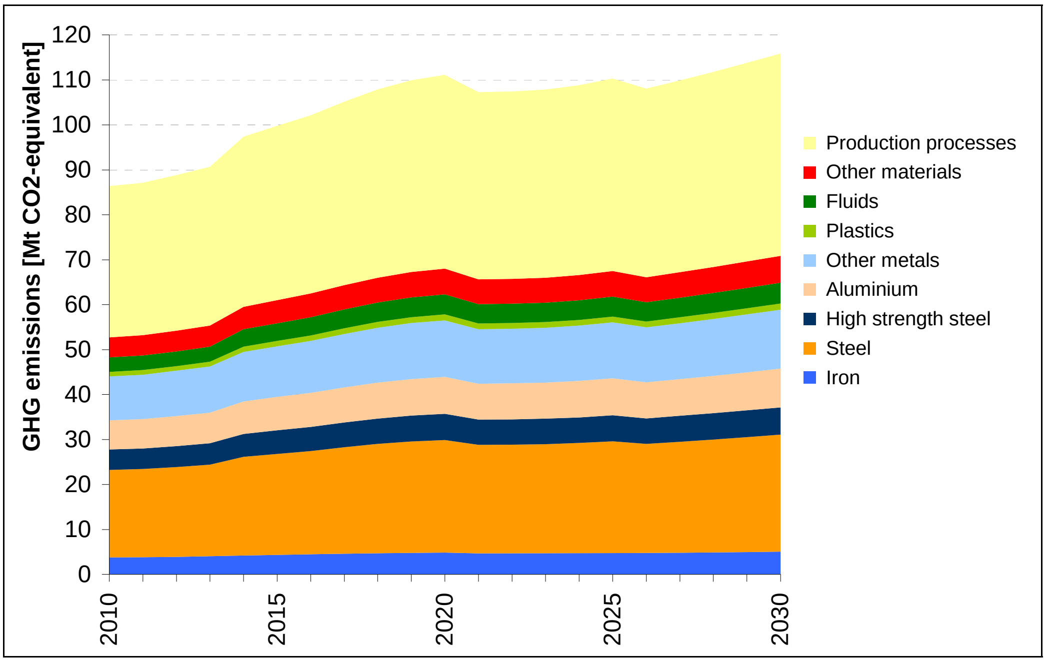
The environmental life-cycle impacts due to the production of cars are shown in Table 7 for the years 2010, 2020 and 2030. The life-cycle impacts are related to the total material flows for the production of cars (Figure 11). However, different trends are seen amongst the individual impact categories: compared to 2010, the increases in impacts in the year 2030 range from 34% (abiotic depletion, global warming, photochemical pollution) to 49% (acidification) while material flows increase by 34% (compare also Section 5.1.5.1). This is due to the changing car composition over time.

Table 7: Total life-cycle impacts due to car production according to impact categories

Year	Abiotic depletion	Greenhouse gases	Photochemical pollution	Acidification potential	Eutrophication potential	Bulk waste
	1000 t Sb eq	Mt CO2 eq	Mt C2H4 eq	Mt SO2 eq	Mt PO4 eq	Mt
2010	8.92	86.36	0.13	1.20	0.10	4.06
2020	11.48	111.15	0.16	1.72	0.13	5.44
2030	11.98	115.86	0.17	1.80	0.14	5.67

As an example, Figure 17 displays the greenhouse gas emissions disaggregated into the main material categories. The respective shares depend on the relative share on the total material flow for car production but also on the emission factor for the supply of the respective material. Similar to the material flows, the importance of GHG emissions associated with steel decreases while high strength steel and aluminium show a relative increase. The shares of the other materials remain almost constant.

Figure 17: Greenhouse gas emissions due to car production according to material



The production of spare parts leads to lower environmental impacts compared to the production of new cars (Table 8). Again, the life-cycle impacts are closely related to the total material flows for the production (see Figure 18).

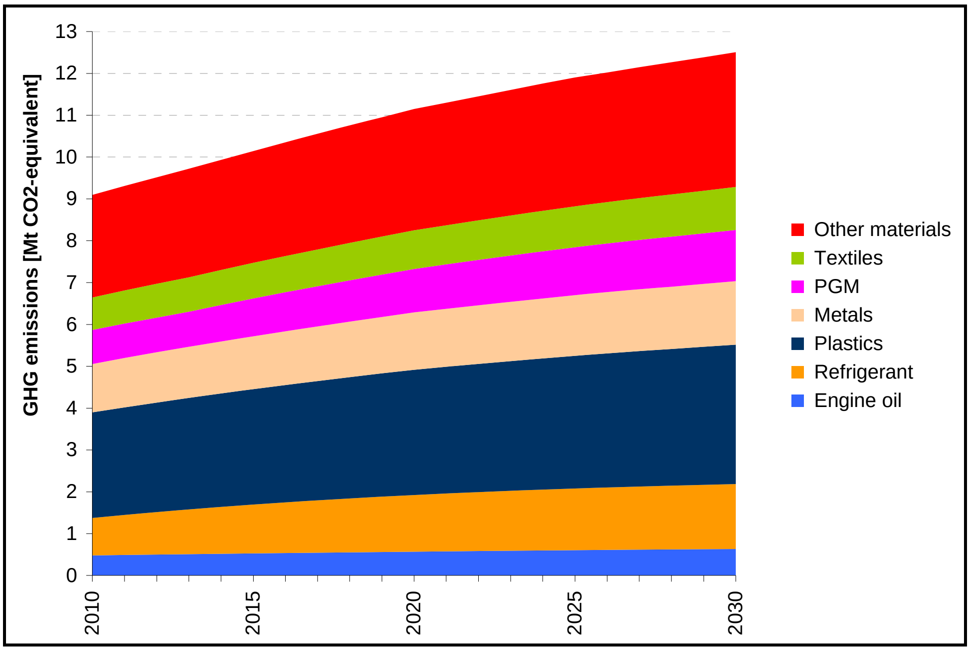
Table 8: Total life-cycle impacts due to spare parts production according to impact categories

Year	Abiotic depletion	Greenhouse gases	Photochemical pollution	Acidification potential	Eutrophication potential	Bulk waste
	1000 t Sb eq	Mt CO2 eq	Mt C2H4 eq	Mt SO2 eq	Mt PO4 eq	Mt
2010	11.96	9.16	0.02	0.46	0.01	1.08
2020	13.95	11.22	0.03	0.64	0.01	1.39
2030	15.46	12.59	0.03	0.76	0.01	1.61

The impacts according to materials (Figure 18 shows GHG emissions), show similarities with respect to the share seen for material flow (Figure 14). For GHG emissions, plastics (26% to 28%), other materials (26% to 27%), and metals (12% to 13%) dominate the results. Refrigerants and PGMs show considerable high shares compared to their low share of mass flows which is of course due to their high GHG emission factor for production and supply compared to the other materials.

The environmental impacts can also be calculated according to spare parts. The results are more in line with the results for the total material flow.

Figure 18: Greenhouse gas emissions due to spare parts production according to material



5.1.6 Life-cycle impacts

The life-cycle impacts induced by the car fleet up to 2030 are derived from the WTW emissions as given in section 5.1.4 and from the impacts from the production of cars and spare parts (section 5.1.5.4). The WTW emissions are completed with estimates of the impacts in terms of bulk waste and abiotic depletion, using the same coefficients as in IMPRO-car. Then, the emissions are converted into mid-point indicators by using the corresponding characterization factors. The results are given in table Table 9.

Table 9: Mid-point indicators for the WTW impacts for the years 2010, 2020 and 2030.

Year	Abiotic depletion	GHG	Photochemical pollution	acidification	eutrophication	Bulk waste
	1000 t Sb eq	Mt CO2 eq	Mt C2H4 eq	Mt SO2 eq	Mt PO4 eq	Mt
2010	0.00	1089	3.34	3.90	0.55	0.03
2020	0.00	1238	2.23	3.43	0.37	0.04
2030	0.00	1377	2.03	3.55	0.35	0.04

These mid-points indicators are summed with those derived for the car production and spare parts processes, giving the life-cycle impacts (Table 10).

Table 10: Mid-point indicators for the life-cycle impacts for the years 2010, 2020 and 2030.

Year	Abiotic depletion	GHG	Photochemical pollution	acidification	eutrophication	Bulk waste
	1000 t Sb eq	Mt CO2 eq	Mt C2H4 eq	Mt SO2 eq	Mt PO4 eq	Mt
2010	20.88	1185	3.49	5.56	0.66	5.18
2020	25.44	1360	2.42	5.79	0.52	6.86
2030	27.44	1505	2.23	6.10	0.50	7.32

5.2 Lightweight Case

For the lightweight basecase, ambitious weight reductions assumed to be achievable by 2030 have been assumed. The reviewed literature suggests that a weight reduction of up to 25-30% seems technically achievable in the medium term by means of an intensive use of lightweight materials (e.g. aluminium, high-strength, other advanced steels and magnesium) (Table 11).

Table 11: Overview of weight reduction potentials based on reviewed lightweight studies

Source	Project	Lightweight concept	Material	Weight reduction
(DeCico, 2005)[29]	ULSAB	Material substitution	High-strength steels (HSS)	~25% (BIW)
(Dhinga, 2001)[30]	NewSteelBody	Material substitution	HSS, modern steel grades & tailored blanks	25% (BIW)
(Weiss, 2000)[31]	Baseline scenario	Material substitution & secondary weight savings	HSS	~16% (CW)
(Wallentowitz, 2006)[32]	–	Optimised steel design	HSS	25% (BIW)
(Stodolsky, 1995)[33]	Aluminium-intensive vehicle (AIV) I	Limited material substitution	Aluminium	19% (CW)
(Stodolsky 1995)	AIV II	Maximum material substitution	Aluminium	31% (CW)
(Stodolsky 1995)	Ford Mercury Sable	Material substitution	Aluminium	20% (CW)
(Dhinga 2001), (Wallentowitz, 2006)	Ford P2000	Material substitution	Aluminium	40% (CW)
(Weiss, 2000)	Advanced scenario	Material substitution & secondary weight savings	Aluminium	~24% (CW)
(Pehnt, 2001)[34]	Space frame concept	Material substitution & modified construction concept	Aluminium	30-40% (BIW)
(Dinga, 2001)	Chrysler ESX2	Material substitution	Polymer composites	~60% (BIW)
(Pehnt, 2001)	RMI study	Material substitution	Polymer composites	~65% (BIW)
(Cheah, 2007)[35]	Lightweight scenario I	Material substitution	Aluminium, HSS & magnesium	~20% (CW)
(Cheah, 2007)	Lightweight scenario II	Material substitution & vehicle redesign	Aluminium, HSS & magnesium	~28% (CW)
(Cheah, 2007)	Lightweight scenario III	Material substitution, vehicle redesign & downsizing	Aluminium, HSS & magnesium	~35% (CW)

A broad market penetration of such light cars is not realistic. The maximum scenario variant was limited to a 15% reduction by 2030, and assumed to be primarily based on an increased use of high-strength steels and aluminium.

In accordance with the literature, the fuel saving potential achievable by vehicle weight reduction was assumed to be 0.66% fuel saving for each% weight reduction. The average manufacturer costs (3€/kg saved vehicle weight) considered are in line with the costs depicted by TNO el al (2006)[15] for 9% weight reduction.

The required weight reduction is assumed to be mainly achieved by the replacement of conventional steel and iron by HSS and the increased use of aluminium. As a consequence of the vehicle weight decrease brought about by material substitution, additional secondary weight effects that cover one fourth of the targeted weight reduction (3%) are assumed to be achievable due to a stronger modification of the structure of the vehicle, a decrease in the weight of the chassis and a downsizing of further components.

A more radical scenario (also included in the material database) with higher weight reductions (up to 30% by 2030) would depend on the substitution of conventional steel with composite materials. However, the use of polymer composites in vehicle construction would entail higher additional costs and, its mass production is much more hypothetical.

The assumptions have been translated into TREMOVE through:

- The vehicle purchase cost of new vehicles in a given (base) year. This parameter is updated to include the increased purchase price due to lightweight technology.
- An adjustment of the_fuel consumption in order to include the reduced CO_2-emissions as a result of lightweight vehicles.

The resulting new baseline can be compared with the original baseline (0% lightweight) with respect to stock, demand, emissions.

5.2.1 Stock

As cost of vehicle categories change due to increased purchase cost and decreased fuel cost, this leads to recalibration of TREMOVE (basecase) vehicle stock. The recalibration causes a (small) shift from diesel to petrol when lightweight vehicles are introduced (Table 12).

Table 12: Share of sales in 2030 per vehicle category for the two basecases (EU27)

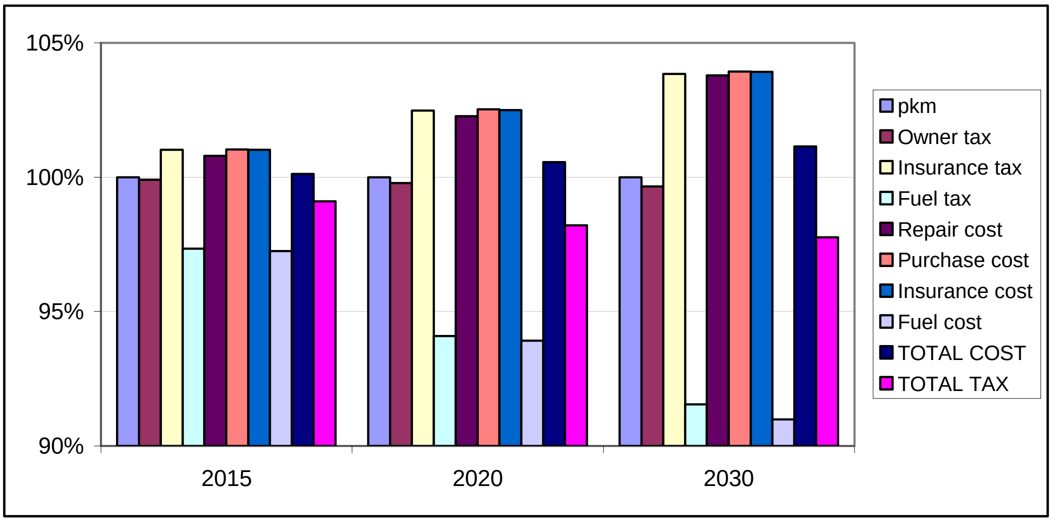
	PCDB	PCDM	PCDS	**total diesel**	PCGB	PCGM	PCGS	**total gasoline**
Central baseline scenario	8.5%	31.1%	4.2%	**43.8%**	5.1%	22.2%	28.7%	**56.0%**
Lightewight variant	8.5%	30.3%	4.0%	**42.8%**	5.6%	23.0%	28.6%	**57.2%**

5.2.2 Demand

Demand (vkm) is influenced by the changed input values are purchase cost and related cost components (e.g. insurance cost and tax, repair cost,…). Also fuel cost and tax revenue will decrease very substantially due to increased fuel efficiency. A comparison for all relevant components is given in Figure 19).

Overall, total cost increases by about 1% in 2030 due to increased purchase cost (and repair and insurance cost). Taxes on ownership decrease very little, while insurance tax increases slightly. Fuel tax decreases significantly due to increased fuel efficiency. Total taxes decrease by about 2.5% in 2030. The increase (or decrease) over years is due to the increasing penetration in the market of lightweight vehicles as a consequence of constant fleet renewal.

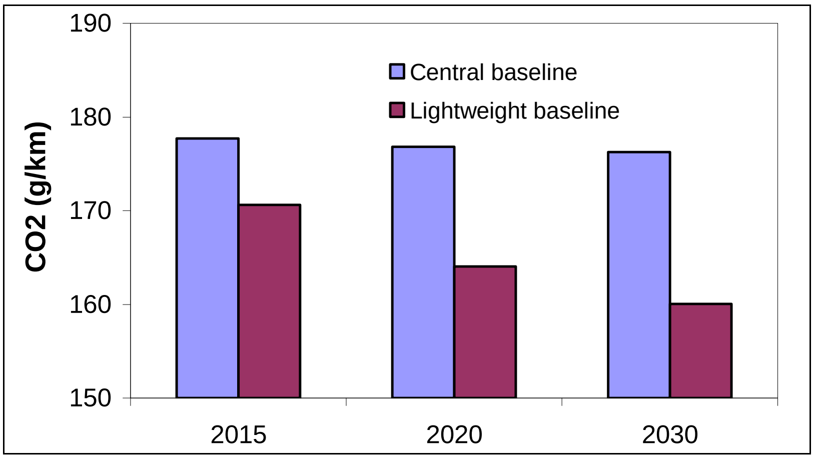
Figure 19: Difference in cost and tax components in lightweight variant compared to center basecase



5.2.3 Well-to wheel emissions

The main effect of the inclusion of lightweight cars concerns CO_2 emissions. The other pollutants are only affected at WTT level as a result of lower fuel consumption. Exhaust gas emissions are unchanged. All new cars starting in 2012 will be reduced in weight, and in 2030 all cars will emit 10% less CO_2 emissions due to this weight reduction. This decrease causes average fleet CO_2 emissions to decrease over time, as fuel efficient lightweight vehicles will continue to replace older non-lightweight vehicles:

Figure 20: CO_2 emissions per car in both basecase variants (central: blue, lightweight: purple)

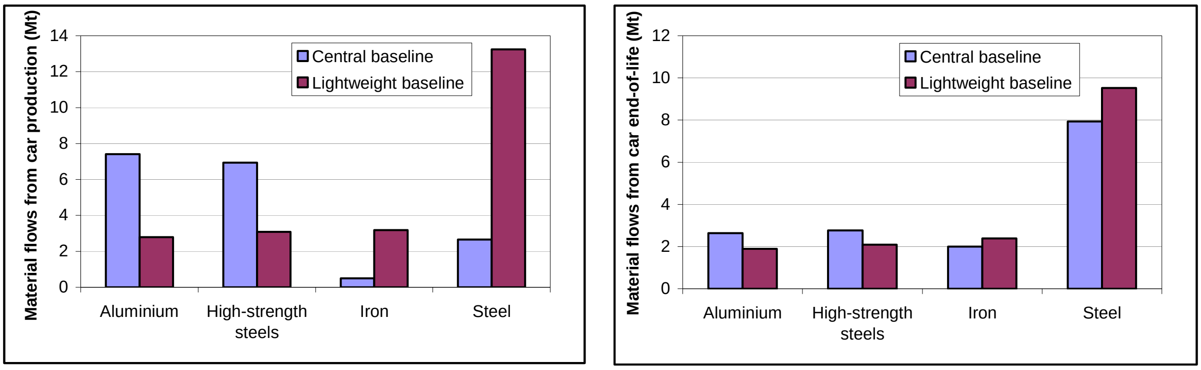


The WTW CO_2 emissions in the baseline variant decrease by approximately 10% in 2030 compared to the central basecase, under the effect of constant fleet renewal with less fuel consuming cars.

5.2.4 Material flows and associated impacts

The weight reduction results from a change in the material composition of the car, especially with regard the contribution of aluminum, HSS, iron and steel. This is visible for both production and ELVs (Figure 21).

Figure 21: Difference in material flows between central baseline and lightweight baseline scenario in 2020 (car production – left – and ELV - right)



In car production, there is a major shift from iron and steel towards aluminum and high-strength steels. The ELVs in 2020 are a mix of lightweight vehicles produced in 2012 or later and vehicles with no assumed weight reduction, built prior to 2012. Therefore, the effects are less significant for ELV than for new car production. In both scenarios, the total ELV weight is lower than new car production weight because the vehicle stock continues to increase over the years.

5.2.4.1 Life-cycle impacts due to the production of cars and spare parts

The environmental life-cycle impacts due to the production of cars are shown in Table 16 for the years 2010, 2020 and 2030.
The production of spare parts leads to lower environmental impacts compared to the production of new cars (Table 14).

Table 13: Total life-cycle impacts due to car production according to impact categories

Year	Abiotic depletion	Greenhouse gases	Photochemical pollution	Acidification potential	Eutrophication potential	Bulk waste
	1000 t Sb eq	Mt CO2 eq	Mt C2H4 eq	Mt SO2 eq	Mt PO4 eq	Mt
2010	8.92	86.36	0.13	1.20	0.10	4.06
2020	11.36	107.51	0.16	1.65	0.13	6.85
2030	11.83	111.92	0.16	1.72	0.14	7.14

Table 14: Total life-cycle impacts due to spare parts production according to impact categories

Year	Abiotic depletion	Greenhouse gases	Photochemical pollution	Acidification potential	Eutrophication potential	Bulk waste
	1000 t Sb eq	Mt CO2 eq	Mt C2H4 eq	Mt SO2 eq	Mt PO4 eq	Mt
2010	11.96	9.16	0.02	0.56	0.01	1.08
2020	13.95	11.21	0.03	0.73	0.01	1.39
2030	15.46	12.58	0.03	0.85	0.01	1.60

5.2.5 Life-cycle impacts

The life-cycle impacts induced by the car fleet up to 2030 are derived from the WTW emissions as given in section 5.1.4 and from the impacts from the production of cars and spare parts (section 5.1.5.4). The WTW emissions are complete with estimates of the impacts in terms of bulk waste and abiotic depletion, using the same coefficients as in the IMPRO-car study. Then, the emissions are converted into mid-point indicators by using the corresponding characterization factors. The results are given in Table 15.

Note should be taken that the estimates are the least reliable for the long term because the estimates assume unchanged process technologies. This means that for these periods, the impacts are likely to be overestimated.

