Emission Trading System for Road Transport

An exploratory study on possible impacts and policy interactions

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This report was prepared by:
Arno Schroten, Anco Hoen, Julius Király, Peter Scholten

A collegial review on the final draft was carried out by Jos Sijm from TNO Energy Transition Studies

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Further information on this study can be obtained from the contact person Arno Schroten (CE Delft)

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Content

Summary

The European Green Deal announced that the Emission Trading System (ETS) could be extended to emissions from road transport and the built environment. In a legislative proposal to be presented in July 2021, the European Commission is expected to present plans for an adjacent system to the current EU ETS for road transport and the built environment. In this light, the Dutch Ministry of Infrastructure & Water Management requested CE Delft to assess the implications of the introduction of a separate European ETS for road transport (ETS-RT), focusing on three topics:
1. The interaction of an ETS-RT with existing policies.
2. The level of allowance prices that might arise in an ETS-RT.
3. The impacts that may be expected for the Netherlands.

What is an ETS-RT and how does it work?
In this study, an ETS-RT is considered a cap-and-trade emission trading scheme for road transport, which sets a cap on CO_2 emissions of road transport in the EU. Participants in the scheme need allowances for emitting CO_2. These allowances are allocated to participants for free or auctioned. The level of the cap determines the number of allowances available in the system. At the end of each year participants must submit allowances for the amount of CO_2 emitted during that year. If a participant has an insufficient number of allowances, it must either implement CO_2 reduction measures or buy allowances on the market (from other participants or at an auction).

The restricted supply of allowances creates scarcity and puts a price on CO_2. This incentivises participants to look for CO_2 reduction measures that are cheaper than the allowances. The opportunity to trade allowances ensures emission reduction at lowest costs. In other words, an ETS-RT results (in theory) in a cost effective reduction of CO_2 emissions in the road transport sector. Furthermore, an ETS-RT provides certainty that emissions are reduced thanks to the fixed cap.

Interaction of an ETS-RT with existing policies

An ETS-RT incentivises all CO_2 reduction options available for road transport and will therefore also complement the existing EU policy mix. It will speed up the uptake of fuel-efficient and zero emission vehicles, low-carbon fuels and all types of non-technical reduction options. As such, an ETS-RT can contribute to meeting national reduction targets, although this depends on the level of the cap since it aims for an average European reduction target. Furthermore, it will strengthen the EU's control over the total CO_2 emissions in this sector, providing more certainty that overall European CO_2 reduction targets set for road transport will be met.

European and national policies will also complement an ETS-RT by targeting market failures which an ETS-RT will not address. Some examples are:
- *CO_2 vehicle standards* and *national CO_2 differentiated vehicle taxes* address the existence of consumer myopia, i.e. the fact that consumers are not taking the life-time fuel cost (including the ETS costs) savings of low or zero emission vehicles into account, but only the savings for a small number of years.
- The *Renewable Energy Directive* (RED) sets conditions for the sustainability of renewable fuels, as the market will not ensure that sustainable fuels will be used.

- The *Alternative Fuel Infrastructure Directive* complements an ETS-RT by stimulating the deployment of an harmonised network of recharging/refuelling infrastructure throughout Europe.
- The *Car labelling Directive* addresses the imperfect knowledge of consumers about CO_2 emissions of the wide range of vehicles offered on the market by making the availability of energy labels mandatory.

Interaction with existing policies also warrants a level of caution. An ETS-RT may reduce the support for maintaining and/or tightening the targets set for other EU and national policies. Given that an ETS-RT should be considered as complementary to these measures and not as a substitute, lowering the ambition levels for these other policies would harm the effectiveness of the entire policy mix (including an ETS-RT).

Estimated allowance prices in an ETS-RT

In this study we have estimated the allowance prices in an ETS-RT in 2030 for three different emission reduction scenarios for the European road transport sector (see Table 1). Compared to the current allowance price in the EU ETS (about € 50 per tonne CO_2 in June 2021), much higher allowance prices are expected in an ETS-RT, particularly in the most ambitious scenarios. These high prices reflect that the uptake of relatively expensive reduction measures is required to meet ambitious CO_2 reduction targets in the road transport sector.

It should be mentioned that the uncertainty in the estimated allowance prices is high, as is shown by the bandwidths presented in Table 1. Despite the uncertainties, we think the results of our analyses provide a good indication of the order of magnitude of the allowance price that may be expected.

Table 1 - Overview estimated allowance prices in 2030 for three CO_2 reduction scenarios in the European road transport sector

	Scenario 1	Scenario 2	Scenario 3
CO_2 reduction compared to 1990	11% CO_2 reduction	30% CO_2 reduction	55% CO_2 reduction
Allowance price (€/tonne CO_2)	€ 75 (€ 65-€ 90)	€ 220 (€ 180-€ 270)	€ 690 (€ 390-€ 1,025)

The allowance prices in an ETS-RT will become lower if the targets of other policies, like CO_2 vehicle standards or the RED fuel standards, are tightened, since it reduces the demand for allowances in the market. Our analyses show, however, that the ambition levels of CO_2 vehicle standards and the Renewable Energy Directive RED) need to be very high, or need to be tightened well before 2030 to have a significant downward impact on allowance prices in 2030 in a well-functioning ETS-RT with an ambitious reduction target (-30 or -55%). This is because with ambitious targets an ETS-RT in itself will already result in high levels of low and zero emission vehicles and low carbon fuels. But even if vehicle and fuel standards will not immediately lead to additional reduction measures taken by transport users compared to an ETS-RT in itself, combining them with an ETS-RT may still be worthwhile as they complement an ETS-RT in other ways as well. For example, stricter RED fuel standards will stimulate the use of biofuels in the years before an ETS-RT becomes fully effective, increasing the short term effectiveness of climate policy in the road transport sector.

Impacts of an ETS-RT for the Netherlands

High allowance prices in an ETS-RT result in significant increases in fuel prices, as is shown in Table 2. In the most ambitious reduction scenario (55% CO_2 reduction) fuel prices will (almost) double, leading to a petrol price of almost € 3 per litre and a diesel price of about € 2.4 per litre (2019 price level).

Table 2 - Relative increase in fuel prices and transport costs due to an ETS-RT in The Netherlands in 2030 (compared to 2019 price/cost levels)

Financial impacts		Scenario 1: 11% CO_2 reduction	Scenario 2: 30% CO_2 reduction	Scenario 3: 55% CO_2 reduction
Fuel prices (incl. taxes)	Petrol	12%	32%	92%
	Diesel	15%	40%	112%
Transport costs	Private transport users	3%	9%	27%
	Freight transport sector[a]	1-4%	3-10%	8-28%

[a] The impact of an ETS-RT differs per type of truck. This is reflected by the ranges shown in this row.

The higher fuel prices also lead to higher transport costs for both private transport users and the freight transport sector. For private transport users, lowest-income households are most severely hit by an ETS-RT, as fuel cost increases affect their disposable income most strongly in relative terms. At the same time the lowest-income households have limited financial means to mitigate these cost increases. Mitigating the price impacts of an ETS-RT to some extent may therefore be warranted to ensure public support for an ETS-RT.
This can be done by recycling the auction revenues (partly) to those transport users most severely hit by an ETS-RT. Other options are to make use of a price ceiling or a (temporary) linkage to the current EU ETS. In this case, additional instruments will be essential to ensure that sufficient CO_2 reduction is taking place.

The increased fuel prices will stimulate freight transport companies to further improve the (fuel)efficiency of their activities, e.g. by buying more fuel-efficient vehicles or optimising the load factors of their trucks. Part of the additional fuel costs will be passed on to customers, resulting in higher prices of final goods. However, as transport costs are, in general, only a minor share in the total product costs, the drop in demand due to this price increase is expected to be small. Therefore, the impacts on total road freight transport volumes are likely to be limited, also because the potential for a modal shift to rail or inland navigation is relatively small.

An ETS-RT may also affect public finances significantly. Revenues from fuel taxes, VAT and vehicle taxes are expected to decrease. These reductions may be (partly) compensated by the revenues from auctioning allowances, although these revenues may also be used for other purposes.

Overall main conclusion

An ETS-RT can help in reaching the more ambitious climate targets set out in the European Green Deal. Ambitious reduction targets however will increase fuel prices and transport costs substantially, particularly for private transport users. Compensatory measures will be needed to prevent growing income inequalities and public resistance to an ETS-RT. As an ETS-RT and existing (national and EU) policies are complementary in several aspects, they should be aligned properly if the EC proposes implementation of an ETS-RT.

1 Introduction

1.1 Background

On September 17th 2020 the European Commission published its proposal for a more stringent 2030 target for the reduction of greenhouse gasses (GHG) (EC, 2020c). The target was tightened from at least 40% to at least 55% reduction in 2030 compared to 1990 levels. The tightening of the GHG target had been announced previously in the European Green Deal (EC, 2019). The Impact Assessment which accompanied the Green Deal concluded that the more ambitious target of 55% GHG reduction is economically feasible and attainable (EC, 2020a). The European Council approved the proposal of the Commission on December 11th 2020.

To bring the more ambitious targets within reach, many proposals for additional policy measures have been announced in the Green Deal. One of the measures considered is an extension of the EU Emissions Trading System (EU ETS) to emissions from road transport and the built environment (EC, 2019). The European Commission intends to present a legislative proposal for this on July 14, 2021.

There are several options for the inclusion of road transport in an ETS. Based on the Impact Assessment of the Climate Target Plan (EC, 2020a), three main options can be defined[1]:
- Extension of the current scheme to the road transport sector.
- A separate EU-wide emission trading scheme for road transport (ETS-RT). Such a scheme will be a closed system, only covering the road transport CO_2 emissions in the EU Member States. An alternative option would be to implement an closed ETS system covering both road transport *and* built environment.
- Obligatory national trading mechanisms for road transport.

The European Commission is planning to propose an adjacent system to the current EU ETS for road transport and built environment[2]. This could be operationalised by establishing separate emission trading schemes for road transport and built environment. Therefore, this study focusses on a closed ETS for road transport.

In response to the Commission's intention, the Dutch Ministry of Infrastructure & Water Management has asked CE Delft to investigate the effects of an ETS-RT. Of particular interest to the Ministry is information about the added value such an instrument could have compared to other (European and national) climate policies for road transport and the interactions between these different types of instruments.

1.2 Objective and scope of the study

The main objective of this study is to gain a better understanding of the implications of the introduction of a separate Emission Trading System for the road transport sector (ETS-RT) in the EU in general and the Netherlands in particular.

[1] All kinds of sub options are possible as well. For example, a separate EU-wide ETS for road transport can be extended to other sectors that are currently out of the scope of the EU ETS, e.g. the built environment.

[2] See: Reuters: European Commission planning emissions trading for buildings, transport, von der Leyen says

More specifically, this study investigates:
- in a (mainly qualitative) way the interactions of an ETS-RT with policies currently already in place or planned at the European (e.g. CO_2 standards for road vehicles) and national (e.g. zero emission zones for urban logistics) level;
- the level of allowance prices that might arise in an ETS-RT (for different emission reduction targets);
- the impacts that may be expected for the Netherlands, such as the impacts on fuel prices, household disposable incomes, freight transport and public finances.

This study is explorative in nature as there are considerable uncertainties en route to attaining the 55% reduction target. To the extent possible, we address these uncertainties by adopting a scenario approach and the use of sensitivity analyses.

This study is limited to the road transport sector. Non-road sectors such as rail transport and inland navigation are thus out of scope.

1.3 Overview of the study

In the remainder of this study, we start by providing an introduction on a closed (EU-wide) emission trading system for road transport (Chapter 2). In Chapter 3 we provide a rough estimation of long term allowance prices in an ETS-RT for three CO_2 reduction scenarios. The potential interactions of an ETS-RT and other European and national CO_2 reduction policies in the road transport sector are discussed in Chapter 4. Some main impacts of an ETS-RT for The Netherlands are assessed in Chapter 5, including the impacts on fuel prices, transport prices, and public finance as well as distributional impacts. Finally, the main conclusion and recommendations are presented in Chapter 6.

2 Closed ETS for road transport

2.1 Introduction

This chapter gives a brief introduction of the main features on a closed (EU-wide) emission trading system for road transport (ETS-RT). We start in Section 2.2 by explaining how an ETS-RT works. In Section 2.3, some main design options of an ETS-RT are discussed. Issues with respect to the implementation of an ETS-RT are briefly discussed in Section 2.4. Finally, we assess the impacts of extending the scope of an ETS-RT to other sectors currently not covered by the EU ETS, in particular the built environment.

2.2 Basic principles of an ETS-RT

In this study we consider a closed cap-and-trade[3] emission trading scheme for road transport (ETS-RT), covering all Tank-to-Wheel (TTW) CO_2 emissions of this sector in the EU. Under a cap-and-trade system, a fixed ceiling (cap) is set that equals the total amount of CO_2 emissions that can be emitted by road transport in the EU. This cap will be gradually lowered, reflecting the path to the long-term (and any interim) CO_2 reduction targets set for the road transport sector. Because of the fixed cap, an ETS-RT provides certainty on the emission reduction that will be achieved in road transport in the EU.

Within the ETS-RT, emission allowances are initially allocated to participants for free (grandfathering) or are auctioned. Each emission source covered by the scheme must surrender a quantity of allowances equal to its CO_2 emissions in tonnes. If participants of an ETS-RT produce more emissions than their available allowances, they have to buy additional allowances through trade or auction. In case participants emit less CO_2 emissions than their available allowances (e.g. due to increasing transport efficiency), they can sell their surplus of allowances to ETS-RT participants with a shortage of allowances.

The restricted supply of allowances creates scarcity and puts a price on CO_2.
This incentivises participants to look for abatement opportunities that cost less than the allowances. The opportunity to trade allowances ensures that emission reduction is achieved against least costs. As more abatement reduces the number of allowances parties have to buy, polluters that can reduce emissions at low cost will tend to do more, while those facing high abatement cost will choose to do less. An emission trading scheme also ensures dynamic efficiency, i.e. it provides an continuing incentive for participants for further reducing their CO_2 emissions (OECD, 2008). This is because polluters always face a price for any CO_2 emission they produce in the form of payments for allowances or foregone revenue from the sale of allowances that can be saved through additional abatement.

[3] An alternative option would be a baseline & credit scheme, where a target for the emissions intensity is set for emitting activities against a baseline. Credits are created for activities that achieve emissions intensities below the baseline and activities that result in emissions intensities above the baseline have to buy credits. Specifically for the transport sector, the baseline can be defined in terms of emissions per kilometre, tonne-kilometre, horsepower, etc. (Van Essen, et al., 2010). For example, in a baseline & credit system with car manufacturers as trading entities, manufacturers will receive credits for vehicles sold with emissions below the baseline. These credits can be used to compensate for vehicles sold with emissions higher than the baseline or can be sold to other manufacturers.

To fully benefit from the efficiency of market-based instruments like an ETS-RT, economically rational behaviour of the participants is required. They should be aware of all possible reduction options and their abatement costs and they should choose for the option with the least cost (OECD, 2008). However, in reality transport users are often not acting economically rational, e.g. because of a lack of information or consumer myopia[4] (Van Essen, et al., 2010). This could undermine the efficiency of an ETS-RT and may ask for additional policies as will be discussed in more detail in Section 4.2.4. Furthermore, a well-functioning market for emission allowances should be low-cost and competitive, i.e. without high transactions costs or monopoly power (CE Delft, et al., 2014) (OECD, 2008). These issues should therefore be considered carefully when designing an ETS-RT (see also Section 2.3).

2.3 Design of and ETS-RT

For the actual design of an ETS-RT, choices have to be made on a large number of parameters. In this section, we briefly discuss four main design options, i.e. ETS cap setting, the regulated entity, the allocation method for allowances and recycling of revenues.

ETS cap setting

Setting the level of the cap and its development over time (annual reduction factor) is the most important element of a cap-and-trade ETS. The cap limits the overall quantity of emissions and thereby guarantees the effectiveness of the instrument. The cap can be set top down at the EU level or can be determined bottom up by summing up national reduction objectives. The latter approach was applied in the first two phases of the EU ETS. In these phases, Member States submitted National Allocation Plans (NAPs), which had to be approved by the European Commission. These national plans set the quantity of allowances that each Member State was intended to issue during that phase, as well as the rules for the allocation of allowances for individual installations. By summing up the NAPs, the overall cap was determined. From Phase 3 onwards, an EU-wide cap was set top down and the allocation of allowances was determined through common rules agreed directly at EU level (EC, 2015).

Compared to a bottom up approach, a top down approach has lower administrative costs (i.a. because cap setting is a one-off exercise, as only the annual factor by which the cap is lowered needs to be regularly updated). Furthermore, a top-down approach is expected to be more effective in achieving large scale CO_2 emissions under an emission trading scheme, as a tighter cap can be more easily set (Umweltbundesamt, et al., 2015). On the other hand, an advantage of a bottom up approach may be that differences in welfare between countries can be taken into account, as low income countries can submit less ambitious NAPs than high income countries (CE Delft, 2021). However, this issue can also be addressed in a top down allocation of the allowances to countries, as this will be the result of political negotiations (Umweltbundesamt, et al., 2015).

An important element in cap-setting (assuming a top down approach) is the reduction factor by which the cap is annually decreased. In the current EU ETS a linear reduction factor is used, which was set on 1.74% in 2013 and is increased to 2.2% in 2021. Possibly this factor will be increased even further in order to bring the EU ETS cap in line with the -55% CO_2

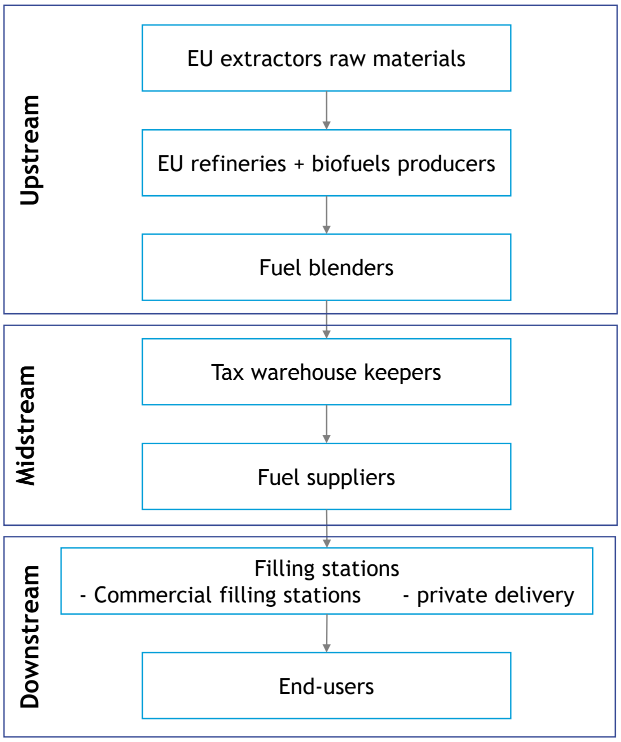
[4] This refers to the fact that consumers (both private consumers and companies) do often not take the life-time savings from improved fuel efficiency into account, but only the savings for small number of years (3 to 5 years).

reduction target set by the EU. An alternative variant for an ETS-RT would be to apply a non-linear (i.e. progressive) reduction factor, reflecting the cost reductions that are expected (due to scale and learning effects) for main low carbon technologies in the road transport sector like electric vehicles.

