Energy research Centre of the Netherlands

Well-To-Wheel based fiscal systems

Can a WTW fiscal basis accelerate the introduction of alternative fuels?

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Abstract

This report explores to which extent alternative, (partially) Well-To-Wheel based fiscal systems may accelerate the introduction of low-carbon fuels and vehicles. The design of two alternative fiscal systems is described, as well as the challenges that any fiscal system must meet. The alternative systems are compared to the existing fiscal system with regard to (i) the extent to which they honour the ‘polluter pays’ principle, (ii) the extent to which they are expected to accelerate the introduction of (alternative) gaseous fuels, liquid biofuels, and zero-emission vehicles, (iii) their expected impact on the vehicle stock, and (iv) a number of (undesired) side-effects. The results show that the alternative systems provide a stronger fiscal support for some alternative fuels and vehicles, but not for all.

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List of abbreviations

BEV - Battery-Electric Vehicle, a vehicle that use batteries as only means of energy storage
BPM - Belasting van personenauto's en motorrijwielen / Registration tax
BTW - Belasting toegevoegde waarde / Value-added tax
CNG - Compressed Natural Gas
E85 - A blend of 85% ethanol and 15% petrol (based on volume)
FCV - Fuel Cell Vehicle, a vehicle fuelled with hydrogen
FFV - Flex-Fuel Vehicle
LPG - Liquefied Petroleum Gas
MRB - Motorrijtuigenbelasting / Ownership tax
PHEV - Plug-in Hybrid Electric Vehicle, a vehicle that can use electricity stored in batteries as well as petrol for propulsion, and that can recharge the battery from the electricity grid
RED - Renewable Energy Directive
SDE - Stimulering Duurzame Energieproductie (Dutch subsidy scheme to stimulate the production of renewable energy)
TTW - Tank-To-Wheel
WTT - Well-To-Tank
WTW - Well-To-Wheel

Executive summary

Can WTW-based fiscal systems accelerate the introduction of alternative fuels?
Fiscal policy is a proven powerful instrument to influence vehicle sales and use, and, consequently, emissions in the transport sector. So far, fiscal instruments were only aimed at vehicle efficiency and the fuels of vehicles. A fiscal system that is (partially) based on Well-To-Wheel (WTW) CO_2 emissions has the potential to reduce direct and indirect emissions in the transport sector by accelerating the introduction of alternative (lower-carbon) fuels. This report explores whether this is the case, by addressing the following questions:

- How could the design of the current, fuel-specific, fiscal system be transformed into a similar[1], albeit generic, fiscal system with a WTW-emission tax base? Are there any undesired side-effects that need to be resolved?
- What is the impact of alternative WTW-based fiscal system(s) on the taxation and cost competitiveness of alternative and conventional fuels? Could this lead to an acceleration of vehicle sales with alternative fuels and to a substantial change in the total vehicle stock?

WTW-based systems can stimulate the introduction of alternative fuels
Based on an analysis of the existing fiscal system and two alternative systems, this study concludes the following:

- WTW based systems seem to provide feasible alternatives for the existing system.
- Compared to the existing system, the alternative systems provide higher incentives for liquid biofuels and biogas, and lower incentives for gaseous fuels and zero-emission vehicles.
- An important side effect is that, in a WTW-based fiscal system, diesel vehicles will be much more attractive than petrol vehicles from a cost perspective, and a major shift in car sales can be expected if such a system is implemented.
- In the existing as well as in the alternative systems, vehicle efficiency for conventional fuels is a very powerful alternative for a switch to alternative fuels. The current expected efficiency improvement will require substantial increases in tariffs (in all systems) to avoid substantial loss of tax revenue. Only after all cost-effective efficiency improvements are realized for conventional fuels, alternative fuels are expected to gain market share.
- Contrary to the existing fiscal system, WTW based systems are likely to increase the share of biofuels (liquid and biogas) used by conventional vehicles.

This study has analysed two alternative fiscal systems
The two systems that this report presents are generic, i.e. they do not have specific tariffs for specific fuels. The types of taxation (i.e. BPM, MRB, and excise duties) that are used in the current system are kept intact in both alternative systems. The first system (Alternative 1) is fully WTW-based, implying that all taxes are based on vehicle WTW-emissions. In the second system (Alternative 2), excise duties are fully WTW-based, whereas vehicle-related taxes are Tank-To-Wheel (TTW) based. Table S.1 summarises the main characteristics of the two alternative systems.

[1] The alternative system should have a similar set-up (e.g. progressive tariff structure) to ensure a clear assessment of the relevant differences as result from the tax base change.

Table S.1 *Fiscal systems considered in this report*

	Existing system	Alternative 1	Alternative 2
Tax base BPM/MRB	TTW g/km of vehicle derived from MJ/km (fossil equivalent).	WTW g/km of vehicle/fuel combination	TTW g/km of vehicle derived from MJ/km (fossil equivalent).
Tariff structure BPM/MRB	Progressive with exemption for low TTW g/km	Progressive with exemption for low WTW g/km	Progressive, based on TTW emissions, no exemptions, tariffs lower to compensate higher excise duty tariffs (see below)
Tariffs Excise duty	Separate tariffs for all fuels	Tariff per g WTW based on current average over all fuels	Tariff per g WTW based on current "petrol tariff"
Government income	-	For each tax: rates are chosen so government income is equal to the existing system	Variabilization: Total income stable, but shifting from BPM/MRB to Excise duty

Evaluation of the alternatives along four main aspects

The performance of the three systems has been qualitatively assessed[2] with respect to four aspects[3] (Table S.2):

- The extent to which the principle of the 'polluter pays' is honoured.
- The extent to which the introduction of alternative fuels is accelerated, based on the cost reductions of alternative fuels for users.
- The impact on vehicle sales and stock.
- The extent to which four side-effects are likely to occur: (i) increase in passenger car travel, (ii) improvement of security of supply, (iii) increase in administrative complexity, and (iv) impact on air quality.

Table S.2 *Assessment of the potential of the three fiscal systems to accelerate the introduction of alternative fuels*

	Existing system	Alternative 1	Alternative 2
Implementation of 'polluter pays' principle	Limited	Very strong	Strong
Acceleration introduction alternative fuels & vehicles			
• Gaseous fuels	Moderate	Moderate/Strong	Moderate
• Liquid biofuels	None	Strong	Moderate
• Zero-emission vehicles	Strong	Moderate	Moderate
Impact on vehicle sales & stock			
• Required tariff increases	Substantial	Substantial	Substantial
• Potential shifts	n/a	Substantial	Substantial
Other side-effects			
• Passenger car travel	n/a	Stimulating effect	Reducing effect
• Improvement of security of supply	Moderate	Moderate	Limited
• Admin. complexity	Limited	Complex	Complex
• Impact on air quality	Moderately positive	Uncertain	Uncertain

2 The assessment is partly based on expert judgment. The conclusions are not equally valid for each vehicle-fuel combination. Chapters 4, 5, and 6 provide a more detailed basis for the assessments presented in this summary.

3 On top of the aspects listed in Table S.2, a stable level of government income and the competitiveness of the freight sector are important aspects. It is assumed that good performance on these aspects is incorporated in the design of the systems (see Sections 2.4.2 and 2.4.3, respectively), and they are therefore not considered in this chapter.

Alternative fiscal systems make the polluter pay

Alternative 1 performs very well on the polluter pays principle, since all taxation is based on WTW-emissions in this system. This implies that those users that drive vehicles with high emissions pay (much) more than users that drive vehicles with low emissions. Alternative 2 also has a strong performance in this respect, because it includes some WTW-elements. The existing system does not take Well-To-Tank (WTT) emissions into account and therefore only honours the polluter pays principle to a limited extent. Moreover, the fuel-specific tariffs in the existing system lead to tax burdens that are not strongly related to vehicle emissions.

The introduction of some low carbon fuels is accelerated

The performance with respect to the acceleration of alternative fuel and vehicles is mixed. In all three systems, gaseous fuels are attractive options for consumers from a cost perspective. The incentive is strongest in Alternative 1, followed by Alternative 2 and the existing system respectively. The alternative systems also provide a strong incentive for biogas, which is not available within the existing system.

- Liquid biofuels have a good WTW-performance[4], and are, due to the low tax burden, very attractive from a cost perspective in Alternative 1. In Alternative 2, although only excise duties are WTW-based, the tax burden is still sufficiently low to make the use of E85 and biodiesel cheaper than conventional fuels. In the two alternative systems, the (partial) WTW tax basis ensures that fuels produced via low-emission production pathways receive an even stronger incentive, which is in the existing system fiscally not possible[5]. In the existing system, there is no special fiscal treatment for biofuels and they are more expensive than conventional fuels[6].
- Zero-emission vehicles receive strong fiscal support in the existing system – they are exempt from all vehicle-related taxes, and the tax burden on electricity is low. Consequently, despite their high purchase cost, these vehicles are almost cost competitive now. Vehicle-related taxation on zero-emission vehicles in the alternative systems are low, but positive[7], and therefore the acceleration of the introduction of these vehicle types is only deemed moderate in these systems.

A long-term impact on the diesel/petrol composition of vehicle stock

To compensate for lower tax revenues due to the expected efficiency improvements of vehicles, tariffs will have to increase substantially in all three fiscal systems. The largest impact on vehicle sales and stock, however, comes from the change of relative costs of diesel and petrol vehicles. In the alternative systems, the costs for diesel vehicles are substantially lower than in the existing system. Consequently, a shift from petrol to diesel vehicles in the vehicle stock can be expected.

Alternative fuels are stimulated, but very efficient conventional vehicles as well

The various fiscal systems provide incentives for alternative fuels, with different systems providing incentives for different types of alternative fuels (see Table S.1). However, in all systems, incentives are also available for very efficient conventional vehicles. From a user perspective, these vehicles will, now and in the future, be about equally attractive as alternative fuel ve-

[4] Note that land use changes and non-CO_2 greenhouse gas emissions have not been taken into account in these calculations and may raise emissions from biofuels substantially.

[5] The Renewable Energy Directive and the Fuel Quality Directive do provide some incentives for low-emission fuels.

[6] Note that in all systems, factoring biotickets into the price of the fuel may make biofuels competitive from a cost perspective. The *Besluit Biobrandstoffen* requires fuel suppliers to annually provide sufficient biotickets (equal to fuel sales times required renewable share), which are obtained for renewable fuels that are sold (in transport sector). For fuel suppliers that have more biotickets than needed, the surplus can be traded. As a result, fuels that contribute more than the required renewable share (such as E85 or biogas), should have a correction on their fuel cost based on the value of a bioticket.

[7] Except for BEVs in Alternative 1.

hicles. Therefore, whether the fiscal systems (existing and alternative) would also lead to an uptake of alternative fuels is not certain.

Side effects are different for different fiscal systems

The fiscal systems may result in some side-effects. The relatively low excise duties in Alternative 1 may create additional passenger car travel demand, whereas the relatively high excise duties in Alternative 2 may have the opposite effect. None of the three systems is expected to lead to a strong improvement of security of supply, because none are expected to lead to short-term uptake of gaseous fuels and/or zero-emission vehicles. The two alternative systems require the introduction of a separate excise duty tariff for the freight sector to ensure this sector's competitiveness – this makes the systems administratively complex. Finally, the strong support for zero-emission vehicles in the existing system has a positive effect on air quality – at least in the long run. The alternative systems stimulate vehicles using E85 as well as diesel vehicles – consequently, the overall impact on air quality is uncertain.

How are policy objectives addressed in alternative fiscal systems?

Any fiscal system faces the challenge to fulfil a range of policy objectives, which have to be taken into account in the system design. The following challenges are considered:

- *Passenger car travel demand* may increase if the excise duty for certain fuels decreases compared to the current system. Petrol vehicles make up a large share of the existing vehicle stock, so lower petrol excise duties may lead to more passenger car travel, with congestion as an one of the undesired side-effects.
- The fiscal system for passenger cars forms an important source of *government income*. Systems that are (partly) based on emissions will lead to lower income when the vehicle stock becomes more efficient, and average emissions per vehicle decrease, unless tariffs are regularly adjusted upwards.
- The *competitiveness of the freight sector* is partially based on the relatively low excise duties for diesel. Any raise in the excise duty of diesel should be compensated to safeguard this competitiveness, e.g. through an administrative solution.
- In TTW-based systems, *zero-emission vehicles* are not taxed with vehicle-related taxes. In these systems, a major uptake of zero-emission vehicles will lead to significant loss of government income.
- A single fuel may be produced via *multiple production pathways*, with significantly varying chain emissions. In (partly) WTW-based systems, these differences need to be accounted for.
- Large price differences with fuels offered in neighbouring countries may lead to an increase in *refuelling abroad*, leading to undesired effects such as less tax income and more passenger car travel.
- *Multifuel vehicles* are capable of handling more than one fuel. In the design of fiscal systems, a choice must be made as to which fuel to base vehicle-related taxation on. The fuel that vehicle-related taxation is based on may however not be the fuel used in practice.
- Finally, fiscal systems must be *aligned with existing (European) law and regulations*. It is outside the scope of this research to determine whether the alternative systems are fully compliant with existing rules and regulations, and this is therefore a topic for further research.

The design of the existing and alternative fiscal systems puts constraints on the extent to which these challenges can be addressed effectively. Table S.3 summarises whether the challenges are addressed in each of the fiscal systems, and indicates that particularly the challenges related to multiple production pathways and refuelling abroad will need more attention.

Table S.3 *Evaluation of the extent to which policy challenges are addressed*

	Existing system	Alternative 1	Alternative 2
Passenger car travel demand	n/a[a]	Issue	Solved
Government income	Solved[b]	Solved[b]	Solved[b]
Competitiveness freight sector	Solved	Solved[c]	Solved[c]
Energy use zero-emission vehicles	Issue	Solved	Solved
Multiple production pathways	Irrelevant	Partly solved[d]	Partly solved[d]
Refuelling abroad	Limited issue	Limited issue	Issue
Secondary fuel use in multifuel vehicles	Solved	Issue	Solved
Alignment with existing law and regulations	n/a	Potential issue	Potential issue

[a] Arguably, there are also problems with mobility in the current system, e.g. congestion. Therefore, this challenge is only considered in relation to the existing situation under the existing fiscal system.
[b] Assuming tariffs and emission brackets are updated appropriately, see Section 2.4.2.
[c] Assuming that a separate excise duty tariff for diesel in the freight sector is created administratively.
[d] Assuming the emissions of the average production mix of fuels consumed in the Dutch market.

Conclusion: WTW-based fiscal systems can accelerate the introduction of alternative fuels

The WTW-based fiscal systems, evaluated in this report, provide strong fiscal incentives for alternative fuels, which have been compared to the strong fiscal incentives in the existing systems. Which of the systems provides the strongest incentive depends on the fuel type. The existing system primarily stimulates zero-emission vehicles and gaseous fuels. These are also stimulated by the alternative systems, but these provide stronger incentives for liquid biofuels and biogas, due to their low WTW emissions.

However, all systems also provide a strong incentive for very efficient vehicles, including vehicles using conventional fuels. Whether vehicles on alternative fuels will pick up in the future therefore also strongly depends on the marginal costs of (further) efficiency improvements of conventional vehicles. Irrespective of this development on the vehicle side, a WTW-based fiscal system will accelerate the introduction of low-carbon fuels (e.g. biogas and liquid biofuels) that can substitute[8] the conventional fossil fuels.
In conclusion, a WTW-based fiscal system provides strong fiscal incentives to increase vehicle efficiency as well as to reduce WTW emissions of the fuel involved, and could accelerate the introduction of low carbon fuels. The alternative systems do not seem to have major disadvantages compared to the existing system.

[8] The substitution could be complete (e.g. fungible biofuels, like FT-diesel) or partly (e.g. via blending of ethanol).

1. Introduction

Fiscal policy is a powerful instrument in the transport sector and has a long tradition of contributing to various policy goals. Taxation helps to manage mobility and provides a major source of government income.

Recent changes to the fiscal system have contributed to a reduction of emissions from passenger cars. Starting 2006, passenger car taxation has been differentiated with respect to energy efficiency labels. From 2008 onwards, the fiscal system taxes vehicles with higher CO_2 emissions more heavily. Partly as a consequence of this differentiation, the sales of energy efficient passenger cars has increased significantly (Figure 1.1).

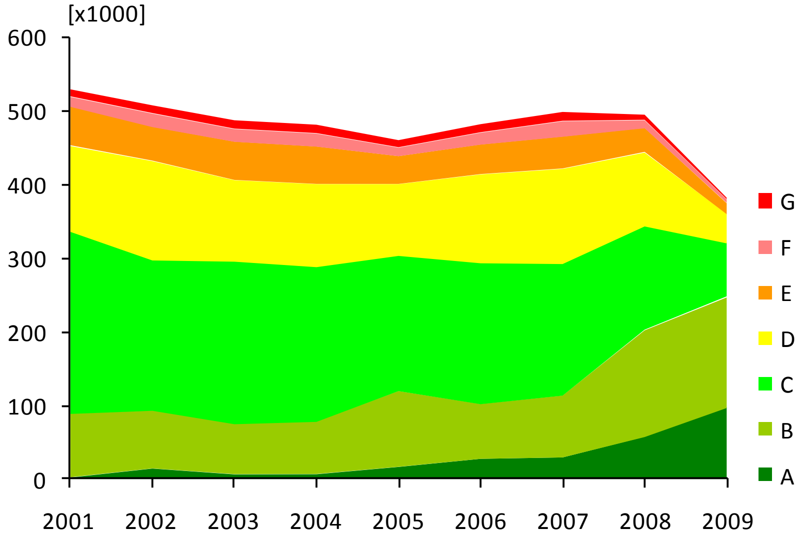

Figure 1.1 *Passenger car sales by energy efficiency label*
Source: (RDC, 2010).

1.1 Challenges for the existing fiscal system

The transport sector faces a twofold challenge. Firstly, the emissions of CO_2, which result from the combustion of fossil fuels, induce climate change. Secondly, the supply of fossil fuels is increasingly constrained, leading to increasing and more volatile fuel prices.

Broadly speaking, there are three options to address these challenges: (i) a reduction of transport volume, (ii) more efficient vehicles, and (iii) alternative, preferably renewable and low(er)-carbon, fuels. The existing fiscal system contributes to all aspects: (i) the substantial price impact of fuel excise duty and value added tax limits the transport demand, (ii) the incentives in purchase (belasting van personenauto's en motorrijwielen; BPM) and ownership taxes (motorrijtuigenbelasting; MRB), combined with increased fuel price, have recently contributed to the improvement of vehicle efficiency (as illustrated above), and (iii) the government has been able to stimulate fuels such as Liquefied Petroleum Gas (LPG) via fuel-specific taxation[9]. Progress is needed on all these three aspects to address the challenges adequately.

Both the reduction of CO_2 emissions and the introduction of alternative fuels are addressed by European legislation. Addressing CO_2 emissions, Regulation 443/2009/EC stipulates that the average emissions from new passenger cars shall not exceed 130 g/km from 2015 onwards. The same Regulation includes a target of 95 g/km for 2020. Furthermore, the Fuel Quality Directive

9 The extent to which fuel-specific policy contributes to combating climate change naturally depends on which fuels are fiscally stimulated.

(2009/30/EC) stipulates that fuel providers shall reduce the CO_2 emissions in the entire chain (from fuel production to use) by 6% in 2020. Addressing alternative fuels, Directive 2009/89/EC, also known as the Renewable Energy Directive (RED), stipulates that a minimum of 10% of energy use in transport shall come from renewable sources by 2020.

Some of this legislation is effective in itself (e.g. Regulation 443/2009/EC), some needs national policy to ensure that the targets are met (e.g. the RED). In this last respect, the fiscal system can be of particular importance. Alternative fuels and technologies are typically more expensive than their conventional counterparts. Consumers are not willing to pay these additional costs directly. If these additional costs are compensated by subsidies, alternative fuels may become very expensive for the government if successful. Although subsidies are an effective measure to stimulate the early market introduction phase, they may suffer from their own success and should at a certain moment be replaced by more appropriate policies (Hanschke et al, 2009).
The fiscal system may help to improve the attractiveness from a total cost perspective of alternative fuels, for example by aligning taxes with environmental impact (e.g. Well-To-Wheel emissions). In such case the tax burden for (alternative) fuels with low emissions would be lowered, whereas the burden for (fossil) fuels with high emissions is increased. As taxation forms a large part of the costs of driving a vehicle, the impact of such a fiscal system could compensate for the additional costs of alternative fuels to conventional fuels.

Basing part of the fiscal system on Well-To-Wheel (WTW)-emissions also offers the opportunity to make the fiscal system more robust and fair. BPM and - to some extent - MRB are based on the tank-to-wheel (TTW)-emissions of vehicles. Some vehicle technologies - notably Battery-Electric Vehicles (BEVs) and Hydrogen Fuel Cell Vehicles (FCVs) - do not produce any TTW-emissions. At this moment zero emission vehicles are exempted from BPM and MRB in the Netherlands. If these technologies capture a significant market share, this could significantly reduce government income. Introducing a tariff structure that also taxes zero-emission vehicles will therefore make the system more robust[10]. An option is to base taxation of BEVs and FCVs on their WTW-emissions, thus including the emissions of the TTW-part.

Using WTW-emissions as a basis for taxation can also make the fiscal system fairer. The tariff structure in the existing system is differentiated with respect to the various fuels and technologies, allowing to influence which fuels and technologies are currently in use. If these fuel-specific different tariffs are replaced by a single tariff, e.g. linked to WTW-emissions, ensures that vehicles that emit more CO_2 are taxed more heavily. Such a system more rightfully honours the principle of “the polluter pays”.

1.2 The objective of this report

This report explores whether alternative, more WTW-based, fiscal systems have the potential to (effectively) accelerate the introduction of alternative (lower-carbon) fuels. The following key research questions are addressed:

- How could the design of the current (fuel-specific) fiscal system be transformed in a similar[11] generic fiscal system with a WTW-emission tax base? Are there undesired side-effects that need to be resolved?
- What is the impact of alternative WTW-based fiscal system(s) on the taxation and cost competitiveness of alternative and conventional fuels? Could this lead to an acceleration of vehicle sales with alternative fuels and to a substantial change in the total vehicle stock?

[10] Currently, FCVs and EVs are exempt from BPM and MRB to support these technologies during the (expensive) early stages of market introduction.
[11] The alternative system should have a similar set-up (e.g. progressive tariff structure) to ensure a clear assessment of the relevant differences as result from the tax base change.

The key questions will be answered for private passenger cars, for a number of fuel-vehicle combinations. The impact of the alternative fiscal system on the attractiveness of alternative fuels, as compared to conventional fuels (petrol, diesel, and Liquefied Petroleum Gas, LPG), will be assessed in more detail for three clusters:

- Gaseous fuels: Compressed Natural Gas (CNG), biogas.
- Liquid biofuels: ethanol (E85), biodiesel.
- Zero-emission vehicles: Battery-Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs [12]), Hydrogen Fuel Cell Vehicles (FCVs).

Please note that the changes announced in the 'Autobrief' (Ministerie van Financiën, 2011) could and have not been taken into account in this study.