Table 15: Mid-point indicators for the WTW impacts for the years 2010, 2020 and 2030.

Year	Abiotic depletion	GHG	Photochemical pollution	acidification	eutrophication	Bulk waste
	1000 t Sb eq	Mt CO2 eq	Mt C2H4 eq	Mt SO2 eq	Mt PO4 eq	Mt
2010	0.00	1089	3.34	3.90	0.55	0.03
2020	0.00	1189	2.19	3.32	0.37	0.03
2030	0.00	1303	1.98	3.39	0.34	0.04

These mid-points indicators are combined with those derived for the car production and spare parts processes, giving the life-cycle impacts (Table 16).

Table 17 shows the effects of the car weight reductions assumed in the scenario by comparing the life-cycle impacts with the central basecase. GHG emissions, together with emissions contributing to photochemical pollution, acidification and eutrophication are reduced over time. Impacts on raw material resources are also slightly reduced. On the contrary, the lightweight option results in larger amounts of waste.

Table 16: Mid-point indicators for the life-cycle impacts for the years 2010, 2020 and 2030.

Year	Abiotic depletion	GHG	Photochemical pollution	acidification	eutrophication	Bulk waste
	1000 t Sb eq	Mt CO2 eq	Mt C2H4 eq	Mt SO2 eq	Mt PO4 eq	Mt
2010	20.88	1185	3.49	5.66	0.66	5.18
2020	25.31	1307	2.38	5.70	0.51	8.27
2030	27.29	1427	2.17	5.96	0.49	8.78

Table 17: Consequences of the car weight reduction on the life-cycle impacts (% changes compared with the central basecase assuming no weight reduction)

Year	Abiotic depletion	GHG	Photochemical pollution	acidification	eutrophication	Bulk waste
2010	0.0%	0.3%	0.0%	1.7%	0.0%	0.0%
2020	-0.5%	-3.9%	-1.6%	-1.6%	-1.0%	20.5%
2030	-0.5%	-5.2%	-2.4%	-2.4%	-1.6%	19.9%

6 Feebate

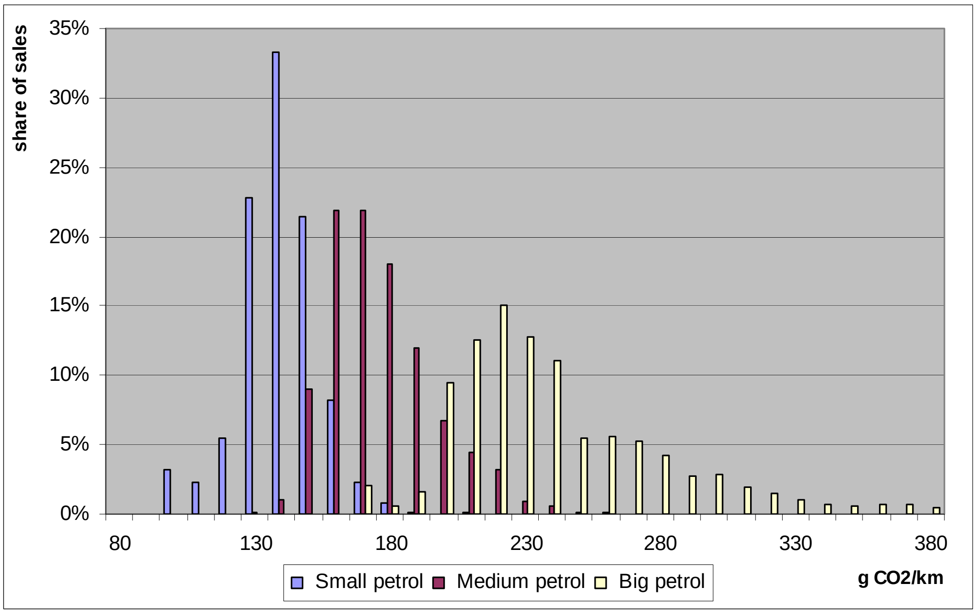
6.1 Introduction

The feebate approach provides a lot of flexibility due to the different possible settings for the **tax/subsidy** and for the **pivot-point**. Both can be set constant over the policy period and across all car classes. But the **pivot-point** can also move to lower values over time. This would enable an adjustment of the feebate to an increasing penetration of cleaner technologies over time, and to the evolving target in terms of CO_2 emission from cars.

These parameters will influence the reactions of the consumers which will result in effects on vehicle sales, GHG emissions and, also costs for the governments. In theory, since a feebate consists of both a tax and a subsidy, the system could be designed in accordance with public budget availability. In this respect, the fact that the net costs for the governments will depend on revenues from both registration tax fuel taxation should be kept in mind.

As in the case of the labelling of CO_2 emissions (see section 2.3), two extreme approaches can be considered. In the first approach, the "**full absolute approach**", the level of tax/subsidy is only determined by the CO_2 emissions produced by a car. Given the emission pattern of the different car classes (see Figure 22), bigger cars will therefore be subject to higher taxes.

Figure 22: Distribution of the different car classes in terms of CO_2 emissions (g/km)



In the **"relative approach"**, the level of feebate is not only determined by the CO_2 emissions, but also by an additional parameter which relates to the utility of the car. Such an approach would be guided by the higher abatement costs for e.g. big family cars, which inherently require a larger engine. On the other hand, a small car which is equipped with an “unnecessarily” large engine would be taxed above average. The additional utility-related parameter can be the vehicle weight, surface, number of seats, etc.

From a modeling perspective, this approach requires more data than required by the absolute approach, especially on two aspects:

- market data for the additional utility parameters considered;
- cost for CO_2 emission reduction, which requires a differentiated abatement cost curve with respect to the chosen utility-parameter.

Due to a lack of such data, **the report focuses on absolute feebates** for which the model was developed by using existing data on the abatement costs of the technologies to reduce CO_2 emission from cars and on observed (type-approval) CO_2 emission of new cars in the different Member States.

6.2 Modelling approach

A two-step approach was set up in order to model the effects of this policy instrument at the EU27 level with TREMOVE. The method fits with the features of the TREMOVE car sales logit which distinguishes between 6 vehicle categories (diesel/petrol and small/medium/large engine classes).

In the first step, the expected new preference in terms of fuel efficiency and CO_2 emissions is calculated within every car category in an ad hoc model developed outside TREMOVE.

In the second step, the new CO_2 emission levels per vehicle category have been introduced in TREMOVE, together with the corresponding feebate registration tax and vehicle cost changes (abatement costs). The effects on demand, vehicle stock and emissions are then calculated with TREMOVE.

6.2.1 Step 1: reaction within vehicle categories

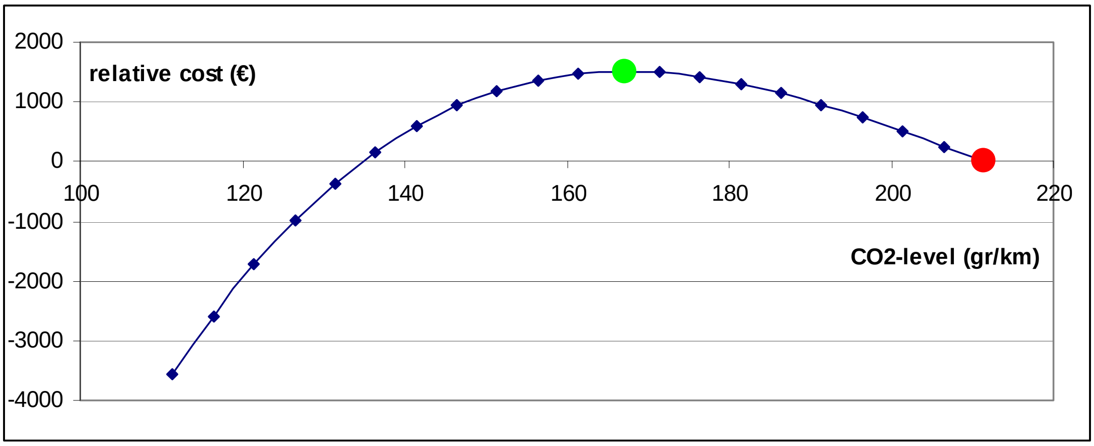
The full cost of a passenger car in relation to the test cycle CO_2 emissions is affected by two cost components:

- The **lifetime fuel cost**, assuming no changes in fuel price in time, correlates linear with CO_2 emissions. A low CO_2-emitting car is proportionately fuel efficient.
- The **purchase cost** of the vehicle increases with the vehicle's fuel efficiency. TNO et al. (2006)[15] estimated this correlation for every vehicle category (polynomial function).

CO_2 emission reductions entail higher purchase costs as a result of the abatement technology while lifetime fuel costs decrease. This means that, at least in theory, an optimal CO_2 level exists for the consumer.

The latest available CO_2 monitoring database (EC, 2007)[3] which included the year 2006, suggests that this optimal level is not met when consumers buy a new car: Figure 23 displays the net additional costs (abatement costs and fuel costs savings) as a function of the CO_2 emission of cars, relative to the value observed in 2006 in the case of big diesel cars. The green dot represents the optimal CO_2 level (about 167 g/km) with corresponding benefits compared to the reference; the red dot represents the observed CO_2 emission level in 2006. At the left-hand side of the optimal level (green dot), the costs start to increase because the increasing fuel costs saving (which is linear with CO_2 emissions) does not compensate the increasing abatement cost. At the right-hand side from the optimal level, the abatement cost is lower than the saved fuel cost. From an economic point of view, it thus makes sense to abate.

Figure 23: Relation between CO_2 emission level and additional costs compared to reference (year 2006): Big diesel car (positive value equals a benefit for the car purchaser)

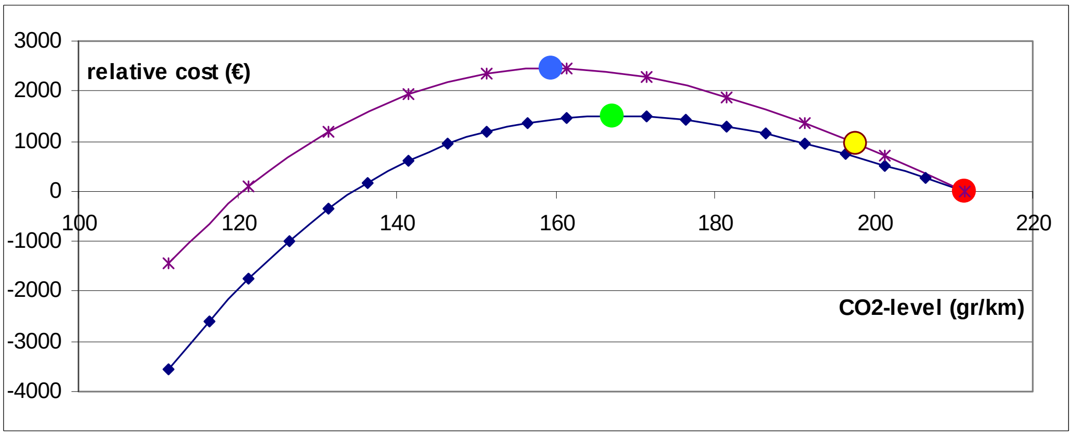


Since the observed CO_2 level is higher than the optimal level, it would be logical to abate to this point. This observation suggests that there is an additional disutility perceived by the consumer for low CO_2 emitting cars (e.g. acceleration, size). In the observed CO_2 level this "economy gap" is approximately 1500€ per vehicle.

Introducing a feebate system adds a third cost component to the cost function (see Figure 24) which is the CO_2 dependant registration tax. In practice, the feebate system could be introduced as discrete categories, relating to the CO_2 level. However, for calculation purposes, the feebate tax is assumed to be a continuous function.

Due to the introduction of the additional registration tax, the optimal CO_2 emission level shifts to the left (blue dot). When estimating the reaction of consumers, it is assumed that they will not move to the new optimum level, but that they will again internalize the earlier determined "economy gap" in the decision, in addition to the additional taxation.

Figure 24: Relation between CO_2 emission level and additional costs compared to the reference (year 2006), including feebate registration tax. Big diesel car (positive value equals a benefit)



Therefore, in order to determine the new average CO_2 emission level of new cars, with the feebate system in place, the new optimal CO_2 emission level is first calculated (blue dot). Then, the identified "economy gap" is subtracted (yellow dot).

Note that this calculation assumes that the identified “economy gap” is the same for all CO_2 emission levels. This assumption has not been proven. Unfortunately, the available data did not enable further investigation on that.

6.2.2 Step 2: TREMOVE run

The output of the first step holds 3 major parameters:

- the CO_2 emission level under the incentive of the feebate
- the increase or decrease of the registration tax due to the CO_2 differentiated feebate tax
- the increase of purchase cost.

All three parameter values have been determined for the 6 vehicle categories and imported into TREMOVE and then converted to match existing model parameters. The car sales logit in the TREMOVE stock module reacts to cost changes of fuel cost, purchase cost and registration tax. This consequently affects demand as the generalized price of transport with passenger vehicles is altered due to changes in vehicle lifetime cost and purchase behavior. Both demand (via changes of total demand and shifts between modes), and stock (via changes in average CO_2 emission level, fuel consumption and shifts between vehicle categories), affect the emission calculation.

6.3 Policy cases considered

The French feebate system (see section 3.3) was considered as a first reference to start with. The bonus/malus is a discontinuous function of CO_2 emissions. However, in order to adjust to modeling constraints, a continuous function was built upon this reference as a regression function which best fitted the French function[a]. The function is shown in green (solid curve) in Figure 25 (130_1_1) and is referred to as the "reference policy case".

Several variants were also tested, covering different options with respect to the pivot point (120 or 140 g/km), and with respect to the level of the rebate and/or fee part. The removal of the rebate part was also included.

The variants are labelled as follows:

"Pivot point (g/km)"_"rebate level relative to central case"_ "fee level relative to central case"

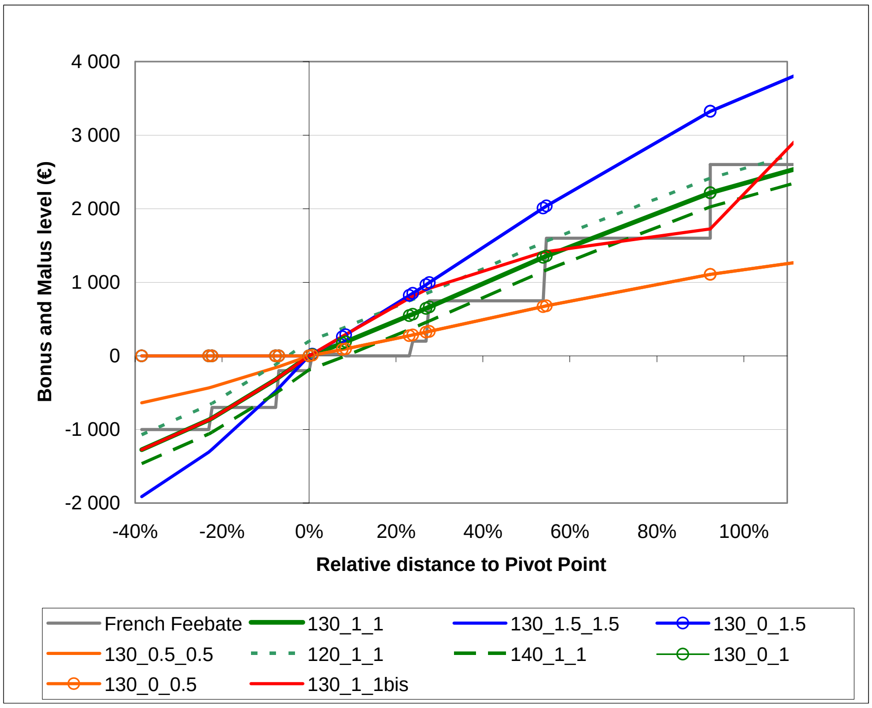
An additional alternative case was also considered, where the shape of the reference policy feebate curve was modified. This alternative case is labelled 130_1_1bis (see red curve in the figure).

When changing the pivot point, the new function was derived from a vertical shift of the initial curve.

In all cases, the feebate system was assumed to be implemented between 2010 and 2015.

[a] A first component was derived as the 5 degree polynomial function which best fits the negative part of the French function. The second component was derived similarly for the positive part of the French function.

Figure 25: Different feebate functions analysed



6.4 Reaction of car purchasers to the feebate system

The following presents the results from the first step of the modeling, namely, the response of the consumer, including the resulting new CO_2 emissions, abatement costs and taxes. As an example, Table 18 provides the results for all vehicle categories, for the reference policy case (130_1_1).

Table 18: Modelled consumer reaction to the feebate system by vehicle category (130_1_1 case)

		PCDB	PCDM	PCDS	PCGB	PCGM	PCGS
Current situation (without feebate)	CO2 emissions level in 2006 (g/km)	211	150	121	249	178	143
	theoretical optimal CO2 emissions level (g/km)	167	134	118	162	138	119
	"utlity gap" (€)	1509	327	17	3496	976	292
Expectation with a feebate	theoretical optimal CO2 emissions level (g/km)	159	124	110	151	124	105
	expected CO2 emissions level (g/km)	198	141	113	225	162	121

The gaps between the theoretical optimal value and the observed value from 2006 sales are significant, especially for the larger vehicle categories (87 g CO_2/km for PCGB). The "utility gap" is also the highest for big vehicle categories, with PCGB again as the extreme case. This suggests the importance of other features of vehicles besides just the fuel cost. For smaller vehicle categories, the gap is smaller, possibly because small cars owners have more stringent budget constraints, therefore making them more sensitive to price.

Also interesting is the fact that the utility gap for diesel cars is narrower than for petrol cars. This may be related to the lower abatement costs for petrol cars or higher utility of petrol cars versus diesel cars, although diesel technology has improved significantly. There may be other unexplained reasons.

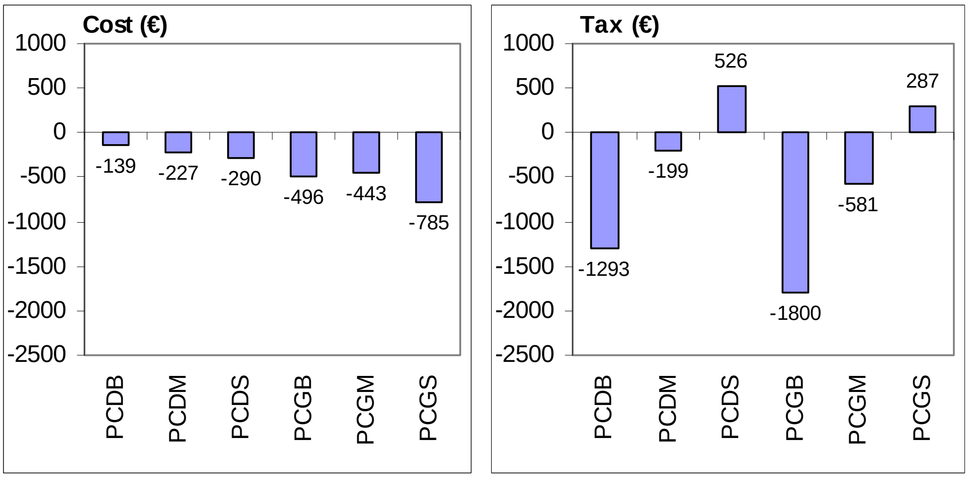
Given the tax function and the identified "utility gap", the expected CO_2 emission level per vehicle category is calculated with the ad hoc model. As expected, the CO_2 emission levels are modeled to decrease under the influence of the feebate registration tax. This decrease is the largest for bigger cars.

Abatement is also greater for petrol cars than for diesel cars because of a higher abatement potential. In relative terms, however, the abatement is the same for all size classes; approximately 6% for diesel cars. For petrol cars a 10% abatement is expected for big and medium cars whereas 15% abatement is expected for small cars. In theory, one would expect higher abatement for bigger cars (including in relative terms), because the abatement cost is lower compared to smaller cars. However, the higher "economy gap" shown in the calibration suggests that bigger car-users are more reluctant to buy more fuel efficient cars.

The importance of taking into account the "utility gap" is clear. The difference between the base case and optimum level is greater than the difference between the base case and the expected level (for PCGB: a factor 4). This indicates that purchase cost and fuel cost are not key parameters in the decision of buying a car (especially for consumers of big cars). Other parameters relating to utility appear to be more important. Further research on the importance of purchase cost and fuel cost in consumer decision-making would contribute to improving the accuracy of the simulations.

The CO_2 level is determined by the abatement cost compared to the base case and the feebate registration tax level. The difference of the abatement cost and registration tax is presented for all vehicle categories in Figure 26.

Figure 26: Abatement cost (left) and registration tax (right) as compared to reference per vehicle category (negative = a cost for consumer)



The figures show that the willingness to pay for more efficient technologies (abatement costs) is stronger for smaller cars. However, as the cost per CO_2 abated is also higher for smaller cars, the actual CO_2-emissions abatement will be lower than for big cars. The abatement potential is indeed much higher with bigger cars. The abatement cost is higher with petrol cars because the CO_2 emission levels decrease stronger than with diesel cars. The saved fuel costs are more important for petrol than diesel, explaining the stronger abatement level.
The results for the different policy scenarios are summarized in Table 19 and Table 20. The values are averages for the EU-27.