Regulated entity

The regulated entity is the entity that is required to surrender emission allowances. Theoretically, each entity in the supply chain for transport fuels could be the regulated entity (see Figure 1). In this respect, it should be noticed that one organisation could include several types of regulated entities. For example, integrated oil companies are not only extractors, but also refineries, fuel blenders, tax warehouse keepers, fuel suppliers and owners of filling stations.

Figure 1 – EU transport fuels supply chain



Based on a thorough assessment, CE Delft et al. (2014) conclude that midstream entities are the most appropriate regulated entities in an emission trading scheme for (road) transport. Compared to a downstream approach, the transaction costs are significantly lower in a midstream approach. First, because the number of regulated entities is significantly lower at a midstream level[5]. Second, entities at the midstream level are considerably bigger than at the downstream level and, as shown by Heindl (2012), average transaction costs (€/tonne CO_2) are significantly higher for small entities than for large entities. The implementation of upstream approaches, on the other hand, is hampered by difficulties to draw clear

[5] The number of end-users and filling stations is estimated to be in the order of 250 million and 134,000, respectively. At the midstream level, there are about 5,000 to 10,000 tax warehouse keepers and fuel suppliers

boundaries for the entities (CE Delft, et al., 2014). First, at this level in the supply chain it is still unclear which share of fuels will be used in the transport sector. Second, the correct amount of imports and exports of (transport) fuels in the full supply chain are not yet known at the upstream level. For example, transport fuels could be imported at the level of tax warehouse keepers and hence are not (automatically) taken into account if upstream entities are appointed as regulated entities. Third, at the level of extractors and refineries it is not yet known which biofuels are blended to the final fuels and therefore the exact carbon content of the fuels is not yet known. At the midstream level, these issues with respect to defining and monitoring the boundaries of regulated entities are not relevant.

From the entities at the midstream level, tax warehouse keepers[6] are considered the preferred option as regulated entity by CE Delft et al. (2014). There is already an extensive monitoring scheme available at these entities, registering all relevant transport fuel flows. The monitoring accuracy is also high and risk of fraud low, mainly because of the strict monitoring requirements that are set for charging excise duty at this entity. At the level of fuel suppliers, comparable monitoring schemes could be implemented, but may in some cases require additional investments. This is particularly the case with respect to monitoring the share of biofuels blended, as intensive trading in fuels take place between fuel suppliers.

CE Delft et al. (2014) estimate that there are between 5,000 and 10,000 tax warehouse keepers for energy products in the EU (and about the same number of fuel suppliers). To have a well-functioning market, this number of entities should be sufficient[7]. However, it should be considered that some of the tax warehouse keepers may be part of the same integrated oil companies, reducing the number of unique trading entities. Therefore, market power of (integrated) entities is an issue that merits further investigation if an ETS-RT is considered.

Allocation of emission allowances

In general three main options for the allocation of emission allowances can be distinguished (CE Delft, et al., 2014):

1. *Free allocation*, where the amount of allowances is allocated based on the share of the regulated entity's historic emissions (grandfathering) or based on an activity benchmark. In case of a midstream approach, such a benchmark could be defined in terms of CO_2 per Joule[8], for example based on the most efficient fuel. Compared to grandfathering the use of an activity benchmark rewards early action, e.g. in case a tax warehouse keeper or fuel supplier already supplied a large share of biofuels.
2. *Auctioning of allowances*.
3. *Hybrid approach*; in this model a share of the allowances are issued for free, while the other part of the allowances is auctioned.

[6] Tax warehouse keeper is defined as "a natural or legal person authorised by the competent authorities of a Member State, in the course of his business, to produce, process, hold, receive or dispatch excise goods under a duty suspension arrangement in a tax warehouse." An tax warehouse is an authorized place where the above mentioned activities could take place under duty suspension arrangements (EC, 2008).

[7] Cozijnsen (2001) argues that about 15-30 participants to an ETS are required for a well-functioning market, while KPMG (KPMG, 2002) assumes that several hundreds of participants are required. These limits are largely exceeded by the number of tax warehouse keepers/fuel suppliers in the EU.

[8] Implying that the tax warehouse keepers offering fuels with the lowest CO_2 levels per Joule will get the most allowances.

Based on an extensive analysis, CE Delft et al. (2014) conclude that auctioning is the most efficient/effective allocation approach. In contrast to free allocation of allowances auctioning does not require that detailed data have to be collected for new entrants. Furthermore, auctioning avoids risks of windfall profits[9], while it rewards early action of actors (notice that early action is also rewarded by benchmarking). Finally, auctioning is also expected to result in the lowest transaction costs. A potential disadvantage of auctioning is that buying permits costs money, with potential negative effects on companies' (international) competitiveness. Correspondingly, free allocation of allowances is mainly used in the current EU ETS to protect the competitiveness of companies competing internationally. However, as road transport is not (or only very marginally) exposed to extra-EU competition, this argument does not hold for an ETS-RT.

In recognition of the advantages of auctioning above free allocation, the share of auctioning has gradually increased throughout the operation of the current ETS to about 57% of all allowances.

Recycling of revenues

As mentioned above, in case auctioning is used to allocate the emission allowances, revenues will be raised for the government. These revenues can be used for several objectives, including:

- *Improving the overall efficiency of the economy by lowering distortionary taxes.* The revenues can be used to reduce the distortive effect of other taxes (e.g. income tax, corporate tax) in order to promote economic activity and boost employment (OECD, 2008).
- *Reducing the financial burden for transport users;* in order to minimise any adverse financial impact on transport users from rising fuel prices, revenues can be channelled to compensate (certain groups of) transport users (CE Delft, et al., 2014) (Cambridge Econometrics, 2021) (CERRE, 2020).
- *Improving public acceptance of an ETS-RT;* research shows that the public acceptability of an ETS may be improved by actually using the auction revenues for climate and energy purposes (Gavard, et al., 2018).
- *Stimulating innovative low-carbon technologies;* channelling revenues towards innovative reduction options may help these technologies to improve their market-readiness, e.g. by achieving learning and scale effects (CE Delft, et al., 2014) (Cambridge Econometrics, 2020).

Although these objectives may compete with each other for the available revenues, some of them can also be addressed simultaneously by the same instrument. For example, using revenues for stimulating innovative reduction options may also improve public acceptance. And by using revenues to support low-income households to invest in reduction technologies, distributional impacts may be mitigated while at the same time (innovative) reduction options are stimulated.

[9] Free allocation can deliver windfall profits to entities that pass through some or all of the market value of the freely obtained allowances to consumers (EC, 2015). These entities pass on their opportunity costs of having to use the allowances for compliance instead of being able to sell it. Several econometric studies have shown that (some) participants of the EU ETS obtaining (some of their) allowances for free have gained windfall profits (e.g. CE Delft (2010), Sijm et al. (2006), Hobbie et al. (2019).

The effectiveness of recycling revenues in achieving specific objectives depends on the (design of the) instrument used. For example, Cambridge Econometrics (2021) shows that a lump sum transfer to consumers is more beneficial for low-income households than lowering income taxes and social security contributions. These households pay relatively small amounts of taxes, and hence lump sum transfers are a larger portion of their incomes than equivalent tax discounts. However, it should be noticed that from an economic efficiency point of view lowering income taxes is preferable, as this removes some of the distortive impact these taxes have on the labour market. These kind of trade-offs should be considered carefully in selecting and designing the instruments used for recycling auction revenues.

Recycling of auction revenues can be used to address national issues, but also to address impacts across Member States (CERRE, 2020). For example, by allocating allowances disproportionately to poorer countries and/or countries with more CO_2 intensive road transport sectors, any distributional impacts of an ETS-RT across Member States can be addressed. This principle is also applied in the current EU ETS, as 10% of the auctioned allowances are divided between countries with low per capita income. Auction revenues can also be used to finance cross-border investments in low-carbon infrastructure. For these reasons, allocating some part of the auction revenues of an ETS-RT to the European Commission instead of Member States can be an option.

2.4 Implementation of an ETS-RT

According to CE Delft et al. (2014) and CERRE (2020), the implementation of an emission trading scheme for (road) transport is technically feasible. As mentioned above, monitoring facilities are available at the level of tax warehouse keepers. All transport fuels pass through these warehouses with the exception of natural gas (LNG or CNG), which account for about 1% of CO_2 emissions from the transport sectors[10] (CE Delft, et al., 2014).
Tax warehouses monitor the quantity of fuels accurately, and in many Member States they also register the amount and type of biofuels blended in the fuels. The carbon content of transport fuels is well known and does not vary much (with the possible exception of natural gas), which means that default emission factors can be used. Furthermore, as tax warehouses are required to register fuels accurately for fiscal reasons, the risk of fraud is small. In case fuel suppliers are appointed as regulated entities, additional monitoring mechanisms have to be implemented. This is feasible, but will lead to additional costs.

The introduction of an ETS-RT implies that an additional policy instrument will be introduced, resulting in additional operational cost for the government and transaction costs for participants to an ETS-RT. Their experience with the EU ETS may limit the operational costs for the European Commission and national governments (e.g. the same (kind of) platform infrastructure may be used for the auctioning of allowances). In case tax warehouse keepers are designated as regulated entities, transaction costs are expected to be relatively low, as at this level the required monitoring and regulation mechanisms are already available (CE Delft, et al., 2014).

[10] In order to include the natural gas used in the transport sector in ETS-RT, it could either be required to pass through tax warehouses, or the fuel supplier could be designated as the regulated entity.

2.5 A combined ETS for road transport and the built environment

In the European Green Deal (EC, 2019), road transport and the built environment are explicitly mentioned as sectors to be incorporated into an emission trading system. In this study we focus on an ETS scheme for road transport only (ETS-RT), but a combined ETS for road transport and the built environment is an option as well. In this section we briefly discuss some implications of incorporating road transport and the built environment in a combined ETS together, compared to the ETS-RT (only) variant.

According to EC (2020b), the European CO_2 emissions of road transport and the built environment together were about 1,200 Mton in 2015, of which about 60% were from road transport. By implementing a combined ETS for these two sectors, the total amount of CO_2 emissions covered by an emission trading scheme in the EU will almost double (from about 1,600 Mton to 2,800 Mton, based on 2015 emission figures).

In a combined ETS system, the overall CO_2 reduction is achieved in a more cost effective way than in two separate schemes (CERRE, 2020). This is because a larger range of reduction options is available and emission reductions will be achieved in the sector where this can be done against least costs. However, based on evidence in literature, it is hard to conclude in which sector most emission reductions will take place. Cambridge Econometrics (2021) found in a modelling study on the impacts of an ETS for all sectors falling under the Effort Sharing Regulation[11], that the response level of road transport and the built environment to a carbon price set by a combined ETS is expected to be comparable (in relative terms). DIW (2019), on the other hand, finds in a study on the impacts of an ETS covering road transport, the built environment and non-ETS industry, that relatively more emission reductions will take place in the road transport sector than in the built environment. However, the conclusion of the Impact Assessment of the EU Climate Target Plan is the opposite: they expect that emissions of the built environment will respond significantly stronger to carbon prices than transport emissions. The reasoning is that in the transport sector, there are currently already high carbon prices due to national carbon or energy taxation, unlike in the buildings sector. Therefore, the additional incentive of the ETS price might be smaller in the road transport sector compared to built environment (EC, 2020a).

As it is uncertain which levels of emission reductions will be achieved by individual sectors in a combined ETS, it is unclear whether the allowance price in a combined system will be higher or lower than in an ETS-RT. The allowance price is expected to be more volatile in a combined system, though. This can be attributed to the fact that weather patterns may cause substantial short-run changes in energy consumption in the built environment (e.g. more gas will be used for heating in cold weather) and hence in the demand for allowances from this sector. This may result in high prices in some periods and a drop of prices in other periods (CE Delft, et al., 2014).

Finally, a combined ETS for road transport and the built environment may result in lower transaction costs compared to two separate schemes. As for both sectors (partly[12]) the same regulated entities can be appointed (tax warehouse keepers/fuel suppliers), economies of scale may be achieved in setting up a monitoring, reporting and verification framework. Also operational costs may be lower, as the governments have to operate just one instead of two schemes.

[11] Transport, the built environment, non-ETS industry, agriculture and waste.

[12] For the built environment tax warehouse keepers are best appointed as regulated entities for liquid fuels, while fuel suppliers are the most appropriate regulated entities for solid and gaseous fuels (CE Delft, et al., 2014).

3 Estimation of allowance prices

3.1 Introduction

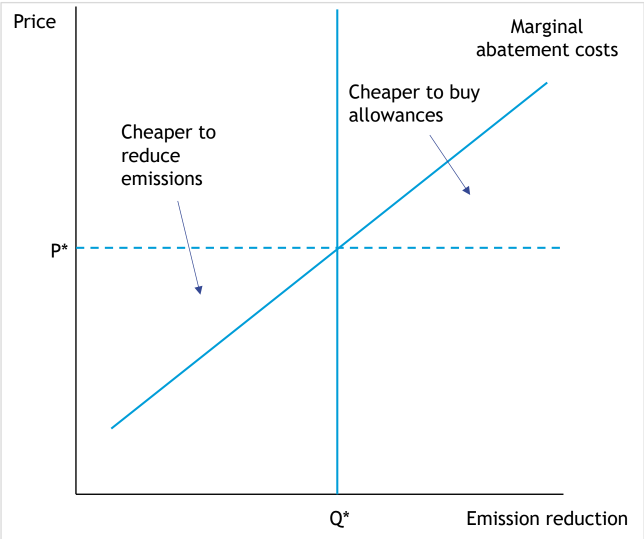
In this chapter we examine the possible long-term allowance price in an ETS-RT in 2030 under three different emission reduction targets for the road transport sector. We start by discussing, in general terms, how the price of allowances in an ETS-RT is set (see Section 3.2). Based on this theoretical framework, we briefly present the methodology that is used to estimate the 2030 allowance prices in Section 3.3 (a more detailed explanation of the methodology used can be found in Annex B). In Section 3.4, the estimations of the allowance prices for the various scenarios are presented and discussed. Finally, we discuss briefly the issue of price volatility in Section 3.5, as too much volatility may hamper the functioning of an ETS-RT.

As price setting in an emission trading system is a dynamic and complex process affected by many factors, it is very difficult to estimate the expected allowance price with a high level of certainty. Therefore, the results presented in this chapter should be considered as an indication of the order of magnitude of the allowance price instead of a very precise estimation.

3.2 Price setting in an ETS-RT

In an ETS-RT, the allowance price is the outcome of the market mechanism. Policy makers set the emission reduction target (Q* in Figure 2) and hence the cap for emission allowances. This cap determines the supply of allowances in the market. The demand for allowances is determined by the costs of reduction options and the initial emission levels within the road transport sector. In principle, actors will reduce emissions if taking action is cheaper than using allowances. On the other hand, reduction options that are more expensive than the allowance price will not be taken (but allowances will be used instead). As is shown in Figure 2, the interaction of demand and supply results in an allowance price (P*) that equals the marginal cost of reducing emissions to a level consistent with the cap.

Figure 2 – Price setting in an ETS-RT



As mentioned in Section 2.3, the most likely regulated entities in an ETS-RT are the tax warehouse keepers (or the fuel suppliers). However, these entities have no or only a limited number of reduction options that they could take themselves. Their main option is to increase the fuel price[13], thereby incentivizing consumers to demand less fuels.
Tax warehouse keepers/fuel suppliers will do this up to the level that the cost of increasing the fuel price equals the cost of using allowances. Notice that this level reflects the marginal cost of reducing emissions to the level consistent with the cap[14]. Therefore, even if the regulated entities cannot take many reduction options themselves, the market mechanism still results in an allowance price that equals the marginal cost of reducing emissions consistent with the cap. Additionally, it can be concluded that the full cost of the ETS-RT are borne by the transport users[15].

Factors affecting the long-term allowance price

Long-term price setting for emission allowances is affected by a large range of factors. The main factors are:

- **The cap for emission allowances set**. The cap set by policy makers directly affects the allowance price. A tighter cap will, for example, result in a higher allowance price. In order to assess the impact of the cap on the allowance price, we consider three cap scenarios in this study (see Section 3.3) that differ in terms of emission reduction targets set.
- **Other GHG emission reduction policies.** At the European and national levels, various policies to reduce the GHG emissions of road transport have been taken or are proposed. If a part of the required emission reduction is met by these other policies, the demand for allowances will decrease and this will, under the right conditions (see Section 4.2.4), result in lower allowance prices. The other way around, as targets for these complementary policies are weakened, there may be an upward impact on the allowance price. All relevant European GHG emission reduction policies are considered as part of the baseline scenario used in this chapter (see Section 3.3.2). The impact of changes in these policies on the allowance price is discussed in more detail in Chapter 4.
- **Design of the ETS-RT**. Several design parameters may affect the price setting of allowances. Price ceilings or floors may be used to regulate the allowance price. Also the option of banking and lending of allowances may affect the allowance price. Finally, the extent by which certificates from outside the ETS-RT (e.g. Clean Development

[13] Some of the tax warehouse keepers (the ones that are part of an integrated oil company, see Section 2.3) may also have the option to increase the amount of biofuels blended. However, this will only be done to the extent that it results in lower costs than reducing the demand for fuel by increasing prices. Otherwise, fuel companies increasing the share of biofuels will lose market share to competitors that choose to increase prices of (current blends of) fuels.

[14] If fuel prices are set too low, transport users will not take sufficient reduction options to meet the emission target set by the cap and hence fuel prices have to be increased further. On the other hand, if fuel prices have been set too high, too many reduction options are taken by transport users (in order to meet the cap) and hence it may be profitable for fuel companies to reduce the fuel price.

[15] Even if tax warehouse keepers will buy allowances, they will probably pass on the associated cost to transport users. Although some studies (e.g. CE Delft (2006), Eckerhall (2005)) argue that some of the additional costs may be ‘internalised’ (i.e. not passed on to transport users) by the actors in the fuel supply chain, most evidence suggests full cost pass-through. For example, an empirical study by Andersson (2019) finds evidence of full pass-through of the carbon tax in Sweden. And also gasoline taxes are usually fully passed on to transport users, as is shown by studies like Meyler (2009) and (Li, et al., 2014). Based on this evidence, we conclude that 100% of the costs are probably passed on to the transport users.

Mechanism[16] (CDM) credits or emission allowances from the EU ETS) can be used also affects the allowance price. In the text box below, the impact of these three design parameters on allowance prices are discussed in a bit more detail.

- **External factors** (e.g. state of the economy, energy prices, technological changes). For example, high economic growth or low energy prices may result in additional demand for transport and hence more transport related emissions. In this case, a higher level of emission reduction compared to baseline emissions in 2030 should be achieved, resulting in higher allowance prices. Fuel prices also significantly affect the payback period of reduction options and hence at higher fuel prices lower allowance prices are required to achieve specific reduction levels. For all the relevant external factors we have defined the most likely development in the baseline scenario.