1.3 Outline

Chapter 2 introduces two alternative fiscal systems, which differ from the existing system on a number of aspects. Fiscal policy goals and future developments present challenges for the fiscal systems. The chapter offers an explanation how these challenges can be met in the existing system and in alternative systems.

Chapter 3 provides a high-level comparison between the existing fiscal system and the two alternative fiscal systems. The chapter assesses for each system (i) the extent to which the 'polluter pays' principle is implemented, (ii) whether the introduction of alternative fuels is accelerated, (iii) the impact on vehicle sales and stock, and (iv) whether (undesired) side-effects occur.

The next three chapters provide a more in-depth discussion of this assessment. Chapter 4 details the design of the various forms of taxation in the three fiscal systems and the implications for the tax burden for the various fuels. Chapter 5 presents the resulting competitive position of the different vehicle-fuel combinations. Chapter 6 discusses the implications for the vehicle sales and stock.

Three appendices provide background information. Appendix A provides detailed information on the calculation of WTW-emissions in the scope of this report. Appendix B provides a guideline for the interpretation of some of the graphs in this report. Appendix C lists some statistics on annual distances covered by passenger cars and some assumptions on vehicle properties in the context of this report.

[12] A PHEV is only a zero-emission vehicle when operating in all-electric mode.

2. Alternative fiscal systems

This chapter starts with a brief description of the existing fiscal system (Section 2.1). Section 2.2 introduces the differences in emissions between various vehicle-fuel combinations, which form a rationale for considering the implementation of WTW-elements as tax base in the fiscal system. Based on this, two alternative fiscal systems with a (partial) WTW-base are described (Section 2.3). These two alternative systems will be compared in this study with the existing fiscal system to assess the impact on the attractiveness of alternative vehicle-fuel technologies. Section 2.4 describes a number of important challenges for a fiscal system and how these have been addressed in the three fiscal systems.

2.1 The existing fiscal system: Fuel-specific, partially tank-to-wheel

Besides value-added tax, private passenger cars[13] can currently be subject to up to three different forms of taxation:

- *Registration tax (BPM)* is levied once, upon first registration of the vehicle in the Netherlands[14]. In the current system, the tax base for the BPM is the vehicle CO_2 emission per kilometre (TTW)[15], as determined in the New European Driving Cycle using fossil-derived fuels. The BPM is a progressive tax, implying that the tariffs per gram of CO_2 emitted are higher when the vehicle emissions are higher. Tariffs differ per fuel. There is an exemption for vehicles that emit less CO_2 per kilometre (TTW) than certain threshold levels, which also differ per fuel.
- *Ownership tax (MRB)* is levied monthly, quarterly or annually for each vehicle that is registered in the Netherlands[16]. In the current system, the most important base for the MRB is the deadweight of the vehicle. The MRB increases largely linear with weight. Tariffs differ per fuel. There is an exemption for vehicles that emit less CO_2 per kilometre (TTW) than certain threshold levels, which also differ per fuel.
- *Excise duty* is added to the price of fuels on a volume basis (i.e. per litre). In the current system, amounts per litre differ per fuel.

Value-added tax (BTW) is added to the purchase prices of vehicles and fuels. The BTW-rate in the Netherlands is 19%. For the vehicle, BTW is calculated over the list price excluding BPM. For fuels, BTW is calculated over the fuel price including excise duties. Changes to the value-added tax system are outside the scope of this report. However, value-added tax is included when tax burden and cost comparisons are presented.

In the Netherlands, the fiscal system has evolved over the last decades to a system with some fuel-specific elements to address specific strategic issues, including local air quality, competitive position of the freight transport sector and security of supply. The three main fuels are therefore attractive for different market segments, as is clear from the following observations:

- Petrol has a high excise duty tariff, but relatively low vehicle-related taxes (BPM and MRB).

[13] For motorists that use a company-owned vehicle for private purposes (lease car segment) for more than 500 km per year, an amount is added to their taxable income (as it is considered a fringe benefit). Currently, the amount is dependent on the vehicle CO_2 emissions (TTW) per kilometre, fuel type, and list price of the vehicle. The actual amount that is taxed depends on the marginal income tax rate of the person using the vehicle.
[14] Cars registered abroad, but used on Dutch roads by Dutch citizens, are also required to pay BPM.
[15] Currently, the BPM is also dependent on the list price of the vehicle, but this is due to change. The list price component will be fully replaced by the CO_2 dependent component by 2013. In this study, it has been assumed that this process has already been completed. The rates assumed for the CO_2 based component have been adapted accordingly.
[16] An exemption can be obtained if the vehicle is not used on public roads.

- Diesel has a lower excise duty tariff, but relatively high vehicle-related taxes (BPM and MRB), and is therefore in general only attractive for annual usage exceeding a certain break-even point.
- LPG has an even lower excise duty tariff. Vehicle registration taxes are similar to petrol, ownership taxes are higher than petrol.

The system has been further refined, e.g. including tax reductions for vehicles that emit relatively little particulate matter. These original differences should be kept in mind when analysing the change to an alternative system, as they will explain some of the main differences.

2.2 WTW-emissions differ for different vehicle-fuel combinations

The existing fiscal system includes elements that take into account CO_2 emissions, but is not fully based on emissions. Moreover, the parts that are based on emissions (e.g. BPM) are based on TTW-emissions, thus only taking into account the emissions related to the use of the fuel in a vehicle.

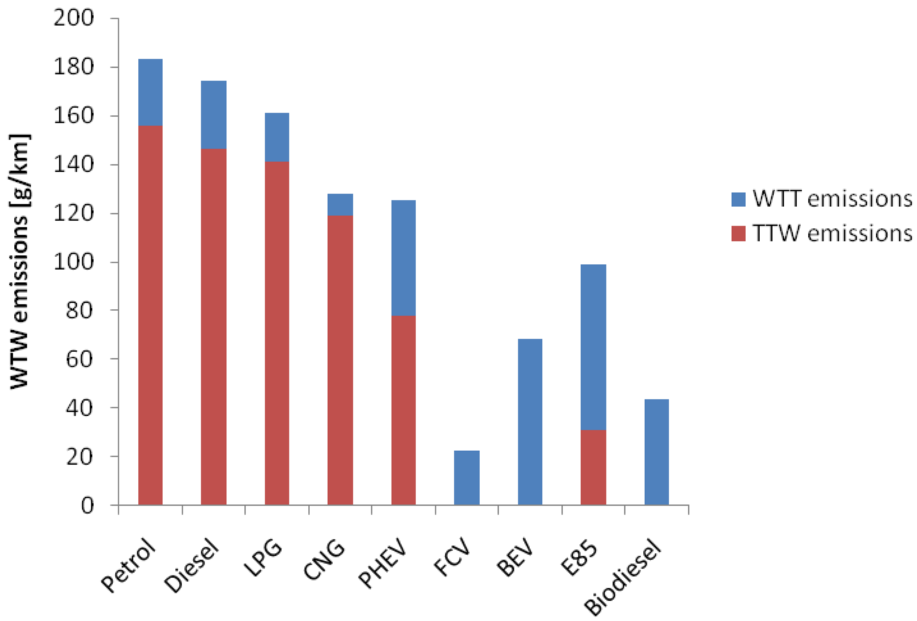

Figure 2.1 *WTW-emissions of different vehicle-fuel combinations*
Note: Excluding emissions from land use changes and non-CO_2 greenhouse gases.
Numbers reflect values for vehicles equivalent to a medium-sized, average-efficiency new vehicle.

Taking into account the Well-To-Tank (WTT) emissions, and thus considering WTW-emissions, can make a substantial difference. How much a vehicle-fuel combination emits depends on the carbon intensity of the fuel from a well-to-wheel perspective (in g CO_2 per MJ) and the vehicle efficiency (in MJ/km). Figure 2.1 shows WTW-emissions of various vehicle-fuel combinations for an average-efficiency, medium-sized, new vehicle.

For conventional fuels (petrol, diesel, LPG), WTT-emissions add approximately 15% to 20% to the TTW-emissions. The WTW-emissions of CNG are considerably lower than the emissions of conventional fuels. Although CNG-vehicles are approximately as efficient as petrol vehicles, the carbon intensity of CNG is lower. Moreover, in the case of CNG, WTT-emissions add only approximately 8% to the TTW-emissions. From a WTW-perspective, CNG is therefore less polluting than conventional fuels[17]. For all fuels, the WTW emissions depend on the production

[17] See Appendix A for a more detailed explanation of the calculation of emissions in this report.

pathway. An overview of the potential variation in WTW-emissions is provided in Figure 5.4 (gaseous fuels) and Figure 5.7 (liquid biofuels). Note that emissions from land use changes and non-CO_2 greenhouse gases have not been taken into account in this report and may raise the WTT-emissions of CNG and biofuel options significantly.

FCVs and BEVs are zero-emission vehicles, i.e. they have no TTW-emissions. Since CO_2 is emitted when hydrogen and electricity are produced, these options do have WTW-emissions. For PHEVs the WTT-emissions associated with the production of electricity have been included in the TTW-emissions as well. Their WTW emissions are still lower compared to conventional fuels, but smaller than the difference in TTW emissions.

Due to the biogenic origin of their feedstock, no TTW-emissions are associated with biofuels. Hence, their emissions are considerably lower than the emissions of their conventional counterparts. E85 includes 15% of petrol (on an energy basis) and therefore also has some TTW-emissions. Note that the existing fiscal system does not take into account the lower TTW-emissions as result of (blended) biofuels in the calculation of the vehicle related taxes (BPM/MRB).

Introducing WTW-elements can help to stimulate those vehicle-fuel combinations that have the lowest emissions from a WTW-perspective, as indicated in Figure 2.1. The next section describes two alternative fiscal systems that include WTW-elements.

2.3 Alternative system design

A number of alternative fiscal systems have been evaluated[18], two of which will be presented and used in this report. Both systems are introduced briefly, including an overview of the main changes compared to the existing fiscal system design. Please refer to Appendix A for a detailed description of how WTW-emissions are determined in this study.

2.3.1 Alternative 1: Generic WTW

This alternative system relates all vehicle and fuel related taxes to WTW-emission performance. In essence the system differs from the existing fiscal system on the following aspects:

- The tax base for the vehicle-related taxes (BPM and MRB) is changed to WTW-emissions per kilometre. The tax structure remains progressive with a generic exemption limit for low-emission vehicles.
- The tax base for the fuel-related excise duty is changed to WTW-emissions.
- Vehicle and fuel related taxes will no longer have fuel-specific tariff structures. Instead, they are taxed based on the expected WTW performance of the fuel or fuel-vehicle combination.
- Multifuel vehicles are taxed assuming that they are propelled by their ‘primary’ fuel. This implies that Flex Fuel Vehicles (FFVs) are taxed based on their WTW-emissions using E85, CNG-vehicles using CNG, and LPG-vehicles using LPG. PHEVs are taxed based on the mix of petrol and electricity used to complete type-approval test procedures[19].

By relating all taxes to the WTW-performance, all fuel-vehicle combinations that have very low WTW-emissions per kilometre will have a relative low tax burden, and will be more attractive from a total cost perspective. By including the TTW-emissions in the tax base, this system improves alignment with the ‘polluter pays’ principle from the perspective of greenhouse gas

[18] Note that the alternatives have been constructed for this study and are not based on actual scenarios from the government and/or political organisations.

[19] What the shares of petrol and electricity in this mix are is unclear, as no test data from PHEVs are available. For the purpose of this report, it is assumed that half of the energy consumed by a PHEV comes from electricity from the grid and the other half comes from petrol.

emissions[20]. Due to the removal of fuel-specific tax structures, this might no longer be the case for certain air quality related aspects of the existing fiscal system.

2.3.2 Alternative 2: Generic hybrid TTW/WTW

This alternative system relates parts of the system to WTW-emissions and parts to TTW-emissions. Specifically, Alternative 2 differs from the existing system in the following ways:

- The tax base for vehicle-related taxes (BPM and MRB) is TTW-emissions per kilometre. This implies a change for MRB (which is based on weight in the current system) but not for BPM. For zero-emission vehicles (BEVs, PHEVs, and FCVs), a share of the WTW-emissions is assigned as TTW-emissions. These vehicles are therefore also taxed in this system. The tax structure remains progressive.
- The tax base for the fuel-related excise duty is changed to WTW-emissions.
- Tax exemptions for low-emission vehicles are removed.
- Similar to Alternative 1, vehicle and fuel related taxes will no longer have fuel-specific tariff structures.
- Excise duties are based on the level (in euro per gram CO_2 per MJ) that is implied by the current excise duty on petrol. As a result, the excise duty (in euro per litre or other appropriate unit) for the other fuels is higher than in the existing system. To compensate, the tariffs of the vehicle-related taxes have been adjusted downwards, such that the overall income from taxation equals the tax income of the other two fiscal systems.

Alternative 2 is a hybrid between the existing system and Alternative 1, which is fully WTW-based. The system places a low tax burden on vehicles that have low TTW-emissions and stimulates the use of fuels with low WTW-emissions. Table 2.1 summarises the properties of the existing and the two alternative systems.

Table 2.1 *Fiscal systems considered in this note*

	Existing system	Alternative 1	Alternative 2
Tax base BPM/MRB	TTW g/km of vehicle derived from MJ/km (fossil equivalent).	WTW g/km of vehicle/fuel combination	TTW g/km of vehicle derived from MJ/km (fossil equivalent).
Tariff structure BPM/MRB	Progressive with exemption for low TTW g/km	Progressive with exemption for low WTW g/km	Progressive, based on TTW emissions, no exemptions, tariffs lower to compensate higher excise duty tariffs (see below)
Tariffs Excise duty	Separate tariffs for all fuels	Tariff per g WTW based on current average over all fuels	Tariff per g WTW based on current “petrol tariff”
Government income	-	For each tax: rates are chosen so government income is equal to the existing system	Variabilization: Total income stable, but shifting from BPM/MRB (-> lower) to Excise duty (-> higher)

[20] Note that for this study only CO_2 emissions are included, in line with current EU-legislation. For some fuels (especially gaseous fuels) other greenhouse gases are also relevant. This is discussed where appropriate.

2.4 Challenges

This report focuses on the possibility to use the fiscal system to accelerate the introduction of alternative fuels and technologies. Yet, there are additional policy objectives that a fiscal system needs to address, e.g. maintaining passenger car travel at an acceptable level, the stability of government income, and a competitive freight sector. The changes embedded in the alternative fiscal systems may hamper or promote the attainment of these policy goals. Also, future changes, e.g. related to properties specific to alternative fuels, may present challenges for fiscal systems.

Table 2.2 provides an overview of the challenges that a fiscal system must meet. The table indicates whether the challenges are addressed in each of the fiscal systems. The next sections discuss the challenges in more detail, including - if applicable - how the challenges have been addressed in the various systems.

Table 2.2 *Challenges facing the various fiscal systems*

	Existing system	Alternative 1	Alternative 2
Passenger car travel demand	n/a[a]	Issue	Solved
Government income	Solved[b]	Solved[b]	Solved[b]
Competitiveness freight sector	Solved	Solved[c]	Solved[c]
Energy use zero-emission vehicles	Issue	Solved	Solved
Multiple production pathways	Irrelevant	Partly solved[d]	Partly solved[d]
Refuelling abroad	Limited issue	Limited issue	Issue
Secondary fuel use in multifuel vehicles	Solved	Issue	Solved
Alignment with existing law and regulations	n/a	Potential issue	Potential issue

[a] Arguably, there are also problems with mobility in the current system, e.g. congestion. Therefore, this challenge is only considered in relation to the existing situation under the existing fiscal system.
[b] Assuming tariffs and emission brackets are updated appropriately, see Section 2.4.2.
[c] Assuming that a separate excise duty tariff for diesel in the freight sector is created administratively.
[d] Assuming the emissions of the average production mix of fuels consumed in the Dutch market.

2.4.1 Passenger car travel demand

Demand for passenger car travel (i.e. the number of vehicle-kilometres travelled) is an important factor for reducing emissions, as well as for reducing congestion. Compared to the existing system, Alternative 1 potentially leads to an increase in passenger car travel demand. In this system, the excise duties are merged into a single tariff, based on the fuel sales mix. In the existing system, the excise duty on petrol (in gram CO_2 per MJ) is relatively high and the excise duty on diesel is relatively low. The sales-weighted average tariff is therefore lower than the existing excise duty for petrol. This implies that the variable costs for driving a petrol vehicle will decrease, i.e. driving a petrol vehicle becomes cheaper. Since a large share (~80%) of the current vehicle stock are petrol vehicles, it can be expected that more kilometres will be driven with these vehicles.

In Alternative system 2, this issue has been solved by fixing the (single) excise duty tariff (in gram CO_2 per MJ) at the level of the petrol excise duty in the existing system. This effectively keeps the excise duty for petrol at the same level, whereas the excise duties for the other fuels increase.

2.4.2 Government income

Passenger car related taxation is an important source of government income. Alternative systems must ensure that this income can be kept at current levels. All fiscal systems should be designed such that future tax proceedings can be kept at current levels.

In all systems, it is assumed that government income is kept stable by design. This does require changes to the tariff structure in all the systems, including the existing system. As indicated in Section 1.1, it is expected that the emissions of vehicles will decrease in the future. In a system in which taxation is based on emissions with a progressive structure (including exemptions), total tax income will therefore drop more than proportional for two reasons if the average emissions per vehicle drop:

- An increasing share of vehicles will end up in tax brackets with lower tariffs given the progressive tariff structure.
- An increasing share of vehicles even becomes exempt from BPM and MRB[21].

In this study, two adjustments are made to the tariff structure to compensate for this potential drop in tax income. First, the relative tariffs (e.g. euro per g CO_2/km (TTW or WTW)) will be raised. However, in a progressive system with exemptions, this will not be sufficient, as tax revenues need to come from a smaller share of vehicles. Without other adjustments, tariffs for vehicles that are not exempt from taxation will therefore rise very substantially. Therefore, as a second adjustment, the emission boundaries of the various tax brackets in the BPM and MRB need to be lowered. It is assumed that this is done in such a way that the distribution over the tax brackets is approximately constant.[22]

This approach is illustrated in Figure 2.1. It ensures for all fiscal systems that government income is stable towards the future.

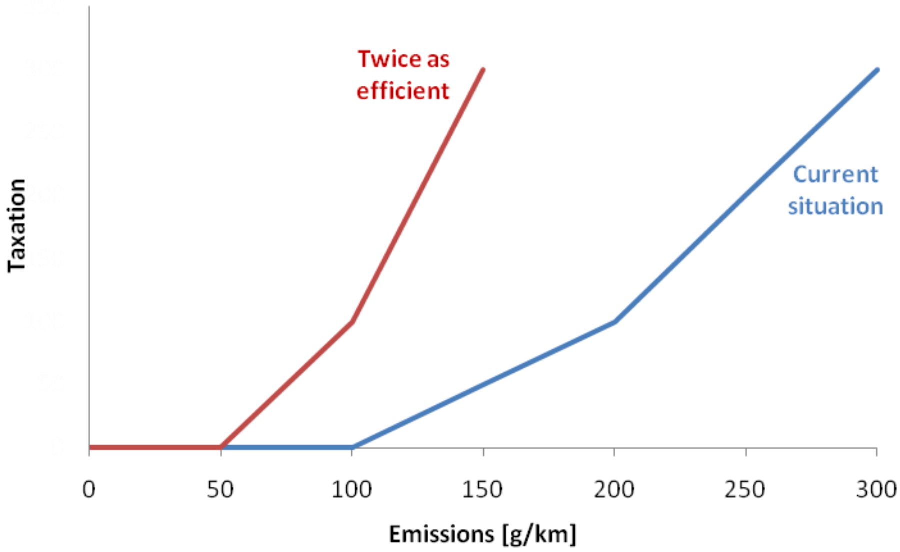

Figure 2.1 *Illustration of adaptation of tariffs and brackets to maintain a stable level of government income. The red line represents the tariff structure for a situation in which the vehicle stock is twice as efficient as the situation represented by the blue line*

2.4.3 Competitiveness of the freight sector

The freight sector almost exclusively uses diesel as a fuel. In the existing system, the excise duty on diesel is relatively low, which helps to keep the operational costs in the freight sector low.

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[21] Note that Alternative 2 does not have exemptions and is less sensitive to this aspect.

[22] In the existing system, petrol vehicles are exempt from BPM if they emit less than 110 g CO_2/km (TTW), and pay 129 euro per gram CO_2 per kilometre above 110 g CO_2/km but below 180 g CO_2/ km. In the design used in this study, if vehicles become twice as efficient, all petrol vehicles that emit less than 55 g CO_2/km, and pay 258 euro per gram CO_2 per kilometre for emissions above 55 g CO_2/km but below 90 g CO_2/km.

Both alternative systems have a single tariff for excise duty, which in both cases is higher than the excise duty in the existing system, threatening the competitiveness of the freight sector. To solve this issue, a separate excise duty tariff would need to be created for diesel used in the freight sector in the two alternative systems. The original ideas for adjustments of the Energy Tax Directive contained this concept of a different tax level for diesel for commercial use[23]. In this concept, diesel for the freight sector will be equal to the diesel for other sectors physically and have a similar price (including taxes). However, the excise duty for the freight sector would be partially reimbursed, so that the resulting tax burden is equal to the current situation. This does result in a considerable administrative burden (see also Section 3.4.3).

2.4.4 Energy use of zero-emission vehicles

BEVs and FCVs do not have TTW-emissions and are therefore exempt from MRB and BPM in the existing system. In any system that bases taxation on TTW-emissions, these vehicles will not be taxed except for excise duties on the fuels they use. If numbers of BEVs and FCVs increase, this may affect government income.

In both alternative systems, taxation for zero-emission vehicles is introduced. Alternative 1 is based on WTW-emissions and, effectively, the WTT-emissions of FCVs and BEVs are therefore used as a tax base. As explained in Section 2.2, in Alternative 2 TTW-emissions are assigned to BEVs and FCVs based on their energy use.

2.4.5 Multiple production pathways

A single fuel may have multiple production pathways, each with different emission levels. For example, the ethanol part in E85 may be produced from different feedstocks, all with different emission levels. Similarly, CNG may be fossil-based (including via energy-intensive distribution routes using LNG) or derived from biomass. Even the carbon footprint of petrol and diesel may vary in the future as more carbon-intensive sources (e.g. oil sands) are exploited. If WTW-emissions are introduced as the tax base for (some forms of) taxation, a method must be devised to account for the differences in emissions from different pathways.

The existing system does not have WTW-elements – and this is therefore not an issue in this system – but the two alternative systems do. For the WTW-based elements in these systems, the emissions of the average production mix of the fuels consumed on the Dutch market are assumed. Provided that this can be arranged administratively, the alternative systems will be able to determine the tax burden for related fuel-vehicle combinations. However, this approach has some disadvantages as consumers that use fuels that lead to less or more emissions than the average mix are not taxed more lightly resp. more heavily (see also Section 2.4.7). As a result individual fuel suppliers will not have the right incentives to provide low emission fuels (WTW) if these are more expensive.