Table 19: Expected new CO_2 emission levels as a result of the feebate variants (g CO_2/km)

VehType	130_1_1	130_1_1bis	120_1_1	140_1_1	130_1.5_1.5	130_0_1.5	130_0.5_0.5	130_0_0.5	130_0_1	CO2 initial level
PCDB	198	200	198	198	192	192	204	204	198	211
PCDM	141	139	141	141	136	141	146	146	143	150
PCDS	113	113	113	113	110	121	117	121	121	121
PCGB	225	233	225	225	215	215	235	235	225	249
PCGM	162	157	162	162	154	158	170	170	163	178
PCGS	121	121	121	121	115	135	129	139	137	143

Table 20: Expected additional purchase tax as a result of the feebate variants (€)

VehType	130_1_1	130_1_1bis	120_1_1	140_1_1	130_1.5_1.5	130_0_1.5	130_0.5_0.5	130_0_0.5	130_0_1
PCDB	1 293	1 410	1 093	1 483	1 780	1 780	707	707	1 293
PCDM	199	241	-1	390	153	278	142	142	228
PCDS	-526	-526	-726	-335	-922	0	-209	0	0
PCGB	1 800	1 524	1 600	1 991	2 452	2 452	992	992	1 800
PCGM	581	712	381	771	646	752	367	367	602
PCGS	-287	-287	-487	-96	-690	133	-17	74	111

Despite their identical parameters (PP, fee/rebate levels), the two alternative feebate curves (130_1_1 and 130_1_1bis) differ in terms of expected emission reduction for medium and big petrol cars. The emissions from medium petrol cars would decline more in the alternative case. The opposite would occur for the big petrol cars. Smaller deviations are seen for medium and big diesel cars.

These deviations result from the **difference in shape** of the alternative function: the comparative results depend on the respective derivative of the two compared functions, in the range in which the emissions of the car is placed. The abatement is the stronger where the derivative is higher because the economic gain per CO_2 emission reduced is the greatest, thus representing a higher incentive to move to smaller emission levels. The effects of the feebate will thus potentially depend on the form of the function considered. One can indeed expect such effects in real-life (and especially if the function is discontinuous). Predicting the size of this effect cannot however, be done with a high degree of accuracy.

The emission reductions do not differ when moving the **pivot-point** from 120 g/km to 140 g/km. This is because the way to shift the function (vertically) preserves its initial form. In light of the previous paragraph, some deviations may occur in the case of other shift modes.

From a cost perspective, the new taxation level is sensitive to PP: When the PP is lowered (raised), the taxation would become higher (lower) for all car types.

The **fee and rebate levels** have a clear influence on the expected reaction. The effects coincide with what is expected: higher fee levels result in higher emission reductions for big/medium cars. Higher rebate levels result in higher emission reductions for small cars. The cancellation of the rebate part results in almost no emission reduction for small cars.

6.5 Effects on transport demand and vehicle purchases

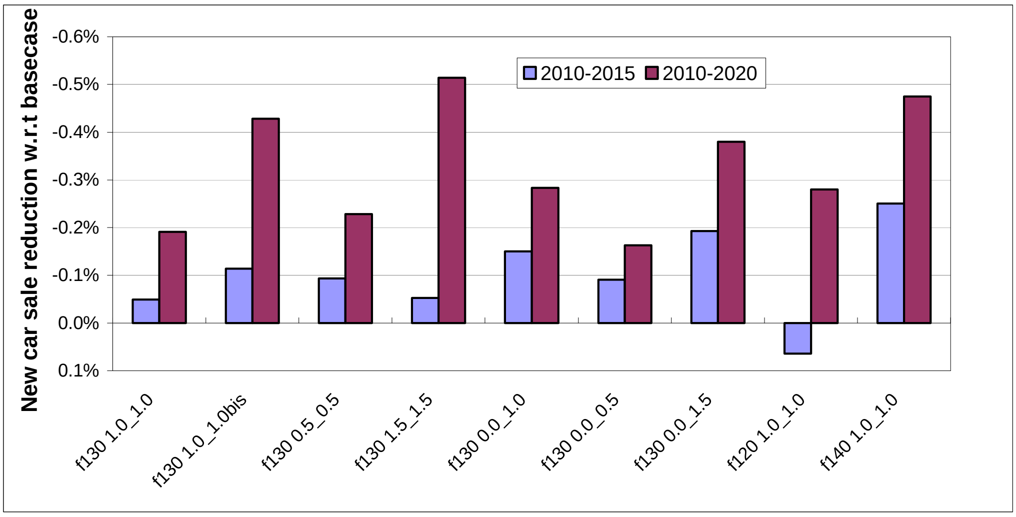
For each policy variant, the parameters derived from previous section have been introduced in TREMOVE for the period 2010 to 2015. The following presents the results from the different policy simulations in terms of transport demand and new car sales.

In most cases, total costs of car transport are projected to increase due to increased abatement costs and registration tax, in spite of the decrease in fuel cost (see section 6.6.1). This induces a small decrease in demand (vkm) and in desired stock, thus determining car sales.

Most scenarios indeed result in a small decrease in demand (0.05% to ~0.32% compared to total base case new stock) over the period 2010-2015, and even beyond (-0.2% to -0.5% of the basecase over the period 2010-2020). This is shown in Figure 27.

The sales decreases are more important in the longer term. This higher increase is explained by the increasing generalized passenger car transport costs considered in TREMOVE. These costs include the annualized purchase costs of all cars in the fleet (including those from the more expensive cars purchased during the 2010-2015 period).

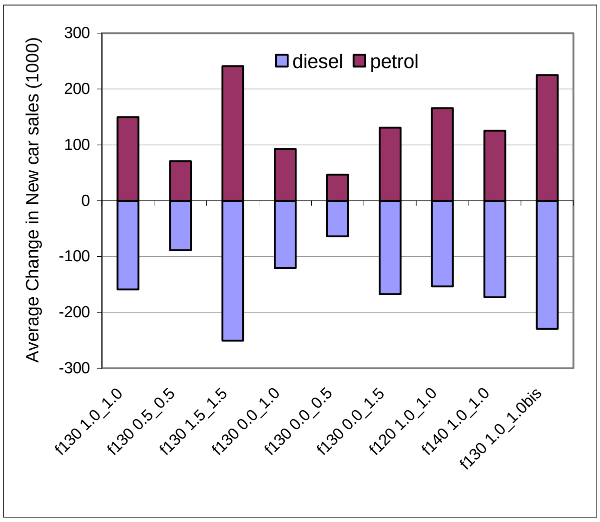
Figure 27: Total decrease in car sales (% of basecase)

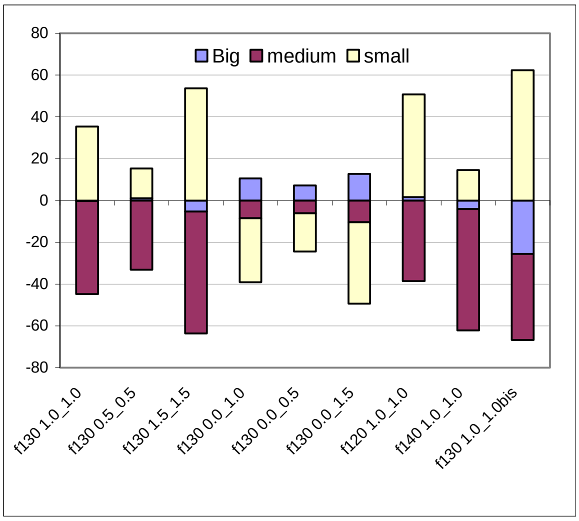


New diesel car sales are reduced in all cases (because these cars become more expensive than gasoline ones (all additional costs being taken into account, including abatement costs) (see Figure 28).

The sales of medium cars are decreased, being, in most cases, compensated by additional small car sales. The only exception is when the bonus is removed as this cancels the incentive to move from medium to small cars.

Figure 28: Changes in new car sales by size and fuel (2010-2015 average) – comparison with the basecase (positive = increase)





6.6 Environmental effects

6.6.1 Well-to-Wheel emissions

Tank-to-Wheel (TTW) emissions are obviously reduced as a result of lower CO_2 emissions per km driven (see Table 19). The sales-averaged (real-world) CO_2 emission reductions of new cars are shown in Table 21.

Table 21: Real-world emission factors of new cars

veh type	BC	f130 1.0_1.0	f130 0.5_0.5	f130 1.5_1.5	f130 0.0_1.0	f130 0.0_0.5	f130 0.0_1.5	f120 1.0_1.0	f140 1.0_1.0	f130 1.0_1.0bis
PCDB	243	227	234	221	227	234	221	227	227	230
PCDM	173	164	169	158	165	169	163	164	164	161
PCDS	137	128	132	124	137	137	137	128	128	128
PCGB	275	249	260	239	249	260	239	249	249	257
PCGM	211	192	201	183	193	201	187	192	192	187
PCGS	177	151	161	144	170	172	168	151	151	151
realworld average	*190*	*172*	*180*	*166*	*179*	*184*	*176*	*172*	*172*	*171*
type approval average	*161*	*146*	*152*	*140*	*152*	*156*	*149*	*146*	*146*	*145*

The emissions from cars over the period 2010-2015 are reduced by 0.7% to 2.6% w.r.t. the basecase. The Well-to-Tank (WTT) CO_2 emissions and GHG emissions change in the same relative magnitude. Changes are primarily determined by the feebate/rebate level.

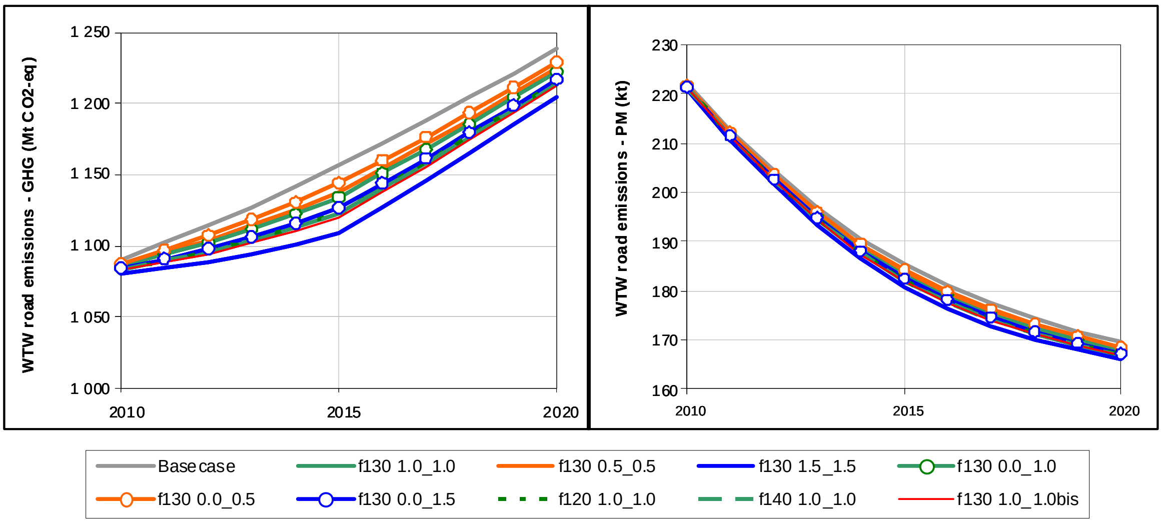
The feebate system also induces small benefits in terms of air pollution:

- SO_x emission reduction result from fuel savings. This effect is however negligible at the WTW level as TTW SOx emission represent a tiny fraction of WTW emissions.
- NO_x and PM emissions are slightly reduced as a result of fewer diesel cars.
- CO and VOC emissions are very slightly decreased.

The different trends for WTW emissions up to 2020 are shown in Figure 29 in the case of GHG emissions and PM emissions. In the first case, the emission reduction w.r.t to the basecase increase over the period 2010-2015. Then the gap is kept almost constant over the next 5 years because the more efficient cars introduced during the feebate period remain in the car fleet. The evolution of PM emissions is explained by both the fuel efficiency improvement and by the shift from diesel to petrol cars that are emit fewer particulates.

SOx emissions follow the same pattern as GHG emissions. The other emissions stay almost at the same level as the basecase.

Figure 29: Trends in WTW road emissions: GHG emissions and PM emissions



6.6.2 Material flows and associated impacts

The following presents the estimated effects of the feebate policy on the different material flows and on the environmental impacts resulting from the car production and from the spare parts production. To this end, we consider the feebate scenario 130_1_1. Similar results are expected for the other scenarios.

Over the period 2010-2015, the total material flow for the production of cars in the feebate case is only slightly reduced compared to the base case (Table 22). This overall decrease reflects the decreases in sales. A reduction is observed for all single material flows except for other plastics and for rhodium. The largest absolute reductions occur for steel, iron, and aluminum (44 kt, 39 kt, and 31 kt, respectively). The largest relative reductions are for platinum, iron, and aluminum.

The material flows due to the EOL of cars shows a reverse picture. For all materials, the mass flow is increased compared to the base case. The largest absolute increases occur for steel, PP, and iron (19.8 kt, 4.2 kt, 3.5 kt, respectively). In relative terms, the greatest increases occur for high-strength steels, palladium, and refrigerants.

Table 22: Material flows due to the car and spare part production for the feebate scenario (average of 2010 to 2015)

		Car production			End-of-life		
Material group	**Material**	**Base case**	**Feebate scenario**		**Base case**	**Feebate scenario**	
		kt	kt	[% of BC]	kt	kt	[% of BC]
Metals	Aluminium	2 046	2 015	98.5	1 238	1 241	100.3
	Copper	216	216	99.9	158	158	100.3
	High-strength steel	2 248	2 246	99.9	497	501	100.7
	Iron	2 321	2 283	98.3	1 967	1 970	100.2
	Lead	164	164	99.9	121	122	100.3
	Magnesium	50	50	99.9	30	31	100.3
	Steel	9 628	9 584	99.5	8 092	8 112	100.2
	Zinc	47	47	99.9	34	34	100.3
	Other metals	94	94	99.9	68	68	100.3
Plastics	ABS	193	193	99.9	109	109	100.4
	PA	95	95	99.9	91	91	100.2
	PE	559	559	99.9	347	348	100.3
	PET	34	34	99.9	21	22	100.3
	PP	2 080	2 078	99.9	1 219	1 223	100.3
	PUR	534	534	99.9	370	372	100.3
	PVC	7	7	99.9	25	25	100.1
	Rubber/Elastomer	494	494	99.9	367	368	100.3
	Other plastics	472	491	103.9	461	463	100.4
Fluids	Refrigerant	10	10	99.9	4	4	100.5
	Oil	141	141	99.9	105	105	100.3
	Other fluids	477	476	99.9	345	346	100.3
PGM	Palladium	0.035	0.035	100.0	0.015	0.015	100.5
	Platinum	0.03	0.029	98.2	0.023	0.023	100.2
	Rhodium	0.002	0.002	101.3	0.003	0.003	100.4
Other materials	Textile	240	239	99.9	175	175	100.3
	Glass	543	542	99.9	395	396	100.3
	Other	678	677	99.9	764	766	100.2
Total		**23 372**	**23 269**	**99.6**	**17 003**	**17 048**	**100.3**

Table 23: Material flows due to production or EOL of spare parts for the feebate scenario (average of 2010 to 2015)

		Base case		Feebate scenario			
		Production	**EOL**	**Production**		**EOL**	
		kt	kt	kt	[% of BC]	kt	[% of BC]
Metals	Lead	338	338	338	99.93	338	99.93
	Zinc	19	19	19	99.87	19	99.87
	Other metals	284	284	283	99.87	283	99.87
Plastics	PP	34	34	34	99.93	34	99.93
	Rubber/Elastomer	908	908	907	99.87	907	99.87
	Other plastics	17	17	17	99.93	17	99.93
Fluids	Refrigerant	11	11	11	100.01	11	100.01
	Oil	491	491	490	99.89	490	99.89
PGM	Palladium	0.03	0.03	0.03	100.02	0.025	100.02
	Platinum	0.03	0.03	0.03	99.55	0.027	99.55
	Rhodium	0.00	0.00	0.00	100.15	0.003	100.15
Other materials	Textile	95	95	94	99.87	94	99.87
	Other	785	785	784	99.89	784	99.89
Total		2 980	2 980	2 976	**99.89**	2 977	**99.89**

As regards spare parts, the material flows due to production and EOL are similar (Table 23). The mass flow increases only for refrigerants, palladium, and rhodium.
No significant change in different waste treatment activities are expected (Table 24).

Table 24: EOL treatment of the ELVs and spare parts for the base case and the feebate scenario (average from 2010 to 2015)

kt	Recycling, recovery & reuse	Shredder	ARS disposal & landfill	Hazardous waste incinerator	Export	Total
Base case	8 429	7 494	3 865	5	189	19 983
Feebate scenario	8 439	7 513	3 879	5	189	20 025
Difference	0.13%	0.24%	0.35%	-0.11%	-0.13%	0.21%

The environmental impacts due to the production of cars and of spare parts have been calculated according to the LCA methodology presented in Section 4.4. Environmental impacts are reduced for all impact categories compared to the base case (Table 25). The reduction of the impacts is more pronounced for the production of new cars compared to the production of spare parts. Overall environmental impacts are reduced by 0.09% to 0.52%.

Table 25: Environmental impacts from the production of cars and spare parts for the feebate scenario (average from 2010 to 2015)

		Production of cars			Production of spare parts			total		
		Base case	Feebate scenario		Base case	Feebate scenario		Base case	Feebate scenario	
				[% of BC]			*[% of BC]*			*[% of BC]*
AD	kt Sb eq	9.47	9.46	*99.9%*	12.45	12.44	*99.9%*	21.92	21.90	*99.9%*
GHG	Mt CO2 eq	91.68	91.35	*99.6%*	9.69	9.68	*99.9%*	101.37	101.03	*99.7%*
POCP	kt C2H4 eq	134.5	134.1	*99.6%*	24.7	24.6	*99.9%*	159.2	158.7	*99.7%*
AP	kt SO2 eq	1327.3	1323.1	*99.7%*	495.9	495.3	*99.9%*	1823.2	1818.4	*99.7%*
EP	kt PO4 eq	109.7	109.5	*99.8%*	9.9	9.8	*99.9%*	119.6	119.4	*99.8%*
BW	Mt	4.37	4.35	*99.4%*	1.15	1.14	*99.9%*	5.52	5.49	*99.5%*

6.6.3 Life-cycle impacts

The life-cycle impacts from the car fleet in the base case and in the policy scenario are calculated by combining the results derived in sections 6.6.1 and 6.6.2. The results are shown in Table 26 in the case of the feebate 130_1_1 for the period 2010-2015.

Table 26: Effects of the feebate instrument on the life-cycle impacts from the car fleet

	WTW			Production of cars and spare parts			Total		
	basecase	f130_1_1	% change w.r.t basecase	basecase	f130_1_1	% change w.r.t basecase	basecase	f130_1_1	% change w.r.t basecase
abiotic depletion (kt Sb eq)	0.00	0.00	-1.8%	21.92	21.90	-0.1%	21.93	21.91	-0.1%
GHG emissions (Mt CO2-eq)	1 122	1 101	-1.8%	101	101	-0.3%	1 223	1 202	-1.7%
acidification (kt SO2 eq)	7 421	7 331	-1.2%	1 823	1 818	-0.3%	9 244	9 150	-1.0%
eutrophication (kt PO4 eq)	980	975	-0.5%	120	119	-0.2%	1 099	1 095	-0.4%
Photochemical Pollution (kt C2H4 eq)	5 920	5 893	-0.5%	159	159	-0.3%	6 079	6 052	-0.5%
Bulk waste (Mt)	0.03	0.03	-1.8%	5.52	5.49	-0.5%	5.55	5.52	-0.5%

The table shows that the feebate instrument would result in reductions in GHG emissions, acidification, eutrophication and photochemical pollution of the same magnitude as what is expected for the WTW part.

6.7 Economic impacts

6.7.1 Effects on household expenditures and taxation

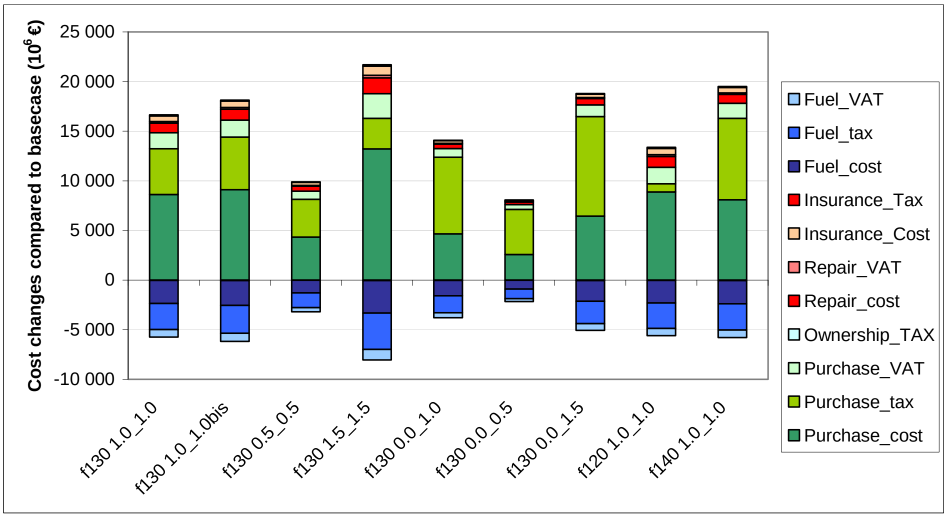
The primary consequences of the feebate system concern the following costs (Figure 30):

- Purchase costs (retailer price): the incentive to the purchase of more efficient cars indirectly results in more expensive cars due to of costs from abatement technologies. The total purchase costs at EU27 level are determined by the new car sales patterns.
- Registration tax: the main effect depends on the feebate system.
- Fuel costs: the penetration of more efficient cars reduces the fuel consumption and thus the fuel costs (including taxes).

