EMISSIONS OF ROAD TRAFFIC IN BELGIUM

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January 2006

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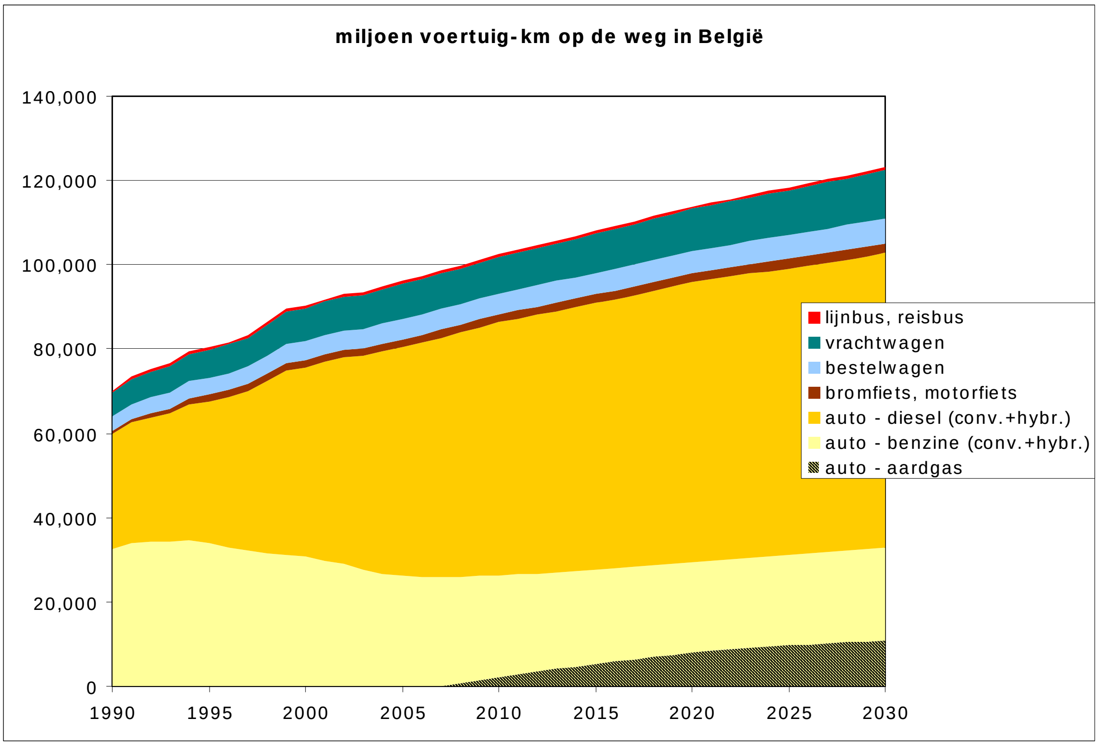
Tussen 1990 en 2030 leggen auto's en vrachtwagens steeds meer kilometers af op de Belgische wegen. De uitstoot van vervuilende stoffen, behalve het broeikasgas CO_2, zal echter afnemen dankzij technologische verbeteringen.

Het wegverkeer blijft toenemen

In 1990 legden personenwagens 60 miljard kilometer af, in 2004 waren dat er al 80 miljard en in 2030 zullen het er volgens experts 100 miljard zijn. Dieselvoertuigen, hybride en conventionele, nemen daarvan een steeds groter aandeel voor hun rekening.

De groei in de afgelegde kilometers is groter voor vrachtwagens dan voor personenwagens. Vrachtverkeer evolueert van 5,6 miljard voertuigkilometer in 1990 tot 11,5 miljard in 2030.

De voorspellingen tot 2030 zijn opgesteld met een Europees transportmodel dat rekening houdt met het BNP (Bruto Nationaal Product), demografie en transportinfrastructuur. De voorspellingen zijn verder verfijnd in onderling overleg met experts van de FODMV, FEBIAC en TML.

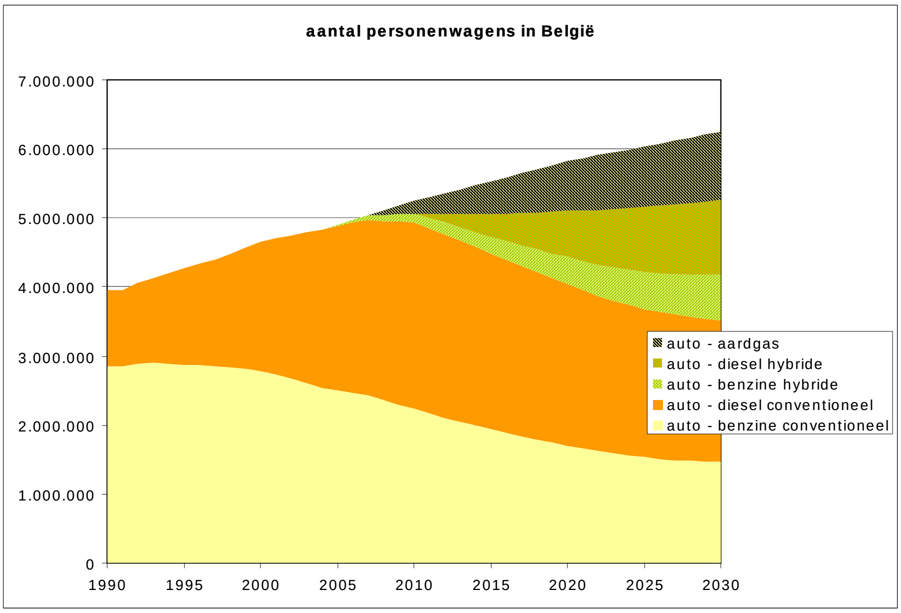


Figuur 1: Evolutie wegverkeer in België tussen 1990 en 2030

Hybride auto's en auto's op aardgas doen hun intrede

Vandaag is het aandeel van hybride auto's en auto's op aardgas in de voertuigvloot zeer beperkt. Het model voorspelt dat deze voertuigtypes geleidelijk hun intrede zullen doen in het wagenpark. In 2030 zal ongeveer 30% van de voertuigen een hybride voertuig zijn en meer dan 15% een voertuig op aardgas[1]. Autos met brandstofcellen zijn niet in het model opgenomen.

De samenstelling van het wagenpark tot 2030 is bepaald met een simulatie van het aankoopgedrag. Nieuwe auto's worden aangekocht op basis van onder andere totale kosten per kilometer, grootte en prestaties van de motor.



Figuur 2: Groei en samenstelling van het park personenwagens

Sterke daling luchtvervuiling

Ondanks de groei in wegverkeer, neemt de uitstoot van vervuilende uitlaatgassen aanzienlijk af. Tussen 1990 en 2030 daalt de uitstoot van fijn stof (PM_{10}) met 90%, stikstofoxides (NO_x) met 70 %, koolstofmonoxide (CO) met 80% en koolwaterstoffen (VOC) met 86%. Een deel van deze emissiereducties is reeds verworven. Een deel zal in de toekomst gerealiseerd worden. Tussen 2005 en 2030 zal de uitstoot van PM10 nog met 80%, die van NOx met 50%, die van VOC met 50% en die van CO met 40% dalen. Alle deze stoffen veroorzaken ademhalingsproblemen.

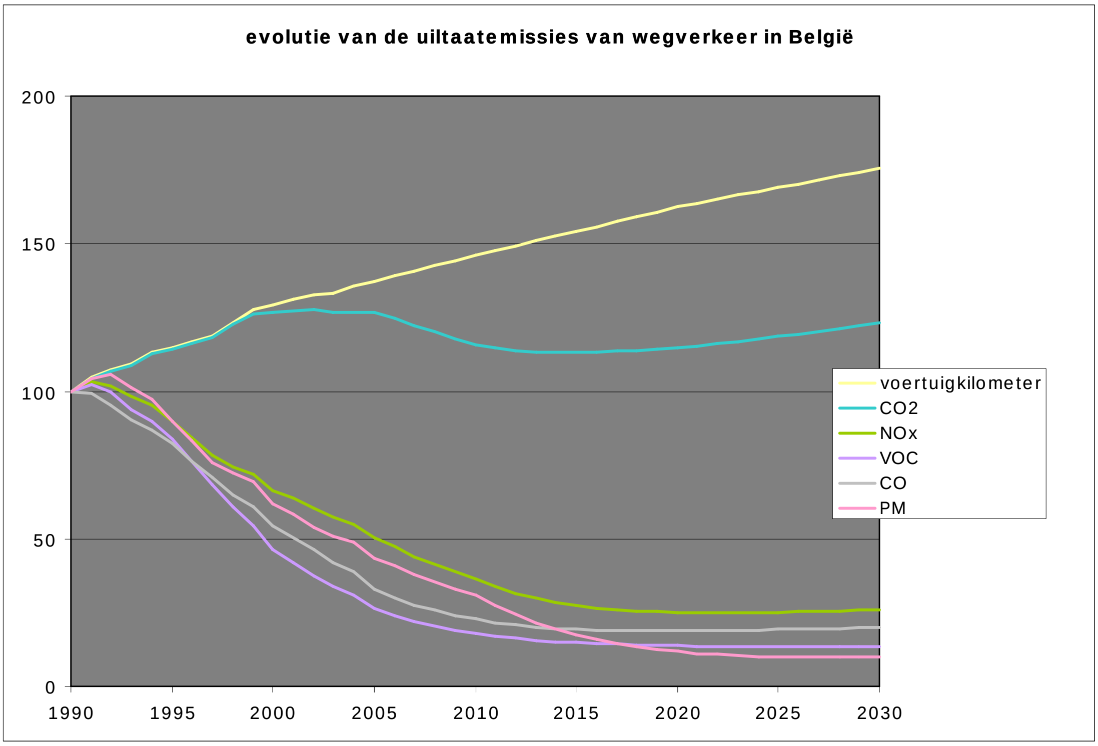
[1] Auto's met brandstofcellen zijn niet in het model opgenomen

Deze gunstige evolutie is te danken aan de sterk verbeterde motortechnologie. Die kwam er onder impuls van Europa, dat sinds de jaren '90 steeds strengere normen voor uitlaatgassen afvaardigt. Vanaf 2006 moeten nieuwe auto's voldoen aan de euro 4 norm. Recent werd bekend dat er ook een euro5 norm komt, die het fijn stof vermindert met nog eens 80%.

Ook voor vrachtwagens gelden Europese emissienormen, die voor een aanzienlijke daling van vervuilende stoffen zorgen, ondanks een sterk stijgend aantal vrachtwagenkilometer.

Tabel 1: Jaarlijkse evolutie van vervuilende uitlaatgassen van wegverkeer

	periode 1990-2005	periode 2005-2015	periode 2015-2030
voertuigkilometer	+ 2,1%	+ 1,2%	+ 0,9%
broeikasgas (CO_2)	+ 1,6%	- 1,1%	+ 0,6%
koolwaterstoffen (VOC)	- 8,4%	- 5,7%	- 0,6%
koolstofmonoxide (CO)	- 7,1%	- 5,3 %	+ 0,2%
stikstofoxiden (NO_x)	- 4,5%	- 6,0%	- 0,3%
fijn stof (PM10)	- 5,4%	- 8,8%	- 3,7%



Figuur 3: Evolutie van uitlaatemissies van wegverkeer, 1990 = 100

De uitstoot van het broeikasgas CO_2 stijgt, maar minder snel dan de stijging in voertuigkilometers

De uitstoot van het broeikasgas koolstofdioxide (CO_2) steeg tot het jaar 2000. Omstreeks 2000 stabiliseerde de uitstoot om vervolgens te dalen tot 2015. In die periode heeft een ontkoppeling plaats tussen het stijgende transportvolume en de dalende CO_2 emissies.

Vanaf 2015 stijgen de CO_2 emissies opnieuw. Inspanningen om CO_2 emissies terug te dringen zullen dus ook in de toekomst nodig blijven.

De daling in CO_2 emissies in de periode tussen 2000 en 2015 komt er dankzij een trend naar zuinigere wagens, met kleine motoren, en op diesel. Een groot effect valt ook te verwachten van inspanningen van de autosector op het gebied van nieuwe technologieën, zoals hybride wagens, aardgas en biobrandstoffen.

Aardgas en diesel stoten iets minder CO_2 uit per kilometer dan benzine. Hybride wagens rijden zuiniger omdat ze overtollig motorgebruik tijdens bijvoorbeeld het remmen omzetten in elektriciteit, die weer kan gebruikt worden.

Bij de productie van biobrandstoffen wordt – door de gewassen – weer CO_2 uit de lucht gehaald, zodat ze in feite het broeikaseffect van de uitlaatgassen weer deels neutraliseren. Voor ander polluenten zoals NO_x en PM_{10} hebben biobrandstoffen mogelijk een negatief effect. Op basis van de modelhypotheses zorgt de productie van biobrandstoffen voor extra NO_x en PM_{10} emissies ten opzichte van de productie van conventionele brandstoffen.

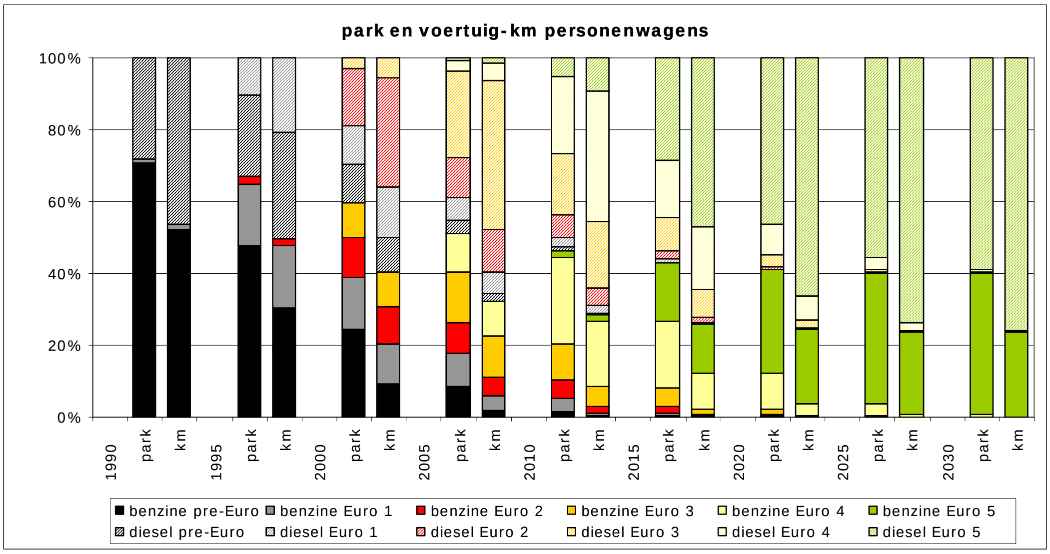
Bovenstaande grafiek toont de uitlaatemissies voor de verschillende polluenten (tank-to-wheel emissies). De CO_2 emissies in de grafiek houden rekening met de CO_2 die tijdens de productiefase van biobrandstoffen aan de atmosfeer werd onttrokken. Het is met andere woorden alsof de biobrandstof geen CO_2 emissies veroorzaakt.

De veralgemening van de uitrusting van personenwagens met airconditioning gaat in tegen deze tendens van verlaagde CO_2 emissies. Air conditioning in personenwagens verhoogt de uitstoot van broeikasgassen met 6% tot 9% in de periode tussen 2005 en 2030.

Het wagenpark wordt schoner

De steeds strengere Europese normen voor nieuwe personenwagens zorgen ervoor dat het wagenpark langzaam schoner wordt.

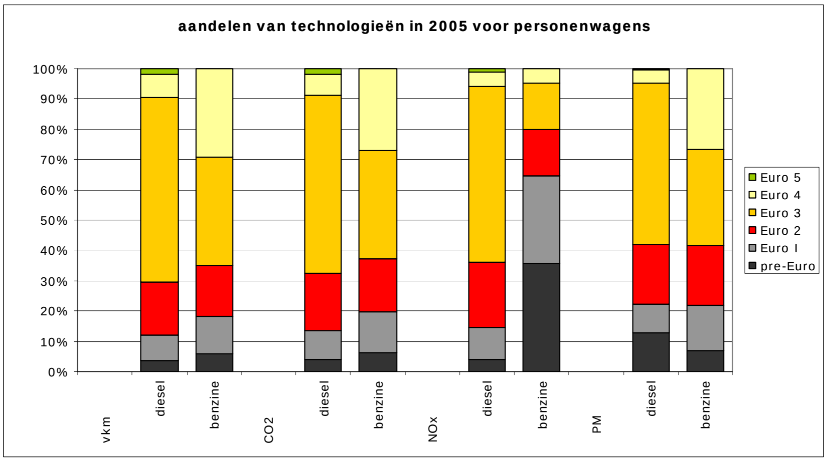
In 2005 zijn er nog 25% van de benzinewagens erg oud: ze voldoen zelfs niet aan de euro 1 norm. Dit zijn wagens zonder katalysator. Gelukkig rijden ze relatief weinig kilometers: slechts 6% van het totaal aantal afgelegde kilometer van de benzinewagens. Dat komt omdat nieuwe wagens meer kilometer per jaar afleggen dan oude wagens. Ook leggen dieselwagens meer kilometer af dan benzinewagens.

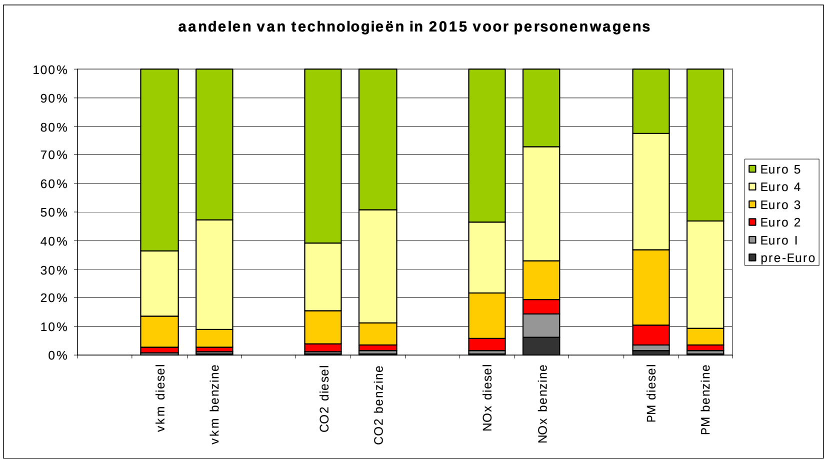


Figuur 4: Relatieve bijdrage in wagenpark en voertuigkilometer volgens type personenwagen

Toch veroorzaken die relatief weinige (6%) kilometers van oude benzinewagens 36% van de uitstoot van stikstofoxiden (NO_x) en 13% van het fijn stof (PM_{10}). Ook voor euro 1 en euro 2 benzinewagens is de NO_x uitstoot beduidend hoger dan voor meer recente benzinewagens.

Tegen 2015 wordt verwacht dat de huidige euro 4 en nieuwe euro 5 genormeerde auto's de overhand hebben in het wagenpark.

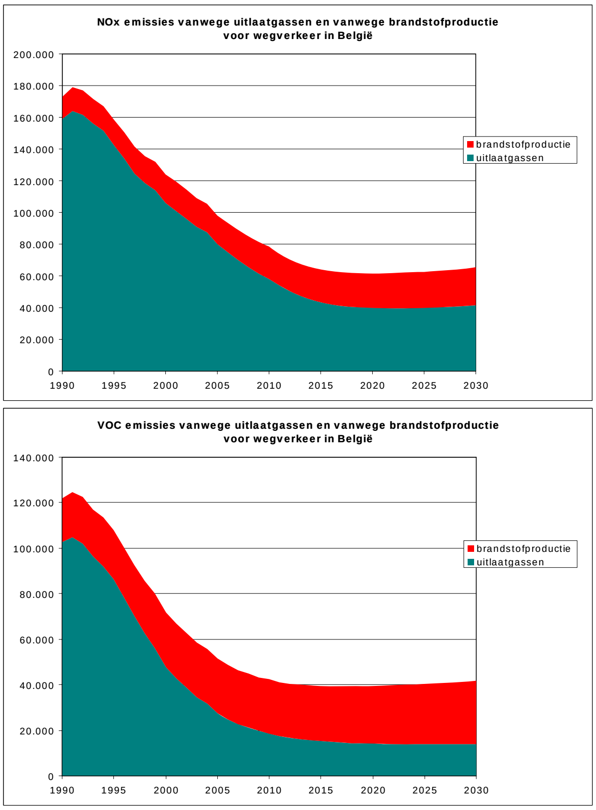




Figuur 5: Relatieve bijdrage in voertuigkilometer en uitlaatgassen volgens type personenwagen, 2005 en 2015

Emissies van brandstofproductie worden relatief belangrijker

De brandstofproductie (raffinage, transport) zorgt ook voor luchtvervuiling. Die stijgt wél mee met het verkeersvolume, en wordt zelfs groter dan de uitlaatgassen voor sommige polluenten tegen 2030.



Figuur 6: Evolutie van NO_x en VOC emissies van uitlaatgassen en van brandstofproductie voor wegverkeer

Drie scenario's: wat brengt een hervorming van de prijs van het wegverkeer teweeg?

1. *Mobiliteitstaks van 25% leidt tot 1% minder verkeer en tot 1,5% minder uitstoot*

Veronderstel dat alle accijnzen op brandstoffen en alle relevante verkeersbelastingen op het wegverkeer stijgen met 25%. Rijden met een personenwagen, motorfiets, bestelwagen of vrachtwagen wordt dus fiks duurder. De overheidsinkomsten stijgen gevoelig: 8 tot 10%.

Het gevolg is dat er ongeveer 1% minder wegverkeer zal zijn dan eerst verwacht. Een klein deel daarvan wordt opgevangen door de bus, trein en binnenschip, het overgrote deel verdwijnt gewoon.

Door de vermindering van het aantal afgelegde kilometers daalt de uitstoot van uitlaatgassen met 1,5%.

2. *Hogere brandstofprijzen: kleine daling van de uitstoot maar welvaartsverlies*

Wat gebeurt er als de brandstofprijzen sterker stijgen dan verwacht? Veronderstel een stijging door een hogere ruwe olieprijs én door hogere taksen tot 1,6 euro per liter voor zowel benzine als diesel in 2030 (zonder rekening te houden met inflatie).

Dat leidt tot 3% minder wegverkeer dan onder normale omstandigheden. Ook hier weer zal maar een klein deel worden opgevangen door alternatieven.

De overheidsinkomsten stijgen, maar de geldstroom naar het buitenland groeit door de duurdere ruwe olie. Hierdoor ontstaat een negatief effect op onze welvaart.

Door de vermindering van het aantal afgelegde kilometers daalt de uitstoot van vervuilende uitlaatgassen. Door de hogere brandstofprijs worden er ook zuinigere voertuigen gekocht, zoals hybride voertuigen, voertuigen op aardgas en kleine dieselwagens. Deze voorkeur voor zuinige voertuigen zorgt voor een bijkomende daling van de emissies. De totale vermindering is 2 tot 5%.

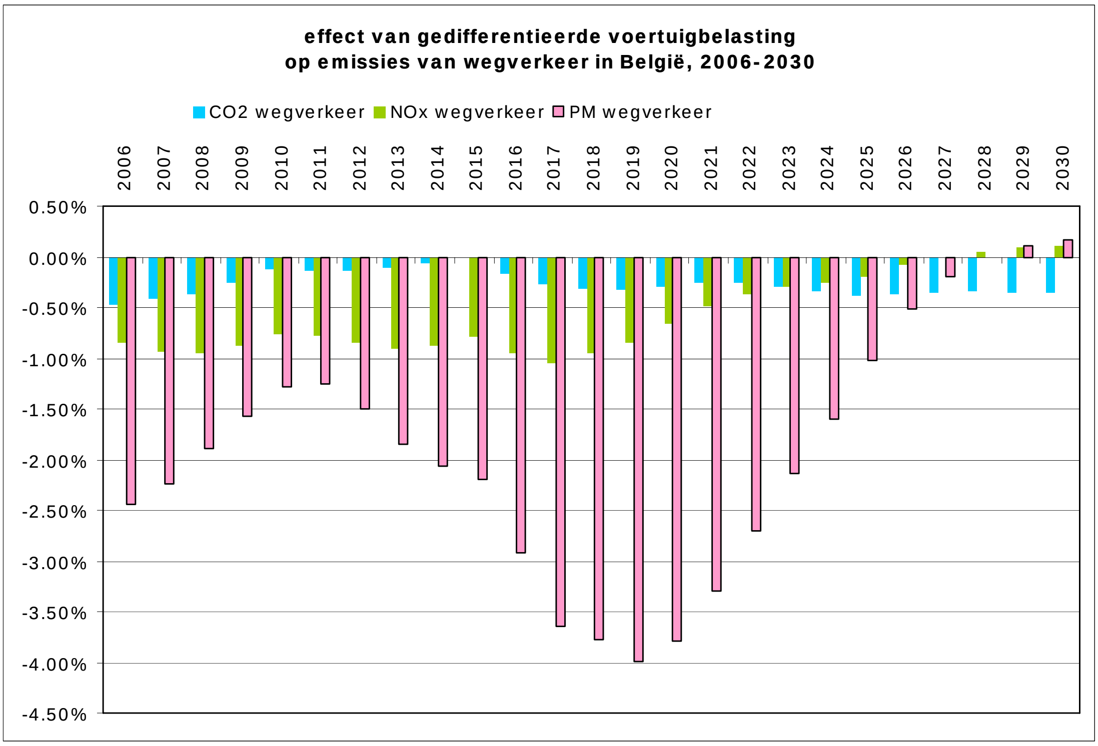
3. Differentiatie van de voertuigbelasting leidt tot verjonging wagenpark en reductie van fijn stof

In het derde scenario worden de huidige jaarlijkse verkeersbelasting en de belasting bij inverkeerstelling van nieuwe wagens vervangen door een gedifferentieerde jaarlijkse taks. De taks is afhankelijk van cilinderinhoud en milieuprestaties van de wagen.

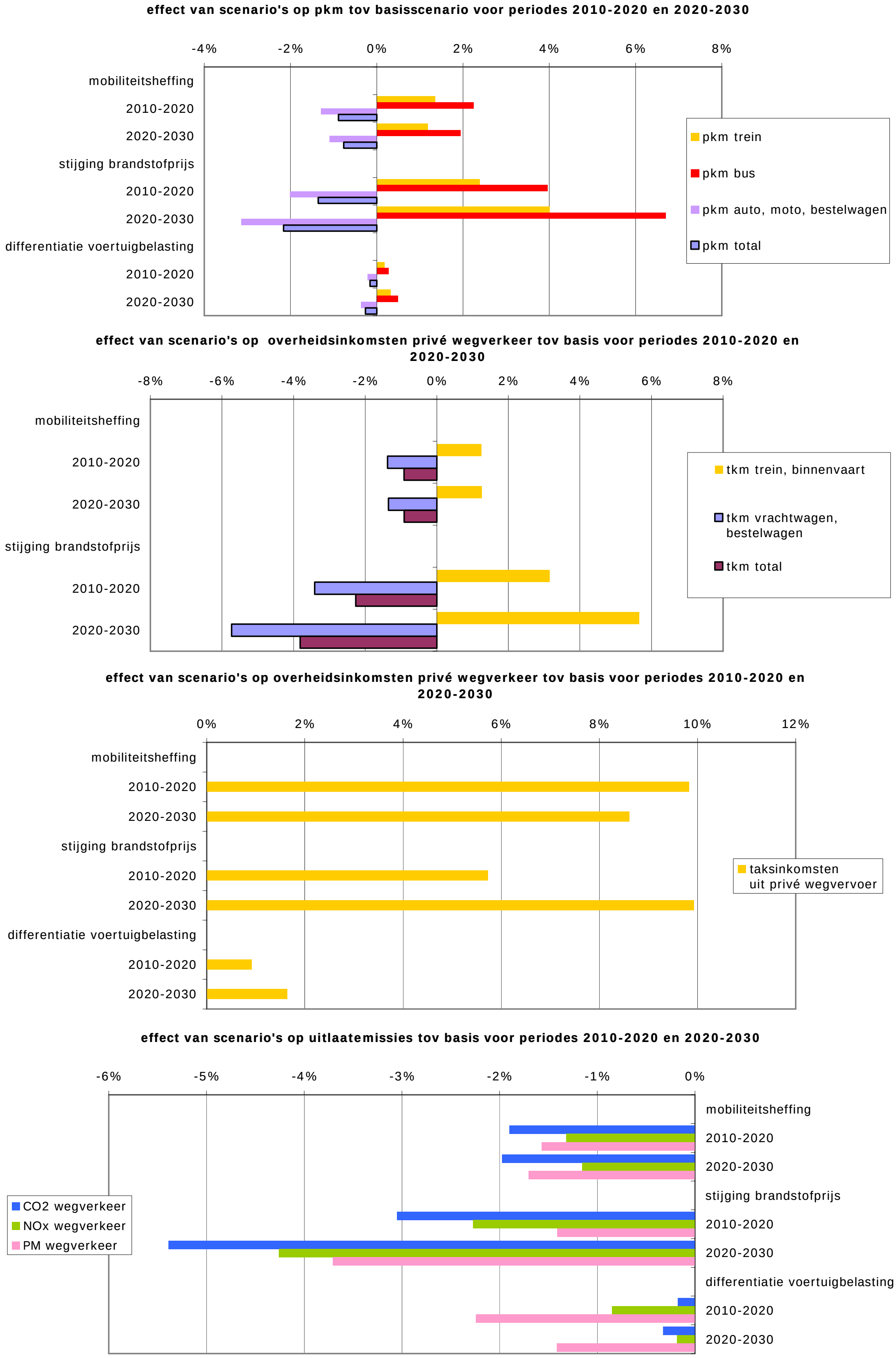
Wagens met een lage uitstoot aan stikstofoxiden en fijn stof, en zuinige wagens met lage CO_2 emissies betalen relatief weinig taksen. Oudere wagens, die minder milieuvriendelijk zijn, worden zwaarder belast. Dit motiveert automobilisten tot het vervangen van hun oude wagens door nieuwere wagens, met een voorkeur voor de milieuvriendelijke types.

De belastingsniveaus worden zo bepaald dat de totale belastingsinkomsten voor de overheid nagenoeg ongewijzigd blijven.

Zo'n belastinghervorming heeft weinig tot geen invloed op het aantal afgelegde kilometers, maar het leidt wel tot een verminderde uitstoot van uitlaatgassen. In 2020 wordt er 4% minder fijn stof (PM_{10})uitgestoten dan in het basisscenario. Dat komt door de veranderingen in de samenstelling van het wagenpark. Wagens die voldoen aan de nieuwe euro 5-norm (auto's met roetfilter) zullen veel eerder dan tegen het geplande 2008 in het wagenpark verschijnen. Tegen 2030 is het effect uitgewerkt: dan zullen er in elk geval nog nauwelijks dieselwagens zijn zonder roetfilter. Indien intussen een nieuwe, strengere emissienorm wordt uitgevaardigd zou het effect kunnen doorlopen.



Figuur 7: Verschil in uitlaatemissies door differentiatie van de voertuigbelasting 2006-2030



Figuur 8: effecten van scenarios tov basisscenario voor de periodes 2010-2020 en 2020-2030

Bij de interpretatie van de resultaten is het belangrijk te weten dat:

- Een taks geen kost voor de maatschappij is. De manier waarop de taksen en belastingen gebruikt worden zal wel de winst of het verlies van het beleid voor de maatschappij bepalen.
- Een variabilisering van taksen in functie van tijd en plaats een significant effect kunnen hebben op congestie. De emissie reducties van zulke maatregel kan dan als een interessant neven effect beschouwd worden.

Het TREMOVE model: een economisch transport- en emissie-model

Dit onderzoek maakt gebruik van het TREMOVE model. Dit simulatiemodel werd mee ontwikkeld door TML voor de Europese Commissie. Het model voorspelt voor 21 landen de verkeersvolumes, het voertuigenpark, het brandstofverbruik en de emissies als gevolg van beslissingen van het beleid.
Dankzij de economische onderbouw is het model ook in staat de welvaartseffecten van maatregelen te berekenen.

Executive summary in French
Les émissions du trafic routier en Belgique 1990-2030

Entre 1990 et 2030 les voitures et les véhicules utilitaires parcourent toujours plus de kilomètres sur les routes belges. Les émissions de polluants, excepté le gaz à effet de serre CO_2, diminueront de manière importante grâce aux progrès technologiques.

Le trafic routier continue d'augmenter

En 1990, les voitures avaient parcouru 60 milliards de kilomètres, en 2004 80 milliards et selon les experts en 2030, on devrait atteindre les 100 milliards. Les véhicules diesel y représentent une part croissante.

La croissance des kilomètres parcourus est plus importante pour les véhicules utilitaires que pour les voitures. Le trafic routier de marchandises progresse de 5,6 milliards de kilomètres en 1990 à 11,5 milliards en 2030.

Les projections jusqu'en 2030 ont été réalisées à l'aide d'un modèle européen de transport qui tient compte du PNB (Produit National Brut), de la démographie et des infrastructures de transport. Les prévisions ont ensuite été affinées en concertation réciproque avec les experts du SPFMT, de FEBIAC et TML.

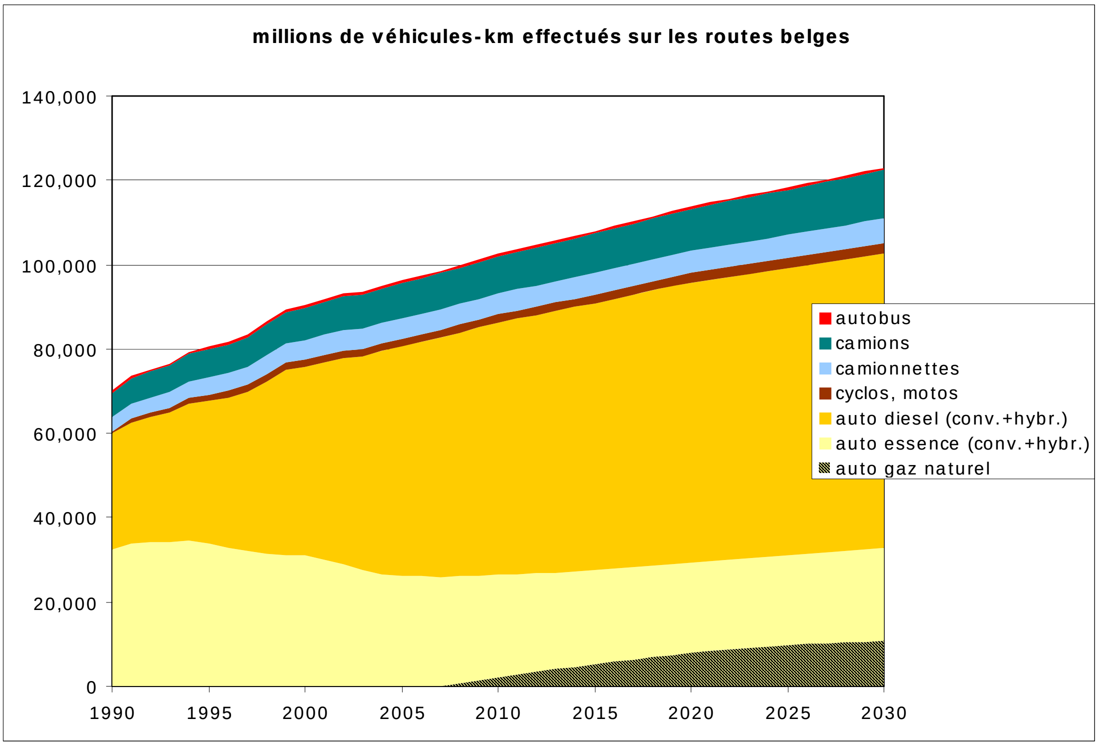


Figure 1: evolution du trafic routier en Belgique entre 1990 et 2030

Les voitures hybrides et au gaz naturel font leur apparition

Aujourd'hui, la part des voitures hybrides et au gaz naturel dans le parc est très limitée. Le modèle prévoit que ces types de véhicules feront progressivement leur apparition dans le parc des voitures. En 2030, environ 30% des véhicules auront une motorisation hybride et plus de 15% rouleront au gaz naturel[2]. Des véhicules à piles à combustibles n'ont pas été prises en compte.

La composition du parc jusqu'en 2030 est déterminée à l'aide d'une simulation sur le comportement d'achat. Les voitures neuves sont acquises sur base, entre autres, des coûts totaux au kilomètre, de la taille et des prestations du moteur.

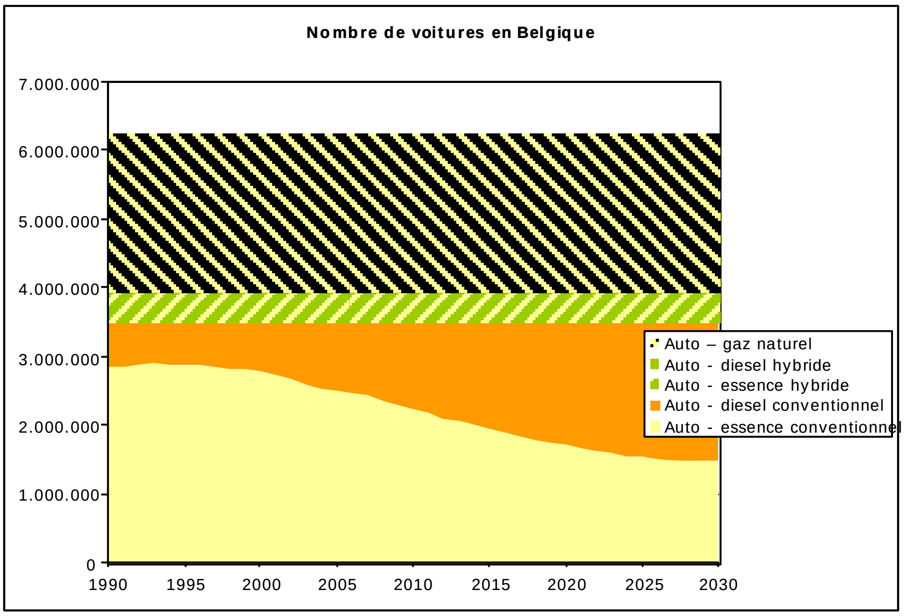


Figure 2: Croissance et composition du parc des voitures

Forte diminution de la pollution atmosphérique

Malgré la croissance du trafic routier, les émissions de gaz d'échappement polluants diminuent considérablement. Entre 1990 et 2030, les émissions de fines particules (PM_{10}) baissent de 90%, celles d'oxydes d'azote (NO_x) de 70% , celles de monoxyde de carbone (CO) de 80% et celles des hydrocarbures (VOC) de 86 %. Une partie de ces réductions est déjà acquise. Une autre partie sera réalisée dans le futur. Entre 2005 et 2030 les émissions des PM_{10} seront encore réduites de 80%, celles des NOx de 50%, celles des VOC de 50% et celles du CO de 40%. Ces polluants sont tous à l'origine de problèmes respiratoires.

[2] Des voitures à pile à combustible n'ont pas été inégrées dans le modèle

Cette évolution favorable est due à l'importante amélioration de la technologie des moteurs. Ceci sous l'impulsion des autorités européennes qui ont, dès les années '90, imposé des normes de plus en plus strictes pour les gaz d'échappement. Depuis 2006 toutes les nouvelles voitures doivent répondre à la norme euro 4. Il a récemment été révélé qu'une norme euro 5 allait arriver, qui réduira encore les fines particules de 80%.

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Les normes d'émissions européennes s'appliquent également aux véhicules utilitaires, permettant une diminution sensible des substances polluantes et ce, malgré une forte croissance du nombre de véhicules-kilomètres.

Tableau 1 : Evolution annuelle des émissions de gaz polluants du trafic routier

	période 1990-2005	période 2005-2015	période 2015-2030
Véhicules-kilomètres	+2,1%	+ 1,2%	+ 0,9%
Gaz à effet de serre (CO_2)	+1,6%	- 1,1%	+ 0,6%
Hydrocarbures (VOC)	-8,4%	- 5,7%	- 0,6%
Monoxyde de carbone (CO)	-7,1%	- 5,3 %	+ 0,2%
Oxydes d'azote (NO_x)	-4,5%	- 6,0%	- 0,3%
Fines particules (PM_{10})	-5,4%	- 8,8%	- 3,7%

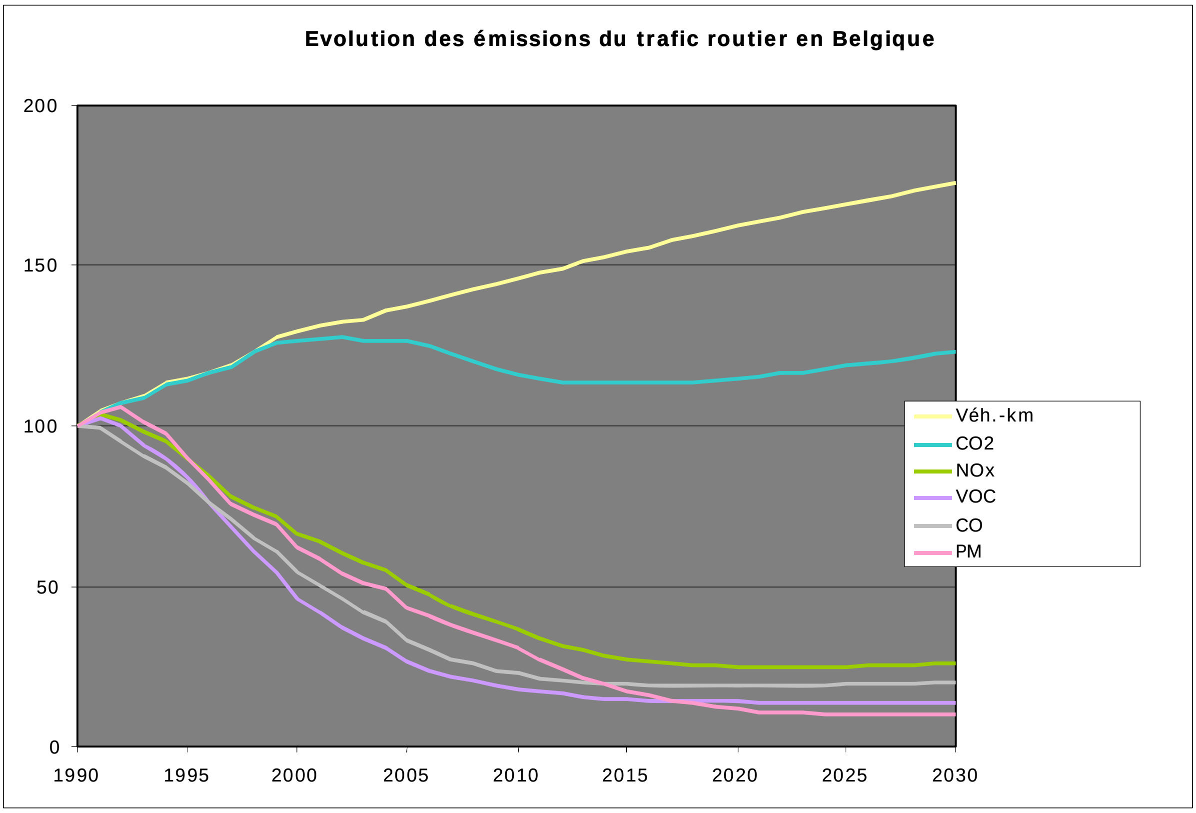


Figure 3: Evolution des émissions polluantes du trafic routier, 1990 = 100

Les émissions du gaz à effet de serre CO_2 augmentent quoique de manière moins rapide que l'augmentation des vehicules-kilomètres

Les émissions du dioxyde de carbone « à effet de serre » (CO_2) augmentent jusqu'en 2000. A partir de 2000, les émissions se sont stabilisées pour ensuite diminuer jusqu'en 2015. Dans cette période, on observe un découplage entre le volume du trafic routier croissant et la diminution des émissions de CO_2. A partir de 2015, les émissions de CO_2 augmentent à nouveau. Des efforts pour réduire les émissions de CO_2 resteront donc également dans le futur nécessaire.