2.4.6 Fuelling at foreign stations

The effectiveness of Dutch fiscal policy is constrained by the fiscal policy in neighbouring countries. Of specific importance are the excise duties in Belgium and Germany. If low excise duties in these countries result in fuel prices that are lower than in the Netherlands, it is likely that a larger share of Dutch vehicles will be refuelled at foreign refuelling stations than is currently the case. More fuelling at foreign stations leads to undesired effects such as less tax income and more passenger car travel.

[23] Current proposal does no longer allow for this different treatment.

In the existing system, the petrol price in the Netherlands is higher than in Belgium and Germany. The diesel price is approximately equal to the German price, and slightly below the Belgium price. The existing system thus provides an incentive for users of petrol vehicles to fuel abroad, whereas diesel vehicles are best fuelled in the Netherlands. This issue is limited to visitors of the border regions.

Clearly, the exact impact of the introduction of the alternative systems will be dependent on whether and how neighbouring countries adjust their fiscal systems. In Section 4.1.3, an overview of the expected changes in the excise duty is given per fuel. Note that the actual excise duty paid will also depend on the share of biofuels included.

Assuming that neighbouring countries do not adjust their fiscal systems, the main consequences of the alternative systems can be summarized as follows:

- The net effect of the introduction of Alternative 1 is uncertain as the exact effects for the two major fuels are opposing and partly still uncertain:
  - The incentive for users of petrol vehicles to refuel at foreign stations decreases due to the reduction in excise duty on petrol.
  - A new incentive is created for users of diesel vehicles to use Belgian or German diesel, due to the increase in excise duty on diesel.
  - Both incentives are still dependent on the share of blended biofuels. If these shares are increased, the excise duty will decrease. If this share also increases abroad (as could be expected due to EU legislation) and/or the decreased excise duty offsets the production cost increase, the fuel prices in the Netherlands become more attractive.
- In Alternative 2 excise duties for petrol are kept constant, whereas excise duties for all other fuels increase. Consequently, it is quite likely that fuelling abroad is approximately constant for petrol vehicles but increases for all other fuel types. Fuelling abroad is a serious issue in Alternative 2. Note the above remark regarding the impact increased share of blended biofuels, which could offset the general impact.

2.4.7 Secondary fuel use in multifuel vehicles

To determine the vehicle taxes (BPM/MRB) for multifuel vehicles for WTW or TTW based fiscal systems, one primary fuel (or a mix) should be used as a starting point. Without this assumption the TTW or WTW emissions per kilometre cannot be determined. However, in practice it may be more attractive to fuel the vehicle with another fuel. Whether this is the case is analysed for a selected number of multifuel vehicles in Chapter 5.

This opens the possibility for consumers to purchase a petrol-fuelled vehicle, while paying lower vehicle taxes (based on the lower-emissions of the secondary fuel). If total cost of purchasing, owning, and using an FFV, CNG-vehicle or LPG-vehicle fuelled by petrol is lower than if fuelled by E85, CNG, and LPG, respectively, and this total cost is higher than for a comparable petrol vehicle, then many consumers may decide to buy these vehicles instead of regular petrol vehicles. Since BPM and MRB for petrol vehicles are higher, this will lead to a loss of tax revenue, without an actual emission reduction.

Alternative 1 potentially creates this situation. In this system, BPM and MRB for FFVs are based on the emissions assuming the FFV is fuelled by E85. Consequently, purchasing and owning an FFV is very cheap. However, due to low excise duties, E85 is cheaper than petrol in this system. Therefore, consumers are likely to fuel their FFVs with E85, but this will clearly also depend on the difference in cost between fossil fuels and ethanol.

An increased use of FFVs and E85 will lead to lower tax income, which is compensated by increasing tariffs and adapting emission boundaries of tax brackets (see Section 2.4.2). As a result, the taxation of conventional fuels will increase.

Note that this issue is not relevant for the fuel related taxes, as the user always pays excise duties for the actually used fuel.

2.4.8 Alignment with existing law and regulations

By definition, the existing fiscal system is in line with existing law and regulations. The changes to the existing system that are embodied in the two alternative systems have not been extensively checked on this aspect. Therefore, there may be conflicts between existing regulation and these two systems.

3. Fiscal system comparison

This report investigates what the impact is of alternative, WTW-based, fiscal system(s) on the taxation and cost competitiveness of alternative and conventional fuels, in comparison with the existing fiscal system. Table 3.1 presents a qualitative assessment[24] of the performance of the three systems with respect to four aspects[25]:

- The extent to which the principle of the 'polluter pays' is honoured.
- The extent to which the introduction of alternative fuels is accelerated, based on the cost reductions of alternative fuels for users.
- The impact on vehicle sales and stock.
- The extent to which four side-effects are likely to occur: (i) increase in passenger car travel, (ii) improvement of security of supply, (iii) increase in administrative complexity, and (iv) impact on air quality.

Table 3.1 *Assessment of the potential of the three fiscal systems to accelerate the introduction of alternative fuels*

	Existing system	Alternative 1	Alternative 2
Implementation of 'polluter pays' principle	Limited	Very strong	Strong
Acceleration introduction alternative fuels & vehicles			
• Gaseous fuels	Moderate	Moderate/Strong	Moderate
• Liquid biofuels	None	Strong	Moderate
• Zero-emission vehicles	Strong	Moderate	Moderate
Impact on vehicle sales & stock			
• Required tariff increases	Substantial	Substantial	Substantial
• Potential shifts	n/a	Substantial	Substantial
Other side-effects			
• Passenger car travel	n/a	Stimulating effect	Reducing effect
• Improvement of security of supply	Moderate	Moderate	Limited
• Admin. complexity	Limited	Complex	Complex
• Impact on air quality	Moderately positive	Uncertain	Uncertain

3.1 Polluter pays principle

The tax bases of all forms of taxation in the alternative systems include CO_2 emissions. By contrast, the existing system features tariffs that are partly based on fuel-specific policies. The existing system does however include aspects based on emissions (though limited to TTW). The alternative systems are considered fairer in this respect, in the sense that high-emission vehicle-fuel combinations are taxed more heavily from a WTW perspective.

24 The assessment is partly based on expert judgment. The conclusions are not equally valid for each vehicle-fuel combination. Chapters 4, 5, and 6 provide a more detailed basis for the assessments presented in this chapter.

25 On top of the aspects listed in Table 3.1, a stable level of government income and the competitiveness of the freight sector are important aspects. It is assumed that good performance on these aspects is incorporated in the design of the systems (see Sections 2.4.2 and 2.4.3, respectively), and they are therefore not considered in this chapter.

In this respect, Alternative 1 performs even better than Alternative 2, as Alternative 1 is fully WTW-based, and includes the WTW emissions of the expected fuel to determine the vehicle related taxes. Still, Alternative 1 is not fully perfect in this sense, as it is impossible to predict the actual WTW-emissions of the fuel that will be used (and, if desired, to incorporate future WTW-emission reductions). In this report, all WTW based taxes are based on the WTW-emissions of the average production mix of the relevant fuel. As a result, consumers that use fuels that have fewer emissions than average are not compensated, neither through lower vehicle taxation nor through lower excise duties. Conversely, users that use fuels that emit more than average are not charged extra.

Furthermore, it must be noted that fairness cannot only be related to CO_2 emissions. For instance, tax revenues are also used to construct and maintain road infrastructure. From this point of view, it is fair that heavy users pay a larger share of taxation than light users. This does not necessarily conflict with the 'polluter pays' principle. Heavy users also emit more and will therefore also pay more taxes in a system that honours the 'polluter pays' principle.

Chapter 4 provides a detailed overview of the tax burdens of the different fiscal systems.

3.2 Acceleration of the introduction of alternative fuels

In general, alternative fuels and technologies have higher costs than conventional fuels. Lower taxation may help to lower the cost gap between conventional and alternative fuels and can accelerate the introduction of alternative fuels.

In this way, the alternative systems help to introduce alternative fuels, although the results are mixed. In the existing system, strong incentives exist to stimulate zero-emission vehicles - in effect, these vehicles are exempt from all taxation except for energy tax (in the case of BEVs and PHEVs). The alternative systems do place taxation on zero-emission vehicles, although to a limited extent.

The alternative systems do provide a good incentive for more short-term options such as biogas and liquid biofuels. These options have relatively low WTW-emissions, which results in relatively low taxation in the alternative systems. Moreover, both alternatives stimulate low-emission pathways for producing biogas and liquid biofuels.

Chapter 5 discusses the details of the competitive position of various fuels in the three fiscal systems.

3.3 Impact on vehicle sales and stock

The expectation for 2020 is that vehicle efficiency will still improve substantially, leading to steadily increasing efficiency of the complete vehicle fleet until 2030. As all fiscal systems are (partly) based on emissions, this improved efficiency implies that tariffs should go up. The required tariff increases are substantial for all three systems, and slightly larger in the alternative systems than in the existing system.

The changed competitive position of fuels in the alternative systems may lead to changes in vehicle sales and, eventually, the vehicle stock. Most notably, merging the fuel-specific tariffs of the existing system into a single tariff significantly improves the attractiveness of diesel vehicles, whereas the majority of the current vehicle stock (~80%) consists of petrol vehicles.
The various fiscal systems provide incentives for alternative fuels, with different systems providing incentives for different types of alternative fuels (see Table 3.1). However, it is expected that in the future, user costs for vehicles using these alternative fuels are comparable to using a

very efficient conventional vehicle. Therefore, whether the systems would also lead to an uptake of these respective fuels is less certain.

The alternative systems also result in a shift in the tax burden between owners of old (less efficient) and new vehicles. Chapter 6 discusses details on the impact of the fiscal systems on vehicle sales and stock.

3.4 Other side-effects

3.4.1 Passenger car travel

If the alternative systems reduce the variable costs for certain vehicle-fuel combinations, owners of these vehicles may respond by making more use of their vehicles. This rebound effect increases CO_2 and air quality related emissions and may also cause an increase of congestion.

In Alternative 1, this is the case as, compared to the existing system, excise duty on petrol is significantly lowered. Alternative 2 creates the opposite situation. In this system, the relatively high petrol tariff is used as a basis for taxation for all fuels. The costs for operating a petrol vehicle remain the same, whereas the costs for operating other vehicle-fuel combinations increase. This is likely to lead to a (moderate) reduction of non-petrol passenger car travel.

3.4.2 Security of supply

Security of supply implies that a supply of affordable energy is available now and in the future. Security of supply is weak if energy is derived from scarce and geographically unevenly distributed primary fuels and/or if the operational reliability of energy systems is low (Jansen & Seebregts, 2010).

An increased use of gaseous fuels, zero-emission technologies, and - to a lesser extent - liquid biofuels improves security of supply. Gaseous fuels can be produced from domestic gas fields or domestic feedstock in the form of biogas. PHEVs, BEVs and FCVs use electricity or hydrogen that can be produced from different feedstocks that, up to a certain amount, can be sourced domestically. This is also the case for liquid biofuels, although the bio-ethanol used in the Netherlands is almost all imported (CBS, 2010).

The existing system provides strong incentives for the purchase and use of zero-emission vehicles. At this moment, zero-emission vehicles are not very attractive options for consumers, because cost advantages are absent or minimal and the variety of zero-emission vehicles on offer is small. Although zero-emission vehicles outperform conventional vehicles on some aspects (e.g. lower noise production), they also offer disadvantages (e.g. limited range of BEVs and lack of refuelling infrastructure for FCVs). The impact of the existing system on security of supply is at present therefore only moderate.

Alternative 1 provides strong incentives for the use of biogas and liquid biofuels, but only moderate incentives for the use of zero-emission options. Therefore, the impact of this system on security of supply is assessed as moderate.

Finally, the impact of Alternative 2 on security of supply is limited. The system only provides moderate incentives for all three clusters of alternative fuels.

3.4.3 Administrative complexity

Administrative complexity is increased in the two alternative systems due to the need to introduce a separate excise duty tariff for diesel used in the freight sector. In practice, companies active in the freight sector would have to pay the 'consumer' tariff at the pump and be reimbursed afterwards. This requires an administration of the amount of diesel consumed by the company, which needs to be checked by the tax authorities. The administrative burden would therefore increase, on the part of the freight companies as well as on the part of the tax authorities. Furthermore, additional measures may be needed to avoid misuse and deal with certain aspects such as how to treat foreign freight companies.

3.4.4 Air quality

Different vehicle-fuel combinations have different impacts on air quality. Specifically, the impact of diesel vehicles on air quality is worse than the impact of petrol vehicles, although the differences between the two fuels are expected to converge in the future[26]. Although the emission of pollutants from diesel vehicles is expected to decrease in the future, the situation for air quality is likely to deteriorate if the share of diesel vehicles would increase. Clearly, local air quality will benefit from an increased use of zero-emission vehicles.

The impact of the existing system on air quality is moderately positive. The system has historically succeeded in limiting the penetration of diesel vehicles. Additionally, the system provides strong incentives for zero-emission vehicles, which may have further positive effects on air quality in the future.

For both alternative systems, the effect on air quality is uncertain as it is unclear what the effect will be on the share of diesel vehicles. On one hand, both systems improve the attractiveness of diesel vehicles due to their WTW-advantage versus petrol vehicles. However, on the other hand, there are other vehicle-fuel combinations, such as E85 fuelled FFVs, that provide an even more attractive alternative from a cost perspective, especially in Alternative 1.

[26] European emission standards regulate the amount of pollutants that passenger cars are allowed to produce. With the introduction of the euro 6 standard, emissions of pollutants from petrol and diesel vehicles significantly converge, although diesel vehicles are still allowed to produce more NO_x and PM emissions.

4. Tax burdens in the three fiscal systems

The differences in the design of the three fiscal systems lead to differences in the tax burden for different fuels. The tax bases of the two alternative systems are different from the tax bases in the existing system. Also, the fuel-specific tariffs of the existing system have been merged into a single tariff in the alternative systems. In this chapter, the impacts of these changes are discussed, and the tax burden for various fuels in the three fiscal systems is presented. Please refer to Appendix A for a detailed description of the calculation of WTW-emissions for different vehicle-fuel combinations.

4.1 Impact of fiscal system changes

4.1.1 BPM

Figure 4.1 shows the structure of the BPM tariffs in the three fiscal systems[27]. There are four differences between the three systems with a possible impact on the BPM tax burden:

- The two alternative systems have a single tariff, whereas the existing system has separate tariffs for petrol vehicles, LPG-vehicles, FFVs and PHEVs on the one hand, and diesel vehicles and CNG-vehicles on the other hand. The single tariff in the two alternative systems is based on an average weighted by the sales mix of new vehicles. Purchasing a petrol vehicle is therefore more expensive than in the existing system, and purchasing a diesel vehicle is cheaper. Moreover, because petrol vehicles form the majority of current sales (approximately 80%), the relative decrease in taxation of diesel vehicles is larger than the increase in the taxation of petrol vehicles.
- The tax bases differ: WTW-emissions in Alternative 1 versus TTW-emissions in the other two systems[28]. Changing the tax base to WTW-emissions primarily impacts fuels with a biogenic origin and zero-emission vehicles. For these fuels, there is a substantial difference between WTW-emissions and TTW-emissions: the TTW-emissions of biofuels are not counted in Alternative 1, whereas zero-emission vehicles are no longer 'zero emission' because their WTT-emissions are counted. See Section 2.2 for the differences in emissions between various fuels and Chapter 5 for the implications of the changing tax base.
- Alternative 2 does not feature tax exemptions. The impact of this difference is minor (and therefore barely visible in Figure 4.1), because the tariff chosen for vehicles emitting up to the original average exemption limit (105 g/km (TTW)) is low. Adjustments in this assumption (low starting tariff) will have a substantial impact on the resulting tariff structure, and need further analysis and additional starting points.
- The tariffs in Alternative 2 are lower than the tariffs in Alternative 1 and in the existing system, to compensate for higher excise duty tariffs (see also Sections 2.3.2 and 4.1.3).

Note that for the BPM, certified test results are needed. For petrol vehicles that are retrofitted to be fuelled with CNG and LPG (next to petrol), the BPM is based on the emissions of the original petrol vehicle (i.e. prior to the retrofit). In this study, all LPG and CNG bi-fuel vehicles are assumed to be original ex-factory vehicles for which the BPM will be determined based on their LPG or CNG emissions.

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[27] As already mentioned before, this study assumes that replacement of the list price component in the current BPM by the CO_2 dependent component has already been completed (rates have been adapted accordingly).

[28] Note that in the existing system and Alternative 2, TTW-emissions per kilometer, of a vehicle-fuel combination, are determined based on the use of 100% fossil fuel (i.e. as if no biofuels are blended). For vehicle-related taxes, the existing system and Alternative 2 do not include the impact of the (mandatory) blending of biofuels, whereas Alternative 1 does.

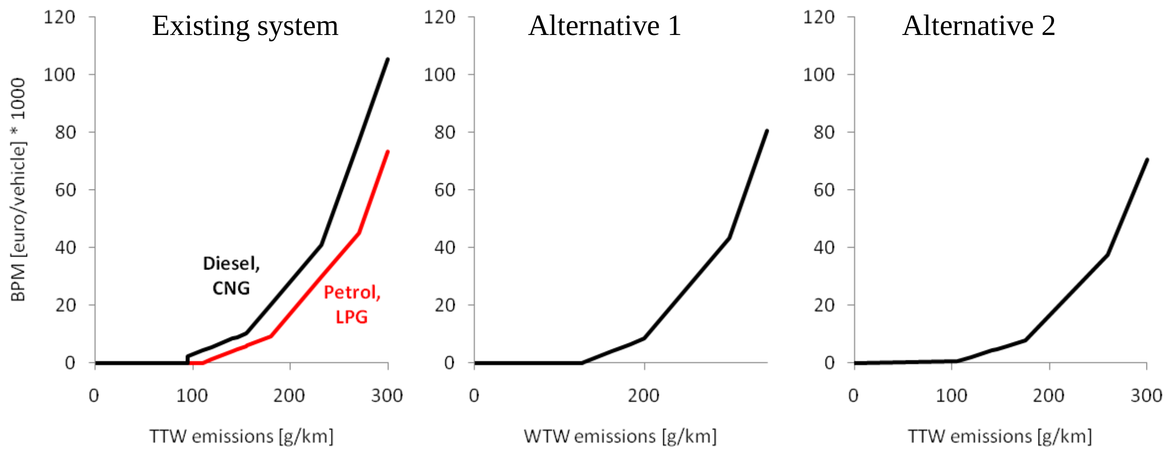

Figure 4.1 *Tariff structure of the BPM in the three fiscal systems*

4.1.2 MRB

The following differences in the design of the three systems have an impact on the MRB tax burden (Figure 4.2):

- The tax base in the existing system is the deadweight of a vehicle, whereas the tax bases in the alternative systems are WTW-emissions and TTW-emissions respectively. The tariffs in the alternative systems have been chosen in such a way that the distribution of the tax burden over the vehicle stock is similar, i.e. 10% from MRB revenue come from the 20% lightest (in the existing system) or lowest-emission (in the alternative systems) vehicles, whereas more than 50% comes from the 20% heaviest/highest-emission vehicles.
- As a consequence of the change of tax base, the MRB tax burden shifts from new vehicles to older vehicles. New vehicles are typically heavier (resulting in high MRB in the existing system), but have lower emissions (resulting in low MRB in the alternative systems) than older vehicles.
- Also for the MRB, the replacement of fuel-specific tariffs into a single tariff results in decreasing tariffs for diesel vehicles and increasing tariffs for petrol vehicles.
- The effect of removing tax exemptions in Alternative 2 is minor, because the tariff chosen for vehicles emitting up to 105 g/km (TTW) is low.
- The tariffs in Alternative 2 are lower than the tariffs in Alternative 1 and in the existing system to compensate for higher excise duty tariffs (see also Sections 2.3.2 and 4.1.3).

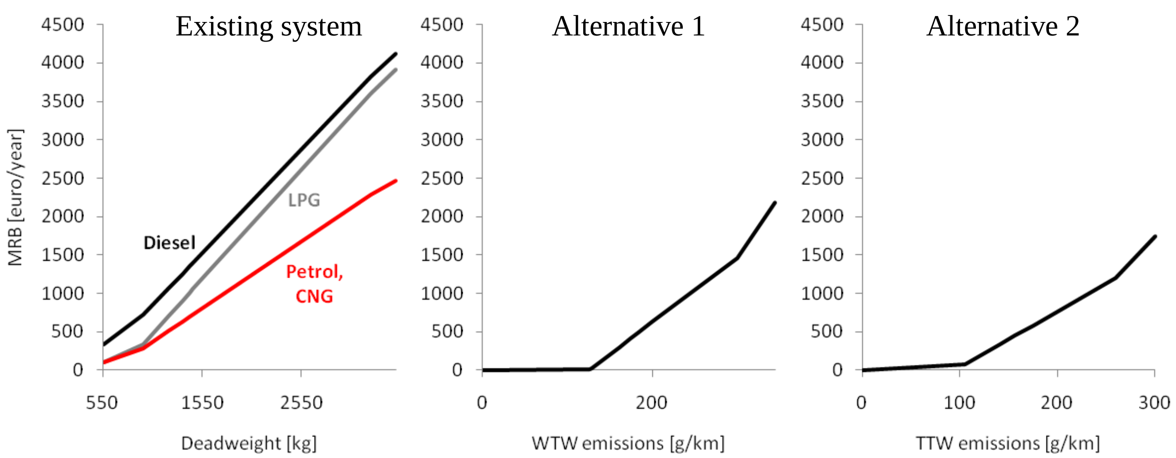

Figure 4.2 *Tariff structure of the MRB in the three fiscal systems*

Note: Low-emission vehicles are exempt from MRB in the existing system. All horizontal axes have different units (tax base).

4.1.3 Excise duties

The only change for excise duties is that in the alternative systems, tariffs have been merged based on WTW carbon intensities (in gram per MJ) of the various fuels. Because different fuels are marketed based on different units - petrol, diesel, LPG, and E85 in litres, CNG in Nm^3, hydrogen in kg, and electricity in kWh - and the energy intensities (in MJ per applicable unit) differ, the excise duty in euro per unit delivered vary per fuel in the alternative systems as well (Figure 4.3). The effect is that in the alternative systems, the excise duty is higher for fuels with high WTW-emissions.

This change impacts excise duty levels in the following ways:

- The excise duty on petrol decreases whereas the excise duty on diesel increases. This reflects the fact that, in the existing system, diesel is taxed relatively lightly in relation to WTW-emissions and petrol is taxed relatively heavily. In the short-term, a reduction of the excise duty on petrol will make driving a petrol vehicle cheaper. As petrol vehicles make up a large share of the current vehicle stock, this may increase passenger car travel. In Alternative 2, this effect is countered by fixing the excise duty tariff at the current (implied) level of taxation of petrol in relation to WTW-emissions (i.e. euro per gram CO_2). Because current excise duties on petrol are relatively high, excise duty levels in Alternative 2 are consistently above the levels in Alternative 1.
- With the exception of E85 and petrol, excise duties increase. The tax burden on these other fuels in the existing system is therefore low in relation to their WTW-emissions.
- In the existing system, taxation of E85 and petrol is equal on an energy basis[29]. However, the WTW-emissions of E85 are much lower than the emissions of petrol. The design of the alternative systems takes this into account, resulting in a substantially lower excise duty level (in euro/litre).
- Note that due to the use of the applicable (mainly volume-related) units, Figure 4.3 should be used carefully when trying to compare the absolute tax burden between the fuels. The reason for this are differences in energy content and vehicle efficiency. As an example, the energy content of a litre diesel is larger than the energy content of a litre petrol (which exceeds the energy content of a litre E85). Furthermore, the vehicles that use these fuels may have a different fuel efficiency (see Appendix C).