Other costs (e.g. repairing, insurance) are indirectly affected in the same direction as purchase costs because they are assumed to be proportional to the purchase costs.

The average costs incurred in the different scenarios over the period 2010-2015 are summarised in Figure 30 and in Table 27 (costs differences between the simulations and the basecase). Over all scenarios considered, consumer expenditures for cars would increase by 0.6% to 1.2% compared to the basecase. Regarding tax, the purchase tax (and VAT) revenue is expected to increase in all cases whereas the fuel tax revenue would decrease as a result of improved fuel economy. In most cases, the total tax revenue is expected to increase.

Figure 30: Differences in costs between simulations and basecase scenario – average over the period 2010-2015



When considering these costs over the longer period 2010-2020 (Table 28), the absolute and relative importance of fuel costs changes is higher and the average net costs for the consumers are lower (~2% BC) whereas the expected average tax revenue is lower and even becoming negative in several cases. Considering such a longer term perspective is relevant when assessing ex ante the implications for public budgets. Indeed, when only looking at registration tax, the feebate system appears to generate revenue for the government. However, if loss of fuel tax is taken into account, this revenue is completely balanced out.

Table 27: Cost differences between simulations and basecase scenario – average over the period 2010-2015 (10^6€)

	f130 1.0_1.0	f130 1.0_1.0bis	f130 0.5_0.5	f130 1.5_1.5	f130 0.0_1.0	f130 0.0_0.5	f130 0.0_1.5	f120 1.0_1.0	f140 1.0_1.0
purchase cost & others	13 212	14 473	7 980	16 920	11 837	6 782	15 798	10 029	16 042
fuel cost	-2 315	-2 501	-1 280	-3 269	-1 547	-882	-2 068	-2 268	-2 339
total cost	10 897	11 972	6 700	13 651	10 289	5 900	13 730	7 761	13 703
(%BC)	*(0.9%)*	*(1.0%)*	*(0.6%)*	*(1.2%)*	*(0.9%)*	*(0.5%)*	*(1.2%)*	*(0.7%)*	*(1.2%)*
registration tax	4 600	5 302	3 790	3 082	7 725	4 549	10 008	811	8 198
fuel tax	-2 620	-2 802	-1 472	-3 644	-1 706	-982	-2 272	-2 566	-2 642
other tax	1 060	1 120	503	1 748	441	238	630	1 165	935
total tax	3 039	3 620	2 822	1 187	6 459	3 805	8 365	-590	6 491
(%BC)	*(0.9%)*	*(1.1%)*	*(0.9%)*	*(0.4%)*	*(2.0%)*	*(1.2%)*	*(2.6%)*	*-(0.2%)*	*(2.0%)*

Table 28: Cost differences between simulations and basecase scenario – average over the period 2010-2020 (10^6€)

	f130 1.0_1.0	f130 1.0_1.0bis	f130 0.5_0.5	f130 1.5_1.5	f130 0.0_1.0	f130 0.0_0.5	f130 0.0_1.5	f120 1.0_1.0	f140 1.0_1.0
purchase cost & others	5 815	5 664	3 107	6 721	4 872	2 769	6 546	3 746	6 466
fuel cost	-3 435	-3 705	-1 897	-4 831	-2 277	-1 299	-3 039	-3 353	-3 464
total cost	2 381	1 958	1 210	1 890	2 595	1 470	3 506	392	3 003
(%BC)	*(0.2%)*	*(0.2%)*	*(0.1%)*	*(0.2%)*	*(0.2%)*	*(0.1%)*	*(0.3%)*	*(0.0%)*	*(0.2%)*
registration tax	2 483	2 854	2 048	1 633	4 191	2 468	5 428	412	4 436
fuel tax	-3 785	-4 032	-2 114	-5 237	-2 439	-1 404	-3 245	-3 685	-3 799
other tax	52	-71	-84	122	-207	-127	-251	70	-155
total tax	-1 250	-1 249	-150	-3 482	1 544	937	1 931	-3 203	482
(%BC)	*-(0.4%)*	*-(0.4%)*	*(0.0%)*	*-(1.0%)*	*(0.5%)*	*(0.3%)*	*(0.6%)*	*-(0.9%)*	*(0.1%)*

6.7.2 Indirect economic impacts

The indirect economic impacts of the feebate scenarios have been calculated according the methodology described in Section 4.5.

The total household expenditure according to industry sectors is summarized in Table 29. Compared to the base case, household expenditure is increased for passenger cars, trade services, and (for most scenarios) other motor vehicles and market services. This is due to the effect of the policy which increases the demand for passenger cars.

Table 29: Base case expenditures by households (M€) and relative change in the feebate scenarios – average of the period 2010-2015

Sector	BC	f130 1.0_1.0	f130 1.0_1.0bis	f130 0.5_0.5	f130 1.5_1.5	f130 0.0_1.0	f130 0.0_0.5	f130 0.0_1.5	f120 1.0_1.0	f140 1.0_1.0
Agriculture	132695	-0.12%	-0.12%	-0.04%	-0.24%	0.01%	0.01%	0.00%	-0.17%	-0.06%
Construction	1113110	-0.01%	-0.01%	0.00%	-0.01%	0.00%	0.00%	0.00%	-0.01%	0.00%
Market services	3341999	0.04%	0.05%	0.04%	0.02%	0.08%	0.05%	0.10%	0.00%	0.08%
Non-market services	3180579	-0.03%	-0.03%	-0.01%	-0.06%	0.00%	0.00%	0.00%	-0.04%	-0.01%
Trade services	1656805	0.06%	0.07%	0.05%	0.06%	0.09%	0.05%	0.12%	0.02%	0.10%
Metals	149605	-0.02%	-0.02%	-0.01%	-0.04%	0.00%	0.00%	0.00%	-0.03%	-0.01%
Chemicals	286680	-0.06%	-0.06%	-0.02%	-0.11%	0.00%	0.00%	0.00%	-0.08%	-0.03%
Non-metallic minerals	39994	-0.07%	-0.07%	-0.02%	-0.14%	0.00%	0.00%	0.00%	-0.10%	-0.04%
Pulp, paper & printing	144014	-0.11%	-0.11%	-0.04%	-0.21%	0.00%	0.01%	0.00%	-0.16%	-0.05%
Food, beverages & tobacco	635418	-0.13%	-0.13%	-0.05%	-0.26%	0.01%	0.01%	0.00%	-0.19%	-0.07%
Textiles	198496	-0.11%	-0.12%	-0.04%	-0.23%	0.00%	0.01%	0.00%	-0.17%	-0.06%
Machinery & equipment	984844	-0.02%	-0.02%	-0.01%	-0.04%	0.00%	0.00%	0.00%	-0.03%	-0.01%
Other industries	309777	-0.08%	-0.08%	-0.03%	-0.16%	0.00%	0.00%	0.00%	-0.12%	-0.04%
Passenger cars	225624	2.29%	2.42%	1.17%	3.46%	1.29%	0.72%	1.78%	2.31%	2.19%
Other motor vehicles	251280	0.00%	0.01%	0.01%	0.00%	0.01%	0.01%	0.02%	0.00%	0.00%
Automotive fuels	99928	-1.33%	-1.43%	-0.72%	-1.93%	-0.82%	-0.47%	-1.11%	-1.36%	-1.31%
Other energy	169672	-0.12%	-0.12%	-0.04%	-0.23%	0.00%	0.01%	0.00%	-0.17%	-0.06%
Total	**12920518**	**0.02%**	**0.03%**	**0.02%**	**0.01%**	**0.05%**	**0.03%**	**0.06%**	**0.00%**	**0.05%**

Total employment increases for all feebate scenarios. The only exception is the scenario 120_1_1 which shows a very slight employment decrease (Figure 31). Total employment effects range from -26 000 to 187 000 employees, corresponding to a change of -0.01% to 0.08% compared to the base case.

Sectoral results show positive employment effects in the sectors passenger cars, other motor vehicles, market services, trade services, and metals for all scenarios. Impacts in other sectors are either neutral or negative.

Total value added shows an increase for all scenarios except for the scenario 120_1_1 and follows closely the pattern of sectoral employment (Figure 32). Impacts on value added are – in general – less pronounced than for employment. Total value added impacts range from -0.002% to +0.067% which corresponds to about -270 to 7 780 M€).

The impacts on value added for individual industry sectors follow the same pattern than for employment. All scenarios result in positive value added effects in the sectors passenger cars, other motor vehicles, market services, metals and trade services. Small negative impacts occur in the automotive fuel sector for all scenarios. For the other sectors, positive effects are expected in the majority of scenarios. The value added impacts of the individual sectors range from range from -0.9% to +3.5%.

Figure 31: Employment effects of the feebate scenarios (1 000 employees) for the period 2010-2015.

A: Total employment effects; B: Sectoral employment effects

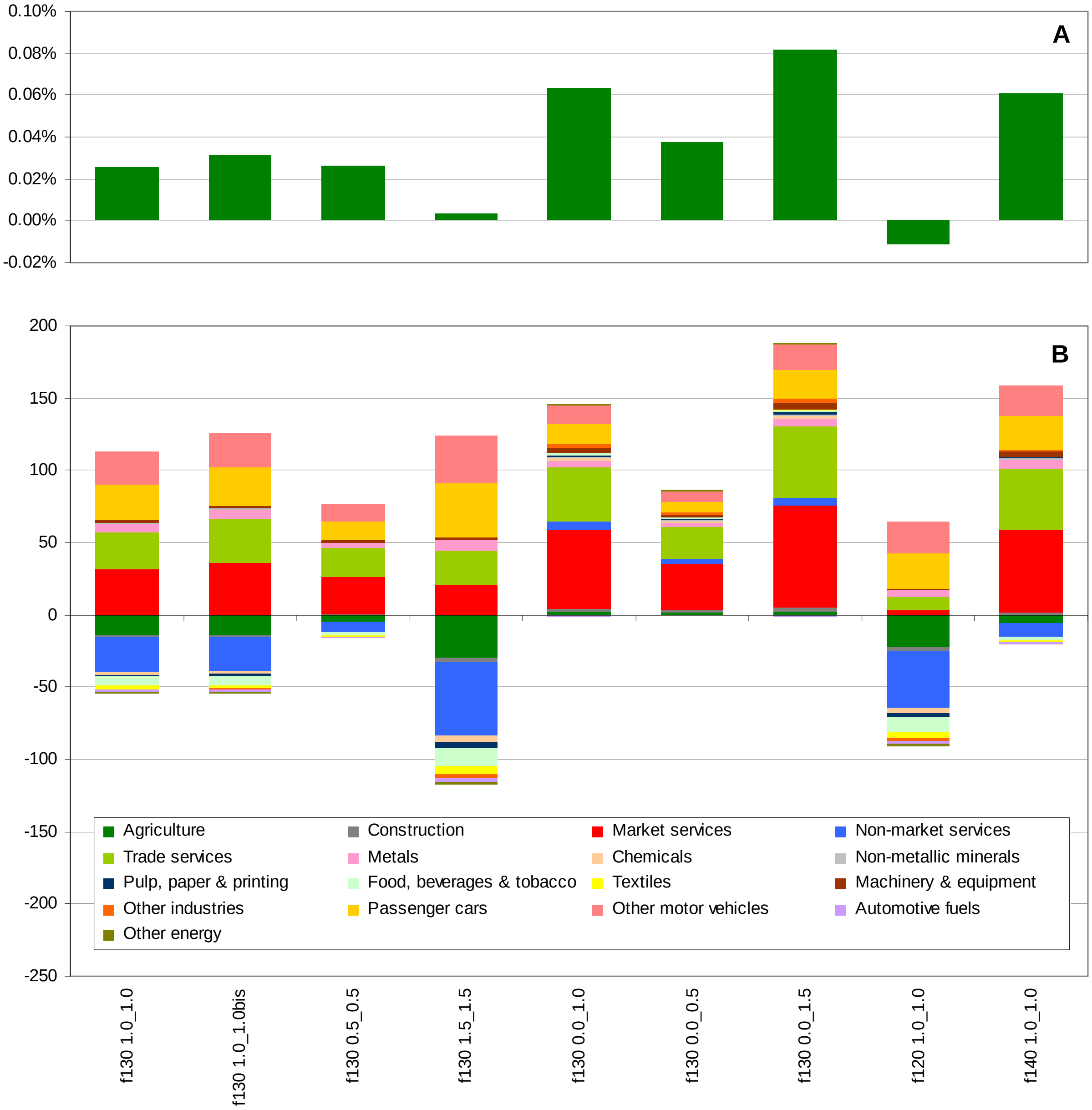
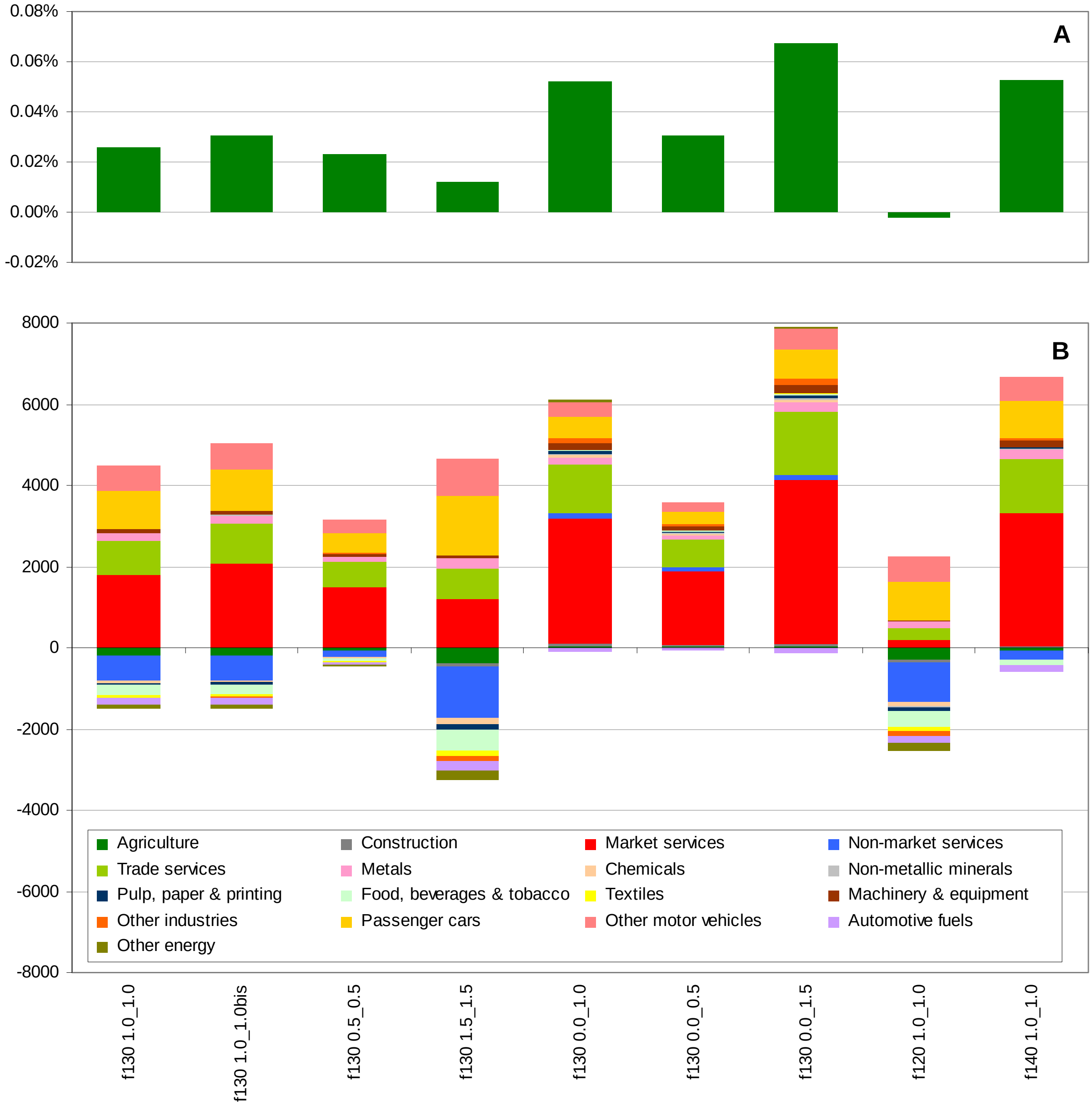


Figure 32: Value added effects of the feebate scenarios (M€) for the period 2010-2015.

A: Total value added effects; B: Sectoral value added effects



6.8 Concluding remarks

The above analysis and results provide an overview of the environmental and economic impacts of a feebate instrument if applied at EU27 level. According to the TREMOVE scenarios, slight vehicle sales decreases are expected. Small car sales could significantly increase, mostly on the expense of medium cars. A shift is also expected from diesel to petrol cars.

The instrument would result in reductions of the WTW GHG emissions from the EU27 car fleet, because consumers would be encouraged to choose more efficient cars when purchasing a new vehicle. This holds true both in the short term (0.7% to 2.6% reductions of over the period 2010-2015, compared to basecase) and for the longer term. Positive effects on air pollution are less significant.

The conclusion is also valid when the life-cycle impacts indirectly caused by the car and spare parts production are included.

The analysis also illustrates some of the various possibilities regarding the feebate scheme (PP, respective levels of fee and rebate and form of the feebate curve), showing how the environmental effects and costs would vary.

In general the effects are the most sensitive to the fee and to rebate levels. Some of the specific schemes can be discriminated with a certain level of confidence: the higher the fee level is, the higher the tax revenue and emission reductions will be. Higher bonus levels result in higher CO_2 emission reductions from small cars. On the other hand, the bonus removal guarantees higher tax revenues for the governments.

The exact effects have however to be envisaged with cautious: The modeling approach would gain in robustness with better data to better capture the influence of the different parameters. Also, some aspects of the feebate (the form of the function) are likely to have effects in real-life that can not be fully assessed ex ante. Finally, the outcome may vary substantially depending on the initial purchasing patterns and initial taxation regime which both depend on the situation of each country.

The scenarios made with TREMOVE have been performed against a baseline where CO_2 emissions have been kept at a level which does nott reflect the recently adopted regulation on CO_2 emissions from cars (see section 2.2) which sets a target for 2015 (130 g/km) and a long term target for 2020 (95 g/km). In this new regulatory context, achieving emission reductions with the feebate instrument would imply adjusting the parameters accordingly.

Overall, slight increases in household expenditures are estimated and the tax revenue would also increase, at least in the short term.

The estimation of the macroeconomic impacts made with the Input-Ouput tables, shows that the sectors directly concerned (the automotive sector and supply sectors, including metal industry) would gain both in terms of value added and employment. Depending on the feebate scheme, the effects on the other sectors would be either neutral or negative.

Overall, the feebate instrument offers benefits both to the environment and to the economy. From an environmental standpoint, it can contribute to the EU strategy to reduce CO2 emissions from cars. From an economic point of view, the instrument may be adjusted in accordance with public budget constraints and employment goals.

7 Cash for replacement policy

7.1 Modeling approach

The modeling of the cash for replacement policy requires modeling the expected response of the owner of an old car to the proposed subsidy for car scrappage.

This entailed further developments in the available TREMOVE version (3.1). In this model version, the car renewal is based on exogenously estimated probability (an exogenous scrappage function) that a vehicle in year t will survive in the subsequent year vehicle stock (year t+1). The probability is a function of the age of the vehicle and differs for all countries. To enable a simulation of scrappage policy with TREMOVE, the exogenous scrappage functions had to be converted into an endogenous function.

Two main driving forces for scrappage were taken into account:
- circumstances the owner cannot control (accident)
- economic considerations influencing the decision of the owner.

The first is captured through the differentiated probability of accident per age and vehicle category which was estimated by using European statistics from ERSO[36] and CARE[37] on accidents and the average yearly mileage already in the TREMOVE input database.

The latter was estimated with a discrete choice model[a] representing the economic decision of a car owner to remove his/her car by either scrapping it or selling it. This decision was assumed to be dependent on the following variables:
- repair & maintenance costs
- cost of a new car
- residual value (i.e. the second hand market price)
- scrap subsidy (an exogenous policy parameter)

In the following section we first discuss the data availability and then the modeling approach implemented.

7.1.1 Data availability

The **repair and maintenance costs** are a function of the age of the vehicle. The younger the vehicle, the lower the total repair and maintenance costs will be. In the TREMOVE 2.7 version, the maintenance costs are conceived of a percentage of the purchase cost and increase linearly up to an age of 6 years. After 6 years, cost is assumed constant. Data collected from the German ADAC database[b] were used to check and, where relevant, refine TREMOVE assumptions.

[a] Background on discrete choice models: "Discrete choice methods with simulation", Kenneth E. Train, Cambridge University Press, 2003. Available online at http://elsa.berkeley.edu/books/choice2.html.

[b] The ADAC database holds cost data including repair cost for all existing passenger vehicles (by brand, type, subtype).

