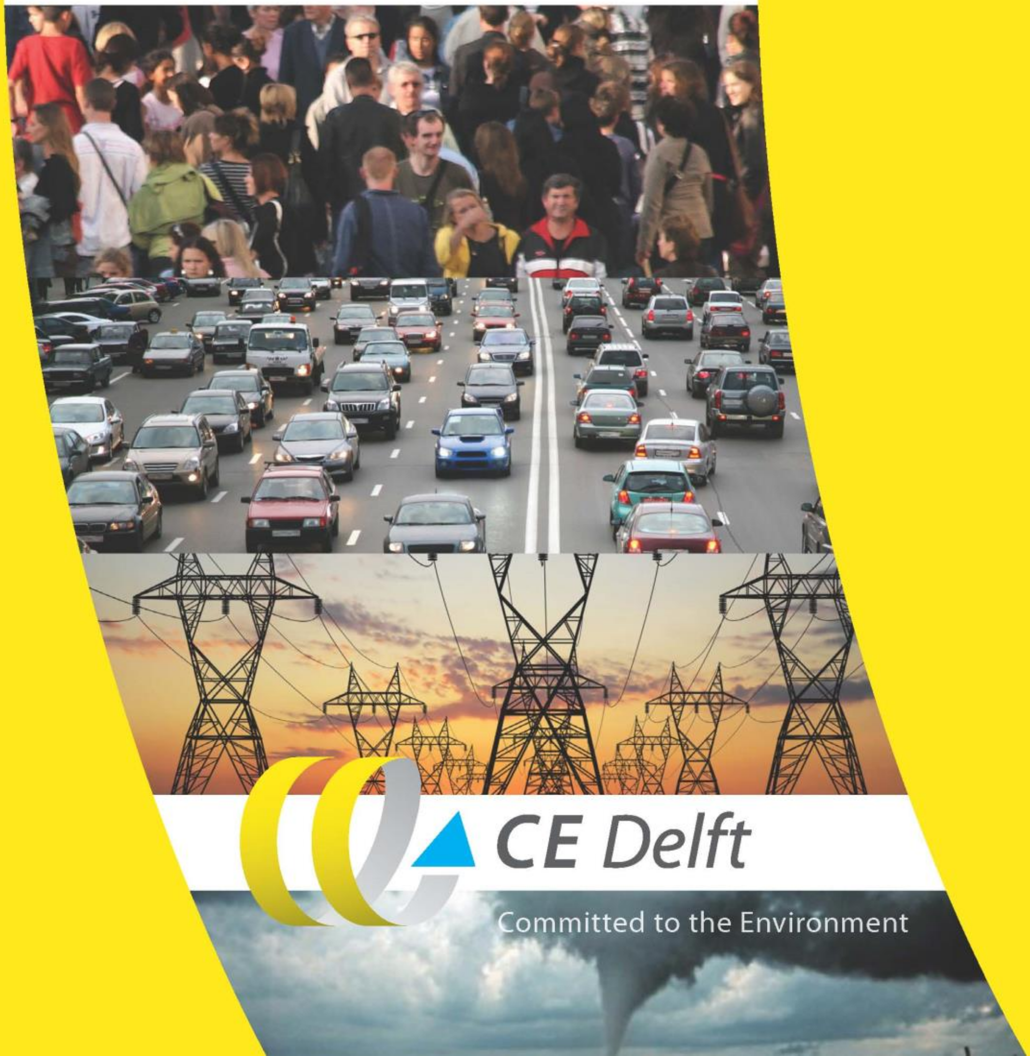
CO_2-differentiated road charges for HGVs

Scoping study



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Summary

Background and objective

The German government has announced that it would like to differentiate the HGV MAUT to the energy efficiency of trucks. Such a differentiation is currently not allowed by the Eurovignette Directive. However, because of the intentions of the German government and the introduction of EU requirements on measuring and monitoring the CO_2 emissions of new Heavy Goods Vehicles (HGVs), it is expected that this will become a topic of discussion soon.

In this paper we present the results of a scoping study on the desirability and feasibility of CO_2-differentiation in HDV road charging schemes, as well as on the options to actually design such a differentiation.

CO_2-differentiated road charges at a European scale

Differentiating HGV road charges to CO_2 emissions could be a good policy instrument to reduce HGVs' CO_2 emissions, particularly as there is little support for other potential instruments (e.g. increasing fuel taxes, CO_2 regulation for new HGVs or CO_2-differentiated purchase taxes). Experiences with differentiation of HGV road charges to EURO standard show that such schemes can be effective.

In case in the future CO_2-differentiated road charging will be allowed, it is recommended that the methodology for such differentiation is harmonised at the EU-level. This will increase its effectiveness (HGV owners receive the same incentive in all EU countries), ensure that the internal market is maintained, reduce the administrative burden to international hauliers and public authorities and lower the risk that national charging schemes are designed in favour of domestic OEMs.

Implementation issues

The implementation of CO_2-differentiated road charges seems (technically) feasible, although some significant challenges have to be overcome to guarantee a fair and effective system. The most important issue is the availability of certified CO_2 information for HGVs. Although the European Commission is currently preparing legislation requiring the certification and reporting of CO_2 information of HGVs, this information will only be available for part of the European HGV fleet. For example, existing vehicles and trailers are probably not (immediately) covered by this regulation. An option to deal with this issue is to apply a bonus-malus scheme to those vehicles for which CO_2 information is available, while for other vehicles the average/current charge is applied. A possible disadvantage of this solution is that existing fuel-inefficient trucks are charged a lower fee than some of the new, relatively more fuel-efficient trucks. This disadvantage can be avoided by charging all vehicles for which no CO_2 information is available the highest charge level. However, this may be perceived unfair as it may result in relatively high charge levels for some relatively fuel-efficient vehicles.

Irrespective of the solution chosen to deal with the unavailability of certified CO_2 information of some of the vehicles/trailers, none of them will stimulate retrofitting existing vehicles or trailers. This can (partly) be solved by providing credits or discounts to hauliers which have purchased add-on fuel-saving technologies for their existing vehicles and/or trailers. However, this solution requires a verification and monitoring process, e.g. to check whether these add-ons are replaced at the end of their lifetime or when they are damaged. This may be realised by adding these technologies to the

vehicle's registration document and by checking their status during the annual maintenance call.

Finally, it is expected that for some vehicles, which can be used for different mission profiles, more than one CO_2 figure (i.e. one figure for each mission profile) will become available. Currently, it is not clear how this will be addressed in the EU monitoring and reporting requirements. Alternative options to address this is by choosing the highest CO_2 figure or by choosing the CO_2 figure for the mission profile that uses highways most (as road charging is focussed on these roads). However, these solutions may result in market distortions as a truck with two mission profiles can have a(n) (dis)advantage compared to trucks with only one mission profile, while CO_2 performance of both vehicles in the real world may be the same. By distinguishing different vehicle categories (based on mission profile) in the charging scheme this risk can possibly be addressed.