Impact of some design parameters of an ETS-RT on allowance prices

The long-term allowance price is affected by the actual design of the ETS-RT. Some relevant parameters in this respect are:

- *Price ceilings/floors*; in some emission trading schemes, price ceilings or floors are used to regulate the allowance price. For example, in the German CO_2 emission trading scheme for transport and the built environment, a (annually increasing) fixed price is set for the period 2021–2025, followed by a minimum and maximum price of € 55 and € 65 per tonne CO_2 for 2026 (and maybe also the years afterwards) (Umwelt Bundesamt & DEHSt, 2020). Price floors and ceilings can be used to reduce the volatility of allowance prices, providing investors in reduction options more certainty on the payback period of their investment. They can also contribute to soften the price impacts of an ETS in the early years after introduction in order to enhance the public support for the scheme. On the longer run, a price ceiling may also be used to reduce the burden for trading entities in the scheme, while price floors can make for more stable government revenues (a minimal level of revenues is guaranteed). However, using price ceilings also implies that the environmental effectiveness of an ETS-RT becomes uncertain, as it may be the case that the long-run allowance price will be too low to achieve the emission reduction required to meet the cap. In case of a price floor, there is a risk of overshooting (higher level of reduction than required to meet the cap), which may also lower the cost effectiveness of the instrument.
- *Banking and lending of allowances;* banking and lending facilities allow intertemporal flexibility of the emission allowance market without changing the overall amount of emissions capped over the entire period the scheme is effective (Vollebergh & Brink, 2020). Participants with a surplus of allowances at the end of a trading phase can bank these allowances, such that they can be used in the next trading phase. Lending facilities provide participants the opportunity to use allowances from a future allocation. Banking and lending of allowances may be an effective tool to smoothen price variations (but at the same time lending may hamper the effectiveness of the scheme in the short run). However, they should be designed carefully. For example, generous banking facilities in early phases of the EU ETS have exacerbated oversupply of allowances which resulted from an initial overallocation of allowances combined with a lower demand due to the economic crisis. Thereby banking facilities contributed to the long-term depression of ETS-allowance prices (although it reduces the short term downward impact on the allowance price).
- *The use of external credits*; allowing trading entities to use external credits like CDM credit can lead to a decrease in allowance prices in an ETS-RT. This effect may also result when linking an ETS-RT to the current EU ETS (Achtnicht , et al., 2015). Linking both systems would allow the trading entities in the road transport sector to purchase part of the required allowances in the EU ETS, such that they can take advantage of the lower mitigation costs in the EU ETS sectors. As a result the allowance price in the ETS-RT will decrease (and the allowance price in the EU ETS will increase). The downward impact of using external credits on ETS-RT allowance prices goes along with a lower level of emission reduction within the road transport sector.

[16] CDM is a mechanism which allows industrialized countries to earn certified emission reduction (CER) credits (each equivalent to one tonne of CO_2 emission) by reduction projects in developing countries. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol.

3.3 Methodology to estimate allowance prices in an ETS-RT

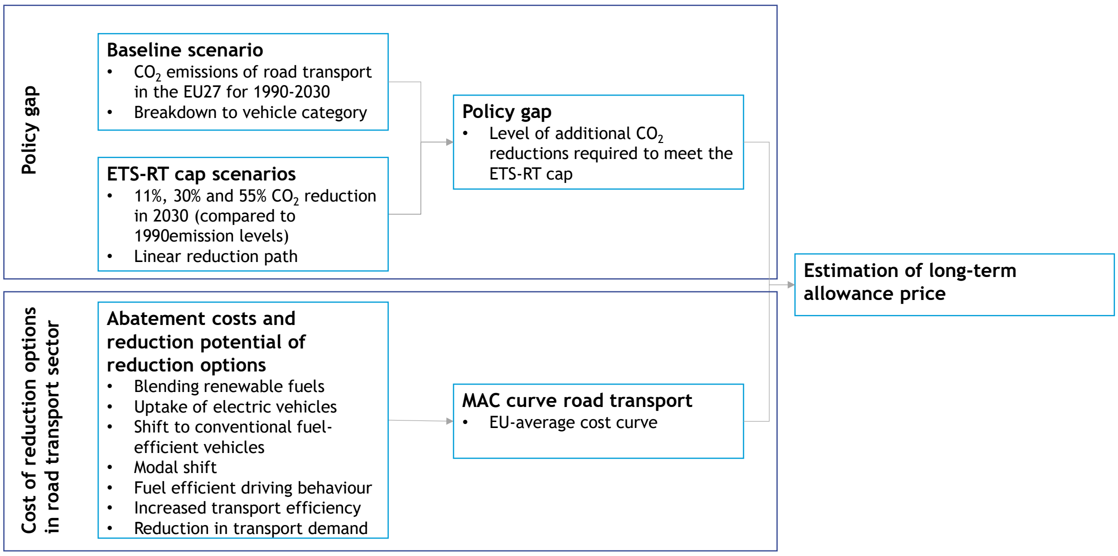
3.3.1 Overview of the methodology

Figure 3 provides an overview of the methodology applied to estimate allowance prices for an ETS-RT in 2030. As became clear in Section 3.2, the allowance price equals the marginal cost of reducing emissions to a level consistent with the cap. To estimate these marginal costs, we have developed a marginal abatement cost (MAC) curve, which shows the minimum costs for which a certain reduction target is met[17]. This MAC curve covers all kinds of reduction options like reduced transport demand, modal shift, more efficient transport operations (e.g. higher load factors), the uptake of zero emission vehicles and blending higher levels of renewable fuels.

In this study we have considered three scenarios for the level of the cap. The CO_2 emission reduction required to meet the cap (the policy gap) has been calculated for each of these scenarios taking the baseline scenario (e.g. reductions due to current policies like vehicle emission standards and the Renewable Energy Directive) into account.

In the remainder of this section we first describe in more detail the way the policy gap is determined (see Section 3.3.2). Next, we briefly present the development of the MAC curve (see Section 3.3.3).

Figure 3 - Overview of methodology to estimate the long-term allowance price



[17] More specifically, a MAC curve presents measures to reduce CO_2 emissions in the order of their cost effectiveness. The most cost effective measure is located at the left of the curve and going to the right, the abatement costs (in €/ton CO_2) increases. In addition, the MAC curve also shows the reduction that could be achieved by the individual measures and combinations of them (in tons). Therefore, the MAC curve shows what the minimal abatement costs are of achieving a certain emission reduction (and which measures are taken in that case). This makes the MAC curve useful to estimate the marginal costs of meeting the ETS-RT caps.

3.3.2 Policy gap: level of additional CO_2 reductions to meet the ETS-RT cap

In order to estimate the long-run allowance price we first establish the emission reduction required to meet the ETS-RT cap. This is the difference between the baseline emission levels and the emission level corresponding with the respective cap. We refer to this difference as the 'policy gap'. The marginal costs to fill this policy gap equals the long-run allowance price.

In this section we first describe the baseline scenario used in this study. Next, the ETS-RT cap scenarios applied in this study are presented. Based on these two elements, the policy gaps are finally estimated.

Baseline scenario

The baseline scenario is derived from the reference scenario used by the European Commission in the impact assessment for the Green Deal (EC, 2020a). This reference scenario is based on modelling exercises with updated editions of the PRIMES – GAINS - GLOBIOM models. Assumptions on socio-economic developments, energy price projections and technological developments are based on the periodically updated EU Reference scenario on energy, transport and GHG emissions. A brief overview of the main assumptions used is given in Annex A.

The baseline scenario covers all relevant EU policies, including the CO_2 standards for cars, light commercial vehicles and heavy goods vehicles, the Alternative Fuels Infrastructure Directive, the Clean Vehicles Directive, the Eurovignette Directive, the Fuel Quality Directive (FQD), Renewable Energy Directive (RED), the vehicle emission norms (Euro standards), and the Energy Taxation Directive (ETD). Additionally, some key national (tax) measures are covered as well.[18]

In the baseline scenario, intra-EU passenger transport activity (in terms of passenger kilometres) is increasing by 19% between 2015 and 2030. The activity of private cars is expected to grow at a slower pace, by 14% during 2015-2030. Freight transport (in terms of tonne kilometres) is expected to grow faster than passenger transport, at around 33% between 2015 and 2030. The growth in heavy goods vehicles activity is in the same order (34% increase by 2030). In addition to these developments in transport volumes, the baseline scenario also incorporates relevant developments in the composition of the vehicle fleet. Driven by the CO_2 emission standards, the average CO_2 emissions of fossil-fuelled vehicles are projected to go down. Furthermore, the stock of full electric cars is projected to go up to 11% of all passenger cars by 2030, while the share of all low and zero emission cars (including plug-in hybrid cars as well) is expected to be 16%. For vans, these shares are 7 and 12%, respectively. In the heavy goods vehicle segments, hybrids are projected to represent around 16% of the fleet in 2030, while trucks running on gaseous fuels (LPG and LNG) are around 6% of the fleet. No significant share of electric trucks is projected in the baseline scenario.

[18] The effects of the final National Energy and Climate Plans (NECPs) have not been included in the baseline scenario as the NECPs where not finalized at the time of writing. A preliminary analysis was conducted separately based on preliminary versions of the NECPS (EC, 2020a). This analysis shows that the NECPs do not lead to large additional carbon reductions.

The total amount of liquid biofuels used in transport increases to 10% in 2030 in the baseline scenario. The share of liquid biofuels is, however, calculated using the RES-T target calculation for which specific caps and multipliers apply. For the baseline scenario, we assume that a 10% administrative contribution of biofuels is equivalent to an actual share of biofuels of about 7.5%.

Based on the projections described above, the total baseline CO_2 emissions of road transport in the EU27 equal 610 Mton in 2030 (see Table 3). This is slightly lower than the emission level in 1990 (620 Mton). Compared to the 2015 levels, a reduction of 16% is expected for 2030. The largest source of carbon emissions in 2030 is passenger cars followed by heavy goods vehicles (HGV). Light commercial vehicles (LCV) also contribute significantly to the total CO_2 emissions of road transport. Other forms of road transport (mainly buses and two-wheelers) have the lowest impact in terms of absolute carbon emissions.

Table 3 - Baseline CO_2 emission levels of road transport in 2015 and 2030 for the EU27 (Mton)

Vehicle category	2015	2030
Passenger car	461	345
Light commercial vehicles	88	80
Heavy duty vehicles	155	150
Other road transport	55	35
Total road transport	**759**	**610**

Source: EC (2020b).

Table 4 shows a further breakdown of the CO_2 emissions by fuel type in 2030[19].

Table 4 - Baseline CO_2 emission levels of road transport per fuel type in 2030 for the EU27 (Mton).

Vehicle category	Petrol	Diesel	Gas	Total
Passenger car	186	143	16	345
Light commercial vehicles	4	75	1	80
Heavy duty vehicles	0	141	9	150
Other road transport	15	20	-	35
Total road transport	**205**	**379**	**26**	**610**

Source: EC (2020b).

ETS-RT Cap scenarios and corresponding policy gaps

As mentioned in Section 3.2, the ETS-RT cap heavily affects the allowance price. However, the size of the cap is not yet known and subject to negotiations on the forthcoming proposal by the European Commission. Because of this uncertainty, we have assessed the long-term allowance price in an ETS-RT for three illustrative scenarios, which differ with respect to the reduction target set.

[19] As is shown, a small fraction of the fleet is expected to use gaseous fuels instead of petrol or diesel. To avoid complications in the calculations, we treat private gas driven passenger cars as petrol cars in our calculations. Gas driven LCVs and HGVs are considered as diesel vehicles in this study, for the same reason.

For illustrative purposes, we directly translate the overall European 55% reduction to a 55% reduction target in the ETS-RT, resulting in a scenario (S3, see Table 5). However, this scenario is rather ambitious, particularly as abatement options in the road transport sector are relatively expensive compared to other economic sectors. Therefore, we have defined two additional scenarios that represent a more realistic view on contribution of the road transport sector to the overall emission reduction target. The first one (S2) assumes a 30% reduction target for the road transport sector (compared to 1990 levels). This number is derived from a recent study (Van Geest, 2021) which investigates the policy options available to the Netherlands to contribute to a more ambitious EU target of 55% instead of 49%. According this study, 30% emission reduction in 2030 would be a (challenging but) feasible goal for Dutch road transport. The final scenario (S1) is the least ambitious one and represents a situation in which current ambition levels for the transport sector remain unchanged in spite of the increased EU target. The reduction level for this scenario is derived from measures set out today in the Dutch Climate Agreement (Ministry of Economic Affairs and Climate Policy, 2019) plus some additional EU and national measures that have been implemented more recently.[20] In line with the climate impact of these already existing measures in scenario 1 we assume a reduction target of 11% for road transport (compared to 1990 levels) in 2030[21].

Table 5 presents an overview of the three scenarios in order of their level of ambition.

Table 5 - Three scenarios for the reduction target for the road transport sector

Scenario	CO_2 reduction target (compared to 1990 levels)	Short description
S1	11%	Based on target and measures set out in the Dutch Climate Agreement (plus some additional EU and national measures).
S2	30%	Emission reduction that is feasible in the Dutch transport sector according to Van Geest (2021) in case the overall reduction target of 55% is adopted.
S3	55%	Direct translation of the overall GHG emission reduction target of 55%.

In Table 6 the three scenarios are translated into the corresponding ETS-RT caps in 2030 (in terms of Mtons of emissions). For the period 2025–2030, it is assumed that the cap is linearly reduced every year. The resulting policy gap for each scenario is shown in Table 6 as well. In S1, about 58 Mton have to be reduced in 2030 (additional to the emission reductions in the baseline scenario) to meet the ETS-RT cap. In S2 and S3 this is 176 Mton and 331 Mton, respectively.

[20] This refers to stricter EU CO_2 standards for passenger cars and HGV’s and the introduction of a lower speed limit of 100 km/h on Dutch freeways.

[21] This target is significantly lower than the overall target of the Dutch Climate Agreement (i.e. 49%), which is, among other things, because of the higher expected costs to implement CO_2 reduction options in transport compared to other economic sectors.

Table 6 – CAP levels and policy gap per scenario

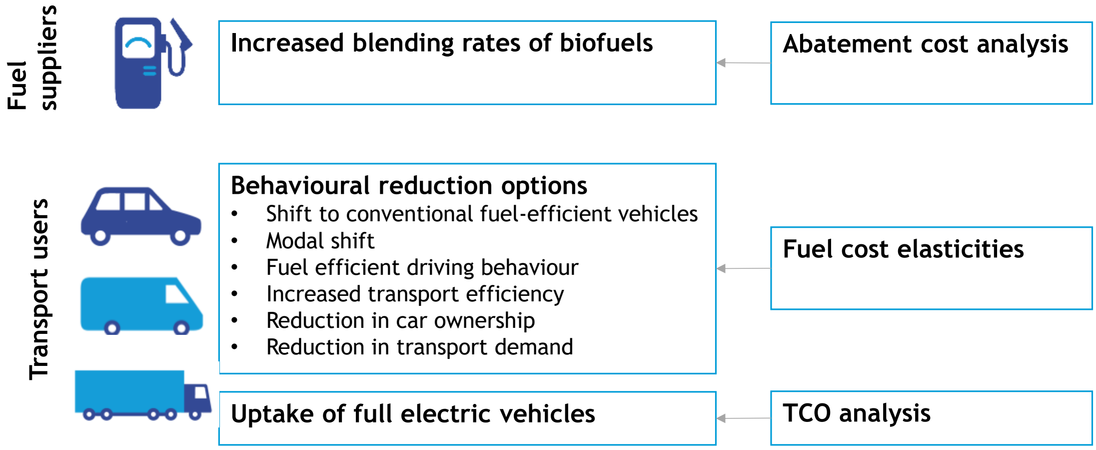
EU27 CAP Scenarios	S1: 11% CO_2 reduction	S2: 30% CO_2 reduction	S3: 55% CO_2 reduction
2030 Baseline CO_2 emissions (Mton CO_2)		610	
2030 ETS-RT cap emissions (Mton CO_2)	552	434	279
Policy gap: required CO_2 emissions to meet the ETS-RT cap	58	176	331

3.3.3 Marginal abatement cost curves

As mentioned in Section 3.3.1, a marginal abatement cost (MAC) curve is used to estimate the marginal costs of achieving the emission reductions required to meet the ETS-RT cap (and hence the long-run allowance price). Recent MAC curves for road transport at the EU level are not available in the literature. The MAC curves that are available are outdated (e.g. McKinsey&Company (2009)) or focussed on specific subsets of reduction options or vehicle categories (e.g. Ricardo et al. (2016), TNO et al. (2018)). Additionally, the MAC curves available are mainly covering the financial costs (i.e. investments and operational costs) only. However, consumers (and also companies) are not only considering financial costs when deciding on implementing reduction options. Furthermore, people are sometimes lacking knowledge on financial costs or are reluctant to invest in innovative concepts (like an electric car) because of risk aversity. These effects should be considered in the MAC curve as well in order to avoid the risk of being too optimistic on the uptake of abatement options in the road transport sector. For all these reasons, we have decided to develop an EU-wide MAC curve ourselves for the purpose of this study.

The MAC curve developed in this study contains a wide range of reduction options. As shown in Figure 4, three categories of reduction options are distinguished: increased blending rates of biofuels, behavioural reduction options (covering a wide range of reduction options like modal shift, lowering transport demand and applying a fuel efficient driving style) and the uptake of electric vehicles. For each of these three categories we first develop a separate MAC curve, using different methodologies as indicated in Figure 4. Finally, these three individual MAC curves are combined into one integrated MAC curve for the road transport sector. Below we briefly discuss these different steps. A more detailed description of the approach followed to derive the MAC curve can be found in Annex B.

Figure 4 - Overview of reduction options per actor and methodologies used to estimate the three individual MAC curves



Increased blending rates of biofuels

Fuel suppliers have the option to increase the share of biofuels in the fuel blends in order to reduce CO_2 emissions. In our calculations we assume that fuel suppliers will act economically rational and hence will increase the blending rates of biofuels if this becomes financially attractive. This implies that at higher CO_2 prices, larger shares of biofuels are added to the fuel blends.

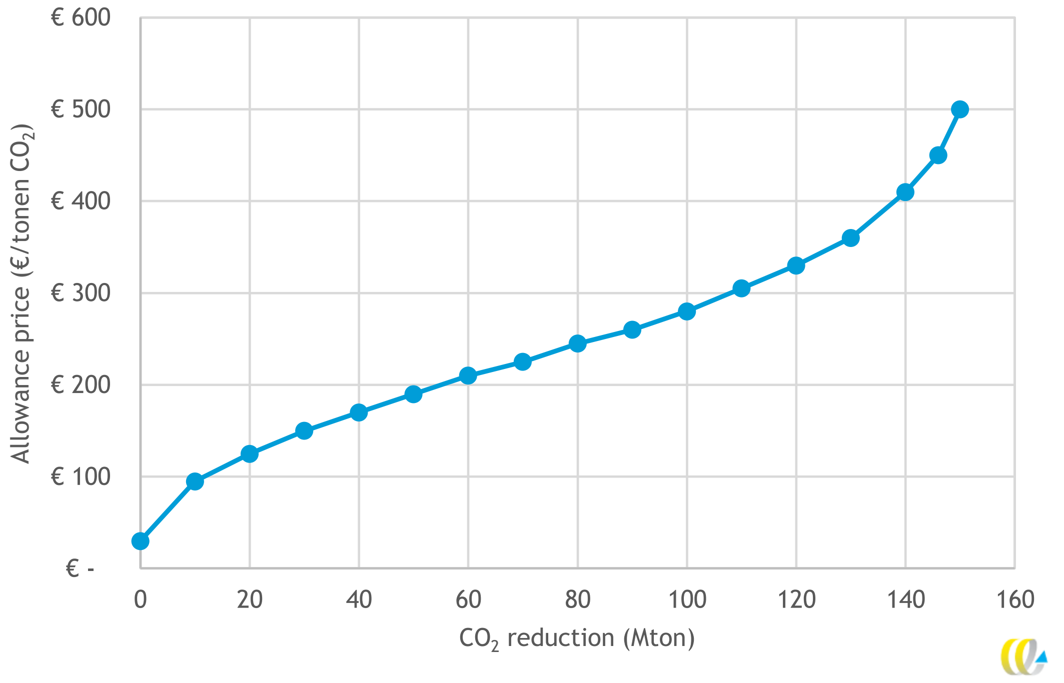
The abatement costs of biofuels are highly uncertain and depend on many factors, including the production pathways considered, the potential scale and learning effects that could be achieved, the demand for biofuels and biomass from other transport sectors (e.g. aviation) and other economic sectors, etc. In addition to the uncertainty on the abatement costs of biofuels, there is also uncertainty on the maximum amount of biofuels that will be available (at which costs) to be used in road transport in the EU27. This depends on factors like the price of biofuels, the capacity of each production pathway and the demand of biofuels from other sectors or countries outside the EU. See Annex B.2 for a more detailed discussion on these issues.