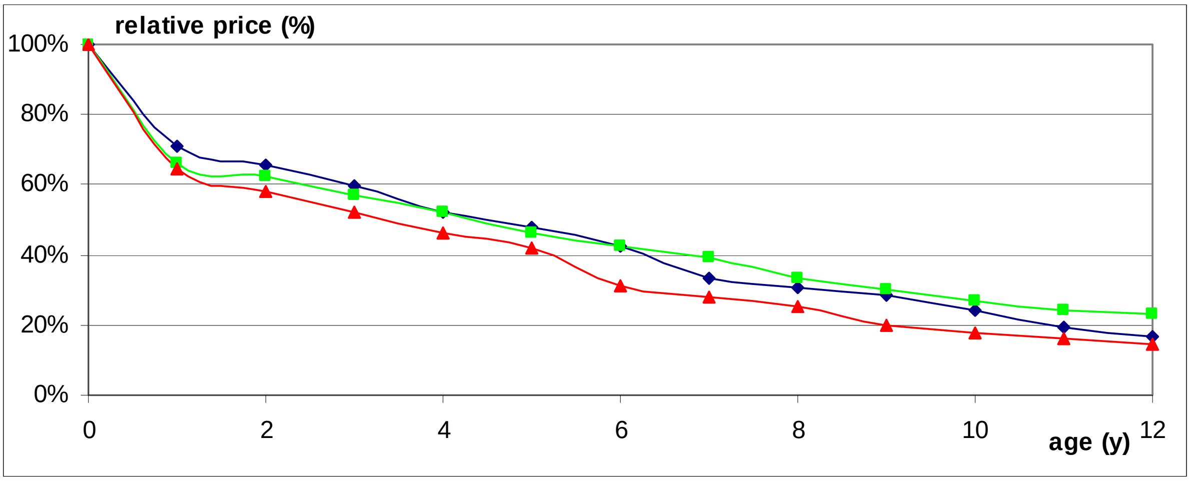
When building the exogenous function, it was uncertain which new vehicle type would be assumed to be subsequently purchased (this is determined by the car sales logit), It was assumed that the new purchased vehicle is of the same type (size, fuel) as the one that will be removed from the stock. The **purchase cost** (and registration tax) assumed in the new scrappage function were set accordingly using the costs already embedded in the TREMOVE database. Note that TREMOVE assumes a constant increase in purchase cost of passenger vehicles over time. This increase reflects the increased cost of new features (e.g. air-conditioning).

The **residual value** for a vehicle is, in fact, the price of the car on the second hand market. The second hand market value is a function of the age of the vehicle. Clearly, younger vehicles are more valuable than older ones. The estimation of the residual value is based on the Schwacke database[38] which holds estimations of second hand value of all passenger vehicles (brand, type, subtype) per manufacturing year for Germany. This dataset is the most extensive and consistent with respect to second hand market prices. To make the estimation applicable for other countries as well, the value estimation was set up as a second hand value compared to the new vehicle price. The database is too large to cover all vehicles; therefore 3 representative samples were taken to reflect small, medium and big cars:

- Small: Ford Fiesta 1.3 G-Kat
- Medium: Audi A4 1.6
- Big: BMW 5er - 520i

The analysis showed that, with an offset of about 35% after the first year, the value deprivation is similar for all vehicles types, in relative terms. A regression (exponential) function is fitted and applied in the scrappage model.

Figure 33: Second hand market value (% of new vehicle price), for small (blue), medium (green) and big cars (red)



7.1.2 Model for scrappage decision

The decision for scrapping the vehicle can be modeled as a discrete choice, considering the following two possible choices and the associated utilities for the consumer:

- Keeping the vehicle: utility U1.
- Removing the vehicle: utility U2.

The choice between the two alternatives only depends on the difference ΔU = U2-U1. Based on the information gained as to the choice process, the following variables are expected to be relevant (the removal of the vehicle being the ‘positive’ outcome):

- Repair and maintenance costs: keeping a vehicle in operation for another year will come at a given cost. As mentioned earlier, this is dependant on the age of the vehicle. A positive sign for the coefficient is expected.
- Cost of a new vehicle: A negative sign for the coefficient is expected.
- Residual value: the vehicle currently owned still has a value to the car owner. This value is equated to the price the owner could get for his car if he were to sell it on the second hand market. Whether the car owner decides to scrap or sell his car, he still loses this value. As the residual value decreases with increasing age, a negative sign for the coefficient is expected.

We can determine the shares of scrapping or keeping the vehicle with the exogenous survival functions and the given scrappage subsidy (in the reference case: 0€). On the one hand, we can determine the utilities for both options, derived from repair & maintenance costs, new car prices, scrap subsidies and residual values. On the other hand, we know how many vehicles are scrapped or sold on the second hand market and how many are kept (from the exogenous scrappage functions). With these known figures, we can estimate and calibrate the discrete choice model for keeping or removing a car from circulation. Calibration of the model was made for the existing scrappage curves for the year 2005.

When modeling the scrappage scheme, one has to bear in mind that some car owners who would scrap their vehicle anyway will benefit from the subsidy together with consumers who will shift from selling their cars on the second hand market to scrapping, given that the subsidy is high enough.

7.1.3 Results of the scrappage model

Simulations of the survival probability under possible scrappage policies are presented in Figure 34, Figure 35 and Figure 34. *Psur0* is the baseline probability without a subsidy, *Psur2000* is the case with a subsidy of 2000€ for cars older than 10 years, *Psur2000_8* is the case of a subsidy of 2000€ older than 8 years old, *Psur3000* is for the case of a subsidy of 3000€ for cars older than 10 years, *Psur500* is for the case of a subsidy of 500€ for cars older than 10 years old, *Psur1500* is for the case of a subsidy of 1500€ for cars more than 10 years old.

They all look very similar. Because smaller cars are cheaper and have a lower residual value, the scrappage policy takes effect much sooner. Allowing the polices to start two years earlier has no impact because even for small cars the residual value has not dropped enough by then to make the policy effective.

All of the graphs suggest that the policies have a very strong effect on the scrappage once they become operational. The main difference between the policies is the amount of the scrap subsidy. The higher the subsidy amount is, the earlier the scrappage starts. The reaction may be overestimated compared to what would be expected in reality, although there is no data to compare with. These graphs also suggest that scrappage policies would primarily remove small and medium old cars.

Figure 34: Simulated probabilities that a car will reach a given age (big gasoline cars, Germany).

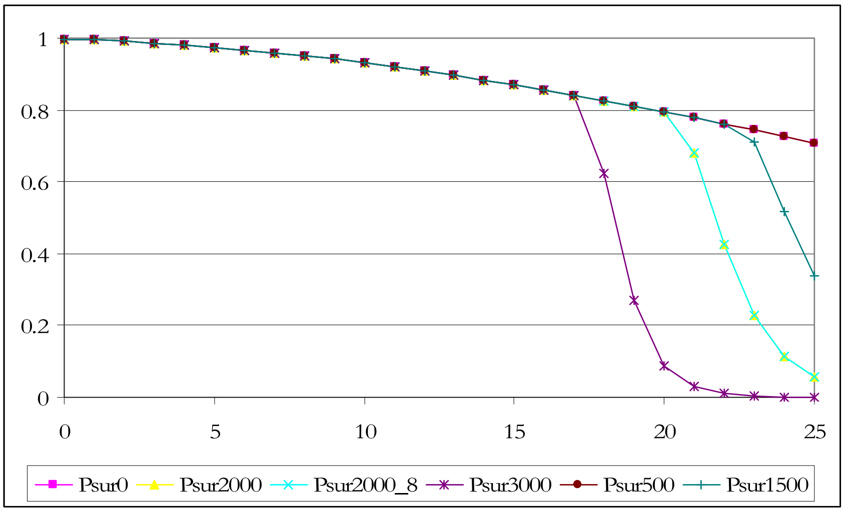


Figure 35: Simulated probabilities that a car will reach a given age (medium gasoline cars, Germany).

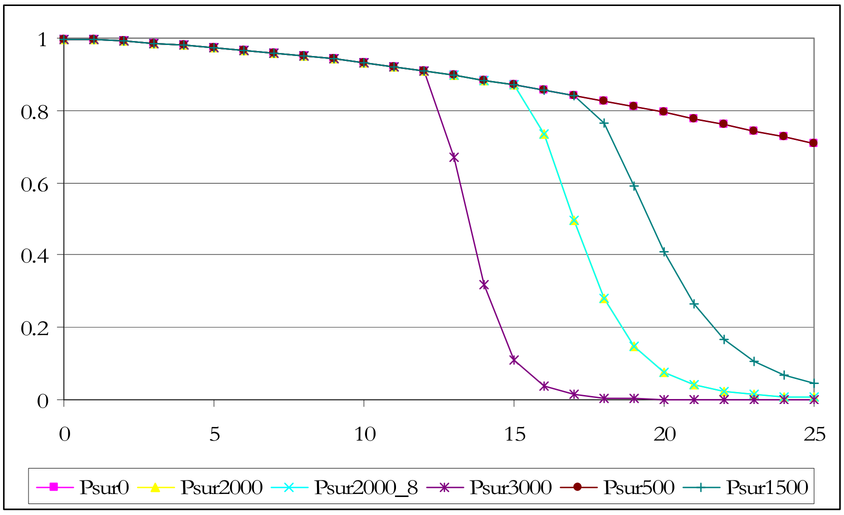
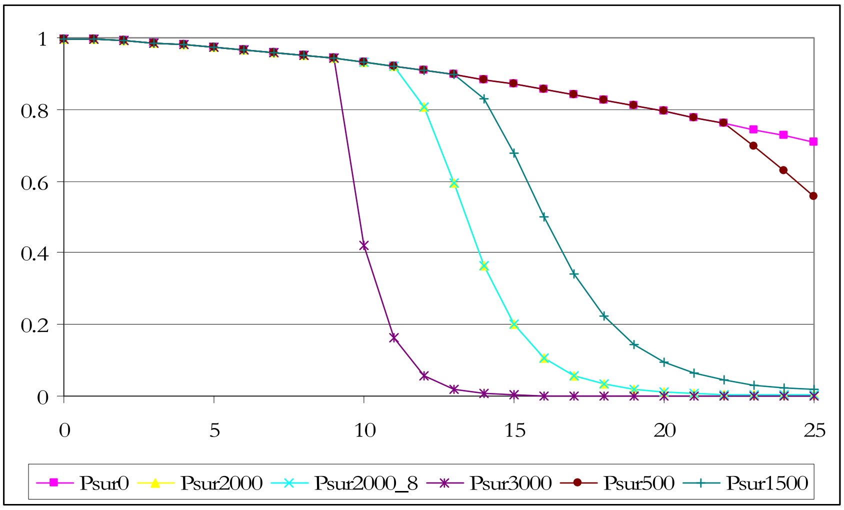


Figure 36: Simulated probabilities that a car will reach a given age (small gasoline cars, Germany).



7.2 Policy cases considered

A cash-for-replacement policy can be based on parameters such as the old car age threshold, the subsidy level, the environmental performance of the old car (as compared to the new one), car mileage. However, this last parameter is more difficult to monitor. The environmental performance, especially regarding air pollution, is rather closely linked to the car age.

An optimal set of parameters cannot be preselected. However some first insight can be gained as to the effects of choosing a certain age threshold in terms of environmental efficiency improvement. One can indeed associate the car age with its environmental performance through the Euro standard it complies with.

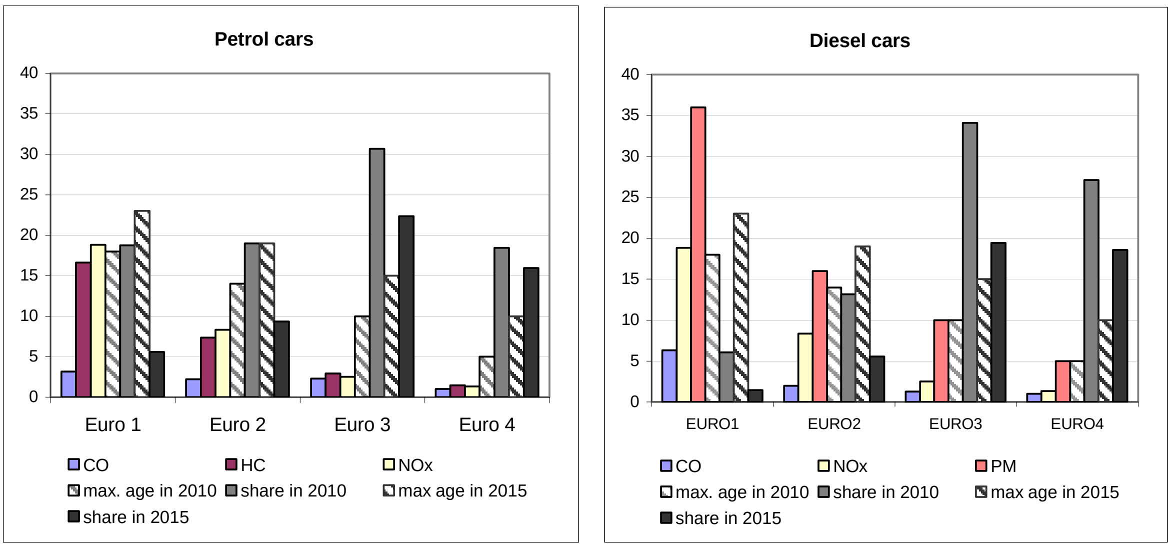
Figure 37 displays some relevant information about petrol and diesel cars that will be part of the 2010/2015 car fleet. It first (three first bars) shows the maximum air pollutant emission levels prescribed by the different Euro standards relative to the Euro5 standard which will be obligatory as of 2009. Next come the maximum age and share in car fleet in 2010 and 2015.

The literature suggests that the most realistic age threshold is in a range of 8 to 12 years. When comparing 8 and 10 year thresholds, the eligibility to the system would not differ in terms of Euro standard coverage. In 2010, both cases would potentially cover cars up to Euro3 and, at the end of the period, Euro4 cars would be concerned as well. There would be differences in the intermediate period. With a 12 year threshold, the system would potentially tackle cars up to Euro2 (Euro3) in 2010 (2015).

Consequently, the decision was made to concentrate on 8 and 10 year constant thresholds.
Regarding the **subsidy**, section 7.1 suggests that the subsidy would not only make a real difference if it is greater than 1000€.

Figure 37: Key factors in determining the age threshold for the scrappage policy: in both diagrams

The three first bars represent the performance of air standard in terms of air pollutant emission levels, relative to the Euro5 standard. Next come the maximum age (years) and share in car fleet (%) in 2010 and in 2015



Three subsidy amounts are then considered: 1000€, 2000€, 2500€ constant cases. Regarding the last case, one can expect that the modelling will lead to less reliable results because the magnitude of change introduced would lay beyond the scope of consistency expected with TREMOVE. This has to be kept in mind when interpreting the results. As will be seen later, (section 7.3), the last case may lead to an extreme outcome in terms of car purchases.

Also interesting is to consider subsidies that evolve over the policy period. Two options have been selected, with a subsidy steadily increasing and decreasing respectively. The first option would, in principle, reduce the public budget burden in the short term. The second option would, on the contrary increase the effects in the short time.

Table 30 provides the list of cash-for –replacement scenarios considered for the modelling. The last column provides the average level of the subsidy over the period considered, which is relevant when comparing scenarios such as s10_2000_2000 and s10_1000_3000.

Table 30: List of cash-for-replacement policy scenarios

scenario name	old car age threshold	subsidy (euros)		
		2010	2015	average over the period 2010-2015
s8 1000_1000	8	1 000	1 000	1 000
s8 2000_2000	8	2 000	2 000	2 000
s8 2500_2500	8	2 500	2 500	2 500
s10 1000_1000	10	1 000	1 000	1 000
s10 2000_2000	10	2 000	2 000	2 000
s10 2500_2500	10	2 500	2 500	2 500
s10 500_1500	10	500	1 500	1 000
s10 1000_3000	10	1 000	3 000	2 000
s10 1500_ 500	10	1 500	500	1 000
s10 3000_1000	10	3 000	1 000	2 000

7.3 Effects on transport demand and vehicle stock

The transport demand in the policy scenario is projected to decrease over the period 2010-2015 (by up to 2.7% in the case of the most extreme scenario - s10_2500_2500).

This somewhat contradicts the intuition that the subsidy - making passenger cars cheaper - would result in a transport demand increase.

However, this driver is counterbalanced by other cost components: In TREMOVE (see Table 31), new cars purchase costs are assumed to increase over time (due to new luxury features, safety features, emission standards and increased fuel efficiency). This shifts running costs (fuel cost) to purchase costs. Therefore, in any given year, new vehicles are more expensive in purchase cost than the scrapped vehicles. Consequently, the higher renewal rate of vehicles stimulated by the subsidy results in higher annualized purchase costs of the car fleet. Overall, the higher purchase cost is not compensated by the lump sum of subsidy - which is allocated to the registration tax -, saved fuel cost and repair cost. On the contrary, the generalized price for passenger car transport is increased.

Also, after the scrappage scheme, the decrease gradually fades out, as explained by the quick renewal rate already achieved during the scrappage scheme period, resulting in a stock which is older compared to the basecase. Older also means cheaper, thus resulting in a lower cost for passenger vehicle transport in the simulation.

Table 31: Purchase cost of cars assumed in TREMOVE

	PCDS		PCDM		PCDB		PCGS		PCGM		PCGB	
	€	% 2000 price	€	% 1995 price	€	% 1995 price	€	% 1995 price	€	% 1995 price	€	% 1995 price
1995	-	-	14 286	100%	26 035	100%	8 777	100%	16 392	100%	33 637	100%
2000	11 073	100%	15 855	111%	28 181	108%	8 970	102%	16 472	100%	33 722	100%
2005	11 507	104%	16 626	116%	29 400	113%	9 031	103%	16 154	99%	33 869	101%
2010	11 353	103%	16 469	115%	29 303	113%	9 454	108%	16 696	102%	34 678	103%
2015	11 671	105%	16 766	117%	29 987	115%	9 587	109%	16 958	103%	35 058	104%
2020	11 980	108%	17 169	120%	30 743	118%	9 496	108%	17 026	104%	35 501	106%

This has to be kept in mind when interpreting other results (see emissions in section 7.4.1). Regarding the effects on the car fleet, compared to the basecase scenario, more old cars will be disposed of and subsequently will be replaced by new cars. Table 32 presents the car fleet composition in 2015 by different age classes, showing the accelerated renewal of the car fleet. The share of cars older than 10 years is reduced in all scenarios in comparison to the basecase. The biggest changes are seen when the average subsidy level during the policy period is as high as 2000€.

Table 32: Composition of the car fleet by of car age classes (year 2015)

	1-10 years	>10 years
Basecase	62.9%	37.1%
s8 1000_1000	65.0%	35.0%
s8 2000_2000	72.3%	27.7%
s8 2500_2500	71.4%	28.6%
s10 1000_1000	65.0%	35.0%
s10 2000_2000	72.3%	27.7%
s10 2500_2500	71.1%	28.9%
s10 500_1500	65.7%	34.3%
s10 1000_3000	74.0%	26.0%
s10 1500_ 500	65.7%	34.3%
s10 3000_1000	72.9%	27.1%

The dynamic of the car fleet renewal for the different scenarios (Figure 38) is shown to be highly influenced by both the size of the subsidy and its evolution. In all cases where the subsidy is either kept constant over time or set to gradually decline, the effects (car sales increases) are the greatest at the beginning of the period. This is because very old vehicles, with low residual value are scrapped in large amounts already in the first year. After this first year, the average age of the stock is considerably lower, thus reducing the effect of the scrappage scheme.

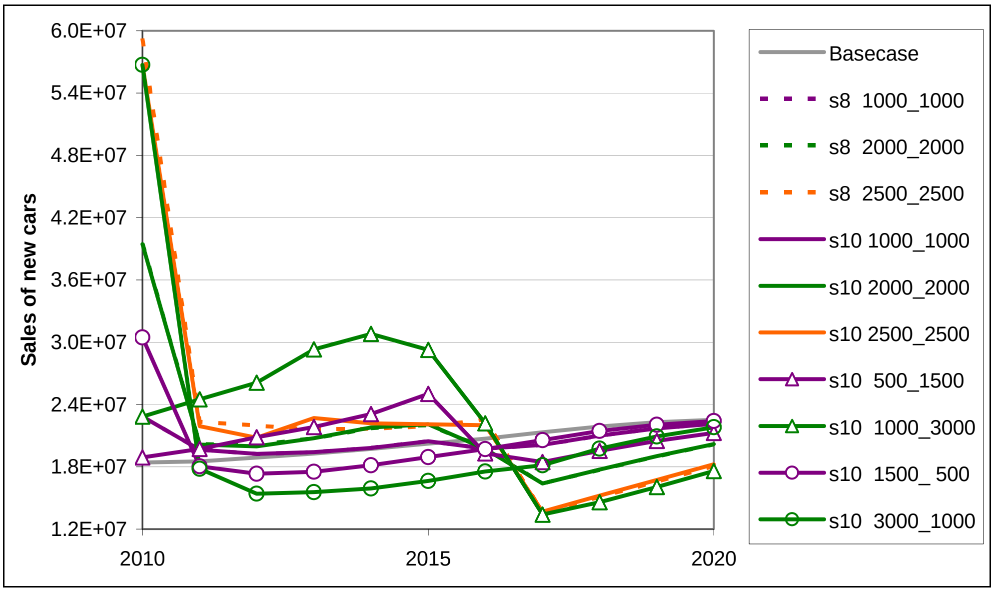
The size of the initial subsidy determines the level of car sales increases. This is especially true when the subsidy is beyond 2000€. When the subsidy is kept lower or equal to 1000€, the effects are not as strong.

A general key insight for these policy cases is the fact that the system will induce its main effects – including on the manufacturing sector - after a couple of years and that it does not need to be maintained for a long period of time.
On the contrary, when the subsidy is gradually increased, the effects increase over time (see for instance 10_2000_2000 and s10_1000_3000).