Design issues

Including a CO_2-based component in existing road charging schemes can be done in myriad ways. The following design issues are discussed in this report:

- *Differentiation between vehicle categories*: differentiating the scheme to various vehicle categories provides the opportunity to take differences between vehicle categories better into account. However, it also provides manufacturers/hauliers the opportunity for gaming (e.g. if charges are relatively lower for regional delivery trucks than for long-haul trucks, there may be an incentive to sell/buy regional delivery trucks to long-haul hauliers).
- *Metric for the road charges;* the two main options for a metric measuring the CO_2 performance of a truck are g/vkm and g/tkm. The latter aligns better views of the market, while the former aligns better with the design of road charging schemes. Furthermore, the risks on unintended effects are expected to be smaller with g/vkm as metric.
- *Continuous or step-based differentiation of performance*; by basing the CO_2-differentiation of the road charging scheme on a continuous function, a continuous incentive to improve fuel efficiency is given, while a step-based function only provides an incentive to improves fuel-efficiency to reach a better category. On the other hand, step-based functions may provide the opportunity to apply larger differences in charge levels between comparable vehicles, although this may also be (partly) realised by applying a continuous exponential function. Finally, a step-based function may result in market distortions.
- *Amount of revenues*; compared to a budget neutral scheme, a budget increasing scheme is more (environmentally) effective, but less acceptable to the market. Moreover, a budget increasing scheme is not in line with the principles of the current Eurovignette Directive.

It should be noticed that the actual design of a CO_2 based component also interacts with the current design of the HGV road charging scheme.
For example, most of the existing HGV road charging schemes in Europe are already differentiated to EURP standards, number of axles and/or maximum load of the truck, and when designing the CO_2-based component these differentiations should be taken into account. This was, however, out of the scope of this study. Further research on this topic is therefore recommended.

1 Introduction

1.1 Background

The Eurovignette Directive (Directive 2011/76/EU) defines certain rules which Member States have to follow when they decide to levy charges (e.g. tolls, vignettes) to Heavy Goods Vehicles (HGVs) above 3.5 tonnes for using their road transport infrastructure (EC, 2011). The Directive contributes to the internalisation of external costs caused by HGVs (air pollution in particular), as it *requires* tolls and vignettes to be differentiated by the EURO emission class of the vehicle and *allows* charges to be differentiated in such a way that they reduce congestion (EC, 2013).

Differentiating charges by CO_2 emissions is currently not allowed by the Eurovignette Directive. However, as the Commission is currently working on general means for measuring and monitoring CO_2 emissions from HGVs and Germany has announced it would like to introduce charges based on the energy efficiency of trucks, it is expected that this will become a topic of discussion soon. Therefore, T&E has asked CE Delft to conduct a scoping study on possible implementation and design issues of broadening the scope of the Eurovignette Directive to (regulating) CO_2 emissions.

1.2 Objectives

The objective of this scoping study is to assess the desirability and feasibility of CO_2-differentiation in HDV road charging schemes, as well as on the options to actually design such a differentiation.

More specifically, this study has the following objectives:
- to discuss whether CO_2-differentiated road charges effectively contribute to CO_2 reduction of HGVs;
- to explore whether such schemes should be harmonised at the EU-level;
- to identify the main issues that may hamper the implementation of such schemes and discuss potential options to address these issues;
- to identify key design issues and discuss options to operationalise them.

In this study we focus on distance-based charging schemes (such as the German Maut). Time-based charging schemes (e.g. vignettes) are not considered, although they are covered by the current Eurovignette Directive.

1.3 Outline of the report

In the remainder of this report we first discuss the main reasons for implementing (harmonised) CO_2-differentiated road charges (Chapter 2). Next, the implementation and design issues are discussed in Chapters 3 and 4, respectively. Finally, in Chapter 5 the main conclusions of this study are presented.

2 Reasons for (harmonised) CO_2-differentiated road charges

2.1 Introduction

As mentioned in Chapter 1, the Eurovignette Directive currently does not require nor allow CO_2-differentiation of road charges levied on HGVs. This chapter outlines whether this may be a desirable instrument for reducing CO_2 emissions of HGVs (Section 2.2). It also discusses why, if this would be allowed in the (near) future, it is preferable that there will be certain EU-wide rules about how this differentiation should be implemented at the Member State level (Section 2.3).

2.2 Effectiveness of CO_2-differentiated HGV road charges

This section first explains the ways in which CO_2-differentiated road charges for HGVs can reduce their CO_2 emissions. Hereafter, a comparison is made between road charges and other policy instruments which can be used to reduce the CO_2 emissions of HGVs.

2.2.1 Impact of CO_2-differentiated road charges on CO_2 emissions

Including a CO_2-based component in existing road charging schemes intends to reduce CO_2 emissions in two main ways; HGV owners may:

- buy (or use) relatively **more fuel-efficient vehicles** compared to the vehicles they would buy (or use) without CO_2-differentiated road charging schemes and/or retrofit existing trucks with fuel-efficient technologies;
- **improve operational/logistical efficiency** (e.g. reduce kilometres driven, increase load factors, etc.).

Each of these intended impacts is described in more detail below.

Impact on fuel-efficiency of HGVs

The first impact of CO_2-differentiated charges relates to improving the fuel efficiency of trucks which are used. In the short-term, hauliers can increase the use of their most efficient vehicles in their existing fleet, especially on the longer distance trips (CTS, 2012; AEA, 2014). However, in the longer term it is likely to mainly result in improvements in the efficiency of the HGV fleet (CTS, 2012; AEA, 2014). It is well-known that there are many technologies available for reducing CO_2 emissions of HGVs and studies estimate there exists a potential of ca. 30% to improve HGV fuel-efficiency in a cost-effective manner (CE Delft, 2012a). Examples include aerodynamic side skirts, low rolling resistance tires, increased transmission gears, and so on (TIAX, 2011).

Hauliers can obtain the benefits of such fuel-saving measures when buying new trucks or they can retrofit existing trucks (CE Delft, 2012b). The latter is usually not the preferred option of hauliers, as it can result in additional costs for the haulier in the short-term (e.g. if existing technologies are not yet fully depreciated and/or because of the required vehicle downtime) (ibid.). Hence, the effect of CO_2-differentiated charges on the purchase of more efficient vehicles may be larger than the effect on retrofits (although there still may be an effect on retrofits as well if the incentive provided by the CO_2-differentiated charges are big enough).