La réduction des émissions durant la période 2000-2015 est possible grâce à une orientation vers des voitures plus économiques, avec de plus petits moteurs et roulant au diesel. Un important effet est encore à attendre des efforts du secteur automobile dans le domaine des nouvelles technologies telles que les voitures hybrides, le gaz naturel et les biocarburants.

Le gaz naturel et le diesel émettent un peu moins de CO_2 par kilomètre que l'essence. Les voitures hybrides sont plus économiques parce qu'elles transforment le superflu d'utilisation du moteur, par exemple lors du freinage, en énergie électrique, qui peut à nouveau être utilisée.

Lors de la production de biocarburants du CO_2 est à nouveau retiré de l'atmosphère – par les plantes – de telle sorte qu'il neutralise en partie l'effet de serre des gaz d'échappement. Pour d'autres polluants comme les NO_x et les PM_{10}, les biocarburants peuvent avoir un effet négatif. Sur base des hypothèses du modèle, la production des biocarburants cause plus d'émissions de NO_x et de PM_{10} que la production des carburants conventionnels.

La figure ci-dessus montre les émissions d'échappement pour les différents polluents (emissions tank-to-wheel). Les émissions dans la figure prennent en compte le CO_2 qui a été retiré de l'atmosphère lors de la production des biocarburants. En d'autres mots, c'est comme si le biocarburant ne causait aucune emission de CO_2.

La généralisation des équipements d'air conditionné dans les voitures va à l'encontre de cette tendance. Elle augmente les émissions de gaz à effet de serre avec 6% à 9% entre 2005 et 2030.

Le parc des voitures devient plus « propre »

Les normes européennes de plus en plus sévères qui s'appliquent aux voitures neuves font que le parc devient progressivement plus « propre ».

En 2005, 25% du parc des voitures était vraiment ancien, ne répondant même pas à la norme euro 1. Ces voitures ne possèdent pas de catalyseur. Heureusement, elles parcourent relativement peu de kilomètres: 6% des kilomètres parcourus par les voitures à essence. Ceci parce que les voitures neuves parcourent plus de kilomètres que les vieilles. C'est également le cas des voitures diesel qui roulent plus que les voitures à essence.

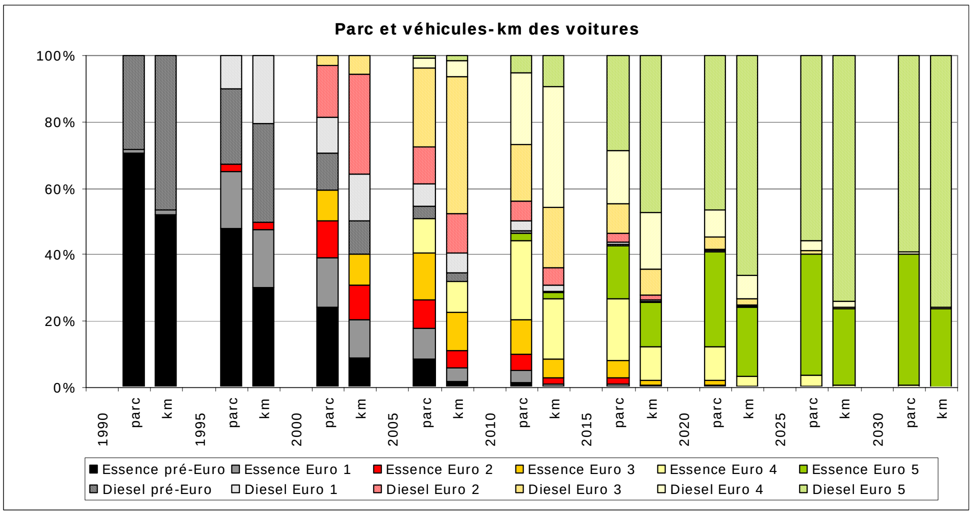
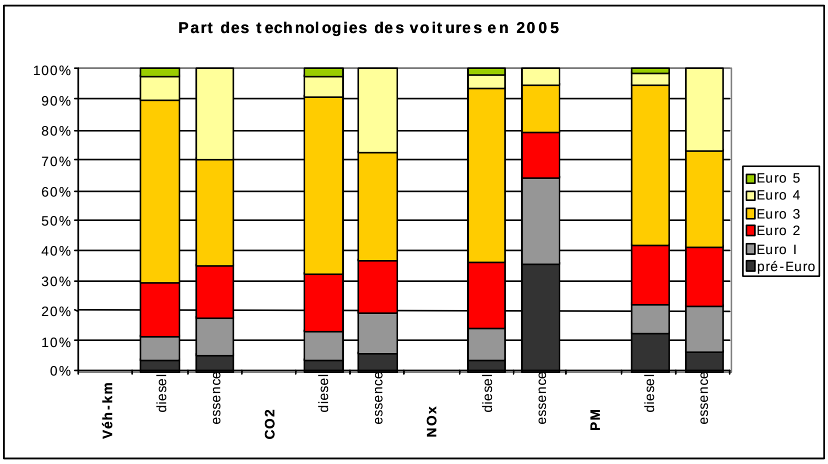


Figure 4: Part relative des véhicules-km dans le parc suivant le type de voiture

Cette faible part relative de kilomètres des anciennes voitures à essence sont cependant responsables pour 36% des émissions d'oxyde d'azote (NO_x) et pour 13% de fines particules (PM_{10}). Même pour les voitures à essence répondant aux normes euro 1 et euro 2, les émissions de NO_x sont considérablement plus élevées que pour les voitures à essence les plus récentes.

D'ici 2015, l'on peut s'attendre à ce que l'actuelle norme euro 4 et la future norme euro 5 constituent l'essentiel du parc des voitures.



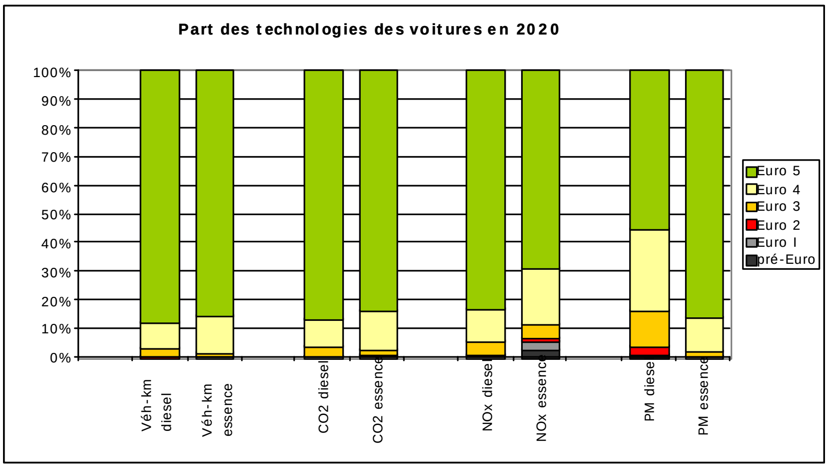
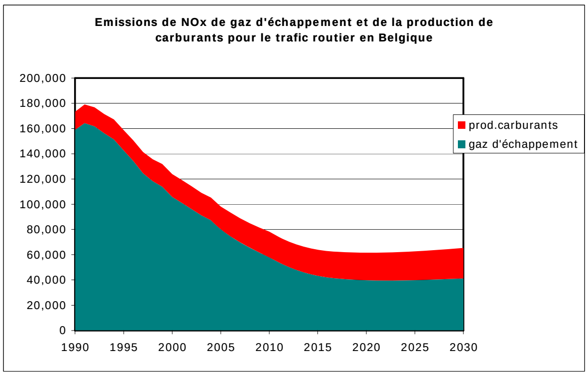


Figure 5: Part relative des véhicules-km et des émissions suivant le type de voiture

Les émissions provenant de la production de carburants deviennent relativement plus importantes

La production de carburants (raffinage, transport) occasionne également une pollution de l'air. Celle-ci croît de concert avec le volume du trafic, et dépasse même celle des gaz d'échappement d'ici 2030 pour certains polluants.



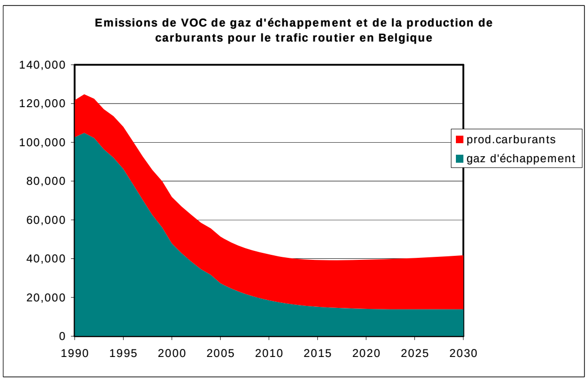


Figure 6: Evolution des émissions de NO_x et de VOC des gaz d'échappement et de la production de carburants pour le trafic routier

Trois scénarios: quel est l'effet d'une réforme du prix du trafic routier?

1. *Une taxe de mobilité de 25% a pour résultat 1% de trafic en moins et une réduction de 1,5% des émissions*

Prenons pour hypothèse que toutes les accises sur les carburants et toutes les taxes de circulation augmentent de 25%. Rouler en voiture, moto, camionnette ou camion devient donc nettement plus cher. Les recettes de l'Etat augmentent sensiblement : 8 à 10%.

La conséquence est qu'il y aura environ 1% de trafic routier de moins que prévu précédemment. Une petite partie de celui-ci est absorbée par les autobus, le train, la navigation intérieure, mais la majeure partie disparaît tout simplement.
La diminution du nombre de kilomètres parcourus engendre une baisse des émissions des gaz d'échappement de l'ordre de 1,5%.

2. *Des prix plus élevés pour les carburants: faible baisse des émissions mais perte de prospérité*

Que se passe-t-il quand le prix des carburants augmente plus fort que prévu? Prenons comme hypothèse une augmentation due à un prix du pétrole brut plus élevé et à des taxes plus élevées de telle sorte que l'on atteigne 1,6 euro par litre en 2030 tant pour l'essence que pour le diesel (sans tenir compte de l'inflation).

Ceci implique une baisse du trafic routier de 3% par rapport aux conditions normales. Ici aussi, seule une faible part du trafic est recueillie par les alternatives.

Les recettes de l'état augmentent mais les flux de capitaux vers l'étranger croissent de par l'augmentation du prix du pétrole brut. De là l'effet négatif sur notre prospérité.

La diminution du nombre de kilomètres parcourus implique une baisse des émissions polluantes de gaz d 'échappement. Les prix élevés des carburants induisent l'achat de véhicules plus économiques, comme les véhicules hybrides, au gaz naturel ou les petites voitures diesel. Il résulte de cette préférence pour des véhicules économiques une baisse supplémentaire des émissions. La réduction totale est de l'ordre de 2 à 5%.

3. *Une différenciation des taxes de circulation a pour conséquence un rajeunissement du parc des voitures et une réduction des particules*

Dans le troisième scénario l'actuelle taxe de circulation annuelle et la taxe de mise en circulation sont remplacées par une taxe annuelle différenciée selon les performances environnementales et le cylindrée de la voiture.

Les voitures ayant de faibles émissions d'oxydes d'azote, de particules et les voitures économiques émettant moins de CO_2 paient relativement moins de taxes. Les voitures plus anciennes, moins respectueuses de l'environnement sont plus lourdement taxées. Ceci motive les automobilistes à remplacer leurs vieilles voitures par des voitures plus récentes et avec une préférence pour celles respectueuses de l'environnement.

Les niveaux de taxes ont été déterminés de telle sorte que les recettes totales de l'état soient quasiment inchangées.

Une telle réforme fiscale n'a peu ou pas d'effet sur le nombre de kilomètres parcourus mais conduit bien à une baisse des émissions de gaz d'échappement. En 2020, 4% de particules (PM_{10}) sont émises en moins que dans le scénario de base. Ceci est dû à une modification de la composition du parc des voitures. Les voitures qui répondent à la nouvelle norme euro 5 (équipées d'un filtre à particules) apparaissent dans le parc bien avant la date de 2008 prévue. En 2030, la mesure n'a plus d'effet: il n'y a quasiment plus de voitures diesel sans filtre à particules dans le parc. Si entretemps, une nouvelle norme d'émissions entre en vigueur, l'effet pourrait se prolonger.

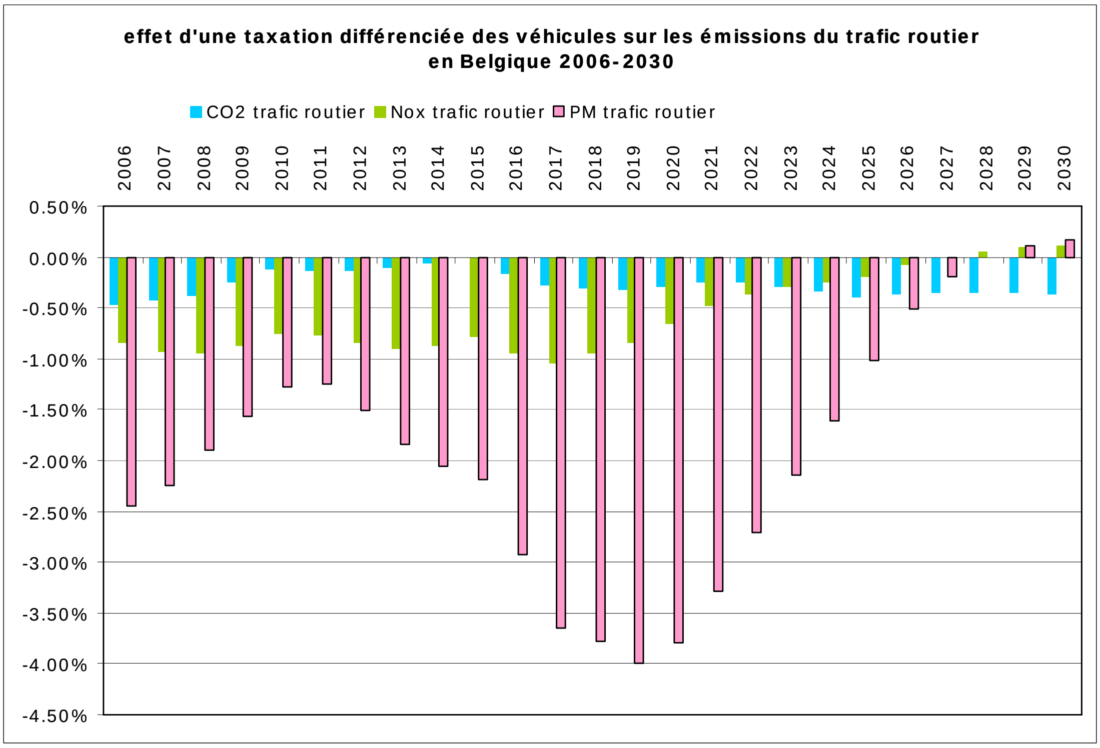


Figure 7:Différence dans les émissions induite par une différenciation de la taxe de circulation 2006-2030

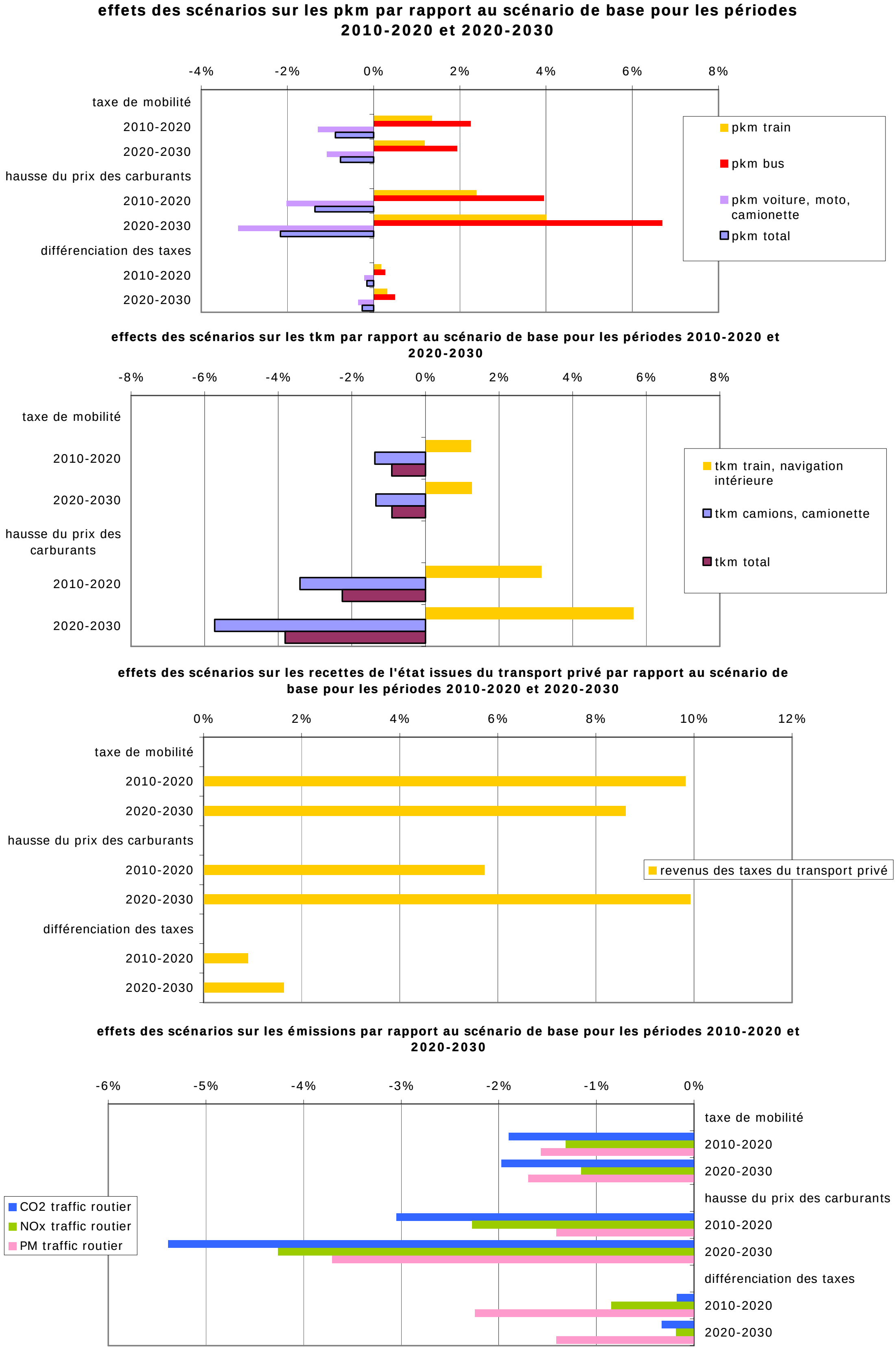


Figure 8: effets des scénarios par rapport au scénario de base pour les périodes 2010-2020 et 2020-2030

Lors de l'interprétation des résultats, il est important de savoir que :

- Une taxe n'est pas un coût pour la société. La manière avec laquelle les taxes sont utilisées par les autorités influence néanmoins les bénéfices ou les pertes d'une politique.
- Une variabilisation des taxes dans le temps et dans l'espace peuvent avoir un effet significatif sur la congestion. Les réductions d'émissions qui vont de pair avec une telle mesure peuvent alors être considérées comme un effet secondaire intéressant.

Le modèle TREMOVE: un modèle économique de transport et d'émissions

Cette étude utilise le modèle TREMOVE. Ce modèle de simulation a été développé par TML pour la Commission européenne. Il effectue des prévisions de volumes de transport, de parc, de consommations de carburants et d'émissions pour 21 pays en conséquence des décisions politiques.
Grâce à son fondement économique, le modèle permet également de calculer les effets des mesures sur la prospérité.

1 Introduction

This study analyses and forecasts the total emissions from the road transport sector in Belgium, and this based on the most recent data available (chapter 2). Also the driving variables behind the emission evolution are analyzed, emission standards and specific emissions (chapter 3), the vehicle fleet (chapter 4) and transport volumes (chapter 5).

It is a follow-up for the IFEU-study "Energy consumption and pollutant emissions from road transport in Belgium 1980 to 2020" commissioned by FEBIAC in 2000. The current study covers the period from 1990 to 2030. The 40 years coverage assures that effects of the penetration of new technologies and emission standards in the vehicle stock can be fully analysed. Next to fuel consumption, a wide range of pollutants is covered, including carbon dioxide (CO_2), carbon monoxide (CO), nitrous oxides (NO_x), hydrocarbons (VOC) and particulate matter (PM_{10}). The study goes beyond the scope of the earlier IFEU-study. Well-to-tank emissions related to the generation of fuels are included. These emissions become relatively more important as exhaust emissions decrease significantly. This report also accounts for the effects of air conditioning systems and includes hybrid and CNG technologies for cars. Furthermore the influence of the euro 5 European Commission proposal is accounted[3].

The quantitative analysis in this study has been performed using the TREMOVE model. TREMOVE is a policy assessment model to forecast the effects of different transport and environment policies on the emissions of the transport sector. It is an integrated simulation model developed for the strategic analysis of the costs and effects of a wide range of policy instruments and measures applicable to local, regional and European transport markets. It contains a transport demand module, vehicle stock module, an emission module, a life cycle emission module and a welfare module.

The TREMOVE model is used since nearly a decade by the European Commission to support its environmental transport policy. TREMOVE has been for example used in the Auto Oil II programme (1998) and the Clean Air for Europe (CAFE) framework.

21 European countries are modelled in country sub modules, so the model can be run for an individual country. For this study specific runs for Belgium have been performed. The model input data has been significantly improved and extended using specific Belgian data collected during this study project. Nearly every country specific historic input parameter has been updated/re-calibrated in collaboration with FEBIAC and the FPSMT Mobility and Transport (FPSMT).

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[3] European Commission; COM(2005) 683 final Proposal for a regulation of the European Parliament and the Council on type approval of motor vehicles with respect to emissions and on access to vehicle repair information, amending Directive 72/306/EEC and Directive ../../EC

TREMOVE is a transport model that is specifically developed for the environmental and economic analysis of different policies to reduce atmospheric emission from all modes of transport. Also, this study investigates the effects of policy scenarios (chapter 9). Next to a business-as-usual forecast, three policy scenarios have been developed within this study:

- A homogeneous increase in road transport taxation
- A sensitivity scenario on the influence of fuel costs and fuel taxes, introducing changes in fuel resource costs and harmonization of diesel and gasoline taxation
- A variabilisation of ownership taxes in function of emission characteristics

All technical information on the TREMOVE model, the assumptions and the input data is grouped in the annexes. Detailed model outputs are available in Excel pivot tables and Access databases that are provided in digital format.

2 Total pollutant emissions from road traffic

Generally speaking, all exhaust pollutants, evolve in the same way. Carbon dioxide emissions are the exception. Emissions peak between 1990 and 1995 and decrease then over the whole period thanks to tightening emission standards and in spite of a growth in road traffic. From 2020 on, there is stabilization or a slight increase of emissions. The latter increase is due to a continuous increase in transport volumes and the current absence of emission standards beyond the actual standards. After 2011, no emission standards tightening the actual standards are foreseen. The model takes also the adoption of the proposal of the European Commission for euro 5 for passenger cars into account. Table 1 illustrates the evolution of emissions with 1990 and 2005 as reference.

Table 1: relative emission evolution from road traffic compared to 2005 and 1990

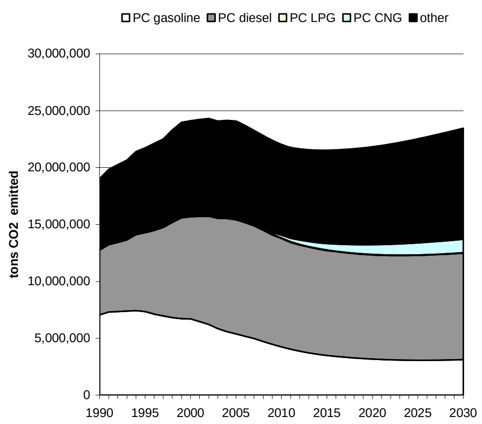
	relative emission evolution compared to 2005					relative emission evolution compared to 1990				
	CO2	Nox	PM	NMVOC	SO2	CO2	Nox	PM	NMVOC	SO2
1990	78.90%	198.50%	229.80%	386.40%	2501.70%	100.00%	100.00%	100.00%	100.00%	100.00%
2005	100.00%	100.00%	100.00%	100.00%	100.00%	126.70%	50.40%	43.50%	25.90%	4.00%
2010	91.50%	72.50%	70.90%	67.30%	26.60%	115.90%	36.50%	30.80%	17.40%	1.10%
2015	89.30%	54.00%	39.70%	54.20%	26.40%	113.10%	27.20%	17.30%	14.00%	1.10%
2020	90.60%	49.80%	27.10%	49.90%	27.20%	114.80%	25.10%	11.80%	12.90%	1.10%
2025	93.50%	49.80%	22.90%	48.60%	28.10%	118.50%	25.10%	10.00%	12.60%	1.10%
2030	97.30%	51.60%	22.40%	48.60%	29.30%	123.30%	26.00%	9.80%	12.60%	1.20%

When the life cycle emissions[4] are also taken into account, the evolutions remain similar. Though for most pollutants the evolution is weakened. This means that reductions go less far. The reason is that the model takes no improvement (reduction) in the life cycle emissions into account. Life cycle emissions (or well-to-tank emissions) are not presented in this chapter, but in annex.

The figures below show the evolution over the 1990-2030 period for diesel, gasoline and CNG passenger cars and for "other vehicles". The other vehicles are mainly heavy duty vehicles (HDV). This category contains also light duty vehicles (LDV's), motorcycles (MC), mopeds (MP), buses and coaches.

For *carbon dioxide* the overall increase between 1990 and 2030 is 22.5%. Three phases can be distinguished in this evolution.

[4] Life cycle emissions take only emissions from fuel production and fuel transport into account. These emissions are, among others, influenced by the introduction of biofuels (see also the annexes). For similar fuels, life cycle emissions are assumed to remain constant. For example, a cleaner functioning of refineries is not taken into account.. Reported life cycle emission can therefore be seen as an upper limit.



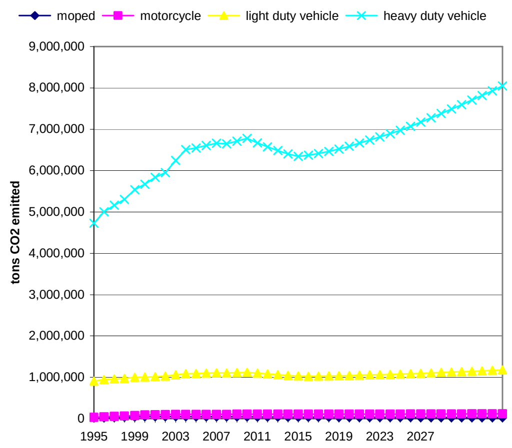


Figure 9: CO2 exhaust emissions from road traffic with correction for biofuel CO2 from atmosphere withdrawal

Between 1990 and 2000 carbon dioxide (CO_2) emissions increase significantly. The increasing transport volume is the main reason. Also, the emission reduction technologies cause some extra fuel consumption and as a consequence some extra CO_2 emissions.

Between 2000 and 2015, a reduction in exhaust emissions of passenger cars results from:

- The voluntary agreement between the EC and the European, Japanese and Korean car manufacturers to reduce average CO_2 car emissions per km to 140 gram per kilometre in 2008-2009 (for new cars on the type approval test cycle).
- The increasing share of diesel vehicles in the fleet.
- The introduction of hybrid cars.
- The introduction of CNG powered cars.
- The introduction of biofuels, see chapter 8 and annex.

Between 2015 and 2030, CO_2 emissions increase again, but at a lower pace. The reason is the growing transport volume with a nearly constant CO_2 emission per km. Although the ACEA agreement contains a clause indicating further negotiations for a 120 g/km limit once the 140 g limit/km obtained, this is not taken into account as results of the negotiations are not clear yet. Further on, nearly all new vehicles entering the fleet have air conditioning equipment causing some extra fuel consumption, while not all vehicles they replace had this equipment. As a result, total CO_2 emissions increase still by 8% in the 2015-2030.

This can also be observed from the above figure. The figure shows the CO2 exhaust emissions (thank to wheel). The CO2 that is withdrawn from the atmosphere during the biofuel production phase has been withdrawn from the emissions. In other words, the

CO2 emissions of the biofuel burnt is fully compensated by the CO2 withdrawn form the atmosphere during biofeul production [5].

Concerning the other vehicles, it are not surprisingly the heavy duty vehicles that are responsible for the major part of CO_2 emissions. For HDV's, no voluntary agreement or specific more fuel efficient technologies are available. The two wheelers part is very small.

For *carbon monoxide,* the overall forecasted decrease in CO emissions is 80% in 2030, despite the future increase of transport volumes[6]. Exhaust emissions of gasoline cars were historically most important. These emissions were reduced significantly in the nineties by the introduction of catalytic converters. Between 1990 and 2030, the emissions of gasoline passenger cars will decrease with 92%. For diesel passenger cars, emissions will increase with 50%. The 2 main reasons are the dieselisation of the vehicle stock and the fact that CO emissions are not regulated for diesel cars.

In the other vehicles category, moped and motorcycle emissions take an important part. They account for the major part of the CO emissions of the other vehicles.

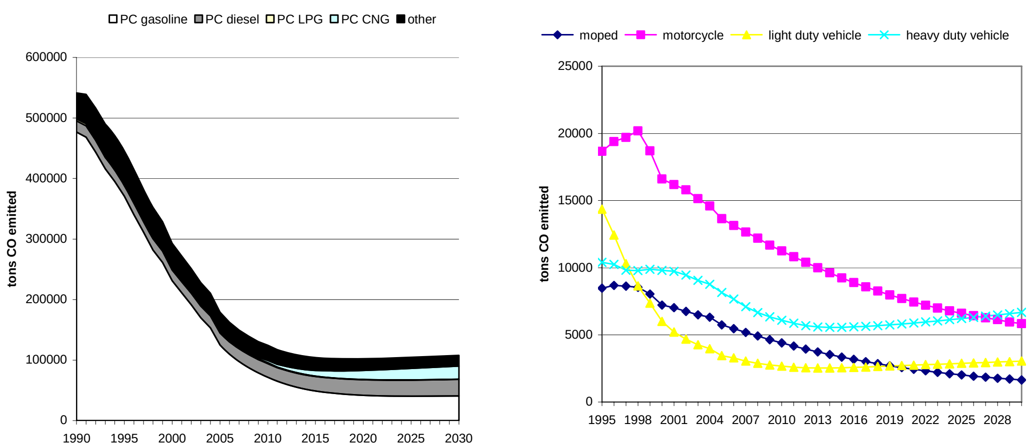


Figure 9: CO exhaust emissions from road traffic

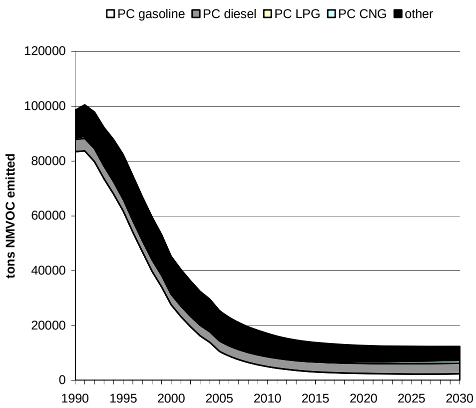
For *Non Methane Volatile Organic Components (NMVOC)* emissions, the story is similar to the CO story. Global reductions are even more important for NMVOC. The emissions from gasoline cars are reduced by more than 97% over the 1990-2030 period. Also emissions from diesel vehicles are reduced, albeit much less significantly. The overall reduction in NMVOC emissions from the road transport sector is still more than 90%.

[5] Chapter 8 studies in more detail the life cycle emissions (well to thank) of biofuels.

[6] Overall transport volumes increase, but gasoline cars transport volumes decrease by 30% over the modeling period.

From 2010 on, life cycle emissions from the production of fuels could become more important than exhaust emissions.

Similar to CO emissions, the importance of two wheelers for the NMVOC emissions can be observed from the figure below. Especially mopeds are responsible for those emissions. Thanks to European emissions standards, there is however an important reduction in emissions from more than 8000 tons in 1997 to around 1500 tons in 2030.



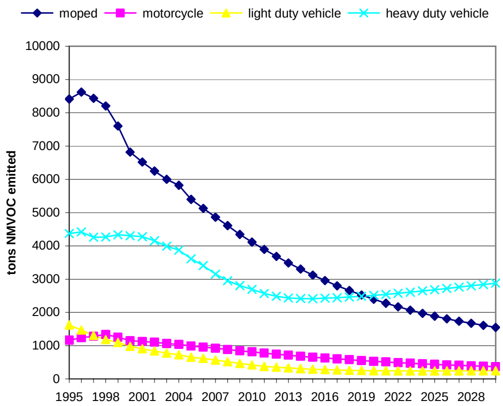


Figure 10: NMVOC exhaust emissions from road traffic

Also, the reduction of *nitrous oxide* (NO_x) is for a great part attributable to the catalyst converters on gasoline vehicles. Gasoline vehicles reduced their NO_x emissions by 98% in 2030 compared to 1990. Also, diesel heavy duty vehicles emissions decrease by 70% over the same period in spite of an important increase in transport of goods. Emission standards for diesel cars have not been strict enough to compensate the growth in vehicle kilometres driven by those cars even with the future euro 5 emission standard. The global forecasted emission reduction is around 74%. Without a future euro 5 emission standard for passenger cars, emission reduction should only be slightly less. The reduction should be around 71%.

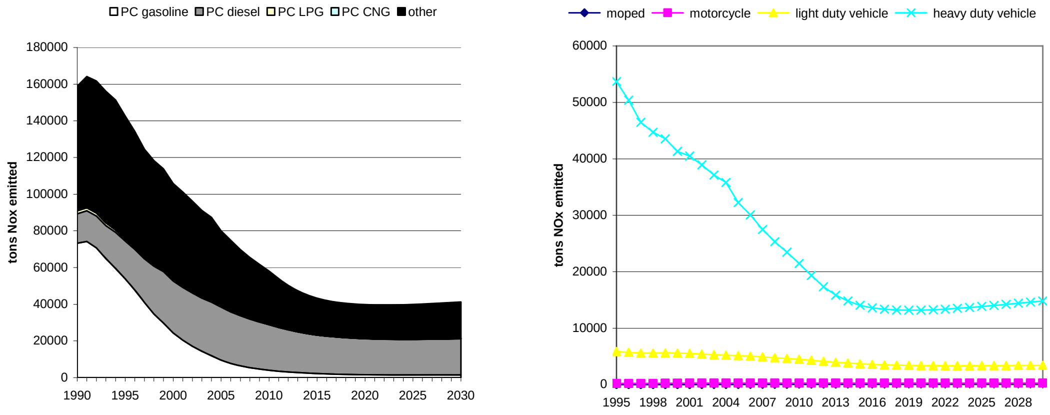


Figure 11: NO_x exhaust emissions from road traffic

The emissions of the "other vehicles" are mainly caused by the HDVs, but an important reduction in their emissions can nevertheless be observed.

Particulate matter (PM_{10}) is nearly exclusively emitted by diesel engines. Also for this pollutant, emission standards contributed to a significant decrease in emissions. The improvement in fuel specifications (low sulphur fuels) also contributes to lower PM_{10} emissions. The model expect future global emissions to fall by more than 90% if the euro 5 proposal will be implemented. This performance is even more important compared to the increase in diesel vehicle kilometres by a factor 2.5 in the 1990-2030 period. Without a future euro 5 emission standard, forecasted reductions should only be about 70 % for the whole vehicle stock and only about 60% for diesel passenger cars.

Concerning the PM_{10} emissions of the "other vehicles", in the nineties, nearly only diesel powered vehicles were responsible for those emissions. Thanks to emission standards, their emissions decreased significantly.

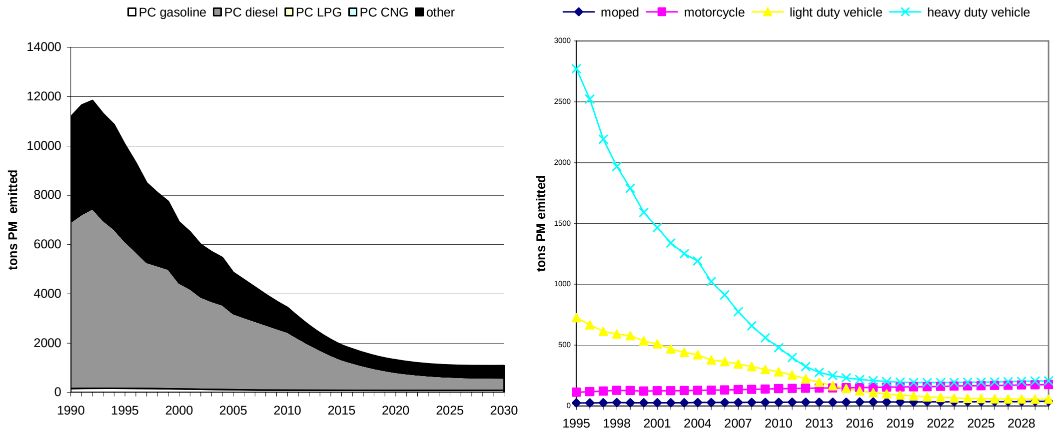


Figure 12: PM_{10} exhaust emissions of road traffic

The exhaust emissions of *sulphur dioxide (SO_2)* decreased very significantly thanks to tightening fuel quality standards. For diesel, sulphur content falls from 1700 ppm to 10 ppm in 2009. The gasoline sulphur content falls from 300 ppm in 1990 to 10 ppm in 2009. The detailed assumptions on sulphur content of fuels can be found in Annex 3. SO2 life cycle emissions are more important than exhaust sulphur dioxide emissions over the whole period (Annex 6).

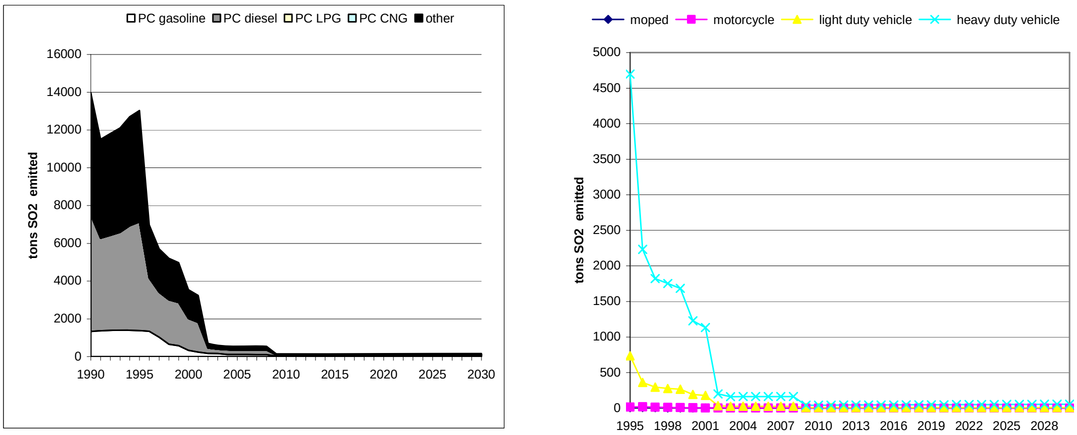


Figure 13: SO2 exhaust emissions from of road traffic

Concerning the SO_2 emissions of the "other vehicles", observations are very similar to the observations made from the general SO_2 figure.

The study pays also attention to the *tropospheric ozone formation potential* (TOFP). This is an indicator used to give an indication for the potential formation of ozone due to emissions of NMVOC, NO_x and to a lower extent CO and CH_4[7]. The evolution of the TOFP is in line with that of the underlying pollutants. The relative contribution of gasoline cars decreases significantly thanks to the reduction in emissions of the driving pollutants. The relative contribution of diesel passenger cars increases in relative and absolute terms due to the increasing market share of diesel cars.

Concerning the “other vehicles” HDV’s are the main contributors.

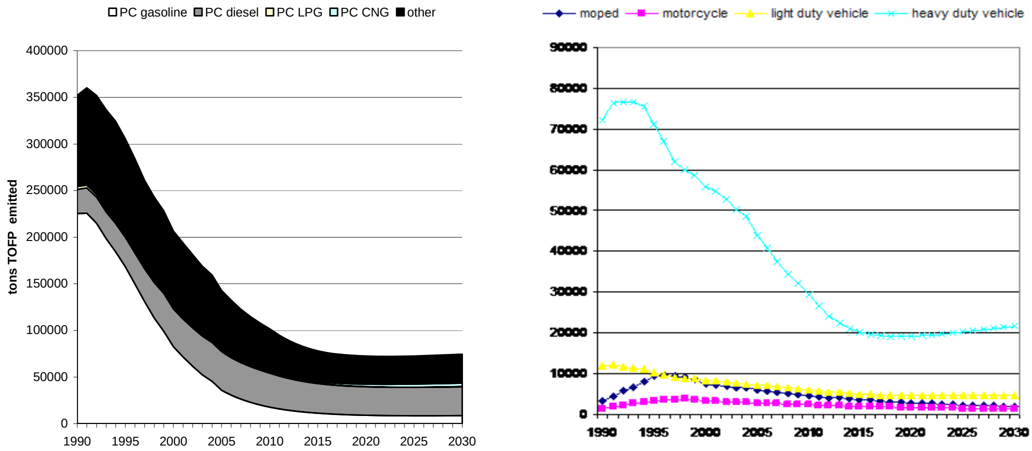


Figure 14: tropospheric ozone formation potential of exhaust emissions from road traffic

[7] Proper ozone modelling is not feasible in the scope of this study. For this reason we use an indicator for troposphoric ozone formation potential. This indicator has been developed by Frank de Leeuw (de Leeuw, 2002) of the EEA.