Over time, sales actually experience a wave effect: In all cases, the sales increases induced by the scrappage policy are later reduced as compared to the basecase, when the bulk of the cars sold at the beginning of the scheme are replaced.

The age threshold is shown to be of less importance than the subsidy level and its evolution (at least when considering 8 or 10 years). This is especially true when the subsidy is kept low. This is because the residual value of 8 year cars is higher than for older cars and the subsidy is not attractive enough to encourage car scrappage.

Figure 38: New car sales over time for the different policy scrappage schemes



As shown in Figure 39, over the scheme period (2010-2015), the total new car sales are substantially increased over the period (5% to 42% w.r.t basecase). The magnitude of the effect is obviously linked to the size of the subsidy.

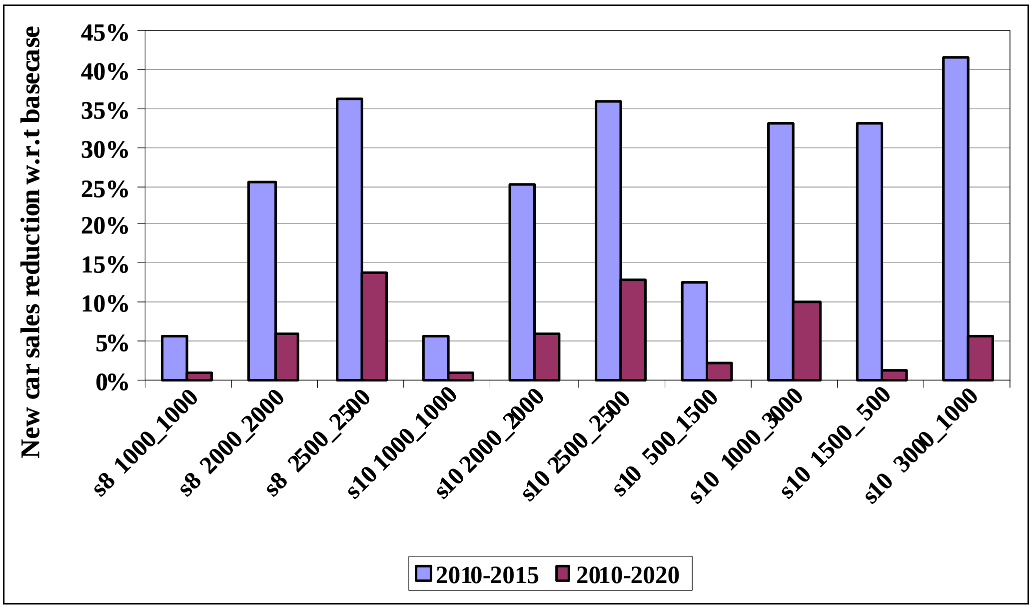
The dynamic of the scrappage instrument is also an influencing factor. For one given average subsidy over 2010-2015 (for instance s10_2000_2000 and s_10_1000_3000), the case where the subsidy is gradually increased results in the larger average sales increase.

The effect of the scrappage policy on car sales might be amplified by the modeling approach where the scrappage decision logit strongly reacts for very old vehicles (see section 7.1.3).
Also, the reliability of these high figures has also to be assessed in the light of the ability of the automotive industry to react accordingly.

When considering the long-term perspective, the average car sales increases are lower (1.1% to 12.8% w.r.t basecase).

No particular trend is seen in either fuel share or size class shares.

Figure 39: Total change in car sales (% w.r.t basecase)



7.4 Environmental effects:

7.4.1 Well-to-Wheel emissions

The environmental effects of the scrappage policy concern both GHG emissions and air pollutant emissions. These effects over the period 2010-2020 are displayed in Figure 40.
In all cases, the scrappage policy is expected to entail emission reductions as compared to the basecase, especially during the policy scheme. The size and dynamic of effects depend on the nature of emissions and different drivers:

- The influence of fuel efficiency versus end-of-pipe technologies: GHG emissions and SOx emissions are primarily dependent upon the first factor, whereas the air pollutants are more dependent upon the abatement technology.
- The gain in efficiency when shifting from an old to a new car is also a key factor. The gain is the lowest for GHG and SOx emissions and the highest for VOC and CO emissions.

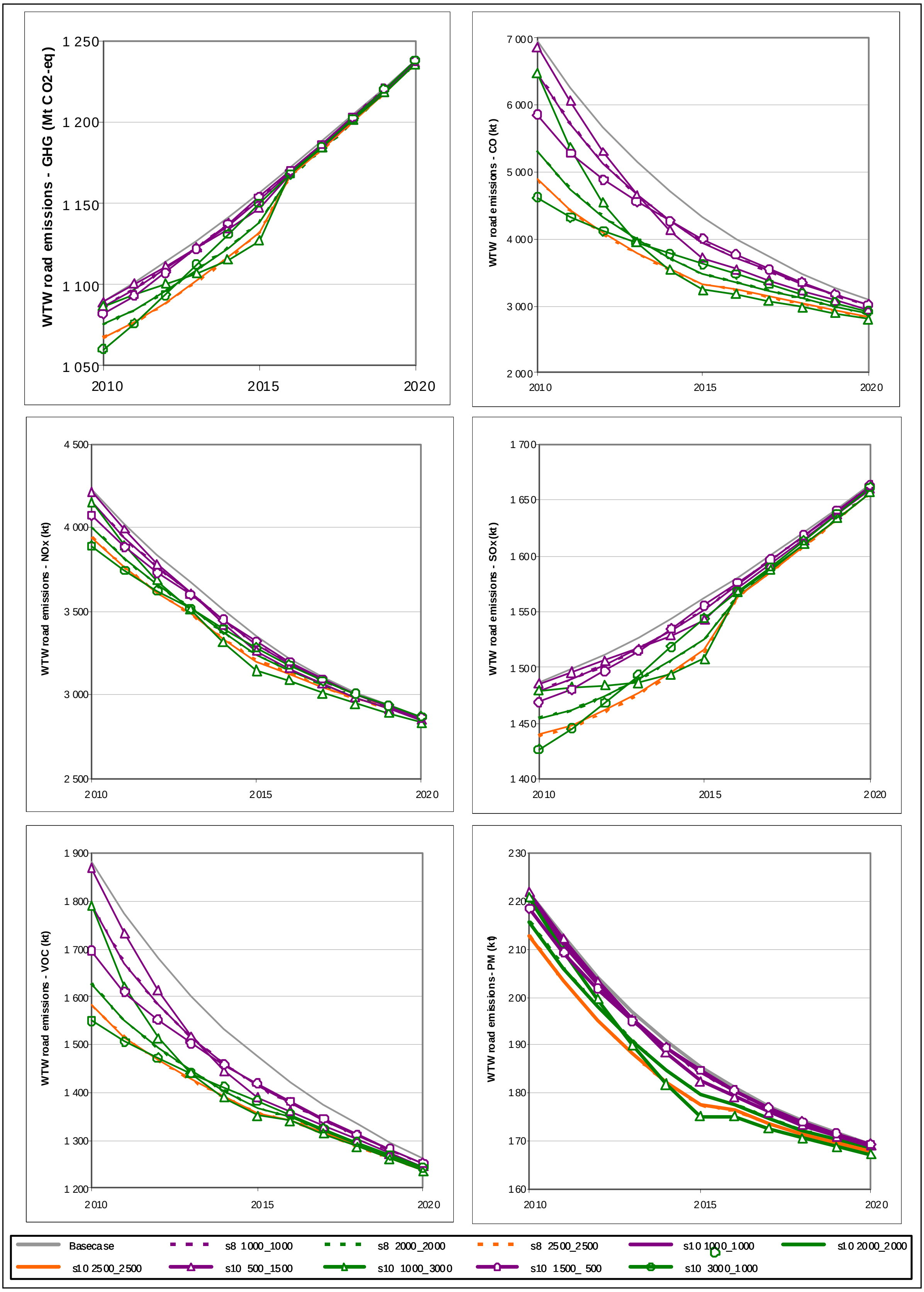
The effects on CO_2 emissions differ from those expected for air pollutant emissions.

The improvements expected for air pollutants are unambiguous and significant. However, it has to be noted that these emissions are expected to decline in the basecase anyway thanks to the phase in of Euro5 (2009) and Euro6 (2014). One can thus consider that a scrappage policy would have had more effects if implemented some years ago.

The modeling suggests smaller and more temporary improvements regarding CO_2 emissions; the effects disappear once the system is phased out.

The robustness of these emission reductions is also lower: the projected emission reduction is indeed almost entirely driven by the unexpected transport demand decrease (see section 7.3).

Figure 40: Effects of scrappage policy cases on WTW emissions



The fact that the policy scenario assumes baseline emissions that are more pessimistic than the emission pathway aimed at with the new CO_2 & car regulation (emissions decline to 130 g/km by 2015) should be also remembered. This means that, during the period when the subsidy is in place, emissions should start to decrease. However, because the effects of the policy instrument are the stronger during the 2 first years (unless the subsidy is initially set low and then increases over time), the emissions might still be close to the current level (160 g/km). The emission reductions would thus only be slightly higher than what is modeled.

A higher energy efficiency leap from the old scrapped car to the new one would actually be needed to observe significant gains which should be the case later as a result of the regulation on CO2 emissions from cars. Stronger positive effects would indeed happen with a subsidy put in place later when the emissions from new cars are closer to the 2015 target, and, even more when they approach the 2020 target (95 g/km).

In addition, given the fact that a scrappage policy instrument would, in the short term, pull up sales of slightly more efficient cars, the car fleet renewal would later be reduced, when car emissions are substantially declining. Therefore, the scrappage policy could potentially reduce the effects of the 2020 policy target on CO2 emissions.

From an environmental point of view, the scrappage policy would thus come late with regard to air pollution, and, too early with regard to GHG emissions.

7.4.2 Material flows and associated impacts

The material flows (and associated environmental impacts) due to car and spare parts production and to the ELVs and spare parts have been estimated. The following shows the results for one selected scrappage scenario (s10_1000_1000) as an example of these effects.

In this case, the total material flows due to the production of cars over the period 2010-2015 are shown to increase by about 5% compared to the base case (Table 33). This increase is in line with the expected sales increases as stimulated by the scrappage policy (Figure 38). This increase also holds true for the individual material flows. The greatest increases in absolute terms occur for steel, iron, and HSS (0.50 Mt, 0.12 Mt, and 0.12 Mt, respectively). Relative increases do not differ so much between the individual material flows.

The material flows due to the ELVs react similarly to the material flows for car production. For almost all materials, the mass flow is higher in the scrappage scenario compared to the base case. Steel, PP, aluminum, and iron show the greatest increases (0.11 Mt, 0.03 Mt, 0.02 Mt, and 0.02 Mt, respectively). Again, the relative changes are similar across the individual materials. Interestingly, the increase in ELVs material flows is smaller than the increase for the production of new cars. This reflects the gradual weight increase of cars in the past. Reductions for some materials (e.g. PVC, others) also occurs.

Total material flows of spare parts are slightly increased compared to the base case (Table 34). For some material flows, there is an increase, for some others, the mass flow decreases compared to the base case. The mass flows due to the production and EOL of spare parts are almost exactly the same (the small deviation results from the small reduction in transport demand – see Section 7.3). Biggest increases occur for rubber/elastomers (2.2 kt), others (0.71 kt), and other metals (0.69 kt) which are mainly due to an increase of demand for tyres. Absolute decreases are greatest for lead (-1.1 kt), PP (-0.1 kt), and other plastics (-0.1 kt) because the demand for batteries are reduced. Overall, spare parts only play a minor role compared to the mass flows from car production and EOL of cars (Table 33 and Table 34).

Table 33: Material flows due to car production for the scrappage scenario (average of 2010 to 2015)

		Car production			End-of-life		
Material group	Material	Base case	Scrappage scenario		Base case	Scrappage scenario	
		kt	kt	[% of BC]	kt	kt	[% of BC]
Metals	Aluminium	2 046	2 152	105.2	1 238	1 259	101.7
	Copper	216	228	105.2	158	160	101.3
	High-strength steels	2 248	2 365	105.2	497	506	101.6
	Iron	2 321	2 443	105.2	1 967	1 982	100.8
	Lead	164	172	105.2	121	123	101.1
	Magnesium	50	52	105.2	30	31	101.9
	Steel	9 628	10 130	105.2	8 092	8 199	101.3
	Zinc	47	49	105.2	34	35	101.3
	Other metals	94	99	105.2	68	69	101.3
Plastics	ABS	193	204	105.2	109	112	102.7
	PA	95	100	105.2	91	91	100.6
	PE	559	589	105.2	347	357	102.9
	PET	34	36	105.2	21	22	102.1
	PP	2 080	2 188	105.2	1 219	1 248	102.4
	PUR	534	562	105.2	370	377	101.7
	PVC	7	8	105.2	25	24	96.5
	Rubber/Elastomer	494	520	105.2	367	370	101.1
	Other plastics	472	497	105.2	461	464	100.7
Fluids	Refrigerant	10	10	105.2	4	4	102.0
	Oil	141	148	105.2	105	106	101.1
	Other fluids	477	502	105.2	345	349	101.2
PGM	Palladium	0.035	0.037	104.7	0.015	0.016	103.1
	Platinum	0.03	0.031	105.2	0.023	0.023	102.0
	Rhodium	0.002	0.002	104.4	0.003	0.003	104.4
Other materials	Textile	240	252	105.2	175	177	101.3
	Glass	543	571	105.2	395	399	101.3
	Other	678	713	105.2	764	756	99.0
Total		**23 372**	**24 590**	**105.2**	**17 003**	**17 220**	**101.3**

Table 34: Material flows due to production or EOL of spare parts for the scrappage scenario (average of 2010 to 2015)

Material group		Base case		Scrappage scenario			
		Production	EOL	Production		EOL	
		kt	kt	kt	[% of BC]	kt	[% of BC]
Metals	Lead	338	338	337	99.66	337	99.66
	Zinc	19	19	19	100.24	19	100.24
	Other metals	284	284	284	100.24	284	100.24
Plastics	PP	34	34	34	99.66	34	99.66
	Rubber/Elastomer	908	908	910	100.24	910	100.24
	Other plastics	17	17	17	99.66	17	99.66
Fluids	Refrigerant	11	11	11	101.44	11	101.44
	Oil	491	491	491	100.01	491	100.01
PGM	Palladium	0.03	0.03	0.03	101.06	0.025	101.06
	Platinum	0.03	0.03	0.03	100.59	0.028	100.59
	Rhodium	0.00	0.00	0.00	98.4	0.003	98.4
Other materials	Textile	95	95	95	100.24	95	100.24
	Other	785	785	785	100.09	785	100.09
Total		2 980	2 980	2 982	100.09	2 983	**100.09**

The material flows from the EOL of cars and spare parts according to treatment technologies are shown in Table 35. The policy is expected to result in small increases in the different material flows and related waste treatment activities.

Table 35: EOL treatment due to the EOL of cars and spare parts for the base case and the scrappage scenario (average of 2010 to 2015)

kt	Recycling, recovery & reuse	Shredder	ARS disposal & landfill	Hazardous waste incinerator	Export	Total
Base case	8 429	7 494	3 865	5	189	19 983
Scrappage scenario	8 499	7 583	3 926	5	190	20 202
Difference	0.84%	1.18%	1.57%	0.01%	0.24%	1.10%

The environmental impacts due to the production of cars and spare parts are shown in Table 36. Compared to the base case, these environmental impacts increase for all impact categories, except for abiotic depletion and eutrophication associated with spare-parts production. The increase is the most pronounced for the production of new cars. Overall environmental impacts are increased from 1.7% to 4.5%.

Table 36: Environmental impacts due to the production of cars and spare parts for the scrappage scenario (average from 2010 to 2015)

		Production of cars			Production of spare parts			Total		
		Base case	Scrappage scenario		Base case	Scrappage scenario		Base case	Scrappage scenario	
				[% of BC]			*[% of BC]*			*[% of BC]*
AD	kt Sb eq	9.47	9.96	*105.2*	12.45	12.41	*99.7*	21.92	22.38	*102.0*
GWP	Mt CO2 eq	91.68	96.45	*105.2*	9.69	9.72	*100.3*	101.37	106.17	*104.5*
POCP	kt C2H4 eq	134.5	141.5	*105.2*	24.7	24.7	*100.2*	159.2	166.2	*104.3*
AP	kt SO2 eq	1327.3	1394.3	*105.0*	495.9	499.0	*100.6*	1823.2	1893.3	*103.4*
EP	kt PO4 eq	109.7	115.4	*105.2*	9.9	9.8	*99.9*	119.6	125.3	*104.2*
BW	Mt	4.37	4.60	*105.2*	1.15	1.15	*100.3*	5.52	5.75	*104.7*

7.4.3 Life-cycle impacts

Combining the results derived in section 5.2.3 and in 5.2.4, the life-cycle impacts from the car fleet in the base case scenario and in the policy scenario can be calculated. The results are shown in Table 37 in the case of the scrappage policy case s10_2000_2000. The benefits expected at the WTW level are shown to be (at least) partly offset by the additional impacts induced by the production of cars and spare parts.

Table 37: Impacts of the scrappage instrument on the life-cycle impacts from the car fleet

	WTW			Production			Total		
	basecase	s10 2000_2000	% change w.r.t basecase	basecase	s10 2000_2000	% change w.r.t basecase	basecase	s10 2000_2000	% change w.r.t basecase
abiotic depletion (kg Sb eq)	0	0	-1.6%	22	22	2.1%	22	22	2.1%
GHG (Mt CO2-eq)	1 122	1 104	-1.6%	101	106	4.7%	1 223	1 210	-1.0%
acidification (kt SO2 eq)	3 710	3 582	-3.4%	1 823	1 893	3.8%	5 534	5 476	-1.0%
eutrophication (kt PO4 eq)	490	468	-4.5%	120	125	4.8%	609	593	-2.7%
POCP (kt C2H4 eq)	2 960	2 777	-6.2%	159	166	4.4%	3 119	2 943	-5.7%
bulk waste (Mt)	0	0	-1.6%	6	6	4.2%	6	6	4.1%

7.5 Economic impacts

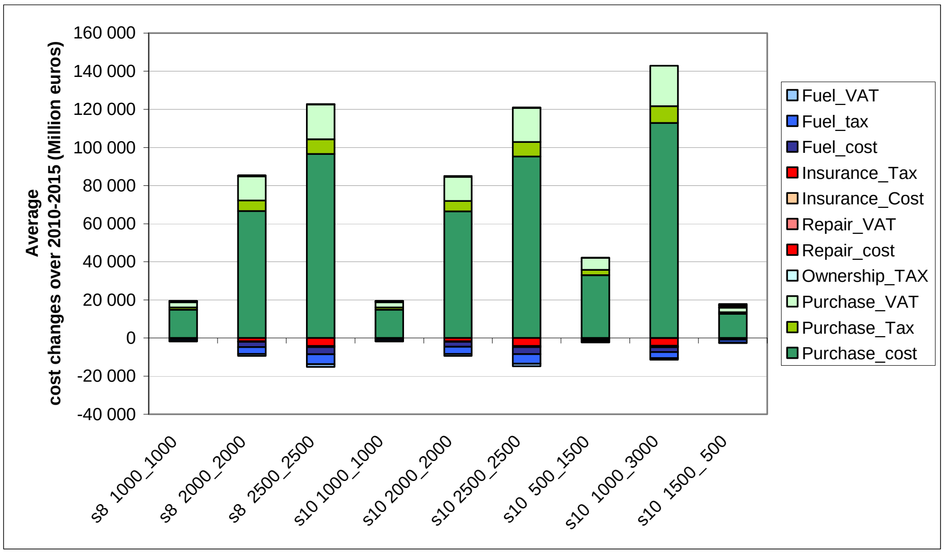
7.5.1 Effects on household and expenditures and taxation

The major consequences of the scrappage system on costs incurred at EU27 level concern the following cost components (Figure 41) and include:

- Purchase costs (retailer price): the scrappage policy stimulate the new car market and results in very high additional car sales.
- Registration taxes (and also owner taxes): the net effect mainly results from the combination of more car sales (thus more revenue from the pre-existing registration tax) and the subsidy which is granted to car scrappage. The subsidy does not compensate the increase in purchase cost thus causing total transport cost to increase.
- Fuel costs (and fuel tax): The penetration of more efficient cars reduces the fuel consumption and thus the fuel costs.
- Repair costs may be lower during the scheme and even in the first years after the scheme, as the vehicle fleet will be considerably younger, requiring less repair cost. When looking at the period 2015-2020, there is an increase of repair costs.

These costs over the period 2010 and 2015 are detailed in Figure 41.

Figure 41: Differences in costs between simulations and basecase scenario – average over the period 2010-2015



In total, costs and tax revenue is expected to show a trend similar to the car sales (Figure 42).

Over the period 2010-2015, the consumer expenditures for cars would, on average, increase by 1.5% to 11.4% compared to the basecase (Table 38). The purchase tax (including VAT) revenue is expected to increase (4.5% to 42%) while fuel tax revenue would decrease (0.7%-4.2%). The total tax revenue is expected to increase (0.6%-7.8%).