Empirical evidence on the impact of CO_2-differentiated kilometre charges on the fuel-efficiency of HGVs is not available. However, there is some evidence that differentiation of these charges by EURO class is effective. The ex-post evaluation of the current Eurovignette Directive (which is differentiated by EURO class) has shown that differentiated charges have significantly accelerated fleet renewal in Germany, which has implemented the maximum level of variation currently allowed by the Directive in its MAUT scheme (EC, 2013). The accelerated fleet renewal has resulted in a younger and cleaner fleet: the share of EURO V and Environmentally friendly vehicles (EEVs) has increased from 1% to 60% over a five year period. Likewise, the share of the most polluting vehicles (EURO II or less) has decreased from 34% to 2% during the same period. This is significantly faster than the rate of fleet renewal prior to the implementation of the MAUT (EC, 2013). Moreover, cleaner vehicles are used on longer distance trips and therefore, the share of cleaner vehicles in the total distance travelled (70%) is even larger than the share of clean vehicles in the fleet (40%) (AEA, 2014). This increases the impact of the differentiated charges further.

It should be highlighted that it is difficult to isolate such effects from other effects, such as the purchase subsidies that were provided by the German government for the cleaner EURO classes (EC, 2013; CTS, 2012).

However, in general, EURO class differentiated kilometre charges are argued to have an effect on air polluting emissions (AEA, 2014; CTS, 2012) and hence it may be expected that a differentiation by CO_2 emissions may have an effect on the fuel-efficiency.

Improved logistical efficiency
If implementing CO_2-differentiation results in higher overall charge levels, this measure may lead to improved logistical efficiency. Significance and CE Delft (2010) show, for example, that an (overall) price increase of 10% per vehicle or tonne kilometre may result in 3% higher transport efficiency. Such efficiency improvements have also been found in Germany and Austria in the short-term, after the introduction of the road charging schemes (AEA, 2014; Significance & CE Delft, 2010). Long-term impacts are still unclear, though (AEA, 2014).

If the CO_2-differentiation would be applied to already existing schemes, without raising average charge levels, the impact of the CO_2-differentiation on transport efficiency depends on its specific design (see Section 4.2).

Potential rebound effects
The design of the CO_2-differentiated road charges can result in several rebound effects which can reduce the impact on HGVs' CO_2 emissions.

If charge levels vary significantly between Member States for example, hauliers may decide to use detours to avoid countries with higher charge levels. This would obviously negatively impact transport efficiency and result in more kilometres driven. This in turn results in a larger absolute amount of CO_2 emissions. To avoid this rebound effect harmonisation of CO_2-differentiated schemes at the EU-level is desirable (see also Section 2.3).

Other rebound effects may result from the actual design of the CO_2-differentiated charges. These rebound effects are discussed in Section 4.

2.2.2 CO_2-differentiated road charges vs. other policy instruments

There are multiple policy instruments which can potentially contribute to the two intended impacts that were described in the previous section (i.e. improved fuel-efficiency of HGVs and improved logistical efficiency), although very few instruments (mainly fuel taxes and subsidies) are actually implemented yet. Well-known examples of (potential) instruments include vehicle standards, fuel excise duties, differentiated purchase and ownership taxes and purchase subsidies.

CE Delft et al. (2008) argue that both from a fairness perspective (polluters pay principle) and an efficiency perspective, internalising the costs of CO_2 emissions by using **fuel taxes** is the first-best option. In this way the internalisation of the climate change costs is directly linked to its main cost driver, which is fuel consumption. Consequently fuel taxes incentivise all CO_2 reduction options, such as reducing transport demand, applying a fuel-efficient driving style, buying fuel-efficient vehicles, etc. However, diesel taxes are currently often relatively low compared to gasoline and in several EU countries hauliers can receive a rebate on the amount paid for fuel taxes (and VAT). Increasing diesel taxes if often regarded difficult due to adverse impacts on the competitiveness of the domestic hauliers, tank tourism in border regions and lack of public and political support. Furthermore, at European level energy taxation is subject to unanimity which makes it difficult to increase the minimum levels for fuel taxes at an European level. Therefore, alternative ('second-best') policy options to reduce the CO_2 emissions of HGVs must be considered. These instruments can be used instead of fuel taxes, but often also together with them. Below various other instruments are discussed.

Vehicle standards (i.e. CO_2 regulation of the vehicle) have been known to be very effective in reducing the CO_2 emissions of passenger cars and for HGVs in the US, Japan and China. For HGVs, however, they have not yet been implemented in the EU. Currently, the Commission is developing a reliable CO_2 measurement and monitoring scheme for HGVs, which may provide the possibility to implement vehicle standards in the future. However, vehicle standards and CO_2-differentiated road charges may be (partly[1]) complementary, as they target different actors (i.e. manufacturers and shippers/hauliers, respectively). As an example, CO_2-differentiated road charges may stimulate the demand for more fuel-efficient vehicles, which supports manufacturers in meeting their target.

CO_2-differentiated purchase and/or ownership taxes may be another policy option. CO_2-differentiated purchase taxes may provide a particularly effective incentive for HGV owners to buy relatively more-fuel efficient vehicles (as they are for passenger cars, e.g. see CBS, 2015). However, HGV purchase taxes are currently not levied in any of the EU Member States. Ownership taxes, on the other hand, are levied for HGVs in all Member States (as required by the Eurovignette Directive), but not differentiated to CO_2.

Subsidies to buy fuel-efficient trucks or retrofit existing trucks are provided by some countries, but the scope and budget of these subsidies varies significantly between EU Member States. Moreover, subsidies are generally an expensive instrument and are therefore not a sustainable means for reducing CO_2 emissions due to the large impact on governmental budgets (CE Delft,

[1] These policy instruments also partly overlap, e.g. vehicle manufacturers are indirectly affected by CO_2-differentiated road charges as well, due to an increasing demand for fuel-efficient trucks.

2010). Moreover, other instruments, such as differentiated vehicle taxes, road charges and fuel taxes, are more efficient (ibid.).

Given the arguments discussed above, introducing CO_2-differentiation in road charges can be useful. Furthermore, this policy instrument has the advantage of fuel taxes in terms of targeting the whole HGVs fleet – at least in those countries that have road charging - while most other measures only impact the purchase of new vehicles.