Because of these uncertainties, the development of abatement cost curves for biofuels in transport is very complex. That is probably the reason why detailed abatement cost curves for biofuels are not available in the literature. It is also out of scope of this study to develop such a detailed curve ourselves. Instead, we have applied a pragmatic approach, in which we have estimated an abatement cost curve based on the range in abatement costs presented by IEA (2020b): € 0-€ 365 per tonne CO_2-eq. For this curve, we have assumed a S-shape which reflects the relatively low availability of low-cost biofuels in 2030 as well as the (sharply) increasing costs of biofuels as more expensive production pathways are required at higher demand levels[22].

[22] Due to a lack of data on costs and capacity of each production pathway for biofuels, no information is available on the actual shape and slope of the MAC curve for biofuels. The use of a S-shape is therefore arbitrary. Internal checks show, however, that applying a linear curve would have resulted in allowance prices that are in the same order of magnitude.

We have limited the availability of biofuels for road transport to 50% of the theoretical maximum (i.e. 42 Mtoe per year in Europe (Concawe, 2019)) in order to have sufficient availability for other modes and sectors. The resulting abatement cost curve is shown in Figure 5. The abatement costs are slightly higher than the production cost (€ 0-€ 365) because we assume that it takes a couple of years for biofuel production to catch up in reaction on allowance price increases.

Figure 5 - MAC curve for biofuels in 2030



The large uncertainties in the abatement cost curve for biofuels have been assessed in more detail in Section 3.4.2, where the impact of different levels of biofuels availability and associated production cost levels on the long-term allowance prices have been modelled.

Behavioural reduction options

Road transport users have many options to reduce the CO_2 emissions of their movements. People and companies could choose for another transport mode (e.g. rail transport), increase the efficiency of their transport movements (e.g. by increasing loading rates of trucks or by carpooling), apply a more fuel efficient driving style, buy a more fuel-efficient vehicle or buy less vehicles, travel less often, etc. The abatement costs of these reduction options differ widely, ranging from options with negative abatement costs (e.g. fuel efficient driving) to options with relatively high abatement costs (e.g. modal shift in freight transport) (Schroten, et al., 2012).

However, detailed evidence on the abatement cost of all different types of behavioural reduction options is limited (Schroten, et al., 2012). This complicates the development of an abatement cost curve that distinguishes all the individual reduction options. Therefore, we have chosen for an alternative approach, using fuel price elasticities to integrate these reduction options in the MAC curve[23]. Fuel price elasticities give the effect of a fuel price increase on the demand for fuel, which is the effect we want to model here[24]. An additional advantage of using an approach based on fuel price elasticities is that also non-financial costs affecting the choice of people or companies to take a certain reduction option are taken into account[25]. A similar approach has been used in the past by CE Delft (2007) and Cambridge Econometrics (2014) to integrate these type of reduction options in a MAC curve.

Based on a literature review (De Jong, et al., 2010) (PBL & CE Delft, 2010) (VTPI, 2021), we have selected a set of (long-term) fuel price elasticities to estimate the MAC curve. For passenger cars, a fuel cost elasticity of -0.7 has been used for petrol cars and -0.6 for diesel cars[26]. For vans and heavy goods vehicles, a fuel price elasticity of -0.4 has been applied. These elasticity values are in line with (but a bit more conservative than) the values used in recent studies on emission trading for road transport like Cambridge Econometrics (2014)and DIW (2020). Both studies use a fuel price elasticity of -0.7 for all transport. To investigate the impact of the elasticities selected on the MAC curve and hence the allowance price, a sensitivity analysis applying higher and lower elasticities is presented in Section 3.4.2.

A simplified version of the MAC curve for behavioural reduction options is shown in Figure 6, distinguishing separate curves for private transport by petrol vehicles, private transport by diesel vehicles and commercial transport (i.e. freight transport) by diesel vehicles.
The shape and slope of the curves depend on:
- *Level of fuel price elasticity*; The more price sensitive (higher elasticity) agents within a segment, the flatter the curve will be. Higher levels of CO_2 reductions can be achieved at lower allowance prices.
- *Size of the market segment in terms of total fuel consumption*; the higher the initial total fuel consumption within a segment, the flatter the curve will be. For example, as petrol passenger cars have a much larger market share than diesel passenger cars, the absolute reduction potential of applying a more fuel efficient driving style is much larger for petrol cars than for diesel cars. Hence, at the same abatement costs, more CO_2 reduction can be achieved by petrol passenger cars than by diesel passenger cars.

These two factors explain why the MAC curve for private transport by petrol cars is the flattest one (relatively high price sensitivity and largest segment), while the MAC curve for private transport by diesel cars is the steepest one (smallest segment).

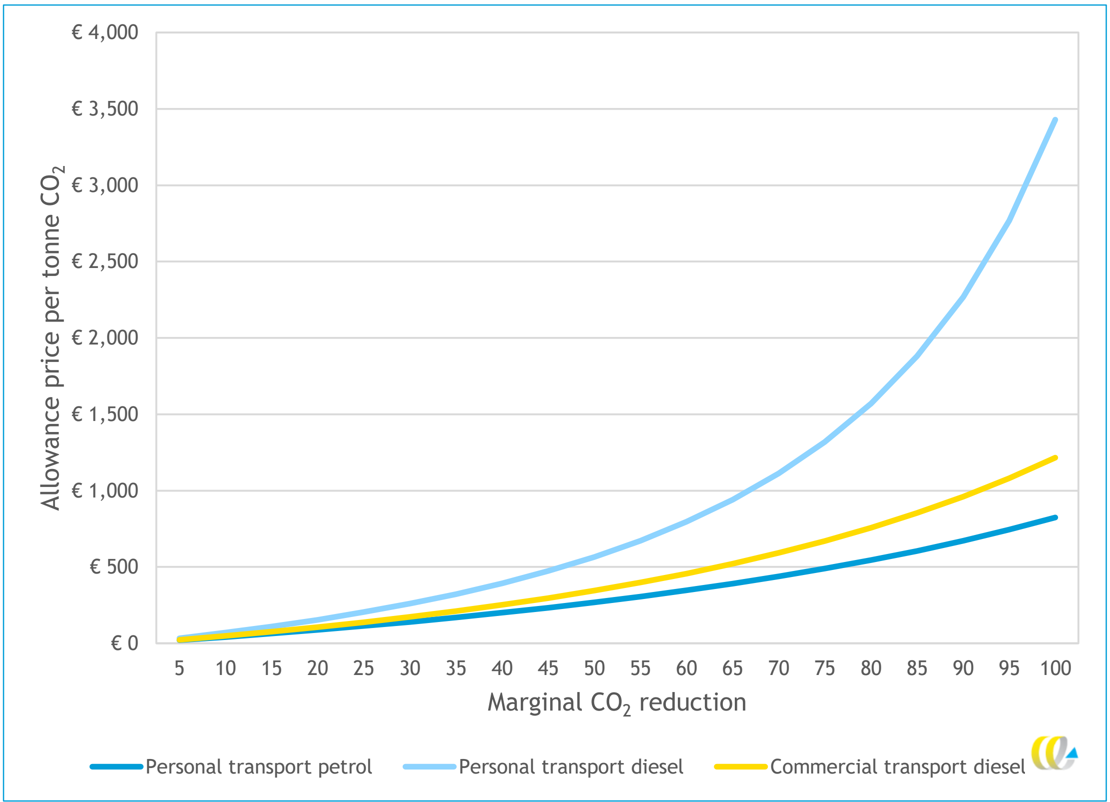
[23] Notice that fuel price elasticities represent a large number of responses to price changes and hence cover (almost) all behavioural reduction options mentioned above.

[24] The change in fuel demand is directly linked to the change in CO_2 emissions (by the CO_2 content of the fuel). Because of the same reason, fuel prices could be easily converted in CO_2 prices as well.

[25] As price elasticities are estimated based on empirical data, all types of factors affecting people's choices are (implicitly) taken into account, including the non-financial ones.

[26] The slightly lower fuel cost elasticity for diesel cars reflects the larger share of business use of diesel cars and the higher fuel efficiency compared to petrol cars.

Figure 6 - MAC curve for behavioural reduction in 2030



Uptake of full electric vehicles

The main reduction option that is not covered by the fuel price elasticity approach explained above is the uptake of zero-emission vehicles[27]. In the period up to 2030, the uptake of full electric vehicles will become an important alternative to reduce the CO_2 emissions of road transport[28]. Therefore, we have estimated the abatement costs and reduction potential of this option separately.

In order to analyse the relationship between CO_2 prices and the uptake of electric vehicles, we have applied a total cost of ownership (TCO) analysis using the TCO model COSTREAM. In this TCO analysis we have estimated the impact of CO_2 prices on the total costs of a vehicle over its lifetime. We have done this for both electric and fossil-fuelled vehicles (separately for private passenger cars, company cars, light commercial vehicles and trucks) for each year between 2025 and 2030 (in order to take the impact of scale and learning effects on the abatement costs of electric vehicles into account). By comparing the results

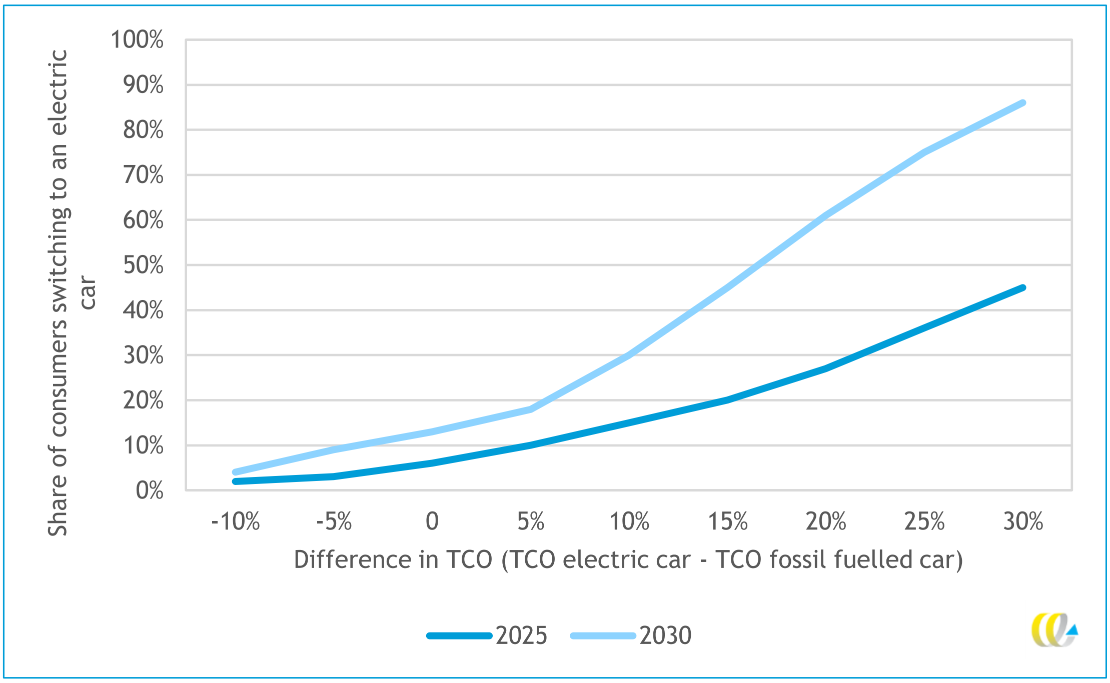
[27] The fuel price elasticities used are all estimated based on empirical data from before 2015. As zero emission vehicles were hardly available in the fleet before 2015, this response mechanism is not covered by the elasticities.

[28] Other zero-emission vehicle technologies are possible as well (e.g. hydrogen vehicles). But as these technologies are just in early phases of development and still have very high abatement costs (compared to electric vehicles), they will probably not be a suitable alternative for EVs in the period up to 2030. Therefore, these types of zero-emission vehicles have not been considered in this study.

for both types of vehicles, it becomes clear at which CO_2 prices electric vehicles become favourable from a financial point of view.

However, as we mentioned earlier, consumers do not always act economically rational and this is certainly the case with respect to the purchase of an electric vehicle. Consumer myopia and risk aversion are just two reasons why many consumers do not buy an electric vehicle although it has a lower TCO compared to a fossil-fuelled vehicle. For this reason, we have made use of indicators determined by RevNext (as input for the Dutch CarbonTax model), linking the share of consumers switching from a fossil-fuelled vehicle to an electric vehicle to the difference in TCO between both types of vehicles. For private passenger cars this is illustrated in Figure 7 for 2025 and 2030. It shows that in case the TCO of electric cars is higher than the TCO for fossil-fuelled cars, only a small share of the consumers will switch to an electric car (early adopters). Once the TCO of electric vehicles becomes financially favourable, an increasing share of consumer will switch, but there is still a significant part of the consumers who will choose for a fossil-fuelled car. Figure 7 also shows that in 2030 people are expected to be more positive about electric cars (as they are more familiar with them) and hence will sooner choose for such a car once it becomes financially favourable.

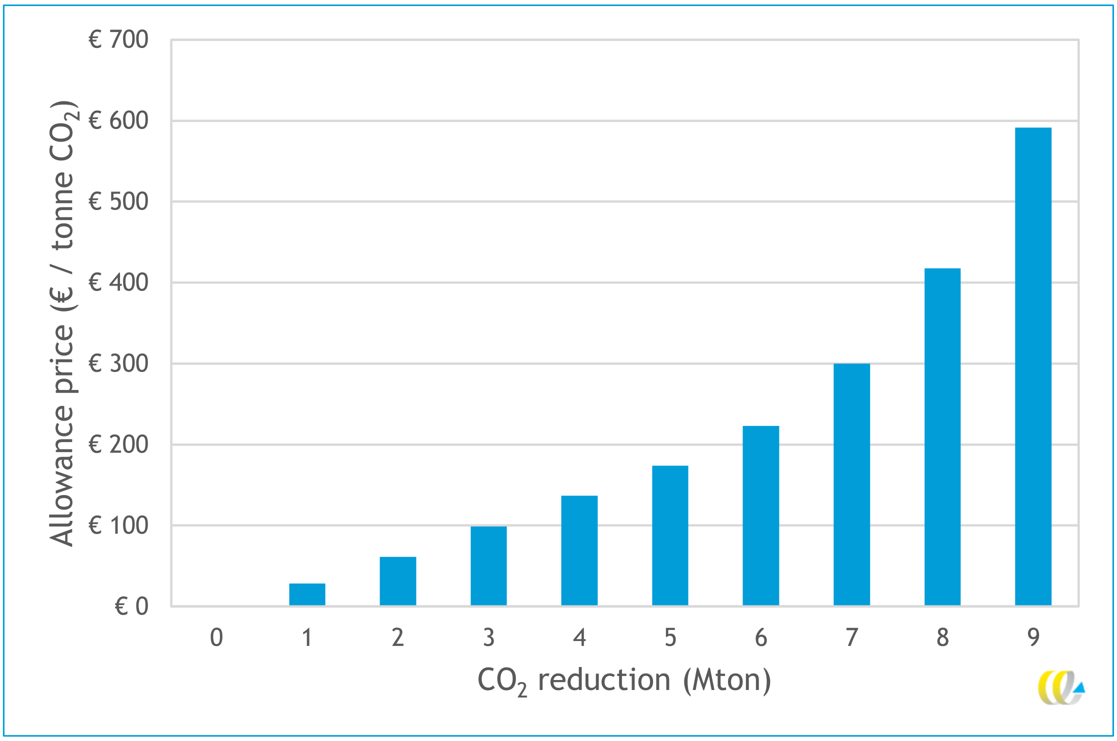
Figure 7 - Relationship between TCO difference of EV and fossil-fuelled cars and the share of private consumers choosing a new electric passenger car in 2030



Based on the extended TCO analysis described above, abatement cost curves for the uptake of electric vehicles have been composed for each year between 2025 and 2030. This means that the impact of the allowance price on the additional number of newly sold electric vehicles is estimated for each year. Based on this information and assuming that annual mileage is the same for electric and fossil-fuelled vehicles, the annual CO_2 mitigation due to the uptake of electric vehicles can be estimated for each allowance price.

For illustrative purposes the resulting MAC curve for newly sold passenger cars in 2030 is presented in Figure 8. As this MAC curve only includes electric vehicles sold in 2030, the potential emission reduction achieved by the uptake of these vehicles in 2030 is relatively small compared the baseline emissions of passenger cars (365 Mton)[29]. At the fleet level, the reduction potential in 2030 is larger, as also in the years before 2030 electric vehicles are entering the market. This effect is included in our analyses by considering annual MAC curves for the period 2025-2030.

Figure 8 - MAC curve for newly sold electric passenger cars for the year 2030



In our assessments, we have assumed that the supply of electric vehicles on the European market is sufficient to replace the newly sold fossil-fuelled vehicles by electric ones (see also Annex B.4.2).

Integrated MAC curve for the road transport sector

As a final step, we have combined the abatement cost curves for the three categories of reduction options in order to compose an integrated MAC curve for the road transport sector in the EU.

[29] Additionally, it should be considered that the impact of newly sold cars on the total annual fleet emissions is lower in the year the cars are sold, as not all cars are entering the fleet on the first of January. To take this effect into account we assumed that the annual emission reduction achieved by electric vehicles in the first year is 50% of their total annual reduction potential.