TOFP in NMVOC equivalent = 1,22 NO_x+NMVOC + 0,11 CO + 0,014.

3 Specific emissions of vehicles

The most important driving force behind the reduction in overall emissions of road transport, described in the previous chapter, is the European emission standard legislation and the subsequent reduction in emissions per km (specific emissions). A diesel car equipped with a PM trap, which will be most probably necessary to comply with the European Commission euro 5 proposal, will emit nearly 90 % less particles than a new diesel car in the early nineties. The catalytic converters had a similar effect for gasoline car NMVOC and NO_x emissions.

The bars in the figures below show the evolution of the European emission standards. They show the real world emissions of new cars complying with the standard. Those real world emissions are higher than the theoretic test cycle emissions. The (blue) background part represents the actual exhaust emissions for an average vehicle of the fleet. The upper (purple) part the life cycle emissions of the used fuels. Pre-euro is indicated in 1991, the following bars represent euro 1, euro 2, euro 3 and euro 4. The next bar for passenger cars is indicated in another color as it concerns a proposal for a euro 5 standard that is not yet approved. The assumptions concerning CNG specific emissions of CNG powered cars are given in Annex 3. For most pollutants, a consequence of the significant reduction in exhaust emissions is the growing relative importance of life cycle emissions.

In the years following the introduction of a more severe emission standard for new cars, the whole vehicle stock will be replaced and also the average specific emissions will decrease. The average specific emissions are given by the colored background in the figures. The average specific fleet emissions take the introduction of a euro 5 emission standard into account for passenger cars.

Gasoline (CNG included) passenger cars

For gasoline passenger cars, the figure below shows that the most important reduction took place in the early nineties with the introduction of catalytic converters. NO_x, VOC and CO emissions were considerably reduced. Also post euro 1 standards further reduced emissions, though to a more limited extent. The reduction in emissions from a pre euro 1 car to a euro 4 car is more than 95% for NO_x and VOC per km. For the euro 5 standard, this could be slightly more. This reduction can also be observed in the average specific emissions of the vehicle stock. Concerning CO_2 emissions, less important reductions are observed. CO_2. This is logic as CO_2 is not a regulated pollutant. On the other hand is a reduction of the fuel cost of cars (and more for HDV's) also of interest for manufacturers as it reduces user costs. A voluntary agreement between EC and the car manufacturers is in place. In this agreement, manufacturers will reduce specific CO_2 emissions of new sold cars to 140 g/km in 2009. For the years after 2010 also the penetration of hybrid and CNG cars cause a decrease in specific emissions. CNG cars are included in the observed stock here. In general, CNG cars emit less than a gasoline car for most pollutants, except CH_4 (TNO 2005). The life cycle emissions of CNG for CH_4 are also significantly higher due to the CH_4 that is lost during transport.

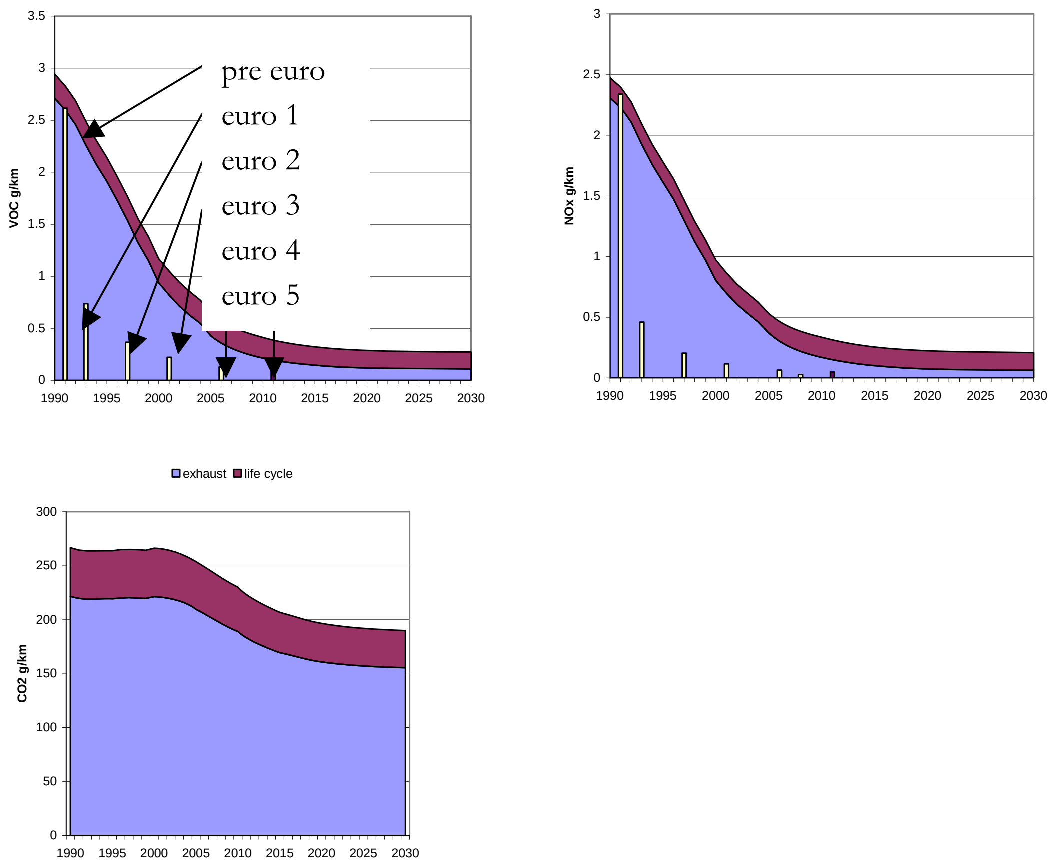


Figure 15: Evolution of emission standards (bars) and average exhaust (bleu shaded) and life cycle emissions (purple shaded) for VOC, NO_x and CO2 for gasoline passenger cars.

Diesel passenger cars

Also for diesel passenger cars, important emission reductions have been achieved, though less important than for gasoline cars (Figure 16). The most important achievement concerns reductions of particulate matter. An important reason is the decreasing sulphur content of fuels and the improving technology. A euro 4 car emits significantly less per km compared to a pre euro car. A euro 5 car could emit still 80% less particulate matter than an actual euro 4 car, this is only 3% of a pre euro standard diesel car per km. NO_x emissions per km have been reduced by 40% in a euro 4 diesel car compared to the pre euro standard. A further 20% NO_x reduction is taken into account for the euro 5 standard. For carbon dioxide emissions, the story is similar as for gasoline cars.

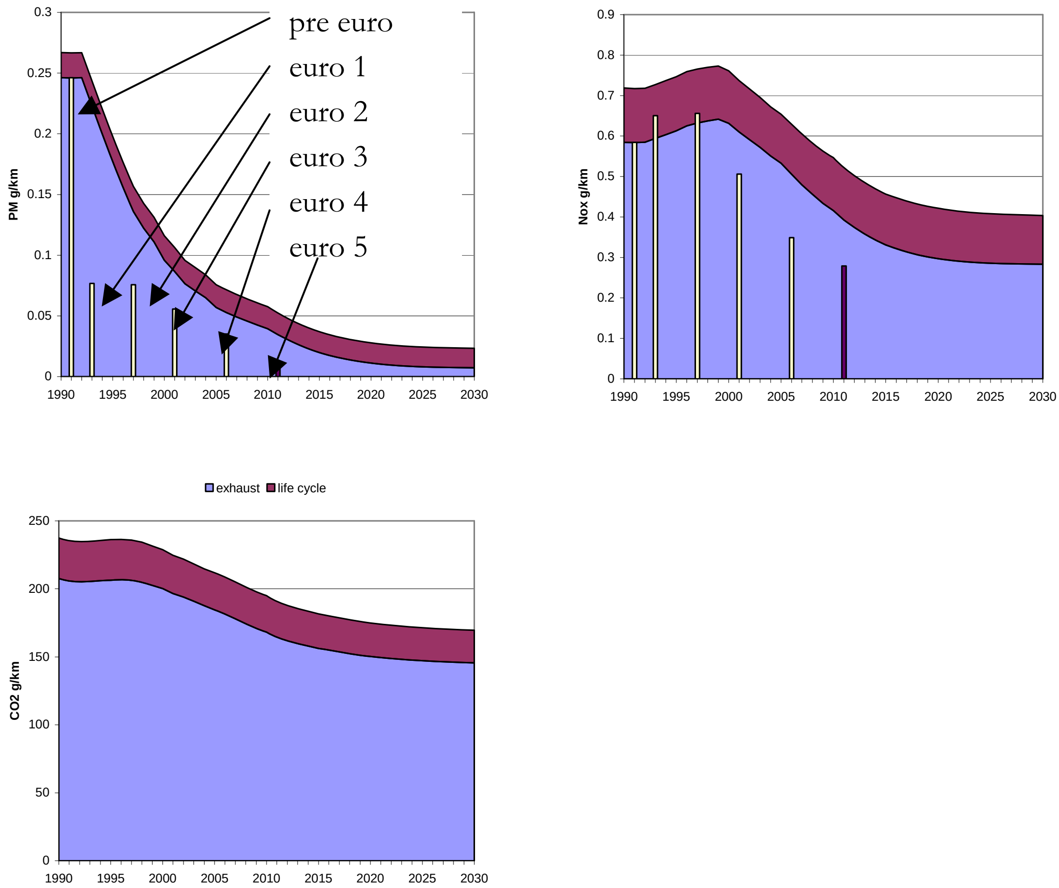


Figure 16: Evolution of emission standards and average (bars) exhaust (blue shaded) and life cycle emissions (purple shaded) for PM_{10}, NO_x and CO_2 for diesel passenger cars

Heavy duty vehicles

Emission standards also reduced significantly PM_{10} and NO_x emissions of heavy duty vehicles. They were respectively reduced by more than 95 and 85% per km thanks to emission standards.

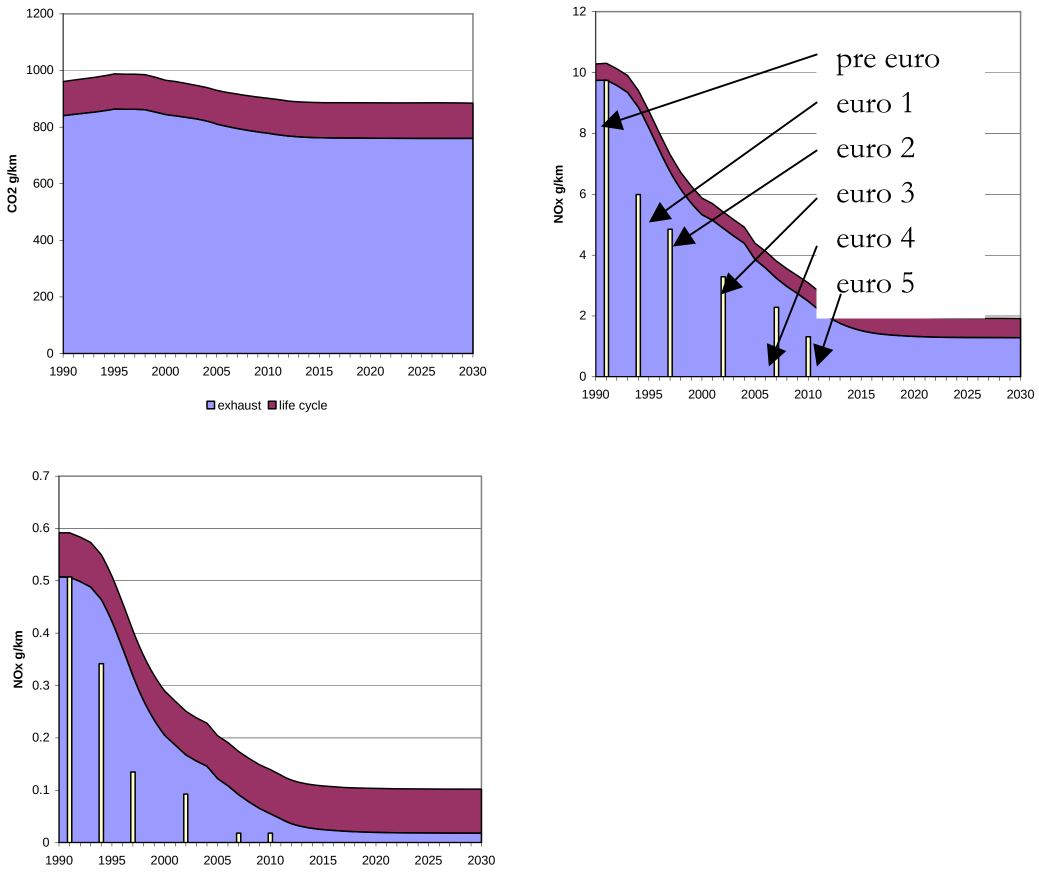


Figure 17: Evolution of emission standards (bars) and average exhaust (bleu shaded) and life cycle emissions (purple shaded) for PM_{10}, NO_x and CO_2 for heavy duty vehicles

Tightening emission standards: another approach

The evolution in specific emissions can also be illustrated in another way as can be seen from Figure 18. In 2005, 6% of the gasoline vehicle kilometres were driven by pre euro vehicles but their contribution to NO_x emissions is 36%. Also euro 1 gasoline cars emit significantly more NO_x than recent gasoline cars. For CO and NMVOC, the situation is similar. This illustrates in anther way the evolution in emissions thanks to the emission standards.

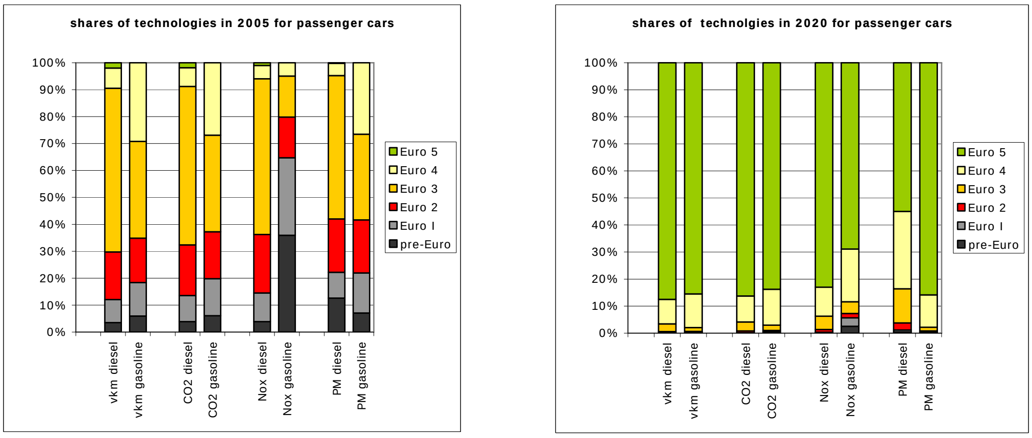


Figure 18: exhaust emissions of gasoline and diesel vehicles in function of emission standards in 2005 and 2020

A similar story can be told for PM_{10} emissions of diesel vehicles. Pre euro 1 diesel cars represent 6% of the diesel vehicle kilometres driven in 2005 but cause 13% of PM_{10} emissions. Figure 18 shows that in 2020, euro 5 diesel vehicles drive 87% of diesel vehicle kilometres but cause only 55% of the total PM_{10} emissions.

4 Vehicle fleet

In the previous paragraph, we mentioned the tightening European emission standards as an important driving force for the reduction in emissions. To translate these emission standards into real emission reductions of road transport, vehicles complying with recent emission standards needs to enter the stock. How and at what speed these standards enter the fleet depends on the vehicle stock evolution. This evolution is discussed in the next section.

For the 1990-2004 period, the vehicle stock is an input we get from FEBIAC[8]. For the 2005-2030 period, TREMOVE determines the amount of vehicles in the stock by type endogenously based on transport demand and average vehicle mileage (Annex 3).

The vehicle stock module in TREMOVE determines the number and characteristics of new vehicles entering the stock. For passenger cars, the purchase behaviour is simulated using car cost per km, car performances and car size. The moment of entering the stock determines the euro standard with which these vehicles comply. A passenger car entering the stock in 2012 for example will be considered as a car complying with the euro 5 emission standard (EC proposal). The annexe 3 shows the allocation of euro standards to new vehicles dependant on their entry in the stock. In general, new vehicles complying with the latest emission limits begin to penetrate the fleet slightly prior to the mandatory dates.

We see from the figures below that new technologies take some time to penetrate into the fleet, though, after some years the new technologies become important. At the end of the period for example, nearly the whole fleet will comply with the most recent euro standard that will come into force around 2010. Around 2010 there are nearly no longer passenger cars not complying with the euro 1 standard.

[8] The FEBIAC vehicle stock figures detail the FPSMT vehicle stock figures

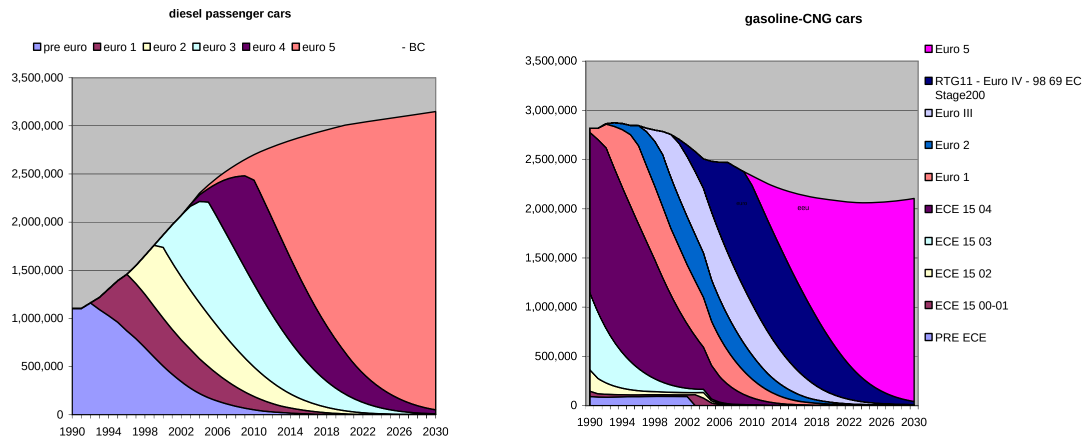


Figure 19: Penetration of new emission standards in the fleet of gasoline (CNG included) and diesel passenger cars

The model forecasts a further diesel stock increase in the future, but at a lower growth rate than in the period 1990-2010. In 2030 it could reach around 3 million vehicles, triple the 1990 stock. The gasoline-CNG stock on the other hand decreases slightly and stabilizes between 1990 and 2010. The model sees a new growth from around 2015 for these vehicles. In 2030 the stock will be again larger -somewhat more than 3 million vehicles- than the stock at the beginning of the nineties.

The pace of entry of emission standards for heavy duty vehicles is very similar to that of passenger cars. Note that light duty vehicles follow the evolution of passenger cars.

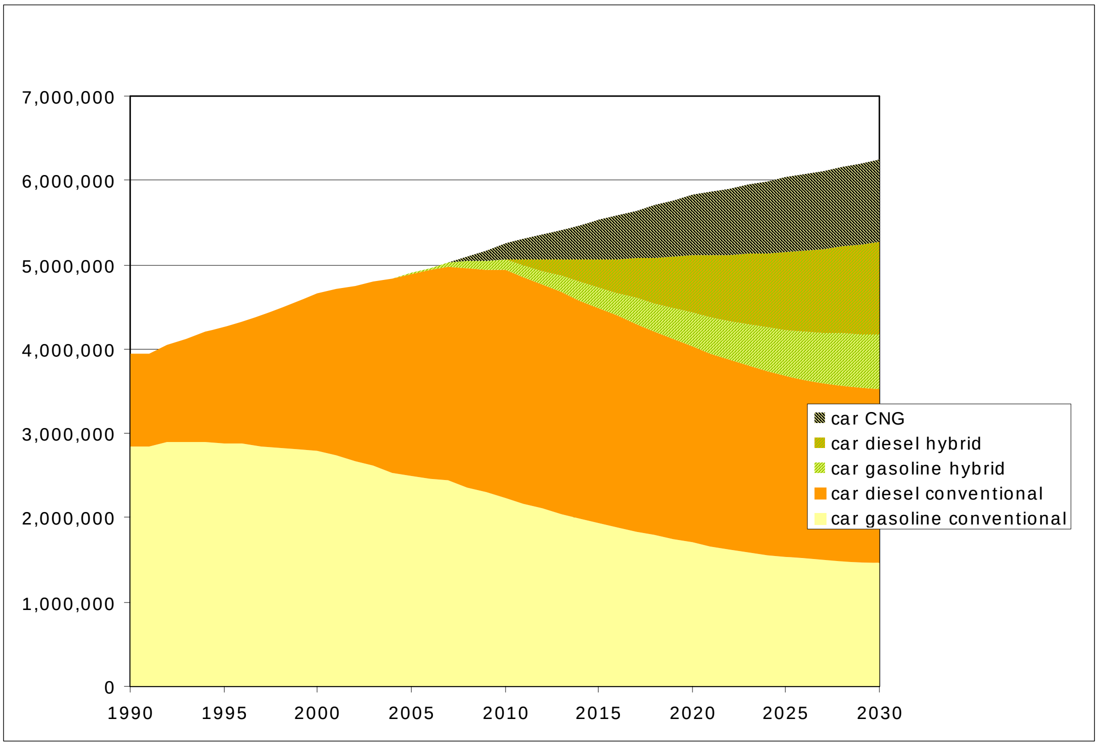


Figure 20: Evolution of the composition of the car stock

Figure 20 shows also the importance in the future of new technologies like hybrids and CNG vehicles. In 2010 their share in the stock is only 5% while in 2030 conventional vehicles account only for slightly more than half the fleet. Hybrids (nearly 30%) and CNG (more than 15%) are projected to be well present in the fleet at that moment. As stated above, those shares are endogenously determined by the model and are not the result of exogenous assumptions.

Note that cars with fuel cell technology have not been integrated in the model. The uncertainty about producing and using such cars at reasonable costs is to big.

5 Transport demand baseline

This section pays attention to a third driving force in the evolution of emissions, transport demand. Growing transport demand influences emissions from transport in a direction opposite of the introduction of emission standards. The transport volumes between 1990 and 2030 are discussed. Based on statistics, an accurate overview is made of the historical transport volumes in Belgium from 1990 on. Furthermore, a forecast of transport volumes until 2030 is developed as a trend scenario. The resulting baseline is presented with details for different transport modes. Some attention is paid to non road modes as in TREMOVE the transport demand is a coherent whole. As a consequence, non-road mode volumes also influence road modes.

The forecasted transport demand is not calculated endogenously in TREMOVE, but it is a result of another model, the SCENES model (Annex 2). This is a European transport model and bases its forecast on general data like growth in GDP, car ownership, demographic factors… The forecasts have been further refined and adapted to the Belgian situation by mutual agreement of the experts of the FPSMT, FEBIAC and TML. The Annex 3 clarifies further the underlying data, models, methodologies and assumptions that are used to construct the transport baseline. The Annex 4 pays also attention to the equation between kilometres of Belgians abroad and foreigners in Belgium.

5.1 Passenger cars

Total volume of passenger cars in 1990 was 60 thousand million vehicle kilometres. Since then, the amount has increased until almost 80 thousand million in 2004. Within the baseline, this volume increases until more than 100 thousand million in 2030. Figure 21 sketches the evolution per road type.

This growth in transport volume is not uniform.

- The annual growth rates is supposed to decrease slightly from 1.31% between 2000 and 2010, 1.05% in the next decade until 0.70% between 2020 and 2030.
- Travel motives change slowly. In the early nineties, almost 29 % of total passenger car volumes were made for commuting purposes, while this rate will be 26.3% in 2030. Business trips will relatively decrease from 13.2% in 1990 to 11.9¨% in 2030. The largest growth can be seen in travelling for leisure and non-commuting private transport.
- Car volumes will increase in both peak and off-peak period. However, the growth during off-peak period is slightly larger.

- The link between passenger volumes and the number of cars is the occupancy rate. The occupancy rates of cars differ according to travel motive and road type. Commuting trips have an overall occupancy of 1.12 persons per car, business travel 1.20 and non-work transport 1.59.

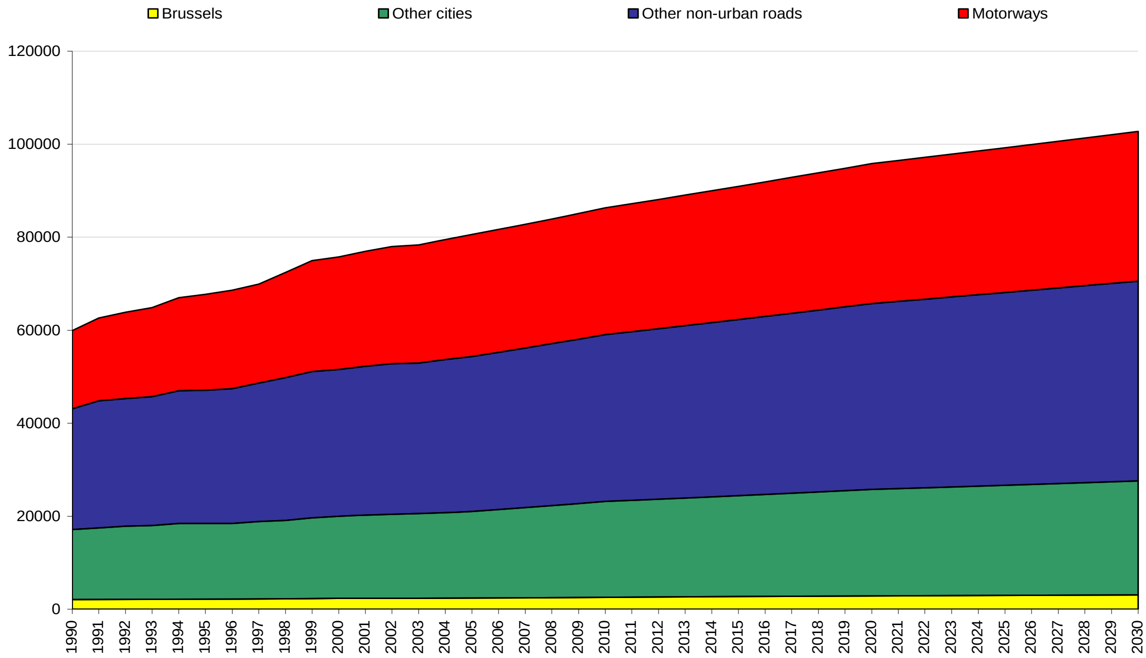


Figure 21 : Car volumes per road type [million veh-km/year]

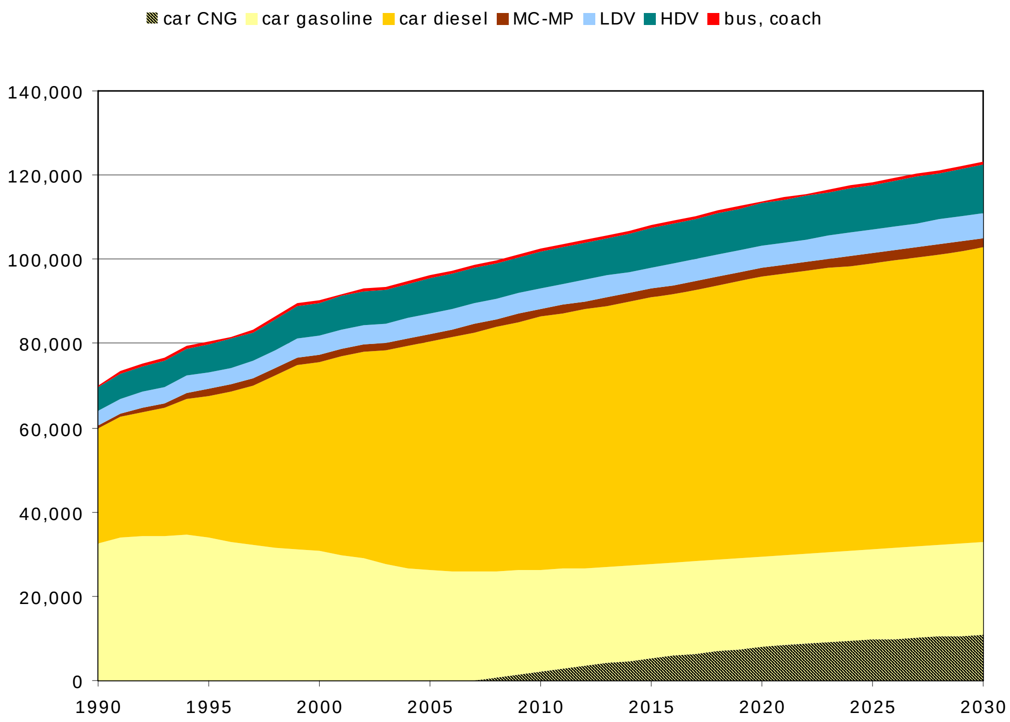


Figure 22: Transport volumes per vehicle type [million veh-km/year]

The speed of cars depends on the road type and the period of the day. Figure 23 represents the evolution of car speeds. Due to the larger transport volumes, the speeds decline slightly. Speeds are higher in the off-peak period compared to the peak period. Speeds on motorways are higher than on 'other non-urban roads' (regional roads) and urban roads.
The speeds of trucks are 13% lower than those for cars for urban roads and 18% lower for the other road types.

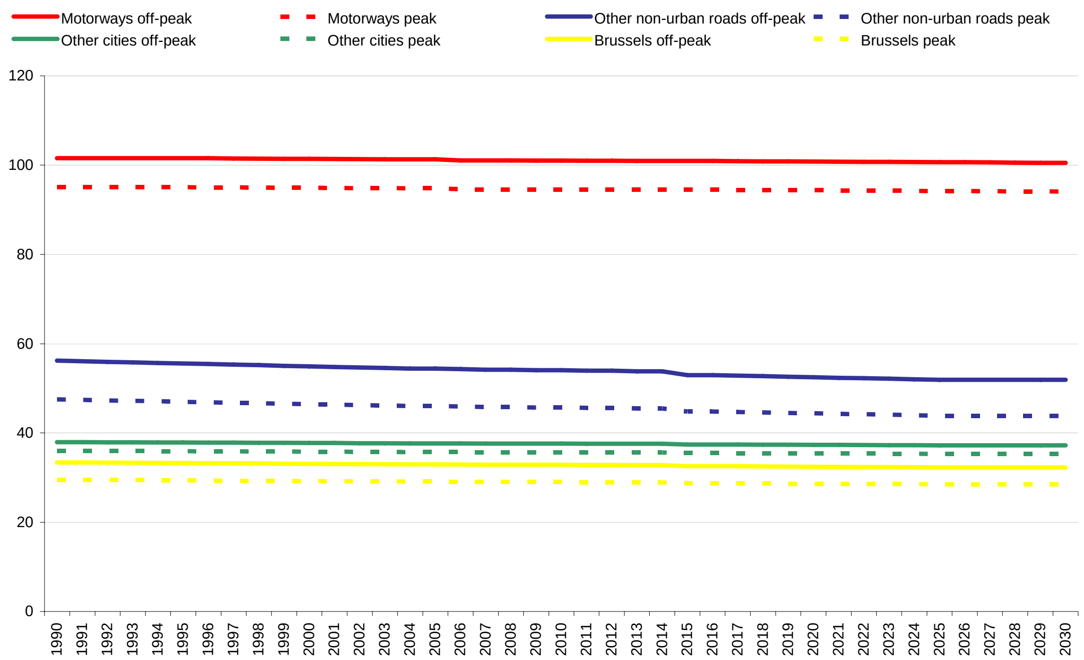


Figure 23 : Car speeds for different road types and periods [km/h]

The speeds are of importance in the calculation of time costs and emissions.

5.2 Trucks

Truck vehicle volumes comprise all transport in the Belgium area. Road vehicles with a maximum admitted weight of more than 3.5 ton are considered as trucks. These trucks are further subdivided by age and technology in the calculations of vehicle stock and emissions. Truck volumes are also divided according to road type and freight category. Figure 24 represents the evolution of truck volumes dependant on freight category. Overall we can see that truck volumes grow faster than the car volumes. Especially unitized transport and general cargo are the main growing freight categories. Motorways take the largest truck volumes and this share still grows. Overall load factor for all trucks (>3.5ton) is 8.17 ton per vehicle in 2005.

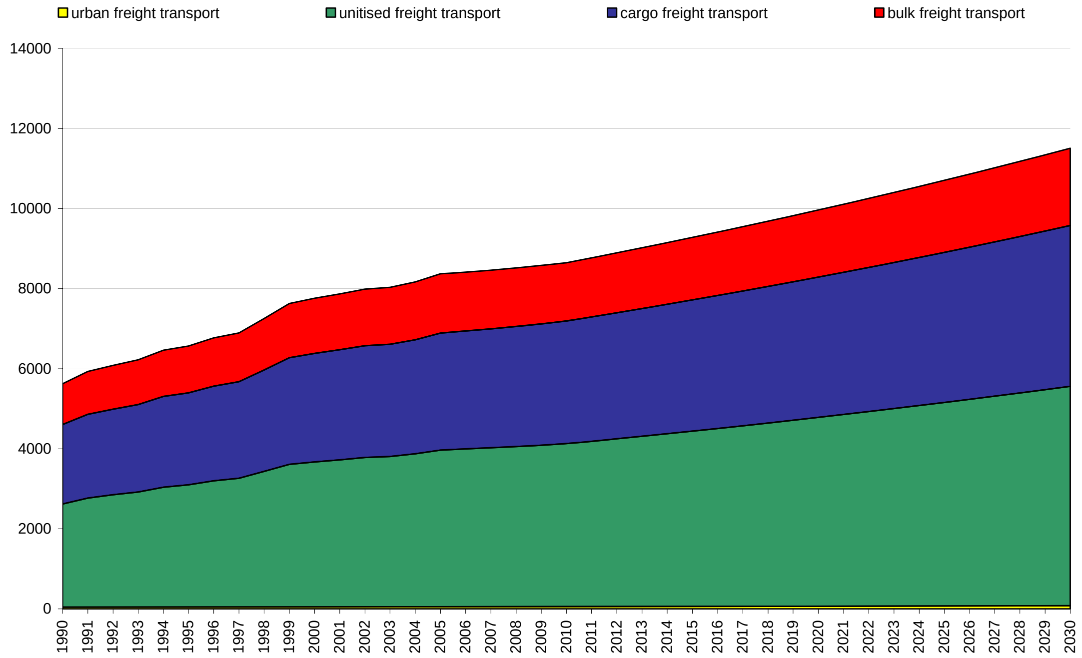


Figure 24: Truck vehicle volumes per freight category [Mvehkm/year]

5.3 Other road modes

Other road modes are also considered, their volumes are nevertheless much smaller. In the model "*Light Duty Vehicles (LDV)"* refers to vans. They can be used for both passenger and freight transport. Statistics for these vehicle classes are of low quality. Estimates have been made based on different sources. LDV vehicle volumes grow from 3,4 thousand million in 1990 to 5,8 thousand million in 2030.

Numbers for *motorcycles* and mopeds are also difficult to estimate, but are relatively small. In 1990 there were 1.2 thousand million kilometres with motorcycles and mopeds. A growth is foreseen (overall annual growth of 3,6%) to 2,4 thousand million in 2030.

Bus and coach vehicle volumes are 0,6 million vehicle kilometres in 1990 and they remain stable except for some fluctuations.

5.4 Non-road passenger modes

Passenger train was the largest non-road passenger mode in 1990 with 6,8 thousand million passenger kilometres. A relatively large growth is expected until 2010 (annual +1,8%) and a slower growth in the next 20 years (annual + 0,5%) to have 10,7 thousand million passenger kilometres in 2030.

In TREMOVE, all kilometres travelled by passengers leaving at Belgium airports are considered as Belgian air passenger-kilometres. This plane traffic grows significantly (annual + 4,2%) from 3,9 thousand million in 1990 to 19,7 thousand million in 2030.

A complete overview of all passenger travel modes can be made by comparing passenger-kilometres as represented in Figure 25. We see a strong growth of passenger transport. The share of the car mode dominates but declines (from 78,0% in 1990 to 74.6% in 2030). The share of the plane mode is growing very fast (from 3.3% in 1990 to 9.7% in 2030).

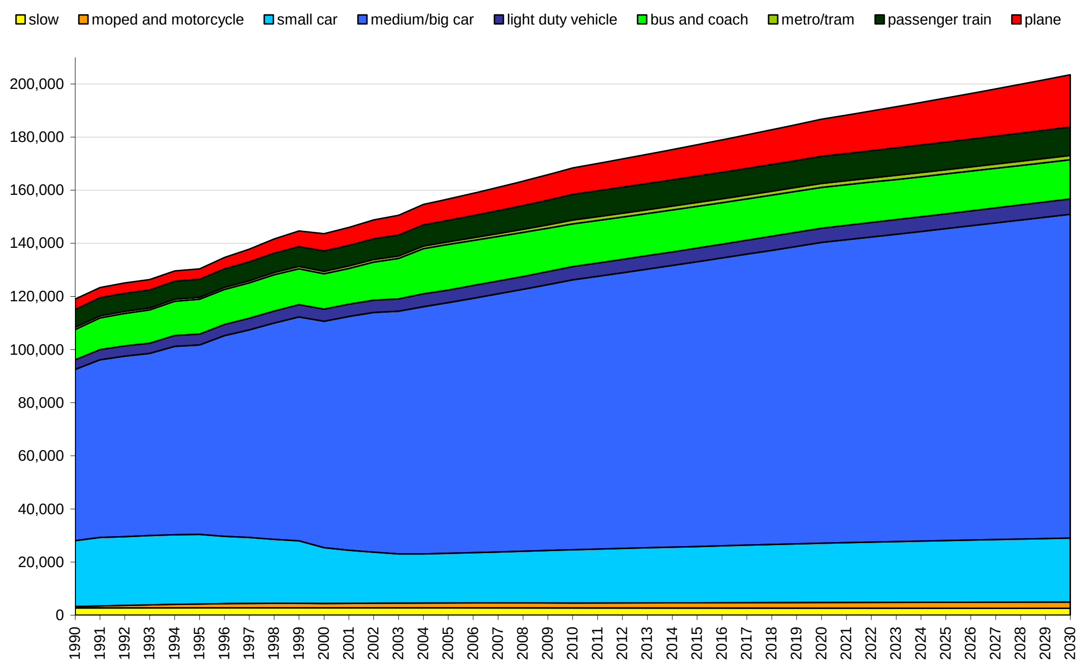


Figure 25 : Evolution of passenger volumes per mode [million psg-km/year]

5.5 *Other freight modes*

Freight transport on non-road modes comprises rail and inland waterways. Rail freight volume is about 8,3 thousand million tonne-kilometers in 1990. The same number is estimated for 2030. Freight volume on inland waterways increases (annual growth rate of 1,9%) from 5,4 towards 11,4 thousand million tonne-kilometers.

Figure 26 represents the freight evolution for the different modes. The figure represents tonkilometers. A distinction is made between long and short distance, where 500km functions as boundary between these distance classes. The road modes are dominant and their share even increases (from 70,9% in 1990 to 83,3% in 2030).

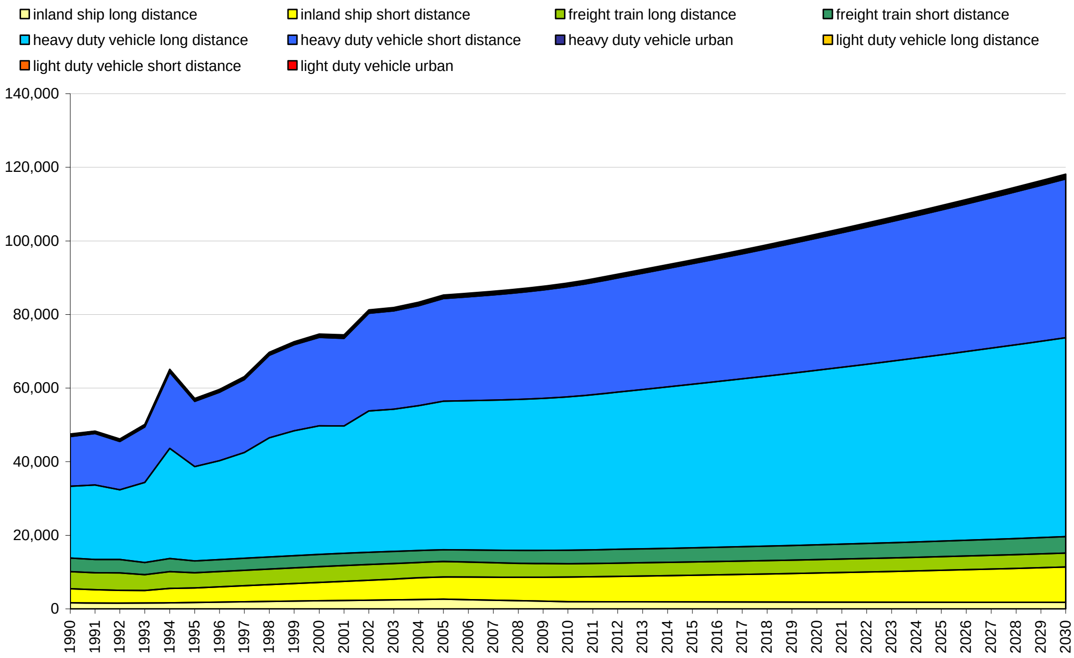


Figure 26 : Evolution of goods transport [million tonne-km/year]

6 Validation of results

In this section section we verify whether the TREMOVE model results are coherent with the real world. Therefore we compare the official fuel sales with the calculated fuel consumption in the model. Fuel sales is the only model parameter for which statistics are available. All the other model parameters (emissions) can only be estimated and not measured. A second validation method consists of a comparison with the results of the earlier IFEU study.