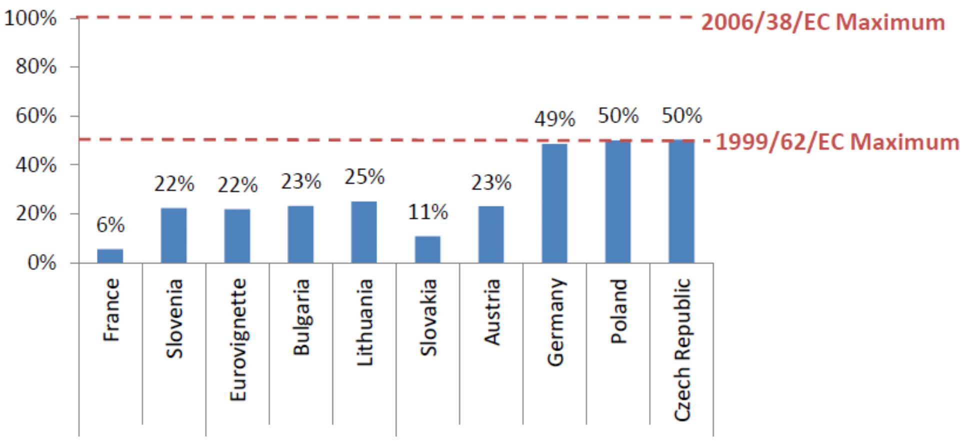
The effect can be enlarged however, by combining these CO_2-differentiated charges with other policy instruments, such as differentiated vehicle taxes, financial support for the acquisition of vehicles and vehicle standards (EC, 2013).

2.3 Reasons for EU action on CO_2-differentiated road charges

In case road charges are allowed to be differentiated by CO_2, several reasons can be thought of for harmonising these charges at the EU-level to some extent.

Firstly, freight transport is an international market and therefore, (some) harmonisation of CO_2-differentiated road charging schemes of HDVs results in a better functioning market. Firstly, this will increase the **effectiveness of these schemes**, as the incentive given to HGV owners will be stronger if the same type and level of incentive is given in all countries of operation compared to a situation where only some countries apply the CO_2-differentiated charges or where the level of CO_2-differentiation varies between countries. This is already the case with the rules laid down in the current Eurovignette Directive. The ex-post impact assessment of this Directive (EC, 2013) concludes that large differences currently exist between national road charging schemes, as is also shown in Figure 1. Consequently, “users do not receive, across the EU, consistent price signals capable of steering them towards a more sustainable use of the infrastructure” they conclude.

Figure 1 Maximum charge differentiation according to EURO class



Source: AEA, 2014.

Furthermore, harmonising CO_2-based charges may **reduce the administrative burden and costs** of both international hauliers and public authorities (EC, 2013). Currently, international hauliers need 11 on-board units/tolling contracts/devices and 5 vignettes to be able to drive on all European roads, all with their own design and tariffs (ibid). As mentioned in the previous section, this may also result in detours around those Member States with relatively higher charges (ibid.), which can actually increase CO_2 emissions (more kilometres), is inefficient from a logistical point of view and may distort competition between international hauliers (EC, 2011).

Thirdly, without rules about CO_2-differentiated targets, Member States may design the road charging scheme in such a way it provides larger benefits to HGVs manufactured by domestic OEMs (Original Equipment Manufacturers) compared to those from non-domestic OEMs. Situations like this are argued to exist for CO_2-based car labelling schemes. In Germany for example, car labelling takes into account the relative weight of the car when determining a CO_2 label. This has led to criticism from both (German) environmental groups (e.g. Verkehrsclub Deutschland, T&E) and from non-domestic OEMs to be 'Greenwashing', as heavy cars with relatively high CO_2 emissions can receive the same label as small and light cars with relatively low CO_2 emissions (Reed, 2011). The major car OEMs from Germany have most vehicles falling in the former category (e.g. BMW, Audi, Mercedes-Benz), while non-domestic OEMs (e.g. Renault and Fiat) have many cars falling in the latter one. Hence, the car labelling scheme was argued to **favour domestically produced vehicles** and hence, distort the fair level playing field (ibid.). Similar issues may result if Member States do not have to follow rules on the design of CO_2-based road charging schemes for HGVs.

3 Implementation issues

3.1 Introduction

In this chapter we discuss implementation issues that need to be addressed when differentiating road charges by CO_2 emissions as well as options to overcome these issues. We focus on technical, operational, and social feasibility. Legal feasibility is outside the scope of this paper.

There are several issues with the implementation of CO_2-differentiated HGV road charges, which should be taken into account when discussing this policy instrument and its design. The most important issues are:
– availability of certified CO_2 information;
– robustness of CO_2-differentiated charges in real world conditions;
– certified CO_2 information differentiated to mission profile.

These issues are described in more detail below.

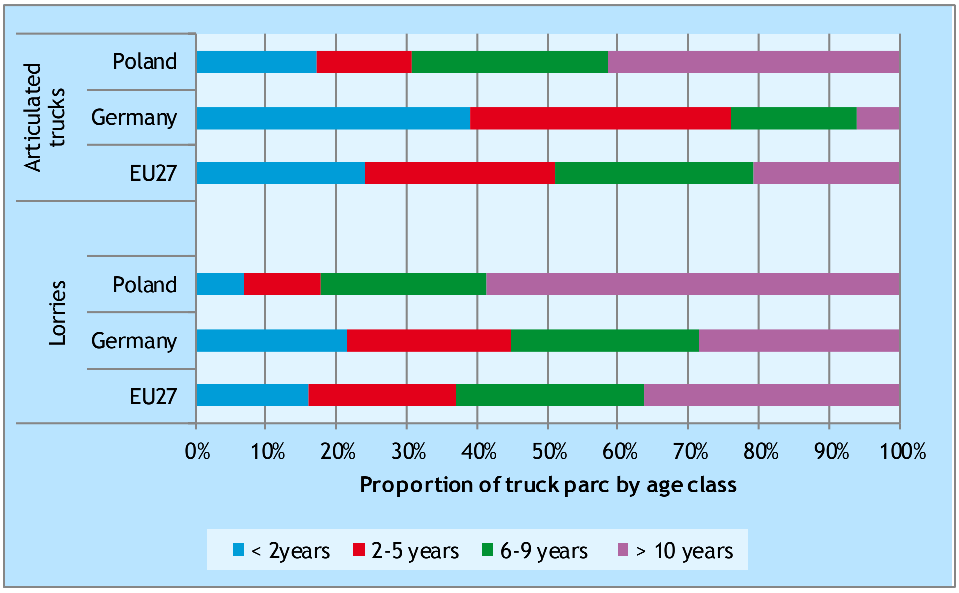
3.2 Availability of certified CO_2 information

An important requirement for CO_2-differentiated road charging is the availability of certified CO_2 information about the performance of the vehicle in terms of the metric chosen (e.g. g/vkm, g/tkm, etc.). The European Commission is currently working on this issue with the development of a simulation tool (VECTO). In the future OEMs will have to test new vehicles with this tool and report their CO_2 emissions. This in turn, could provide input for CO_2-differentiated road charging schemes. It is still unsure when the requirement to certify and report CO_2 emissions from new HDVs will be implemented, although the European Commission has announced 2018 would be the first monitoring and reporting year.