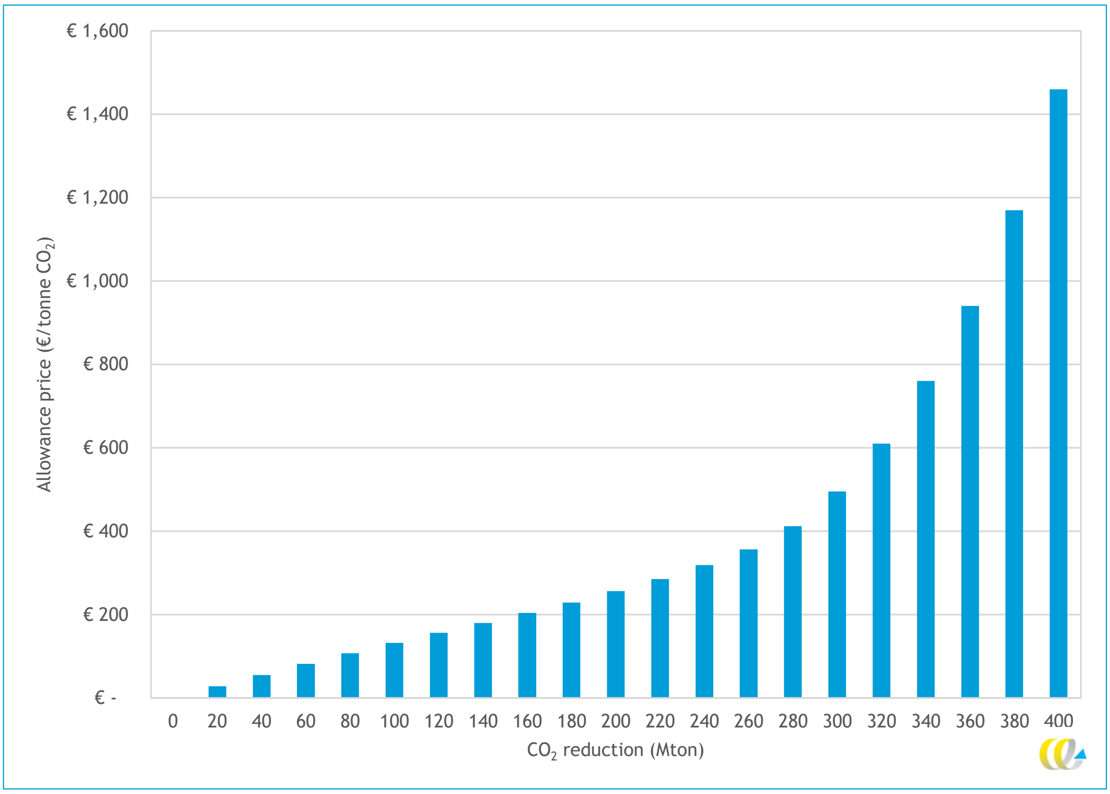
In short, the development of the integrated MAC curve consists of two main steps. First, the cumulative CO_2 reduction at each CO_2 price is calculated by summing up the reduction potential of the three separate types of reduction options at that price. This gives a first-order indication of the integrated MAC curve. In a second step we have corrected this MAC curve for the main interactions between the three types of reduction options.

More specifically, corrections have been made for the following interactions:
- Additional biofuels blended reduces the CO_2 content of fuels, reducing the reduction potential of uptake of EVs and behavioural measures[30].
- Additional biofuels blended increase fuel prices (as the production costs of biofuels are higher compared to fossil fuels), providing an additional incentive for the uptake of EVs or behavioural measures.
- Additional uptake of EVs may decrease the reduction potential of (some) behavioural measures. For example, fuel efficient driving will result in less CO_2 reduction when there are more EVs in the fleet.

By correcting for these interactions, the final CO_2 reductions per CO_2 price are estimated in an iterative process.

A simplified version of the integrated MAC curve in 2030 is shown in Figure 9.

Figure 9 - Integrated MAC curve 2030



[30] For example, if the CO_2 content of fuels are lower, reducing fuel consumption by buying a more fuel efficient vehicle results in less CO_2 reduction.

3.4 Overview of estimated allowance prices

3.4.1 Estimated long-run allowance prices in 2030

The estimated allowance prices in the three ETS-RT cap scenarios are shown in Table 7. The bandwidths for these estimates are based on the various sensitivity analyses discussed in Section 3.4.2.These bandwidths provide a first, rough indication of the large uncertainties in the estimation of the allowance prices, caused by simplifications and uncertainties in the approach followed but also by the large variance in the projections of key factors affecting the allowance price (e.g. cost and availability of biofuels). Despite these uncertainties, we think the results of our analysis provide a good indication of the order of magnitude of the allowance price in the various scenarios.

Table 7 – Overview of estimated allowance prices in 2030

	S1: 11% CO_2 reduction	S2: 30% CO_2 reduction	S3: 55% CO_2 reduction
Allowance price (€/tonne CO_2)	€ 75 (€ 65-€ 90)	€ 220 (€ 180-€ 270)	€ 690 (€ 390-€ 1,025)

In S1, where a CO_2 reduction target of 11% is considered, the estimated allowance price in 2030 is € 75 (€ 65-€ 90) per tonne CO_2. At this allowance price, the blending rate of biofuels will only be slightly increased by fuel suppliers (from 7.5 to 9%), as is shown by Table 8. In other words, the contribution of biofuels in the total CO_2 reduction achieved in this scenario is relatively low (about 11%). This is due to the fact that on average higher allowance prices are required to make the blending of biofuels economically attractive.

The above stated allowance prices, however do have a significant impact on the TCO of electric vehicles compared to that of cars powered by fossil fuels. Consequently, there is a significant impact on the number of newly sold electric vehicles in the EU. For example, in 2030 the share of electric passenger cars in total car sales increases from 30 to 42% (and for LCVs/light HGVs from 19 to 26%). However, the impact on the total number of electric vehicles in the fleet (and hence the contribution of EVs in the total CO_2 reduction in 2030) is smaller, as the newly sold vehicles in 2025-2030 are only a part of the total vehicle fleet in 2030[31]. Finally, the largest part of the CO_2 reduction in S1 (about 70%) is achieved by the behavioural reduction options (like reductions in transport demand, modal shift, and shifts to fuel-efficient conventional vehicles). In other words, generally behavioural reduction options will dominate for allowance prices in the range of € 65–€ 90, because the average abatement costs of other options are higher.

The estimated allowance price in S2 (30% CO_2 reduction) is € 220 (€ 180–€ 270) per tonne CO_2. Compared to S1, particularly the use of biofuels increases significantly which results in an average blending rate of 21%. This rise can be explained by the fact that at this allowance price, it is for a significant share of biofuels economically profitable to be added to the fuel mix. As a consequence, the share of biofuels in the total CO_2 reduction achieved in S2 is significantly higher than in S1 (39% vs. 11%). The increase in the uptake of electric vehicles is also considerably higher than in S1. For example, more than 50% of all newly sold passenger cars in 2030 in the EU are estimated to be fully electric. However, as mentioned before, the full potential of this impact on the shift to electric vehicles is expected on the longer run, when these vehicles have a larger share in the total vehicle fleet.

[31] An additional explanation is that the annual number of newly sold EVs has been increasing in the period 2025-2030 (due to increasing allowance prices and decreasing TCO of electric vehicles) reaching the highest level in 2030.

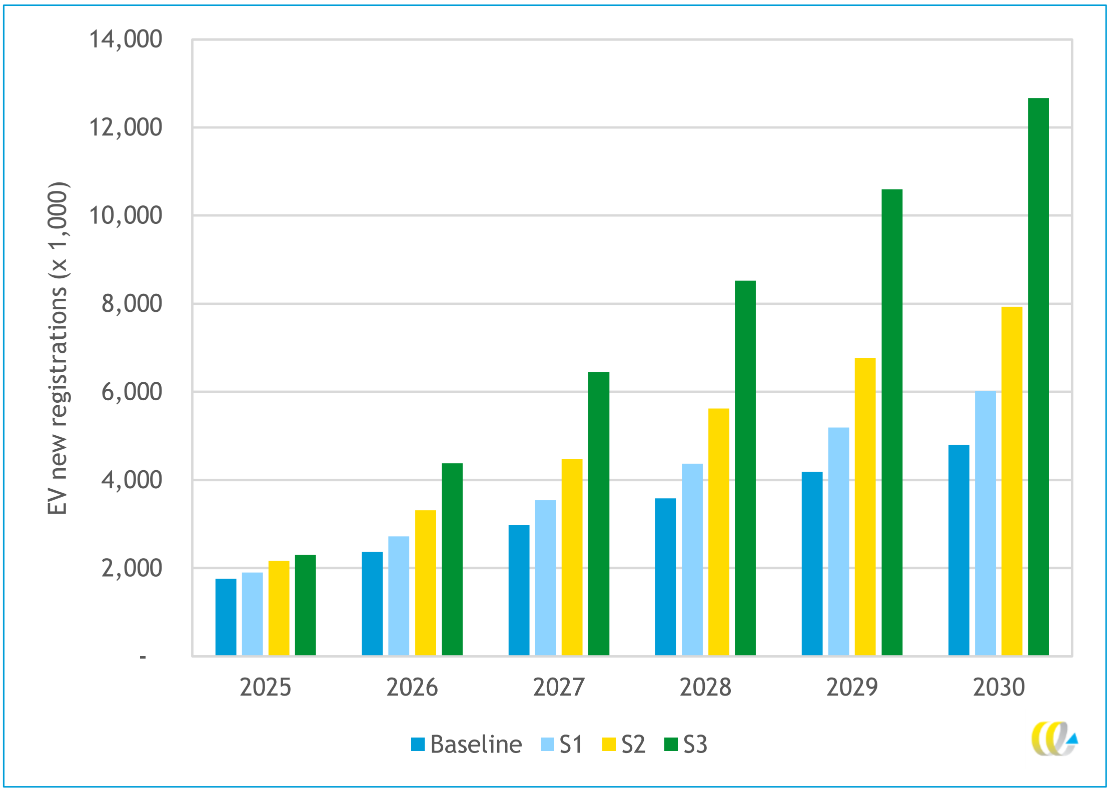
Finally, the estimated allowance price for S3 (55% CO_2 reduction) is high: about € 690 (€ 330 to € 1,025) per tonne CO_2. This reflects the high ambition level set by this scenario. At the same time it makes clear that expensive abatement options have to be taken to achieve the target of -55%. The full potential CO_2 reduction by blending biofuels (i.e. 150 Mton) is achieved in this scenario[32], resulting in average blending rates of 38%. The high allowance price also stimulates most (73%) buyers of new vehicles in 2030 to purchase an electric one, resulting in a doubling of the number of electric vehicles in the European fleet compared to the baseline scenario. Additionally, a significant share of CO_2 reduction has been achieved by the behavioural reduction options. As fuel prices will almost double in this scenario (see Section 5.2), people are expected to reconsider their travel behaviour drastically (e.g. by living closer to work or change jobs to work closer to home).

Table 8 - Reduction options applied in the various scenarios in 2030 (main analysis)

	S1: 11% CO_2 reduction	S2: 30% CO_2 reduction	S3: 55% CO_2 reduction
Share of reduction options in total CO_2 emission reduction achieved (percentage and Mton CO_2)			
Uptake of EV	18% (11)	14% (25)	14% (47)
Increased blending rates of biofuels	11% (6)	39% (69)	45% (150)
Behavioural reduction options	70% (41)	47% (82)	41% (134)
Biofuel blending rate (baseline = 7.5%)			
Blending rate (%)	9%	21%	38%
EV fleet information in 2030			
Cars sales share (baseline = 30%)	42%	54%	73%
Cars stock share (baseline = 10%)	12%	14%	18%
LCV/light HGV sales share (baseline = 19%)	26%	40%	73%
LCV/light HGV stock share (baseline = 8%)	8%	12%	20%

[32] As the 2030 abatement cost of the most expensive biofuels are estimated at € 360 per tonne CO_2 (see Section 3.3.3).

Figure 10 – Number of new EV registrations per year in the EU



3.4.2 Sensitivity analyses

The estimated long-run allowance price levels depend on several assumptions and uncertain input parameters. By applying some sensitivity analyses, we investigate the impact of the individual elements of the MAC curve on the allowance prices. As shown in Figure 4 the main elements of the MAC curve are:
- the uptake of electric vehicles;
- the costs and supply of biofuels;
- the fuel price elasticities.

Uptake of electric vehicles

The difference in TCO between an electric vehicle and a fossil fuel vehicle is an important driver for consumers to switch to an electric vehicle. In the main analysis (see Section 3.4.1), the impact of this TCO differential on the share of consumers switching to electric vehicles was based on estimations for the Dutch context. However, as discussed in Annex B.4, the Netherlands is a frontrunner in the uptake of electric vehicles and it is unclear whether the Dutch situation is representative to the European EV market. In case EV charging facilities in Europe are not on par with the Netherlands, relatively less buyers in Europe (than in the Netherlands) will opt for an electric vehicle at similar TCO levels of electric vehicles. Therefore, we have investigated the effect when a 10% larger TCO differential between electric vehicles and fossil-fuelled vehicles is required to stimulate the same percentage of consumers to switch from a fossil fuelled vehicle to an electric one (see also Table 36 in Annex B.4). Based on our expertise, we think this may be a realistic reflection of the differences between the Netherlands and other European countries.

Table 9 shows the allowance prices for the sensitivity analysis called 'Low EV' (compared to the main analysis). As expected, the lower uptake of EVs results in slightly higher allowance prices. The price impacts are, however, limited. This is mainly because in all three scenarios the contribution of EVs to the overall CO_2 reduction was already limited (as discussed in the Section 3.4.1). Therefore, only a limited amount of additional CO_2 reduction from biofuels and/or behavioural measures has to be achieved (see Table 10), resulting in just slightly lower marginal abatement costs.

Table 9 - Allowance prices for EV sensitivity setting

	S1: 11% CO_2 reduction		S2: 30% CO_2 reduction		S3: 55% CO_2 reduction	
	Main	Low EV	Main	Low EV	Main	Low EV
Allowance price (€/tonne CO_2)	€ 75	€ 82	€ 221	€ 230	€ 690	€ 700

Table 10 - Reduction options applied in the various scenarios in 2030 (EV sensitivity setting)

	S1: 11% CO_2 reduction		S2: 30% CO_2 reduction		S3: 55% CO_2 reduction	
	Main	Low EV	Main	Low EV	Main	Low EV
Share of reduction options in total CO_2 emission reduction achieved (percentage and Mton CO_2)						
Uptake of EV	18% (11)	12% (7)	14% (25)	11% (19)	14% (47)	14% (46)
Increased blending rates of biofuels	11% (6)	13% (8)	39% (69)	41% (73)	45% (150)	45% (150)
Behavioural reduction options	70% (41)	75% (43)	47% (82)	48% (84)	41% (134)	41% (136)
Biofuel blending rate (baseline = 7.5%)						
Blending rate (%)	9%	9%	21%	22%	38%	38%
EV fleet information in 2030						
Cars sales share (baseline = 30%)	42%	22%	54%	31%	73%	54%
Cars stock share (baseline = 10%)	12%	6%	14%	8%	18%	12%
LCV/light HGV sales share (baseline = 19%)	26%	10%	40%	18%	73%	42%
LCV/light HGV stock share (baseline = 8%)	8%	4%	12%	6%	20%	11%

Costs and supply of biofuels

The reduction potential for increased blending rates of biofuels is high, but the availability of biofuels to the EU road transport sector is very uncertain. This uncertainty applies also to the potential cost reduction for the production of biofuels. Learning effects may be large especially when large volumes of biofuels are deployed.

As discussed in Annex B.2, there are only theoretical predictions for the maximum supply of (sustainable) biofuels for transport. The amount available in practice depends on the demand from other sectors and targets set by policy makers. In order to investigate the allowance price impact of both the availability of biofuels to the EU road transport sector and the production costs of biofuels, two alternative biofuel settings are investigated (see Table 11):

- *Low setting*: it is (arbitrarily) assumed that 25% instead of 50% of the total biomass potential available in Europe can be used to produce biofuels for road transport. This will result in lower scale and learning impacts and hence higher biofuel costs. Based on IEA (2020b) it is estimated that the abatement costs per tonne in 2030 equal € 50-€ 400 per tonne in the low biofuel setting (instead of € 0–€ 365 per tonne in the main analysis).

— *High setting*: it is (arbitrarily) assumed that 75% instead of 50% of the total biomass potential available in Europe can be used to produce biofuels for road transport. Loosely based on Daniëls & Koelemeijer (2016), abatement costs of € 0 to € 300 are estimated for this scenario.

These two scenarios are expected to be relatively optimistic/pessimistic on the availability and costs of biofuels and hence assessing these scenarios is considered useful to show the range in impacts these parameters may have on the allowance price.

Table 11 - Biofuels availability and abatement costs in the various biofuel settings

2030	Low setting	Main analysis	High setting
Total available biofuel reduction potential (Mton CO_2)	75	150	225
Abatement costs range (€/tonne CO_2) in 2030	50-400	0-365	0-300

Table 12 shows the allowance prices for the low and high biofuel settings.

Table 12 - Allowance prices for optimistic and pessimistic biofuel setting

	S1: 11% CO_2 reduction			S2: 30% CO_2 reduction			S3: 55% CO_2 reduction		
	Main	Low biofuel	High biofuel	Main	Low biofuel	High biofuel	Main	Low biofuel	High biofuel
Allowance price (€/tonne CO_2)	€ 75	€ 80	€ 70	€ 220	€ 270	€ 180	€ 690	€ 1,025	€ 390

As expected a more positive ('High') biofuel setting decreases the allowance price since more emission reduction can be achieved for less costs via biofuels (also resulting in higher blending rates). This impact is highest in S3, because in that scenario of the main analysis all biofuels available were actually used. As a consequence of relaxing the supply constraint much more biofuels are used in S3 (resulting in blending rates of 45%), leading to significantly lower allowance prices (as the use of biofuels is cheaper than the additional uptake of EVs or behavioural measures). Due to this increased use of biofuels, less uptake of EVs and behavioural reduction options are expected, as is shown by Table 13. Particularly in S3, the uptake of electric vehicles is reduced significantly.

The low biofuel setting leads to a reduction of the biofuel blending rate (particularly in S3, as there the reduced supply of biofuels is a binding constraint, implying that a significant share of biofuel use is replaced by the more expensive marginal reduction options of EV uptake and behavioural measures), resulting in higher allowance prices.

Table 13 - Reduction options applied in the various scenarios in 2030 (biofuels sensitivity setting)

	S1: 11% CO_2 reduction			S2: 30% CO_2 reduction			S3: 55% CO_2 reduction		
	Main	Low	High	Main	Low	High	Main	Low	High
Share of reduction options in total CO_2 emission reduction achieved (percentage and Mton CO_2)									
Uptake of EV	18% (11)	19% (11)	17% (10)	14% (25)	17% (29)	12% (22)	14% (47)	19% (63)	11% (35)
Increased blending rates of biofuels	11% (6)	6% (3)	19% (11)	39% (69)	25% (44)	5% (89)	45% (150)	23% (75)	66% (217)
Behavioural reduction options	70% (41)	75% (44)	64% (37)	47% (82)	58% (103)	38% (67)	41% (134)	59% (195)	24% (78)

	S1: 11% CO_2 reduction			S2: 30% CO_2 reduction			S3: 55% CO_2 reduction		
	Main	Low	High	Main	Low	High	Main	Low	High
Biofuel blending rate (baseline = 7.5%)									
Blending rate (%)	9%	9%	10%	21%	18%	24%	38%	27%	45%
EV fleet information in 2030									
Cars sales share (baseline = 30%)	42%	43%	42%	54%	58%	50%	73%	86%	61%
Cars stock share (baseline = 10%)	12%	12%	12%	14%	15%	14%	18%	20%	16%
LCV/light HGV sales share (baseline = 19%)	26%	26%	25%	40%	46%	35%	73%	90%	51%
LCV/light HGV stock share (baseline = 8%)	8%	9%	8%	12%	13%	11%	20%	23%	15%

Fuel price elasticities

To derive the abatement cost curve for behavioural reduction options a set of fuel price elasticities was used. In this sensitivity analysis we investigate the impact of these elasticity values on the estimated allowance prices. Therefore, we have constructed a range of elasticity values, based on values found in the literature[33] (see Table 14). The low and high elasticities thus represent a pessimistic and optimistic setting for the uptake of behavioural reduction options.

Table 14 - Range for long run elasticities derived from the literature

	Low	Average	High
Personal transport			
Petrol	-0.6	-0.7	-0.8
Diesel	-0.5	-0.6	-0.7
Commercial transport			
Diesel	-0.3	-0.4	-0.5

Table 15 shows the results when lower and higher fuel elasticities are applied.