6.1 Fuel sales

Figure 27 shows the limited differences between the TREMOVE fuel consumption estimates and the official EUROSTAT fuel sale statistics for Belgium (year 2000). For diesel, the TREMOVE estimation is only 4% above and for petrol the difference is even smaller, i.e. 2 %. The overall difference, gasoline and diesel together, is only 3%.
These are remarkable consistent results for a modelling exercise of this type. Note that perfect equality between reported fuel sales and modelled fuel consumption would not be realistic, e.g. due to the impact of tank tourism to Luxemburg. It can be expected that the official figures of fuel sales are lower than the fuel consumption on the Belgian territory due to this phenomenon. The small overestimation by the model is therefore very normal. It is interesting to see that the estimates of the TREMOD model were not as close to the official fuel sale figures. TREMODs fuel consumption estimates are 16% below the official sales statistics. For diesel there was an underestimation of 25%, for petrol an overestimation of 6%.

A clear reason why TREMOVE obtains better results than TREMOD is difficult to single out. It concerns most probably a combination of different factors. Amongst others, the estimated speeds, the used fuel consumption functions, the mobile air conditioning impacts, ... certainly differ between TREMOVE and TREMOD. Furthermore, in the previous IFEU study, using TREMOD, the year 2000 was already “future”. Vehicle stock and vehicle kilometres were thus forecasts and not inputs.

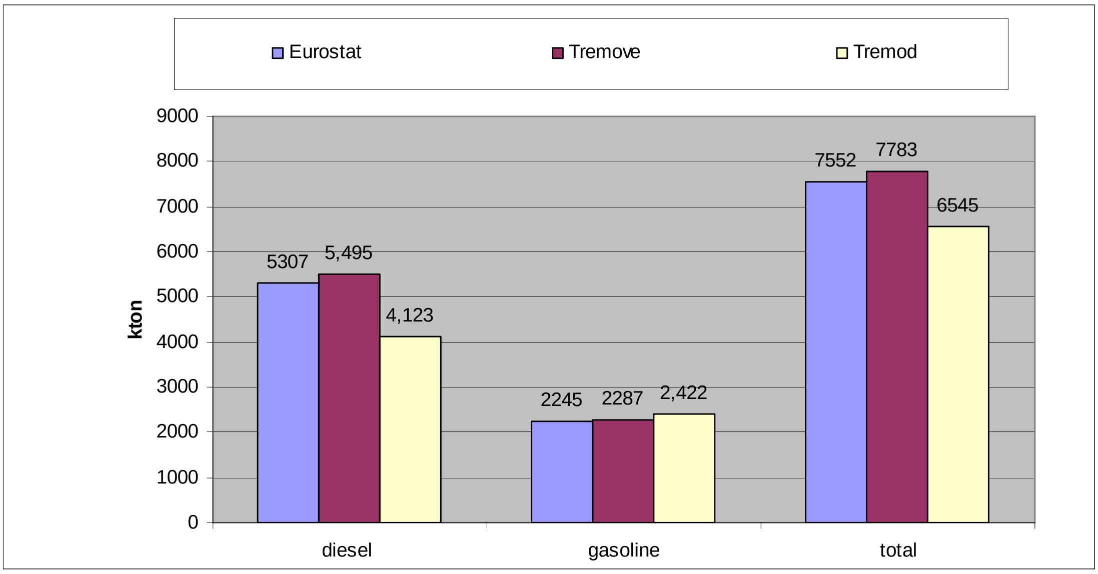


Figure 27: Comparison fuel consumption EUROSTAT-TREMOVE-IFEU 2000 in kiloton

6.2 Comparison of previous TREMOD results and current TREMOVE results

The results of both models present similar evolutions. The tendencies remain the same in both models as can be seen in Figure 28. Reduction in CO and VOC emissions are obtained from gasoline cars, PM_{10} reductions especially from diesel engines.

Inevitably, some differences can be distinguished between results of both models. Different factors explain those differences as for the differences in fuel consumption.

The TREMOVE passenger *vehicle stock* is smaller than the forecasted TREMOD stock (Figure 29), but the relative and absolute share of diesel vehicles is larger in the TREMOVE stock. A stock that grows faster, as in TREMOD, signifies that new technologies enter faster the stock and emissions can therefore be reduced somewhat faster.

The increase in *vehicle kilometres* is bigger in TREMOVE than in TREMOD (Figure 29). This is on the one hand due to the fact that more recent information was available for the TREMOVE modelling exercise. TREMOVE used mileage figures as input up to 2004, while TREMOD had those figures only available till 1998. The second reason is that the vehicle kilometres growth rates are different. TREMOVE counts with an average growth rate of 1.15% while TREMOD counted with a growth rate of 0.75% over the 2005-2020 period[9].

[9] Assumptions behind the TREMOVE growth figure can be found in annex.

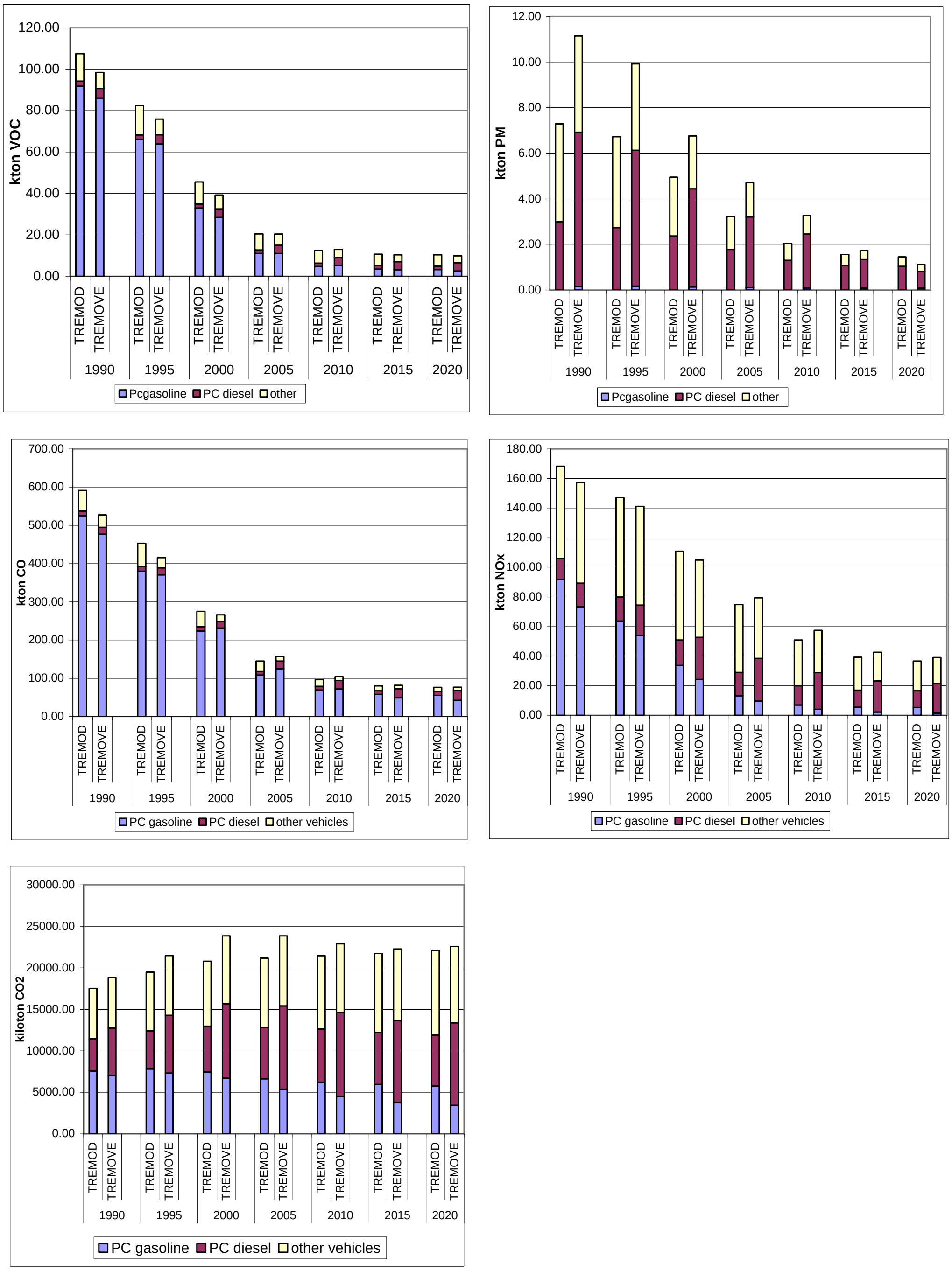


Figure 28: Comparison of exhaust emissions of VOC, PM_{10}, CO, NO_x, and CO_2 in TREMOVE and TREMOD

COPERT *calculates emissions* in a somewhat different way compared to the TREMOD model due to the complexity of emission formation (especially for pre-euro PM_{10} emissions). The emission calculation is also dependant on speeds and speeds are also calculated in another way in both models. Furthermore TREMOVE introduces for passenger cars also the euro 5 EC proposal, that is not present in the IFEU study.

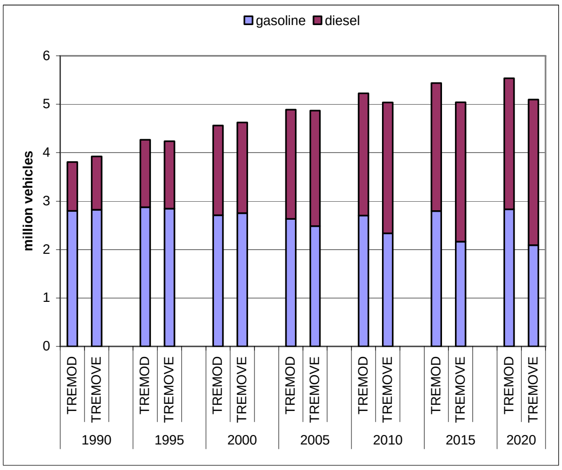
Specifically for CO_2 emissions, differences can also be explained by the presence of hybrid and CNG vehicles in the fleet, absent in TREMOD. Also the bigger forecasted share of diesel vehicles is part of the explanation.

The biggest differences between TREMOVE and TREMOD can be observed for PM_{10} emissions. The whole difference is due to the diesel passenger cars. The table below gives some insight in the differences. Part of the explanation is probably the higher diesel fuel consumption. The higher diesel consumption estimated in TREMOVE is confirmed by the statistics (cfr paragraph 6.1.) Especially after 1995 this explanation seems plausible. The order of magnitude of the extra TREMOVE CO_2 emissions, proportional to diesel fuel consumption is the same as for the extra TREMOVE PM_{10} emissions after 1995.

For the earlier years, there is another explanation. The TREMOD model takes an emission standard into account that is unknown in the COPERT emission modelling used in TREMOVE. It is a standard with which diesel cars had to comply from 1986 on in the TREMOD modelling. This standard reduces PM_{10} emissions by 50% compared to the previous pre euro standard. COPERT (and thus TREMOVE) does not take this intermediate standard into account. (IFEU report p3)

Table 2: comparions of PM_{10} emissions for diesel passenger cars in TREMOVE and TREMOD (ktons)

Year	pollutant	TREMOD	TREMOVE	difference (%)
1990	CO2	3881	5701	47%
	PM_{10}	2.99	6.76	126%
1995	CO2	4600	6951	51%
	PM_{10}	2.74	5.96	117%
2000	CO2	5526	8976	62%
	PM_{10}	2.37	4.30	81%
2005	CO2	6203	10035	62%
	PM_{10}	1.78	3.10	74%
2010	CO2	6411	10101	58%
	PM_{10}	1.31	2.36	81%
2015	CO2	6275	9894	58%
	PM_{10}	1.08	1.25	16%
2020	CO2	6154	9961	62%
	PM_{10}	1.04	0.74	-29%



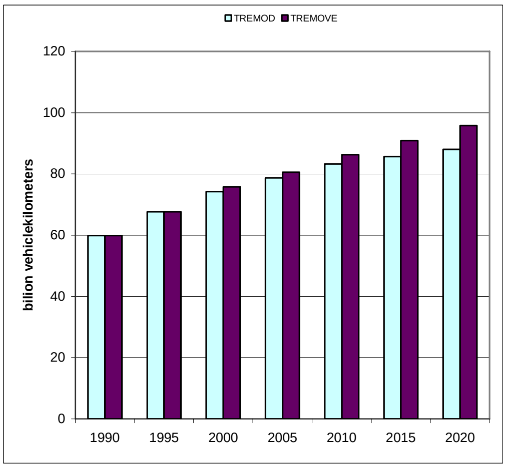


Figure 29 Comparison of vehicle stock and vehicle kilometres development in TREMOVE and TREMOD

7 Air conditioning

The TREMOVE model also accounts for the effect of air conditioning systems in passenger cars. The extra fuel consumption and related CO_2 and SO_2 emissions are included in the figures reported in the previous sections[10]. Air conditioning systems cause also emissions due to leakages of the refrigerants. These can be relatively important. One can distinguish regular leakage (normal use), irregular leakage (accidental), leakage at maintenance, leakage during mounting the equipment in the vehicle and leakage at scrappage of the vehicle. In this study, the focus is on regular and irregular leakage. Total leakage is nearly twice the leakage accounted for here. More information on assumptions and hypothesis can be found in the annex.

The figure below shows the ever growing regular leakage due to air conditioning systems in cars. The refrigerant used is initially HFC134a and will be gradually replaced in the period 2011-2017 by another refrigerant, HFC152a. For this reason, in 2015 both refrigerants are present. The reason for the replacement is a recently adopted EU legislation. The essential difference between both refrigerants is their global warming potential (GWP) in CO2 equivalents, which is 1300 for HFC134a versus 140 for HFC152a. The lower GWP of HFC152a results in a significant decrease in leakage emissions, when expressed in global warming potential terms, from 2011 on.

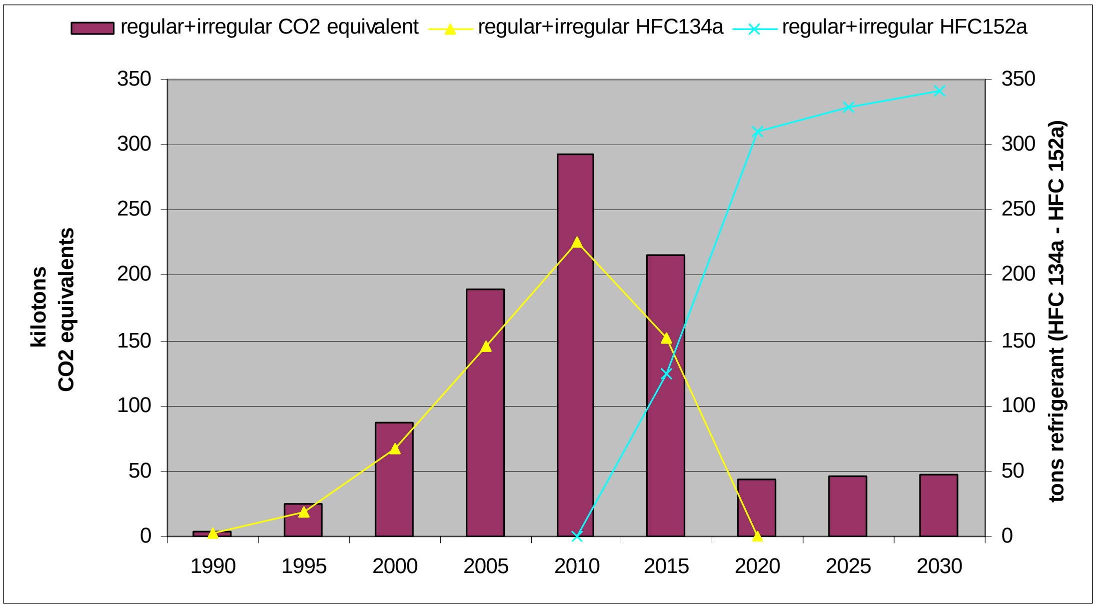


Figure 30: evolution of emissions of airco refrigerants between 1990 and 2030

[10] There is probably also an influence on emissions of other pollutants, but there are no good measurements yet available about the changes in these emissions.

In 2010, when leakage is maximal in GWP terms, the regular and irregular leakage represents 1.8% of total passenger cars exhaust emissions[11]. If also the extra CO2 exhaust emissions caused by air conditioning equipment are taken into account, the contribution of air conditioning equipment accounts for 7.4% of CO2 equivalent of cars emissions in 2010[12]. This percentage will decrease somewhat thanks to the replacement of the refrigerant in the years after 2010. The contribution of airco systems after 2017 is forecasted to be slightly below 7%. The reason is that from 2017 airco systems cause nearly only extra exhaust emissions as from 2017 on all airco systems will have HFC152a as refrigerant.

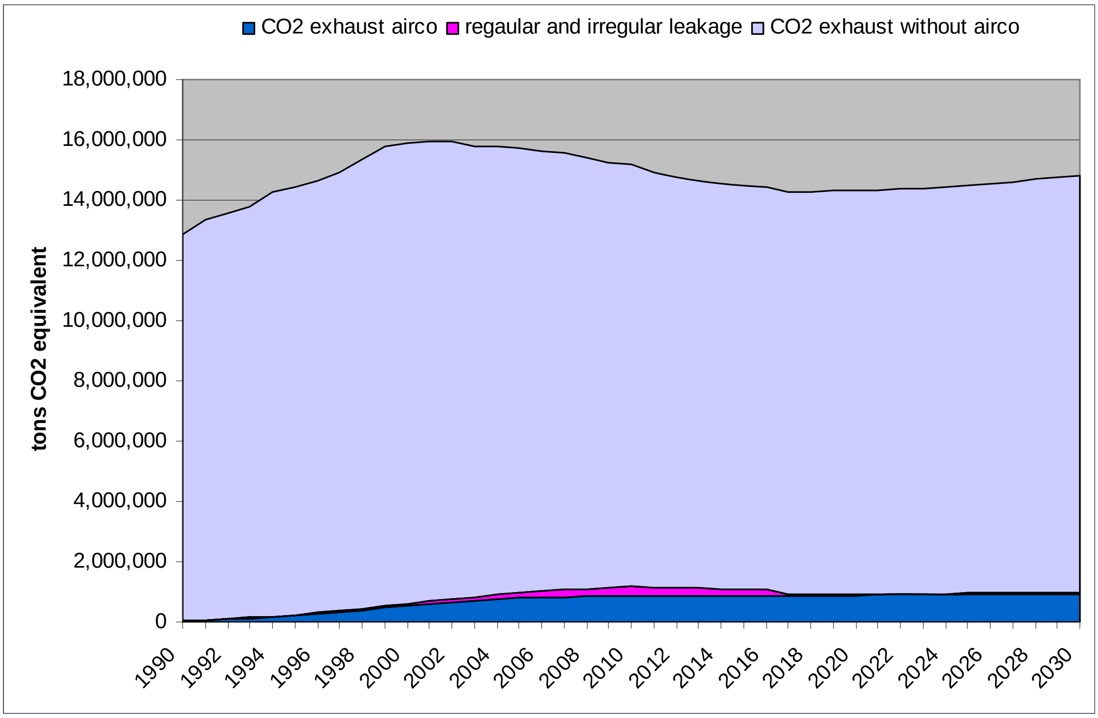


Figure 31: CO2 equivalent emissions (exhaust and leakage) of passenger cars

11 Total leakage emissions represents 3.3% of total passenger cars exhaust emissions in 2010.

12 The contribution of air conditioning equipment accounts for 8.9% of passenger car GWP emissions in 2010 if total leakage emissions are taken into account

8 Biofuels

The TREMOVE model takes the introduction of biofuels into account. From 2006 on gasoline and diesel are considered to be blended with biofuel additives. In 2010 the biofuel share in gasoline and diesel is 5.75%, in 2020 this percentage increases to 8% in accordance with the European Directive on biofuels.

Hereunder we make a first analysis of the environmental effects of the introduction of biofuels based on the model results. To perform the analysis, exhaust emissions from biofuels are considered similar to those of conventional fuels (TNO-Senternovem 2005). The biofuel life cycle emissions are based on lifecycle emissions of rapeseed production (Annex 3 – Lewis 1997). Life cycle emissions are considered here as the emission from the production and transport of fuels. It is important to note that the results of this analysis are very much dependant on the type of biomass used to produce the biofuel.

It is well known that the introduction of biofuels has a positive effect on total CO_2 emissions (exhaust + life cycle[13]). This is also confirmed by our analysis. The model results show a decrease of CO2 emissions of 65% for the conventional fuel replaced by biofuel.

The effects on total emissions (exhaust + life cycle) of other pollutants are often less known and their environmental impact is rather negative. Based on the model results, PM_{10} emissions increase by around 6%, NOx emissions by 7.3% while SO_2 emissions decrease by approximately 3.7% with the introduction of 8% biofuels in the conventional fuels. For the biofuel replacing conventional fuel, well to weel emissions are 70% higher for PM_{10} and 90% higher for NOx. Figure 32 shows the effects graphically.

The table below gives some insight in the absolute figures. The total emissions are the sum of exhaust (tank to wheel) and lifecycle (well to tank) emissions. The gains are the emissions that can be avoided thanks to the introduction of biofuels. The losses are the supplementary emissions caused by the use of biofuels compared to the use of conventional fuels.

The observed effects are in general the net result of a decrease (CO_2) or a statusquo in exhaust emissions and often an increase in life cycle emissions (CO_2, PM_{10}, NO_x).

[13] Exhaust emissions are synonym for tank to wheel emissions and life cycle emissions are synonym for well to tank emissions. Total emissions are then well to tank emissions.

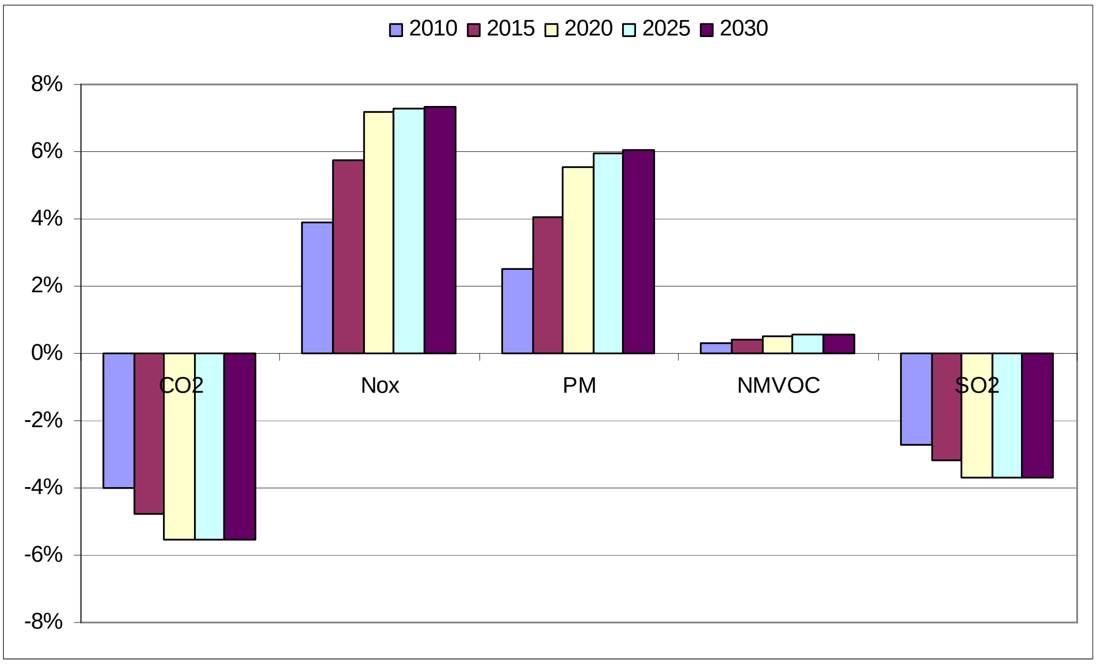


Figure 32: effects of the introduction of biofuels on well to wheel emissions of road transport (5.75% biofuel in 2010 – 8% biofuel between 2020 and 2030)

Table 3: effects of the introduction of biofuels on well to wheel emissions from road traffic in tons (lc= life cycle emissions – exhaust = exhaust emissions)

		2010	2015	2020	2025	2030
CO_2	lc+exhaust	26756703	25987014	26324194	26977852	27967673
	biofuel gain	1067819	1239025	1459857	1495765	1550514
Nox	lc+exhaust	17630	17139	17316	17687	18261
	biofuel loss	-2877	-3352	-3958	-4060	-4210
PM_{10}	lc+exhaust	2429	2351	2377	2433	2522
	biofuel loss	-149	-174	-206	-211	-219
NMVOC	lc+exhaust	14142	11963	11474	11540	11899
	biofuel loss	-83	-97	-116	-119	-123
SO_2	lc+exhaust	38512	35722	35406	35970	37197
	biofuel gain	953	1086	1268	1292	1337

As already mentioned, the reader should be aware that this analysis is very much dependant on the biomass used to produce the biofuel. If waste cooking oil is for example used as biofuel, the effects will of course be beneficial for the environment. The reason is that the waste product, cooking oil can nearly directly be burnt in the car combustion engines. In the future, also significant efficiency improvements are expected in the biofuel production with for example biofuels based on ligno cellullosic species like willow (VIEWLS, 2005). Future research is ongoing and needed in this domain.

9 Policy and scenario simulations

The TREMOVE model makes it possible to simulate policies or scenarios in the transport sector and to see their effects. TML simulated the effects of three policy scenarios within this project. A "mobility tax" scenario, a "fuel price" scenario and a differentiated ownership tax scenario. Hereunder, we first give some general explanations on the principles of scenario calculations. Later on, we explain each scenario separately, comment the results and compare the results between each other.

9.1 Scenario calculation in TREMOVE :the principles

The TREMOVE model is able to model the effects of policy measures. The determination of transport demand and transport volumes is crucial here. Baseline transport demand has been described in chapter 5 and is based on a combination of FPSMT (past period) data, Scenes data (future period) and expert judgements. The TREMOVE demand module then enables to assess changes in transport demand under various policy scenarios. Policy measures will affect the generalised prices of transport in the demand module. The prices can be affected by technological measures, fiscal policies or regulation policies. A government can for example increase fuel excise. Within the demand module, these new prices will lead to a change in transport demand. Higher fuel excise means a higher fuel price and thus lower demand for transport. Overall transport volumes will alter and substitution between modes will occur. As a consequence also congestion, travel speed and the time price of transport will be affected. Also vehicle stock and emissions will be influenced.

Scenario and simulations are used as synonyms in the next section. A scenario or a simulation is compared to the base case or the base case scenario.

9.2 Effects considered to evaluate scenarios

The effects considered to evaluate the scenario outcomes are:

- Effects on transport volumes: For transport of goods and passenger transport global transport volumes are considered. Transport volumes for the different transport modes are also considered separately. As a consequence, modal shifts can be observed.
- Effects on exhaust emissions: The effects on the main pollutants and the reasons behind these changes are considered.
- Effects on vehicle stock: A policy can influence the vehicle stock in different ways. Some examples are: a further switch from gasoline to diesel, a faster

penetration of new technologies like hybrid cars, an earlier replacement in the vehicle stock.

- Effects on tax revenues: Tax revenues will be of course be influenced by fiscal policies, but also other policies could influence tax revenues. If public transport gets more comfortable, tax revenues from private transport could decrease.

TML proposes also a measure for the *welfare changes* for each scenario. This welfare measure is one aggregated value that takes all differences between scenario and base case into account. The differences are calculated in monetary values for each modelling year and actualized to 2005. The advantage of such a measure is that it facilitates comparisons between scenarios. The welfare measure is commonly used to evaluate European policies.

For this study the emphasis is on the emissions effects. TML adds the welfare evaluation for the reader's information. Some explanations on the welfare measure are given below.

The changes in welfare can be subdivided into four components.

- *Household utility*
  The difference in the aggregate utility level of all households based on the aggregate change in utility level of households.

  The utility of households in TREMOVE is calculated with a nested CES utility function. The utility calculation is based on the total quantity of goods and (transport) services consumed by households. TREMOVE takes more than 200 transport services into account. Non transport goods are represented by one "other" good in the CES utility structure. With a policy or a scenario, prices of one or different goods and services will change. With changing prices, consumers will change the goods and services they consume (buy). With an increasing price for a service, some consumers will start to consume other services, other consumers will pay the higher price. In any case, in the new situation, consumers will have to pay more to get the same utility as in the initial situation. As a consequence, the overall quantity of goods and services consumed will also be lower. With the CES utility function the utility in the new situation will be calculated. The difference between the new and the old utility value can than be derived.

  An example:
  Suppose the car peak driving price increases from 10 to 20 cent/km. People who drove the car in the peak at 10 cent/km can now choose:

- To continue car driving in the peak while paying 20 cent
- To drive car at another moment
- To stop travelling and spend the money at something else
- To travelling by another means of transport…

All these alternatives have in common that their utility per euro will be lower than in the initial situation with car peak driving at 10 cent/km. If not, the alternatives had already been chosen in the initial situation. The total utility calculated by the CES utility function will thus be lower in the new situation.

- *Producer costs*
  The difference in production costs for all industry and service activities based on the aggregate change in production costs of firms.

  The producer costs are a proxy for the utility of producers. This utility, based on the costs, are also calculated with the help of a nested CES utility function in a way comparable to the calculation of the household utility.

- *Environmental costs*
  The difference in external environmental costs. Exhaust and life cycle emissions are taken into account.

  The values for the environmental costs per unit of pollutant have been taken from the cost benefit analysis performed within the framework of the European Clean Air For Europe programme. (AEA, 2005)

- *Tax revenues*
  The difference in government tax revenues from the transport sector.

The transport taxes taken into account by TREMOVE are:

- *Fixed taxes*: road ownership tax, registration tax and insurance tax
- *Variable taxes*: fuel excises
- *VAT on fixed resource cost:* e.g. VAT on purchase price
- *VAT on variable resource cost:* e.g. VAT on fuel price

The basic TREMOVE assumption is that an increase in tax revenues from the transport sector enables politicians to decrease other taxes. Politicians can decide to reduce a general tax or a labour tax thanks to transport taxes. In other words, a new transport tax (fuel excise, ownership tax,.. for example) will be used to reduce another tax or to avoid increasing another tax. The transport tax is considered a general tax, except for the transport taxes paid by commuters. The latter transport tax has the same effects as a labour tax.

A tax shift from a labour tax to a general tax has a positive effect on welfare as it decreases distortions in the much distorted labour market. A 1 EURO labour tax that is replaced by a 1 EURO general tax creates a welfare gain of 1.41 EURO[14] in Belgium. A general tax replacing another general tax is neutral. For the simulations done within this project, all welfare calculations have been done twice. The first calculation assumes for the welfare calculations that the transport taxes replace a general tax; the second calculation assumes that the transport taxes replace labour taxes.

Note that from a welfare point of view taxes decrease utility from households and thus social welfare, but increase social welfare as those same taxes are beneficial for society in another way.

More information can be found in Annex 1 and in the TREMOVE documentation on www.tremove.org.

9.3 Mobility tax scenario

9.3.1 Scenario definition

In this scenario the effect of a general increase in road transport taxes of 25% is investigated. The increase takes effect in 2006. The scenario was defined by FEBIAC and FPSMT[15].

The changes in taxes of road transport are given in the table below.

Table 4: input parameters for scenario of increasing road taxes

Car and LDV	Registration tax	+25%
Car, LDV, HDV	Ownership tax	+25%
Car, LDV, HDV, two-wheelers	Fuel excise	+25%
HDV	Eurovignette	+25%

[14] More information can be found in the general TREMOVE report in chapter 7 : "The welfare module" and in the paper "The marginal cost of public funds in OECD countries: hours of work versus labour force participation", H.J.Kleven and C.T.Kreiner, CESifo Working Paper Series, April 2003

[15] The initial aim of this scenario was to simulate a variabilisation of the fixed road taxes while holding global road fiscality constant. TREMOVE is not able to simulate this as all taxes and costs are transformed by the model into a cost-tax/km..

For consumers, the fuel price at the filling station will be increased by around 9% for diesel and nearly 13% for gasoline compared to the basecase due to the difference in excises on gasoline and diesel. The relative price increase remains similar over the period.

Note that public transport fares are not altered in this scenario.

9.3.2 Scenario results: comparison between base case and simulation

9.3.2.1 Effects on transport volumes

This scenario causes an important increase in the costs for private road transport while prices for the other modes do not change. As a consequence global transport volumes decrease and transport choices are oriented towards public transport.

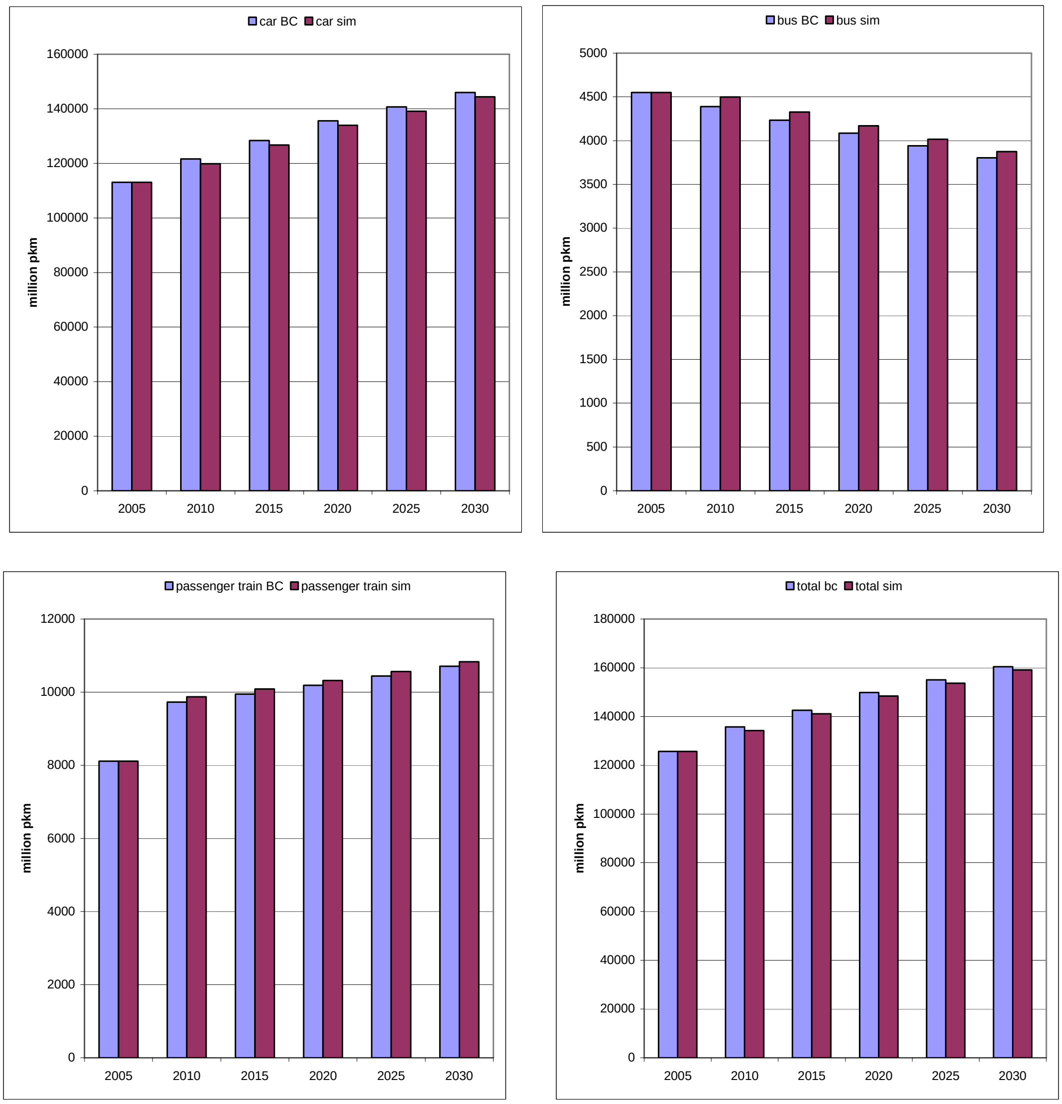


Figure 33: Effects on person kilometres for different modes

Total *person kilometres* decrease by 0.8% in 2030 in the simulation compared to the basecase with the 25% price increase. Person kilometres by car decrease by 1% while person kilometres on buses and trains increase by respectively 1.9% and 1.1%. The latter train and bus km increase covers only a small part of the decrease in car km due to the low absolute transport volume of train and bus in the basecase. Bus and train cover only around 10% of the total passenger transport volume. The effects are somewhat stronger at the beginning of the period with a 1.1% global transport volume decrease in 2010.

The results are similar for transport of goods. Ton kilometres decrease as a whole by 0.9% in 2030 compared to the basecase. Heavy duty ton kilometres are reduced by 1.3% while inland waterways and rail kilometres increase by respectively 1.1% and 1.5% in 2030. Effects are similar over the whole period.

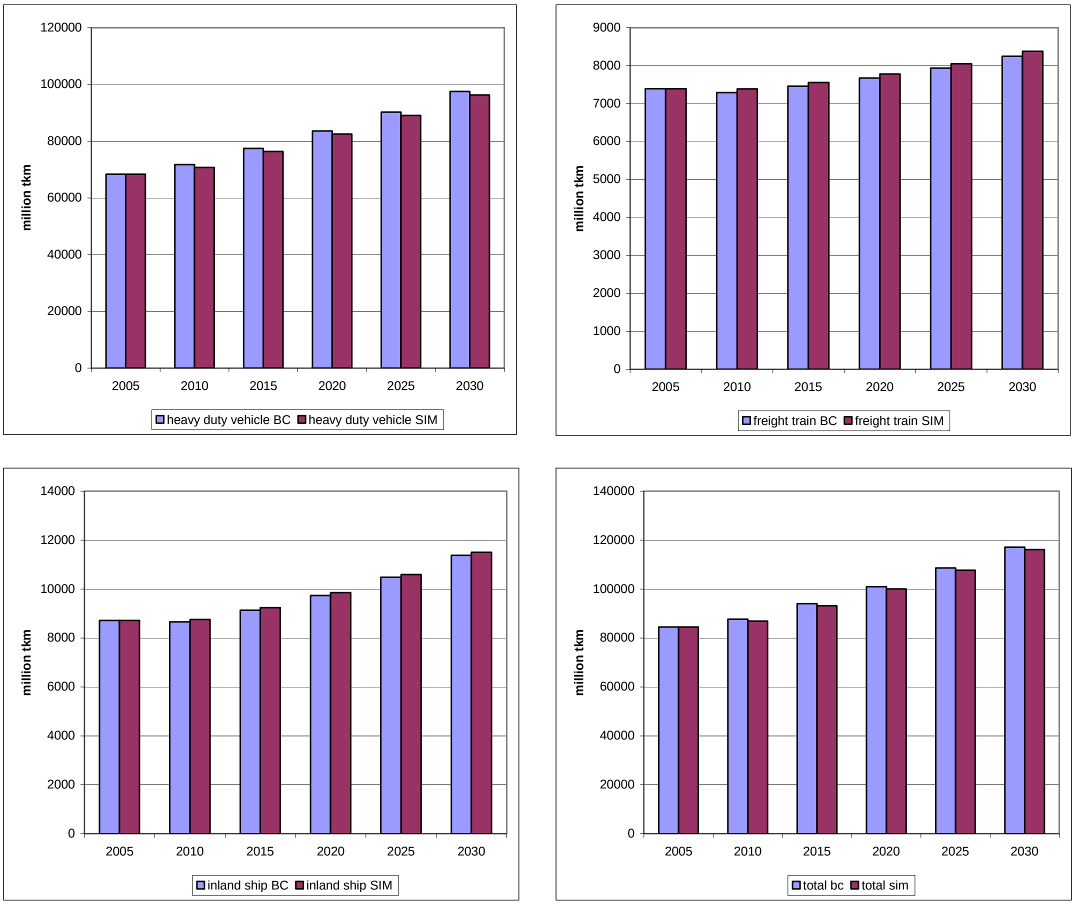


Figure 34: Effects on tonkilometer for different modes

9.3.2.2 Effects on exhaust emissions

The reduction in transport volumes causes a reduction in emissions of all pollutants. Figure 40 shows the evolution for CO_2 exhaust emissions. The evolution is similar for the emissions for the other pollutants. Nevertheless, there are some differences in the evolution between pollutants as also the vehicle stock changes due to the changes in relative fuel prices and taxes (by vehicle type). Also HDV and passenger cars are affected in a different way by the tax and excise changes.

In 2030 CO_2 emissions are reduced by 1.8%, NO_x emissions by 1.1%, PM_{10} emissions by 1.7% and VOC emissions by only 0.8%. The reductions in NO_x and PM_{10} are lower than the CO_2 reduction. This is due to the growing importance of diesel vehicles in the fleet. The low reduction in VOC emissions is due to the increase in CNG fuelled vehicles. The small reduction in VOC is the net result of a decrease in NMVOC emissions and an increase in CH_4 emissions. The CH_4 emission increase is due to the increase in the use of CNG cars.

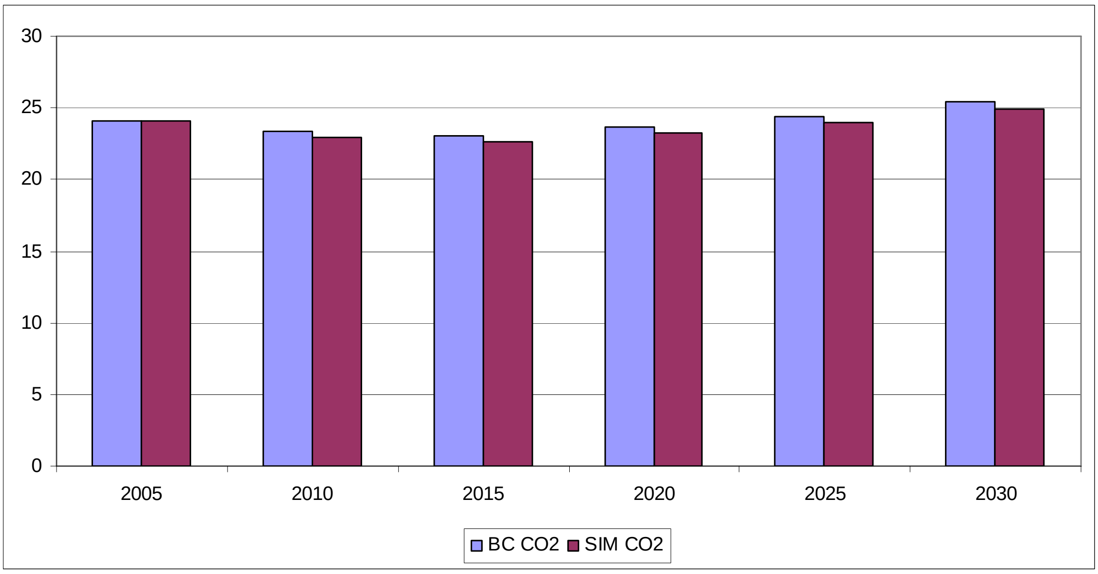


Figure 35: Evolution of CO_2 exhaust emissions

9.3.2.3 Effects on vehicle stock

Figure 41 shows the effects on the passenger car stock of increasing taxes and excises for passenger cars. The vehicle stock as a whole decreases by 1% in 2030. The passenger car gasoline stock decreases even more, 9.2% compared to the base case in 2030. The decrease in gasoline passenger car stock is lower in the early years of the simulation, 4% in 2010. Diesel car stock is reduced by around 1% over the whole simulation period. The only increasing stock is the CNG car stock. The number of CNG cars in 2030 is 16% higher in the simulation than in the base case.