Certified CO_2 information will not be (immediately) available for all vehicles though:
– It is likely that the introduction of CO_2 emission figures for new vehicles will be phased, e.g. first focussing on vehicle categories responsible for the main part of the CO_2 emissions.
– The performance of the trailers is measured with reference trailers. Therefore, performance of actually used trailers will not be covered in the simulation in the short-term. There are several fuel-saving technologies which can potentially reduce CO_2 emissions from trailers significantly though (e.g. side skirts and boat tails (TIAX, 2011). Within the EU, over a quarter of all vehicles are truck-trailer combinations (AEA & Ricardo, 2011), and therefore, a large share in the reduction potential is not stimulated with such simulations.
– For existing vehicles no certified CO_2 information will be available as well. This problem is only temporary though, as fleet renewal will result in an increasing share of vehicles for which information is available. The average lifetime of a truck varies significantly between vehicles, but is 11 years on average (EC, 2014). As is illustrated in Figure 2, the majority of the trucks in Germany are younger than 10 years, while in Poland trucks older than ten years are still a large share of the fleet. Considering the HGV kilometres, more than 85% of the kilometres are driven by trucks younger than 10 years (see Figure 3); in Germany, this is even 95%. Hence, within

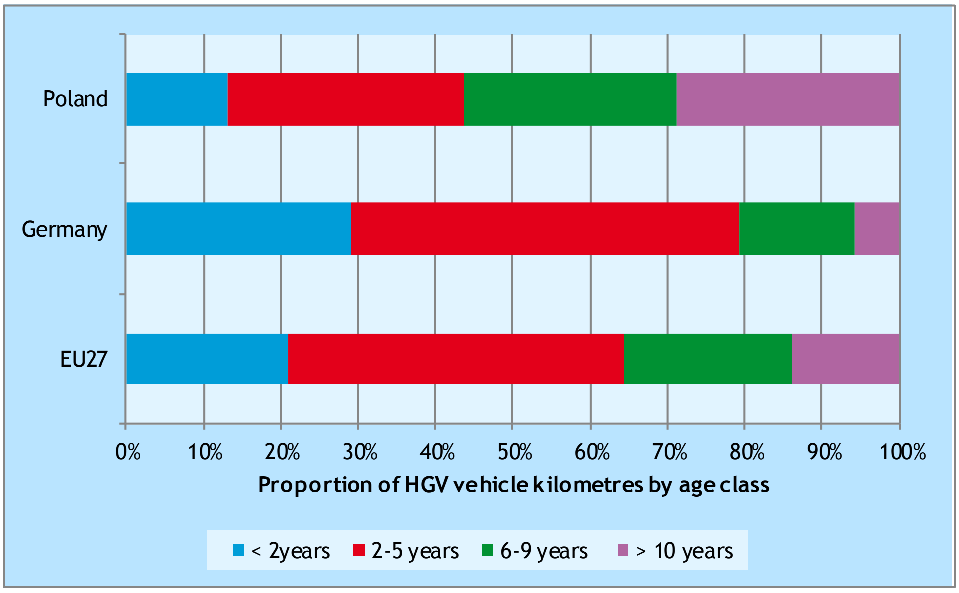
10 years, certified CO_2 information would be available for almost all vehicles in the HGV fleet (using tolled roads) in Western European countries like Germany, while in Eastern European countries it may take some more years. This may also take shorter, if new vehicles get a benefit in the form of lower road charges.

Figure 2 **HGV fleet, by age category, for the EU27, Germany and Poland in 2008**



Source: AEA & Ricardo (2011), adjusted by CE Delft.

Figure 3 **HGV vehicle kilometres by age category, for the EU27, Germany and Poland in 2008**



Source: AEA & Ricardo (2011), adjusted by CE Delft.

In order to deal with the lack of certified CO_2 information for these vehicles, the road charging scheme could continue with current charges for vehicles for which this information is not available and with CO_2-differentiated charges for new vehicles for which this information is available, or could provide a CO_2 based bonus/malus on current charges for new vehicles for which the required CO_2 information is available. However, in this case, it should be evaluated

whether all new vehicles which can be used for the same duty cycle have certified CO_2 information available in order to avoid market distortions.
A possible disadvantage of these approaches is that fuel-inefficient older vehicles may be favoured to some of the newer vehicles receiving a malus but which are still more fuel-efficient than the older vehicles which are charged the average fee. With a bonus-malus scheme this disadvantage can be reduced by setting the pivot point[2] relatively high, such that older vehicles are levied a relatively higher charge level. Closely related to this is the option which charges all vehicles for which no certified CO_2 information is available with the highest charge level. This approach is currently used in the Eurovignette Directive with respect to the EURO class differentiation. However, the link between vehicle age and CO_2 emission is less strong than between vehicle age and EURO class, and hence such an approach may result in rather high charge levels for older vehicles that are relatively fuel-efficient, which may be perceived unfair. Finally, the schemes could also start very simple, e.g. just a discount for hybrid vehicles, and become more complex when CO_2 information has become available for more vehicles.

However, all of these solutions would not result in any incentives for existing trucks (for which no CO_2 emission value is available), as it is unlikely that OEMs are willing to provide CO_2 information on existing trucks and as retrofit technologies on existing vehicles/trailers are not rewarded in this case.
The latter issue could (partially) be solved by providing credits or discounts to hauliers which have purchased add-on technologies for their existing vehicles. To implement this, the CO_2 reduction realised by a specific add-on technology should be certified and credits or discounts should only be awarded if certified technologies are used. In California, a similar approach is used to regulate the use of fuel-saving technologies for existing vehicles and trailers. For certain truck types it is regulated that all existing vehicles and trailers should be retrofitted with SmartWay[3] verified technologies. Preferably this certification procedure for add-on technologies should be aligned with VECTO calculations, in order to avoid that market distortions are caused by rewarding credits/discounts to add-on technologies for which default values are used in VECTO (in that case vehicles for which no certified CO_2 information is available from VECTO are given an preferential treatment compared to vehicles for which this data is available).

A similar approach could be used for (new) trailers, allowing credits or discounts for using certified add-on technologies. In the longer-term, the approach may also be used to take the entire trailer into account, assuming that CO_2 emission figures for trailers become available. However, this may result in robustness issues (see next section), as hauliers may use different trailers for different trips (CE Delft, 2013).

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[2] The pivot point divides vehicles charged fees from those receiving rebates.