Table 15 - Allowance prices for the low and high elasticities

	S1: 11% CO_2 reduction			S2: 30% CO_2 reduction			S3: 55% CO_2 reduction		
	Main	Low elasticities	High elasticities	Main	Low elasticities	High elasticities	Main	Low elasticities	High elasticities
Allowance price (€/tonne CO_2)	€ 77	€ 88	€ 68	€ 221	€ 240	€ 205	€ 690	€ 890	€ 560

As expected, the allowance price increases in all scenarios in case lower fuel price elasticities are applied in the calculations. As consumers are assumed to be less price sensitive, higher allowance prices are required to incentivise behavioural reduction options. By the same kind of reasoning it can be explained that higher fuel price elasticities result in lower allowance prices.

[33] Studies reviewed for this purpose include DIW (2020), De Jong et al. (2010), PBL & CE Delft (2010), VTPI (2021).

In general, the impacts on allowance prices are relatively small in S1 and S2. The reduction achieved by behavioural reduction options do change a bit, but it is replaced by (or replacing) CO_2 reduction through additional EVs or biofuels blended. As the differences in marginal abatement cost are limited at these reduction levels, the impact on allowance prices is rather small. In S3, however, the price impacts are larger (in the order of 20-30%), because of two reasons:

- The uptake of biofuels is inflexible in this scenario (because of the binding constraint on supply of biofuels), such that less (additional) reduction options are left. As a consequence, there are less alternatives to replace (or to be replaced by) CO_2 reductions through behavioural reduction options, resulting in more severe price impacts.
- The marginal costs of EVs are rather high in S3. A large share of consumers already buys an electric vehicle in S3 and hence the financial incentives required to convince also laggards to purchase an electric vehicle is relatively high.

Table 16 - Reduction options applied in the various scenarios in 2030 (fuel price elasticity sensitivity setting)

	S1: 11% CO_2 reduction			S2: 30% CO_2 reduction			S3: 55% CO_2 reduction		
	Main	Low	High	Main	Low	High	Main	Low	High
Share of reduction options in total CO_2 emission reduction achieved (percentage and Mton CO_2)									
Uptake of EV	18% (11)	20% (12)	17% (10)	14% (25)	15% (26)	14% (24)	14% (47)	16% (52)	13% (43)
Increased blending rates of biofuels	11% (6)	15% (9)	8% (5)	39% (69)	45% (79)	34% (60)	45% (150)	45% (150)	45% (150)
Behavioural reduction options	70% (41)	64% (37)	75% (43)	47% (82)	4% (70)	53% (93)	41% (134)	39% (129)	42% (138)
Biofuel blending rate (baseline = 7.5%)									
Blending rate (%)	9%	10%	9%	21%	23%	20%	38%	38%	38%
EV fleet information in 2030									
Cars sales share (baseline = 30%)	42%	43%	41%	54%	55%	53%	73%	79%	68%
Cars stock share (baseline = 10%)	12%	12%	12%	14%	14%	14%	18%	19%	17%
LCV/light HGV sales share (baseline = 19%)	26%	27%	25%	40%	42%	38%	73%	82%	65%
LCV/light HGV stock share (baseline = 8%)	8%	9%	8%	12%	12%	12%	20%	22%	18%

3.4.3 Expectations on the allowance price after 2030

The development in allowance prices after 2030 depends on several factors. First of all, the ETS-RT cap set for the period after 2030. As we saw in the analysis of the allowance price for 2030, the cap has a huge impact on the long-run allowance prices. More ambitious ETS-RT caps for the period after 2030 will result in higher allowance prices. The cap for the period after 2030 is very uncertain, particularly as this is the outcome of political negotiations. However, it may be expected that the cap will be tightened up more in S1 than S3, as in the long run (towards 2050) the reduction targets in all scenarios should converge to the same point (i.e. zero emission road transport). Therefore, a more significant upward effect of future cap levels on allowance prices is expected for S1 than for S3. Second, the market penetration of electric passenger cars and vans may continue in the years after 2030. As their share in the total vehicle fleet will increase, their contribution to the overall CO_2 reduction target will increase as well. Given their relatively low (or maybe even negative) abatement costs in the years after 2030 (because of scale and learning effects), this will have a downward effect on the post 2030 allowance price. Third, on the longer term CO_2 reduction has to be taken in sectors that are currently having relatively high abatement costs, like long-distance road freight transport. This will have an upward effect on allowance prices. On the other hand, however, due to scale and learning effects the abatement costs of (technical) reduction options in these sectors may decrease.

Because of the opposing effects described above and the uncertainty in the post-2030 ETS-RT cap, it is hard to make a prediction on the allowance prices for the period after 2030. But we could imagine that the increasing market share of full electric passenger cars and vans may limit or maybe even stop the increase in allowance prices in the first period after 2030. This is most likely for S3 (and S2), as the ETS-RT caps in these scenarios may require relatively less additional tightening than S1 (as explained above). This is in line with the results shown by Cambridge Econometrics (2020)[34]. On the longer term (2040), for actors with relatively low abatement costs (e.g. passenger transport in urban areas) there likely is little additional potential to reduce emissions. Additional CO_2 abatement options have to be applied in sectors like long-distance freight transport. As explained above, this may have an upward effect on allowance prices, although this heavily depends on the development in abatement costs within these sectors.

3.5 Price volatility

In the previous sections the price setting of emission allowances in an ETS-RT was discussed for the long term. However, allowance prices within such a scheme may fluctuate on the short term (e.g. within a month or year), and even on a daily basis. This is exactly what you would expect in any liquid financial market. However, when these price changes become large and strong movements in allowance prices are seen in relatively short periods of time, this may become problematic. Such volatility in prices causes high levels of uncertainty at transport users, hampering their investment in CO_2 reduction options (e.g. a more fuel efficient vehicle) (Betz, 2006) (Al Khaja, 2014) which may lead to higher long-run allowance prices as well.

The risk of price volatility in the short to medium term (up to a year) is probably small in an ETS-RT. Total fuel consumption of road transport is rather constant in the short run[35], and hence the short run demand for allowances by the road transport sector is likely to be stable. However, it should be noticed that an implicit mechanism to address any volatility that may arise (e.g. due to external factors) is missing because of the limited number of short-run CO_2-reduction options[36].

On the very short term (day-to-day), high price volatility may arise in an ETS-RT in case relatively small initial changes in prices quickly become large swings (CE Delft, et al., 2014). This may, for example, occur if there is a low level of liquidity in the market (i.e. it becomes difficult to match buyers and sellers), e.g. due to a low number of market

[34] Cambridge Econometrics consider a scenario with 43% CO_2 reduction in 2030 and 63% CO_2 reduction in 2050 (both compared to 2005 levels). In this scenario they expect constant or even slightly decreasing allowance prices after 2030. This is explained by relatively high allowance prices in 2030 which result from relatively expensive short-term investments in low-carbon transport options. But on the longer run, the speed in additional CO_2 reductions in the transport sector can maybe slowed down a bit (as the 2050 target requires on average lower annual reduction rates), which may have a downward pressure on allowance prices.

[35] The average fuel efficiency of vehicles is constant in the short run and also a significant part of transport demand (e.g. commuting) is relatively insensitive to short-run price changes).

[36] For example, in the current EU ETS the power sector can quickly adapt the demand for allowances by switching between gas-fired and coal-fired power stations. In case the allowance price is (very) high, coal-fired power stations are switched off and replaced by gas-fired stations. This results in a lower demand for allowances and hence the allowance price will fall. In the road transport sector, these kinds of mechanisms are lacking.

operators (Betz, 2006). In such a situation, a small price shock could lead to panic buying or selling if individual traders think that they may be unable to buy or sell allowances in the future. The level of knowledge of the trading parties is another example that may facilitate short run price volatility, for example as less-informed traders tend more often to follow the actions of others ('herd' mentality), leading to larger swings in allowance prices. At this point, however, it is unlikely that the above-mentioned factors causing (excessive) price volatility will be very relevant for an ETS RT. First of all, as the trading entities are located upstream, transport users are not directly confronted with day-to-day changes in fuel prices. Probably, tax warehouse keepers or fuel suppliers will 'smoothen' the daily price fluctuations by setting fuel prices on a longer term. Secondly, transport users are already used to some fluctuations in fuel prices, due to the volatility in the oil price (which is, on the longer term, passed on to consumers).

Based on the findings above, we expect that the risk on adverse impacts of price volatility on the effectiveness of an ETS-RT is relatively small. However, the road transport sector will probably lack a mechanism to address any price volatility that may arise. Therefore, it may be good to consider this issue in more detail once the actual design of an ETS-RT is developed.

4 Interaction with other policies

4.1 Introduction

Both at the European and the national level, several policies aiming at (or contributing to) the reduction of GHG emissions of road transport are already in place or planned to be implemented in the near future. At the European level, CO_2 standards for new vehicles and regulation on the share of renewable energy in transport are important policies in this respect. At the national level, fiscal measures, fuel taxes and regulatory measures like zero emission zones are examples of relevant policies. The way these existing measures interact with an ETS-RT is the topic of this chapter.

In Section 4.2, we first discuss the main interactions between an ETS-RT and European policies and reduction targets. Next, we describe the interactions with fuel taxation at the national level and particularly the option to lower fuel taxes in order to (partly) neutralise the impact of an ETS-RT on the transport costs (Section 4.3). Finally, in Section 4.4 we briefly discuss the interactions with other national policies, particularly focussing on the risk of the waterbed effect (i.e. additional reduction measures applied at the national level will lead to less reductions elsewhere in the EU).

4.2 Interaction with EU policies and reduction targets

4.2.1 Overview of the EU reduction targets and main EU policies

EU GHG emission reduction targets

The EU has set an overall GHG emission reduction target of 40% in 2030 compared to 1990 levels (European Council, 2014). In September 2020, the European Commission proposed to tighten this objective to at least 55% reduction in 2030 compared to 1990 levels (EC, 2020c). This proposal was approved by the European Council in December 2020.

In addition to the overall GHG emission reduction target, the EU has also set a reduction target for those sectors that fall outside the scope of the EU ETS (i.e. transport, built environment, agriculture, non-ETS industry and waste). Under this so-called Effort Sharing Regulation (ESR), an EU-wide reduction target of 30% (compared to 2005 levels) was set (no separate targets were set for the different sectors) (EU, 2018b). This overall target was translated into annual national targets for the period 2021-2030. The 2030 target for the Netherlands is set at 36% reduction. It is likely that the tightening of the overall European reduction target to 55% will result in tightening (to some extent) the ESR target as well.

EU CO_2 policies in the road transport sector

At the EU level, several policies have been implemented that contribute to achieving the reduction targets discussed above. The main policies for the road transport sector are:

- CO_2 *performance standards for cars, vans and HGVs*; a cornerstone of the European climate change policy for the road transport sector is the CO_2 regulation of vehicles. This instrument sets mandatory targets for the average fleet CO_2 emissions of passenger cars, vans and large lorries newly registered in the EU. The scope of the CO_2 standards will probably be extended in due course to other heavy duty vehicles (i.e. small lorries, buses, coaches). Both the standards for passenger cars and vans are combined with specific mechanisms for zero and low emission vehicles, in order to accelerate their market uptake.

- *Renewable Energy Directive (RED) (Directive 2009/28/EC)*; the RED sets a target for each Member State of a 10% share of renewable energy in transport by 2020. In the recast of the RED (RED 2), a target of a 14% share of renewable energy in transport in 2030 has been set. Additionally, the RED together with the Fuel Quality Directive (FQD), regulates the sustainability of biofuels, among other things by limiting the use Member States are allowed to make of biofuels with indirect land use effects.
- *Fuel Quality Directive (FQD) (Directive 2009/30/EC);* the FQD requires a reduction of the greenhouse gas intensity of transport fuels by at least 6% (compared to all transport fuels used in 2010), to be achieved by using less CO_2 intensive fuels (e.g. biofuels, electricity, less carbon intense fossil fuels and renewable fuels of non-biological origin) and reducing the CO_2 emissions at the extraction stage of fossil fuel feedstocks. As mentioned above, the FQD also regulates the sustainability of biofuels, together with the RED.
- *Energy Taxation Directive (ETD) (Directive 2003/96/EC);* this Directive provides a European framework for taxing motor fuels, heating fuels and electricity. It sets mandatory minimum levels for fuels taxes that should be used by all EU Member States, but also mandatory and optional exemptions from these taxes (e.g. for energy use by commercial aviation or shipping).
- *Car labelling Directive (Directive 1999/94/EC)*; this Directive aims to inform consumers on the fuel efficiency and CO_2 emissions of new cars, in order to help them to buy or lease cars that use less fuel and emit less CO_2. To achieve this objective, this Directive requires that EU Member States ensure that relevant information on these issues is provided to consumers, among other things by a label showing a car's fuel-efficiency and CO_2 emissions.
- *Clean Vehicle Directive (Directive 2009/33/EC)*; this Directive requires that energy and environmental impacts linked to the operation of vehicles over their whole lifetime are taken into account in public procurement of all road transport vehicles. Two options are offered to meet this requirement: including energy and environmental impacts as award criteria in the purchasing procedure, or setting technical specifications for energy and environmental performance.
- *Alternative fuel infrastructure Directive (Directive 2014/94/EC)*; this Directive requires the EU Member States to provide a minimum infrastructure for alternative fuels (i.e. electricity, Liquid Natural Gas (LNG), Compressed Natural Gas (CNG) and hydrogen) and to develop national frameworks to do so. Furthermore, Member States have to apply common technical specifications for recharging and refuelling infrastructure and to ensure that clear user information is available.
- *Eurovignette Directive (Directive 2011/76/EU);* although the use of distance-related tolls or time-based user charges (vignettes) for heavy goods vehicles is not mandatory for European Member States, this Directive provides some framework conditions that should be met in case these instruments are implemented at the national level. Such tolls and vignettes may contribute to the reduction of CO_2 emissions of HGVs, particularly as it may reduce transport volumes. Furthermore, there is a proposal to introduce a variation of charges according to CO_2 emissions of HGVs, which would increase the impact tolls and vignettes may have on CO_2 emission reductions.

4.2.2 Interaction with the Effort Sharing Regulation

The coverage of road transport by both the Effort Sharing Regulation (ESR) and an ETS-RT may result in several interactions. First, introducing an ETS-RT in addition to the ESR may strengthen the EU's control over the CO_2 reduction achieved in the European road transport sector. This is mainly because an ETS-RT has stronger enforcement at the EU level compared to ESR (EC, 2020a). An ETS-RT addresses the emitting entity more directly and hence enforcement mechanisms in case of non-compliance (including financial penalties) are directly applied to these emitting entities. In the ESR, on the other hand, the compliance obligation is on each Member State, through additional emission factors[37] and standard infringement procedures. Therefore, the EU has more direct control on speed and certainty of the CO_2 reduction achieved under an ETS-RT (at the EU level).

At the national level, an ETS-RT may contribute to achieve the national ESR targets in a more cost effective way (CE Delft, 2021). An ETS-RT provides an EU-wide minimum CO_2 price for road transport, stimulating transport users to take up cost effective reduction options. An ETS-RT, however, does not provide any certainty that the national targets will be met. This is particularly the case for countries with high ESR targets (like the Netherlands)[38]. Therefore, besides an ETS-RT, national policies (or additional EU policies) are required to meet the ESR targets in these countries.

Combining ESR and ETS-RT may adversely affect the cost efficiency of emission reduction (EC, 2020a). Regulating two different parties to reduce the same emissions may lead to potential inefficiencies. As Member States have to meet their national ESR targets, they may be incentivised to stimulate the uptake of domestic reduction options, even if the same level of reduction could be achieved against lower costs abroad. Another source of potential inefficiencies is the situation where road transport reduces more than needed to meet the national ESR target, allowing sectors not covered by the ETS-RT in the ESR to do less than what would be potentially cost-effective. This risk would be reduced as ETS-RT and ESR targets are more aligned or by implementing specific ambitious measures in these other ESR sectors.

Despite these potential inefficiencies by combining ESR and ETS-RT, there are also advantages of this policy mix. First, ambitious national policies implemented to meet the ESR targets may reduce allowance prices by limiting the emission reductions to be achieved under the ETS-RT. Second, national policies may address specific market failures that may hamper the efficient uptake of certain reduction options (see Section 4.4 for a more detailed discussion on both issues). Finally, national policies may have all kind of co-benefits (e.g. less congestion, improved traffic safety, less air pollution) that may addressed less efficiently by an ETS-RT.

4.2.3 Interaction with ambition levels of other EU policies

By implementing an ETS-RT, support for maintaining and particularly increasing the targets of existing policy instruments may decrease. For example, carmakers may argue that there is no need to tighten the CO_2 standards for passenger cars any further, as 'CO_2 emissions are dealt with in the ETS'. And also some Member States may become more reluctant to provide support for higher ambition levels of existing policy measures, for example because they are concerned about the combined effect of an ETS-RT and other EU policies on national industries or car owners in their country. One consequence of lowering the ambition levels

[37] A country missing its ESR target in year X by 1 million tonnes has to over-achieve its ESR target in subsequent year by 1.08 million tonnes.

[38] For countries with very low ESR targets (like Bulgaria) this issue is less relevant.

for other EU policies may be that the allowance price in the ETS-RT will increase, as more reduction options have be taken within the ETS-RT to achieve the reduction targets set for the transport sector. This may result in (increasing) resistance from transport users (and individual Member States), as they are confronted with higher fuel costs. Furthermore, the effectiveness of the entire policy mix may decrease, as other EU policies address market failures hampering the effectiveness of an ETS-RT (see Section 4.2.4).

It is very uncertain to what extent the ambition levels of other EU policies are undermined by implementing an ETS-RT. It will depend on the actual design of the scheme (and particularly on the cap set), but also on other objectives and political strategies of the individual Member States.

The other way around, more ambitious targets for other EU policies may reduce the additional contribution of an ETS-RT in achieving the overall CO_2 reduction objectives for road transport. More stringent CO_2 policies for road transport may also reduce the long-term allowance price, as was discussed in Section 3.2. We investigate these issues by showing the impact of more ambitious targets for the CO_2 performance standards and the RED (see the box below) on the ETS-RT cap required to meet the CO_2 reduction targets and the resulting ETS-RT allowance prices.

Overview of policy options for more ambitious targets for CO_2 performance standards and the RED

The analysis offered in Chapter 3 gives an insight into the effects of an ETS-RT if the ambition level of other policies remains unchanged/in line with today's policy baseline. In this chapter, we further investigate the effects of an ETS-RT for (significantly) higher ambition levels with regard to CO_2 performance standards and the RED. Together with I&W, we have developed both for the CO_2 performance standards and the RED two policy options with higher ambition levels. Policy options 1A) (CO_2-standards) and 2A) (RED) represent a more moderate increase in ambition at the European level, whereas 1B) (CO_2-standards) and 2B) (RED) represent a much more pronounced increase in ambition.

For the CO_2 performance standards the following options are considered:

- *Policy option 1A: In line with the 2030 European Climate Target Plan of the European Commission* (EC, 2020c), *a 50% reduction of the CO2 performance standards for passenger cars and LCVs in 2030 compared to the target of 2020 (95 g/km for passenger cars and 147 g/km for LCVs) is assumed.*
- *Policy option 1B: In line with the ambitions of the Dutch government* (I&W, 2021a) (I&W, 2021b), *a mandate for 100% sales of zero emission passenger cars in 2030 is set, and extended with an ambition for 100%* sales of zero emission vans. This requires new passenger car and LCV sales to comply to a 0 g/km standard.