The increase in CNG cars is a consequence of the absence of excises on CNG. As a consequence, there is no increase in the CNG fuel price for the users. Consumers will be encouraged to shift from petrol to CNG cars. We also observe a further dieselization of the stock as fuel economy becomes more important with increasing fuel prices.

The stock of HDV is reduced by around 1.7% over the whole period.

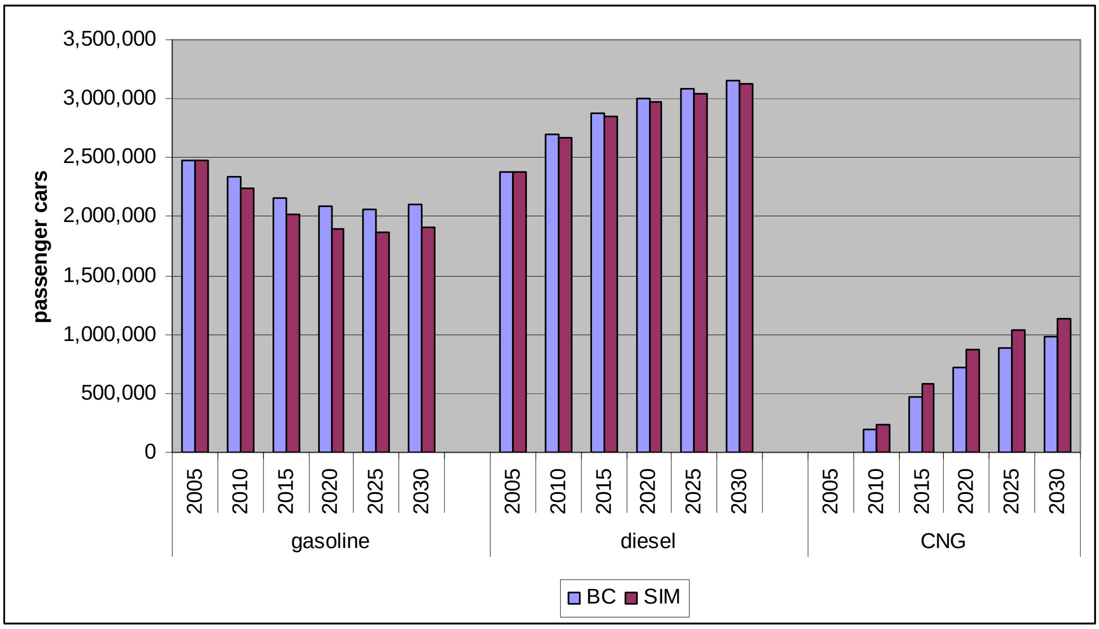


Figure 36: effects on the passenger car stock of increased road transport taxes

9.3.2.4 Effects on taxes

The fixed taxes increase by more than 10% over the whole period. This is much less than 25%. The reason is that also insurance taxes are included in the fixed tax. Those taxes remained unchanged. On the other hand also the vehicle fleet is slightly reduced so that also the number of cars paying ownership and registration taxes decreased.

The variable tax increases by more than 20% compared to the initial situation in each year. This percentage is close to the general 25% tax scenario increase. This is logic as the variable tax concerns only the fuel excises. That the final increase in tax revenue is less than 25% is due to a decrease in private road kilometers.

The small decrease in VAT on fixed resource costs is due to the decrease in the vehicle fleet. The small increase in VAT on variable resource cost is due to the 25% increase in excise taxes. VAT on fuel is not only due on excises but on the whole fuel price. It is therefore logic that the VAT increase is much smaller than 25%. Further on VAT is also paid on other variable resource costs like repair and maintenance.

The figure below presents the changes in tax revenues.

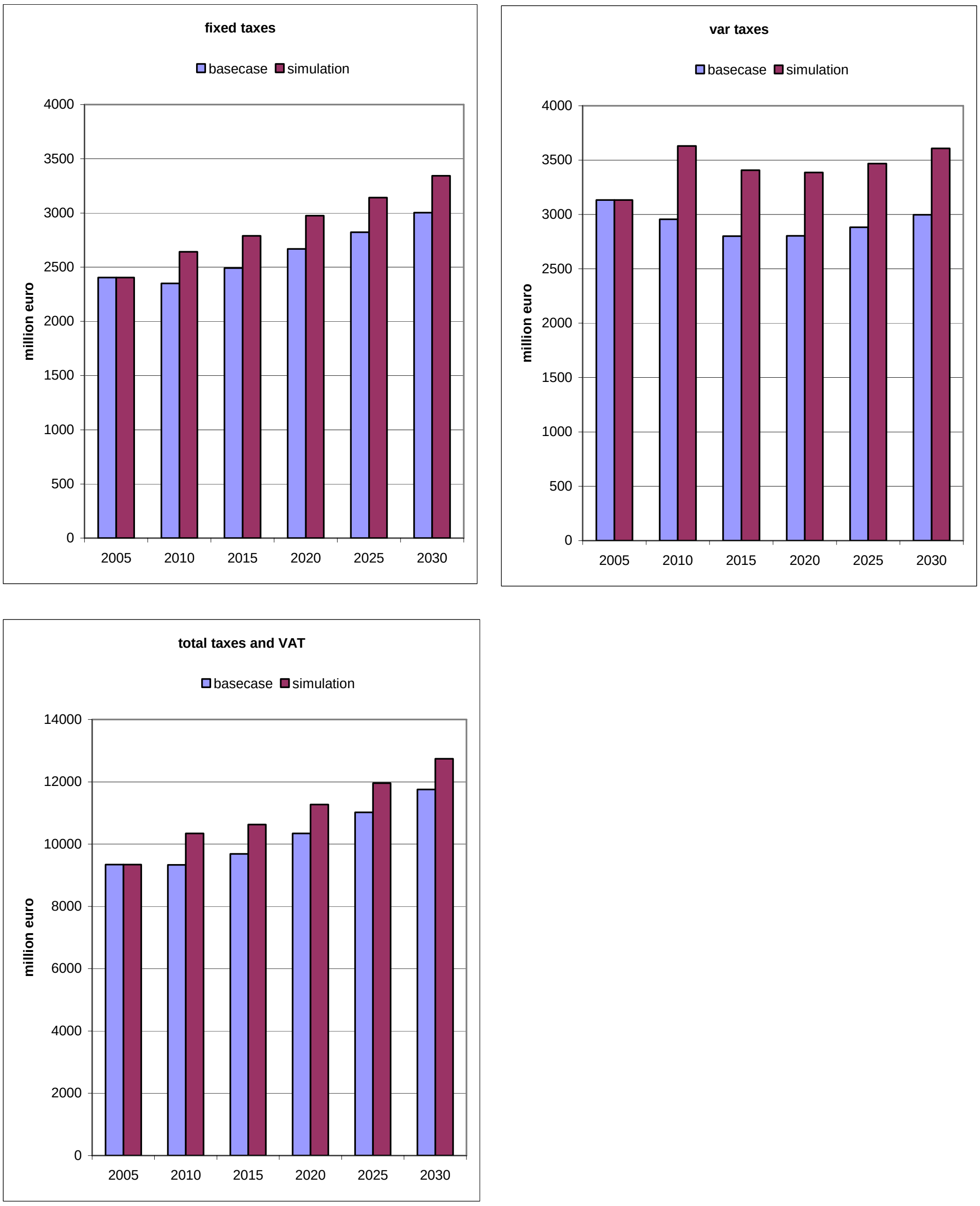


Figure 37: Effects on different tax revenues from private road transport in the road transport scenario (taxes in million EUR; changes in %)

9.3.2.5 Overall welfare effects

To assess the effect of the changes in fiscality on road transport, all changes in the different parameters mentioned under 9.1 are monetized if this is not the case yet, changes in household utility, changes in producer costs, changes in external costs of emissions and changes in tax revenues. Paragraph 9.1 gave some explanation about those concepts.Table 5 gives an overview of those changes. A negative sign means that there is a loss of welfare. The reductions in emissions have of course a positive effect on the welfare. The increase in taxes on transport on the other hand will reduce the utility for consumers and will increase costs for producers. Consumers (producers) will pay more for the transport services and consume less transport services. The total quantity of goods consumed will be reduced and the consumer utility will also be reduced. The extra tax revenues on the other hand can be recycled by the government to decrease other taxes or can be redistributed via investments in public projects.

If the extra taxes are recycled for a reduction of other general taxes the overall effect of the policy remains negative. The net present value of the policy is then estimated to be -5333 million euro. The loss in consumer and producer surplus cannot be compensated by the reduction of general taxes. Labour taxes have a much more negative welfare impact than general taxes due to their distortionary effect on the labour market. If the transport taxes are on the other hand redistributed via a reduction in labour taxes, the overall welfare effect is very positive. (see also 9.1). The net present value of the policy in 2005 is estimated to be 9655 million euro.

Table 5: welfare effects of mobility tax scenario (million euro)

	2005	2010	2015	2020	2025	2030
household utility	0	-826	-791	-791	-790	-808
producer costs	0	-344	-351	-369	-386	-407
external cost CO2 changes	0	5	8	10	11	11
external cost Nox changes	0	15	13	12	12	12
external cost PM changes	0	16	13	12	11	11
extrarnal cost of SO2 changes	0	21	26	29	31	31
external cost of VOCchanges	0	3	2	1	0	0
If transport tax replaces a general tax						
cost of public funds (general)	0	637	611	613	633	669
welfare net present value in 2005 (general)	-5,333					
if transport tax replaces a labour tax						
cost of public funds (labour)	0	2,012	1,898	1,883	1,923	2,020
welfare net present value in 2005 (labour)	9,656					

9.3.2.6 Comments

To evaluate the policy, it is clear that the use of the generated tax revenues is of major importance. A use of these taxes to reduce labour taxes has a positive effect for society. In the other case, the opposite is true.

Other research by TML shows that a differentiation of road taxes in function of time and place offer bigger welfare gains. The reason is that such taxes can focus on negative external effects of road traffic and decrease those negative effects especially congestion and to a lesser extent the environment. This is in line with the economic principles on marginal social cost pricing. An example is the research effectuated by TML for the European Conference of Ministers of Transport (ECMT 2003)[16].

9.4 Scenario: Changes in fuel prices

9.4.1 Scenario definition

At a European level, a harmonization of fuel prices is envisaged in the "White Paper on Transport" (European Commission 2001). There is no objective reason for maintaining a tax difference between gasoline and diesel fuel. From an external cost point of view, diesel should even be more expensive compared to gasoline as diesel vehicles are in general more polluting (in terms of health effects) than gasoline engines. This scenario simulates the effects of a simultaneous increase and harmonization of fuel taxes. The scenario also is a sensitivity analysis on the crude oil price, as it also assumes higher fuel resource costs than the base case scenario. The simulation input was prepared by the FPSMT and was approved by FEBIAC.

The characteristics of the simulation are the following:

- There is a general increase in crude oil resource costs.
- CNG consumer price increases to 1.20 EUR in 2030.
- Gasoline consumer price increases to 1.60 EUR in 2030 due to an increase in crude oil price. Excise taxes remain constant but the user price increases by 40% compared to the base case.
- Diesel consumer price increases to 1.60 EUR in 2030 due to an increase in crude oil price and excises. This is an increase of 64% compared to the initial situation in 2030.
- Gasoline and diesel excise taxes converge by 2020 and from 2020 on gasoline and diesel prices evolve together.
- LPG prices evolve with the crude oil price.
- Biofuel resource costs remain constant. As a consequence, extra tax revenues will be generated. The reason for this is that it is assumed that biofuels will be exempted from taxes (or even subsidised), such that the price of diesel and petrol fuels at the pump is not influenced by the fact if biofuel additives are added or not. In other words, the difference in resource costs between pure diesel/petrol and pure biofuel is compensated by a tax exemption/subsidy for the biofuel. The

[16] Also Dutch research sponsored by the Dutch Ministery of traffic (Ministerie van Verkeer en Waterstaat) shows the beneficial effects of systems of variable roadpricing (March 2005).

higher the diesel and petrol resource cost, the lower the needed tax exemption/subsidy for biofuels. (Annex 3 - biofuels)

Note that public transport fares are not altered in this scenario.

The scenario inputs are summarised in Figure 38. SIM stands for the values in the simulation.

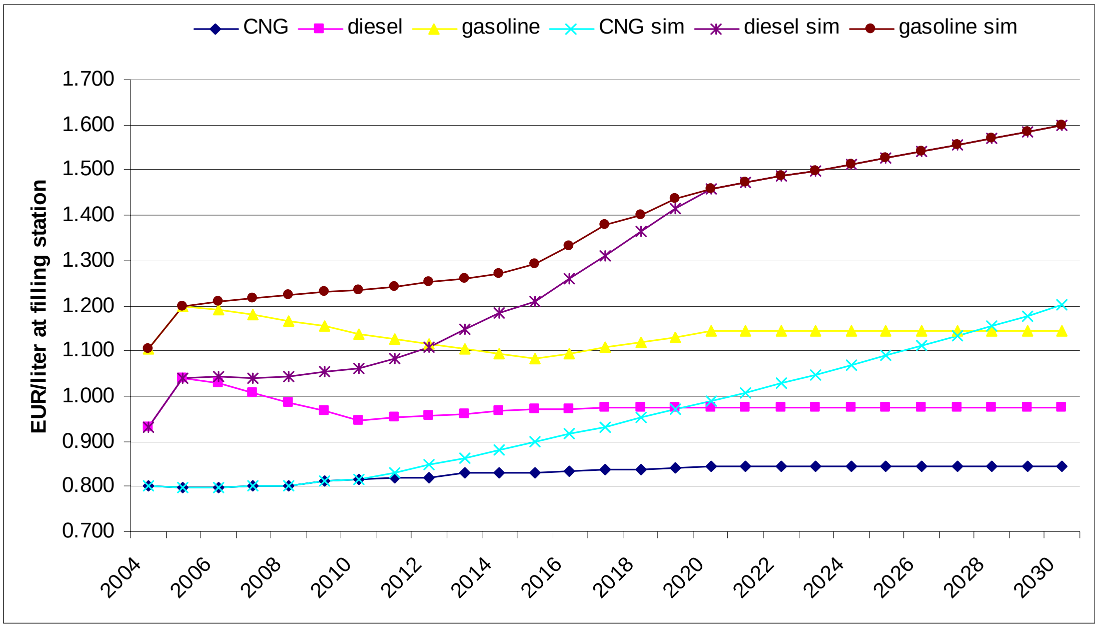


Figure 38: comparison of evolution of fuel prices in basecase and in simulation

It is also important to keep in mind for this scenario that a part of it is determined by a policy measure (harmonisation of diesel and gasoline taxes) and another part is determined by other exogenous factors (increase of resource cost of fuels related to an exogenous change in crude oil prices).

9.4.2 Results: comparison between base case and simulation

9.4.2.1 Effects on transport volumes

This scenario causes an important increase in fuel prices for private road transport. Fuel prices for the other modes have not been adapted. As a consequence global transport volumes decrease and transport choices are oriented towards public transport.

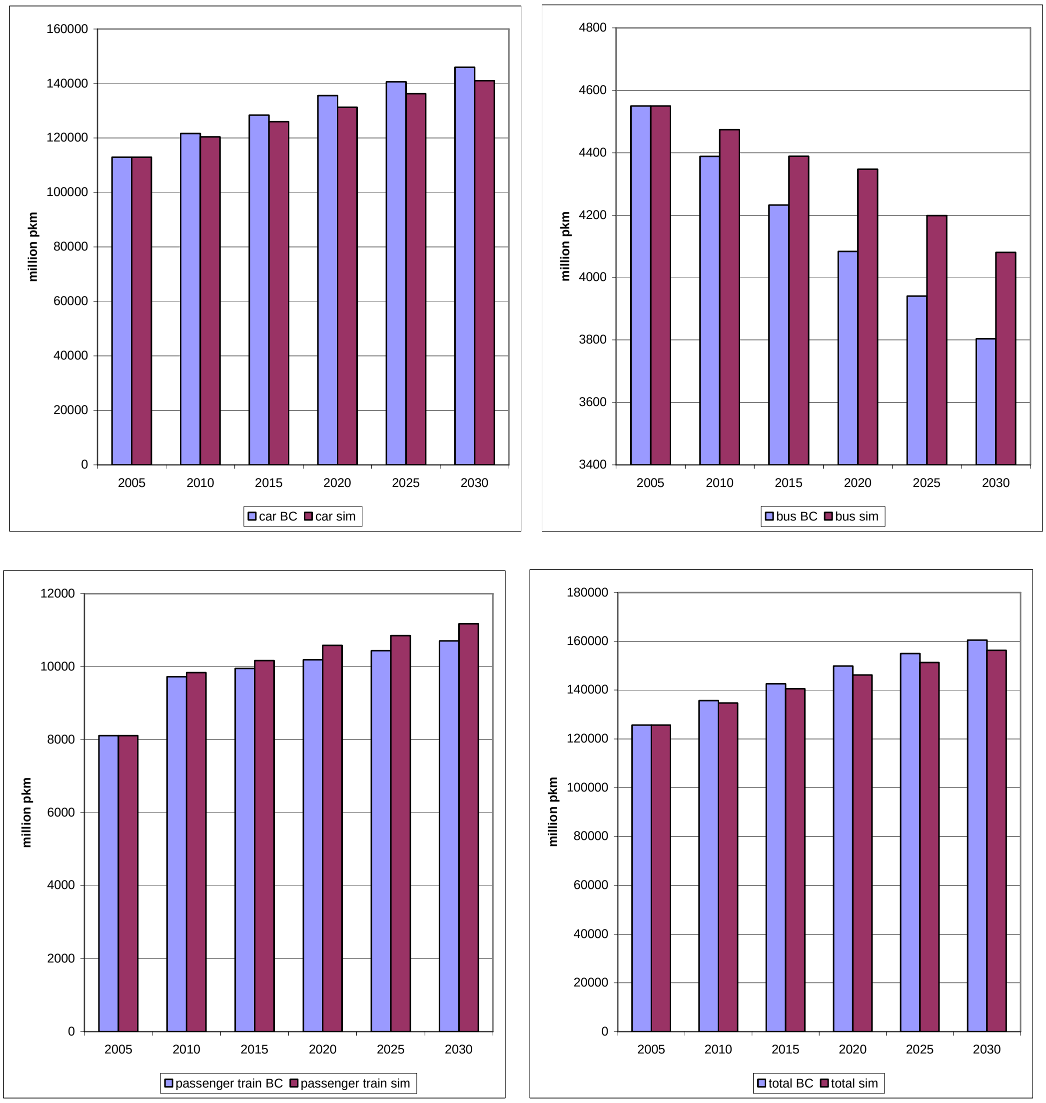


Figure 40: Effects on person kilometres for different modes

Total *person kilometres* decrease by 2.6% in 2030. Person kilometres by car decrease by 3.3% while person kilometres on buses and trains increase by respectively 7.3% and 4.4% in 2030. The latter train and bus km increase covers only a small part of the decrease in car km due to the low absolute transport volume of train and bus in the basecase.

The results are similar for transport of goods. Ton kilometres decrease as a whole by 3.9% in 2030. Heavy duty kilometres are reduced by 5.9% while inland waterways and rail kilometres increase by respectively 5.2 and 7.1%.

At the start of the period, the effects are smaller as fuel prices increase in a progressive way.

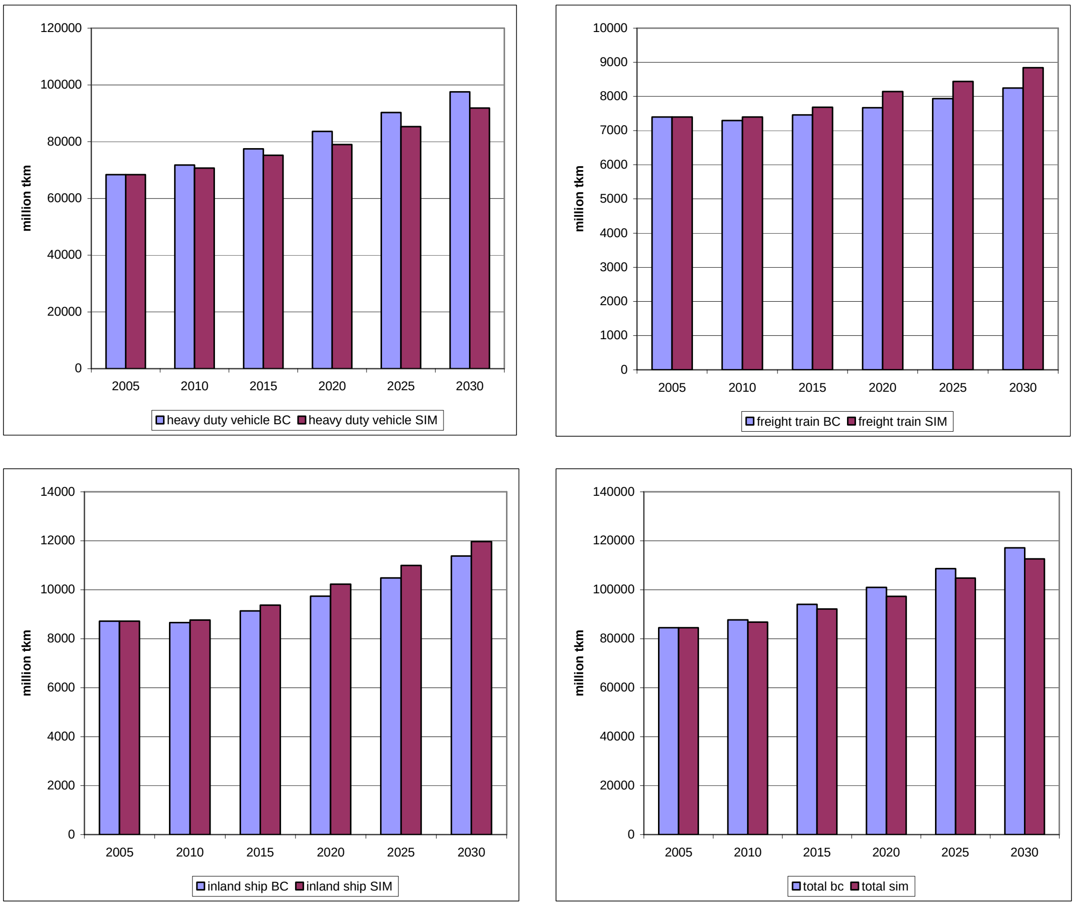


Figure 39: Effects on ton kilometres for different modes

9.4.2.2 Effects on exhaust emissions

The reduction in transport volumes causes a reduction in emissions of all pollutants. Figure 40 shows the evolution for CO_2 exhaust emissions. The evolution is similar for the emissions for the other pollutants. There are nevertheless differences in the evolution as also the vehicle stock changes due to the changes in relative fuel prices, and the influence is different for HDV and passenger cars.

In 2030 CO_2 emissions are reduced by 5.3%, NO_x emissions by 4.4%, PM_{10} emissions by 4.2% and VOC emissions by only 2.2%. The latter low reduction is a consequence of the fact that more CNG cars enter the fleet. The small reduction in VOC is the net result of a decrease in NMVOC emissions and an increase in CH_4 emissions. The CH_4 emission increase is due to the increase in the use of CNG cars.

The reduction in emissions are more important than the reductions in vehicle kilometers. The reason are changes in the vehicle stock as described in the next paragraph.

Also for emissions effects are biggest at the end of the period.

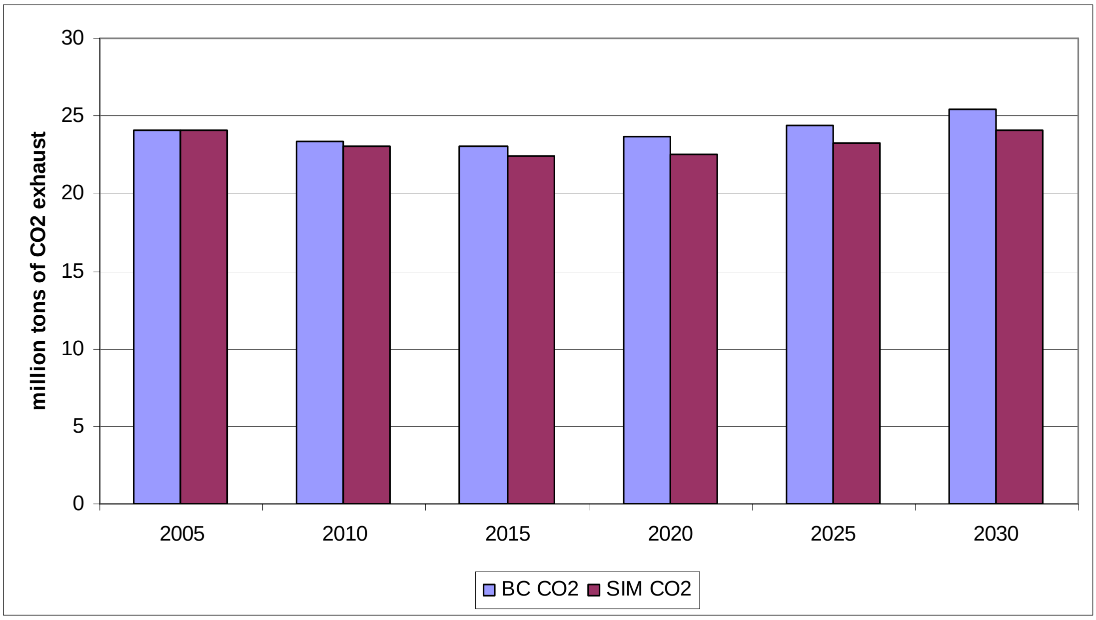


Figure 40: Evolution of CO_2 exhaust emissions

9.4.2.3 Effects on vehicle fleet

Figure 41 shows the effects on the passenger car stock of changing fuel prices. The vehicle fleet as a whole decreases by 3.2% in 2030 due to the different fuel prices. The passenger car gasoline stock decreases even more, 6.2% compared to the basecase. Diesel car stock is reduced by 3.7%. In spite of a slight increase in the price of CNG, CNG cars become more important in the fleet. Their number increases by 5.1% in 2030.

The, at first view, surprising decrease in gasoline cars can be explained by the increase in CNG cars[17] and by the fact that gasoline cars are less fuel efficient than diesel cars. With higher fuel prices, fuel efficiency becomes more important.

The fleet of HDV is reduced by 7.2% in 2030.

Effects are smaller at the start of the period as fuel prices increase in a progressive way.

[17] A CNG cars are based on gasoline engines.

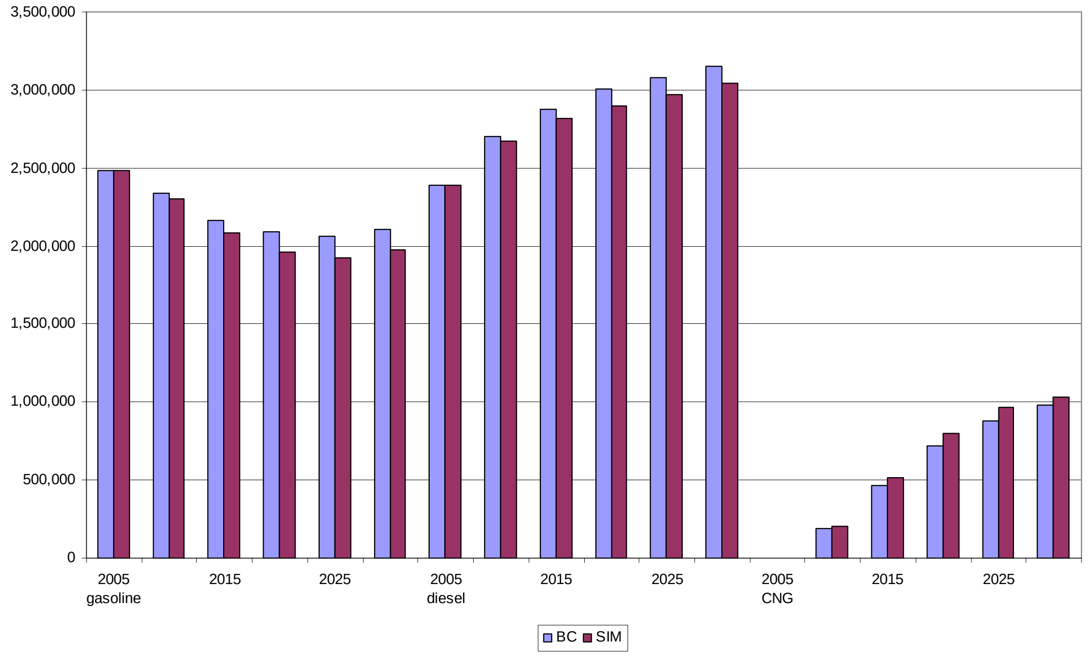


Figure 41: effects on the passenger car fleet of changing fuel prices

9.4.2.4 Effects on taxes

The fixed taxes decrease by in between 1 and 4% over the simulation period. The reason of this decrease is the decrease in the vehicle fleet due to the increase in the fuel cost. The fuel cost increase is maximum at the end of the period and as a consequence also the decrease in fixed taxes.

The variable tax increases by more than 30% during the last decade. This is due to the nearly 50% excise increase on diesel fuel during this period compared to the base case. The gasoline excises remain constant. There is also an overall reduction in fuel consumption due to a decrease in transport volume.

The small decrease in VAT on fixed resource costs is due to the decrease in the vehicle fleet. The increase in VAT on variable resource cost is due to the increase in fuel prices.

The figure below shows the changes in tax revenues.

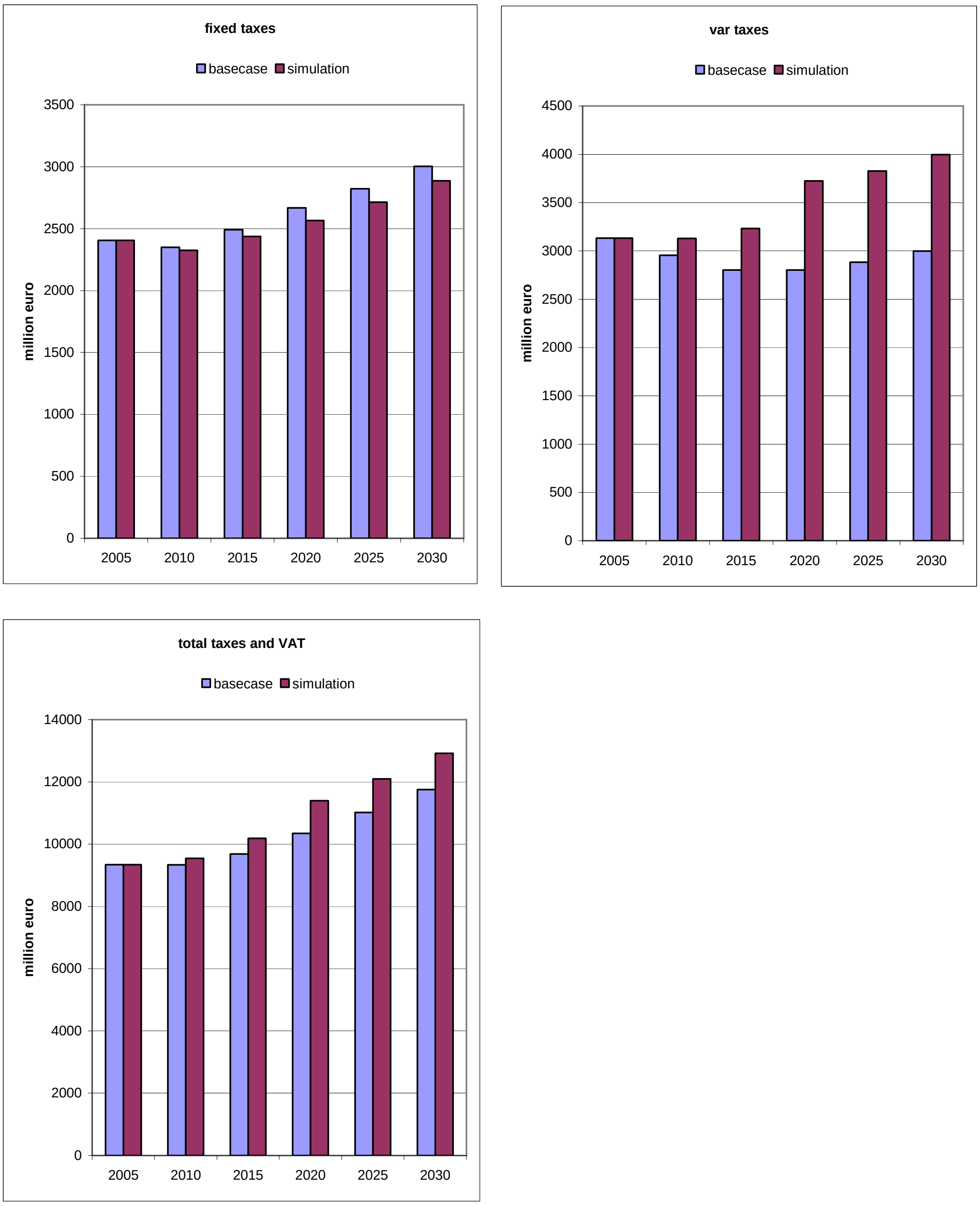


Figure 42: Effects on different tax revenues from private road transport in the fuel scenario (taxes in million EUR; changes in %)

9.4.2.5 Overall welfare effects

To assess the global effect of the change in fuel prices, all changes in the different parameters are monetized (see paragraph 10.1). Table 6 gives an overview of those changes. A negative sign means that there is a loss of welfare. It is normal that with an increase in a resource cost, the utility for consumers and producers is reduced. (producer and consumer surplus measure this) The increase in tax revenue (excises) has a small positive effect if it is recycled in a reduction of other general taxes (last but one line in the table). If it is recycled in a reduction in labour tax, the effect is more positive (last line in the table). Also in the latter case, the negative effect of the increase in resource costs cannot be compensated for by an the redistribution of extra taxe income.

The global welfare change in this scenario is negative in any case, -13018 EURO with tax recycling in general taxes, -8211 with tax recycling in labour taxes.

Table 6: welfare effects of changes in fuel prices (million euro)

	2005	2010	2015	2020	2025	2030
household utility	-2	-575	-1,136	-2,129	-2,262	-2,626
producer costs	0	-322	-677	-1,403	-1,478	-1,702
external cost CO2 changes	0	4	11	26	27	30
external cost Nox changes	0	10	18	34	35	38
external cost PM changes	0	10	14	23	25	26
extrarnal cost of SO2 changes	0	14	29	54	59	64
external cost of VOCchanges	0	2	4	8	7	9
If transport tax replaces a general tax						
cost of public funds (general)	0	101	271	605	630	666
welfare net present value in 2005 (general)	-13,018					
if transport tax replaces a labour tax						
cost of public funds (labour)	0	341	869	1,897	1,956	2,077
welfare net present value in 2005 (labour)	-8,211					

9.4.2.6 Comments:

This second scenario has some similarities with the first scenario, but also some differences. In this fuel scenario only fuel prices increase, but both the tax and the resource part increase and relative prices of different fuels change. In the first scenario, the general transport price increases only due to an increase in taxes. Also non fuel transport taxes are increased. In the first scenario the redistribution of taxes could benefit society as a whole and increase global welfare. In the second scenario, the use of taxes can only limit the negative welfare effects of an increase in the resource cost of fuels for society as a whole.

9.5 Scenario: Differentiated road taxes

9.5.1 Definition of scenario

Due to the introduction of more stringent emission standards, new vehicles become cleaner. As a consequence, the relative small segment of old vehicles cause a relative important share of the emissions.

This simulation assesses a policy to differentiate road ownership taxes in function of emission standards. The FPSMT calculated new levels of ownership taxes differentiated over euro standards, CO2 emissions and over time. The levels were calculated to maintain the actual revenues from registration taxes and road ownership taxes (Annex 8).

To enable TREMOVE to perform this simulation, the standard vehicle stock module has been modified[18]. The vehicle scrappage functions have been adapted. In the standard base case, the total scrappage is not subdivided in an endogenous and an exogenous part. In the adapted scrappage module for this simulation, endogenous and exogenous scrappage are modelled separately.

The endogenous scrappage is based on the idea that there is an age dependant probability of breakdown. Yearly maintenance and repair expenditures are needed to keep vehicles operational. Users will decide whether they keep the vehicle one more year or not. This decision will depend on the actual market value of the car and the estimated repair and maintenance expenditures. The decision will also be influenced by taxes or subisidies, depending on the age of the vehicle. In the case of this scenario, the difference in road ownership taxes is taken into account.

The exogenous scrapping represents scrapping of cars that can no longer be repaired. Also this scrappage is age dependant.

9.5.2 Results: comparison between base case and simulation

9.5.2.1 Effects on transport volumes and exhaust emissions

Figure 43 shows that the new taxation scheme has only limited effects on transport volumes. No modal shifts are observed. This observation is not surprising. The average ownership tax level hardly changes in this scenario. It was the aim to maintain tax revenues at the base case level.

Effects on emissions are also relatively small. Figure 43 makes this clear. Reductions in PM_{10} emissions are largest. This is due to the faster penetration of euro 5 cars with this differentiated tax scheme. Due to the tax difference, users scrap their old cars earlier and replace it with a new car. From 2011 this new car is by definition a euro 5 car. The new euro 5 diesel cars emit significantly less PM_{10} than the pre- euro5 cars.

[18] For this reason, the new base case for this scenario, including this modeling modification, is slightly different compared to the base case mentioned earlier in this report

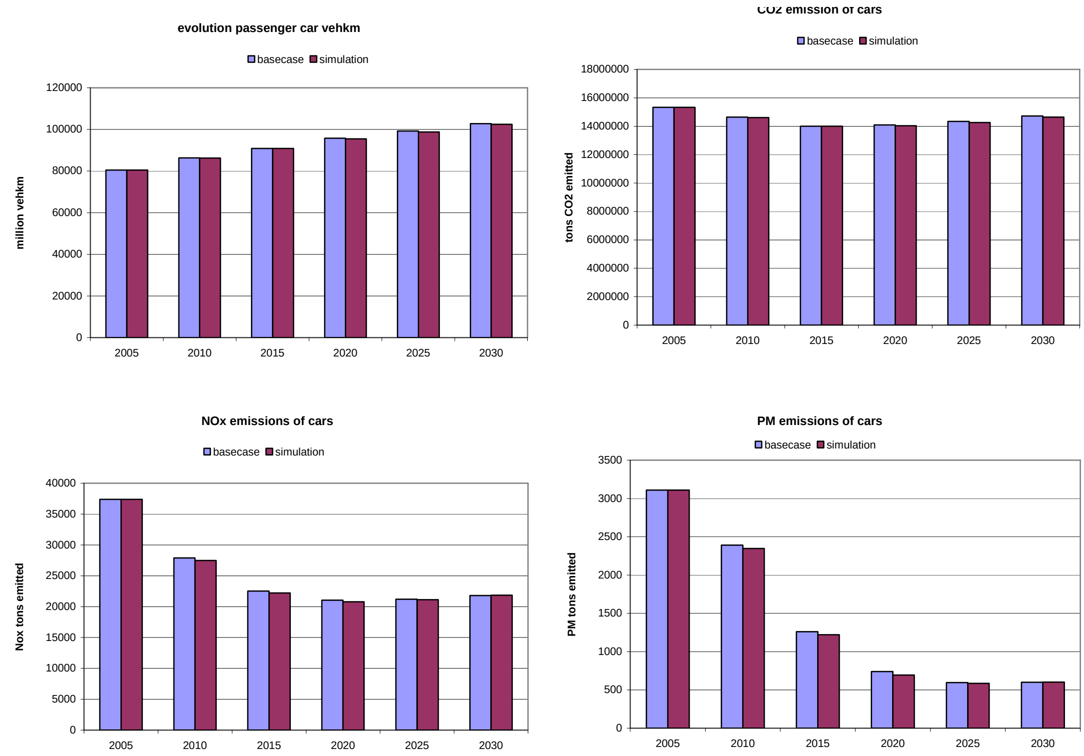


Figure 43: effects on transport volumes and emissions of passenger cars in the differentiated tax scenario

Figure 44 zooms in on the emission reductions thanks to the differentiated taxes. Emissions of PM_{10} are reduced by between 1% and 4 % in the 2006-2025 period. The reductions of other pollutants are maximally 1%. The reduction in CO_2 is the only durable reduction. This reduction is still present in 2030. The reason is that tax scheme also gives an advantage to CO_2 efficient technologies like hybrids and that consumers can choose between CO_2 efficient (hybrids) and less CO_2 efficient vehicle (non hybrid).

Figure 44 shows two peaks in the reduction of PM_{10} emissions one in 2006, another in 2019. The reason for those peaks is the evolution in the vehicle stock. In 2006, the moment of implementing the policy, some pre euro 1 vehicles are still present in the base case fleet. These are replaced by euro 4 and to a lesser extent by euro 5 vehicles. In the following years, the cars replaced are less polluting euro 1 and euro 2 vehicles. The effect of this replacement on emissions is therefore smaller.

From 2011 on the new sold cars are exclusively euro 5 cars. These euro 5 cars emit significantly less PM_{10} than euro 4 cars. The effect of the replacing old cars by new cars becomes therefore again bigger. From 2020 on, the number of pre euro 5 cars decreases and so does the potential for replacement by cleaner cars. As a consequence, the emission reductions get smaller again and in 2026 the effect of the measure has disappeared.