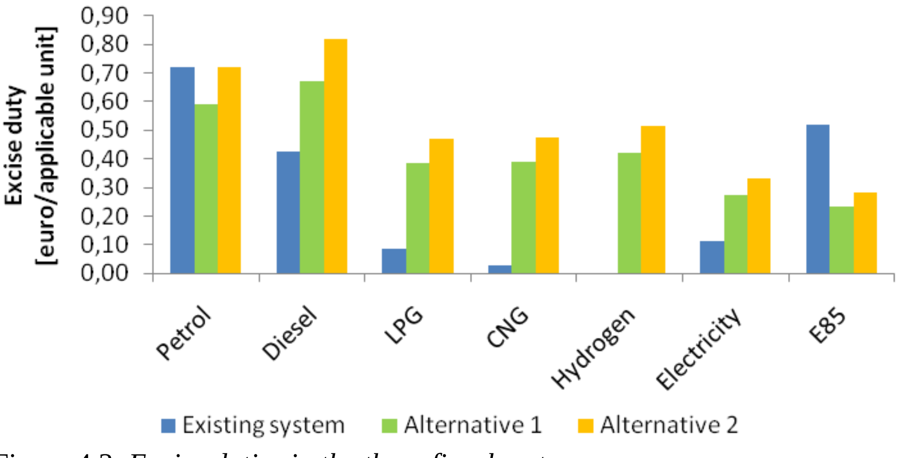

Figure 4.3 *Excise duties in the three fiscal systems*

Note: Amounts in €/litre for petrol, diesel, LPG, and E85.
Amounts in €/Nm^3 for CNG.
Amounts in €/kWh for electricity.
Amounts in €/kg for hydrogen.

[29] The lower energy content of E85 is compensated in the existing system.

4.2 Tax burden in different fiscal systems

This section briefly highlights how the differences between the fiscal systems affect the tax burden for an average user, covering 15000 kilometres per year in a medium-sized, average-efficiency vehicle[30]. This section only considers the present (2010) situation. Because the commercial availability of zero-emission vehicles is currently still very low, these vehicles are not considered in this section. The reader is referred to Chapter 5 for a more elaborate overview of the user costs for various vehicle-fuel combinations in the three fiscal systems. Section 5.4 in this chapter deals with the outlook for zero-emission vehicles.

4.2.1 Total tax burden

In the existing system, the tax burden (excluding BTW) for diesel vehicles is significantly higher than the tax burden for other vehicles for an average user (Figure 4.4[31]). The tax burden on FFVs is comparable to the burden for petrol vehicles. LPG- and CNG-vehicles have a relatively low tax burden, mainly caused by the low excise duty tariffs for CNG and LPG.

In Alternative 1, tax burden for diesel vehicles is slightly lower than the burden for petrol vehicles. Taxation for LPG is comparable to the levels in the existing system. The major difference concerns CNG and FFVs. In comparison with conventional vehicles, CNG-vehicles have very low WTT-emissions, resulting in very low tax burdens for BPM and MRB. FFVs are assumed to use E85 and taxed on the resulting emissions. The tax burden for FFVs is therefore very low in Alternative 1.

The results in Alternative 2 are a mix of the other two systems. As in Alternative 2, the taxation for diesel vehicles is slightly lower than the taxation for petrol vehicles. As in the existing system, the taxation on FFVs is substantial.

The tax burden on CNG is substantially lower in Alternative 1 than in the other two systems. Although the existing system stimulates CNG through very low excise duties, the BPM for CNG-vehicle is relatively high (same tariff as diesel vehicles) and the MRB is relatively high due to the relatively high weight of CNG-vehicles. In Alternative 2, the relatively good emission performance of CNG results in a low BPM and MRB tax burden (at least compared to the existing system). This is offset by the higher excise duties in this system.

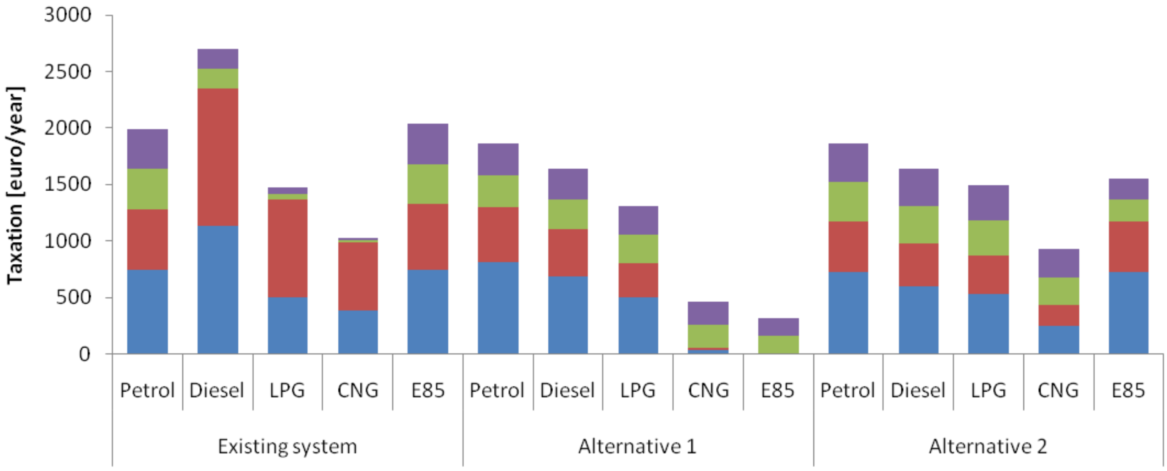

Figure 4.4 *Tax burden (excluding BTW) in the three fiscal systems*

Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr. Appendix B provides a guideline for the interpretation of this graph.

[30] Appendix C provides details on the vehicle sizes and efficiencies considered in this report, as well as an indication of the annual distances covered in the Netherlands.

[31] Appendix B provides a guideline for the interpretation of this figure.

4.2.2 Tax burden in relation to emissions

By relating the tax burden to the emissions of vehicle-fuel combinations, the extent to which the three fiscal systems honour the 'polluter pays' principle can be assessed. A system that fully honours this principle would place an equal tax burden on two vehicles that have equal emissions, even if they use different fuels.

Figure 4.5 shows the tax burden for a fictional vehicle emitting 150 g CO_2/km (WTW). Note that this figure requires careful interpretation due to the differences in carbon intensity of the various fuels. A vehicle emitting 150 g CO_2/km fuelled by a fuel with a low carbon intensity (e.g. E85, CNG) can be much more inefficient (and thus larger, more powerful) than a vehicle fuelled by a carbon intensive fuel (e.g. petrol, diesel). In the two alternative systems, such a vehicle is taxed an approximately equal amount, irrespective of the fuel used[32]. In the existing system, diesel vehicles, CNG-vehicles and FFVs have a much higher tax burden than petrol vehicles and LPG-vehicles. The alternative systems therefore do more justice to the 'polluter pays' principle, if WTW CO_2 emissions are considered the main pollution.

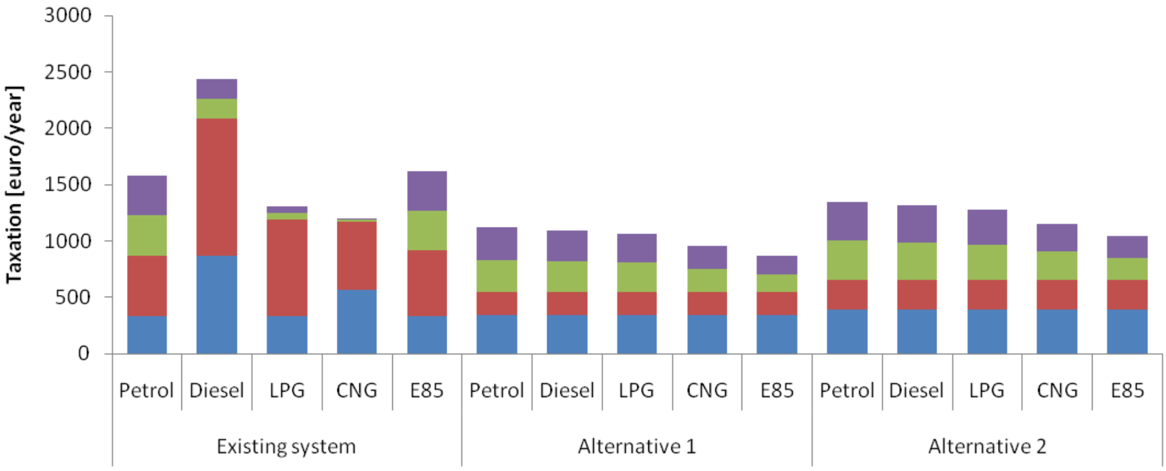

Figure 4.5 *Tax burden (excluding BTW) for (fictional) vehicles emitting 150 g CO_2/km (WTW) based on an average annual use of 15,000 kilometres*

Note: Appendix B provides a guideline for the interpretation of this graph.

[32] Some minor differences between the shown vehicle-fuel combinations are the result from higher or lower BTW due to differences in vehicle and fuel cost.

5. Competitiveness of conventional and alternative fuels

In this chapter, the competitiveness of the various vehicle-fuel combinations in the three different fiscal systems is assessed. This assessment is based on the major part of the annual costs for the user of the vehicle, consolidated into three categories (Table 5.1), and excludes costs related to insurance and maintenance.

Table 5.1 *Costs for vehicle users considered in this report*

Cost categories	Costs considered in this report
Purchase costs	Vehicle costs
(fully depreciated over 8 years)	BPM
	BTW
Ownership costs	MRB
Usage costs	Fuel costs
	Excise duties
	BTW

The analysis in this chapter is restricted to the effects for new vehicles only. Chapter 6 discusses the impact on the existing vehicle stock.

The chapter is split up into four sections, which outline the competitive position of conventional fuels, gaseous fuels, liquid biofuels and zero-emission vehicles respectively. Each of these sections first presents results for an average user, covering 15000 kilometres per year, in a standard vehicle (medium-sized, average-efficiency). Results for users that use less or more efficient vehicles, or drive a different annual distance are provided if insightful. The sections on gaseous fuels and biofuels include the differences for the use of different production pathways.

Appendix A contains a detailed description of the calculation of WTW-emissions for different vehicle-fuel combinations. Appendix B provides a guideline for the interpretation of the graphs used in this chapter. Appendix C provides details on the vehicle sizes and efficiencies considered in this report, as well as an indication of the annual distances covered in the Netherlands.

5.1 Conventional fuels: Petrol, diesel and LPG

In the existing system, an LPG-vehicle is the cheapest option for an average user in a standard vehicle (see Figure 5.1), closely followed by a petrol vehicle, and diesel vehicles are the most expensive option. This picture is quite different in the alternative systems, where the tax burden is determined based on the TTW and/or WTW emissions. In Alternative 1, LPG is the cheapest option, closely followed by diesel, and petrol is the most expensive option. In Alternative 2, diesel is the cheapest option, followed by LPG and then petrol.

The relative positions with respect to costs reflect the differences between the three fiscal systems. In the existing system, the BPM and MRB for diesel vehicles are relatively high. This results in high costs for purchasing and owning a diesel vehicle. The excise duty for diesel is relatively low - primarily to support the freight sector - but this benefit is too small for an average user in a standard vehicle to compensate for the high fixed costs. For LPG-vehicles, the high purchase costs are compensated by a very low excise duty. This makes LPG-vehicles cost-competitive even at the annual distance covered by an average user. The BPM and MRB for petrol vehicles are relatively low, and result in petrol vehicles being the most attractive option from a cost perspective for an average user in a standard vehicle.

The alternative systems reflect the merging of the separate tariffs for each fuel into a single tariff. In Alternative 1, the user costs quite accurately reflect the similar emissions of each of the options: petrol vehicles have the highest emissions, followed by diesel and LPG. In Alternative 2, only excise duties are WTW-based, hence the higher purchase costs of LPG-vehicles are not offset and they are almost as expensive as petrol vehicles. The low emissions of diesel vehicles compared to petrol vehicles result in the relatively low user cost for diesel vehicles, as the tax burden is lower for all vehicle and fuel-related taxes.

In both alternative systems, the costs of the petrol and diesel vehicles, as shown in Figure 5.1, are lower than in the existing system, mainly for two reasons:

- The comparisons in this chapter are based on new vehicles that typically have relative low emissions and high weight. As the MRB in the alternative systems is entirely based on emissions, new, low-emission vehicles pay less and old, high-emission vehicles pay more than in the existing system in which the MRB is based on weight (with exemption for low-emission vehicles).
- The introduction of a single tariff for BPM is beneficial to diesel vehicles (also for CNG) as the fixed amount of BPM – irrespective of emissions and weight – is removed. For the average user and standard vehicle, this is not offset by the increased excise duties, leading to a lower overall cost.

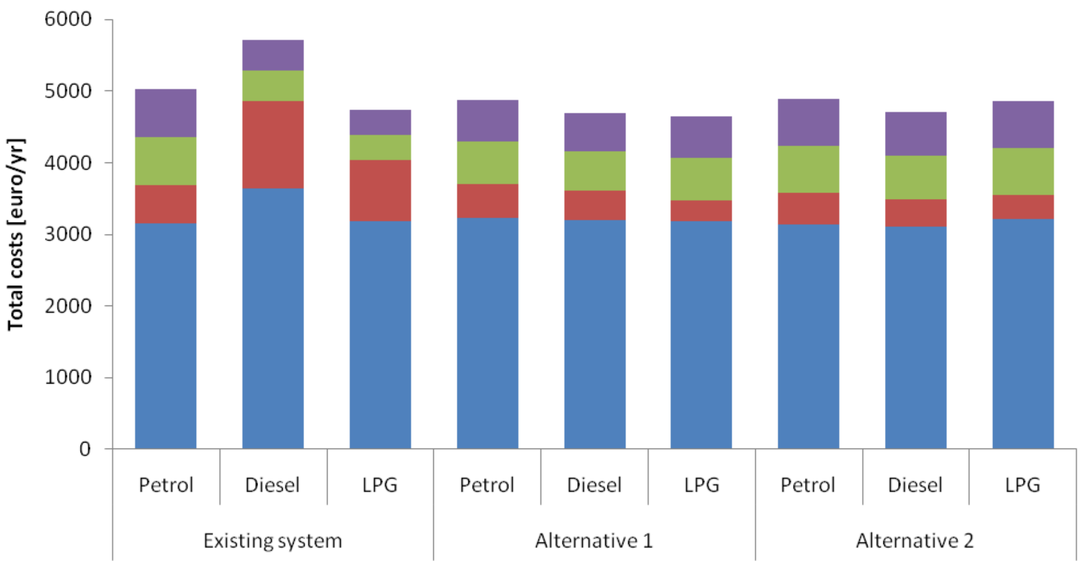

Figure 5.1 *User costs of conventional fuels in the three fiscal systems*

Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr.

The existing fiscal system creates a situation in which diesel vehicles have relatively high fixed costs and low variable costs, whereas petrol vehicles have relatively low fixed costs and high variable costs. Consequently, diesel vehicles are only attractive for users that cover large annual distances. The break-even point for petrol and diesel vehicles is currently (when the BPM transformation is completed) around 35000 km per year for a medium-sized, average-efficiency new vehicle (Figure 5.2).

In the alternative systems, diesel vehicles have both lower fixed costs and lower variable costs than comparable petrol vehicles, irrespective of size. Consequently, diesel vehicles may become the preferred option for a large share of users. Without any other fuel-specific policies included, this is likely to have a large effect on the composition of the Dutch vehicle stock, which currently features a large share of petrol vehicles (see also Chapter 6).

In the existing system, driving an LPG-vehicle is relatively cheap. Despite this cost advantage, the LPG market share is limited. In both alternative systems, the costs of driving an LPG-vehicle relative to the costs of driving a petrol or diesel vehicle increase. This is likely to have a negative effect on the market share of LPG-vehicles.

The above analyses have all been carried out based on an average-efficiency, medium-sized vehicle. A brief sensitivity analyses reveals that varying these two factors - which are important determinants of vehicle emissions - does not have a major impact on the relative positions of conventional fuels with respect to costs. Variation in size and efficiency does however have an important impact on the overall tax burden and the cost comparison with alternative fuels, especially in case the vehicle is exempted from BPM or MRB (see Chapter 6 for consequences). Also the annual distance driven (see Figure 5.2) does not have a major impact on the annual cost of the conventional fuels. The main reason for this is that the introduction of a single tariff structures based on emissions (WTW or TTW) removes the substantial differences in fixed costs, while the fuel costs (including emission based tariffs) turn out to be rather similar.

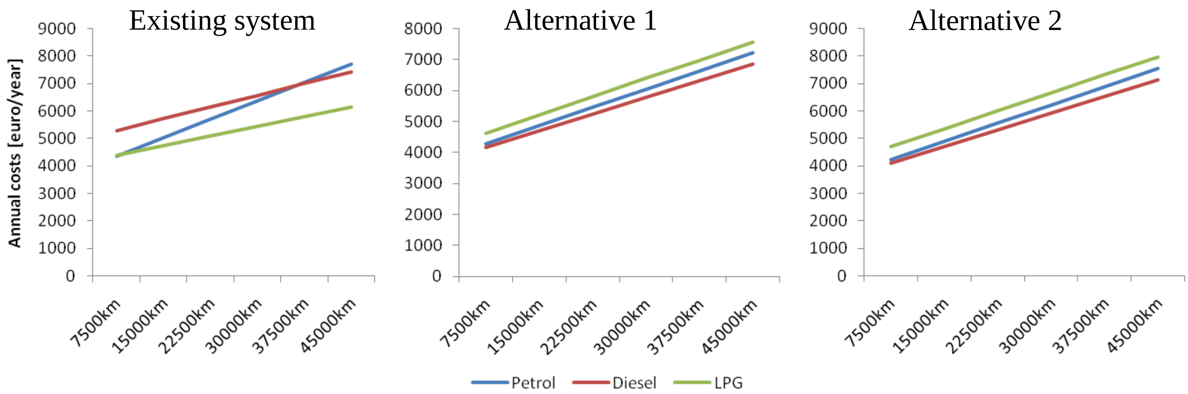

Figure 5.2 *Annual user costs of conventional fuels in the three fiscal systems, for varying annual distances*

Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr

5.2 Gaseous fuels

In the existing system, CNG enjoys a major cost advantage over conventional fuels. The costs of driving a new, medium-sized, average-efficiency CNG-vehicle are approximately 85% of the costs of driving a petrol vehicle (Figure 5.3). In Alternative 1, the competitive position of CNG-vehicles is even better, reflecting their low WTW-emissions. Driving a CNG-vehicle in this alternative comes at approximately 80% of the costs of driving a petrol vehicle. The costs of driving a CNG-vehicle in Alternative 2 are similar to the existing system, at approximately 85% of the costs of a petrol vehicle. The major difference is that in Alternative 2, the excise duties are higher than in the existing system, whereas MRB and BPM are lower.

In the existing system, the fixed costs of driving a CNG-vehicle are higher than the fixed costs of driving a petrol vehicle, whereas the variable costs are lower. Consequently, driving a CNG-vehicle is only attractive beyond a break-even distance. The high fixed costs result partly from the fixed amount of BPM that is due for CNG-vehicles irrespective of emissions (unless emissions are below the exemption limit). In the alternative systems, both fixed and variable costs are lower, implying that CNG-vehicles are cheaper at any annual distance.

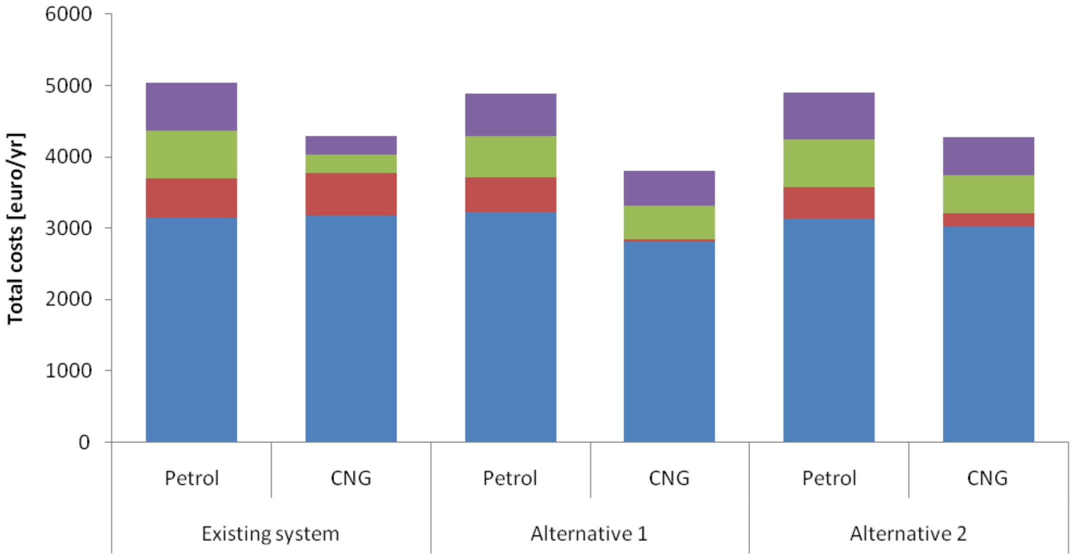

Figure 5.3 *User costs of gaseous fuels in the three fiscal systems*

Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr Biotickets are not included in this figure.

Different production pathways can have a profound effect on the WTW-emissions of CNG. Figure 5.4 shows that the emissions of CNG produced from LNG are approximately 20% higher than the emissions from CNG produced from Dutch gas. No TTW-emissions are associated with CNG produced from biomass, due to the biogenic origin of the carbon, resulting in WTW-emissions almost 70% lower than emissions from Dutch gas.
Note that these emissions only concern CO_2. Some production pathways prevent methane emissions (e.g. wet manure) or result in additional methane emissions (e.g. CNG from Russia and for any production pathway with methane leakage). As methane is a powerful greenhouse gas, the balance of total greenhouse gas emissions of these options can be significantly improved or deteriorated.