For the RED, the following two options are considered:

- *Policy option 2A*: The Dutch policy target for the use of renewable energy in road transport in 2030[39] exceeds present requirements of the REDII. This target equals a share of 26.8% of renewables in 2030 which, after adjustments for double counting, yields a physical target of 13.1%. For this policy option we assume that other Member States will commit to the same level of ambition in 2030.
- *Policy option 2B*: In line with the 2030 European Climate Target Plan of the European Commission (EC, 2020c), we consider a 24% target of renewable energy in the fuel mix. We assume that this is a physical target (no double counting).

[39] In the National Climate Agreement of the Netherlands an ambition of 65 PJ renewable energy for the transport sector in 2030 is presented (Ministry of Economic Affairs and Climate Policy, 2019).

Effect of more ambitious targets for CO_2 performance standards

Based on an ex-ante evaluation of the CO_2 performance standards for passenger cars from 130 g/km to 95 g/km (Daniëls & Koelemeijer, 2016), we have calculated that for every percentage reduction of the CO_2 standards for cars, the total fleet emissions are reduced by 0.07% in the year the tighter standard is becoming effective[40]. By applying the same approach[41], we find that every percent reduction of CO_2 standards for LCVs results in 0.01% reduction of the total fleet emissions. Using these calculation rules, the relative change in LCV fleet emissions in 2030 is calculated[42]. Considering the targets for CO_2 performance standards in the baseline (37.5% reduction compared to 2020 levels for passenger cars and 31% reduction compared to 2020 levels for LCVs), the additional CO_2 reductions in 2030 for these vehicle categories is estimated.

Table 17 shows that the CO_2 reduction achieved in 2030 by Policy option 1A (50% lower CO_2 performance standards for passenger cars and vans compared to 2020 implemented in 2030) is about 7 Mton, while Policy option 1B (100% sales of zero emission cars and LCVs) results in about 31 Mton CO_2 reduction in the EU. The contribution of Policy option 1A in filling the policy gap in 2030 is relatively limited, ranging from 12% in S1 to 2% in S3. The main reason for the limited impact of this measure is that these targets become effective only in 2030. Therefore in 2030, still a very small share (about 4%) of the vehicle fleet will meet the more stringent targets. As new vehicles meeting the targets will penetrate the fleet in the years after 2030, the additional CO_2 reduction achieved by this measure will be significantly higher in, for example, 2035 or 2040. Policy option 1B has a more significant contribution in filling the policy gap, ranging from 53% in S1 to 9% in S3. As for Policy options 1A, the full additional effect of Policy option 1B will only be achieved in the years after 2030.
Higher CO_2 reductions in 2030 are theoretically also feasible by bringing forward the year in which the tightened standards become effective. Therefore, we have assessed the impacts of implementing Policy option 1A for 2025 for illustrative purposes in the following text box.

Table 17 – Mitigated CO_2 emissions and remaining emission reduction required due to different policy options for CO_2 performance standards (Mton in 2030)

	S1	S2	S3
Policy gap: required CO_2 emissions to meet the ETS-RT cap	58	176	331
CO_2 reduction of Policy option 1A		7	
CO_2 reduction of Policy option 1B		31	
Remaining emission reduction required with Policy option 1A	51	169	324
Remaining emission reduction required with Policy option 1B	27	145	300

The roughly estimated impact of more ambitious CO_2 performance standards on the ETS-RT allowance prices is shown in Table 18. In all ETS-RT Cap scenarios the allowance prices decrease compared to the main analysis (see Section 3.4), but the reductions are relatively small. The main reason is that in most scenarios the additional number of electric vehicles

[40] The reduction in the fleet emissions is mainly achieved by new cars entering the fleet in 2030, but to some extent also by the fact that in the years before cars with lower CO_2 emissions per kilometre are bought by consumers.

[41] Using results from Daniëls & Koelemeijer (2016) on the impact of a reduction of the CO_2 performance standards for LCVs from 175 g/km to 147 g/km.

[42] For example, 50% lower CO_2 standards for passenger cars result in ca. 3.5% (50 x 0.07%) lower emissions of the passenger car fleet in the year the standard is enforced.

or fuel-efficient vehicles in the fleet compared to the main analysis is limited[43], because of the reasons explained above. As a consequence, the policy gap (see Section 3.3.2) to be filled with an ETS-RT is only marginally reduced and hence so are the marginal costs of meeting the ETS-RT cap.

Table 18 – Development of allowance prices in response of more ambitious targets for CO_2 performance standards

	S1	S2	S3
Main analysis	€ 75	€ 220	€ 690
Policy option 1A	€ 72	€ 219	€ 675
Policy option 1B	€ 70	€ 212	€ 660

Illustrative case: Stricter CO_2 performance standards in 2025

By bringing forward the year by which the tightened CO_2 standards become effective, the CO_2 reduction of this measure in 2030 can be increased. To illustrate this, we have assessed the impacts of an EU-wide implementation of 50% lower CO_2 performance standards for passenger cars and LCVs from 2025 onwards (compared to the targets of 95 g/km and 147 g/km in 2020). Notice that this is an illustrative case only, as it seems not very realistic to implement such a significant tightening of the standards in such a short time frame.

To estimate the CO_2 emission reduction in 2030 of this policy option, the same approach as for Policy options 1A and 1B has been applied. This implies that again we assume that for every percent reduction of the CO_2 performance standard for cars (LCVs), the total transport emissions decrease by 0.07% (0.01%). Assuming a linear renewal of the fleet, we can add up these figures for every year between 2025 and 2030. We do take into account that the baseline emissions already consider the more stringent CO_2 performance standards for cars and vans in 2030 (respectively 37.5% and 31%). Overall, we find that stricter CO_2 standards in 2025 reduce total CO_2 emissions of road transport in 2030 by 21%, i.e. 128 Mton.

As shown by Table 19, this illustrative policy option will result in sufficient CO_2 reduction to meet the reduction target in S1. Also in the other scenarios, this option contributes a substantial part to the required emission reduction. In S2 this contribution is 73% and in S3 the contribution is 39%. We have also roughly estimated the impact on the ETS-RT allowance prices. In S1, the allowance price will be 0, as the reduction target is met by the tightened standards. In S2 and S3, the allowance prices are significantly reduced as the additional uptake of electric and fuel efficient fossil fuelled cars compared to the situation that only an ETS-RT is implemented (particularly in the first years of the period 2025-2030), has a downward pressure on the demand for allowances and hence the allowance price.

Table 19 - Mitigated CO_2 emissions and remaining emission reduction required to meet the reduction target (Mton in 2030)

	S1	S2	S3
Policy gap: required CO_2 emissions to meet the ETS-RT cap	58	176	331
CO_2 reduction of stricter CO_2 performance standards in 2025		128	
Remaining emission reduction required with stricter CO_2 performance standards in 2025	0	48	203

43 For example, in S3 the share of electric cars in the vehicle fleet increase from 18% in the main analysis to 19.5% in the analysis of Policy option 1B.

Table 20 - Estimated allowance prices for the illustrative policy option

	S1	S2	S3
Main analysis	€ 75	€ 220	€ 690
Policy option	€ 0	€ 95	€ 315

Effect of more ambitious targets for renewable energy in transport (RED)

The targets for the use of renewable energy in transport can be met by applying two different types of renewable energy: (advanced) biofuels and renewable electricity.
The use of renewable electricity, instead of non-renewable electricity, does not contribute to meeting the CO_2 emission reduction targets for the transport sector, as in the official accounts these emissions are reported as part of the energy sector. Therefore, when estimating the effect of more ambitious renewable energy targets on CO_2 reduction in road transport we exclude renewable electricity. This is complex because of the various multipliers that exist for advanced biofuels and renewable electricity. Therefore, we have assumed that for both policy options the share of biofuels not based on renewable electricity in the total amount of (physical) renewable energy is the same as in the baseline (based on (EC, 2020a)). The resulting biofuels deployment for both policy options is shown in Table 21.

Table 21 – Biofuels contribution 2030

	Baseline scenario	Policy option 2A: 13.1% target	Policy option 2B: 24% target
Physical share of renewable fuels in road transport	11.5%	13.1%	24%
Physical contribution of biofuels	7.5%	8.5%	15.7%

The increased use of biofuels (leading to higher blending rates of biofuels) resulting from both policy options have a primary effect due to the lower carbon content of fuels and a secondary effect due to the reduction in fuel consumption as a response to fuel price increases (as the production costs of biofuels exceed the production costs of fossil fuels). The CO_2 impact of the latter effect has been estimated by using fuel price elasticities[44].

Table 22 shows the CO_2 reduction following from the increased blending rate of biofuels. Increasing the physical target to 13.1% renewable energy (Policy option 2A) is estimated to result in 8 Mton additional CO_2 reduction (compared to the baseline). This relatively limited additional CO_2 reduction can be explained by the fact that the (physical) blending rate of biofuels only slightly increases compared to the baseline (8.5% vs. 7.5%). The estimated reduction due to a physical target of 24% renewable energy (Policy option 2B) is 65 Mton. By implementing Policy option 2B, the CO_2 reduction target in S1 could be met. In S2 and S3, however, additional policy actions (like an ETS-RT) are still required to meet the CO_2 reduction targets. Implementing Policy action 2A is insufficient to meet the reduction targets in any of the three ETS-RT Cap scenarios.

[44] See Section 3.3.3 for an overview of the fuel price elasticities used.

Table 22 – Mitigated CO_2 emissions and remaining emission reduction required due to higher RED targets in 2030 in the EU (Mton)

	S1	S2	S3
Policy gap: required CO_2 emissions to meet the ETS-RT cap	58	176	331
CO_2 reduction of Policy option 2A		8	
CO_2 reduction of Policy option 2B		65	
Remaining emission reduction required with Policy option 2A	50	168	323
Remaining emission reduction required with Policy option 2B	0	111	266

The estimated impact of the higher renewable energy targets on the ETS-RT allowance prices are shown in Table 23. In the first ETS-RT Cap scenario, a small reduction in the allowance price is achieved by implementing Policy option 2A. Implementing Policy option 2B even results in an allowance price of 0, as no additional reduction is required by an ETS-RT. For the more ambitious scenarios (S2 and S3) more ambitious RED targets have no effect on ETS allowance prices. This is because the amount of biofuels needed in an ETS-RT to achieve CO_2 reduction of 30% (S2) or 55% (S3) is larger than what is achieved by more ambitious RED targets in Policy option 2A and 2B[45].

Table 23 – Allowance prices after introduction higher RED targets

	S1	S2	S3
Main analysis	75	220	690
Policy option 2A: 13.1% target	71	220	690
Policy option 2B: 24% target	0	220	690

Combined effect of CO_2 performance standards and RED targets

As currently the CO_2 performance standards and the RED regulation exist side by side, tightening the targets for these policies might take place simultaneously as well. On request of the I&W, we therefore have estimated the total reduction potential of Policy options 1B 50% lower CO_2 performance standards for passenger cars and vans compared to 2020) and 2A (physical target of 24% renewable energy in transport) for the EU. The results of this analysis are presented in Table 24.

Table 24 – Combined EU-wide emission reduction effect of Policy options 1B and 2A in 2030 (Mton)

	S1	S2	S3
Required CO_2 emissions to meet the ETS-RT cap	58	176	331
Combined CO_2 reduction of Policy option 1B and 2A[a]		38	
Remaining emission reduction per scenario	20	138	293

[a] Just adding the CO_2 reduction potential of Policy option 1B and 2A results in double counting, because the reduction potential of increasing the share of biofuels in fuel blends decreases as there are more zero-emission vehicles in the fleet (and vice versa). We have corrected for this interaction between these policy options.

[45] As shown in Section 3.4.1, the uptake of biofuels under S2 and S3 for an ETS-RT is estimated to result in 69 and 150 Mton of CO_2 reductions in 2030 , respectively. This demand for biofuels is higher than the additional use of biofuels due to Policy option 2A and 2B.

We find that the introduction of the policies as stated in the aforementioned Policy options 1B and 2A are insufficient to achieve the required emission reductions in all scenarios. Additional policy action (e.g. an ETS-RT) is required to meet the emission targets. However, in S1 almost two third of the required emission reduction is achieved with both policies combined. In S2 and S3 this combined contribution is 22% and 11%, respectively. Table 25 provides rough estimates for the effect of the combined policy options on the allowance prices. The combined introduction of policy options 1B and 2A has a decreasing effect on the allowance prices because more emission reduction efforts are taken than if there was only an ETS-RT in place.

Table 25 - Allowance prices in case of combined introduction of Policy option 1B and 2A in 2030

	S1	S2	S3
Main analysis	€ 75	€ 220	€ 690
Combined EU-wide emission reduction effect of Policy option 1B and 2A in 2030	€ 58	€ 212	€ 660

4.2.4 Impact on effectiveness and efficiency of CO_2 reduction in road transport

Combining an ETS-RT with the current EU CO_2 reduction policies for road transport may affect the effectiveness and efficiency of the overall CO_2 reduction in road transport in different ways. In general, three relevant issues can be considered in this respect:
- an ETS-RT incentivises other reduction options compared to current EU policies;
- current policies address market failures hampering the effectiveness of ETS-RT;
- impact of other CO_2 reduction policies on allowance prices.

These three issues are discussed in more detail below.

An ETS-RT incentivises other reduction options than current EU policies

An ETS-RT and the other European CO_2 reduction policies all contribute to the same overall objective: lowering the CO_2 emissions of road transport in Europe. However, an ETS-RT complements the other policies by incentivising reduction options that are presently not/poorly addressed by other EU policies. Actually, an ETS-RT incentivises all potential reduction options transport users (and fuel suppliers) have[46], while the current package of EU policies mainly focusses on improving the fuel efficiency of vehicles and lowering the carbon content of fuels. Improving transport efficiency, modal shift and curbing transport demand, for example, are not/poorly targeted by current EU policies.

In this way, an ETS-RT also addresses some of the potential rebound effects of CO_2 vehicle standards. Vehicle standards are subject to two potential rebound effects (Creutzig, et al., 2010). First, CO_2 reduction due to the fleet penetration of more fuel-efficient vehicles may be partially offset by greater demand for road transport (as the cost per kilometre will decrease). Second, car manufacturers have the opportunity to partly meet the vehicle standards by pushing additional fuel-efficient cars into the market (e.g. by offering discounts), increasing the overall size of the vehicle fleet and in the end transport volumes. Putting a higher price on fuels by implementing an ETS-RT may curb this additional transport volume.

[46] I.e. using more fuel efficient vehicles, increasing transport efficiency, applying a more fuel-efficient driving style, reducing the amount of kilometres travelled, and increasing the share of biofuels in the fuel blends.

The main current EU policies (CO_2 performance standards, RED) are targeting the supply side of the market of low carbon technologies, while the ETS-RT also addresses the demand side. In this way, an ETS-RT may also improve the effectiveness/efficiency of the current policies. For example, an ETS-RT may incentivise the demand for fuel efficient vehicles, which will help manufacturers to meet the CO_2 vehicle standards in a cost-effective way (CE Delft, et al., 2019b).

At the European level, there is currently one other instrument that encourages a broad range of reduction options and hence is highly similar to an ETS-RT with respect to the issues mentioned above: the Energy Taxation Directive (ETD). This Directive sets minimum fuel excise duties for all EU Member States. As both instruments directly affect fuel prices, applying them simultaneously results in additional implementation costs for two administratively similar systems. These implementation costs are higher than in case only one of both instruments is implemented, reducing the overall efficiency of the policy mix (CE Delft, et al., 2019b). However, as the minimum fuel excise duty levels set by the ETD are relatively low, adding an additional price incentive by the implementation of an ETS-RT in order to stimulate CO_2 reduction in the road transport sector may have added value, even if this lead to higher transaction costs because of the combination of two different policy instruments. Theoretically, an increase of the existing mandatory minimum levels for fuel taxes in the ETD may have a comparable impact. However, such a modification requires unanimity between Member States and is therefore not very likely to happen. From an environmental perspective, there is another advantage of having an ETS-RT in addition to the ETD. While an ETS-RT provides a clear CO_2 price, the minimum tax levels in the ETD are not yet linked to the CO_2 content of the fuels.

Current policies address market failures hampering the effectiveness of an ETS-RT

An efficient ETS-RT requires a well-functioning market. However, the market for reduction options in road transport is affected by some market failures, like knowledge spill overs, myopic behaviour and asymmetric information. In the presence of such market failures, a set of targeted climate instruments can reduce emissions more efficiently than a single pricing option (Marcantonini, et al., 2017).

Compared to market-based instruments like an ETS-RT, CO_2 vehicle standards are considered more effective instruments to address the so-called energy paradox, i.e. consumers/companies do not purchase a fuel-efficient vehicle even if the higher investment costs are fully compensated by lower energy costs (CE Delft, et al., 2019b). This energy paradox may be explained by various factors, including consumer myopia[47] and imperfect information[48] for vehicle buyers, and the existence of split incentives[49] (EC, 2007). As an ETS-RT affects energy costs and not investment costs of a fuel-efficient vehicle, it is not an

[47] Consumers (both private consumers and companies) do often not take the life-time savings from improved fuel efficiency into account, but only the savings for small number of years (three to five years).

[48] Buyers of new vehicles have less accurate information than manufacturers about the potential performance of fuel-saving technologies. Because of this uncertainty, buyers may attach a risk premium to investing in new technologies and give a relatively larger weight to immediate costs than future savings.

[49] This refers to the situation that the buyer of a fuel-efficient vehicle is not the one (fully) benefitting from the fuel savings achieved with that vehicle. This may be the case if the owner of the vehicle is not its operator (e.g. due to leasing constructions) or when fuel provisions are used in transport contracts, implying that the operator's costs do not change with fuel consumption.

effective measure to address the energy paradox. Instead, CO_2 vehicle standards are considered a more appropriate measure, as these directly mitigate the energy paradox. CO_2 vehicle standards may also improve investment security for vehicle manufacturers. Compared to market-based instruments, standards provide more clarity on the (minimum) size of the market for low and zero emission vehicle. This clarity is important for vehicle manufacturers in order to take long-term investment decisions to meet future market demand and optimise compliance costs.

The conditions set for the sustainability of renewable fuels by the RED and FQD is another example of the complementarity of existing EU policies to an ETS-RT, because the price incentive provided by the ETS-RT would not guarantee that sustainable renewable fuels will be used[50]. As for the CO_2 vehicle standards, the RED fuel standards also provides more investment security for biofuels producers than an ETS-RT (because of the uncertainty on the long-term allowance price).

The Alternative Fuel Infrastructure Directive would also complement an ETS-RT, as it stimulates a coordinated deployment of a harmonised network of recharging/refuelling infrastructure throughout Europe (CE Delft, et al., 2019b). This cannot be achieved (effectively) by using market-based instruments for two reasons. The first reason is that market-based instruments like an ETS-RT only provide an indirect incentive to invest in recharging/refuelling infrastructure[51]. Second, such an indirect incentive does not provide any framework or guideline for the infrastructure to be built, potentially resulting in a patchwork of different recharging/refuelling infrastructure throughout Europe.
Finally, the Car labelling Directive complements market-based instruments by providing clear information on the fuel efficiency of vehicles (Ricardo & TEPR, 2015b). This kind of information is not provided by market-based instruments like an ETS-RT.

Impact of other CO_2 reduction policies on allowance prices

As discussed in Section 3.2, policies like the CO_2 vehicle standards and RED may exercise downward pressure on the allowance price by reducing the demand for allowances in the market, as part of the emission reductions required to meet the ETS-RT cap are already achieved by other policies[52].