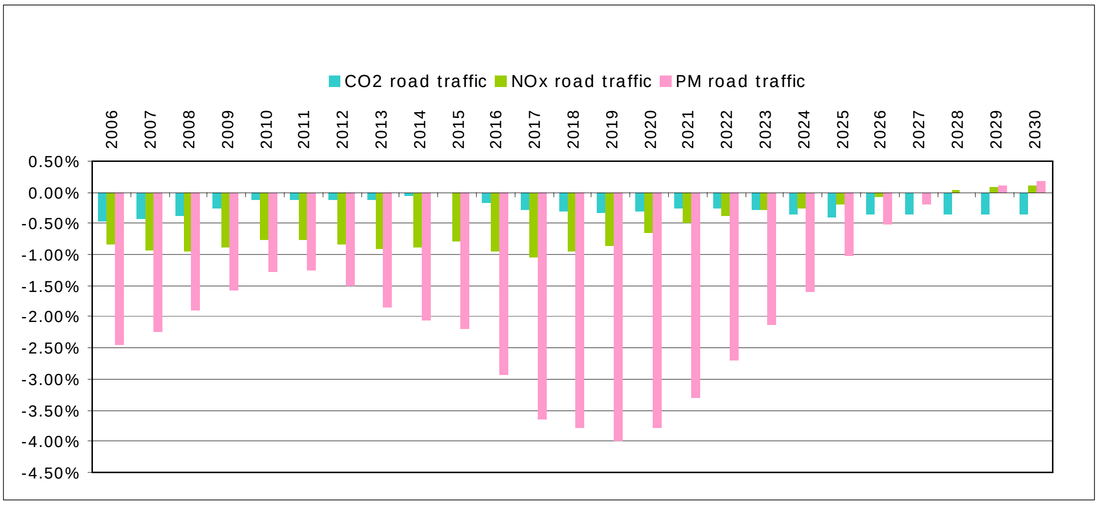


Figure 44: effects of differentiated road taxes on total emissions of road trafic

9.5.2.2 Effects on vehicle fleet

Faster penetration of euro 5 cars

Table 7 shows the evolution of the fleet in function of emission standards. The expected tendency of a faster penetration of euro 5 cars in the simulation compared to the base case is confirmed.

For diesel cars, there is an increase of between 2% and 3% in the number of euro 5 cars.

Table 8 shows that also a shift to hybrid cars can be observed. The reason is the lower hybrid cars road taxes. These taxes remain also lower in the future. As a consequence, the change is durable. .

Table 7: Evolution in diesel and gasoline and CNG fleet in function of emission standards

		2010			2015			2020			2025			2030		
fuel type	vehicle technology	BC	SIM	change %	BC	SIM	change %	BC	SIM	change %	BC	SIM	change %	BC	SIM	change %
gasoline and CNG	pre Euro	45277	42142	-6.9	2437	2027	-16.9	28	18	-35.4	0	0	-48.9	0	0	-100.0
	Euro 1	111170	101939	-8.3	15035	13880	-7.7	628	571	-9.1	5	4	-13.4	0	0	-100.0
	Euro 2	196011	192595	-1.7	44801	42860	-4.3	4362	4172	-4.4	103	97	-5.8	0	0	-9.2
	Euro 3	502399	503196	0.2	205652	203927	-0.8	45623	43731	-4.1	4630	4482	-3.2	146	141	-2.8
	Euro 4	1414513	1445384	2.2	1095056	1120483	2.3	510107	502290	-1.5	118766	115263	-2.9	12432	12190	-1.9
	Euro 5	147711	147950	0.2	1192518	1196161	0.3	2175626	2181937	0.3	2726662	2706205	-0.8	2963209	2923712	-1.3
diesel	pre Euro	6768	7	-99.9	264	0	-100.0	6	0	-100.0	0	0	-100.0	0	0	-100.0
	Euro 1	60373	13135	-78.2	3855	0	-100.0	150	0	-100.0	3	0	-100.0	0	0	-100.0
	Euro 2	279404	263598	-5.7	35122	3190	-90.9	1819	0	-100.0	56	0	-100.0	1	0	-100.0
	Euro 3	931563	931241	0.0	434468	383495	-11.7	55761	4984	-91.1	3833	583	-84.8	259	64	-75.2
	Euro 4	1231988	1285050	4.3	905345	940016	3.8	412735	357983	-13.3	55233	18247	-67.0	4530	1891	-58.3
	Euro 5	301309	307432	2.0	1578816	1611392	2.1	2606808	2694180	3.4	3111838	3142050	1.0	3254609	3270145	0.5
total		5228486	5233669	0.1	5513369	5517431	0.1	5813652	5789865	-0.4	6021129	5986931	-0.6	6235186	6208144	-0.4

Table 8: Evolution in hybrid and conventional vehicles

	2010			2015			2020			2025			2030		
vehicle type	BC	SIM	change (%)	BC	SIM	change (%	BC	SIM	change (%	BC	SIM	change (%	BC	SIM	change (%)
conv. diesel	2,811,404	2,800,463	-0.4	2,597,867	2,554,468	-1.7	2,324,346	2,229,567	-4.1	2,146,540	2,047,423	-4.6	2,101,614	2,006,465	-4.5
hybrid diesel	0	0		360,003	383,624	6.6	752,933	827,579	9.9	1,024,423	1,113,457	8.7	1,157,785	1,265,635	9.3
conv. gasol	2,084,305	2,118,653	1.6	1,804,274	1,875,581	4.0	1,600,474	1,650,470	3.1	1,464,566	1,483,925	1.3	1,408,429	1,388,581	-1.4
hybrid gasoline	136,022	153,918	13.2	259,299	298,396	15.1	398,948	461,978	15.8	525,813	605,164	15.1	626,652	720,857	15.0

vehicle age

Together with the increased presence for newer cars, the scrappage of older cars is also influenced. TREMOVE expects an increased scrappage for cars of 10 years and older due to the modified road tax scheme in the first period of the simulation period.

In the later years of the simulation period, scrap of older vehicles is not longer stimulated by the car sheme as also those vehicles comply already with the euro 5 standard. In 2030, even vehicles of 20 years comply with the euro 5 standard. Figure 45 illustrates the smaller number of older cars in the simulation with a differentiated tax scheme.

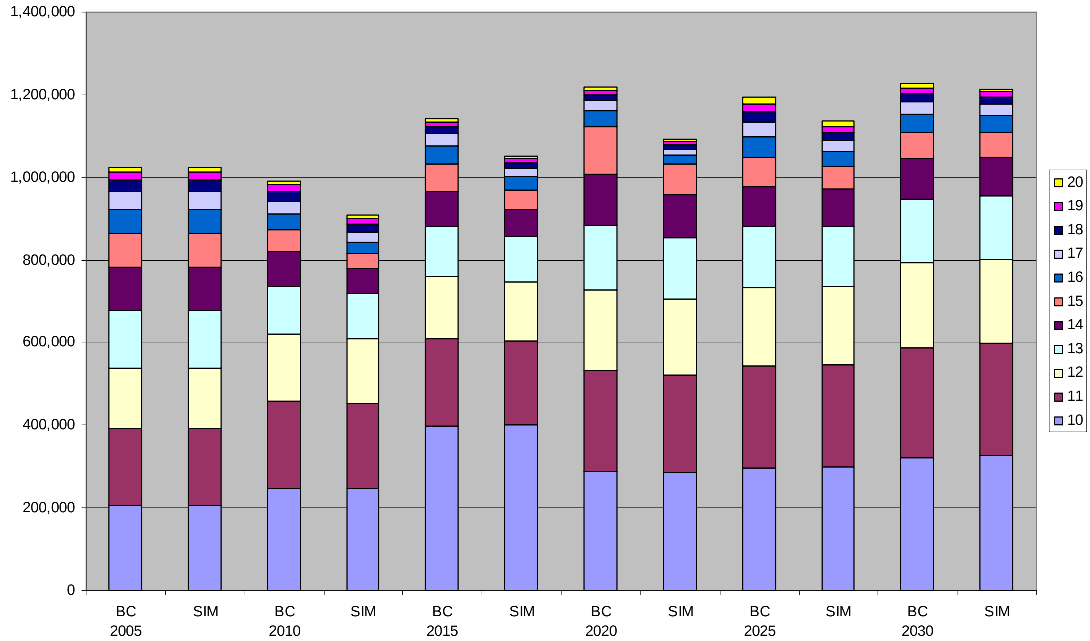


Figure 45: Vehicle fleet of between 10 and 20 years of age in base case and simulation

9.5.2.3 Effects on taxes

The overall tax effect is small, as illustrated in the table below. The biggest change can be observed in the fixed road taxes. This is logic as the fixed taxes were the only taxes that have been changed in this scenario. In the beginning of the simulation period, tax revenues decrease slightly. Old cars paying high taxes are replaced by new cars paying less taxes. At that time the potential for replacement of older cars is biggest and a lot of cars are replaced. Once the first replacement phase passed, the potential for replacement of older cars becomes much more limited and less cars are replaced. At the end of the simulation period, tax revenues increase somewhat due to a higher average tax level in the simulation than in the base case.

Table 9: Evolution of different kind of car taxes over the simulation period for the differentiated tax scenario (BC= base case; SIM= simulation)

	2010			2015			2020			2025			2030		
taxkind	BC	SIM	change	BC	SIM	change	BC	SIM	change	BC	SIM	change	BC	SIM	change
fixed tax	2,310	2,294	-0.7	2,450	2,392	-2.4	2,618	2,759	5.4	2,785	2,999	7.7	2,970	3,151	6.1
var tax	2,885	2,889	0.1	2,737	2,764	1.0	2,746	2,774	1.0	2,850	2,873	0.8	2,982	2,999	0.6
VAT fixed	1,655	1,660	0.3	1,887	1,893	0.3	2,141	2,148	0.3	2,340	2,343	0.1	2,541	2,543	0.1
VAT variable	2,305	2,303	-0.1	2,456	2,461	0.2	2,682	2,677	-0.2	2,916	2,914	-0.1	3,131	3,123	-0.2
total	9,155	9,145	-0.1	9,530	9,509	-0.2	10,188	10,357	1.7	10,891	11,130	2.2	11,623	11,817	1.7

9.5.2.4 *Overall welfare effects*

The overall welfare effects are rather limited. Utility effects for consumers are limited as private transport prices hardly change on average. The same is true for the costs for producers. For the environmental effects, there is a peak in the effect around 2020, but the effect is not durable. There is a small durable reduction in CO_2 emissions. Concerning taxes, the effects are also limited conform the policy objective.

Detailed welfare effects are shown in the table below.

Table 10: welfare effects of the differentiated tax scenario (million euro)

	2005	2010	2015	2020	2025	2030
household utility	0	-11	-19	-242	-355	-236
producer costs	0	-1	-1	-32	-45	-30
external cost CO2 changes	0	0	0	1	2	2
external cost Nox changes	0	6	4	3	1	-1
external cost PM changes	0	9	8	10	2	-1
extrarnal cost of SO2 changes	0	-2	-6	-4	-3	-2
external cost of VOCchanges	0	1	2	3	3	3
if transport tax replaces a general tax						
cost of public funds (general)	0	-7	-16	90	128	109
welfare net present value in 2005 (general)	-754					
if transport tax replaces a labour tax						
cost of public funds (labour)	0	-21	-48	310	441	367
welfare net present value in 2005 (labour)	677	0	0	0	0	0

9.5.2.5 *Comments*

A limited reduction in emissions, especially in PM_{10} emissions, is obtained without an increase in taxes. It is the only measure that is able to decrease emissions without influencing the transport volume.

The analysis could be completed by answering the two understanding questions:

What happens with the scrapped vehicles and what is the environmental impact of it? What about poor people that cannot afford to buy a new car, but will be obliged to pay higher car road taxes?

9.6 Scenario results: summary, comparison and conclusion

Below an overview of the qualitative effects are given. Figure 46 summarizes the quantitative effects.

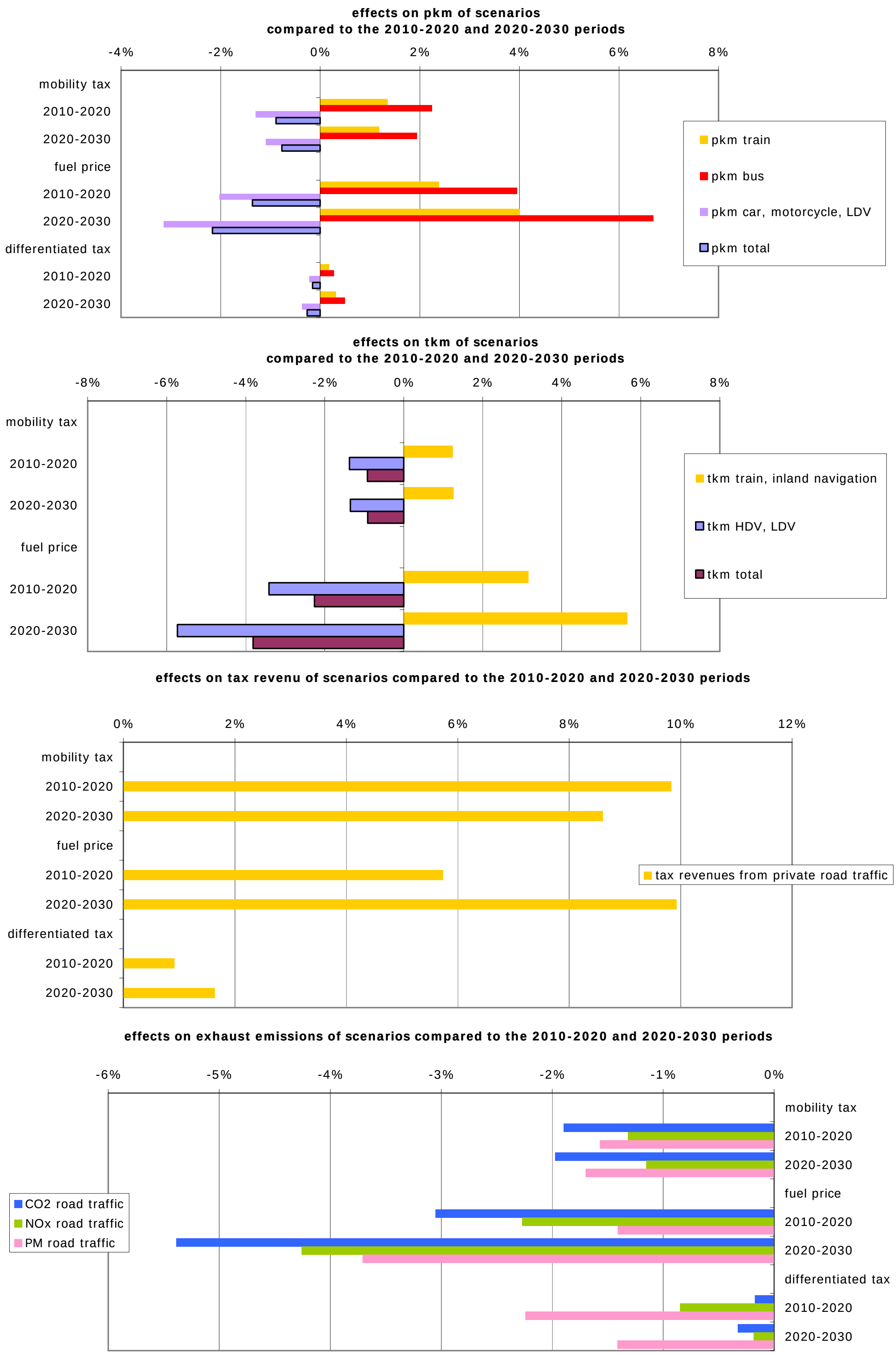
The *mobility tax and the fuel price scenario* have similar effects:

- price of car transport increases
- transport volume decreases
- transport via other modes increases; bus and train for passenger transport, rail and inland navigation for freight transport
- vehicle stock composition changes towards more fuel efficient vehicles, diesel and hybrid vehicles
- tax revenues increase
- emission decrease for all pollutants in the same order of magnitude as the decrease in transport volume.

The effects are strongest for the fuel price scenario as the cost of car transport increases most in the this scenario. Changes in tax revenues are nevertheless similar in both scenarios. The price increase in the fuel price scenario is not only due to the increase of excises but also to the increase of the crude oil price.

The *differentiated tax scenario* shows another combination of effects than those described above:

- price of car transport remains stable
- transport volumes remains stable
- there is no significant modal shift
- vehicle stock composition changes. More recent cars enter the stock (emitting less PM_{10})
- tax revenues increase slightly
- emissions decrease especially for PM_{10} between 2006 and 2026.



welfare difference (million euro)	mobility tax	fuel price	differentiated tax
tax replacing labour tax	9655	-8211	677
tax replacing general tax	-5,333	-13,018	-754

Figure 46: overview of scenario results

This is the only scenario *decoupling transport volumes and emission reductions* thanks to a faster introduction of newer and therefore significant cleaner cars.

For each policy TML calculated also a measure for the change in *welfare*. The use of taxes is crucial in this evaluation. It is important to be aware that taxes cannot be considered as a cost for society. Transport taxes for non business trips have the advantage that they do not distort much the economy unlike labour taxes. Furthermore transport taxes, especially variable road pricing that was not treated here, reduce external social, environmental and congestion effects. Other studies show that a variabilisation of taxes in function of time and place can have significant effects on congestion. Emission reductions of such a measure can be considered as an interesting side effect of the policy.

10 Conclusions

Less negative health effects thanks to emission reductions

The study shows important reductions in exhaust emissions from road transport for particulate matter (PM_{10}) -90%, nitrous oxide (NO_x) -70%, volatile organic compounds (VOC) -86% and carbon monoxide (CO) -86% between 1990 and 2030. A part of these emission reductions is already achieved. Another part of these reductions will be achieved in the future. Between 2005 and 2030 PM_{10} exhaust emissions will still be reduced by 80%, those of NOx by 50%, those of VOC by 50% and those of CO by 40%. These pollutants cause negative health impacts. The important reductions are obtained in spite of an important increase in vehicle kilometres (+75%) from road traffic.

The reason for the emission decrease is the European Commission emission standards legislation translated in the euro standards from 1992 on. Those standards tightened in 4 steps until now and will probably further be tightened in 2011 with a euro 5 standard for passenger cars. An example: The gasoline euro 4 emission standard admits only 3% of the pre euro standard emissions for NO_x.

Green house gas emissions: evolution in 3 phases

The carbon dioxide (CO_2) emissions grow by more than 20% over the 1990-2030 period. This global evolution hides three phases.

Between 1990 and 2000 CO_2 exhaust emissions increase at the same rhythm as transport volumes.

Between 2000 and 2015,a decoupling between decreasing CO_2 exhaust emissions and increasing transport volumes takes place. The reasons for this decoupling are multiple:

- an increasing share of diesel cars in the fleet
- the penetration of hybrid cars in the fleet
- the penetration of CNG cars in the fleet
- the ACEA agreement between the car industry and the European Commission to limit emissions of new cars in 2009 to 140g/km
- the use of biofuels, 5.75% in 2010 and 8% in 2020 as foreseen in the European directive

Between 2015 and 2030, CO_2 emissions increase again because no additional fuel reduction beyond the ACEA agreement has been integrated in the model and vehicle kilometres continue to increase. Further on, nearly all new vehicles entering the fleet have air conditioning equipment causing some extra fuel consumption, while not all vehicles they replace had this equipment.

Future measures to reduce CO_2 emissions in the transport sector remain necessary.

As mentioned, the use of biofuels has a positive effect on green house gas emissions. Concerning the other emissions the effect is less clear and the effects are dependant on the biofuel type used and its production method. Biofuel use can increase emissions of PM_{10} and NO_x if the production of the fuels (conventional fuel compared to bio fuel) is taken into account.

The vehicle fleet undergoes considerable changes

In 2030, the model estimates that 30% of the fleet will be hybrid cars while more than 15% will be CNG cars/

An additional significant emission reduction by a fiscal policy is difficult

The model simulations based on different scenario assumptions, show that:

- Increasing road taxes (without a variabilisation in function of time and place) and fuel prices have effects, though limited, on the transport volumes and emissions.
- The introduction of a vehicle ownership tax scheme dependant on the euro standard to which cars comply obtains some emission reductions. Those emissions take place earlier than without such a scheme. Reductions are most important for PM_{10}. This effect is obtained without a notable increase in taxes.

For a good interpretation of the policy simulations, TML emphasizes that:

- a tax cannot be considered as cost for the society. The use of the taxes can on the other hand influence the gains or losses of a policy.
- a variabilisation of taxes in function of time and place can have significant effects on congestion. Emission reductions of such a measure can be considered as an interesting side effect of the measure.

Bibliography

AEA (2005) Updated results for BeTa, the Benefits Table Database, report for EU

Service Contract for carrying out cost-benefit analysis of air quality related issues, in particular in the clean air for Europe (CAFE) programme
I. De Vlieger, L. Pelkmans, S. Verbeiren, E. Cornelis, L. Schrooten, , L. Int Panis – VITO S. Proost, J. Knockaert – ETE-CES (2005) Sustainability assessment of technologies and modes in the transport
sector in Belgium (SUSATRANS) – Final report, Research contracts n° CP/67/431, CP/01/432 sponsored by the Belgian Science Policy

De Ceuster G. (ed.), Franckx L., (ed.), Van Herbruggen B., Logghe S., Van Zeebroeck B.,. Tastenhoye S, Proost S., Knockaert J., Williams I., Deane G., Martino A., Fiorello D. (2005) TREMOVE 2.30 Model and Baseline Description, report to EC – DG Environment.

ECONOTEC, Emission inventory of ozone depleting substances, HFCs, PFC's and SF6 in Belgium for 2003 and sectoral calculations (2004), Study commissioned by the Vlaamse Mili!eumaatschappij (VMM)

European Commission, Consultation paper How to considerably reduce greenhouse gas emissions due to mobile air conditioners (February 2003)

European Commission (2001), European transport policy for 2010: time to decide.

European Commission COM(2005) 683 final 2005/aaaa (COD) Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on type approval of motor vehicles with respect to emissions and on access to vehicle repair information, amending Directive 72/306/EEC and Directive ../../EC

FEBIAC (FOD-DIV) stock gegevens 1991-2004 (jaarlijks wagenpark ontvangen)

FOD mileage gegevens 2001-2004 (publicatie opmeting van de jaarlijks afgelegde kilometers)

FOD voertuigkilometers vanaf 1970 (digitale xls sheet ontvangen van dhr Labeeuw).

FOD bedrijfsvoertuigenpark 2004

Furness K.P. (1965) *Time function iteration* – Traffic Engineering + Control (7): 458-460.

Hendriksen P., Vermeulen R.J., Rijkeboer R.C., Bremmers D., Smokers R.T.M., Winkel R.G. (2003), Evaluation of the environmental impact of modern passenger cars on petrol, diesel, automotive LPG, CNG, report for the Minestry of VROM, DUTCH LPG Association (VVG) and NGV-Holland.

Hickman (ed.) (1999) MEET Methodology for Calculating Transport Emissions and Energy Consumption. Report to the European Commission.

Immers L.H. en Stade J.E. (2004) Verkeersmodellen – cursustekst H111 verkeerskunde basis.- KULeuven. Zie ook http://www.kuleuven.ac.be/traffic/dwn/h111deel1.pdf

H.J.Kleven and C.T.Kreiner (2003), The marginal cost of public funds in OECD countries: hours of work versus labor force participationCESifo Working Paper Series.

LAT, DTU, PSIAMTK, INFRAS. (2002) Development of a Database System for the Calculation of Indicators of Environmental Pressure Caused by Transport. TRENDS main report to the European Commission

Lewis C.A. (1997) MEET : Methodologies for Estimating Air Pollutant Emissions from Transport. Fuel and Energy Production Emission Factors. Report to the European Commission.

Logghe S. (2005) Het vrachtvolume per voertuigtype en wegtype in België' – Nota voor FOD/FEBIAC

OECD (2003) European Conference of ministers of transport, Reforming transport taxes

Palm, I., Regniet, G., Schmidt, G., Heusch-Boesefeldt (1996) *Ermittlung der Pkw- und Nfz-Jahresfahrleistungen 1993 auf allen Straßen in der Bundesrepublik Deutschland* im Auftrag des Bundesministeriums für Verkehr, Aachen 1996 - Heusch-Boesefeldt

Quirin M., Gärtner S., Pehnt M., Reinhardt G. (2004), CO2 mitigation through Biofuels in the Transport Sector. Main Report funded by FVV Frankfurt, UFOP Berlin FAT Frankfurt, IFEU

Rijkeboer R.C.(TNO), Gense N.L.J.(TNO), Vermeulen R.J.(TNO), (2002), Options to integrate the use of mobile air conditioning systems and auxiliary heaters into the emission type approval test and the fuel consumption test for passenger cars (M1 vehicles) Final report (Service Contract B4-3040/2001/326135/MAR/C1), report prepared for the European Commission (DG Environment)

Schwarz W. (Öko-recherche), Harnisch J. (Ecofys), (2003), Final report on establishing the leakage rates of mobile air conditioners (B4-3040/2002/337136/MARC/C1), report prepared for the European Commission (DG Environment)

Smokers R., Smit R. Compatibility of pure blended biofuels with respect to engine performance, durability and emissions. Report funded by Senternovem, TNO, 2005.

Smokers R, Euro 5 technologies and costs for light-duty vehicles, the expert panels summary of stakeholders responses, TNO, 2005

TNO, Scenarioverkenner, 1998

VUB-etec, ULB-ceese (2001) Schone voertuigen - Verslag WP1 - “Definitie van het begrip Schone Voertuigen”, Brussel

Annex 1 TREMOVE model: structure and principles

Overview of TREMOVE

TREMOVE is a policy assessment model to study the effects of different transport and environment policies on the emissions of the transport sector. It is an integrated simulation model developed for the strategic analysis of the costs and effects of a wide range of policy instruments and measures applicable to local, regional and European transport markets. A detailed report on TREMOVE can be downloaded from www.tremove.org.

The first versions of the TREMOVE model were developed in 1997-1998 by the university of Leuven and Standard & Poor's DRI as an analytical underpinning for the European Auto-Oil II Programme (European Commission, Standard & Poors' DRI, K.U.Leuven, 1999). Other versions of TREMOVE have been developed for different policy studies for different authorities, mainly in a European context especially for the European Clean Air for Europe Programme. The latest TREMOVE version, TREMOVE version 2.41 has also been used in ASSESS to make an assessment of the European white paper on transport. (De Ceuster, Franckx, 2005

For this project some particular adaptations have been introduced to be as close as possible to the Belgian reality. This resulted in a specific TREMOVE-Belgium version.. All relevant transport modes are modelled with a particular emphasis on road transport. The model period has been extended and covers actually the 1990-2030 period, with yearly intervals.

Figure 47 maps the modular structure of TREMOVE. The model performs a year-by-year loop over its modules. The same modules are used for both the construction of the baseline scenario as for the evaluation of policy scenarios.

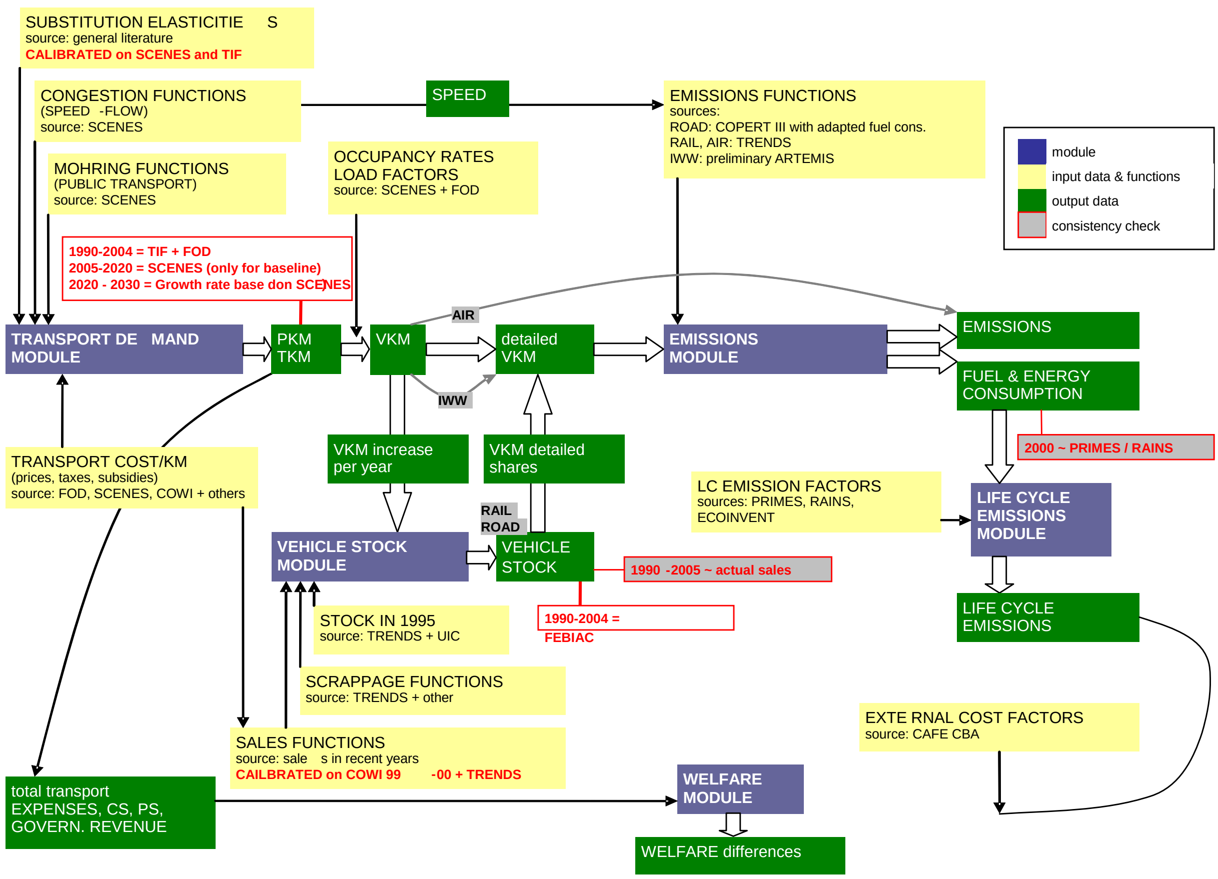


Figure 47 : Modular Structure of TREMOVE 2.41 model

Transport demand

Scope of the TREMOVE demand module

The TREMOVE model of Belgium describes transport flows and emissions in three model regions: one metropolitan area (Brussels), an aggregate of all other urban areas and an aggregate of all non-urban areas. Trips in the non-urban areas are further separated in short (-500 km) and long (+ 500 km - international) distance trips. The model explicitly takes into account that, depending on the area taken into consideration, the relevant modes and road types differ significantly.

The transport demand module calculates, for a given year and transport mode, the number of passenger-kilometres (pkm) or ton-kilometres (tkm) that will be performed in each “model region” of the country considered. Demand is broken down in peak and off-peak demand. With this demand module, the impact of policy measures on the transport quantity of all transport modes is calculated.

Transportation modes for passenger trips comprise small car, large car, light duty trucks, motorcycle, moped, slow mode, bus, train and plane. Freight trips are using inland waterways, freight train, light duty trucks or heavy duty trucks. Furthermore four road types are distinguished as well as three freight categories (bulk, unitized and general cargo) and three passenger trip purposes (non-work, commuting and business trips).

TREMOVE models the transport activities within these areas without explicit network disaggregation. This simplification allows us to calibrate a simple but complete policy simulation model on top of a baseline of transport flows. These baseline transport flows are taken from the SCENES model (ME&P, 2000) which is a genuine network model. Thus, to a certain extent, the TREMOVE demand module is a reconstruction of the SCENES model.

Modelling transport decisions of households and firms

Private transport and business transport are modelled separately in the transport demand module. The demand for private transport (non-work and commuting passenger trips) is the result of the decision processes of all households in a country. Therefore, private traffic demand has been determined assuming that, within the constraints of their available budget, households choose their preferred consumption bundle. I.e. they choose the combination of goods that maximizes their utility. The demand for goods and services follows then from this maximizing behaviour.

The decision processes of households are modelled using nested Constant Elasticity of Substitution (or CES) utility functions (Keller, 1976). These represent the preference relation of all households for the different transport options. Knowing the substitution elasticities between the different transport options, it is possible to model the change in consumed quantities in policy simulations.

The demand for business transport (freight transport and business passenger trips) is modelled as a result of the decision processes within firms. The business transport demand is determined by generalized prices, desired production quantities and substitution possibilities with other production factors.

It is assumed that, in any given year, the production level of all firms in a country is given and kept constant. For a given production level, profit maximization then is equivalent with cost minimization. The cost-minimizing substitution processes is represented by a nested CES production function. At the highest level, there is the total production, which is a function of the components at the lower levels. At the lowest level, the arguments are the inputs in the production process. The latter inputs include, amongst others, freight transportation and business passenger trips.

Transport prices

Transport users react on the generalized price of transport. Therefore, the price is represented as a sum of detailed price components.

The resource cost for transport services consists of the monetary producer costs of all inputs necessary for these services (cars, fuels, maintenance, etc.). The resource costs are calculated in detail in the vehicle stock module or derived from the SCENES model (depending on the mode).

On top of the resource costs, the consumer usually pays taxes or receives a subsidy. Both have been taken into account to calculate the market price. The distinction between user prices and costs is important for the welfare assessment module, as it determines the governments' tax revenue from the transport sector. In the demand module, transport users are assumed to make their decision on the basis of user prices.

Furthermore, time costs are added in the generalized price. Time costs depend on the 'value of time' of the considered travel mode and the travel speed. The speed is modelled explicitly and varies with transport demand, time period and road type. The speed values are also used in the calculation of emissions based on COPERT functions.

Simulations

Baseline transport demand is taken from the SCENES model. The TREMOVE demand module then enables to assess changes in transport demand under various policy scenarios. Policy measures will affect the generalised prices of transport in the demand module. The prices can be affected by technological measures and new taxation or regulation policies. Within the demand module, these new prices will lead to a change transport demand. Overall transport volumes will alter and substitution between modes will occur. As a consequence also congestion, travel speed and the time price of transport will be affected.

Vehicle stock

The demand module produces aggregate transport quantities by mode. The vehicle stock module disaggregates these into detailed vehicle-kilometer figures by vehicle type, vehicle technology and vehicle age. This requires a detailed modelling and forecasting of the vehicle fleet structures for each mode.

Road and rail vehicle fleet evolution is modelled using a classic scrap-and-sales four stap approach (Box below). Each year scrap rates are applied to estimate the number of scrapped vehicles. Total vehicle sales by mode then can be derived by comparing remaining vehicle stock to the stock needed to fulfil transport demands. The following step then is to disaggregate total sales by mode into sales by vehicle type and technology.

Box 1: the four step approach in vehicle stock modelling

- First, for each vehicle category, TREMOVE derives the desired stock. This desired stock depends on the ton and person kilometers asked for by the demand module. These kilometres are dependant on the price used in the demand module, and thus on the policy environment that is modelled.

- Second, for each year *t*, the stock per vehicle category surviving from the year *t-1* is compared with the desired stock needed by transport users in year t. The difference between desired stock and surviving stock is set equal to the total forecasted sales per vehicle category in year *t* for the policy scenario that is modelled.

- Third, the model derives how the total demand for each category is split between different types. For cars this is done using a logit model. Hence, for each vehicle type, we obtain a complete description of the forecasted age structure.

- Fourth, from FPSMT, we have data on how, for each type, annual mileage per vehicle evolves with the vehicle's age. Combing this with the age structure obtained in the previous step allows us to obtain, for each type, an estimate of the number of vkm driven by vehicles of a given vintage.

For cars, motorcycles, light duty trucks and buses the disaggregation by vehicle type is performed using a discrete choice (multinomial) logit model. The logit models have been calibrated on (mainly) data from COWI (COWI, 2001) and EUROSTAT. The most extended logit model is used for car purchase modelling. The market shares of the 16 car types (including 6 hybrid types and 3 CNG types) in total sales are a function of following parameters:

- Engine displacement (< 1.4 litre, 1.4-2.0 litre, > 2.0 litre)
- Fuel type
- Acceleration performance
- Total (lifecycle) cost per vehicle-kilometer

The heavy duty trucks and trains disaggregation in the baseline is based upon exogenous inputs. The share of the four truck weight classes is derived from German and Italian road counts on different road types. The baseline sale shares for trains have been determined such that the 1995-2020 evolution of the train fleet is consistent with the long-term trends in the TRENDS database (Georgakaki, Coffey, Sorenson, 2002)[19]. Both for trains and heavy duty trucks the exogenous assumptions can be changed in policy simulations.

For road vehicles, the vehicle types are further split up according to their technology. The technologies modelled in the baseline correspond with the EU emission standards. They are directly linked to the vintage of the vehicle.

TREMOVE distinguishes 21 inland waterway vessel types, classified according to size and freight category. The model does not include an explicit scrap-and-sales model for vessels. Instead, shares of different vessel types in total transport are exogenous. Though the model includes a module for the simulation of engine replacements/maintenance, retrofit of after-treatment equipment and alternative fuel quality standards. The baseline fleet composition forecast for the 21 vessel types in TREMOVE is based upon detailed Dutch statistics (CBS[20]) and predictions (AVV[21]) on domestic and international movements. Where needed extrapolations to other countries have been performed taking into account differences in inland waterway network characteristics between countries.

No vehicle fleet is modelled for aircrafts. The demand module disaggregates total air transport into 5 distance classes. Fuel consumption and emissions then are calculated using factors that implicitly account for differences in fleet composition for the 5 distance classes.

Fuel consumption and emissions

In the *fuel consumption and emissions module* fuel consumption and exhaust and evaporative emissions are calculated for all modes. Emission factors have been derived consistently from EU sources, thus might deviate from national estimates.

For road vehicles TREMOVE 2.3 emission factors are based upon the copert III emission calculation methodology (Ntziachristos, Samaras, 2000), to which following additions have been made :

[19] Note that, within the ASSESS project, the shares of HST trains in the future fleet has been derived from the SCENES model and its assumptions on the implementation of the TENs.
[20] Dutch Central Bureau for Statistics
[21] Dutch Ministry of Transport, Public Works and Water Management.

- Disaggregation of COPERT diesel car fuel consumption factor into three factors according to engine displacement, based upon EU CO_2 monitoring data[22];
- Upward scaling of COPERT fuel consumption factors for 2002 cars, based upon EU test-cycle monitoring data and information on the difference between test-cycle and real-world fuel consumption (a.o. Van den Brink, Van Wee, 2001);
- Introduction of fuel efficiency improvement factors up to 2009. For cars these are based upon the voluntary agreements between EU and the car industry[23]. For other road vehicles predictions are derived from the Auto Oil II Programme;
- Update of moped and motorcycle emission factors based on recent information (Ntziachristos, Mamakos, Xanthopoulos, Iakovou, 2004);
- Emission factors for CNG buses (based on a.o. MEET : Hickman, 1999), hybrid cars and CNG cars. The assumptions concerning hybrid and CNG cars are detailed in a separate annex.

Fuel consumption and emission factors for diesel trains and aircrafts (by distance class) have been derived from the TRENDS dB (Georgakaki, Coffey, Sorenson, 2002) and pSIA Consult, 2002). For electric trains, trams and metros only total energy consumption (kWh) is calculated in this module.

The fuel consumption and emission factors for inland waterway vessels have been calculated following the *first version* of the approach developed within the ARTEMIS project (Georgakaki, 2003). Factors have been estimated using data on vessel characteristics for the 21 types included in TREMOVE and using estimates on waterway characteristics.

Welfare module

To evaluate policies in TREMOVE, a welfare assessment module has been constructed. Differences in welfare between the base case and the simulated policy scenarios are calculated.

Based on the utility functions for the private transport demand, the aggregate *consumer surplus* of households is quantified. The modelling of business decisions leads to an aggregate measure for the change in *production costs* of firms. The *external costs* caused by emissions are calculated in detail as explained in the next section. The costs of these emissions are also incorporated in the welfare evaluation of policy measures. Additionally, welfare changes stemming from changes in *tax revenues* are incorporated by using the marginal cost of public funds. This latter approach accounts for the options of

[22] The monitoring decision can be found in the Official Journal of the European Communities L 2020, 10.8.2000, p.1

[23] Three agreements have been made. The full texts can be found in the Official Journal of the European Communities L 350, 28.12.1998 p. 58, L 100, 20.4.2000 p. 57 and L 100, 20.4.2000, p. 55.

the government to beneficially use additional tax revenues from the transportation sector to lower taxes in other sectors or to avoid to increase taxes in those sectors. The approach is further explained below.

Accounting for changes in tax revenues between base case and simulation in the welfare module of TREMOVE.

Differences between base case and simulation in taxes and VAT are calculated by the model. These values are transferred to the welfare module for each year and are adapted for the value of marginal cost of public funds. The difference in tax revenue is multiplied by λ, the marginal cost of public funds. λ, expresses the different efficiencies of different taxes.

- λ = 1 when the tax revenue is returned to the households in a lump sum way and when there are no distortions in the economy
- λ = 0 when the money is wasted by the government
- λ > 1 when the tax is more efficient than the tax it replaces

A labour tax for example has a negative effect on the labour market, as it reduces the labour supply and as a consequence social welfare. For Belgium, a country with high labour taxes, each euro that has to be raised by labour taxes has an (in)efficiency cost of 2,52 EUR. At the opposite site, a tax compensating for an externality can be recycled to decrease distortionary taxation. Hence, it increases social welfare beyond its externality correcting effects.

Generally speaking, in a lot of Western European economies, the labour market is among the most distorted markets in the economy. Therefore, if transport taxes enable authorities to avoid more taxes on labour or to reduce these taxes, transport taxes raised have to be multiplied by a factor λ > 1 for the welfare calculation. In reality, things are somewhat more complicated as a road tax supported by a commuter will have an effect comparable to a labour tax. In that case the transport tax has no supplementary beneficial effect compared to the labour tax and λ=1.

In TREMOVE we assume that the transport taxes replace labour or general taxes, or in other words, if no transport taxes were raised, labour or general taxes should be higher. As a consequence, Tremove applies a different λ-value to differences in taxes according to what kind of taxes are replaced by the transportation tax and to whom the transportation tax is applied:

- If a transport tax on commuters replaces a general tax, λ <1 as a supplementary distortion is created on the labour market.