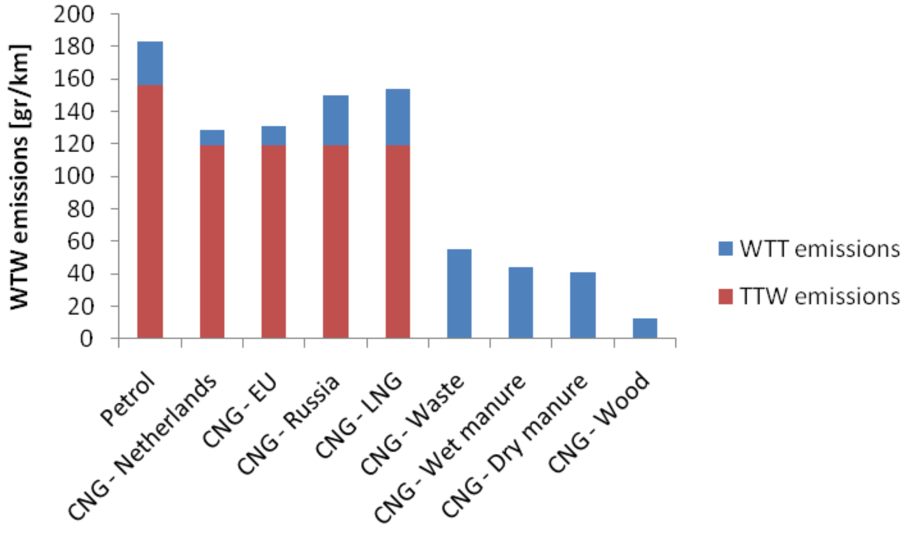

Figure 5.4 *WTW-emissions associated with different CNG production pathway*

Source: JRC et al., 2007.

Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr
These emissions relate to CO_2 only, not CO_2-equivalents. In CO_2-equivalents, the emissions of wet manure would be even lower due to avoided emissions of methane.
Land use changes have not been taken into account in these figures and may raise the emissions of biogas options significantly.

Whereas the existing system does not take these differences in TTW and WTW emissions into account, the alternative systems do. In Alternative 2, excise duties are based on WTW-emissions, and in Alternative 1 all taxes are based on WTW-emissions. Figure 5.5 shows the implications of these differences between the three systems. This figure includes the user costs for CNG from Russia (typical example of high-emission CNG) and CNG from wet manure (typical example of biogas). Petrol and CNG from Dutch gas are also shown for comparison.
In the analyses for each separate fuel Figure 5.5, it is assumed that this fuel provides 100% of the CNG for the Dutch market. Taxation is then based on the associated emissions. For instance the results for biogas assume that all passenger cars use biogas. This implies that in Alternative 1, vehicle taxation (BPM and MRB) is also based on the emissions for biogas[33]. The results in the figure must therefore be interpreted as extreme cases.

In the existing system, there is no difference in taxation between the three sources of CNG. CNG from biogas is more expensive due to higher fuel costs (excluding potential benefits from biotickets; explained further on). Consequently, driving a vehicle on biogas is approximately as expensive as driving a petrol vehicle. However, given the current cost advantage of LPG and the low market share LPG presently has, it is likely that biogas would need a cost advantage over conventional fuels to achieve a significant market share. Due to lower taxation, biogas is more cost-competitive in the alternative systems, but, without biotickets, still not competitive with CNG from Dutch gas in all three fiscal systems, due to its higher fuel cost.

Note that the alternative systems also take into account that natural gas can be sourced from places that result in higher emissions than Dutch gas. Sourcing gas from Russia results in higher costs, especially in Alternative 1.

The picture changes when biotickets are taken into account. The EU Renewable Energy Directive requires all countries to have at least 10% of the energy use of the road transport sector from renewable sources in 2020. In The Netherlands, this is implemented via the Besluit Biobrandstoffen and related legislation. This legislation requires fuel suppliers to yearly provide sufficient biotickets (equal to fuel sales times required renewable share), which are obtained for renewable fuels that are sold (in transport sector). For fuel suppliers that have more biotickets than needed, the surplus can be traded. As a result, fuels that contribute more than the required renewable share (such as E85 or biogas), should have a correction on their fuel cost based on the value of a bioticket[34]. Unfortunately, the bioticket market is not transparent (market prices are not publicly available) and still imperfect (prices may not accurately represent value). Note that certain biofuels (mainly 2nd generation or from waste) count twice towards the EU target and therefore receive double biotickets, which will for certain biogas production pathways result in cost correction that is twice as high. In this analysis, we do not include the possible extra advantage if also production subsidies (SDE) are received for the production of the biogas. Furthermore, the figures are based on a transport sector perspective and do not discuss the broader perspective around virtual green gas and the impact at the national level (for more details, see Hanschke et al, 2010).

[33] As explained in Section 2.4.5, the most practical solution will be to assume an average mix.
[34] The question whether it is correct to still use all WTW-benefits of biogas for determination of the tax burden, once the surplus biotickets are sold, will not be addressed in this report.

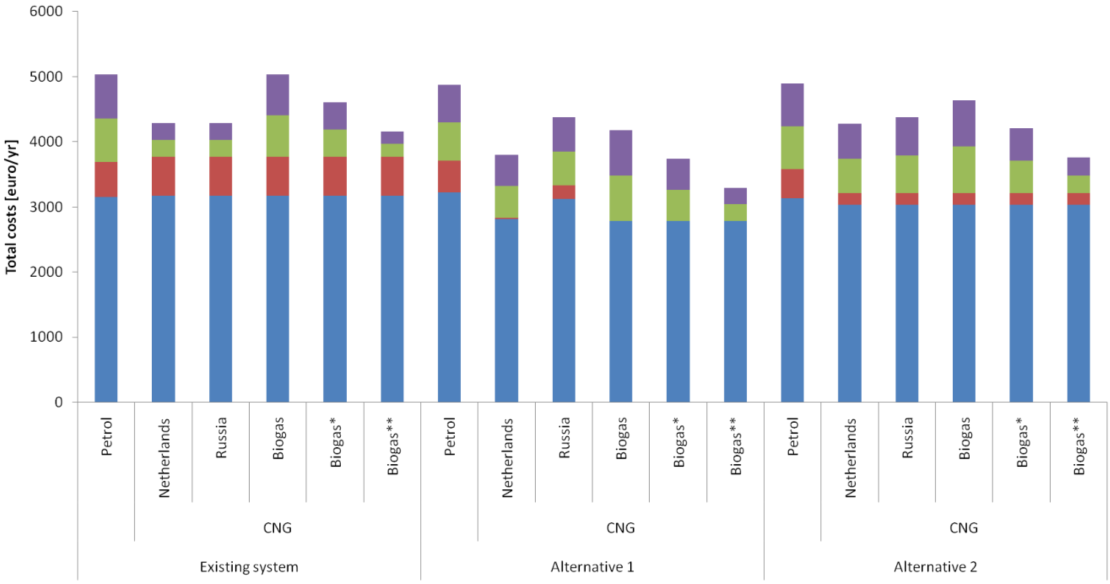

Figure 5.5 *Differences in user costs between the three fiscal systems for different production pathways for CNG*

Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr
Biogas is assumed to be produced from wet manure
* indicates that a single-counting bioticket has been included,
** a double-counting bioticket.

Nonetheless, an indication of the impact of biotickets on fuel costs can be provided, based on the starting points and assumptions from Hanschke et al, 2010. In a fully transparent market, the theoretical value of a bioticket will correspond to the additional production costs of the 'marginal' biofuel, i.e. the biofuel with the highest additional production costs still needed to meet the obligation. Currently, this value would be equal to the additional production costs of ethanol compared to petrol, which equals about €12/GJ (Hanschke et al, 2010). This value is related to actual fossil fuel prices. If these fuel prices change, the value of a bioticket may change substantially.

Note that in case there is more renewable energy used in the road transport sector than needed to satisfy the national minimum (based on RED), the value of additional biotickets will approach zero and the original figures apply. This situation is not expected on the short term (see projections for 2020 which only expect a minor contribution from CNG for road transport).

Using this starting point, the impact of the renewable obligation on fuel costs for E85 is straightforward (see Section 5.3.1), leading to net costs for E85 comparable to the price of petrol with the mandatory renewable share (around 4% in 2010). For biogas, the net costs will depend on whether the biogas qualifies as double-counting, and the mandatory renewable share, as fuel distributers still need biotickets for the use of bio-CNG in the transport sector. Based on a 4% share, this would imply that fuel costs for biogas could decrease with € 12/GJ, or up to € 24/GJ in case of double-counting. If the obligatory renewable share increases further, these cost reductions will become (slightly) lower.

If the value of the biotickets is included in the overall fuel cost of biogas, assuming stable other cost components and margins, this results in a substantial decrease of the overall fuel costs of biogas (including a small decline in value added tax) of about 30% up to 70% in case of double counting. In the case of double-counting biotickets, driving a biogas vehicle is always cheaper than driving a fossil-based CNG-vehicle. In case of single-counting biotickets, the cost decrease is sufficient to compensate the higher cost of biogas only in the two alternative systems (see Figure 5.5). On the contrary, CNG remains cheaper in the existing system even when single-counting biotickets are included.

5.3 Liquid biofuels

5.3.1 E85

E85 and FFVs are treated quite differently in the three fiscal systems. Most notably, in the existing system and in Alternative 2, FFVs are taxed based on their emissions when propelled by petrol.

Alternative 1 assumes that FFVs always use E85 as a fuel. Due to the high costs of E85, FFVs are more expensive than petrol vehicles in the existing system (Figure 5.6). In contrast, FFVs receive a major fiscal incentive in Alternative 1 and are approximately 30% cheaper than petrol vehicles on an annual basis. Interestingly, FFVs are also cost-competitive with petrol vehicles in Alternative 2. This implies that the high costs of E85 are more than offset by the low excise duty, which is based on WTW-emissions in Alternative 2.

In both alternative systems, the fixed costs of an FFV are similar to or lower than the fixed costs of a petrol vehicle, and the variable costs are lower. Consequently, FFVs are cheaper to drive than petrol vehicles at practically all annual distances.

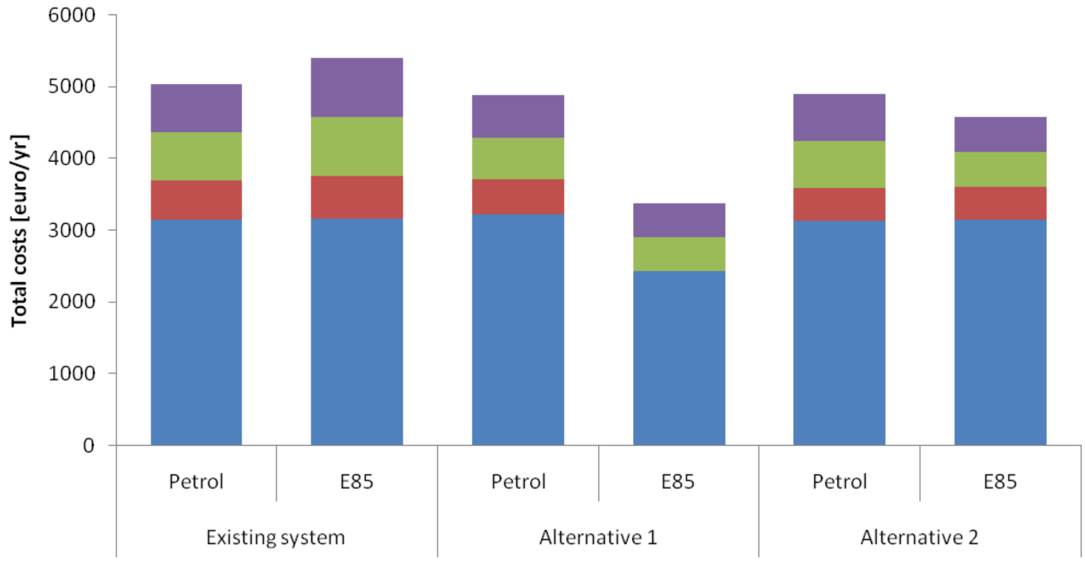

Figure 5.6 *User costs of FFVs in the three fiscal systems*

Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr. Biotickets are not included in this figure.

The production pathway of ethanol has significant consequences for WTW-emissions of E85 (Figure 5.7). The emissions of a pathway depend on the feedstock (here: sugar beet, wheat, sugar cane, wood, and straw), the heat source (natural gas boiler, natural gas turbine with combined heat and power, combined heat and power using straw), and the use of the residual material (animal feed or fuel for heating). The resulting emissions range from approximately 35% lower than petrol to approximately 80% lower than petrol. Note that direct and indirect land-use changes have not been taken into account and may change the emissions of the pathways significantly.

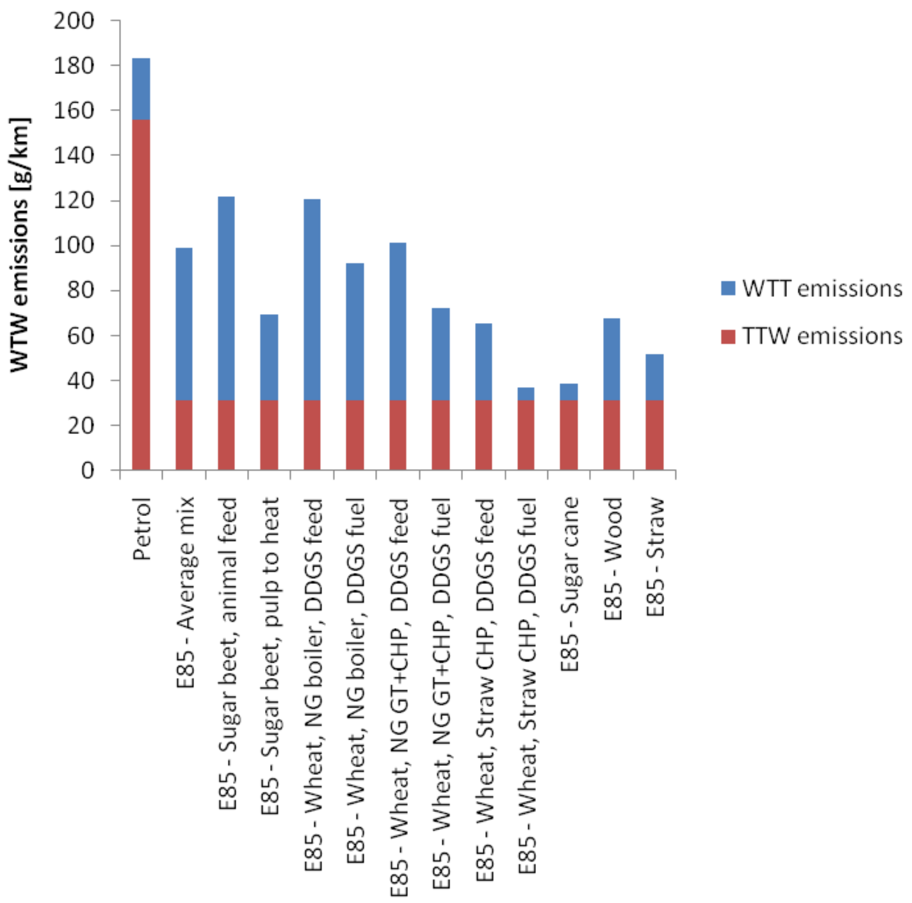

Figure 5.7 *WTW-emissions associated with different ethanol production pathways*
Source: JRC et al., 2007.
Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr
These emissions relate to CO_2 only, not CO_2-equivalents.
Land use changes have not been taken into account in these figures and may raise the emissions of the ethanol options significantly.
NG = Natural Gas.
GT = Gas Turbine.
CHP = Combined Heat and Power.
DDGS = Distiller's Dried Grain with Solubles.

Figure 5.8 shows the implications on the annual costs associated with FFVs for an average user of a medium-sized, new vehicle. It shows the annual costs for FFVs for three production pathways for E85:

- E85 from sugar beet, residual pulp used as animal feed. This is a typical production pathway for the Netherlands.
- E85 from sugar cane, as a typical production pathway for imported E85.
- An average mix of E85 production pathways, as used in Hanschke et al (2009).
- Also, for this average mix, the impact of biotickets has been included.

In the analyses for each separate fuel Figure 5.8, it is assumed that this fuel provides 100% of the E85 for the Dutch market. Taxation is then based on the associated emissions. For instance, the results for E85 from sugar cane assume that all passenger cars use E85 from sugar cane. This implies that in Alternative 1, vehicle taxation (BPM and MRB) is also based on the emissions for E85 from sugar cane[35]. The results in the figure must therefore be interpreted as extreme cases.

[35] As explained in Section 2.4.5, the most practical solution will be to assume an average mix.

Cost data for these different production pathways are not readily available. Consequently, all production pathways have been assumed to have the same production costs, equal to the costs associated with the average mix. Unlike the sensitivity analysis for biogas, the sensitivity analysis for E85 therefore only takes the impact of the fiscal system into account and *not* additional production costs. The results should therefore be interpreted carefully.

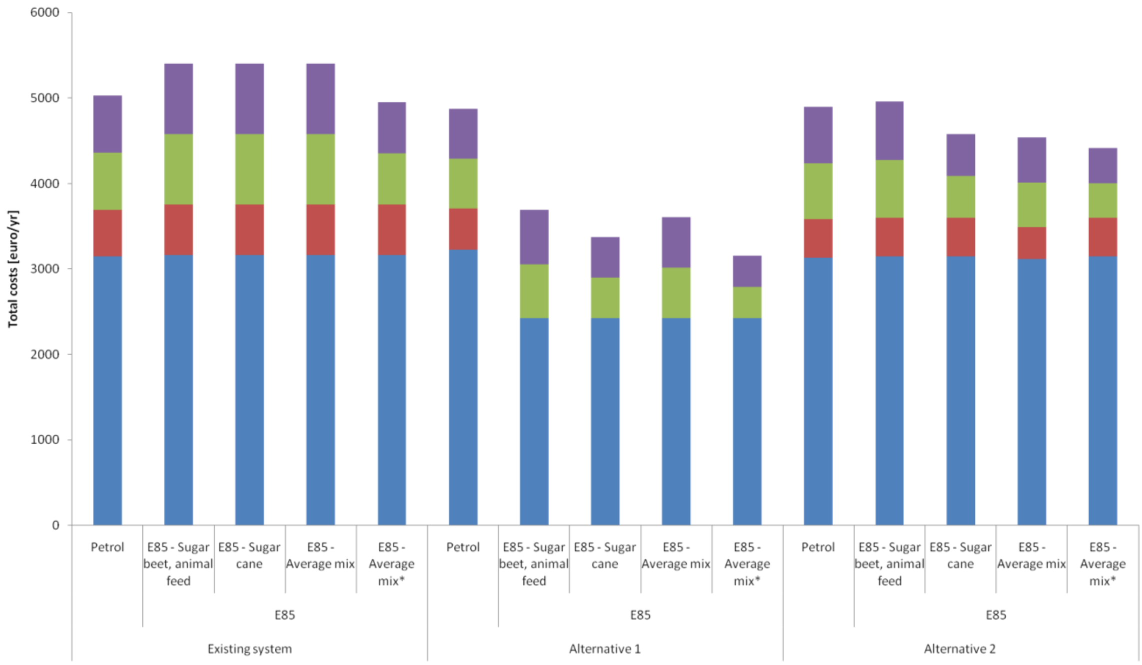

Figure 5.8 *Differences in user costs between the three fiscal systems for different production pathways for E85*

Note: * indicates that a single-counting bioticket has been included.
Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr

In the existing system, differences in emissions associated with the various production pathways are not taken into account. Consequently, all production pathways for E85 are equally expensive, and, due to the higher vehicle and fuel costs, the use of an FFV is always more expensive than the use of a petrol vehicle if the value of biotickets are not included.

Alternative 1 is fully based on WTW-emissions and therefore the differences in emissions in the various pathways are taken into account. However, the emissions of all of the pathways are so low that FFVs are exempt from BPM and MRB[36]. The differences in costs between the various pathways are therefore only due to differences in excise duty and are relatively small (less than +/- 10%). All pathways represent significantly less expensive options than driving a petrol vehicle.

In Alternative 2 the differences between the various pathways are, by design, due to differences in excise duty, as vehicle taxes are based on TTW-emissions assuming 100% fossil fuel. The excise duties in this system are relatively high[37], and consequently the costs for the various production pathways differ slightly more than for Alternative 1. Interestingly, this can determine whether driving an FFV is more or less expensive than driving a petrol vehicle (excluding value of biotickets). E85 from sugar beets is more expensive than petrol, the other options are less expensive.

[36] The emissions of a medium-sized, average-efficiency vehicle are more than 20% below the threshold for exemption (120 g/km WTW). Even a large average-efficiency vehicle would be exempt from MRB and BPM.
[37] Because excise duties are based on the petrol tariff. See Section 2.2 for details.

The production costs of E85 are expected to go down in the future. A brief analysis shows that this does not have a major impact on the competitive position of FFVs. In the existing system, FFVs stay more expensive than petrol vehicles. In Alternative 1, the cost advantage of FFVs increases further. There is no significant change in Alternative 2.

Impact of biotickets
The effect of subtracting biotickets of €12/GJ from the fuel costs associated with ethanol is substantial (Figure 5.8). Given the absence of production cost figures for (second-generation) biofuels that are eligible for double-counting biotickets, double-counting biotickets have not been included in the results.

In Alternative 1, the fuel costs, including taxes and the value of biotickets, are lower than the petrol fuel costs. As a consequence, a FFV owner is expected to fuel in line with the fuel assumed to calculate the vehicle related taxes[38]. As a result, FFVs on E85 will provide an attractive financial alternative for petrol vehicles.

Also in Alternative 2, the inclusion of the value of biotickets, improves the financial attractiveness of FFVs on E85 compared to petrol vehicles. However the total cost difference (including vehicle taxation) is much smaller than in Alternative 1.

5.3.2 Biodiesel

The fiscal treatment of biodiesel is analogous to the treatment of E85. As a result, the competitive position of biodiesel is also comparable to that of E85 (Figure 5.9)[39]. In the existing system, biodiesel is not cost-competitive. In the two alternative systems, the costs of driving a vehicle on biodiesel are lower than driving the vehicle on fossil diesel - in Alternative 1 the difference is approximately 25%. In the alternative systems, both fixed and variable costs of biodiesel are lower, implying that biodiesel is the cheapest option for all annual distances.

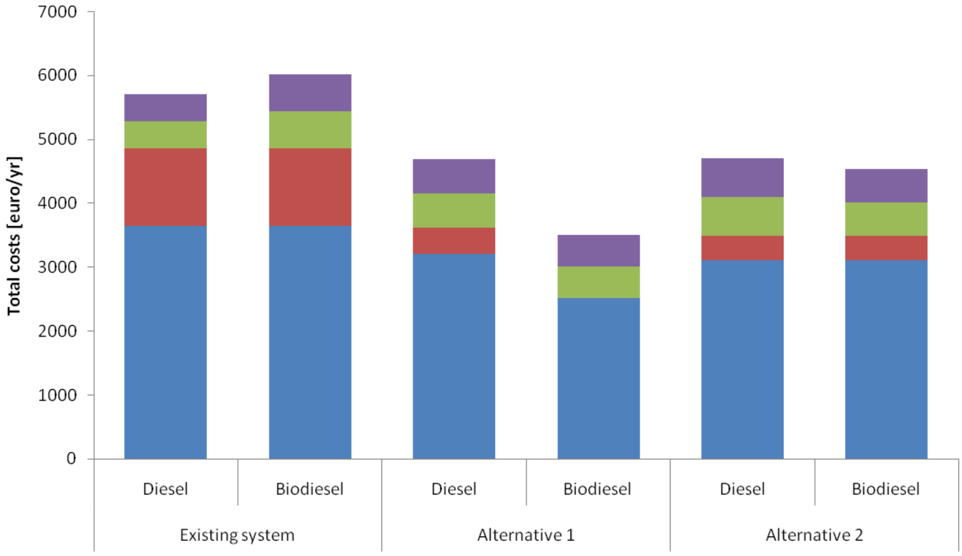

Figure 5.9 *User costs of diesel and biodiesel in the three fiscal systems*

Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr
It is assumed that the costs of a biodiesel vehicle and a regular diesel vehicle are equal.
Biotickets are not included in this figure.