Figure 42: **Total costs and taxation revenue over the period 2010-2020**

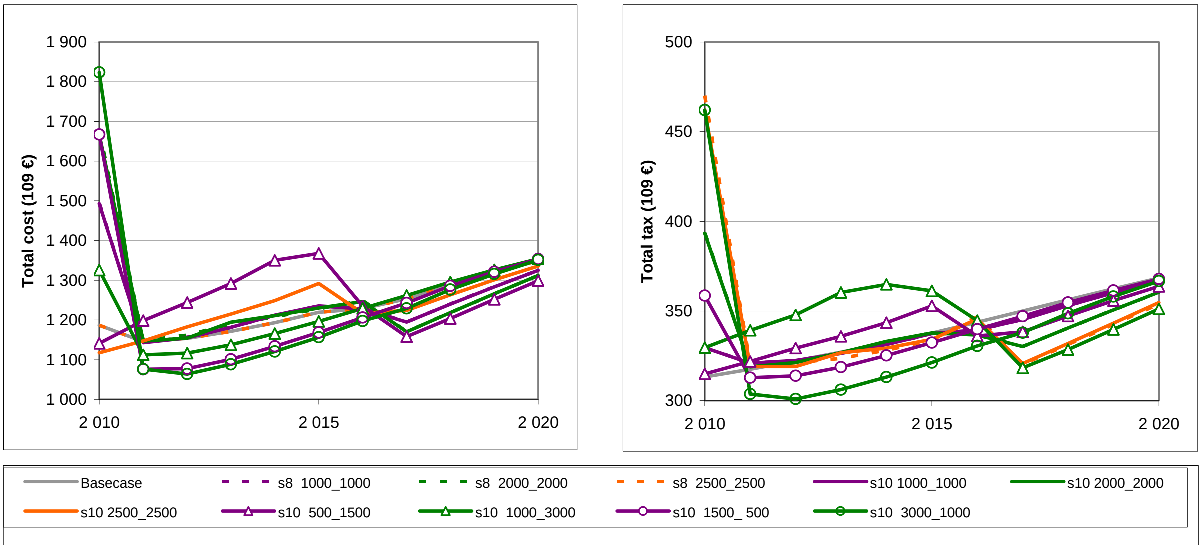


Table 38: **Differences in consumer expenditures and tax revenue between the simulations and the basecase scenario – average over the period 2010-2015**

	s8 1000_1000	s8 2000_2000	s8 2500_2500	s10 1000_1000	s10 2000_2000	s10 2500_2500	s10 500_1500	s10 1000_3000	s10 1500_ 500	s10 3000_1000
purchase cost & others	18 465	79 205	112 169	18 465	78 960	110 614	40 711	134 751	16 168	63 844
fuel cost	-642	-2 675	-3 818	-642	-2 658	-3 706	-619	-2 485	-896	-2 789
total cost	17 823	76 530	108 352	17 823	76 302	106 909	40 093	132 266	15 272	61 055
(%BC)	*(1.5%)*	*(6.6%)*	*(9.3%)*	*(1.5%)*	*(6.6%)*	*(9.2%)*	*(3.5%)*	*(11.4%)*	*(1.3%)*	*(5.3%)*
registration tax	1 175	5 507	7 697	1 175	5 495	7 589	2 820	8 875	898	4 180
fuel tax	-914	-3 701	-5 150	-914	-3 686	-5 016	-812	-3 224	-1 382	-4 096
other tax	2 718	11 711	16 537	2 718	11 669	16 292	6 007	19 836	2 402	9 458
total tax	2 980	13 517	19 084	2 980	13 479	18 865	8 015	25 488	1 918	9 542
(%BC)	*(0.9%)*	*(4.2%)*	*(5.9%)*	*(0.9%)*	*(4.1%)*	*(5.8%)*	*(2.5%)*	*(7.8%)*	*(0.6%)*	*(2.9%)*

Table 39: **Differences in consumer expenditures and tax revenue between the simulations and the basecase scenario – average over the period 2010-2020**

	s8 1000_1000	s8 2000_2000	s8 2500_2500	s10 1000_1000	s10 2000_2000	s10 2500_2500	s10 500_1500	s10 1000_3000	s10 1500_ 500	s10 3000_1000
purchase cost & others	4 784	22 989	35 685	4 784	22 873	34 791	8 291	37 185	6 134	23 401
fuel cost	-470	-1 776	-2 381	-470	-1 762	-2 290	-549	-1 575	-582	-1 693
total cost	4 315	21 213	33 304	4 315	21 111	32 501	7 742	35 610	5 552	21 708
(%BC)	*(0.4%)*	*(1.7%)*	*(2.7%)*	*(0.4%)*	*(1.7%)*	*(2.7%)*	*(0.6%)*	*(2.9%)*	*(0.5%)*	*(1.8%)*
registration tax	208	1 047	1 690	208	1 043	1 647	416	1 933	208	900
fuel tax	-737	-2 756	-3 641	-737	-2 744	-3 521	-867	-2 476	-963	-2 757
other tax	702	3 407	5 294	702	3 388	5 147	1 231	5 512	920	3 527
total tax	173	1 699	3 343	173	1 687	3 273	780	4 968	165	1 670
(%BC)	*(0.1%)*	*(0.5%)*	*(1.0%)*	*(0.1%)*	*(0.5%)*	*(1.0%)*	*(0.2%)*	*(1.5%)*	*(0.0%)*	*(0.5%)*

7.5.2 Indirect economic impacts

The indirect economic impacts of the scrappage scenarios have been calculated according the input-output methodology described in Section 4.5. Table 40 shows the change in total household expenditure according to industry sectors for the scrappage scenarios for the period 2010-2015. Compared to the base case, expenditure is increased for passenger cars, trade services, and market services for all scenarios.

Table 40: Base case expenditure by household (M€) and relative change in the scrappage scenarios – average of the period 2010-2015

Sector	BC	s8 1000_1000	s8 2000_2000	s8 2500_2500	s10 1000_1000	s10 2000_2000	s10 2500_2500	s10 500_1500	s10 1000_3000	s10 1500_500	s10 3000_1000
Agriculture	132695	-0.28%	-1.20%	-1.71%	-0.28%	-1.20%	-1.69%	-0.60%	-2.02%	-0.25%	-0.99%
Construction	1113110	-0.01%	-0.06%	-0.09%	-0.01%	-0.06%	-0.09%	-0.03%	-0.10%	-0.01%	-0.05%
Market services	3341999	0.04%	0.16%	0.23%	0.04%	0.16%	0.23%	0.10%	0.30%	0.03%	0.12%
Non-market services	3180579	-0.07%	-0.30%	-0.42%	-0.07%	-0.29%	-0.42%	-0.15%	-0.50%	-0.06%	-0.24%
Trade services	1656805	0.04%	0.12%	0.12%	0.04%	0.12%	0.12%	0.08%	0.21%	0.05%	0.09%
Metals	149605	-0.04%	-0.19%	-0.27%	-0.04%	-0.19%	-0.26%	-0.09%	-0.31%	-0.04%	-0.15%
Chemicals	286680	-0.13%	-0.56%	-0.80%	-0.13%	-0.56%	-0.79%	-0.28%	-0.95%	-0.12%	-0.47%
Non-metallic minerals	39994	-0.16%	-0.71%	-1.01%	-0.16%	-0.71%	-1.00%	-0.35%	-1.19%	-0.15%	-0.59%
Pulp, paper & printing	144014	-0.25%	-1.09%	-1.55%	-0.25%	-1.08%	-1.53%	-0.54%	-1.83%	-0.23%	-0.90%
Food, beverages & tobacco	635418	-0.30%	-1.30%	-1.86%	-0.30%	-1.30%	-1.84%	-0.65%	-2.19%	-0.28%	-1.08%
Textiles	198496	-0.27%	-1.15%	-1.64%	-0.27%	-1.15%	-1.62%	-0.57%	-1.93%	-0.24%	-0.95%
Machinery & equipment	984844	-0.04%	-0.19%	-0.27%	-0.04%	-0.19%	-0.27%	-0.10%	-0.32%	-0.04%	-0.16%
Other industries	309777	-0.19%	-0.82%	-1.18%	-0.19%	-0.82%	-1.16%	-0.41%	-1.39%	-0.17%	-0.68%
Passenger cars	225624	3.95%	17.65%	25.54%	3.95%	17.59%	25.18%	8.76%	29.89%	3.34%	14.29%
Other motor vehicles	251280	-0.01%	-0.03%	-0.04%	-0.01%	-0.03%	-0.03%	-0.02%	-0.04%	0.00%	0.01%
Automotive fuels	99928	-0.34%	-1.41%	-2.02%	-0.34%	-1.40%	-1.95%	-0.25%	-1.12%	-0.51%	-1.54%
Other energy	169672	-0.28%	-1.19%	-1.69%	-0.28%	-1.18%	-1.67%	-0.59%	-1.99%	-0.25%	-0.98%
Total	**12920518**	**0.02%**	**0.10%**	**0.15%**	**0.02%**	**0.10%**	**0.14%**	**0.06%**	**0.20%**	**0.01%**	**0.07%**

This reflects the increase in car sales (Figure 39). As a consequence, households will reduce their expenditure of other goods accordingly.

Total employment increases for all scrappage scenarios. The only exception is the scenario s10_1500_500 which shows employment change very close to zero (Figure 43). Total employment effects range from about 0 to 133 000 employees, corresponding to a change of 0% to 0.06% compared to the basecase.

Sectoral results show positive employment effects in the sectors passenger cars, other motor vehicles, market services, trade services, and metals for all scenarios. Negative impacts occur in most other sectors for all scenarios.

Impacts on value added (Figure 44) are in general less pronounced than for employment. Impacts at individual industry sector level range from -1.7% to +30%. Total value added increases from 0.01% to +0.16% which corresponds to about 1400 to 18000 M€).

Figure 43: Employment effects of the scrappage scenarios in 1 000 employees over 2010-2015.

A: Total employment effects; B: Sectoral employment effects

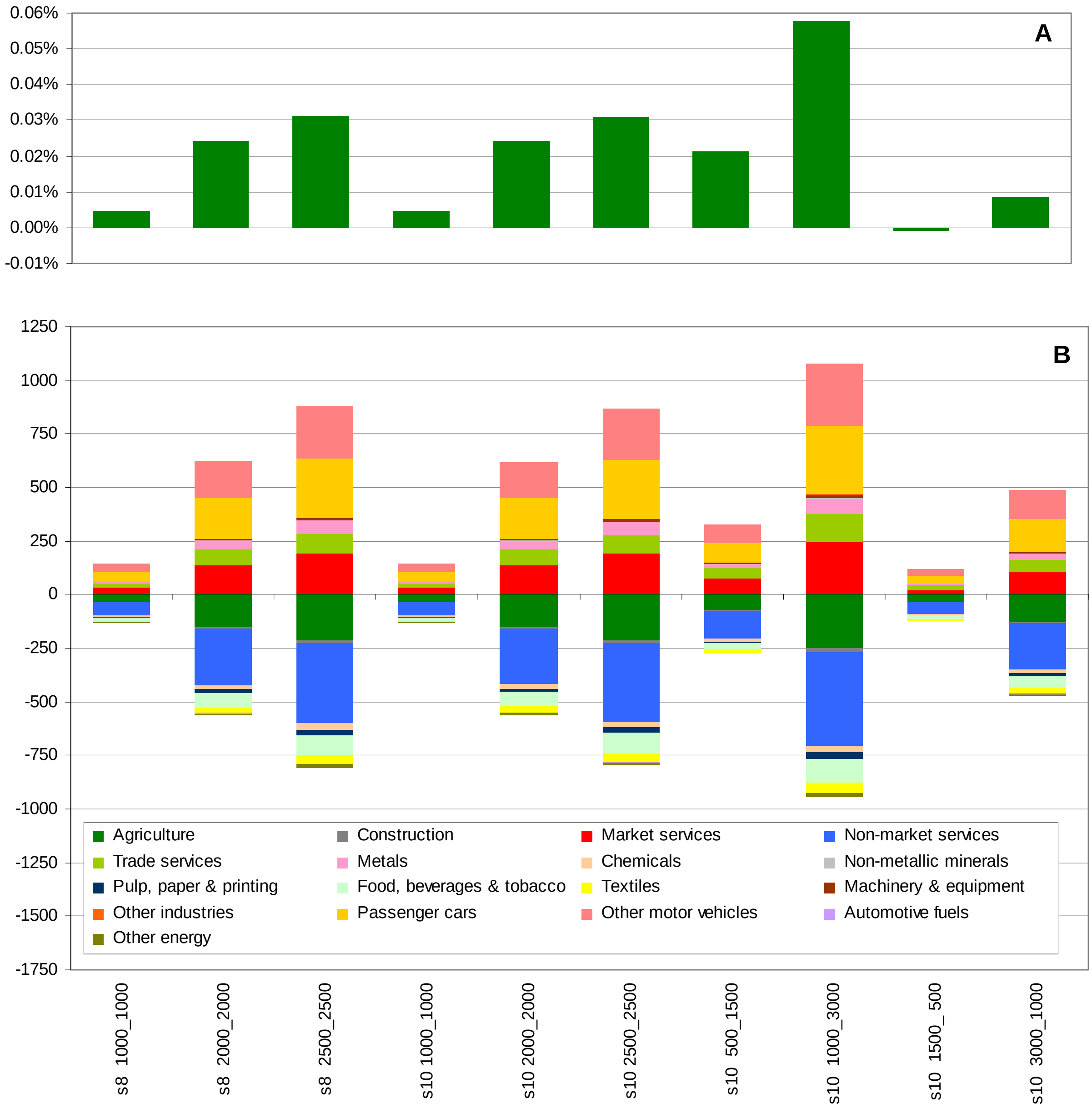
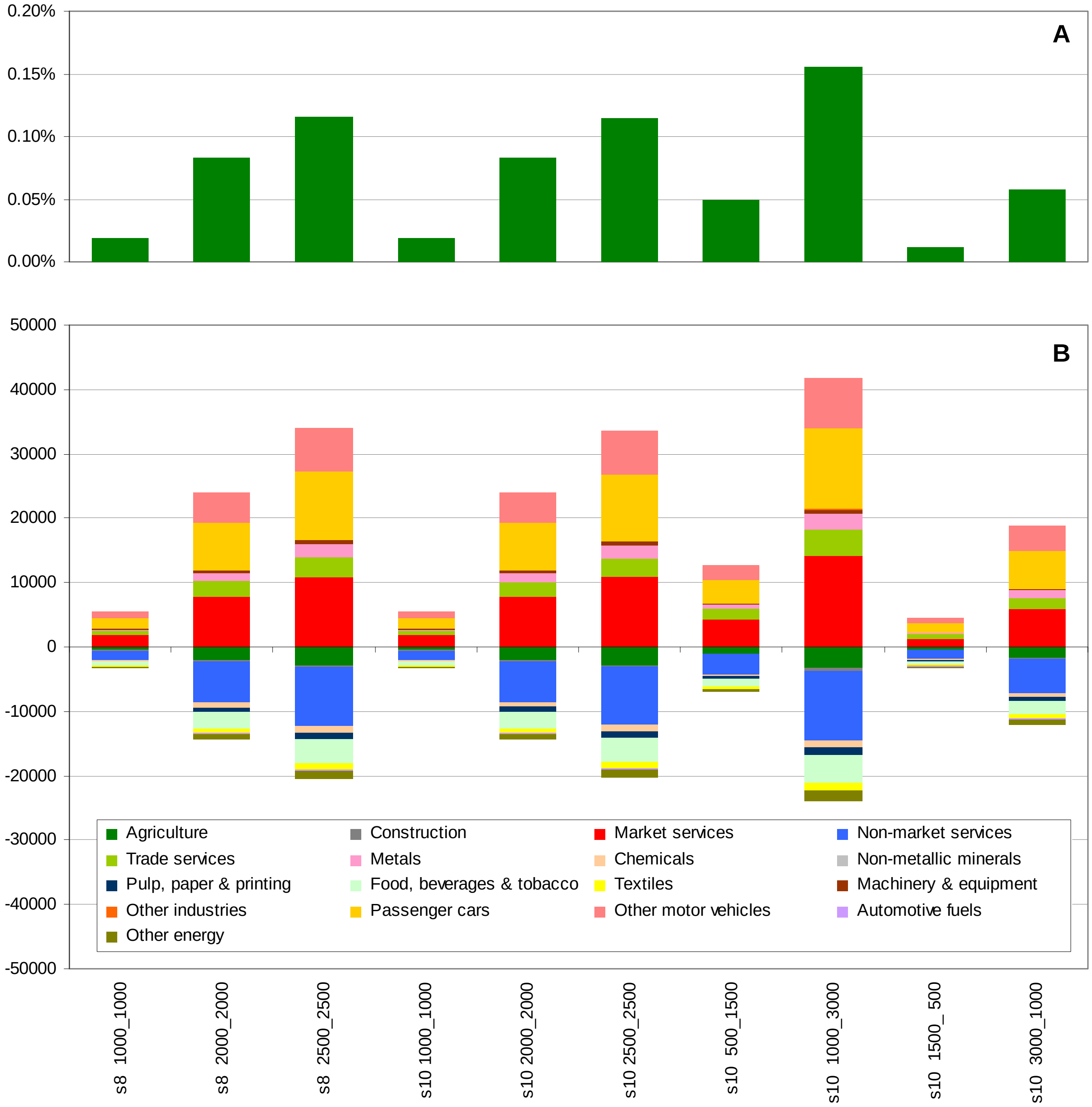


Figure 44: Value added effects of the scrappage scenarios in M€ for the period 2010-2015.

A: Total value added effects; B: Sectoral value added effects



7.6 Concluding remarks

The above analysis and results provide an overview of the environmental and economic effects of a scrappage policy instrument when applied at EU27 level. The focus was on the cash for-replacement case.

The TREMOVE scenario exercise leads to the conclusion that this policy would strongly and swiftly stimulate the removal of old cars and, consequently, boost new car sales.

The size of the effects is predominantly determined by the level of the scrappage subsidy. Dramatic sales increases are projected with subsidies as high as 2000€.

Most of its effects can be expected as soon as after 2 years, unless the subsidy starts with low levels and then gradually increases.

Regarding the old cars scrapped, old small (petrol) cars would be scrapped at a larger scale than others, and overall, the share of bigger cars in the car fleet may be increased.

Concerning the effects on air quality, the instrument is expected to result in a decline of emissions faster than what is already expected in the baseline scenario. Under the scrappage policy, the reduced emission levels expected during the period 2015-2020 in the baseline scenario would be reached 2 years earlier (in the case of NOx and PM emissions) and 4 years earlier (in the case of CO and VOC emissions).

The effects on CO_2 emissions are more ambiguous. Small reductions are modeled, however, with a significant degree of uncertainty. Any benefit disappears once the scheme is phased out.

One key aspect, also pointed out in the literature, is the importance of the expected energy efficiency leap from the old scrapped car to the new one to ensure real benefits. The leap expected under a subsidy implemented today would be modest. It would be much higher if the policy instrument were postponed when the emissions from new cars would be closer to the 2015 target (130 g/km) or even later when the 2020 target (95 g/km) is approached.

Also, the fact that the scrappage policy instrument would, in the short term, pull up sales of slightly more efficient cars, means that the car fleet renewal would later be reduced, when car emissions are substantially declining. This means that the scrappage policy could potentially reduce the effects of the policy target.

From an environmental point of view, the scrappage policy would come late with regards to air pollution, and too early with regards GHG emissions.

In addition, the emissions from the increased car manufacturing partly compensate for the WTW emission reductions.

Overall, the household expenditures for cars would increase. Also the tax revenue from passenger cars would increase because the subsidy far from absorbs the increased revenue of the registration tax resulting from the increased sales. One might expect that in reality, the tax revenue would be lower as some people who would have replaced their car anyway would benefit from the subsidy. The outcome may also depend on the registration tax which varies from country to country.

As regards macroeconomic impacts, the Input-Output tables modeling suggests that the sectors directly concerned (the automotive sector and supplying sectors, including metal sector) would gain both in terms of value added and employment. The extra expenditures that households are expected to dedicate to cars would entail reductions of expenditures to other goods. This would result in employment and value added reductions in the other sectors, in the same order of magnitude as the gain expected for the benefiting sectors. This effect would be only moderated by the recycling of the tax revenue across all sectors.

The net effects would consist of a very small net employment creation and the policy instrument would be close to neutral in terms of employment. This would of course, hold true only if fast adjustments occur (as assumed in the modeling exercise).

In conclusion, the scrappage policy would primarily benefit the automotive sector and supply sectors and only to a certain extent (and only in the short term). Other economic sectors would be negatively affected.

The focus of this analysis was on the cash-for-replacement scheme. One can anticipate that the cash-for-scrappage policy would result in lower car sale increases. However the policy could better address the lower affordability of low-income households for buying a new car (even under a scrappage subsidy) and, would also, stimulate a shift to public transport.

8 Combined scenario

8.1 Introduction

As suggested by the literature, the combination of a feebate system with a scrappage scheme could result in a mutually corrective interaction between some of the perverse effects and could also entail some positive synergies.

These interactions were modelled in TREMOVE by combining the two approaches described in sections 6.2 and 7.1 for the feebate and the scrappage policy respectvely, using the relevant policy parameters.