[3] The SmartWay certification process is part of a broader US wide voluntary program called the SmartWay Transport Partnership Program (Smartway program) (California Environmental Protection Agency, 2011). This program is a public-private initiative aimed to help shippers and hauliers in improving efficiency by measuring, benchmarking and streamlining freight supply chain operations.

3.3 Robustness of CO_2-differentiated charges in real world conditions

There are several robustness issues, which mainly result from the method used to determine a certified CO_2 figure.

First, the certified CO_2 figure is based on modelling exercises and hence will deviate from real-world CO_2 figures. As we know from passenger cars, the difference between test and real-world emissions may turn out to be significant. However, notice that test and real-world emissions are probably highly correlated, such that by differentiating road charges by modelled CO_2 figures will still result that the most fuel-efficient vehicles are incentivised most. This is emphasised by the validation of the VECTO tool, which showed a high correlation between modelled and real-world CO_2 emissions.

Second, as was mentioned above, trucks are measured with reference trailers, while it is very common for transport companies to switch between trailers in practice. These trailers, may not be necessarily comparable to the reference trailer. In this case, the same vehicle can result in two different real-world emissions figures while having received the same road charge. The same reasoning is also valid for possible credits or discounts applied to add-on technologies for trailers (or in the longer-term for the whole trailer), as their effectiveness often relies on the type of truck used.

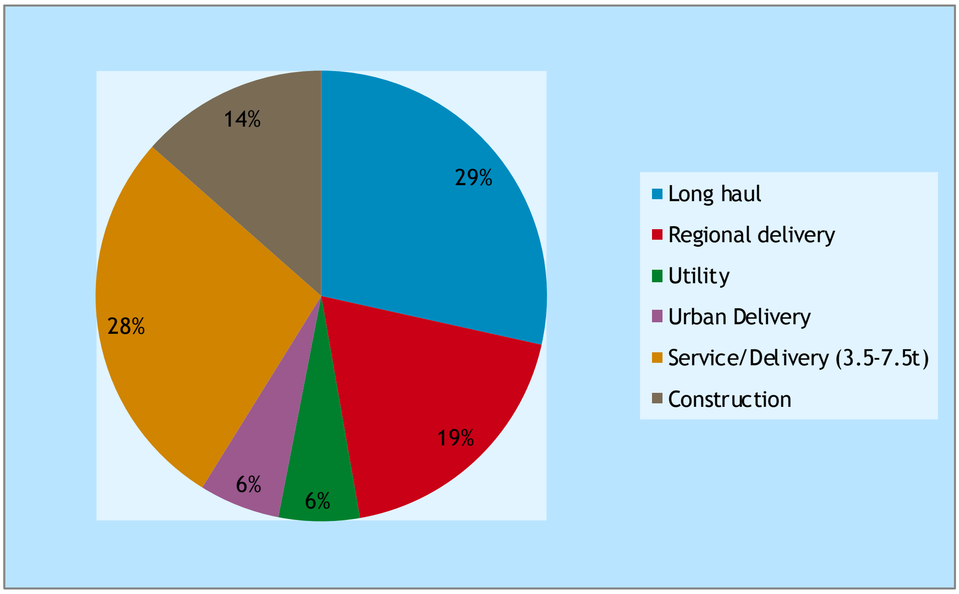
Third, VECTO partially uses default input parameters, which may not measure all fuel-saving technologies accurately. If vehicle-specific parameters or credits for certain technologies are used in the modelling, this problem is reduced, but it would still not be possible to ensure this emission reduction in practice for a longer period of time; tires have a short lifetime and some aerodynamic features can be eliminated from the truck or may not be replaced if damaged if a transport company desires this (CE Delft, 2013).
It may be possible to monitor such technologies during the annual maintenance call and to add them to the vehicle's registration document for example[4]. With respect to trailers, it should also be monitored to what extent they are used. This requires that trailers are equipped with an electronic device, to monitor their kilometres.

3.4 Certified CO_2 information differentiated to mission profile

Figure 4 shows that the EU HGV fleet is highly diverse in terms of types of trucks and trailers (and the truck-trailer combinations) which are bought and used.

[4] This is comparable with the approach applied in the Smartway program in California. In this program haulers are obliged to submit a plan for their fleet, including an overview of all affected vehicles/trailers using a annual conformance number. Authorised representatives of the California Environmental Protection Agency will monitor and enforce these plans by randomly inspecting the vehicles.

Figure 4 Mission profiles of the EU truck fleet in 2010



Note: The shares are based on vehicle numbers, not on tonne or vehicle kilometres. In these latter cases, the shares of those mission profiles that have lower annual driving cycles (e.g. urban, regional) would become even smaller, while the share of long-haul would increase significantly.

Source: AEA & Ricardo, 2011.

Some vehicles are sold for multiple mission profiles. As a consequence, these vehicle may receive more than one CO_2 figure from the CO_2 certification process. In these cases, the implementation of CO_2-differentiated road charges would require rules about which figure to use. The most straightforward solution is to use the CO_2 figure required by the future European monitoring and reporting legislation. However, it is still unclear how this legislation will deal with this subject and whether they will require one CO_2 figure for every vehicle. Alternative options would be to choose for the mission profile which uses highways and important secondary roads relatively most (e.g. regional delivery in case a truck received a CO_2 figure for both a regional and an urban mission profile) as road charging is mostly focussed on these roads, or by always choosing the highest CO_2 figure. However, such solutions may result in market distortion, as a truck with two mission profiles can have an (dis)advantage compared to trucks with only one mission profile, while CO_2 performance of both vehicles in the real world may be the same.
This disadvantage may be addressed by distinguishing different vehicle categories (based on mission profiles) in the charging scheme, as it will make clear which CO_2 figure should be used in the various categories (i.e. CO_2 figure for the mission profile being considered in the respective category). However, this solution may provide manufacturers some opportunities for gaming. This is further discussed in Section 4.2.

4 Design issues

4.1 Introduction

Including a CO_2-based component in existing road charging schemes can be done in myriad ways. This chapter outlines the following key design choices to be made:
- differentiation between vehicle categories;
- metric for the road charges;
- continuous or step-based differentiation of performance;
- amount of revenues.

The actual design of CO_2-differentiation of HGV road charging also depends on the design of the charging scheme itself. For example, most HGV road charging schemes currently implemented in EU Member States are already differentiated to vehicle characteristics (e.g. maximum load, number of axles) and hence any further differentiation in the CO_2-differentiation should preferably align with this differentiation in the main scheme. As the analyses carried out in this paper are not focussed on a specific national HGV charging scheme, we do not take these kinds of interactions into account. However, it may be very useful to consider them in future studies.