[38] In practice, it is virtually impossible to determine which fuel a user will use in his FFV, and consequently to determine the BPM and MRB tariff. See also Section 2.4.5.

[39] In this section, it has been assumed that the costs of a vehicle that is fuelled by 100% biodiesel are equal to the costs of a regular diesel vehicle. Slight technical vehicle modifications for the use of pure biodiesel will add marginally to the vehicle price. This will not alter the conclusions in this section.

The WTW-emissions associated with different production pathways of biodiesel vary (Figure 5.10). Emissions depend on the feedstock (here: rapeseed and sunflower), the conversion technology (here: esterification via methanol or ethanol), and the use of the residual products (here: animal feed or input for the chemical sector). WTW-emissions vary between approximately 30% and as little as 5% of the emissions of conventional diesel. Note that direct and indirect land-use changes have not been taken into account and may change the emissions of the pathways significantly.

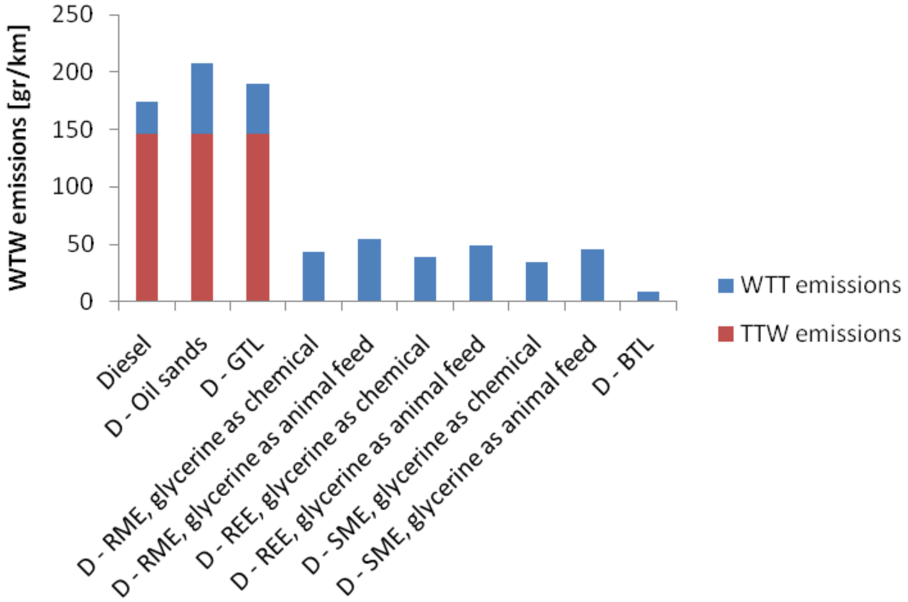

Figure 5.10 *WTW-emissions associated with different (bio)diesel production pathway*
Source: JRC et al., 2007.

Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr
These emissions relate to CO_2 only, not CO_2-equivalents.
Land use changes have not been taken into account in these figures and may raise the emissions of the biodiesel options significantly.
GTL = Gas-To-Liquid.
RME = Rapeseed esterification via methanol.
REE = Rapeseed esterification via ethanol.
SME = Sunflower seed esterification via methanol.
BTL = Biomass-To-Liquid.

For three production pathways, the impact on user costs has been quantified (Figure 5.11):

- Biodiesel from rapeseed in an esterification process via methanol, in which the residual product glycerine is used as animal feed.
- Biodiesel from sunflower seed in an esterification process via methanol, in which the residual product glycerine is used as a chemical product.
- An average mix of biodiesel production pathways, as used in Hanschke et al (2009).

In the analyses for each separate fuel Figure 5.11, it is assumed that this fuel provides 100% of the biodiesel for the Dutch market. Taxation is then based on the associated emissions. For instance, the results for biodiesel from rapeseed assume that all passenger cars use biodiesel from rapeseed. This implies that in Alternative 1, vehicle taxation (BPM and MRB) is also based on the emissions for biodiesel from rapeseed[40]. The results in the figure must therefore be interpreted as extreme cases.

Cost data for these different production pathways are not readily available. Consequently, all production pathways have been assumed to have the same production costs, equal to the costs associated with the average mix. Like the sensitivity analysis for E85, the sensitivity analysis for

[40] As explained in Section 2.4.5, the most practical solution will be to assume an average mix.

biodiesel therefore only takes the impact of the fiscal system into account, and should therefore be interpreted carefully.

Consequently, costs of driving a biodiesel vehicle are equal for the different pathways under the existing fiscal system. In this situation, biodiesel vehicles are not competitive with vehicles that are fuelled by fossil-derived diesel.

The two alternative systems show slight variations with respect to the production pathways considered. These slight variations reflect the slight variation with respect to emissions between the pathways considered, which lie between approximately 20% and 30% of the WTW-emissions of conventional diesel. Variation is particularly low in Alternative 1, in which all biodiesel options are exempt from MRB and BPM and variations are only due to differences in excise duties. In both alternative systems, biodiesel is cheaper than fossil-derived diesel irrespective of the production pathway. Therefore, an owner of a vehicle capable to operate on biodiesel is expected to fuel in line with the fuel assumed to calculate the vehicle related taxes [41]

Impact of biotickets
Biotickets have a substantial effect on the costs of biodiesel options. Only the impact of single-counting biotickets is included. Given the absence of production cost figures for (second-generation) biofuels that are eligible for double-counting biotickets, double-counting biotickets have not been included in the results.

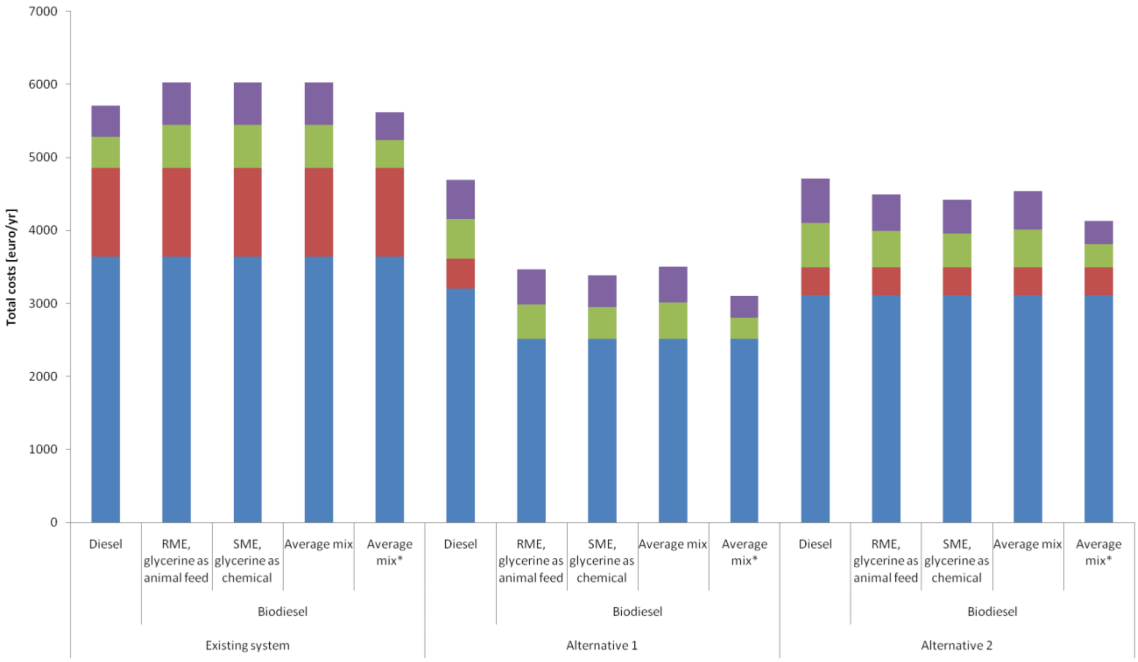

Figure 5.11 *Differences in user costs between the three fiscal systems for different production pathways for biodiesel*

Note: * indicates that a single-counting bioticket has been included.
Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr

Including a single-counting bioticket, biodiesel becomes a cheaper option than conventional diesel in the existing system (Figure 5.11). The reason for this is that the value of a bioticket is expected to be related to the difference between the marginal cost of the production of petrol and the marginal cost of the production of ethanol. This cost difference exceeds the cost difference between the production costs of diesel and biodiesel. A biotickets thus ‘overcompensates’

[41] In practice, it is virtually impossible to determine which fuel a user will use in his FFV, and consequently to determine the BPM and MRB tariff. See also Section 2.4.5.

the additional costs of biodiesel production (versus the production costs of regular diesel). In the alternative systems, the competitive position of biodiesel compared to fossil-derived diesel is further improved.

Biodiesel production costs are expected to go down in the future. At the same time, the costs of driving a regular vehicle are expected to increase. A brief analysis indicates that these developments do not impact the competitive position of biodiesel - without biotickets, biodiesel will remain more expensive than conventional diesel in the existing system and cheaper in the alternative systems.

5.4 Zero-emission vehicles

PHEVs, BEVs, and FCVs are not yet as close to the market as the options discussed in the previous section. PHEVs are only starting to become commercially available, and BEVs are only commercially available at a very small scale. BEVs cannot (yet) match conventional vehicles in terms of performance. FCVs are not at all commercially available yet.

Figure 5.12 shows the current competitive positions of BEVs and PHEVs compared to petrol[42]. Under the assumptions used in this study[43], PHEVs are more expensive than petrol vehicles in all systems (although only slightly in the existing system), while BEVs are cheaper than petrol vehicles.

The vehicle costs of BEVs and PHEVs are (much) higher than the costs of petrol vehicles. In this study, it has been assumed that these additional costs are approximately 10000 to 12000 euro, which is approximately 1200 to 1400 euro per year[44]. These higher costs also lead to a higher burden from BTW (approximately 250 to 300 euro per year).

The annualized costs of MRB and BPM[45] for a medium-sized, average-efficiency petrol vehicle are of the same order of magnitude as the additional vehicle costs of BEVs and PHEVs. The exemption for BPM and MRB in the existing fiscal system thus effectively cancels the higher vehicle costs of BEVs and PHEVs. The low costs and taxation of electricity are then sufficient in the existing system to offset the higher BTW burden, and even make BEVs cheaper than petrol vehicles. PHEVs are approximately as expensive as petrol vehicles. Because the variable costs of driving a BEV or a PHEV are lower than the variable costs of driving a petrol vehicle, BEVs and PHEVs are relatively cheaper for users that cover large annual distances.

[42] Due to their limited commercial availability, FCVs have been excluded in this comparison.
[43] See Appendix C for details.
[44] In this study, it is assumed that vehicle costs are fully depreciated over 8 years.
[45] Assuming that the BPM is fully based on emissions. Currently, the BPM is also still partly based on vehicle price.

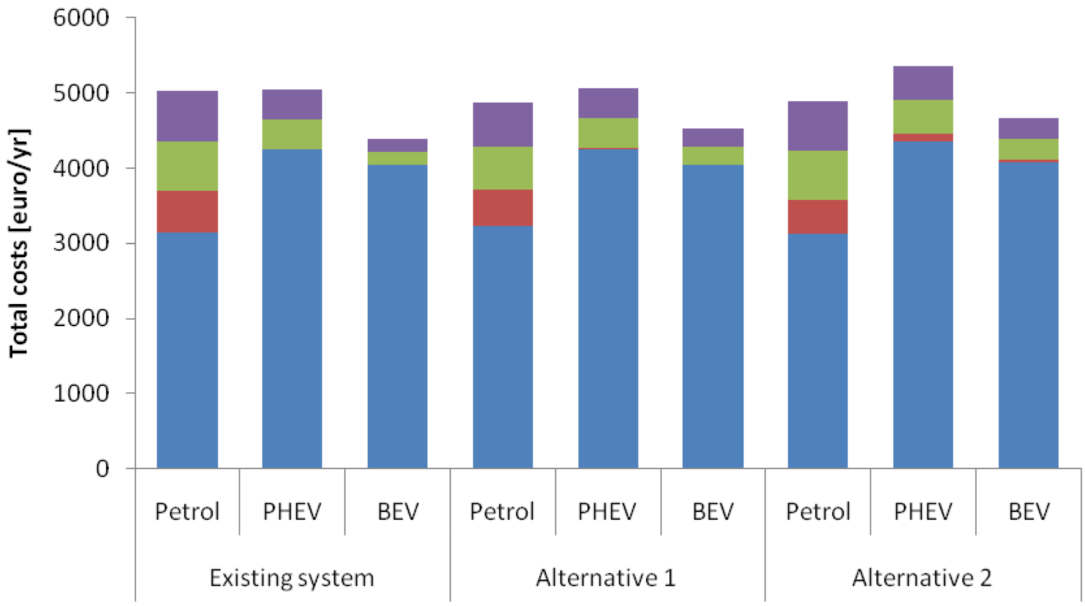

Figure 5.12 *User costs of BEVs and PHEVs in the three fiscal systems in 2010*
Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr

Interestingly, the tax burden on BEVs and PHEVs is higher in the two alternative systems than in the existing system. In fact, the full exemption of BEVs and PHEVs for MRB and BPM, and the relatively low “excise duty” in the existing system implies that introducing any taxation increases the tax burden on BEVs. In Alternative 1, the WTW-emissions are the tax base for all taxation, effectively including the WTT-emissions in the taxation of PHEVs and BEVs. In Alternative 2, excise duties are based on WTW-emissions, and BEVs and PHEVs are assigned a TTW-emission based on their energy use (see Section 2.3 for details).
Note that in the alternative systems, the tax burden for BEVs and PHEVs (partly) depends on the production pathway of the electricity. Here, the average Dutch production mix has been assumed.

In the future, the costs of BEVs, PHEVs, and FCVs are expected to drop drastically, while the costs for petrol vehicles are expected to increase. The major part of the cost changes comes from lower vehicle costs. Also, the emissions associated with hydrogen are expected to drop slightly, which results in a slightly lower tax burden in the two alternative systems. These developments change the relative costs of the various technologies significantly. Most importantly, the relative costs of BEVs, PHEVs, and FCVs become very low compared to petrol vehicles in all systems (Figure 5.13). The differences between the systems are comparable to those of Figure 5.12, with BEVs, PHEVs, and FCVs slightly more attractive in the existing system than in the alternative systems[46]. Clearly, zero-emission vehicles become a very attractive option from a cost perspective, provided the expected cost reductions materialise.

It is hard to assess to which extent specific stimulation of these technologies is required, i.e. whether these technologies need to be significantly cheaper than conventional technologies to capture significant market share. Specific stimulation may be required, if it turns out that consumers demand a significant cost advantage, e.g. to compensate for the range constraints on BEVs. In the short run, this would especially be the case in the two alternative systems, since fiscal stimulation in these systems is weaker than in the existing fiscal system. In the longer run (i.e. from 2020 onwards), all fiscal systems provide significant cost advantages for BEVs, PHEVs, and FCVs, reducing the need for specific financial support.

[46] It is likely that the substantial support for zero-emission vehicles in the existing system are scaled back once substantial numbers start to penetrate the vehicle stock or if the additional costs decrease substantially.

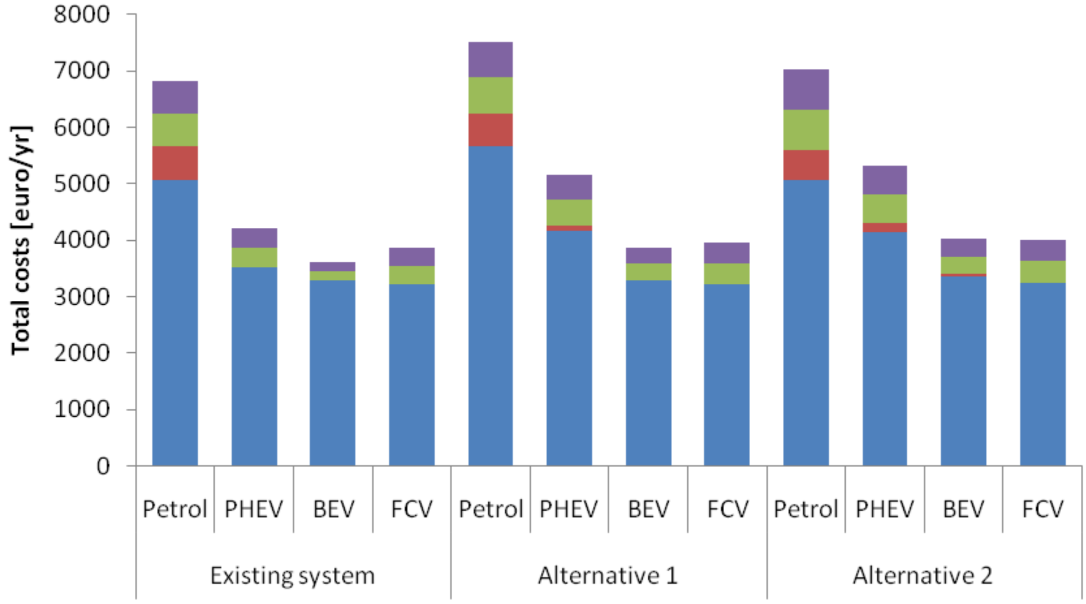

Figure 5.13 *User costs of BEVs, PHEVs, and FCVs in the three fiscal systems in 2020*

Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr.

6. Long term impact on vehicle sales and stock

The previous chapters mainly focused on the impact of WTW-based fiscal systems on the tax burden and the overall cost from a single consumer perspective in 2010. These chapters showed that the WTW-based fiscal systems provide a substantial cost incentive to consumers to purchase more fuel-efficient vehicles using lower carbon fuels. Obviously cost is not the only aspect that influences the purchase decision of a consumer[47], but this cost incentive can lead to substantial changes in the overall vehicle stock and the resulting fuel mix of passenger road transport.

Section 2.4.2 already showed that, to ensure a stable government income, most fiscal systems require tariff adjustments to compensate for expected efficiency improvements in the coming years (e.g. from CO_2 legislation). An effective WTW-based fiscal system may even accelerate the need for these tariff adjustments. It is important to verify if, in the long run, these tariff adjustments do not lead to undesired side effects, such as major shifts in tax burden.

Based on an outlook for 2030, this chapter will provide insight in the expected future differences between the WTW-based fiscal systems and the existing fiscal system. Firstly, it will provide insight in the development of the tax burden and overall cost for different individual fuel/vehicle combinations. Secondly, it will show from which part of the vehicle stock (or sales) the government income is derived. Thirdly, this chapter focuses on the consequences of two specific elements introduced in the alternative WTW-based fiscal systems: i) the introduction of generic tariffs and exemption levels (instead of fuel specific tariffs and exemptions) and ii) the removal of exemptions. The chapter concludes with some qualitative statements on potential shifts if all these developments take place. An example of such a shift is an expected increase of the share of diesel vehicles in the stock, which may worsen the already existing shortage of diesel fuel and surplus of petrol in Europe, possibly increasing the price of diesel and reducing the price of petrol.

6.1 Future tax and cost comparisons: outlook for 2020/2030

For this study, the outlook for 2020 and 2030 is based on the PBL vehicle stock data used for the ECN/PBL reference projections (Daniëls et al, 2010). The scenario chosen also contains future policy options (as expected at the end of 2009), such as the introduction of the 95 g/km CO_2 standard for passenger cars in 2020. The analysis in this and the next paragraphs focuses on the vehicle stock data for petrol, diesel and LPG fuelled vehicles, unless specifically mentioned otherwise.

6.1.1 Impact on future tax income in case tariffs are not adjusted

As already mentioned in Section 2.4.2 government income will be affected by the expected efficiency improvements. Due to these efficiency improvements, the income from vehicle-related taxes decreases substantially (note that the impact on VAT is not included in the overview). Figure 6.1 shows the overall monetary impact, assuming that all tariffs remain at the 2010 level. Note that in 2030 the total vehicle stock is about 25% larger and that the annual sales of vehicles is more than 30% higher. Based on Figure 6.1 the following observations can be made:

- In general, tax revenue from both vehicle-related taxes (BPM and MRB) decrease substantially as a result of the combined effect of two trends:

[47] Especially for new technologies there are several other aspects that will influence a consumer's purchase decision, like range, image and the availability of fuel infrastructure. Given the scope of this report, the impact of alternative fiscal systems has only been evaluated from a cost comparison, and is not intended to provide an integral evaluation of potential future developments.

- The efficiency of new vehicles improves substantially, and the average efficiency of the whole vehicle stock improves accordingly.
- The vehicle-related taxes have a progressive tariff structure and have exemptions (or low tariffs) for very efficient vehicles.

- The BPM revenue is impacted earlier than the MRB, as BPM is only taxed on new vehicles (which are in general more efficient than older vehicles), and not on the total vehicle stock. It takes several years before a significant decrease of the average efficiency of the vehicle stock due to uptake of new, efficient vehicles takes effect.
- For the existing system, the MRB revenue is impacted less as it is still dependent on the vehicle weight. It still decreases substantially after 2020, as an increased share of vehicle stock meets the exemption limit on TTW emissions[48].
- In Alternative 2 the government income is less reduced than in Alternative 1. The main reason for this is that in Alternative 2 the BPM and MRB do not include the improved WTT performance of the fuels, as they only focus on efficiency. The increased share of biofuels (from 4% to about 8.5%) and the improved WTT performance of these biofuels leads to more old and new vehicles meeting the exemption limit in Alternative 1.

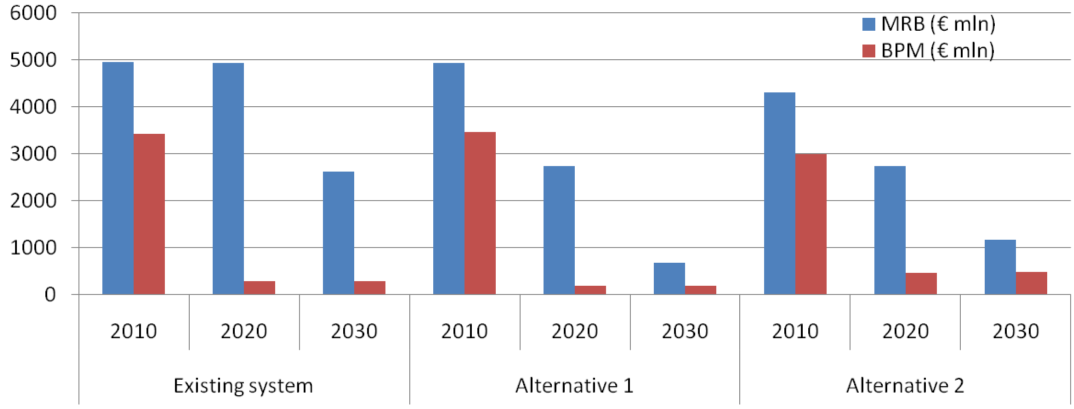

Figure 6.1 *Development of vehicle-related tax revenues, if tariffs remain at 2010 level*

For the fuel related taxes, a similar development can be observed, see Figure 6.2, although the impact is less severe as no exemption limits are involved. For the alternative systems, they are related to the overall expected reduction in WTW emissions.