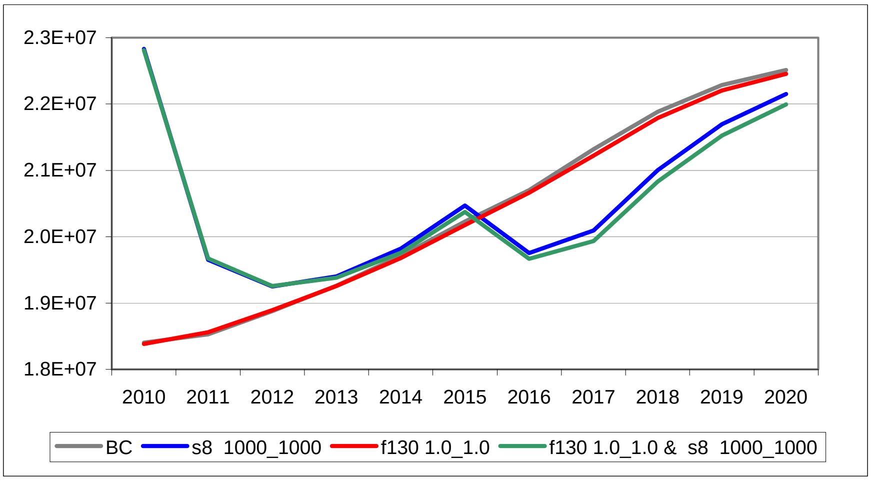
The main purpose in this chapter is to illustrate the effects of the interactions of both policy instruments when implemented simultaneously. To this end, the combination of the feebate 130_1_1 with the scrappage case s8_1000_1000 is used as an illustration of the main effects of such combinations.

8.2 Direct impacts

An important point of interaction between the two combined policy types is the purchase cost of new vehicles. Due to a feebate system, the purchase costs increases because of abatement costs. This gives two effects in combination with the scrappage scheme: first, the decision to scrap a car will alter slightly (the purchase cost of a new vehicle is a decision parameter in the scrappage model); secondly, due to increased purchase cost, in combination with increased vehicle turnover under the scrappage scheme, total transport cost will increase even more than compared to the scrappage simulation exclusively.

The consequences of these interactions on the new car sales are in Figure 45 which provides the evolution of the new cars sales over the period 2010-2020. During the policy period, sales increases are expected, in a similar magnitude as what is expected with the scrappage policy alone. The difference slightly increases at the end of the period. After the policy period, the sales follow the same trend as with the scrappage alone but they are slightly lower.

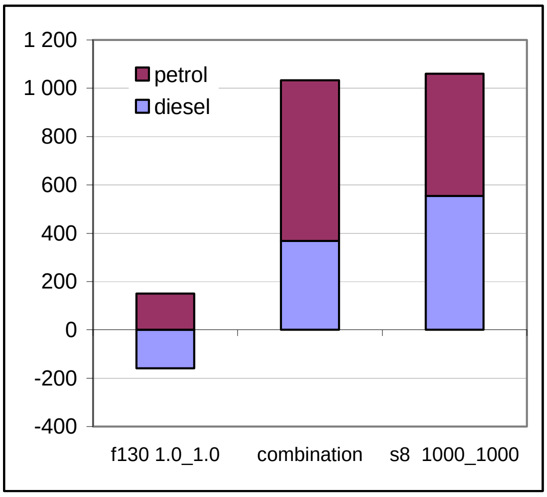
Figure 45: Evolution of new car sales with a combination scenario, compared with the base case and the two corresponding individual feebate and scrappage scenarios



The combination also results in a modified distribution of new car sales in terms of fuel types (Figure 46): Unlike to what happens with the feebate case alone, diesel cars sales are increased together with petrol car. On the other hand, the share of diesel cars in sales is lower than in the case of the scrappage policy alone. The share of new cars sales in terms of size is only slightly changed compared to the scrappage policy.

The average over the periods 2010-2015 and 2010-2020 is summarized in Table 41.

Figure 46: Changes in car sales by fuel types and vehicle size



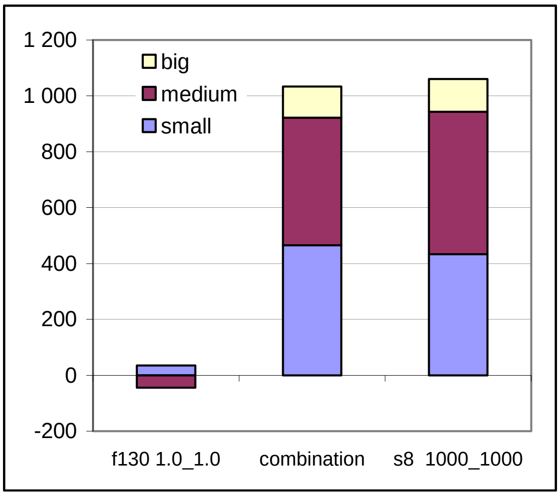


Table 41: Overview of the different impacts over the periods 2010-2015 (average) and 2010-2020 in the case of individual feebate/scrappage scenarios and their combination

		average changes over 2010-2015			*average changes over 2010-2020*		
		f130 1.0_1.0	combination	*s8 1000_1000*	*f130 1.0_1.0*	combination	*s8 1000_1000*
change of new vehicle stock (1000 units)	PCDB	*-21*	64	*96*	*-14*	4	*27*
	PCDM	*-118*	209	*340*	*-74*	-44	*74*
	PCDS	*-20*	96	*119*	*-12*	34	*43*
	PCGB	*20*	48	*21*	*10*	28	*2*
	PCGM	*74*	247	*170*	*33*	113	*30*
	PCGS	*56*	370	*314*	*19*	111	*40*
	total	*-9*	*1 033*	*1 060*	*-39*	*247*	*216*
	% BC	*-0.05%*	*5.43%*	*5.58%*	*-0.19%*	*0.67%*	*1.07%*
WTW emissions reductions (% baseline)	GHG	*-1.8%*	-2.3%	*-0.4%*	*-2.1%*	-2.4%	*-0.3%*
	CO	*-0.1%*	-8.8%	*-8.7%*	*-0.1%*	-7.4%	*-7.3%*
	Nox	*-0.5%*	-2.2%	*-1.7%*	*-0.6%*	-1.9%	*-1.3%*
	Sox	*-2.0%*	-2.7%	*-0.6%*	*-2.2%*	-2.8%	*-0.4%*
	VOC	*-0.5%*	-5.7%	*-5.2%*	*-0.5%*	-5.0%	*-4.5%*
	PM	*-1.1%*	-1.8%	*-0.7%*	*-1.2%*	-1.8%	*-0.6%*
Costs changes (million euros)	registration tax	*4 600*	5 942	*1 175*	*2 483*	2 775	*208*
	fuel cost	*-2 315*	-3 129	*-642*	*-3 435*	-4 071	*-470*
	fuel tax	*-2 620*	-3 660	*-914*	*-3 785*	-4 620	*-737*
	total cost	*10 897*	28 981	*17 823*	*2 381*	6 156	*4 315*
	(%BC)	*(0.9%)*	*(2.5%)*	*(1.5%)*	*(0.2%)*	*(0.5%)*	*(0.4%)*
	total tax	*3 039*	6 076	*2 980*	*-1 250*	-1 187	*173*
	(%BC)	*(0.9%)*	*(1.9%)*	*(0.9%)*	*-(0.4%)*	*-(0.3%)*	*(0.1%)*

The key findings, also expected with other combinations, are as follows:

- The changes in new car sales are only slightly lower than those expected from the scrappage policy case.
- The WTW emissions, as compared with the basecase, are close to the cumulated effects of the individual scenarios. Due to the feebate system, the emissions from newly purchased cars will indeed be lower compared to the basecase. With a scrappage scheme in place, the scrapped-replacing vehicles have lower CO_2-emissions, thus causing a more explicit effect on CO_2-reduction.
- The different cost components are also close to the cumulated costs of the corresponding individual scenarios.

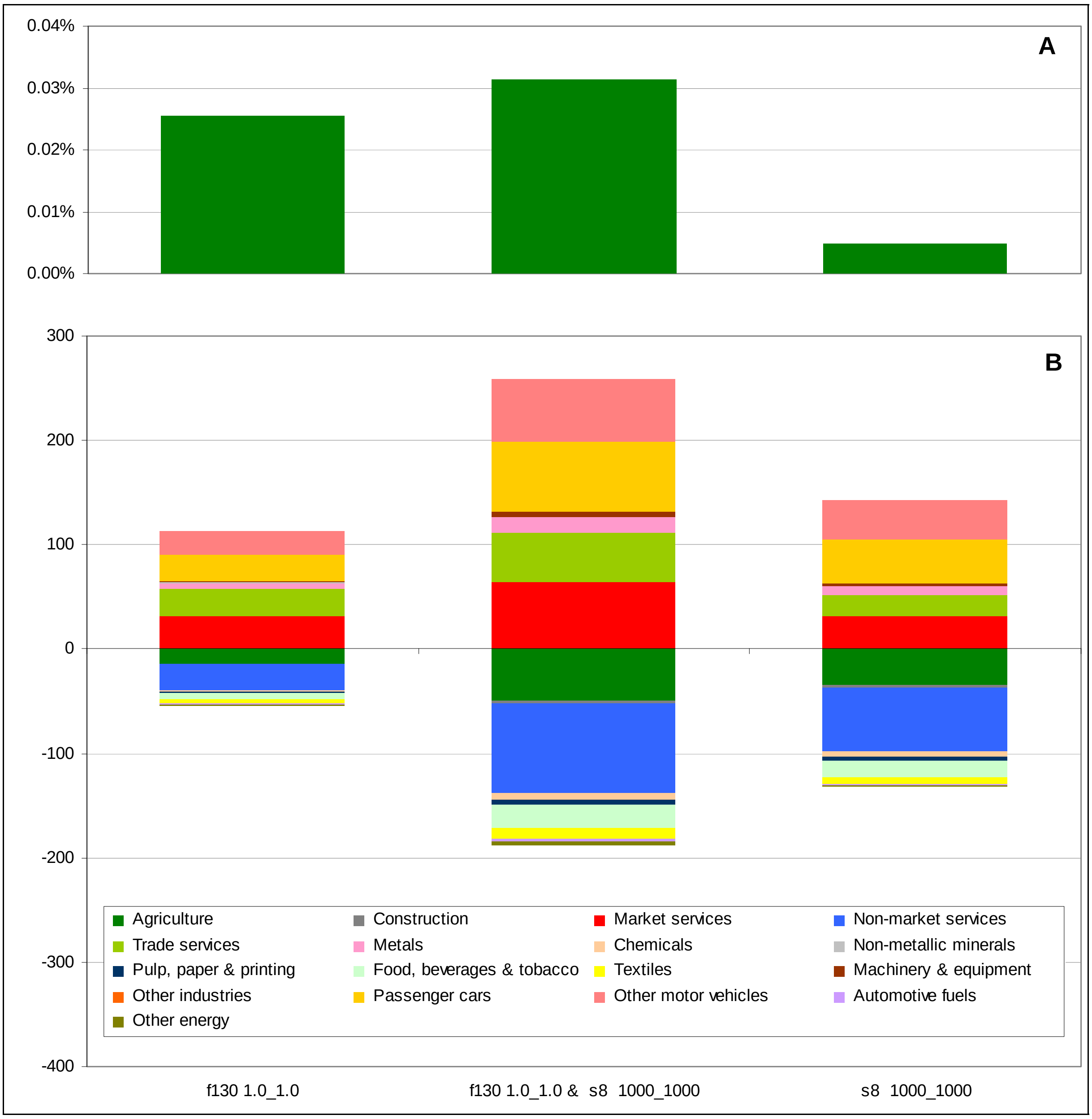
Similar observations are made with respect to long term effects (period 2010-2020).

8.3 Indirect impacts

The impacts on employment and value added were calculated with the approach described in section 4.5. The results for the combination are compared to the estimates made for the corresponding feebate and scrappage policy case (Figure 47). These results show the benefit of combining a scrappage policy with a feebate system as the individual effects on total employments are shown to accumulate. However this accumulation effect might also be expected in terms of sectors that would experience employment losses under the scrappage policy.

Figure 47: Employment effects of one combined scenario (1 000 employees) over 2010-2015.

A: Total employment effects; B: Sectoral employment effects



8.4 Concluding remarks

The above results illustrate the general effects that can be expected when coupling the feebate and scrappage policy instruments.

The sales of new cars would be very close to what the scrappage policy would induce individually.

The respective benefits of both policy instruments would be accumulated, thus, securing the longer term reductions on GHG emissions and, also accelerating the already expected benefit for air quality.

The combination would also enhance the positive effects on employment in the automotive-related sectors but also, potentially worsen the negative effects on the other sectors.

As discussed in sections 3.1 and 3.3, the combination would enable, at least partly, an avoidance of some perverse effects of the individual instruments. One of them is the indirect incentive from the feebate policy to extend the life of old big cars. This effect and possible correction by the scrappage instrument cannot however, be modeled with TREMOVE.

9 Conclusions

This report analyses two policy instruments designed to reduce the environmental impacts from passenger cars. The first instrument, the **feebate system**, is a way to differentiate the registration tax according to the CO_2 emissions from cars and has been implemented in several countries in the recent past. The second instrument, the **scrappage policy** is intended to encourage owners of old cars to scrap their car sooner. In the cash-for-replacement variant, the old car has to then be replaced by a new car. In the other variant, the cash-for-scrappage one, there is no condition regarding the subsequent use of the subsidy.

For both policy instruments, the assessment, made at the EU27 level, has covered the environmental impacts from the car fleet, including those resulting from the fuel used by cars (WTW emissions) and also those associated with the production of cars and spare parts.

The economic impacts were also quantified, both direct impacts (car sales, transport demand and resulting expenditures for households and tax revenues) and indirect impacts on the whole economy (employment and value added in the different economic sectors).

This analysis was carried out by further developing and implementing the TREMOVE model and exploiting its different results in the Input-Ouput table framework.

The methodological developments are based on different types of data of which the availability and quality determine the confidence of the quantified results. There is obvious room for improvement in the future. Nevertheless, some key conclusions can be drawn from this assessment.

For both policy instruments, several policy variants have been considered, giving some indications of the influence of the scheme parameters, but also, providing some ranges of the expected effects. These policy variants and their expected effects are compared in Table 42.

In general, a **feebate system** is almost neutral in terms of total new car sales, but given the incentive to move the purchase decision to lower CO_2 emitting cars, the policy instrument would result in reductions in GHG emissions from cars. This holds true both in the short term but also in the long term. Positive effects on air pollution, though of less importance, are also expected. Both types of effects are preserved even if all life-cycle impacts are considered.

In total, households would spend more money on cars because of higher purchase costs which are not fully compensated by the fuel cost savings. Budget neutrality for the government is also shown to be achievable, especially in the short term, but may be lost in a long term.

In general, the real-life outcome may vary depending on the initial purchasing patterns and the initial taxation regime which both depend on the situation of each country.

At a macro-economic level, the sectors directly concerned (the automotive sector and the supply sectors, including the metal sectors) would gain both in terms of value added and employment. Depending on the feebate scheme, the effects on other sectors would be either neutral or negative.

Table 42: Overview of results for the feebate and for the scrappage policies and their combination

Numbers give the percentage changes relative to the corresponding total baseline quantities (first, average value; second, range of values in italic)

	Feebate policy	Scrappage policy
Car sales		
2010 - 2015		
Total	-0.1% *-0.3% to 0.1%*	25.4% *4.7% to 41.5%*
Fuel	Shift from diesel to petrol	Diesel cars share slightly increased in the fleet
Size	Possible shift from medium to small	Big/medium cars share slightly increased in the fleet
2010 - 2020	-0.3% *-0.5% to -0.2%*	6.0% *1.1%* to *13.7%*
Environmental impacts		
Well-to-wheel emissions		
2010 - 2015		
GHG	-1.6% *-2.6% to -0.7%*	-1.3% *-2.6% to -0.4%* *(Most probably overestimated reductions)*
CO	-0.1% *-0.1% to -0.1%*	-18.4% *-29.9% to -7.0%*
NO_x	-0.4% *-0.7% to -0.2%*	-3.8% *-6.7% to -1.4%*
SO_x	-1.7% *-2.7% to -0.7%*	-1.9% *-3.8% to -0.6%*
VOC	-0.4% *-0.7% to -0.2%*	-8.8% *-13.0% to -3.8%*
PM	-0.9% *-1.5% to -0.4%*	-2.6% *-5.6% to -0.7%*
2010 - 2020		
GHG	-1.8% *-2.9% to -0.8%*	-0.8% *-1.3% to -0.3%* *(Most probably overestimated reductions)*
NO_x, PM	Effects declining slowly up to 2020	Baseline emission reductions expected over 2010-2020 brought forward by 2 years
CO, VOC	Effects declining slowly up to 2020	Baseline emission reductions expected over 2010-2020 brought forward by 4 years
Life cycle impacts (2010-2015)	Of the same order of impacts on Well-to-wheel emissions	Well-to-wheel emissions reductions partly compensated for by the increased impacts from production of cars and spare parts
Economic impacts		
2010-2015		
Total costs for the consumer	0.9% *0.5% to 1.2%*	4.4% *1.0% to 9.0%*
Total tax revenue	1.2% *-0.4% to 2.6%*	2.9% *0.5% to 6.4%*
Total employment	0.04% *-0.01% to 0.08%*	0.02% *0.00% to 0.06%*

The **scrappage policy** leads to a fast car fleet renewal. Most of the effects are observed after only 2 years, unless the subsidy starts with low levels and then gradually increases. The size of the effects is predominantly determined by the subsidy level. Dramatic sales increases are projected with subsidies as high as 2000€.

This rapid car fleet renewal would also help accelerate the expected decline of air emissions. The conclusions regarding CO_2 emissions are more ambiguous. In any case, the effects would be temporary.

The expected leap in energy efficiency from the old scrapped car to the new one during the operation of the system (2010-2015) would not be sufficient to enable real gains in terms of energy and CO_2 emissions. A higher gain would result from a delayed scheme because, in that case, the system would operate when the new car emissions would be declining according to the regulatory CO2 emission targets (130 g/km by 2015, 95 g/km by 2020).

The scrappage policy (as applied alone) can thus be said to come late with regard to air pollution and, too early with regard to GHG emissions. All the environmental impacts (including the impacts from the car manufacturing sector) have to be considered also, including the impacts from car manufacturing, which can substantially increase, and partly compensate for WTW emission reductions.

Overall, the household expenditures for cars would increase alongside the tax revenue from passenger cars.

The policy would clearly benefit to the employment in the sectors directly concerned (the automotive sector and supplying sectors, including metal sector). Employment and value added reductions are expected in the other sectors, in the same order of magnitude as the gain expected for the benefiting sectors. The net effects would consist of a very small net employment creation.

When comparing the two policy instruments and their environmental impacts, it can be concluded that the feebate system offers clear, significant and long-term benefits with regard to energy savings and CO_2 emission reductions. Thus, the feebate system would help reach the goal of the EU strategy to reduce CO_2 emission from cars. The emission reductions (~236 Mt CO_2-eq over the period 2010-2020) would indeed complement the expected effects of the supply-side element of that strategy, namely, the regulation on CO_2 emissions from cars[a].

The benefits from the scrappage policy are less convincing in terms of CO_2 emissions. However, there are rapid and important effects in terms of air pollutant emissions, even though they mainly consist of bringing forward baseline improvements by 2 to 4 years.

Moderate and high increases in car expenditures for the consumers are expected from the feebate and the scrappage policy, respectively. The short term revenue for the Governments is expected to increase in both case, although, specific feebate schemes might result in net costs.

Both instruments are expected to result in a comparable small net creation of employment at EU27 level. However, the sector distribution of benefits would differ: the scrappage policy would the most benefit the automotive and related sectors. It would however entail employment losses in other sectors in all cases, whereas, the feebate instrument offers options to limit such negative consequences.

This report shows the advantages of coupling the two policy instruments, feebate and scrappage. The respective benefits of both policy instruments would be accumulated, thus ensuring long-term reductions in GHG emissions and also accelerating the already expected benefits for air quality.

It has to be noted that, besides such a combination, other options could be envisaged in order to avoid potential negative effects from the scrappage on the long term GHG emissions. One option would consist in applying CO2-based criteria on the new car replacing the scrapped one.

[a] According to the impact assessment made in the framework of the preparation of the CO_2&car regulation (which, at that time, assumed the 130 g CO_2/km target achieved by 2012, and did not assume the later adopted target for 2020 – 95 g CO_2/km) the GHG emission reductions over the period 2006-2020 would be higher than 625 Mt CO_2-eq.

This coupling would secure the environmental benefits, enhance the positive effects on employment in the automotive-related sectors. It could however worsen the negative effects on the other sectors that are expected under the individual scrappage policy.

Another option for reducing the GHG emissions from cars, which is not explicitly addressed by the regulation on CO_2 emissions from cars, is the reduction in the weight of cars. The project has estimated the related technical potential and its impacts. A scenario assuming a gradual decrease in car weight by 15% by 2030 compared to the current situation, suggests that 246 Mt CO_2-eq could be avoided over the period 2006 to 2020.

Worth noting is that the project was initiated and conducted in an economic context which later changed rapidly, including oil price and economic growth. Interpreting the project results against this new context is not straightforward. The objective of creating employment is now converted into an objective to avoid (and even attenuate) losses in employment.

10 References

1 Nemry F., Leduc G., Mongelli I., Uihlein A., 2008, Environmental improvement of passenger cars, JRC report, EUR23038 EN

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Abstract

This report presents the results and conclusions of a research carried out by the JRC/IPTS analysing two demand-side measures that can help improving the environmental performance of cars: The first instrument, the feebate system, is a way to differentiate the registration tax according to the CO2 emissions from cars. The second instrument, the scrappage policy is intended to encourage the owners of old cars to scrap their car earlier. The potential and consequences of technical options to reduce car weight are also analysed.

The report builds a comprehensive assessment of these policy options at EU level, covering all major environmental life cycle impacts and the different economic impacts.

The report is built upon IPTS research work, supported with a study subcontracted to a research consortium led by Transport&Mobility Leuven (TML) and involving Öko-Institut and ISI-Fraunhofer.

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