4.2 Key design issues CO_2-differentiated road charges

Differentiation between vehicle categories

A first design choice is to set one CO_2-differentiated road charge for all vehicles, or to adopt multiple sets for different duty cycles. As was already explained in the previous chapter, the EU HGV fleet is highly diverse and as a consequence it is difficult to compare the CO_2 performance of a long-haul vehicle with an urban or service vehicle. Therefore, it seems more fair and effective to distinguish at least some vehicle categories in the road charging schemes for which different charge functions are defined. Vehicle categories could be determined by mission profile or an alternative parameter, such as the number of axles or vehicle weight. The number of axles is already used in the German MAUT for example.

An advantage of defining different charge functions for some vehicle categories is that differences in charge levels between comparable vehicles can be enlarged, increasing the effectiveness of the instrument. As the differences in CO_2 emissions within a vehicle category are smaller compared to differences within the total fleet, steeper charge functions – that are still socially acceptable - can be applied. However, different charge levels for different mission profiles may result in some opportunities for gaming by manufacturers (CE Delft, 2013). For example, if charges are relatively lower for regional delivery trucks than for long-haul trucks, there may be an incentive to sell/buy regional delivery trucks to long-haul hauliers. This in turn would reduce the emission reductions obtained in the real-world.
The opportunity for gaming will increase if the level of differentiation (i.e. more vehicle categories distinguished) increases. Further research on possible options to minimise these gaming options is needed. Another disadvantage of defining different charge functions for some vehicle categories is that the system becomes more complex and hence difficult to understand

for hauliers. The increased complexity also result in higher operational costs of the scheme.

It seems logical to align the road charging schemes with the 6 mission profiles which VECTO distinguishes for freight transport (see Figure 4), as this minimises the risk that vehicles that are used for the same purposes are treated differently. On the other hand, it may result in relatively more gaming compared to vehicle categories defined with axles for examples.

Metric for the road charges

The metric for measuring CO_2 performance can be g/vkm or g/tkm. Alternatively, fuel consumption can be used as an indirect measure for CO_2 performance, using a metric such as l/100 km,l/tkm, km/l, or tkm/l. However, as these metrics do not provide any benefit compared to the CO_2-based metrics, we will not discuss them in more detail here.

A g/tkm metric has been implemented in the vehicle standard for HDVs in the US, Canada and Japan (CE Delft, 2013). However, using g/tkm as a metric is beneficial to larger trucks, resulting in lower charges for large trucks than for small ones. This will be confusing and contradicting with the philosophy of the policy measure (e.g. charging fuel-inefficient vehicles at a higher level than fuel-efficient ones) and hence may not provide very useful and clear information for hauliers in buying a new truck. Furthermore, it results in an incentive for hauliers to buy larger trucks than would otherwise have been the case. To what extent this effect will take place depends on the additional fuel and investment costs of a larger truck compared to the relative 'discount' on the charge level.

A g/vkm metric aligns better with the design of existing road charging schemes, as these schemes apply charges defined in €/vkm. Moreover, the risk on unintended consequences is smaller; a g/vkm metric is beneficial to smaller trucks, which may result in a shift to smaller trucks or to the replacement of one large truck by two smaller ones. However, the risk of the latter is very small, as it would double purchase costs and drivers salaries, which is roughly half of the TCO of a truck (ING, 2011). Furthermore, a g/vkm metric probably aligns better with the vehicle purchasing process of hauliers. A disadvantage of g/vkm is that it not aligns with the views of the market, as it does not take the commercial function of the vehicle into account.

Continuous or step-based differentiation of performance

The differentiation of the CO_2-differentiated charge can be continuous, stepwise or a combination hereof. With a continuous differentiation, the charge is directly related to the performance of the vehicle (e.g. in € per gCO_2/km). Such a charge function implies that two vehicles with a different CO_2 performance will never be charged the same amount, not even if their fuel consumption only differs slightly (ICCT, 2010). Consequently, a continuous incentive is given to hauliers to buy more fuel-efficient vehicles, as reducing the CO_2 emissions of the fleet will always result in a lower fee (ICCT, 2010). Furthermore, a continuous charge function is easy to understand for users.

Continuous functions can be linear, but also other forms (e.g. exponential forms) can be used. The main advantage of linear functions is that they are more easy to understand for users than exponential functions. However, a potential disadvantage is that linear functions may provide relatively small differences in charges, mainly because the differences in CO_2 emissions between similar truck models is relatively small. In case of exponential (or other form) functions, this disadvantage can be addressed, as these function provide the opportunity to create larger differences in charge levels, mainly affecting the most fuel-inefficient vehicles. Another option to address this issue is by differentiating between vehicle categories, as this narrows down the CO_2 emission range the charge function should cover (per vehicle category), providing the opportunity to apply a steeper function.

Step-based charge functions charge a range of vehicle CO_2 performances the same amount. Such functions may provide significant differences in charge levels between relatively similar vehicles, providing a large incentive to choose for a more fuel-efficient vehicle. Furthermore, a step-based approach may be perceived as providing a more clear and simple signal to the market. A disadvantage of this design is that the incentive for continuous improvement will be lower. Hauliers will mainly have an incentive to buy a more fuel-efficient vehicle if this reduces their charged amount (ICCT, 2010). Consequently, OEMs may only adopt minimal measures to ensure their vehicle falls into a better category, and not improve the vehicle's performance further hereafter. This may also distort competition, as vehicles with CO_2 emissions just above the threshold are charged a higher fee than comparable vehicles that have slightly lower CO_2 emissions just falling below the threshold. This has been a topic of discussion in the step-based company car taxation in the Netherlands for example.

Amount of revenues

CO_2-differentiation of road charging schemes can be designed to be budget increasing (larger revenues than current schemes) or budget neutral (equal revenues as current schemes). The main advantage of the first option is that it maximises the environmental effectiveness of the scheme (e.g. due to an increased incentive to optimise transport efficiency). However, in contrast to a budget neutral design, this option may also result in severe resistance from hauliers and shippers. Finally, a budget increasing design is not in line with the way the differentiation to EURO class is regulated in the current Eurovignette Directive; it is explicitly mentioned that this differentiation is 'not designed to generate additional toll revenue'.

5 Conclusions

5.1 Introduction

In this final chapter we present the main conclusions of this scoping study. We will do this for the three topics discussed in the previous chapters, in Sections 5.2, 5.3, and 5.4, respectively.

5.2 Reasons for (harmonised) CO_2-differentiated road charges

CO_2-differentiated road charges could be a good policy instrument to reduce CO_2 emissions of HGVs, particularly as there is little public support for other potential instruments (such as increasing fuel taxes or implementing differentiated purchase taxes). Experiences with EURO class differentiation of road charges show that such differentiated schemes can be effective.