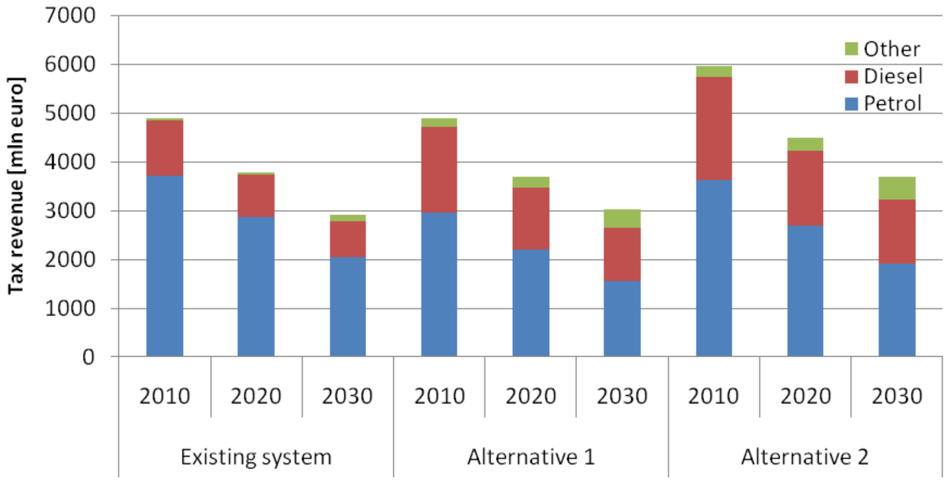

Figure 6.2 *Development of fuel related tax revenues, if excise duty tariffs remain at 2010 level*

Note: Petrol and diesel include the expected share of (blended) biofuels. Other includes LPG, CNG and electricity.

[48] The recent plans of the Dutch Ministry of I&M, as announced in the Autobrief of June 2011 (Ministerie van Financiën, 2011), were too late to be included in the analysis for this study.

6.1.2 Tariff adjustments to ensure stable development of future tax income

To keep the overall government income per vehicle stable, the tariffs and tariff structure (including exemption limits and tariff brackets) of all taxes have been adjusted in line with the expected development of vehicle efficiency and fuel carbon intensity. The tariff structure is adjusted in line with the theoretical adjustment as displayed in Figure 2.1, in such a way that overall government income follows the general growth in either new vehicle sales (BPM) or vehicle stock (MRB and excise duty). In reality, these adjustments will be political choices, and the assumption is not a preferred option, but just a pragmatic choice to allow a proper analysis.

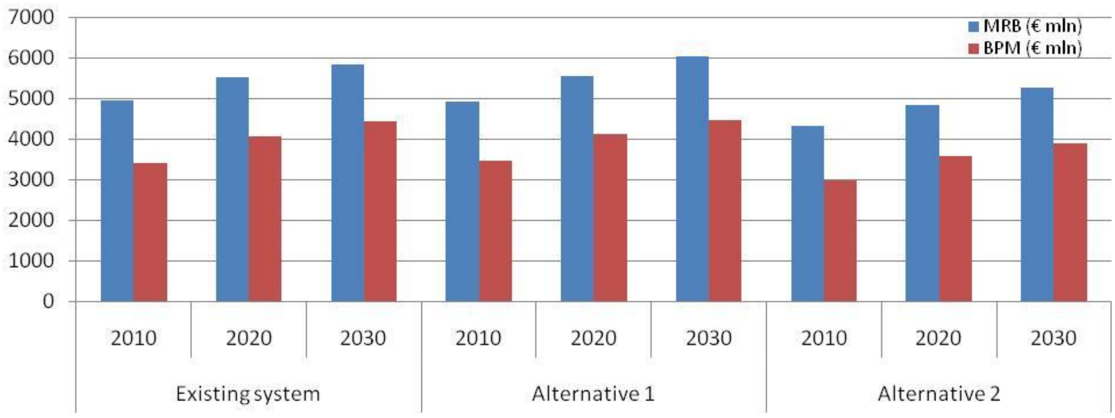

Figure 6.3 *Development of vehicle-related tax revenues, if tariffs are adjusted to ensure government income to develop in line with vehicle stock (MRB) or new vehicle sales (BPM)*

As expected, the resulting government income from the vehicle related taxes show in all systems the same development (Alternative 2 on a lower absolute level, due to the shift from vehicle related taxes to fuel related taxes). By adjusting the excise duty tariffs, a similar trend is achieved for the overall government income from fuel related taxes. For VAT, no adjustments are made to ensure a stable development, as this is not considered a realistic policy option in this context.

Table 6.1 shows that substantial tariff adjustments, for all three taxes, are needed to "compensate" for the expected efficiency development in the Dutch (new) vehicle stock and the related fuel consumption. For example, the excise duty tariff in the alternative systems (expressed in €/g CO_2 WTW), will need to be increased by 50% in 2020 compared to 2010[49], and a similar increase in the period between 2030, leading to 100% higher tariffs. For the BPM and MRB, the dynamics of Figure 2.1 need to be kept in mind. The tariffs per gram CO_2 (WTW for Alternative 1, TTW for alternative 2) will increase as mentioned in the table for all tariff brackets, but all tariff brackets will be adjusted as well. The tariff brackets (including the exemption limit) will be divided by the index for the tariff increase. For example, the exemption limit for the BPM in Alternative 1 will be reduced by about 35% in 2020 (equal to 100% - 100%/158%).

[49] Note that the index is expressed against the tariffs for the tax in 2010 in the same system. Different systems may have different tax bases.

Table 6.1 *Index for BPM, MRB and Excise duty tariffs, compared to 2010 tariffs, to ensure a stable development in government income (in combination with adjustments of tariff brackets)*

Tariff index vs 2010 [%]	BPM		MRB		Excise duty	
	2020	2030	2020	2030	2020	2030
Existing system	156	156	105	116	145	206
Alternative 1	158	158	125	164	149	199
Alternative 2	158	158	125	164	149	199

As the vehicles become more efficient, the average tax revenue per vehicle is stable, although it may of course lead to shifts of tax burden over different user segments, as will be shown in subsequent paragraphs. As the vehicle stock scenario which has been analysed did not contain any further efficiency developments for new vehicles after the implementation of the CO_2 norm of 95 g CO_2/km (TTW) for passenger vehicles in 2020, the BPM tariffs become stable per 2020. As the average efficiency of the complete vehicle stock improves at a slower rate, the tariff increase for MRB takes longer to stabilize. For the same reasons that explain why the government income from the current weight-based MRB did not decrease substantially, the current weight-based MRB also requires only minor tariff adjustments compared to the other adjustments.

Note that the current structure for tariff adjustments (application of an index on the same tariff structure with the same brackets) is only one of the possible solutions to ensure a stable trend in the government tax income from vehicles and fuels. There are several alternative solutions which could result in more progressive tariff structures (or less progressive), which could all have different outcomes to the observations that will be made in this chapter. Further research could help identify and assess the impact of other alternative tariff adjustments.

6.1.3 Cost development for alternative fuels towards 2020 and 2030

Figure 6.4 presents an overview of the expected cost development from a user perspective for a new medium-sized average-efficiency vehicle. Clearly this cost development is dependent on a number of different dynamics:

- Alternative vehicle technologies will still have substantial cost reductions, especially for plug-in hybrid and battery electric vehicles (PHEV/BEV) and fuel cell vehicles (FCV)). This results in a substantial yearly cost reduction of about €500 - €1000 (per year) compared to the purchase cost of a similar vehicle in 2010.
- The production cost of liquid biofuels decreases by 10% to 20% (Hanschke et al, 2009). Also, their WTW emissions will decrease further, making E85 more attractive versus petrol (compared to 2010).
- There are some minor changes between the current fuels based on different expectations regarding efficiency improvements (ICE vehicles on petrol are expected to improve their efficiency slightly more than ICE vehicles on diesel, LPG and CNG), which given the progressive tariff structure especially impacts the cost of diesel vehicles in the current system.
- The medium-sized average-efficiency vehicle on conventional fuels will be taxed more heavily than in 2010. The vehicle efficiency gains are outweighed by the tax increases. This is a result of the increased tariffs to compensate for the expected increased share of smaller-sized and/or higher-efficiency vehicles.

As a result of above dynamics, the difference in the cost, from a user perspective, for alternative fuels versus conventional fuels decreases compared to the cost difference in 2010 for medium-sized average-efficiency vehicles.

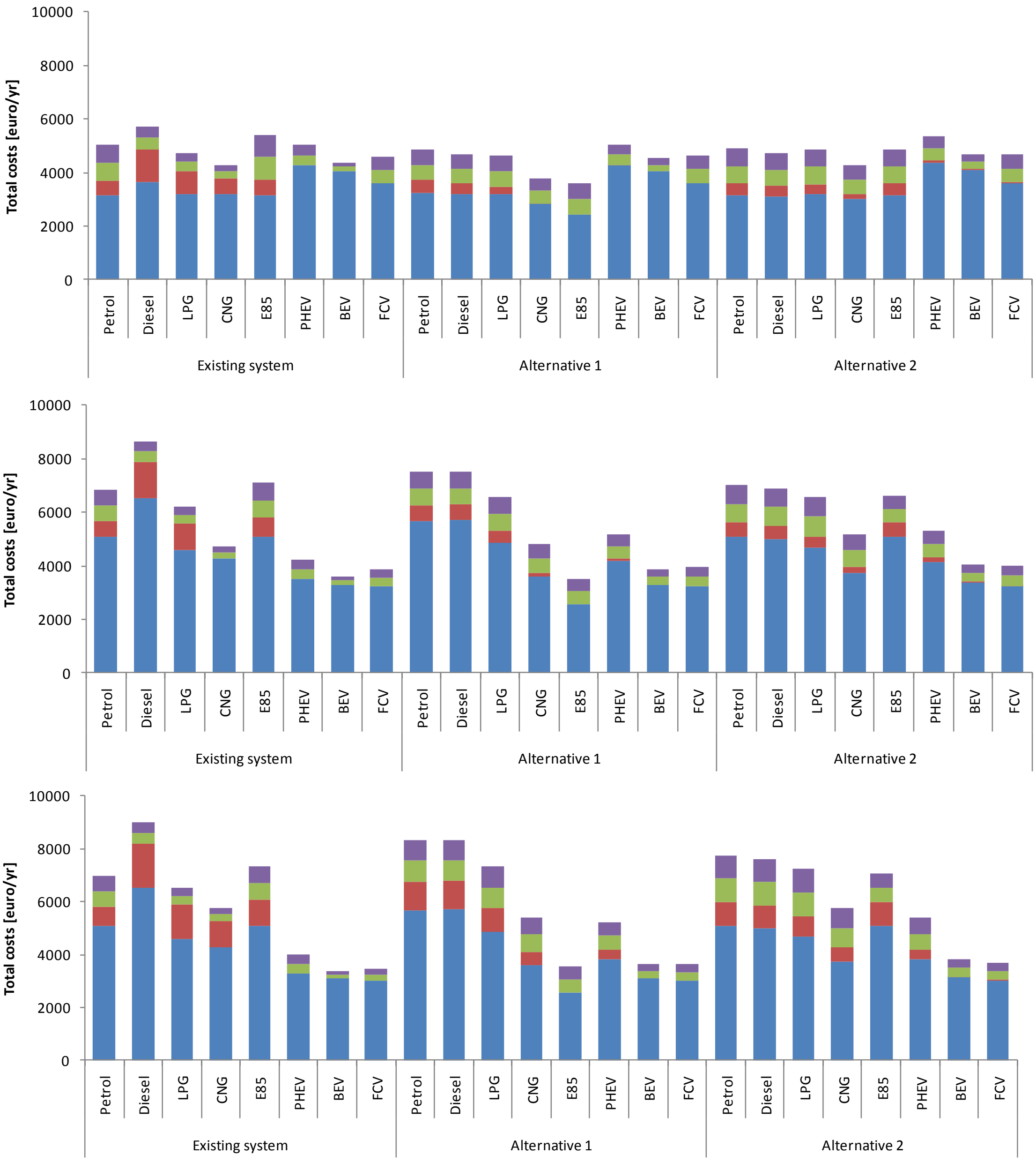

Figure 6.4 *Vehicle costs from user perspective of conventional and alternative fuels in the three fiscal systems in 2010 (above), 2020 (middle) and 2030 (below)*

Note: Numbers are values for vehicles equivalent to a medium-sized, average-efficiency new vehicle, 15000 km/yr.

Figure 6.5 shows that in all fiscal systems in 2030, there is no substantial cost difference for fuels as long as the vehicles used are very efficient (40% more efficient). For a petrol vehicle, this would correspond with a TTW emission of about 80 g/km CO_2. In that case, the vehicle is below the exemption limit (existing system and Alternative 1) or in the tariff bracket with a very low tariff (Alternative 2), which results in no, or very low, vehicle-related taxes. As a consequence, the difference between the conventional and the alternative fuels is very limited from a user cost perspective. In all systems, users will be rather indifferent between very efficient vehicles on conventional fuels and vehicles on alternative fuels. As is shown, the WTW-based fiscal systems give the largest incentive to the alternative fuels. In 2010 and 2020, a similar comparison can be made, but for these years, the cost difference for a number of innovative vehicles (BEV/FCV/PHEV) is still substantial due to the considerable additional vehicle costs. For these years, the attractiveness of these alternative vehicles is lower, from a user cost perspective, than very efficient vehicles on conventional fuels.

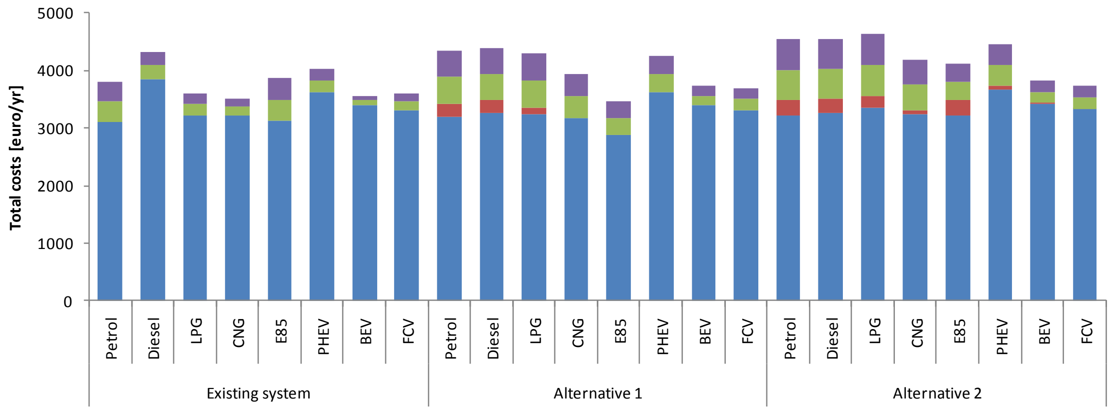

Figure 6.5 *Vehicle costs from user perspective of conventional and alternative fuels in the three fiscal systems in 2030 for very-efficient vehicles*

Note: Numbers are values for vehicles equivalent to a medium-sized, very efficient new vehicle (40% more efficient than average-efficiency vehicles), 15000 km/yr

6.2 Tax burden distribution over vehicle stock and sales

Alternative fiscal systems may lead to a different distribution of the overall tax burden over the different fuels. Currently petrol and diesel passenger cars are responsible for more than 95% of the government tax income from passenger cars. Figure 6.6 shows the distribution of this government tax income split by fuel and tax. In Alternative 1 and Alternative 2 a larger part of the tax income is originating from petrol vehicles, as the increase in vehicle-related taxes is larger than the reduction in excise duty. The total tax income from passenger cars on diesel is almost decreased by 25%. This is in line with the overview of the tax burden in Figure 4.4. The shift from a part of the income from vehicle-related taxes (BPM and MRB) to excise duty as done in Alternative 2, is visible if Alternatives 1 and 2 are compared. The shift of the tax burden towards petrol is somewhat less for this alternative, but still substantial.

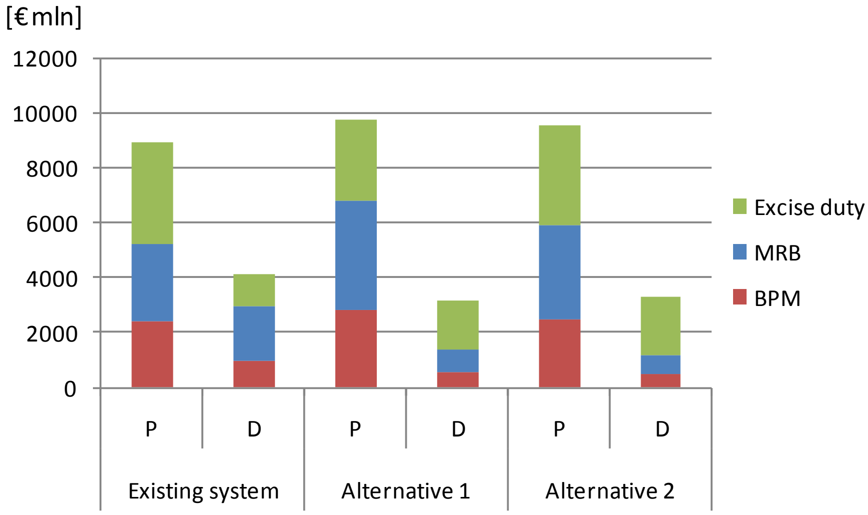

Figure 6.6 *Government tax income related to petrol (P) and diesel (D) vehicles for the three fiscal systems for 2010*

As already mentioned before the decreased tax burden for diesel is a result of the better WTW performance of diesel vehicles, combined with the introduction of a generic tariff structure. For similar-sized vehicles, the advantage of the higher efficiency of the diesel engine will provide a number of tax incentives:

- The progressive tariff structure in combination with the fact that the original tariff brackets (BPM) or tariffs (MRB) were defined different for diesel vehicles, result in a relative lower BPM and MRB (in € per g CO_2/km) compared to diesel vehicles in the current system.
- The more efficient fuel use, results in a lower carbon footprint per kilometre (both on a TTW as a WTW basis), which leads to lower excise duty per kilometre compared to petrol in the new system.

On top of that, the introduction of a generic tariff structure results in the removal of the fixed starting tariff for diesel for the BPM (€2.400). Also the starting tariffs for the MRB are removed, and these are also higher for diesel than for petrol (they are about €240/year higher). These high(er) start tariffs were introduced to ensure a more balanced tax burden versus petrol, to compensate for the relative low excise duty tariffs for diesel (for the competitive position of road transport sector) and partly for other fuel specific policies (e.g. local air quality). Note that the high(er) starting tariffs to compensate are no longer needed in Alternative 1 and Alternative 2 given the introduction of a generic excise duty tariff (per g CO_2 WTW), in line with the polluter pays principle. As a result of all the above observations, the average vehicle-related taxes per vehicle will be substantially lower for the average diesel vehicle in the alternative systems. This is illustrated in Figure 6.7 (BPM) and Figure 6.9 (MRB).

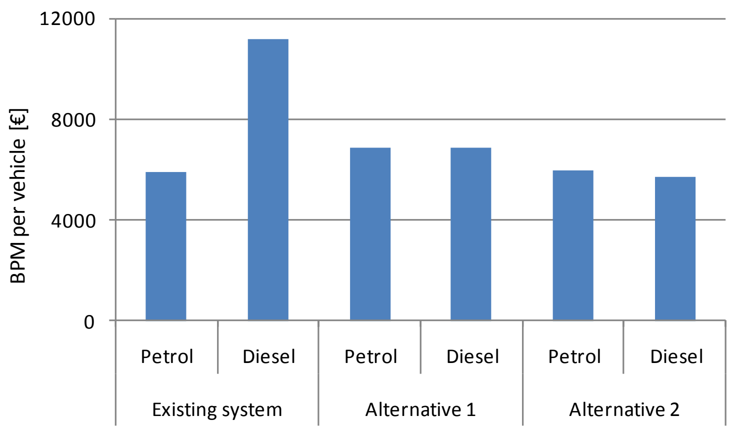

Figure 6.7 *Average BPM per vehicle for the three fiscal systems for the current vehicle stock (2010)*

Figure 6.7 shows that, despite the fact that the average diesel vehicle is larger and heavier than the average petrol vehicle (see Figure 6.8 below), the average BPM for diesel vehicles is similar (Alternative 1) or even lower (Alternative 2) than the average BPM for petrol vehicles. However, based on the changes in the vehicle stock expected for 2020 and 2030, the average BPM for diesel vehicles will still increase (by 10%-20%), whereas the average BPM for petrol vehicles is expected to decrease slightly (by 5%-10%). This trend is not illustrated, but occurs in the alternative systems as well as in the existing system. This is caused, amongst others, by the expected increase in size/weight (both diesel and petrol) and the substantial vehicle efficiency improvements.