- If a transport tax on commuters replaces a labour tax, λ = 1 (no specific supplementary welfare effect)
- If a transport tax (other than on commuters) replaces a labour tax, there is a positive welfare effect (λ > 1).
- If a transport tax (other than on commuters) replaces a general tax, there is no welfare effect (λ = 1).

Based on the above mentioned paper on marginal costs of public funds, λ values have been derived for all EU15 countries, Norway and Switzerland. For the four new member countries, rather low λ values of Greece have been utilized.
The table below shows the marginal costs of public funds used in Tremove [24]. The first column shows the inefficiency of raising one euro by labour taxes. The second column shows the inefficiency of raising one euro by general taxes. The last column gives the difference between the two other columns, this means the gain obtained if a labour tax is replaced by a general tax, or the loss if a general tax is replaced by labour tax. For Belgium, for example, raising 1 EUR by supplementary labour tax costs 2,52 EUR to society, while raising 1 EUR by a supplementary general tax costs only 1,11 EUR. As a consequence, if a labour tax of 1 EUR (social cost=2.52) is replaced by a general tax of 1 EUR (social cost=1.11), the gain for society is 1.41 EUR. As mentioned above, we considered transport taxes for commuters as labour taxes and transport taxes for other persons as general taxes.

Table 11: Marginal costs of public funds for Belgium

	Labour	general	Difference
BE	2,52	1,11	1,41

Lifecycle emissions

In TREMOVE, a restricted lifecycle assessment module is implemented, focusing on the fuel cycle only. To concentrate on fuel implies that not only operational emissions of vehicles, but also emissions due to production and distribution of the fuel (or electricity) are taken into account. I.e. well-to-tank and tank-to-wheel emissions are calculated. Well-to-tank emission factors for fossil fuels were derived from the Swiss ECOINVENT database (Ecoinvent Centre, 2004). Electricity production emission factors by country have been provided by the RAINS (IIASA, 2004) and PRIMES (Mantzos, Capros) modellers, except for CH_4 and CO emission factors, which have been taken from MEET. These emission factors are not adapted in the future for example cleaner refineries as no data are available to do this.

24 Source: "The marginal cost of public funds in OECD countries: hours of work versus labor force participation", H.J.Kleven and C.T.Kreiner, CESifo Working Paper Series, April 2003

Annex 2 The Scenes model

Scenes

The SCENES transport model is an integrated passenger and freight transport model for Europe that has been developed initially for DG TREN of the European Commission. It was itself a development of a model originated during a preceding European Commission research project, STREAMS.
The SCENES model is a European multi-modal passenger and freight model operating at the NUTS 2 zoning level (e.g. provinces for Belgium) over the twenty-three EU countries excluding Malta and Cyprus. SCENES uses a detailed European network for assignment to highways, rail, inland waterways, ferries and coastal shipping. The freight model is based on a sophisticated regional economic model (REM) using input-output techniques. The passenger model uses a more standard trip generation mechanism. The base year is 1995, and the model is designed for forecasting the effect of a range of different scenarios and policies as far as 2020.
The SCENES model has been used within a number of other recent European Commission projects including ASTRA, MC-ICAM, TIPMAC, IASON, EXPEDITE, SPECTRUM, TREMOVE, ASSESS and the pilot Strategic Environmental Assessment of the Trans-European Transport Networks (TEN-Ts).

Model structure

The modelling structure developed is a comprehensive 'framework' for modelling at the European scale, in that all significant aspects of the transport market are accounted for in one shape or form within the model. It is built up using inputs from the detailed zonal level. Many parameters and data inputs within the model are also specified at the country level. The amount of detailed input required would ideally be met by a harmonised European data set, collated with this application in mind. Of course, this level of data is not currently available. Hence many of the model inputs are estimated from the best data available at the time. Therefore the model can be regarded as an initial (but comprehensive) framework, which could be updated and improved over time as more data becomes available. Some of this sort of improvement was carried out within the TREMOVE project using data provided by the member states.
The structure of the SCENES model is in essence that of a traditional four-stage model, with distinct Generation – Distribution – Modal Split – Assignment components. The first two stages are within the freight and passenger demand model, while the latter two stages are in the transport supply model. However, the costs and times of travel which are output from the transport model feed into the demand model in the form of 'disutilities' (derived from zone-pair travel costs and times)– thus the system encompasses a full feedback between the two models. In this way, changes in the

transport model, be it through transport cost or infrastructure changes, have a bearing on the demand for travel.
The model is designed to produce in the first instance European level transport forecasts. Comprising as it does of a wide range of demographic, economic, socio-economic and transport factors, and being built as a 'bottom up' model from the zonal level, a much greater level of spatial detail is however possible. This level of detail can be achieved because the model comprises all transport and travel, including very short distance trips and non-mechanised modes.

The 15 European Union countries and eight Central and Eastern Europe Countries (CEEC) comprise the 'internal' modelled area. That is, all travel within this area is modelled. The rest of the world is treated as 'external', i.e., passenger travel and freight traffic to and from these external zones is modelled. The internal modelled area is represented by 244 zones based mainly on the NUTS2 definitions, and the external area is represented by 17 'European' zones with 4 zones representing the rest of the World. The exception is that freight traffic within the CEEC area is not modelled – only freight traffic between the CEEC and the EU, i.e., only the EU15 countries are treated as internal for the freight model.

The ***passenger demand*** model combines highly segmented, zonal level socio-economic and behavioural data to produce a matrix of travel. There are 20 population groups specified in each zone and 10 trip purpose categories. The ***freight demand*** model is based on a spatial adaptation of a financial input-output structure, in order to represent linkages between industries. These inter-linkages are estimated from zonal final demand. Some 24 economic sectors are used in producing a matrix based on value, which is converted to volumes in an interface module. This freight volume matrix is combined with the passenger travel matrix and assigned to the modal networks in the common transport module.

The ***transport model*** contains a representation of the costs and times of travel by all the different modes between all of the model zones, for passenger and freight traffic. This is achieved using comprehensive and detailed multi-modal transport networks for road, rail, air, shipping, inland waterway and pipeline. An innovative treatment of intra-zonal travel for both passengers and freight allows the characteristics of even the shortest trips to be represented. The passenger and freight traffic is assigned to the network using a stochastic user equilibrium assignment operating for 24 hours. It does not separate out traffic by time of day.

Input assumptions for SCENES

The SCENES model also needs input assumptions of the driving factors of transport. We shortly discussed the underlying hypotheses.

First of all, macro-economic forecasts are taken into account. The annual GDP growth rate between 2000 and 2010 is 2.02%, while the rate between 2010-2020 is assumed 2.03%.
The annual population growth between 2000 en 2020 is 0.30% and between 2010 and 2020 0.22%.
The fuel price evolution is presented in figure x. This numbers incrude crude oil price assumptions (Primes), refinery cost (Institut du Pétrole) and a margin (derived by TML). These equal the IEA fuel cost at filling station. Additional assumptions on taxes (IEA) and VAT rates result in the end user prices.

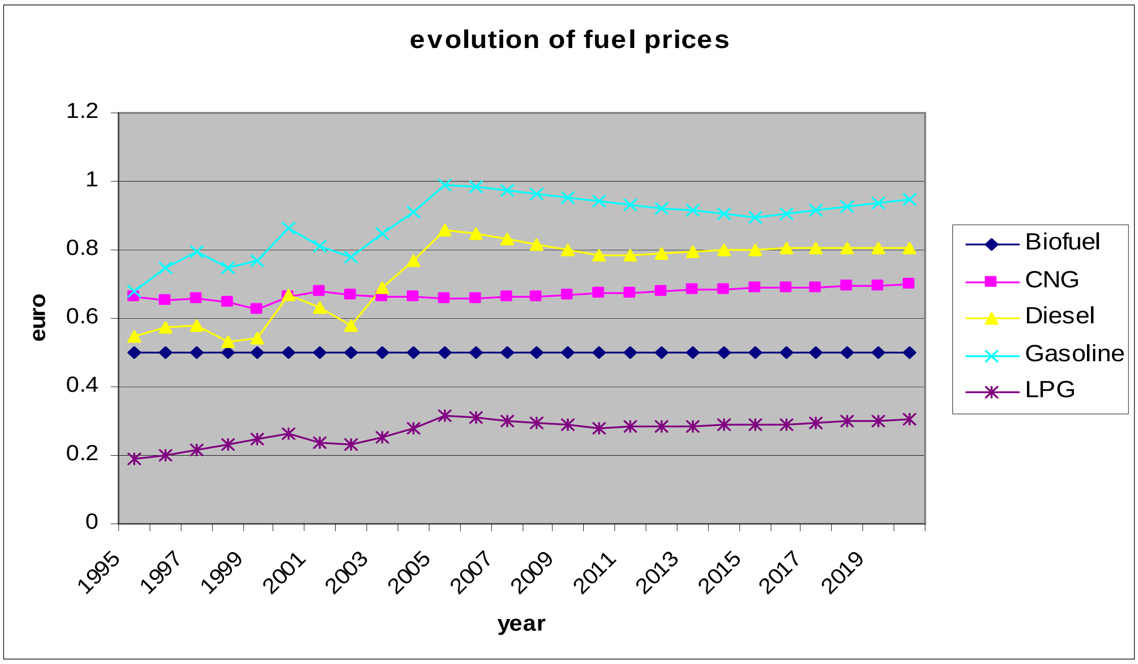


Figure 48 : Fuel price evolution

Furthermore a complete set of detailed price evolutions is incorporated. This is based on the most-likely scenario from the ASSESS project. **Fout! Verwijzingsbron niet gevonden.** gives an overview of these monetary costs evolutions and time costs evolution.

Table 12: Transport costs evolution in SCENES

Monetary costs		**Time costs**	
Road Freight costs	17%	Road Freight time	-1%
Rail Freight costs	-3.5%	Rail Freight time	-13%

Ship costs	8%	Rail border time	-15%
Inland waterway costs	1.5%	Inland waterway time	-2%
Freight Terminal costs	-8%	Freight Terminal time	-22%
Road load factor	2%	Car Time	0%
Car costs	0%	Rail passenger time	-2%
Bus costs	0%	Air time	-5%
Rail passenger costs	-1%	PassTerminal / Border time	0%
Air costs	0%		

Annex 3 Most important input and assumptions in the model

Transport demand

Transport demand statistics (period 1990-2004)

The historical evolution for the years 1990-2004 are mainly based on statistics. Where statistics could not provide enough details, assumptions have been made. Below we give a short overview of the used statistics and the applied assumptions.

The FPSMT provided transport volumes for different road types and vehicle types. Information on travel motives, freight categories, peak and off-peak period and long and short distance transport was not available from the FPSMT statistics, though these figures are input for the model.

The *road types* covered are local and regional roads and motorways. A subdivision for the three Belgian regions was also available. These transport volume data are translated to the four TREMOVE road types as indicated in the table below.

Table 13: The link between road types in TREMOVE and FOD statistics.

TREMOVE	FOD Statistics
Brussels	Local + Regional roads in the Brussels region
Other urban	Sum of all local roads (except Brussels)
Motorways	All motorways
Other non-urban	Sum of all regional roads (except Brussels)

The *vehicles* covered by the FPSMT statistics are cars, bus & coach, two categories of trucks, and motorcycles. TML subdivided some vehicle types further into more detailed categories to correspond to the TREMOVE input needs.

Car vehicle kilometers were subdivided in vehicle kilometers of small and large cars. This was done using vehicle stock data and yearly mileage data. Mileages and stocks for small and large cars were multiplied with each other. The relative weight of both total vehicle kilometers was used to subdivide the total FPSMT car kilometers. More information on mileages is given in a paragraph below.
Moped numbers are calculated as a fraction of new motorcycle numbers. This rate is based on the SCENES model.

Truck vehicle kilometers were subdivided in the same way into four truck types. A detailed load factor was calculated by combining the vehicle volumes per road and truck type (FPSMT statistics), the vehicle stock data (FEBIAC) and the annual mileages (GOCA-FPSMT). We refer to the detailed note[25] in annex . The results are presented in Figure 49. It can be observed that the growth in transport of goods is caused by the large HDV. Vehicle kilometers of small HDV (HDV1and HDV2) are stable over the period.

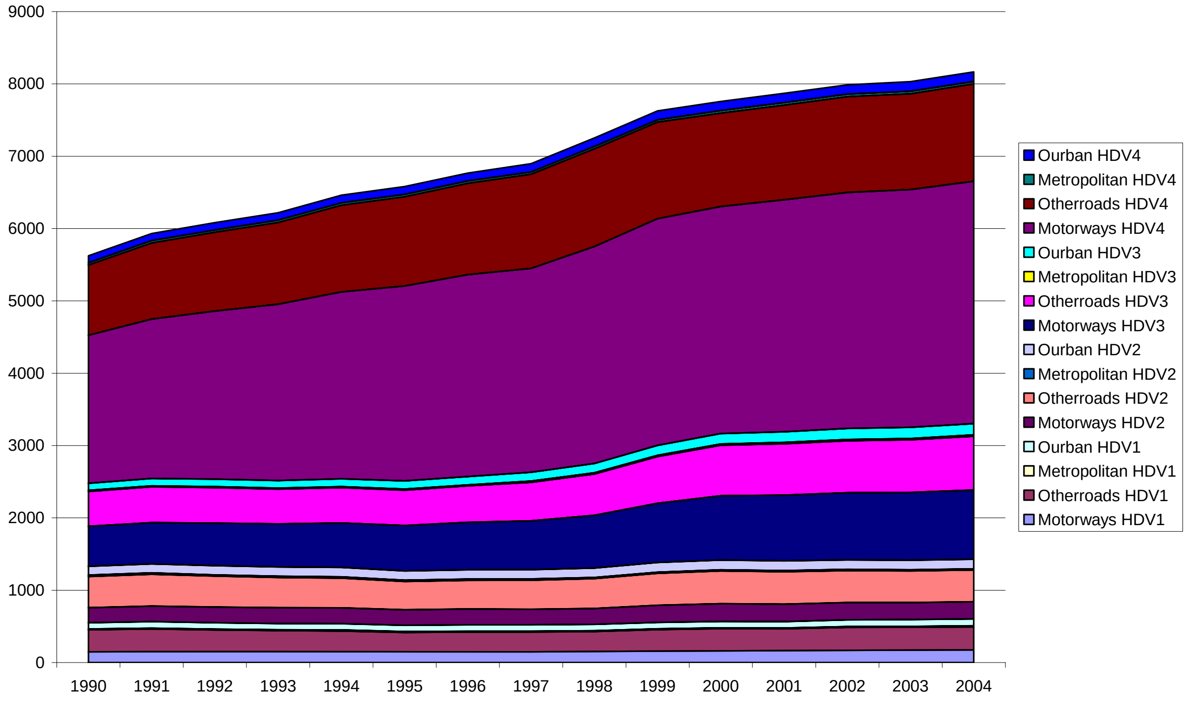


Figure 49 : Evolution of freight volume per vehicle type and road type between 1990-2004 [million veh-km/year].

Additional assumptions were necessary to disaggregate the statistics for following characteristics: travel motives, freight categories, peak and off-peak period and long and short distance transport. We took the same assumptions as those used in the SCENES model. We reproduced the historical data with the SCENES model from 1995 onwards. The detailed disaggregation rates for 1995 were applied also to 1990-1994. Background on the SCENES model can be found in The Scenes model.

The FPSMT activity numbers (passenger and ton kilometers) are used to derive occupancy rates and load factors. These numbers correspond with the European 'Transport in Figures' that are used for other TREMOVE versions, but are more detailed (per road type).

Transport volumes of non-road modes are based on 'Transport in Figures' as produced for TREMOVE 2.41. The 1990-1994 statistics were incorporated for this project.

25 Logghe S. (2005) Het vrachtvolume per voertuigtype en wegtype in België' – Nota voor FOD/FEBIAC

Note that the kilometres travelled in Belgium by Belgians and foreigners are similar to the kilometres travelled by Belgians in Belgium and abroad. This was calculated by Mr Labeeuw from the FPSMT. Results of its calculations are also given in Annex 4.

Transport demand forecast

A consistent trend scenario is produced for the period 2005-2030. This trend scenario is based on the SCENES model and the expert views of FPSMT, FEBIAC and TML. Background on SCENES can be found in Annex 2.

As discussed earlier, the SCENES model is used to disaggregate the statistics between 1990-2004. From 2004 onwards, the model is used to predict the future. To have a consistency between the model and the statistics, the original model output is scaled based on the 2004 values. By doing this, the predictions are consistent with the most recent statistics. Furthermore, the growth rates from the SCENES model are maintained.

The SCENES model is only developed to forecast transport until 2020. The annual growth factors for the different transport options between 2010-2020 are kept constant in the period 2020-2030. For passenger cars, the growth rate during 2020-2030 was set lower based on information from the dutch Scenario verkenner (TNO 1998) . The average growth rates for car transport volumes are 1.3% for the 2000-2010 period, 1.05% for the 2010-2020 period and 0.7% for the 2020-2030 period.

Input for vehicle stock modeling:

Vehicle stock

FEBIAC provided the vehicle stock from 1991 till 2004. The data they provided were as much as possible adapted to fit in the "TREMOVE" categories and framework. TML made some further adaptations for heavy duty vehicles, mopeds and buses and coaches[26].

Heavy duty vehicles:
The main problem here was to determine the vehicle stock of trucks with a maximum admitted weight above 32 tons, called HDV4 in TREMOVE. It concerns essentially tractors with trailers (articulated trucks). Stock data only take the tractors maximum admitted weight into account (without trailer). HDV4 vehicles are therefore nearly absent in the FEBIAC vehicle stock.

[26] The category other vehicles in the FEBIAC vehicle stock has not been taken into account as it is a category of only minor importance

The HDV4 category in TREMOVE is derived based on the assumptions below. The FOD publication "bedrijfsvoertuigenpark" provides the number of tractors in function of their maximum admitted weight. All tractors having a maximum admitted weight higher than 16 tons are considered as HDV4. This means that TML was able to split the initial stock of heavy duty vehicles larger than 16 tons in a category of heavy duty vehicles with a maximum admitted weight between 16 and 32 tons (HDV3) and a category above 32 tons (HDV4).

No specific adaptations has been done for road trains, but this is a category of minor importance in Belgium. In 2004 the number of trailers with a loading capacity of over 16 tons was 2594, while the number of semi trailers with a loading capacity of over 22 tons was 51.573 (Bedrijfsvoertuigen park FOD 2004).

Buses and coaches:
The FEBIAC stock data provides no different data for buses and coaches. To split this category into buses and coaches, the TREMOVE distribution has been adopted. This means that 25% of the category is considered as coaches.

Mopeds:
Figures on the moped stock are not available. Only selling data of new mopeds for the period 2000-2004 are available. We assumed constant sales for the previous years at the 2000 level. To derive the vehicle stock, we applied lifetime functions of MC on these selling data.

LPG-cars:
TREMOVE considers 3% of the medium and big gasoline cars as LPG cars.

1990 stock:
Data for the stock of 1990 are not available. We assumed the 1990 stock similar to the 1991 stock.

Mileages:

The mileages and the decrease in mileages in function of vehicle age have been provided by the FPSMT. They are based on the publication "opmeting van de jaarlijks afgelegde kilometers". For motorcycles no figures were available and the initial TREMOVE figures based on TRENDS (LAT 2002) were used. The table below gives the mileages of new vehicles as used for this project. We assume the same mileages for the hybrid versions of those vehicles. Figure 50 gives the decrease in mileage for a passenger diesel car and a tractor-heavy duty vehicle in function of its age. The figures show also that there is nearly no evolution between 2002, 2003 and 2004.

Table 14: mileages of different types of new vehicles

type	mileage
BUS & COACH	66507
HTD1	55488
HTD2	55488
HTD3	55488
HTD4	132707
LTD	32303
LTG	15421
MC1	3380
MC2	3380
MC3	3380
MC4	3380
MP	1870
PCDB	34921
PCDM	27937
PCDS	15365
PCGB	23430
PCGM	18497
PCGS	13564
PCL	26537

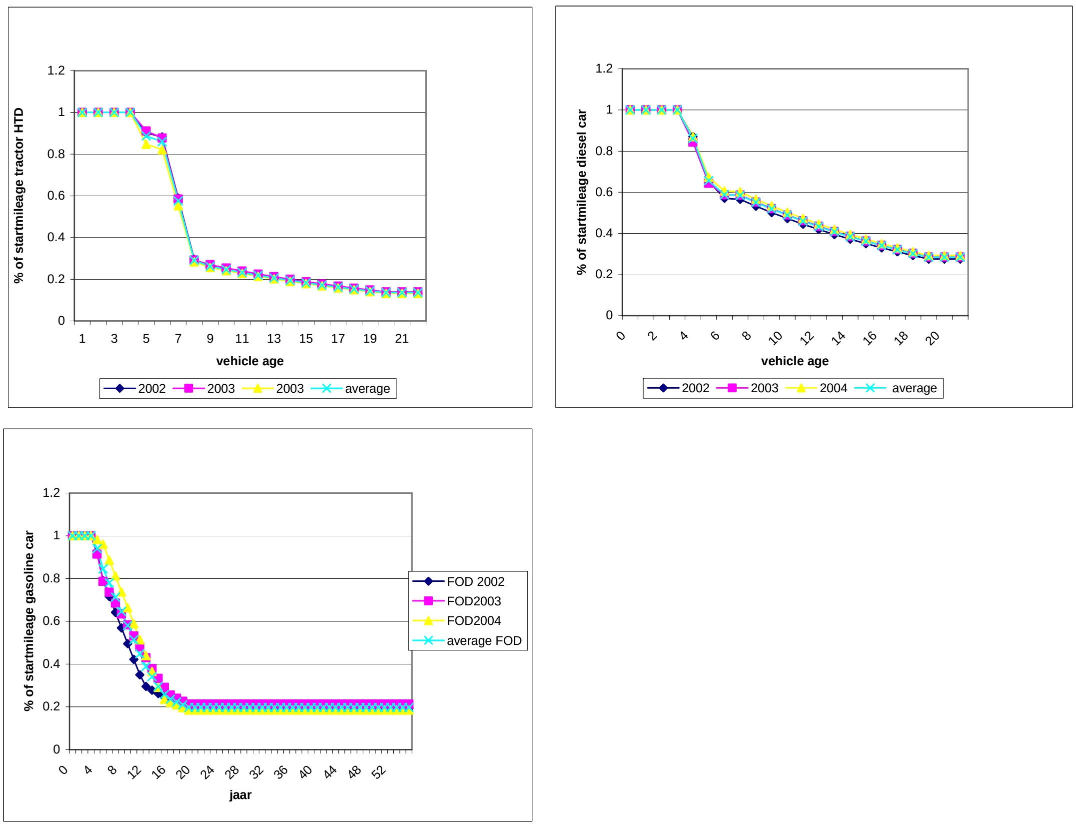


Figure 50: relative decrease in mileage passenger cars and a tractor heavy duty vehicle.

Lifetime functions

To model future vehicle stock, it is important to know when vehicles fall out. This information is given by the lifetime functions. A lifetime function indicates how many vehicles remain in the stock after a certain number of years. The lifetime functions in this project has been based on the survival rates of vehicles between 2003 and 2004. Figure 51 shows lifetime functions for cars used in this project. The hybrid versions of the conventional cars are assumed to have the same life time functions.

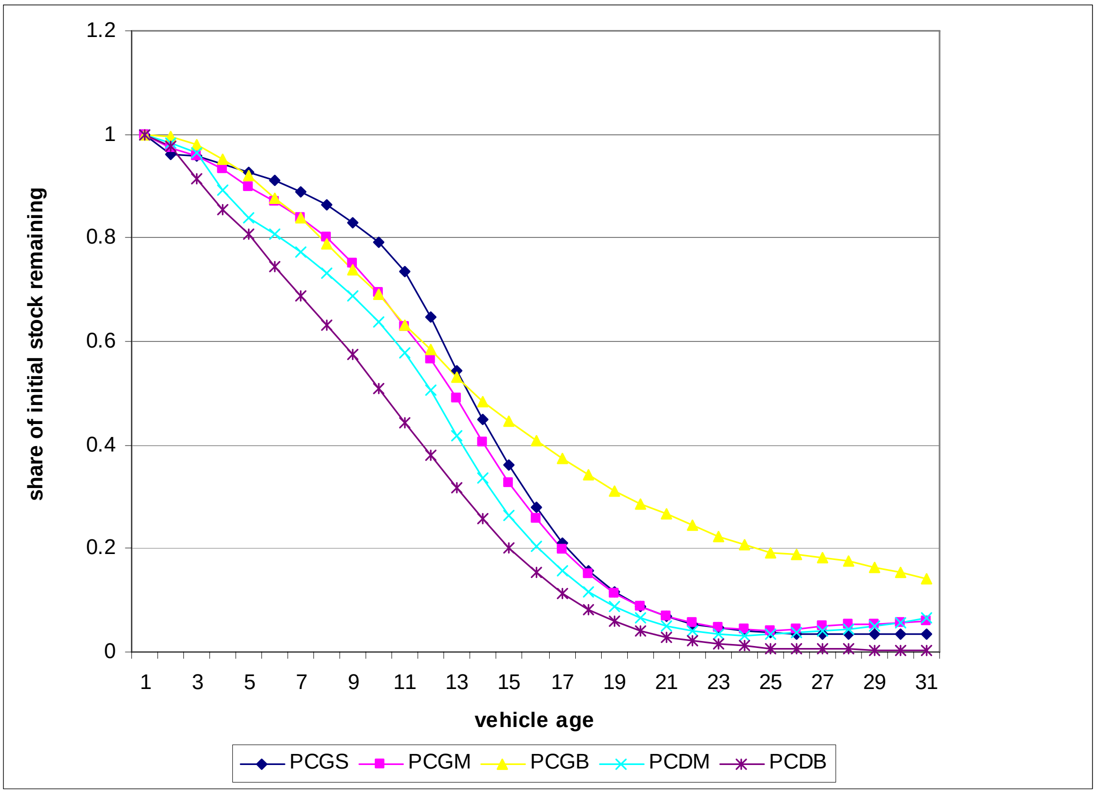


Figure 51: lifetime functions for different car types

Emission categories and allocation of vehicle stock to emission categories

Since the early nineties, the EC applies a policy of stricter emission standards. These are the EURO standards.

Each vehicle of the model vehicle stock is assigned to an emission class based on its selling year. Till the year 2000, the allocation has been based on the previous IFEU study. For the years after 2000, FEBIAC data and FEBIAC expert views has been used.

For cars the most stringent standard for which all details are known is the euro 4 standard. It becomes compulsory for all passenger cars registered in 2006. Within the next years a euro 5 standard will become compulsory. The emission restriction contained in euro 5 is based on the European Commission proposal. This study assumes this standard will become compulsory in 2011. This assumption was proposed by FEBIAC and was approved by the FPSMT. (see below)

The assignment for different vehicle types are given in the tables below. Due to the uncertainty about the implementation of the euro 5 standard the allocation is grey shaded. The hybrid versions of the conventional cars are assumed to have the same allocation of emission standards.

Table 15: introduction of emissionstandards for diesel passenger cars

Year	Tech	PCDB	PCDM	PCDS
1992	pre EURO	1	1	
1993	EURO1	1	1	
1994	EURO1	1	1	
1995	EURO1	1	1	
1996	EURO1	1	1	
1997	EURO2	1	1	
1998	EURO2	1	1	
1999	EURO2	1	1	
2000	EURO2	0.5	0.5	
2000	EURO3	0.5	0.5	
2001	EURO3	1	1	
2002	EURO3	0.994	0.994	
2002	EURO4	0.006	0.006	
2003	EURO3	0.943	0.943	
2003	EURO4	0.057	0.057	
2004	EURO3	0.775	0.775	
2004	EURO4	0.162	0.162	
2004	EURO5	0.063	0.063	
2005	EURO3	0.62	0.62	0.62
2005	EURO4	0.305	0.305	0.305
2005	EURO5	0.075	0.075	0.075
2006	EURO4	0.91	0.91	0.91
2006	EURO5	0.09	0.09	0.09
2007	EURO4	0.88	0.88	0.88
2007	EURO5	0.12	0.12	0.12
2008	EURO4	0.85	0.85	0.85
2008	EURO5	0.15	0.15	0.15
2009	EURO4	0.8	0.8	0.8
2009	EURO5	0.2	0.2	0.2
2010	EURO4	0.6	0.6	0.6
2010	EURO5	0.4	0.4	0.4
2011	EURO4	0.05	0.05	0.05
2011	EURO5	0.95	0.95	0.95
2012	EURO5	1	1	1

Table 16: introduction of emission standards for gasoline cars

Year	Tech	PCGB	PCGM	PCGS
1971	pre ECE 15/00	1	1	1
1972	ECE 15/00	1	1	1
1973	ECE 15/00	0.66	0.66	0.66
1973	ECE15/01-02	0.34	0.34	0.34
1974	ECE 15/00	0.34	0.34	0.34
1974	ECE15/01-02	0.66	0.66	0.66
1975	ECE15/01-02	1	1	1
1976	ECE 15/00	1	1	1
1977	ECE15/01-02	1	1	1
1978	ECE15/01-02	0.8	0.8	0.8
1978	ECE15/03	0.2	0.2	0.2
1979	ECE15/01-02	0.5	0.5	0.5
1979	ECE15/03	0.5	0.5	0.5
1980	ECE15/01-02	0.2	0.2	0.2
1980	ECE15/03	0.8	0.8	0.8
1981	ECE15/03	1	1	1
1982	ECE15/03	1	1	1
1983	ECE15/03	0.8	0.8	0.8
1983	ECE 15/04	0.2	0.2	0.2
1984	ECE15/03	0.5	0.5	0.5
1984	ECE 15/04	0.5	0.5	0.5
1985	ECE15/03	0.2	0.2	0.2
1985	ECE 15/04	0.8	0.8	0.8
1986	ECE 15/04	1	1	1
1987	ECE 15/04	1	1	1
1988	ECE 15/04	1	1	1
1989	ECE 15/04	0.5	1	1
1989	EURO1	0.5	0	0
1990	ECE 15/04	0	0.88	0.94
1990	EURO1	1	0.12	0.06
1991	ECE 15/04	0	0.73	0.805
1991	EURO1	1	0.27	0.195
1992	ECE 15/04	0	0.5	0.6
1992	EURO1	0.98	0.47	0.39
1992	EURO2	0.02	0.03	0.01
1993	EURO1	0.93	0.93	0.8
1993	EURO2	0.07	0.07	0.2
1994	EURO1	0.88	0.88	0.88
1994	EURO2	0.12	0.12	0.12
1995	EURO1	0.79	0.79	0.83

1995	EURO2	0.21	0.21	0.17
1996	EURO1	0.46	0.48	0.42
1996	EURO2	0.54	0.52	0.58
1997	EURO2	0.8	0.8	0.8
1997	EURO3	0.2	0.2	0.2
1998	EURO2	0.6	0.6	0.6
1998	EURO3	0.4	0.4	0.4
1999	EURO2	0.4	0.4	0.4
1999	EURO3	0.6	0.6	0.6
2000	EURO3	1	1	1
2001	EURO3	0.745	0.745	0.745
2001	EURO4	0.255	0.255	0.255
2002	EURO3	0.502	0.502	0.502
2002	EURO4	0.498	0.498	0.498
2003	EURO3	0.322	0.322	0.322
2003	EURO4	0.678	0.678	0.678
2004	EURO3	0.241	0.241	0.241
2004	EURO4	0.759	0.759	0.759
2005	EURO3	0.188	0.188	0.188
2005	EURO4	0.812	0.812	0.812
2006	EURO4	1	1	1
2007	EURO4	1	1	1
2008	EURO3	1	1	1
2009	EURO4	1	1	1
2010	EURO4	0.67	0.67	0.67
2010	EURO5	0.33	0.33	0.33
2011	EURO4	0.05	0.05	0.05
2011	EURO5	0.95	0.95	0.95
2012	EURO4	1	1	1
2012	EURO4	1	1	1

Table 17: introduction of emission standards for heavy duty vehicles

Year	Tech	HTD1	HTD2	HTD3	HTD4
1990	pre-EURO	1	1	1	1
1991	EURO1	1	1	0.1	0.1
1991	pre-EURO	1	1	0.9	0.9
1992	EURO1	0.4	0.5	0.5	0.5
1992	pre-EURO	0.6	0.5	0.5	0.5
1993	EURO1	0.6	0.7	0.8	0.8
1993	pre-EURO	0.4	0.3	0.2	0.2
1994	EURO1	0.8	0.8	0.8	0.8
1994	EURO2	0.2	0.2	0.2	0.2
1995	EURO1	0.5	0.45	0.4	0.4
1995	EURO2	0.5	0.55	0.6	0.6
1996	EURO1	0.25	0.1	0.05	0.05
1996	EURO2	0.75	0.9	0.95	0.95
1997	EURO2	1	1	1	1
1998	EURO2	1	1	1	1

1999	EURO2	1	1	1	1
2000	EURO2	1	1	1	1
2001	EURO2	1	1	1	1
2002	EURO2	0.1	0.1	0.1	0.1
2002	EURO3	0.9	0.9	0.9	0.9
2003	EURO3	1	1	1	1
2004	EURO3	1	1	1	1
2005	EURO3	0.93	0.93	0.93	0.93
2005	EURO4	0.05	0.05	0.05	0.05
2005	EURO5	0.02	0.02	0.02	0.02
2006	EURO3	0.7	0.7	0.7	0.7
2006	EURO4	0.25	0.25	0.25	0.25
2006	EURO5	0.05	0.05	0.05	0.05
2007	EURO3	0.05	0.05	0.05	0.05
2007	EURO4	0.75	0.75	0.75	0.75
2007	EURO5	0.2	0.2	0.2	0.2
2008	EURO4	0.65	0.65	0.65	0.65
2008	EURO5	0.35	0.35	0.35	0.35
2009	EURO4	0.5	0.5	0.5	0.5
2009	EURO5	0.5	0.5	0.5	0.5
2010	EURO4	0.1	0.1	0.1	0.1
2010	EURO5	0.9	0.9	0.9	0.9
2011	EURO5	1	1	1	1

Table 18: introduction of emission standards for motorcycles and mopeds

Year	Tech	MC1	MC2	MC3	MC4	MP
1996	conventional	0	0	0	0	1
1997	conventional	1	0	1	0	0
1997	97/24/EC Stage I	0	0	0	0	1
1998	conventional	1	1	1	1	0
1998	97/24/EC Stage I	0	0	0	0	1
1999	97/24/EC Stage I	1	1	1	1	1
2000	97/24/EC Stage I	1	1	1	1	1
2001	97/24/EC Stage I	1	1	1	1	1
2002	97/24/EC Stage I	1	1	1	1	0
2002	97/24/EC Stage II	0	0	0	0	1
2003	97/24/EC Stage I	0	0	0.5	0	0
2003	97/24/EC Stage II	1	1	0.5	1	1
2004	97/24/EC Stage II	1	1	1	1	1
2005	97/24/EC Stage II	1	1	1	1	1
2006	97/24/EC Stage III	1	1	1	1	1

Other assumptions

Vehicle taxes

The data for the registration tax and the ownership tax already available in the TREMOVE input data base were updated. The TREMOVE registration tax is the "belasting op in verkeersstelling/taxe d'immatriculation". The TREMOVE ownership tax is the sum of the "verkeersbelasting/taxe de circulation" and the "diesel accijnscompenserende belasting/taxe compensatoire d'accise de diesel". The accise compensating tax for diesel cars and its progressive abolition between 2003 and 2008 has been taken into account in the ownership tax. The table below gives an overview of the different taxes as they have been taken into account in the model. Hybrid and CNG cars get the same taxation as their conventional counterparts.

Table 19: Registration and ownershiptax of passenger cars as used in the TREMOVE model

car type	ownership tax						registration tax
	2000-2003	2004	2005	2006	2007	2008 till 2030	2000-2030
PCDS	184	171	158	136	130	130	75
PCDM	340	327	314	288	251	240	245
PCDB	659	646	633	607	567	416	1128
PCGS	119	119	119	119	119	119	75
PCGM	211	211	211	211	211	211	264
PCGB	670	670	670	670	670	670	2035

For heavy duty vehicles, TML calculated road taxes based on the taxrates and the heavy duty vehicle stock composition.

Based on the FPSMT publication "bedrijfsvoertuigenpark 2004" and on detailed tax tariffs for HDVs from the FEBIAC website, road ownership taxes are calculated. The taxes used are given in the table below. Table 21: eurovignet prices in EUR for HDV with maximum admitted weight more than 12 tons as used in the TREMOVE model (EURO 2000) show the eurovignet prices as used in the model.

Table 20: Ownership taxes of heavy duty vehicles as used in the TREMOVE model in (EURO 2000)

	ownershiptax
HTD1	122

HTD2	281
HTD3	486
HTD4	476

Table 21: eurovignet prices in EUR for HDV with maximum admitted weight more than 12 tons as used in the TREMOVE model (EURO 2000)

eurovignet prices		
HTD 3 (Tot 3 assen)	NIET-EURO	960
	EURO I	850
	EURO II en schoner	750
HTD4 (Vanaf 4 assen)	NIET-EURO	1550
	EURO I	1400
	EURO II en schoner	1250

Remark that taxes are used in the vehicle stock module and in the demand module.

Hybrid cars

The model takes hybrid cars into account. The assumptions below has been made concerning those vehicles. They are based on Verbeiren et al, 2003[27].:

Table 22: introduction dates of hybrid cars in the model

	introduction date
gasoline	
small	2005
Medium	2008
Large	2005
Diesel	
small	not foreseen
Medium	2012
Large	2012

The differences between the hybrid car and its conventional counterpart are in fuel efficiency and purchase cost. The fuel consumption of a hybrid car is assumed to be 20% lower for a diesel car and 30% for a gasoline car. TML put the additional purchase cost at 5.000 EUR in 2010 and about 3.250 in 2020.

27 Verbeiren S., De Vlieger I. en Pelkmans L. (2003), Duurzaamheidevaluatie van technologieën en modi in de transportsector in België. Deelrapport eerste screening (Task A), Vito-rappport 2003/IMS/R086.

No particular assumptions have been made on market shares of hybrid vehicles in the future. The obtained market shares are a consequence of the model simulating the purchase behaviour of car buyers.

CNG

The model foresees a first introduction for CNG cars in 2008. The differences with conventional gasoline cars are the higher purchase cost and other fuel consumption and emission factors.

Purchase cost increase, is equal for all car sizes and decreases in the future. The extra cost is 3100 EUR in 2008 and 2500 EUR from 2020[28] on. The CNG fuel consumption is calculated as the conventional fuel consumption multiplied by a multiplication factor, 1.077. The emission factors are based on a TNO study. The study compares emissions from CNG cars with emissions from gasoline cars. The ratios between both are used in this study and given in the table below.

Table 23: emissions of CNG cars compared to emissions of petrol euro 4 cars

	emissions ratio CNG /petrol euro 4
Nox	0.40
VOC	0.85
PM_{10}	0.33
CO2	0.81
CH4	8.41
CO	1.07
C6H6	0.25
N2o	0.33

No particular assumptions have been made on market shares of CNG vehicles in the future. The obtained market shares are a consequence of the model simulating the purchase behaviour of car buyers.

Assumptions on a future euro5 emission standard

The assumptions for the euro 5 standard are based on the EC proposal for regulation (COM(2005) 683 final 2005). The costs are based on the TNO report sponsored by the European Commission (TNO 2005). The assumptions are given in the table below.

Table 24: euro 5 emission standard assumptions

[28] The costs in the years in between are linearly interpollated.

	relative emission reduction compared to EURO4			average absolute emission mg/km			cost increase
	Nox	PM	VOC	Nox	PM	VOC	
PCGS							75
PCGM							102
PCGB	-25%		-25%	75		60	141
PCDS							402
PCDM							475
PCDB	-20%	-80%		200	5		629

For diesel cars, an additional fuel consumption of 1.5% is assumed due the utilization of a PM_{10} trap.

Sulphur content of fuel

The tabel below shows the sulphur contents that have been used in the model. From 1997 on the figures are based on measurements of the FPS Economy. For the years before TML made a choice between values used in the TREMOD model and in the European TREMOVE model with the help of an expert of the FPS Economy.

Table 25: sulphur content of fuels

	gasoline	diesel
1990	300	1700
1991	300	1300
1992	300	1300
1993	300	1300
1994	300	1300
1995	300	1300
1996	300	600
1997	234	480
1998	154	440
1999	136	406
2000	79	294
2001	58	269
2002	43	47
2003	43	38
2004	32	38
2005	32	38
2006	32	38
2007	32	38
2008	32	38
2009	10	10
2010	10	10
> 2011	10	10

Biofuels

Introduction of biofuels

A gradual penetration of biofuel towards 5.75% of all petrol and and diesel fuel consumed by road transport in 2010 and up to 8% in 2020 is assumed. The biofuel will be blended in the oil-based fuels. There will be tax reductions and/ or subsidies for biofuels leading to consumer prices for the blended fuels that are the same as for conventional petrol and diesel. I.e. the tax exemption and/or subsidy cover the difference between the resource cost of the oil-based fuel and the biofuel additive. A resource cost of 0.5 euro per litre of biofuel is assumed, which remains constant over time independent of the crude oil price evolution. As the introduction of biofuels does not affect the fuel prices for the consumer, the policy is assumed not to affect transport demands nor vehicle purchase behaviour[29].

Emission reductions thanks to the use of biofuels.

No sufficient measurements exists to introduce solid assumptions on changes in exhaust emission factors resulting from the use of blended fuels.[30] Tank-to-wheel CO_2 emissions related to biofuel use are excluded from the external environmental emission costs, as they are considered not to contribute to global warming. Well-to-tank emission factors for biofuel production are taken from MEET (Lewis, 1997), which provides estimates for the production of biofuel from rapeseed oil. Figure 52 illustrates these estimates. It should be noted that well-to-tank emission estimates in the existing literature show significant variations depending on the specification of the biofuel and its production process. The life cycle emissions of biofuel produced based on waste cooking oil for example will be very low.