In case road charges are allowed to be differentiated by CO_2, there may be several reasons for harmonising these charges (to some extent) at the EU-level:
- it increases the effectiveness of the scheme if HGV owners receive the same type and level of incentive in all EU countries;
- it ensures the internal market is maintained and reduces the administrative burden and costs of both international hauliers and public authorities;
- it lowers the risk that national road charging schemes are designed to benefit domestic OEMs.

5.3 Implementation issues

The main implementation issues and options to address them are shown in Table 1. Although implementation of CO_2-differentiated road charges seems feasible, some issues have to be addressed to guarantee a fair and effective system.

A prerequisite to implement CO_2-differentiated road charges is the availability of certified CO_2 information for the vehicles covered by the schemes. Although the European Commission is currently preparing legislation requiring the certification and reporting of CO_2 information based on simulations with the VECTO tool, it is not clear when this information will become available. Moreover, this information will only be available for part of the European HGV fleet, as existing vehicles and trailers are probably not (immediately) covered by this regulation. Some options to deal with this issue is to apply a bonus-malus scheme to those vehicles for which CO_2 information is available, while for other vehicles the average/current charge is applied, or to charge all vehicles for which no CO_2 figure is available the highest fee.

Such a scheme would still only partly cover the CO_2 emissions of the EU HGV fleet. This can (partially) be solved by providing credits or discounts to hauliers which have purchased add-on fuel-saving technologies for their existing vehicles and/or trailers. However, this will further complicate the scheme, as the CO_2 reduction realised by these technologies should be verified and monitored. For example, it should be monitored whether add-on technologies are replaced at the end of their lifetime or damaged; this may be realised by adding these technologies to the vehicle's registration document and by checking their status during the annual maintenance call.

Finally, it is expected that for some vehicles, which can be used for different mission profiles, more than one CO_2 figure (i.e. one figure for each mission profile) will be estimated by VECTO. Currently, it is not clear how this will be addressed in the EU monitoring and reporting requirements. Some options are shown in Table 1. They may result in market distortions for new vehicles, as vehicles receiving more than one CO_2 figure can have an (dis)advantage compared to trucks with only one CO_2 figure, while CO_2 performance of both vehicles may be the same in practice.

Table 1 Main implementation issues

Implementation issues	Possible solution(s)
Certified CO_2 information is not (immediately) available for all vehicles	– CO_2-differentiated charges for vehicles for which CO_2 information is available and current charges for other vehicles – Bonus-malus on current/average charges for vehicles for which CO_2 information is available – Highest charge levels for all vehicles for which no CO_2 information is available – Simple scheme, e.g. just a discount for hybrid vehicles
Add-on fuel saving technologies on existing vehicles and trailers are not covered by certified CO_2 information	– Discounts or credits could be awarded to vehicles applying add-on fuel saving technologies for which certified CO_2 information is available
Add-on technologies are replaced if depreciated or broken	– Monitor the presence of these technologies during annual maintenance call and/or add them to vehicle's registration document – For trailers the actual use of the trailer (and hence of the add-on technology) could be monitored by a specific electronic device (next to the device for the truck)
Vehicles receive more than one CO_2 figure (for different mission profiles)	– Using CO_2 figure for mission profile that assumes highest number of highway kilometres – Always using highest CO_2 figure

5.4 Design issues

The main design issues and options to operationalise them are shown in Table 2. For most of the issues it is not possible to identify one best option to operationalise it, as all options have their own advantages and disadvantages. Further research is needed to weight these pros and cons in order to rank the various options.

Table 2 Overview of design issues

Design issue	Main options	Main results of comparison of options
Differentiation between vehicle categories	One CO_2-differentiated road charge for all vehicles vs. multiple sets for different duty cycles	– Different sets of charge levels for some vehicle categories provide the opportunity to increase the difference in charge levels between comparable vehicles, increasing the scheme's effectiveness – One CO_2-differentiated road charge reduces the risk on gaming by manufacturers – Different sets of charge levels for different vehicle categories is more complex for hauliers and may also increase the implementation costs of the scheme
Metric of differentiating charge level	g/tkm vs. g/vkm	– g/vkm aligns better with design road charging schemes. – g/vkm aligns better with the vehicle purchasing process of hauliers – With a differentiation based on g/tkm: would result in perverse incentives as larger trucks within one vehicle class would have lower rates than smaller ones. This will be confusing to hauliers as well.
Charge function	Continuous (linear) vs. step-based function	– Continuous function provides a continuous incentive to improve fuel efficiency, while step-based function only provides an incentive to improves fuel-efficiency to reach a better category – Continuous function may be easier to understand to users – Step-based function may provide the opportunity to apply larger differences in charge levels between comparable vehicles, although this may also be realized by applying a continuous exponential function – Step-based function may result in market distortions
Amount of revenues	Budget increasing vs. budget neutral	– Budget neutrality is less effective in terms of CO_2 reduction – Higher social acceptability for budget neutral option – Budget increasing option is not in line with approach applied in current Eurovignette Directive – Not clear whether budget increasing or budget neutral option is preferred in terms of cost effectiveness

5.5 Recommendations for further research

Based on the scoping study carried out, the following issues for further research are identified:

- *Further assessment of the most promising design options*, also considering the interaction between the various design issues. Both the assessment of the various design issues and their impacts (e.g. environmental impacts, costs, social acceptability) can be further elaborated. Preferably, a quantitative indication of the size of the impacts should be provided.
- *Interaction with design elements of the current HGV road charging scheme can be assessed*. For example, it would be interesting to assess to what extent the various design issues align with the current differentiations

(e.g. to Euro classes, number of axles, maximum loads) applied in HGV road charging schemes.

- *Elaboration of the design of CO_2-differentiation for one or several existing HGV road charging schemes (e.g. Germany)*. Such an analysis provides the opportunity to assess the practical feasibility of CO_2-differentiation in detail.
- *A more detailed comparative analysis of CO_2-based and technology based differentiation schemes;* instead of a CO_2-based scheme, a scheme providing benefits to certain technologies (e.g. hybrid trucks) can be implemented. It should be assessed to what extent the benefits of this approach (e.g. less complex, less risks on perverse incentives) are bigger/smaller than its disadvantages (e.g. limited scope of the scheme, may be perceived unfair).
- *Further assessment of mitigation options for gaming by manufacturers and/or hauliers;* as indicated in the previous sections, some of the design issues (e.g. differentiation of charge functions between vehicle categories) provide opportunities for gaming by manufactures and/or hauliers. Possible mitigation options for such gaming risks should be identified and assessed.
- *Modifications of the current Eurovignette Directive;* it would be useful to further study which modifications of the current Eurovignette Directive are desired to implement CO_2-differentiation of HGV road charging schemes in an effective way.

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