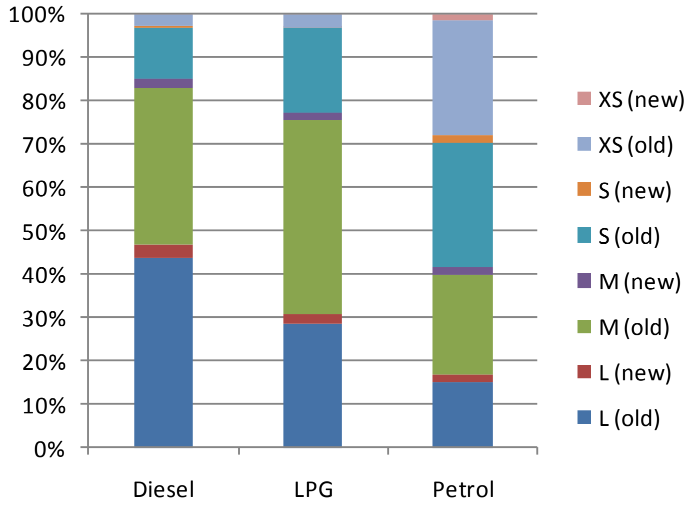

Figure 6.8 *Relative shares of (weight-related) vehicle segments in vehicle stock of 2010*

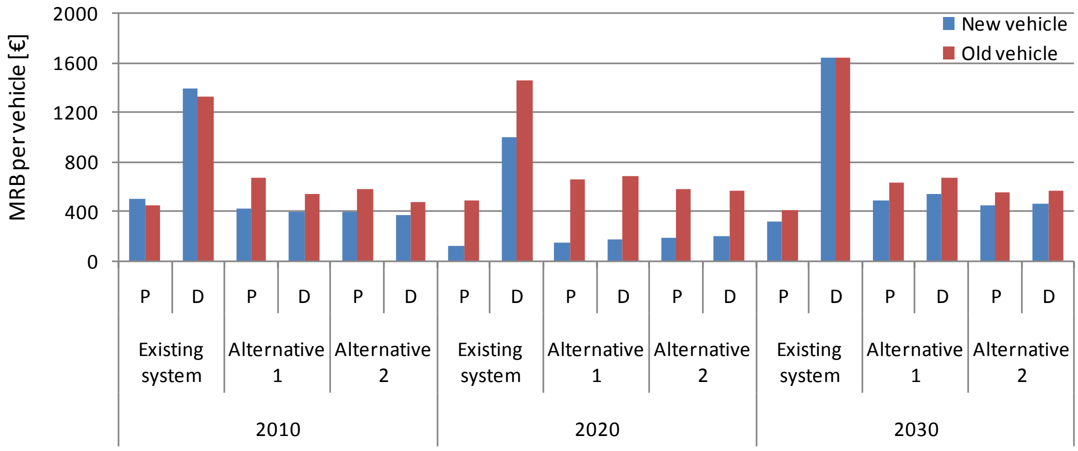

Figure 6.9 *Average MRB per vehicle for the three fiscal systems for the current and future vehicle stock for new and old vehicles*

Figure 6.9 shows that for the MRB, there is one additional dimension (age) to be verified, as the MRB is collected for new[50] as well as for old vehicles. The choice for a generic tariff structure (excluding an age-based component) combined with the expected efficiency improvements has quite some implications over time. Given the mechanism used for tariff adjustments, the tariff adjustments for MRB react slower upon the efficiency gains of the new vehicles than the BPM (new sales only account for about 10% of the total vehicle stock, see Figure 6.8, so their efficiency gains only have a limited effect on the government tax income from MRB). As a consequence, the MRB paid for new vehicles decreases substantially for the alternative systems, by about 45% to 65% (without a correction for increase in size). The existing system, which is still mainly weight-based shows only such a reduction for petrol vehicles, and a much lower decrease for diesel vehicles. In 2030 almost the complete vehicle stock has been replaced by very efficient vehicles that meet the proposed CO_2 legislation for 2020. As a result the efficiency gap between the average old and the average new vehicle has become much smaller, leading to a smaller difference in MRB of about 20% to 25% (except for diesel vehicles in existing system).

[50] For this analysis, new vehicles correspond to all vehicles purchased in the year at which the vehicle stock is assessed. So for 2020, the average MRB displayed for old vehicles corresponds to the average MRB of all vehicles still active in 2020, but purchased before 2020.

Despite this extra dimension, it can also be concluded for the MRB that, although the average (old or new) diesel vehicle is in general larger and heavier than the average (old or new) petrol vehicle, diesel vehicles still have almost similar tax burden in the new system (on average) in 2010 as well as in the future.

6.3 Potential shifts in vehicle sales and stock

The previous paragraphs focused on the impact on shifts in the tax burden for average vehicles, based on tariff adjustments derived from the current outlook for the Dutch vehicle stock. This current outlook was based on the existing fiscal system. If one of the alternative systems will replace the existing fiscal system, the tax burden for consumers will change, potentially influencing their use and purchase behaviour of vehicles. Some of these potential shifts will be discussed below, including their potential effect.

Petrol vehicles will lose market share to diesel vehicles
A switch to one of the alternative systems will make diesel vehicles, on average, much more attractive than petrol vehicles, even at lower mileages than the current break-even point for diesel. Not all purchase decisions are based on total cost over the expected lifetime. Currently, the high tax burden at the time of purchase (BPM) and the higher expected ownership tax (MRB) of diesel vehicles might even be weighed more heavily at the time of the purchase decision for a new car than future savings on fuel costs (resulting in more people opting for petrol). The impact of the introduction of a generic tariff structure, might therefore even be stronger than expected based on the cost comparison only.

An increased market share of diesel vehicles may have several consequences, of which only two will be mentioned:
- The current mismatch in European transport fuel demand and refinery capacity (shortage of diesel and a surplus of petrol) will worsen, and impact the economic results of Dutch and other European refineries.
- Impact of transport on local air quality will be larger as diesel vehicles emit more NO_x and PM_{10} than petrol vehicles. This effect will be lower after introduction of Euro6 norms.

Innovative (low-carbon fuel) vehicles could gain market share, but still face severe competition from fuel-efficient conventional fuels…
In the existing fiscal system as well as in Alternative 1 and 2, BEV's, FCV's and PHEV's, have total ownership costs that are comparable to similar vehicles on conventional fuels. Including expected cost reductions, they are far more attractive in 2020 and beyond if compared to a similar vehicle on conventional fuels (see Figure 6.4). As Figure 6.5 shows, this cost advantage is almost completely lost, if these innovative (low-carbon fuel) vehicles are compared with very fuel-efficient vehicles on conventional fuels. This fact is caused by the exemptions and the progressive tax structure of the involved taxes, and is rather independent of which of our fiscal systems is selected. Currently, the innovative vehicles still have other barriers as well (such as range anxiety and availability of fuel infrastructure). As a result, it is likely that, without additional policies, neither the existing, nor the alternative fiscal systems, will provide a strong acceleration of innovative (low-carbon fuel) vehicles,

… which may be changed in time due fleet dynamics and tariff adjustments …
On the longer term, once the vehicle stock is replaced by more very fuel-efficient vehicles, larger tariff increases will be implemented to maintain a stable government tax income. If this continues for a sufficient period (years), the very fuel-efficient vehicles will become taxed again. If innovative (low-carbon fuel) vehicles are able to (substantially) outperform these very fuel-efficient vehicles with respect to WTW emission, the competition on total ownership cost will eventually be won by BEV's, FCV's and PHEV's. Note that if their own market share increase,

these same dynamics will improve their own position even further, as they also require more tariff adjustments to maintain stable government income.

... which will even lead to stronger tariff adjustments

If the above mentioned fleet dynamics take place and are successful in accelerating alternative fuels and fuel-efficient vehicles, there will be an even larger impact on the tariff levels, further improving the attractiveness of these alternative fuels.

Fiscal incentives: a balancing act as consumers and "the market" do not like frequent (upward) tax adjustments ...

Fiscal incentives often require a balancing act from the government. The market demands predictable, preferable stable, tax tariffs, and consumers as well. Fiscal incentives provide a nice option to stimulate specific alternative technologies that are not competitive yet, but if the technology gets cheaper and is successfully gaining market share, the fiscal incentives need to be reduced to limit lost tax income (or compensated in another way).

... which will be considerable from a consumer perspective

MRB and excise duty will increase substantially during the lifetime of a vehicle if the overall vehicle stock gets more efficient as expected. These increased costs of ownership and use cannot be easily off-set (exception: vehicle replacement and/or mobility reduction). As Table 6.1 shows, the excise duty (currently about 50% (diesel) to 65% (petrol) of the total fuel cost), will increase by about 50% in 10 years. This implies an increase of the total fuel costs of 25% to 30% in 10 years. For the MRB, the same table shows an expected tariff adjustment of 25% between 2010 and 2020. Combined with a reduction of all tax bracket limits (including the exemption limit) of about 20%, this results in an increase of the MRB of at least 50%. The effects of these increased costs require more research for final conclusions, but it could lead to early retirement of vehicles with low-efficiency. It may even restrict the access to mobility for persons with a low-income.

Notice that this effect is limited for the BPM, as the tariff increases (per g CO_2) are off-set (on average) by the increased vehicle efficiency.

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Appendix A WTW-emissions of different fuels

A.1 Calculation of emissions

Vehicle WTW-emissions are a product of the energy efficiency of a vehicle (in MJ/km) and the carbon intensity of the fuel used (g/MJ). In practice, vehicle energy efficiency is in turn often calculated from the TTW-emissions (in g/km) and the TTW carbon intensity of the fuel (Figure A.1).

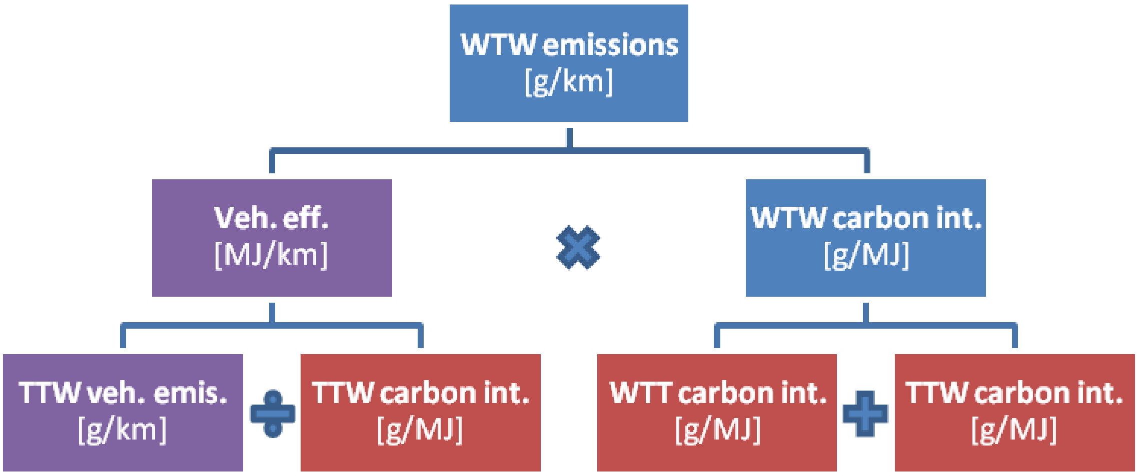

Figure A.1 *Calculation of vehicle WTW-emissions*

The WTT and TTW carbon intensities (red boxes in Figure A.1) have been derived from JRC et al. (2007). The same report has been used to derive the TTW vehicle emissions and vehicle emissions (purple boxes in Figure A.1, but in an indirect way. The TTW vehicle emissions in the report have been used to calculate vehicle efficiency for each fuel. Next, the efficiency of each vehicle type relative to a similar petrol vehicle has been determined. These relative performance figures have then been used to determine the vehicle efficiency and TTW-emissions of a new, average vehicle of each fuel type. For these calculations, the reference is the vehicle efficiency of a new petrol vehicle in the PBL vehicle stock data used for the ECN/PBL reference projections (Daniëls et al, 2010).

Table A.1 shows some example results of this approach. A diesel vehicle requires 91% of the energy that a petrol vehicle requires to cover the same distance (JRC et al, 2007). The PBL data show that a medium-sized new petrol vehicle has an efficiency of 2,2 MJ/km. Consequently, a comparable[51] diesel vehicle has an efficiency of 2,0 MJ/km.

The advantage of this approach is that it can be applied to different vehicle sizes and types. The last column of Table A.1 shows that a large new petrol vehicle requires 2,5 MJ/km (as derived from PBL data); consequently, a large new diesel vehicle requires 2,3 MJ/km.

[51] I.e. same size, comparable engine power, same accessories, etc. See also Appendix C.

Table A.1 *Vehicle efficiency calculation*

	Veh. eff. [MJ/km]	Index vs. petrol [%]	Efficiency medium vehicle [MJ/km]	Efficiency large vehicle [MJ/km]
Petrol	1.9[1]	100[3]	2.2[2]	2.5[2]
Diesel	1.7[1]	91[3]	2.0[3]	2.3[3]
LPG	1.9[1]	98[3]	2.1[3]	2.4[3]
CNG	1.9[1]	97[3]	2.1[3]	2.4[3]

1 Derived from JRC et al. (2007).
2 Derived from Daniëls et al (2010).
3 Calculated.

A.2 Comparison with other studies

The results thus obtained have been compared to the results of a study by TNO on the WTW-emissions of LPG- and CNG-vehicles (Vonk et al, 2010). For this study, LPG- and CNG-vehicles have been subjected to a realistic driving cycle and the resulting emissions have been documented.

Table A.2 *Results obtained in this study compared to results obtained by TNO*

	ECN WTW carbon int.	TNO WTW carbon int.	ECN Veh. eff. vs. petrol	TNO Veh. eff. vs. petrol	ECN WTW emissions vs. petrol	TNO WTW emissions vs. petrol
Petrol	84,5	80,6	100%	100%	100%	100%
Diesel	88,5	82,9	91%	83%	95%	86%
LPG	76,1	73,4	98%	100%	88%	91%
CNG - NL	61,1	61,1	97%	110%	70%	84%

The columns marked ‘ECN’ are based on the approach in this study, columns marked ‘TNO’ are based on the TNO report (Vonk et al, 2010). Values for CNG are based on Dutch natural gas.

There are considerable differences between the results for WTW-emissions for diesel and CNG-vehicles in the TNO report and the approach in this study, as illustrated in the last two columns of Table A.2. The possible explanations for these differences lie in different assumptions (1) regarding carbon intensities and (2) regarding vehicle efficiencies.

The TTW carbon intensities used in this study are exactly the same as the carbon intensities used by TNO[52]. The WTT carbon intensities used in this study are slightly higher than the values used by TNO, with the exception of CNG. This leads to minor differences (ECN figures being 4-7% higher).

There are larger differences in the assumed vehicle efficiencies. The two major differences are in the efficiency of diesel vehicles and CNG-vehicles. Both vehicle types are found to be much less efficient in the TNO report. Two reasons may explain these differences:

- The TNO report is based on measurements using a realistic test cycle, whereas the JRC report is based on simulations of the New European Driving Cycle (NEDC), which is also used for type-approval testing.
- For CNG-vehicles, TNO found tailpipe methane emissions. TNO expresses results in CO_2-equivalents. Using TNO’s TTW-results (g/km) to calculate CNG vehicle efficiency thus leads to a substantially higher value.

52 For this reason, these have not been included in Table A.2.

Appendix B Guideline for the interpretation of graphs

B.1 Graphs displaying total tax burden

These graphs are used in Chapter 4 to show the total tax burden for different vehicle-fuel combinations in the three fiscal systems. The bars in the graphs are composed of the following elements (Figure B.1):

- Purchase taxation: BPM, fully depreciated over 8 years.
- Ownership taxation: MRB.
- Usage taxation: Excise duty.

Note that the BTW is not included in these graphs! The graphs show usage taxation for the use of a vehicle for an annual distance of 7500 km per year, as well as the impact of an additional 7500 km per year (which is basically the same amount). This sums to a total of 15000 km per year, which is approximately the average annual distance of a privately owned passenger car in the Netherlands.

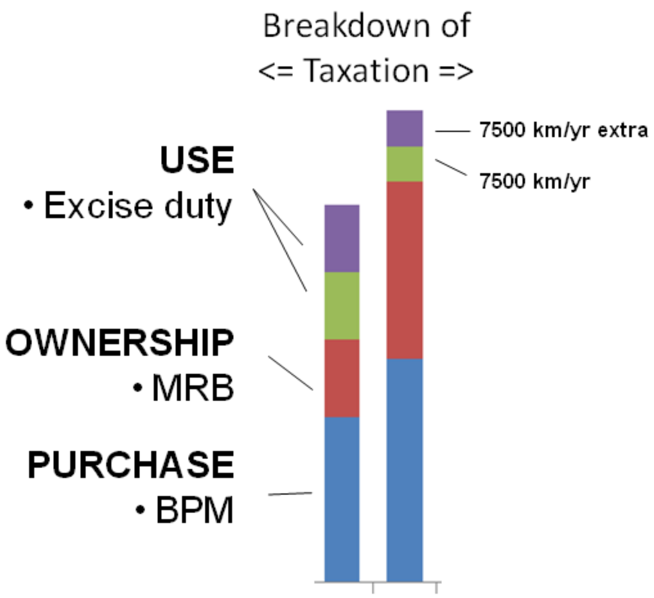

Figure B.1 *Guideline for the interpretation of graphs on total taxation for two alternatives (Chapter 4)*

B.2 Graphs displaying user costs

These graphs are used in Chapter 5 to show the total user costs for different vehicle-fuel combinations in the three fiscal systems. The bars in the graphs are composed of the following elements (Figure B.2):

- Purchase costs: Vehicle costs, BPM, and BTW, all fully depreciated over 8 years.
- Ownership costs: MRB.
- Usage costs: Fuel costs, excise duty, BTW.

Maintenance and insurance costs are not included in these graphs. The graphs show usage costs, including all taxes, for the use of a vehicle for an annual distance of 7500 km per year, as well as the impact of an additional 7500 km per year (which is basically the same amount). This sums to a total of 15000 km per year, which is approximately the average annual distance of a privately owned passenger car in the Netherlands.

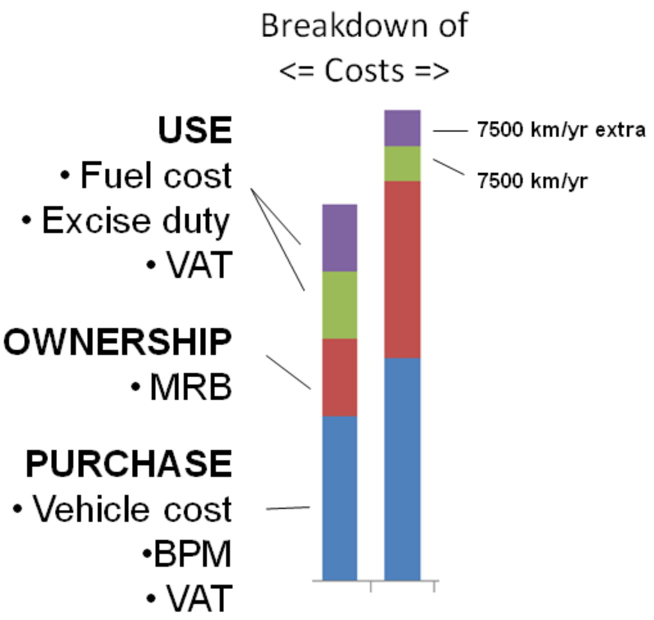

Figure B.2 *Guideline for the interpretation of graphs on user costs for two alternatives (Chapter 5)*

Appendix C Users and vehicles

This appendix provides background on the annual distances covered by passenger cars in the Netherlands, as well as some assumptions regarding vehicle properties used in this report.

C.1 Annual distance

The annual distance covered by passenger cars are shown in Figure C.1. Company cars cover an annual distance that is considerably larger (average approx. 34000 km/year) than the annual distance of private cars (average approx. 14500 km/year).

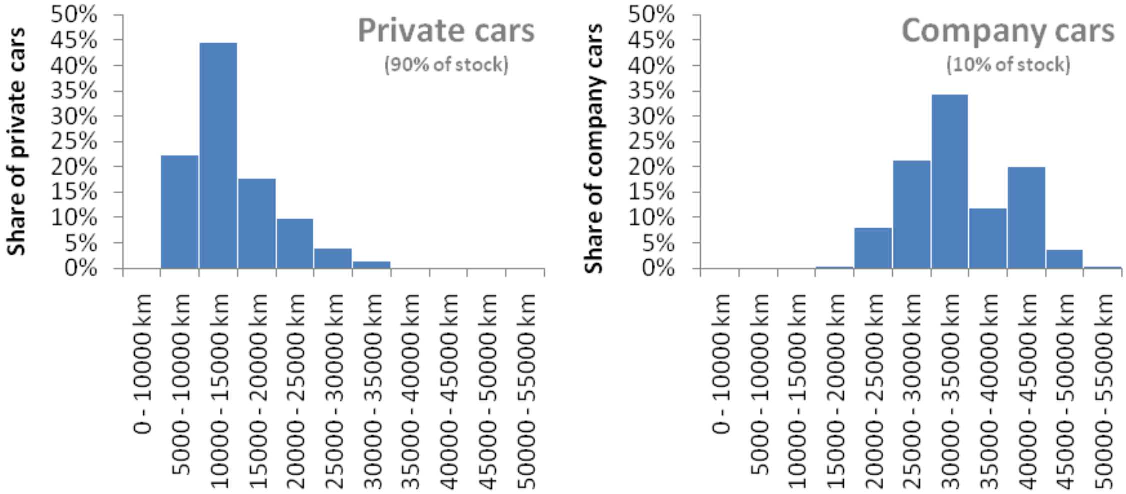

Figure C.1 *Distribution of annual distances for private cars and company cars*
Source: Based on calculations used for Daniëls et al (2010).

C.2 Vehicle size categories

The vehicle stock is composed of cars of all types and sizes. To enable a meaningful comparison of the different fuels and technologies, 4 vehicle size categories have been created. Cars within a category are similar from a consumer perspective, i.e. they are assumed to fulfil the same consumer needs, irrespective of fuel and technology[53].

In each of the categories, a petrol vehicle forms the reference. Table C.1 lists the properties of these reference vehicles for each category. These properties have been selected based on the data used for the latest reference projection (Daniëls et al., 2010). Other properties have been taken from Hanschke et al. (2009), and the reader is referred to this report for details.

Table C.1 *Properties of petrol vehicles in the different vehicle size categories in 2010*

Size		Weight	Energy use
XS:	extra small	0 - 950 kg	1.6 MJ/km
S:	small	951-1150 kg	1.9 MJ/km
M:	medium	1151-1350 kg	2.2 MJ/km
L:	large	1351 - … kg	2.5 MJ/km

Similar-sized vehicles that use technologies and fuels other than petrol feature different fuel ef-

[53] This is valid to a large extent. There are properties inherent to certain technologies that change the value to the consumer, e.g. the limited range associated with EVs.

ficiency. Based on JRC et al. (2007), the energy use of these technologies relative to petrol has been determined (Table C.2).

Table C.2 *Changes in properties of vehicles with different fuels/technologies with respect to reference (petrol) vehicle in 2010*

Fuel/Technology	Energy use (index, petrol = 100)
Diesel	91
LPG	98
CNG	97
FCV	63
BEV	23
FFV	100
PHEV	61

It is expected that some energy use of the different technologies will change in the future. In line with the reference projection, energy use per vehicle is assumed to decrease towards 2020, but no further decrease has been assumed for 2030. Table C.3 documents which values have been assumed for the reference vehicle and other fuels and technologies for 2020 and 2030. Note that in accordance with Hanschke et al. (2009), other properties (e.g. vehicle costs) do change between 2020 and 2030.

Table C.3 *Properties for reference and other vehicles for 2020 and 2030. Changes compared to 2010 are printed in bold*

Size	Energy use
Properties reference vehicle	
XS: extra small	**1.4 MJ/km**
S: small	**1.7 MJ/km**
M: medium	**1.8 MJ/km**
L: large	**1.9 MJ/km**
Energy use (index, petrol = 100)	
Diesel	**95**
LPG	98
CNG	97
FCV	63
BEV	23
FFV	100
PHEV	61

C.3 Vehicle efficiency categories

Vehicle efficiency may vary considerably *within* each vehicle size category. Therefore, sensitivity analysis has been carried out to determine what the effects are of 20% better and worse vehicle efficiency (MJ/km) compared to the average of each vehicle size category.