[29] The use of blended of fuels is expected not to require significant additional costs to convert vehicle engines.
[30] A lot of research work has been consulted to find appropriate emission factors for blended biofuels. Some of these studies suggest a decrease in PM emissions and an increase in NOx emissions. No information is available on emissions of EURO 4 engines. (Senternovem, 2005 – IFEU 2004

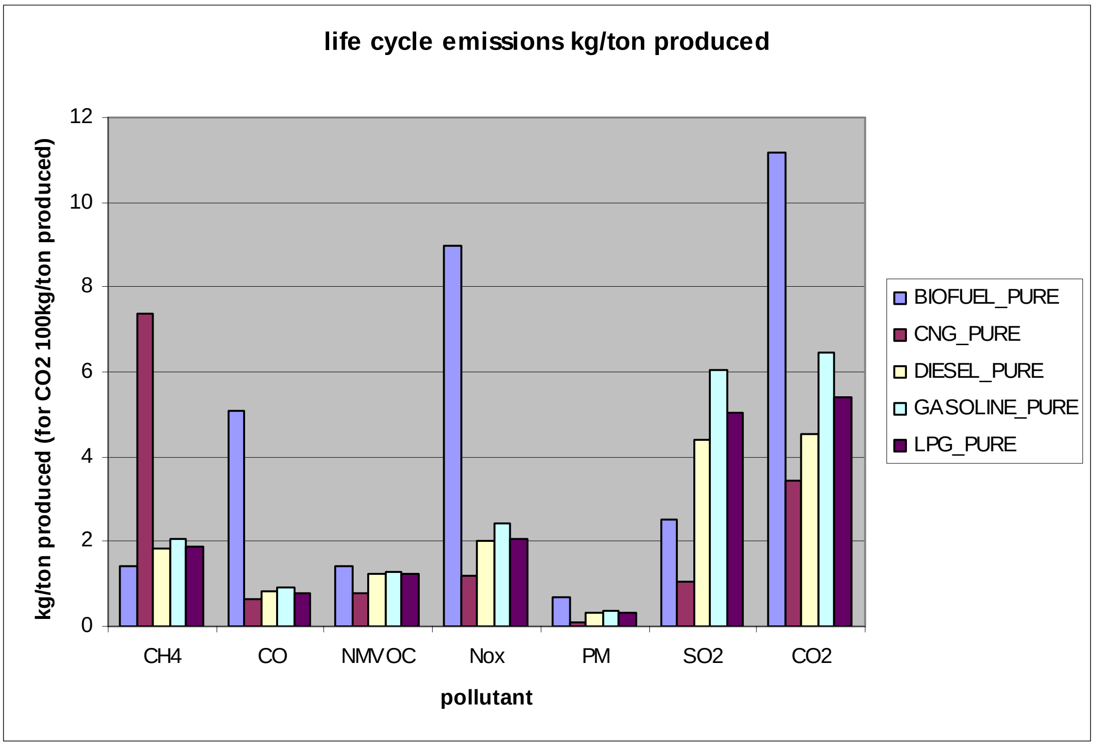


Figure 52: life cycle emissions calculated by MEET

Air conditioning

Mobile air conditioning systems in cars cause different types of emissions.

The functioning of mobile air conditioning equipment causes extra fuel consumption, and therefore extra CO2 and SO2 emissions. The effects on emissions of other pollutants are much more uncertain. They have not been taken into account for this study. We take an average extra fuel consumption of 7 gr CO2/km into account as indicated in a TNO study for the EC (TNO, 2002).

A second source of emissions is the cooling liquid in the air conditioning system. Leakages are reported to take place at the filling of the system, during use of the system (regular and irregular leakage), during maintenance of the system and at disposal of the system (Öko-recherche 2003 and EC consultation paper, 2004). The estimated emissions of cooling liquid are given in the table below. The refrigerant is HFC 134 a with a global warming potential of 1300.

In october 2005 a European directive has been approved banning HFC 134a as refrigerant in car air conditioning systems from 2011 on for new cars and from 2017 on for all cars. The cheapest solution to replacement for HFC134a as cooling liquid is the use of HFC 152a with a global warming potential of 140. We assumed that this solution will be choosen for the model runs. In this study only regular and irregular leakages are accounted for.

Table 26: Emissions of cooling liquid of air conditioning systems

regular leakage	52,4 gr/car/year
irregular leakage	16,3 gr/car/year
service emissions	204,5 gr/4 year
end of live emissions	247,9 gr at car scrappage
Installation emissions	33,75 gr/ car sold

The table below shows the penetration rate of air conditioning systems in new cars.The figures are based on a survey from the FPSMT. The figures before 1990 are based on figures used by ECONOTEC in their inventory of ozone depleting substances. FEBIAC proposed to limit the penetration rate at 95% as it is very probable that low budget cars will not get air conditioning equipment.

Table 27: share of new cars equipped with air conditioning

RSHairco	1980	0
RSHairco	1981	0
RSHairco	1982	0
RSHairco	1983	0
RSHairco	1984	0
RSHairco	1985	0
RSHairco	1986	0
RSHairco	1987	0.009
RSHairco	1988	0.024
RSHairco	1989	0.029
RSHairco	1990	0.034
RSHairco	1991	0.066
RSHairco	1992	0.101
RSHairco	1993	0.128
RSHairco	1994	0.164
RSHairco	1995	0.218
RSHairco	1996	0.273
RSHairco	1997	0.327
RSHairco	1998	0.382
RSHairco	1999	0.436
RSHairco	2000	0.491
RSHairco	2001	0.545
RSHairco	2002	0.600
RSHairco	2003	0.655
RSHairco	2004	0.709

RSHairco	2005	0.764
RSHairco	2006	0.791
RSHairco	2007	0.818
RSHairco	2008	0.845
RSHairco	2009	0.873
RSHairco	2010	0.900
RSHairco	2011	0.905
RSHairco	2012	0.910
RSHairco	2013	0.915
RSHairco	2014	0.920
RSHairco	2015	0.925
RSHairco	2016	0.930
RSHairco	2017	0.935
RSHairco	2018	0.940
RSHairco	2019	0.945
RSHairco	2020	0.950
RSHairco	2021	0.950
RSHairco	2022	0.950
RSHairco	2023	0.950
RSHairco	2024	0.950
RSHairco	2025	0.950
RSHairco	2026	0.950
RSHairco	2027	0.950
RSHairco	2028	0.950
RSHairco	2029	0.950
RSHairco	2030	0.950

Annex 4 : balance between road countings and mileages (Gilles Labeeuw FPSMT)

BALANS TUSSEN VERKEERSTELLINGEN EN KILOMETERSTANDEN VOOR HET JAAR 2004

VOERTUIGCATEGORIEËN				KILOMETERSTANDEN (incl. NIS-cijfers wegvervoer)					TELLINGEN				CONCLUSIE
2004	voertuigcategorie	aantal (1/8/04)	% park	km/jaar Belg+out	vtg-km/jaar Belg+out	% out Belg	Bron / opm.	vtg-km/jaar Belg	vtg-km Belg++	% Belg. Vtgn	Bron / opm.	vtg-km Belg	gelijkheid kmst. tell.
A	motoren	322,762	5.37%	4,000	1.29	20.00	(3)	1.03	1.06	95.0%		1.01	+/-
B1	personenwagens	4,874,426	81.03%	15,938	77.69	4.00	(1)	74.58	79.55	91.5%	(2)	72.78	+/-
B2	bestelwagens	486,025	8.08%	19,373	9.42	10.00		8.47	4.80	95.0%	(9)	4.56	??
C1	vrachtwagens (mono)	103,704	1.72%	29,146	3.02	13.40	(5)	2.62	3.31	80.0%	(6)	2.64	+/-
	(NIS)	*49,578*		*37,558*	*1.86*	13.40	*(5a)*	*1.61*					*not compatible*
	(NIS)	*81,171*		*37,558*	*3.05*	13.40	*(5b)*	*2.64*					*compatible*
C2	trekkers	47,394	0.79%	93,960	4.45	45.50	(4)	2.43	4.86	50.0%	(6)	2.43	+/-
	(NIS)	*30,408*		*101,300*	*3.08*	*45.50*	*(4a)*	*1.68*					*not compatible*
	(NIS)	*39,885*		*101,300*	*4.04*	*45.50*	*(4b)*	*2.20*					*+/- compatible*
D	bussen en autocars	15,328	0.25%	36,895	0.57	9.00	(7)	0.51	0.70	74.0%	(8)	0.51	+/-
E-C3	bijzondere voertuigen	166,111	2.76%	1,584	0.26	0.00		0.26	0.28	100.0%		0.28	+/-
Tot.	totaal (buiten NIS)	6,015,750	100.00%		96.70			89.91	94.56		(9)	84.23	

Zie refertes Bron/Opmerking op het volgende blad

FODMV Directie Mobiliteit - SPFMT Direction Mobilité - 26/10/2005

CONCLUSIES :

1. Er is een zekere evenwicht (nog nader te bekijken) tussen de kilometers van Belgische voertuigen in het buitenland, en de kilometers van buitenlandse voertuigen in België
2. Voor vrachtwagens en trekkers is er op eerste zicht een grote verenigbaarheid tussen de tellingen, de NIS-cijfers en de opnames van de kilometerstanden.
   De invloed v/d "spookvrachtwagens" (niet opgenomen door NIS met bv 39885 trekkers ipv 47394) blijkt goed afgebeeld met een lagere gemiddelde kmstand (93960 km/jaar ipv 101300).
3. Het probleem van de bestelwagens (en van de tellingen in agglomeraties) moet nog uitgeklaard worden.

BRONNEN EN OPMERKINGEN :

(1) 4% = ca 600 km/jaar vlgs Nationale Enquête FUNDP 1999 (8% voor Nederland met ca 1200 km/jaar, 6,3% voor de gelijkheid met tellingen)

(2) vtg-km 2004 : 103/116 = 91.5% Tabl.16d

(3) eigen raming van de km/jaar

(4) NIS "Vervoer over de weg..." 2003 Tabel I-5 : 46.095 km buitenland voor 55.205 km in België

(4a) NIS "Vervoer over de weg..." 2003 30,408 aantal trekkers door 3.08 miljard vtg-km/jaarNIS te delen door km/jaar NIS

(4b) NIS "Vervoer over de weg..." 2003 39,885 aantal trekkers uit Bijlage NIS

(5) NIS "Vervoer over de v park Tabel I-5 : 5.031km buitenland voor32.527 km in België

(5a) NIS "Vervoer over de weg..." 2003 49,578 aantal vrachtw. door 1.86 miljard vtg-km/jaarNIS te delen door km/jaar NIS : zie Berekening hierna

(5b) NIS "Vervoer over de weg..." 2003 81,171 aantal vrachtw. uit Bijlage NIS : zie Berekening hierna

(rouge = ajout calculé)	tot km Belg.	tot km étran	tot km B+é	km Belgique	km étrang	km Belg+ét	nb=tot km/km	nb/ Annex	tot.km/Annex
carrosserie fermée	544.764	51.268	596.033	34.157	3.215	37.372	15,949	26,387	986.135
bâché ou tôlé	170.194	69.734	239.928	35.831	14.681	50.512	4,750	6,965	351.816
plateau	285.329	58.368	343.697	28.914	5.915	34.829	9,868	17,976	626.086
température dirigée	127.223	13.720	140.943	40.501	4.368	44.869	3,141	4,101	184.008
citerne alimentaire	9.648	0.417	10.065	53.307	2.304	55.611	181	271	15.071
citerne non-alimentaire	41.725	0.757	42.481	29.455	0.534	29.989	1,417	2,144	64.296
benne	132.217	8.267	140.484	27.299	1.707	29.006	4,843	9,638	279.560
non classifiable	301.519	46.877	348.396	31.979	4.972	36.951	9,429	13,689	505.822
total camions	1612.619	249.409	1862.028	32.527	5.031	37.558	49,578	81,171	3048.605
tracteurs	1678.674	1401.656	3080.330	55.205	46.095	101.300	30,408	39,885	4040.351
total général	3291.293	1651.065	4942.358	41.149	20.642	61.791	79,985	121,056	7480.171

(6) > l'estimation du nombre de camions étrangers suit l'étude du Recensement quinquennal 1995 = 38% des véh.-km C1+C2

Ici, on a pour C1+C2 (belg+étrang) :		8.17	*	38.00%	=	-------	------->	3.10	(milliards véh-km)
Contrôlons la répartion	= pour C1	3.31	*	20.0%	=	0.66	) soit au	3.09	(milliards véh-km)
	+ pour C2	4.86	*	50.0%	=	2.43	) total		

Cette estimation était basée sur les chiffres de l'INS, et recoupée par les compatges aux frontières en 1990

> une ré-estimation des comptages aux frontières est possible sur base des documents FR, D, NL, LUX (seul disponible ici : D)

> une estimation est possible pour les autoroutes, selon fichier des accidents et document du MET (elle semble confirmer l'estimation de base)

(7) Vooral in aanmerking, de Km in buitenland van erkende autocars : 95.517 - 44.144 = 51.373 (miljoen vtg-km) = 9.08%

(8) Raming voor 1990 : 639 cars binnen en 516 cars buiten op gewone werkdag (donderdag 26 april)
1039 cars binnen en 1225 cars buiten op zondag 1 juli
het aantal buitenlandse vtg-km was dus (miljard/jaar voor ritten van 150km en wetende dat ca 50% van de grensposten geteld werden) :
[(639+516)*300 dagen + (1039+1225)*65 dagen] * 150 * 2 = 0.148 tov het tot. 1990 bus/cars 0.57 = 26.0%

(9) het probleem van de bestelwagens moet nog bestudeerd worden : te weinig tellingen in agglomeraties ? geteld als personenwagens ? Invloed nachtverkeer ?

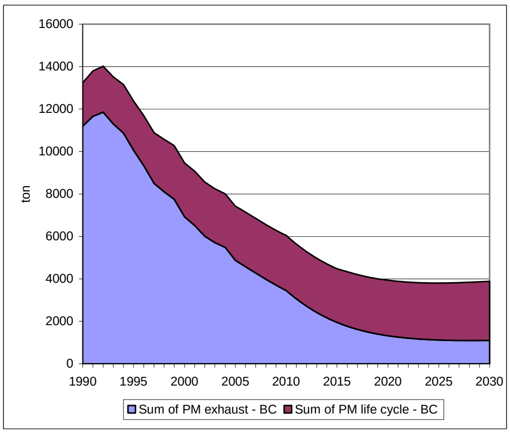
Annex 5 Vehicle categories as used in TREMOVE

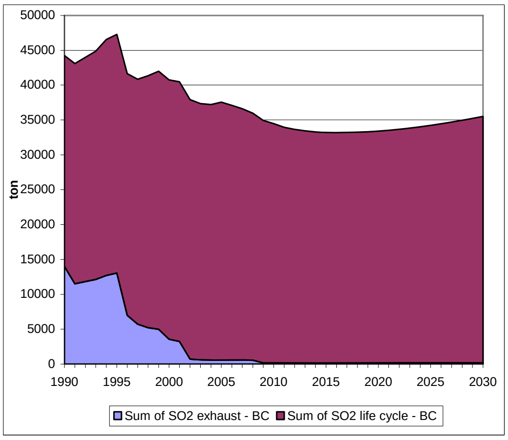
Cars	
PCGS	Small gasoline passenger car (<1400 cc)
PCGM	Medium gasoline passenger car (1400 cc - 2000 cc)
PCGB	Large gasoline passenger car (>2000 cc)
PCDM	Medium diesel passenger car (<2000 cc)
PCDB	Large diesel passenger car (> 2000 cc)
PCL	LPG passenger car
Light duty vehicles	
LTG	Gasoline light duty vehicle
LTD	Diesel light duty vehicle
Heavy Duty Vehicles	
HTD1	Diesel heavy duty vehicle (3.5 - 7.5 ton)
HTD2	Diesel heavy duty vehicle (7.5 - 16 ton)
HTD3	Diesel heavy duty vehicle (16 - 32 ton)
HTD4	Diesel heavy duty vehicle (> 32 ton)
Urban buses	
BUS	Urban Bus
Coaches	
COACH	Coach
Motorcycles	
MP	Moped (2 strokes, < 50 cc)
MC1	Motorcycle (2 strokes, >50 cc)
MC2	Motorcycle (4 strokes, 50 - 250 cc)
MC3	Motorcycle (4 strokes, 250 - 750 cc)
MC4	Motorcycle (4 strokes, >750 cc)

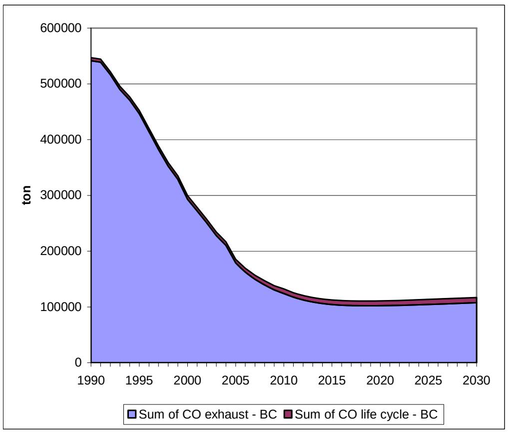
Annex 6 The importance of life cycle emissions

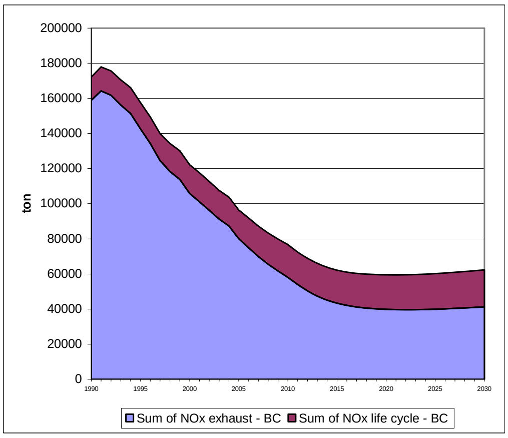
Due to the reduction in global exhaust emissions of roadtransport, the life cycle emissions of fuels used by roadtransport become relatively more important. Especially for SO2 and PM_{10}, life cycle emissions are more important than exhaust emissions of roadtransport.

The TREMOVE Life cycle emissions take only emissions from fuel production and fuel transport into account. These emissions will for example be influenced by the introduction of biofuels. For similar fuels, life cycle emissions remain nevertheless the same. A future cleaner functioning of refineries is for example not taken into account. Reported life cycle emission can therefore be seen as an upper limit.









Annex 7 Het vrachtvolume per voertuigtype en wegtype I België (note of Steven Logghe -31-10-05

In deze nota wordt toegelicht hoe de volumes vrachtverkeer in België variëren per wegtype en per vrachtwagentype tussen 1990 en 2004. Dit geeft een inzicht in de gedetailleerde samenstelling van het vrachtverkeer op het Belgische wegennet. Deze berekening gebeurde in het kader van de studie TREMOVE België in opdracht van de FOD en FEBIAC.

Eerst komen de algemene probleemstelling en de gehanteerde definities aan bod. Daarna volgt een overzicht van de gebruikte gegevens en wordt de methode toegelicht. Tot slot worden de resultaten gepresenteerd.

Probleemstelling

Voor TREMOVE België moet het volume vrachtverkeer (in voertuigkilometer per jaar) in detail opgesplitst worden. Er is een opsplitsing nodig per wegtype en per voertuigtype.

TREMOVE vertrekt van vier wegtypes die gelinkt zijn aan de wegklassificatie van de FOD :

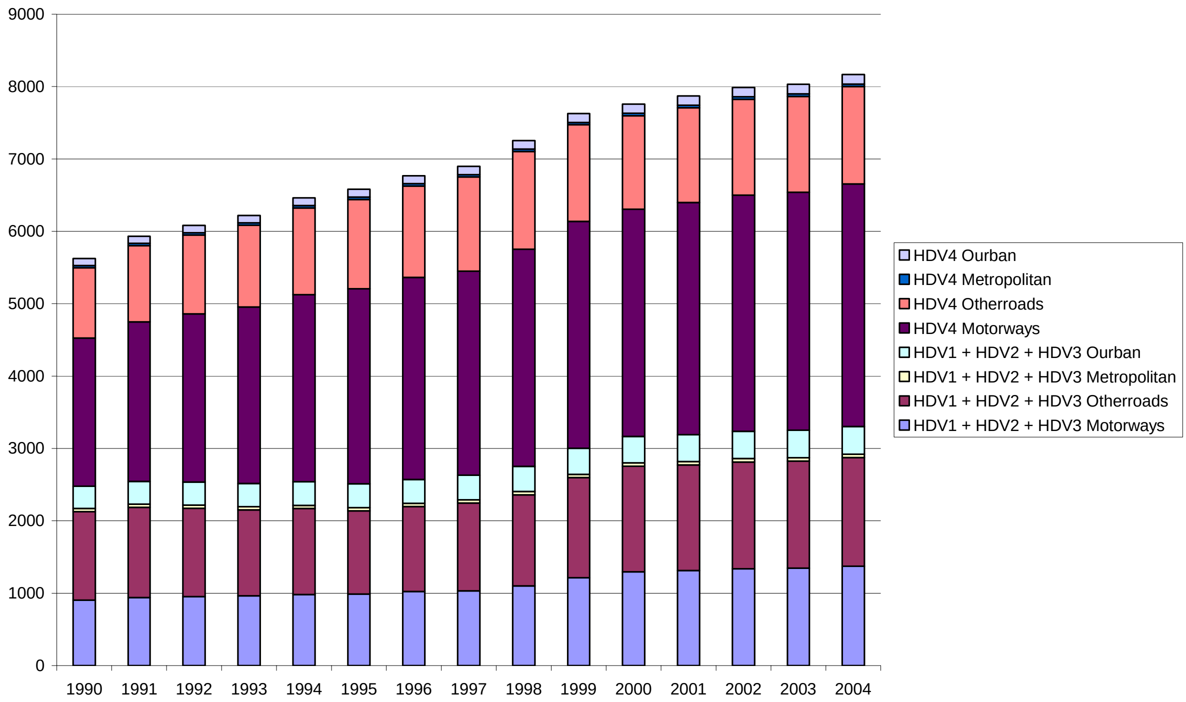
- Metropolitan roads : Dit zijn alle regionale (gewestelijke) en locale (gemeentelijke) wegen binnen het Brussels hoofdstedelijk gewest (BHG).
- Other urban roads : Hiervoor worden alle lokale (gemeentelijke) wegen buiten het BHG beschouwd.
- Motorways : Dit zijn alle snelwegen (inclusief BHG).
- Other roads : Dit zijn alle regionale (gewestelijke) wegen buiten het BHG.

Verder beschouwen we vier klassen van high duty vehicles (HDV) :

- HDV1 : vrachtwagens met een totaal gewicht (tarra + maximaal laadvermogen) tussen de 3.5 en 7 ton.
- HDV2 : vrachtwagens met een totaal gewicht tussen de 7 en 16 ton.
- HDV3 : vrachtwagens met een totaal gewicht tussen de 16 en 32 ton.
- HDV4 : vrachtwagens groter dan 32 ton, inclusief de trekkers met een maximaal toegelaten massa van 16 ton en meer.

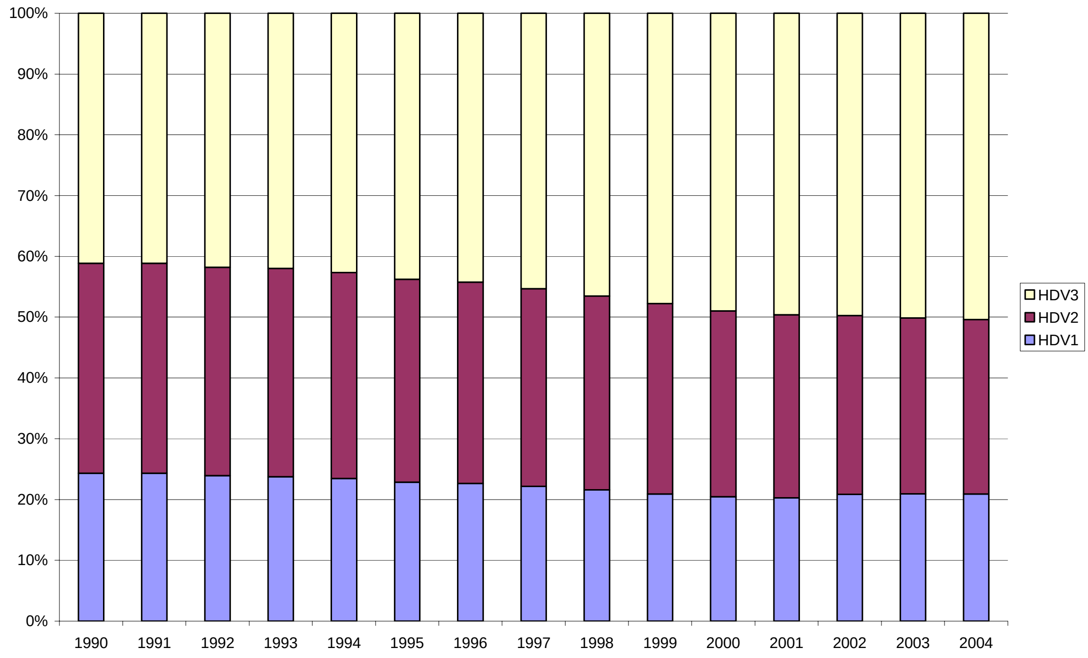
Basisgegevens

Eerst en vooral zijn er de FOD statistieken waaruit per wegtype een inschatting kan gemaakt worden van het totale volume vrachtverkeer. Dit kan enerzijds voor de totale hoeveelheid vrachtverkeer tussen 3.5 en 32 ton (klasse C1) en voor de HDV4 klasse (C2 gegevens). Op basis van deze gegevens zijn de gegevens uit Figuur 9 gekend.



Figuur 9 : Vrachtvolumes per wegtype op basis van FOD statistieken in Miljoen vtgkm per jaar

Per wegtype wordt vervolgens een opsplitsing gemaakt van de HDV1, HDV2 en HDV3 klassen. Hiervoor baseren we ons gedeeltelijk op gegevens van het vrachtwagenpark. Daarbij wordt uitgegaan van een gelijke mileage voor de HDV1, 2 en 3 klassen.. Hierdoor is het mogelijk om een inschatting te maken van de relatieve verhouding van de drie HDV klassen zoals in Figuur 10.



Figuur 10 : Aandeel HDV categorieën op basis van voertuigstock en mileage gegevens

Verder maken we ook gebruik van een Duitse studie die op basis van observaties de samenstelling van het verkeer op verschillende wegtypes in kaart bracht. Tabel 2 geeft een overzicht van de relevante resultaten van deze studie. Voor snelwegen wordt aangegeven dat van alle waargenomen vrachtwagens (tussen 3.5 en 32 ton) er 21.21% tot de HDV1 klasse behoren, 7.95% tot de HDV2 klasse en 70.85% tot de HDV3 klasse. Deze verhouding varieert per wegtype.

Tabel 2 : Aandeel vrachtverkeer per voertuigtype voor de verschillende wegen.

	HDV1	HDV2	HDV3	Totaal
Motorways	21.21%	7.95%	70.85%	100%
Otherroads	35.97%	13.49%	50.54%	100%
Metropolitan	42.07%	15.88%	42.05%	100%
Ourban	42.07%	15.88%	42.05%	100%

Methode

De basisgegevens voor 2004 worden in Tabel 3 gegeven.

Tabel 3 : Overzicht van de beschikbare basisgegevens voor 2004.

	HDV1	HDV2	HDV3	FOD vtgkm
Motorways	21.21%	7.95%	70.85%	**1372.35**
Otherroads	35.97%	13.49%	50.54%	**1501.52**

Metropolitan	42.07%	15.88%	42.05%	**47.33**
Ourban	42.07%	15.88%	42.05%	**382.34**
Vehicle stock	**20.89%**	**28.71%**	**50.40%**	

De laatste kolom geeft de voertuigkilometers weer per wegtype (miljoen km). Deze gegevens worden als harde randvoorwaarden aangenomen. De onderste rij geeft de verhouding weer tussen de voertuigtypes op basis van de voertuigstock en mileage gegevens. Daarnaast hebben we de percentages uit de Duitse studie die als indicatieve waarde meegegeven worden.

Op basis van deze gegevens wordt nu een Furness iteratie opgestart (Furness 1965). Deze methode wordt in de verkeersplanning gebruikt om herkomst-bestemmingsmatrices te genereren. Meer achtergrond rond deze methode vindt u in Immers en Stada (2000).

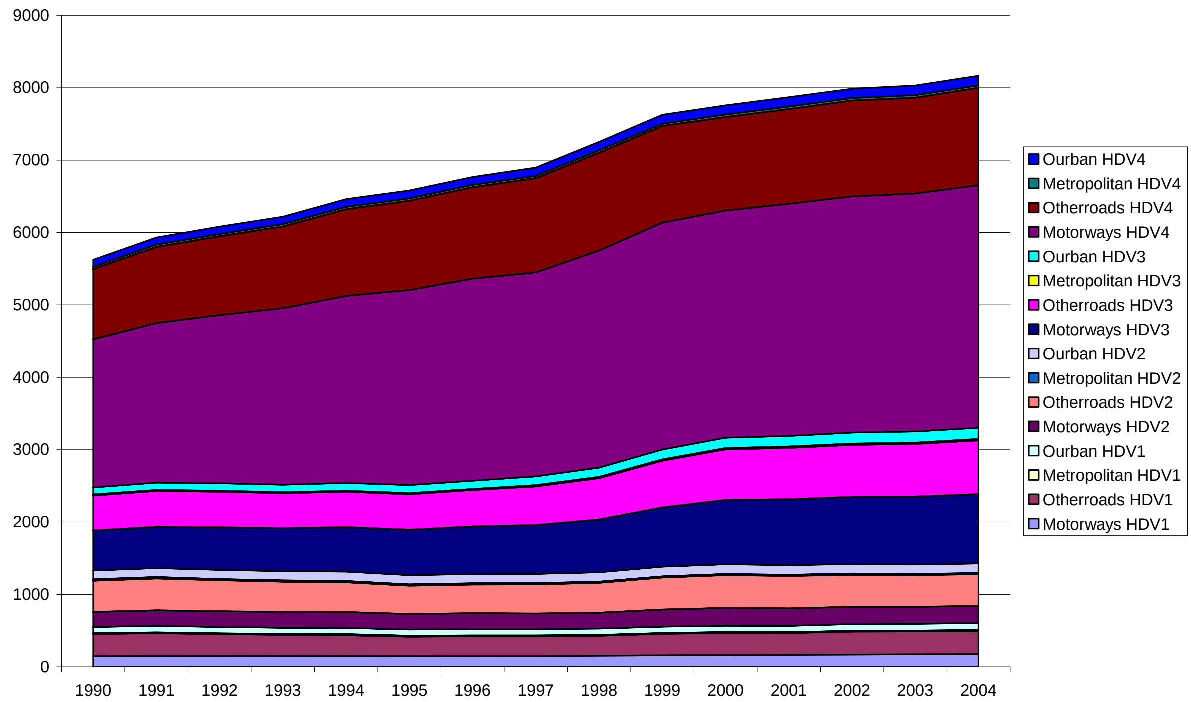
Voor 2004 wordt na een vijftal iteraties de resultaten uit Tabel 4 bekomen.

Tabel 4 : Voertuigkilometer per wegtype en voertuigtype voor 2004 [miljoen vtgkm/jaar]

	HDV1	HDV2	HDV3	FOD km
Motorways	174.50	238.65	959.20	**1372.35**
Otherroads	320.77	439.07	741.68	**1501.52**
Metropolitan	11.77	16.21	19.35	**47.33**
Ourban	95.05	130.95	156.34	**382.34**
Totaal	**18.23%**	**24.97%**	**56.80%**	

Resultaten

De toegepaste methode levert, samen met de gekende HDV4 gegevens per wegtype, een volledige inschatting van het vrachtvolume per voertuigtype en wegtype. Figuur 11 schetst de evolutie van deze verdeling tussen 1990 en 2004. Het cijfermateriaal staat in Tabel 5.



Figuur 11 : Evolutie van het vrachtvolume per voertuigtype en wegtype tussen 1990 en 2004.

Tabel 5 : Evolutie van het vrachtvolume per voertuigtype en wegtype tussen 1990 en 2004.

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Motorways	HDV1	146.28	151.97	150.84	150.90	151.13	146.34	149.60	146.42	150.11	158.57	163.60	163.02	170.60	172.00	174.50
Otherroads	HDV1	305.91	312.19	299.76	290.06	285.91	269.73	272.66	276.09	278.70	296.14	304.77	302.45	314.75	316.48	320.77
Metropolitan	HDV1	12.08	11.89	12.08	12.13	12.06	11.86	11.85	11.73	11.45	11.20	11.30	11.33	11.76	11.76	11.77
Ourban	HDV1	86.80	88.60	88.74	88.72	89.70	87.48	87.26	88.36	88.13	88.68	88.89	89.36	92.99	93.91	95.05
Motorways	HDV2	206.82	214.88	215.28	216.97	217.37	213.03	217.95	213.70	220.65	236.48	243.61	241.56	239.61	236.74	238.65
Otherroads	HDV2	432.91	441.80	428.19	417.42	411.59	392.99	397.56	403.31	410.01	442.03	454.21	448.57	442.45	435.98	439.07
Metropolitan	HDV2	17.21	16.93	17.37	17.57	17.48	17.39	17.39	17.24	16.95	16.82	16.95	16.92	16.64	16.30	16.21
Ourban	HDV2	123.63	126.20	127.58	128.51	129.96	128.28	128.06	129.91	130.50	133.23	133.33	133.39	131.57	130.20	130.95
Motorways	HDV3	550.59	572.03	587.23	595.31	614.49	628.49	656.41	672.88	729.48	820.32	890.35	908.48	926.50	938.30	959.20
Otherroads	HDV3	484.34	494.29	490.89	481.32	488.99	487.27	503.22	533.71	569.68	644.43	697.66	708.99	719.02	726.21	741.68
Metropolitan	HDV3	13.61	13.39	14.07	14.32	14.68	15.24	15.56	16.13	16.64	17.34	18.40	18.90	19.11	19.20	19.35
Ourban	HDV3	97.76	99.80	103.38	104.73	109.13	112.42	114.57	121.51	128.15	137.28	144.75	149.02	151.12	153.29	156.34
Motorways	HDV4	2048.51	2206.49	2323.75	2436.09	2580.91	2693.90	2792.38	2817.01	3000.40	3134.69	3138.59	3206.24	3263.98	3289.22	3351.01
Otherroads	HDV4	969.71	1050.71	1089.70	1129.39	1198.19	1235.55	1260.58	1302.88	1351.01	1333.18	1291.29	1308.15	1322.66	1324.83	1345.25
Metropolitan	HDV4	32.37	31.67	32.73	33.06	33.12	33.29	33.46	33.64	33.37	33.54	34.53	34.90	35.15	35.01	35.01
Ourban	HDV4	95.90	98.85	101.42	103.15	106.35	107.19	109.07	113.63	117.36	122.90	126.95	128.61	129.96	130.52	132.22

Referenties

- FEBIAC stock gegevens 1991-2004 (jaarlijks wagenpark ontvangen)
- FOD mileage gegevens 2001-2004 (publicatie opmeting van de jaarlijks afgelegde kilometers)
- FOD voertuigkilometers vanaf 1970 (digitale xls sheet ontvangen van dhr Labeeuw).

- Furness K.P. (1965) *Time function iteration* – Traffic Engineering + Control (7): 458-460.
- Immers L.H. en Stade J.E. (2004) Verkeersmodellen – cursustekst H111 verkeerskunde basis.- KULeuven. Zie ook http://www.kuleuven.ac.be/traffic/dwn/h111deel1.pdf
- Palm, I., Regniet, G., Schmidt, G., Heusch-Boesefeldt (1996) *Ermittlung der Pkw- und Nfz-Jahresfahrleistungen 1993 auf allen Straßen in der Bundesrepublik Deutschland* im Auftrag des Bundesministeriums für Verkehr, Aachen 1996 - Heusch-Boesefeldt

Annex 8 Road ownership taxes as used in third policy simulation

SYNTHESE : TAX/YEAR DEPENDING ON CAR TECHNOLOGY, REPLACING EXISTING TAXES

NORM	Year	PCGS	PCGM	PCGB	PCDS	PCDM	PCDB	PCGhS	PCGhM	PCGhB	PCDhS	PCDhM	PCDhB	PCGS_CNG	PCGM_CNG	PCGB_CNG
year tax/veh.	2000	119	211	670	170	340	659	119	211	670	170	340	659	119	211	670
EURO 0	2000	168	298	945		658	1,276									
	2005	250	443	1,405		979	1,897									
	2006	289	513	1,629		1,032	1,948									
	2007	329	584	1,854		1,084	2,000									
	2008	369	654	2,078		1,137	2,051									
	2009	409	725	2,302		1,190	2,102									
	2010	449	796	2,526		1,242	2,153									
	2011	523	928	2,947		1,449	2,512									
	2012	598	1,060	3,367		1,656	2,870									
	2013	673	1,193	3,788		1,863	3,228									
	2014	747	1,325	4,208		2,069	3,587									
	>=2015	822	1,458	4,629		2,276	3,945									
EURO 1	2000	110	195	620		464	899									
	2005	164	290	922		690	1,337									
	2006	190	337	1,069		727	1,373									
	2007	216	383	1,216		764	1,409									
	2008	242	429	1,363		801	1,445									
	2009	268	476	1,510		838	1,481									
	2010	294	522	1,657		875	1,517									
	2011	343	609	1,933		1,021	1,770									
	2012	392	696	2,209		1,167	2,023									
	2013	441	783	2,485		1,313	2,275									
	2014	490	869	2,761		1,458	2,528									
	>=2015	539	956	3,037		1,604	2,780									
EURO 2	2000	56	100	318		300	581									
	2005	84	149	472		446	864									
	2006	97	173	548		470	887									
	2007	111	196	623		494	911									
	2008	124	220	699		518	934									
	2009	137	244	774		542	957									
	2010	151	267	849		566	981									
	2011	176	312	991		660	1,144									
	2012	201	357	1,132		754	1,307									
	2013	226	401	1,274		848	1,470									
	2014	251	446	1,415		942	1,634									
	2015	276	490	1,556		1,037	1,797									
	2016	316	561	1,780		1,186	2,056									
	2017	356	631	2,004		1,335	2,314									
	2018	396	702	2,229		1,484	2,573									
	2019	436	772	2,453		1,634	2,832									
	>=2020	475	843	2,677		1,783	3,091									
EURO 3	2000	34	60	189	95	190	368	17	30	95						
	2005	50	89	281	141	282	547	25	44	141						
	2006	58	103	326	152	297	562	29	51	163						
	2007	66	117	371	162	313	577	33	58	186						
	2008	74	131	416	173	328	591	37	66	208						
	2009	82	145	461	183	343	606	41	73	230						
	2010	90	159	506	194	358	621	45	80	253						
	2011	105	186	590	226	418	724	52	93	295						
	2012	120	212	674	259	477	827	60	106	337						
	2013	135	239	758	291	537	931	67	119	379						
	2014	150	265	843	323	597	1,034	75	133	421						
	2015	165	292	927	355	656	1,137	82	146	463						
	2016	204	363	1,151	442	815	1,413	102	181	576						
	2017	244	433	1,376	528	974	1,689	122	217	688						
	2018	284	504	1,600	614	1,133	1,964	142	252	800						
	2019	324	575	1,825	700	1,292	2,240	162	287	912						
(calc. 2025)	>=2020	364	645	2,050	786	1,451	2,515	182	323	1,025						
EURO 4	2000															
	2005	26	46	146	71	142	276	13	23	73	24	48	93	9	15	49
	2006	30	53	169	77	150	283	15	27	84	29	56	106	12	21	65
	2007	34	60	192	82	158	291	17	30	96	34	65	118	15	26	82
	2008	38	68	215	87	165	298	19	34	108	39	73	131	17	31	98
	2009	42	75	238	93	173	306	21	38	119	44	82	144	20	36	114
	2010	46	82	262	98	181	313	23	41	131	49	90	157	23	41	131
	2011	54	96	305	114	211	365	27	48	153	57	105	183	27	48	153
	2012	62	110	349	130	241	417	31	55	174	65	120	209	31	55	174
	2013	70	124	392	147	271	469	35	62	196	73	135	235	35	62	196
	2014	77	137	436	163	301	522	39	69	218	82	150	261	39	69	218
	2015	85	151	479	179	331	574	43	75	240	90	165	287	43	75	240
	2016	114	202	643	240	444	769	57	101	321	120	222	384	57	101	321
	2017	143	254	806	301	556	964	72	127	403	150	278	482	72	127	403
	2018	172	305	969	362	669	1,160	86	153	485	181	334	580	86	153	485
	2019	201	357	1,132	423	782	1,355	101	178	566	211	391	677	101	178	566
(calc. 2030)	>=2020	230	408	1,296	485	895	1,551	115	204	648	242	447	775	115	204	648

NORM	Year	PCGS	PCGM	PCGB	PCDS	PCDM	PCDB	PCGhS	PCGhM	PCGhB	PCDhS	PCDhM	PCDhB	PCGS_CNG	PCGM_CNG	PCGB_CNG
year tax/veh.	2000	119	211	670	170	340	659	119	211	670	170	340	659	119	211	670
EURO 5	2000															
	2005	20	35	110	28	56	108	10	17	55	14	28	54	10	17	37
	2006	23	40	127	30	59	111	11	20	64	15	29	55	11	20	49
	2007	26	46	145	32	62	114	13	23	72	16	31	57	13	23	62
	2008	29	51	162	34	65	117	14	26	81	17	32	58	14	26	74
	2009	32	57	180	36	68	120	16	28	90	18	34	60	16	28	86
	2010	35	62	197	38	71	123	18	31	99	19	35	61	18	31	99
	2011	41	73	230	45	83	143	20	36	115	22	41	72	20	36	115
	2012	47	83	263	51	94	163	23	41	132	26	47	82	23	41	132
	2013	53	93	296	57	106	184	26	47	148	29	53	92	26	47	148
	2014	58	104	329	64	118	204	29	52	164	32	59	102	29	52	164
	2015	64	114	362	70	130	225	32	57	181	35	65	112	32	57	181
	2016	74	130	414	80	148	257	37	65	207	40	74	128	37	65	207
	2017	83	147	466	90	167	289	41	73	233	45	83	145	41	73	233
	2018	92	163	518	101	186	322	46	82	259	50	93	161	46	82	259
	2019	101	180	570	111	204	354	51	90	285	55	102	177	51	90	285
	2020	111	196	622	121	223	386	55	98	311	60	111	193	55	98	311
	2021	123	218	693	135	248	431	62	109	347	67	124	215	62	109	347
	2022	136	241	764	148	274	475	68	120	382	74	137	237	68	120	382
	2023	148	263	836	162	299	519	74	132	418	81	150	259	74	132	418
	2024	161	286	907	176	325	563	81	143	453	88	162	281	81	143	453
(calc. 2030)	2025	174	308	978	190	350	607	87	154	489	95	175	303	87	154	489