However, as shown by the analyses carried out in Section 4.2.3, stricter targets for other policies (i.e. CO_2 vehicle standards and the RED fuel standards) will not always result in lower allowance prices. This only happens if these policies incentivise (some) reduction options that are not implemented under an ETS-RT. Otherwise, the set of reduction options taken will be the same as in the situation without stricter targets for the other policies, resulting in the same marginal costs to meet the ETS-RT cap and hence the same allowance price.

[50] An ETS-RT encourages the uptake of the most cost-efficient renewable fuels and does not discriminate between biofuels with regard to their sustainability (i.e. effects on indirect land-use).

[51] Market-based instruments may result in additional demand for alternatively fuelled vehicles.

[52] Notice that this does not mean that the overall CO_2 reduction in the road transport sector is achieved against lower costs. This is only the case if these other policies stimulate the uptake of cost effective reduction options that are not implemented under an ETS-RT in itself. This could be the case if these policies address market failures that are not addressed by an ETS-RT. In any other case, (increasing the targets of) other policies will probably not lower the costs of meeting the CO_2 reduction targets of the road transport sector, as in a well-functioning market an ETS-RT achieve the targeted CO_2 reduction at lowest costs.

The fact that stricter targets for CO_2 vehicle standards or the RED fuels standards do not result in lower allowance prices does not mean that they are not complementary to an ETS-RT anymore. For example, both instruments may still provide more investment security to vehicle manufacturers or biofuel producers, ensuring that investments are made to develop the production capacity needed to meet future demand for low and zero emission vehicles and low-carbon fuels. Furthermore, CO_2 vehicle standards can be used to stimulate the uptake of innovative, but still expensive vehicle technologies (e.g. hydrogen trucks), in order to create a market for these technologies such that learning (and scale) effects can be achieved. Finally, the RED fuel standards may complement an ETS-RT by stimulating the use of biofuels in the years before 2030 when the allowance prices are considerably lower.

4.3 Overlap and differences between an ETS-RT and fuel taxes

An ETS-RT has considerable overlap with fuel taxation, as was already mentioned in Section 4.2.4. The main difference is that the ETS-RT puts a price on carbon, while fuel tax levels are often not linked to the carbon content of fuels[53]. Therefore, an ETS-RT provides a financial incentive to choose for low-carbon fuels, while fuel taxes often do not[54].

4.3.1 Lower fuel taxes to neutralise price impact of an ETS-RT

Member States may consider to reduce the current level of their existing fuel excise duties in order to (partly) neutralise the impact of an ETS-RT on the transport costs. This could be implemented to get more public support for an ETS-RT or to avoid undesired impacts on the disposable incomes of low-income households[55] (CERRE, 2020) (CE Delft, et al., 2014). Lowering fuel taxes could be a permanent measure, but it could also be used to accommodate the short to medium term price impact of the scheme in order to smooth the implementation of the scheme in the first years (CERRE, 2020). To finance such a (temporary) reduction of fuel taxes, the revenues of the auctioning of emission allowances could be used (assuming that auctioning is the mechanism chosen to allocate the allowances).

Room to lower fuel taxes

Given the minimum fuel excise duty levels mandated by the ETD and the large variance in actual existing excise duties between countries, there are large differences in the room Member States have to lower their fuel excise duties. For example, excise duties for road transport in countries like Bulgaria, Hungary, Luxembourg and Poland are equal to or just above the minimum levels set by the ETD (EC, 2020d). These countries therefore have no opportunity to neutralise the price impacts of an ETS-RT by lowering their excise duties. Countries like the Netherlands, Italy and Sweden, on the other hand, currently have fuel

[53] However, there are a few European countries (e.g. Denmark, Sweden, Slovenia, Portugal) that levy a CO_2 charge as part of their fuel taxes ((EC, 2020d).

[54] Fuel taxes may even provide a perverse incentive to the use of biofuels. As the energy content of biofuels is often lower than for fossil fuels, a similar excise duty rate (per litre) for biofuels and fossil fuels results in a higher excise duty rate per MJ for biofuels. It is expected that this issue will be addressed in the proposal for revision of the ETD.

[55] Although it may be argued that more targeted policies can be developed that will be more efficient in neutralising these kind of income effects. Cambridge Econometrics (2021) shows, for example, that income effects of an ETS for road transport can be neutralised by recycling auction revenues via lower income taxes or lump sum payments to households.

excise duties that significantly exceed the minimum levels and hence they have legal room to lower their tax rates.

The differences between countries in the room they have to lower their fuel taxes may have distributional impacts, particularly as current excise duty rates are in general lower in countries with a lower average income level. However, Member States have other (economically more efficient) options to neutralise the price impacts of an ETS-RT as was discussed in Section 2.3 (e.g. lowering income taxes, supporting schemes for investments in low-carbon technologies).

Impacts of reducing fuel excise duties

Reducing fuel excise duties with the purpose to (partly) neutralise the price impacts of an ETS-RT may have several impacts. First of all, by lowering fuel tax levels, emission reductions are incentivised less than otherwise would be the case. As a consequence, more reduction options have to be taken under the ETS-RT (in order to meet the cap) and hence this will result in a higher allowance price. This implies that Member States reducing their fuel excise duties are actually passing on the price impacts of the ETS-RT to other countries, as all EU countries are confronted with higher allowance prices[56]. Consequently, this may incentivise those other countries to lower their fuel taxes as well, which again will have an upward impact on the allowance price. In case all/a majority of the Member States will join this 'race to the bottom', it may theoretically be the case that the burden of the ETS-RT is particularly borne by the countries that currently have the lowest fuel excise duties (and hence the least room to lower their excise duties). It is unclear to what extent such dynamics would actually take place. The large fiscal impacts this strategy could have, may stop Member States to actually apply such a strategy. Particularly as this strategy may result in more uncertainty in government income as is explained below.

Secondly, reducing fuel taxes may result in lower *domestic* CO_2 emission reductions. This may jeopardise national objectives on CO_2 reduction in the road transport sector. Notice that the environmental effectiveness of the ETS-RT at the European level is not affected by lowering fuel taxes by some countries, as the ETS-RT cap provides certainty on the achievement of the CO_2 reduction targets at the European level.

Thirdly, reducing fuel excise duties means that there will be less fuel tax revenues while at the same time there will be additional auctioning revenues from the ETS-RT. This will very likely result in additional uncertainty on the net government income (Nordic Council of Ministers, 2015). This is mainly because of the uncertainty about emission allowance prices, as compared to the stable fuel tax rates. Additionally, a switch from fossil fuels to biofuels will reduce auctioning revenues, while tax revenues are presently not or only slightly affected in most countries (as fuel taxes on biofuels and fossil fuels are often in the same range). A possible mechanism to increase the predictability of government income is by

[56] We illustrate this by an example. Assume that country A is the only country in the EU that is lowering its fuel tax by 10% and that this results in 5% higher CO_2 emissions in that country. In order to meet the ETS-RT cap, additional CO_2 reduction has to be achieved at the EU level. The relative reduction in CO_2 emissions that should be achieved at the EU level is, however, much lower than 5%, as the overall CO_2 emission in the EU are much higher than in country A. Therefore, a smaller relative increase in the allowance price compared to the relative decrease in fuel tax in country A is required in order to meet the ETS cap. Although this increased allowance price also holds for country A, the sum of fuel tax + allowance price is negative, implying that the fuel cost in country A decreases. In all the other EU countries, on the other hand, the fuel cost do increase (due to the increase in the allowance price).

introducing a top up carbon tax above the allowance price which is switched on if the allowance price is below a specified level (Nordic Council of Ministers, 2015). Such a price-floor reduces uncertainty about auction revenues by securing a minimum price on carbon.

4.4 Interaction with other national policies

In the National Climate Agreement (Ministry of Economic Affairs and Climate Policy, 2019), the Dutch government presents a wide range of policy measures in order to achieve CO_2 reduction in the Dutch transport sector by 2030. Given the broad scope of an ETS-RT, all these policy measures interact with an ETS-RT, often in a similar way as the European climate mitigation measures do (see Section 4.2). For example, discounts on purchase taxes for electric vehicles may address a market failure (consumer myopia) that is not addressed by and ETS-RT. Another example are zero emission zones for urban logistics which may complement an ETS-RT scheme as they address market failures like split incentives that are not addressed by an ETS-RT. On the other hand, an ETS-RT may stimulate the use of zero emission trucks outside urban areas as well.

More in general, an ETS-RT may contribute to achieving national CO_2 reduction targets for the transport sector. Additional policies in the transport sector are required, as the current adopted and intended policies will maximally result in 14% CO_2 reduction in 2030 compared to 1990 levels, according to the Climate and Energy Outlook 2020 (PBL, 2020). An ETS-RT is one of the potential instruments that can be implemented to increase the CO_2 reduction in the Dutch road transport sector.

However, as we discussed for the European policy context as well, an ETS-RT may also lower the support for ambitious national CO_2 reduction policies and hence meeting national reduction targets may become at risk. Particularly, as additional national reduction policies will not actually reduce CO_2 emissions at the EU level. As the ETS-RT cap for CO_2 allowances is set, saving emissions at the national level by implementing reduction policies will lead to freeing up emission allowances, which will be bought and used by other road transport emitters within the ETS-RT. Because of this so-called 'waterbed effect' the net emission reduction achieved by the national measures could even be zero. However, in the current design of the EU ETS, the Market Stability Reserve and its cancellation mechanisms partly neutralise this waterbed effect in the EU ETS (see the following text box), although there is still much debate to what extent and for which period this will be the case (Perino, 2018) (Rosendahl, 2019). More research is needed to assess the effectiveness of this mechanism in addressing the waterbed effect in general and for an ETS-RT in particular.

Puncturing the waterbed effect by the Market Stability Reserve

As a response to low allowance prices and a huge surplus of allowances in the EU ETS, the EU introduced a market stability reserve (MRS) in 2015. When the total number of banked allowances exceeds a certain limit, parts of next year's allowances (24% in the years up to 2023, 12% in the years afterwards) are put into the reserve instead of being auctioned, reducing the short term supply of allowances. These allowances will return from the reserve to the market via auctions once the total number of allowances circulated falls below a certain limit. In 2018, the MSR rules were revised and now state that a number of allowances held in the MSR will be cancelled as of 2023. This happens automatically to all allowances above the auction volume of the previous year. Hence, the long-term supply of allowances is reduced.

Many scientists argue that this new MSR rule (temporarily) punctures the waterbed effect (Perino, 2018) (Agora Energiewende & Oko-Institute, 2018). If more allowances are freed up by national reduction options, more allowances will be transferred to the MSR, and as of 2023, part of these will be cancelled automatically from the reserve. This mechanism will not lead to a 1:1 reduction, as only part of the allowances (12%/24%) in surplus are added to the reserve. But according to Perino (2018), about 80% of CO_2 reduction achieved by national policy measures will end up in long-term CO_2 emission reduction at the European level. The puncturing of the waterbed effect is expected to be temporary, as the cap will become fixed again once the total number of allowances circulated falls below a certain limit and no new allowances will be added to the MSR.

5 Impacts of an ETS-RT

5.1 Introduction

The implementation of an ETS-RT will lead to a wide range of impacts. In this chapter we discuss some of these impacts, i.e. the impacts on fuel prices (Section 5.2), the financial impacts for private transport users (Section 5.3), the impacts on the road freight transport sector (Section 5.4), the environmental impacts (Section 5.5) and the impacts on public finance (Section 5.6). We focus on the impacts for the Netherlands in 2030, but for some impacts we will also briefly discuss the impacts for (a selection of) other EU Member States.

We consider the impacts of an ETS-RT compared to the baseline (i.e. the most likely situation in case no ETS-RT is implemented). Notice that in this baseline no other additional climate policies for road transport are included and hence that the CO_2 reduction targets as defined for the three ETS-RT cap scenarios are not met in the baseline. Instead of an ETS-RT other policies can be implemented in order to meet the CO_2 reduction targets and these policies will have an impact on fuel prices, transport costs and public finance as well. We have not assessed the impacts of such an alternative policy mix and hence we are not able to compare the impacts of an ETS-RT with an alternative policy mix to meet the CO_2 reduction targets.

Most of the impacts discussed in this chapter are directly affected by the allowance price level (except the environmental impacts as these are fixed by the cap). As became clear in Chapter 3, the uncertainty with regard to the long-term allowance price is large. Next to central estimates, bandwidths have therefore been presented for the estimated allowance prices in Section 3.4. To improve the readability of this chapter, we only present the impacts associated to the central estimate of the allowance prices in this chapter. However, it should be mentioned that there is a considerable uncertainty in these impacts that should be considered when interpreting these results.

5.2 Impacts on fuel prices

The implementation of an ETS-RT will have an upward effect on consumer prices of transport fuels at filling stations throughout the EU[57]. In this section we present the impact of an ETS-RT on fuel prices in the Netherlands, Bulgaria, Luxembourg, Italy and the EU27. This selection of countries encompasses the European Member States with the highest and lowest fuel taxes. The fuel tax and VAT levels for the considered countries are shown in

[57] As mentioned in Section 3.2, it can be assumed that the cost of an ETS-RT are fully passed on to the transport users by increasing fuel prices.

Table 26, where we assume that in real terms the tax levels in 2030 are equal to the 2019 levels.

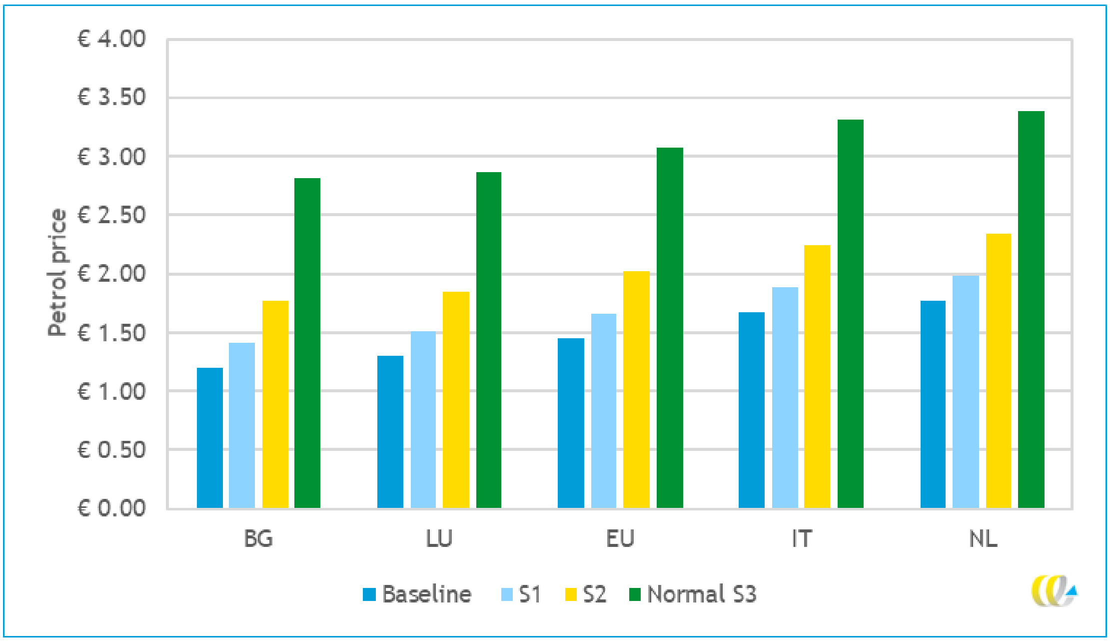
Table 26 - Fuel tax levels of selected EU countries per litre in 2030 (ex. VAT, 2020 price level)

Country	Petrol tax per litre	Diesel tax per litre	VAT level
Bulgaria	€ 0.36	€ 0.33	20%
Luxembourg	€ 0.47	€ 0.36	17%
EU average	€ 0.55	€ 0.44	21%
Italy	€ 0.73	€ 0.62	22%
The Netherlands	€ 0.82	€ 0.54	21%

Source: EC (2020d).

Figure 11 presents the impact of an EU ETS on the petrol prices[58] in the various ETS-RT Cap scenarios[59]. In S1, the EU average petrol prices increases by 15%. In S2, the impact on fuel prices is considerably higher; an EU average increase of 39% can be expected. Finally, in S3, the EU petrol prices increase by 112%. For all three scenarios, the relative increase in fuel prices is highest in the countries that currently have the lowest fuel taxes (i.e. Bulgaria, Luxembourg). In the Netherlands, the relative increases in petrol prices are slightly below the EU27 average. The exact numbers per country and scenario are given in Annex D, Table 41.

Figure 11 - Petrol prices (including VAT) under ETS-RT (2019 price level)

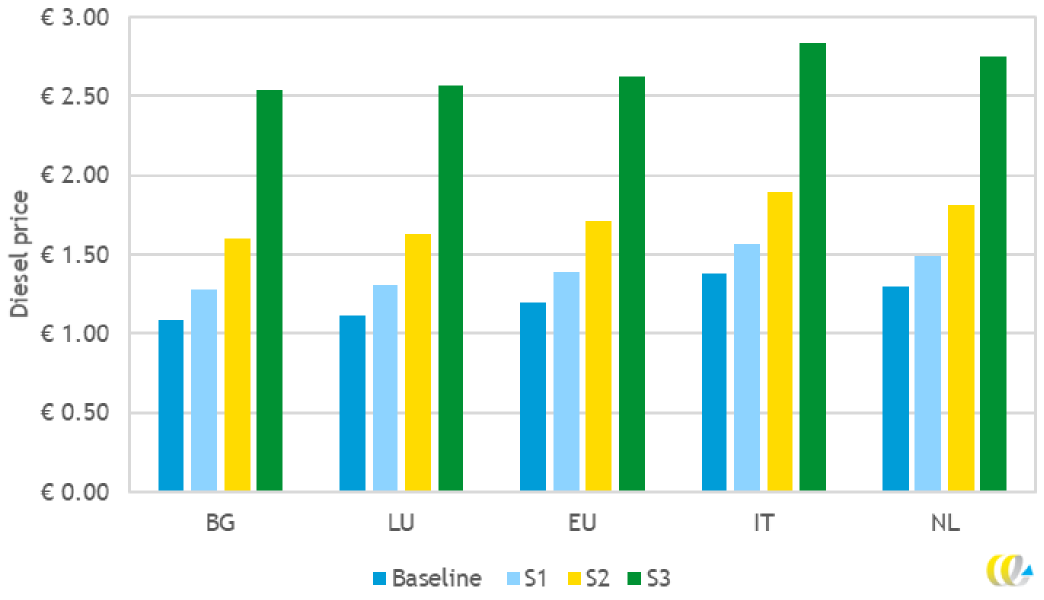


[58] Fuel prices are calculated based on the fuel prices excl. taxes which are used as base fuel prices for all (ETS) price calculations (as stated in Annex A.3). Using the national tax and VAT level from the selected countries, we obtained the national average fuel price (incl. taxes) for the baseline. These figures act as a starting point to which we added the allowance price to calculate the final fuel price under the respective ETS scenario.

[59] This is under the assumption no policy changes occur to fuel excise duties in all countries.

In Figure 12, we present the estimated impact of an ETS-RT on diesel prices (excluding VAT[60]). The same pattern of price increases as for petrol prices is shown. However, the increases differ somewhat in relative terms. Due to the higher carbon content, the price increase per litre diesel is slightly higher compared to the price increase of petrol (+16% in S1 to +119% in S3). For the absolute diesel prices in the various scenarios, see Table 42 in Annex D.

Figure 12 - Diesel prices (excluding VAT) under ETS-RT (2019 price level)



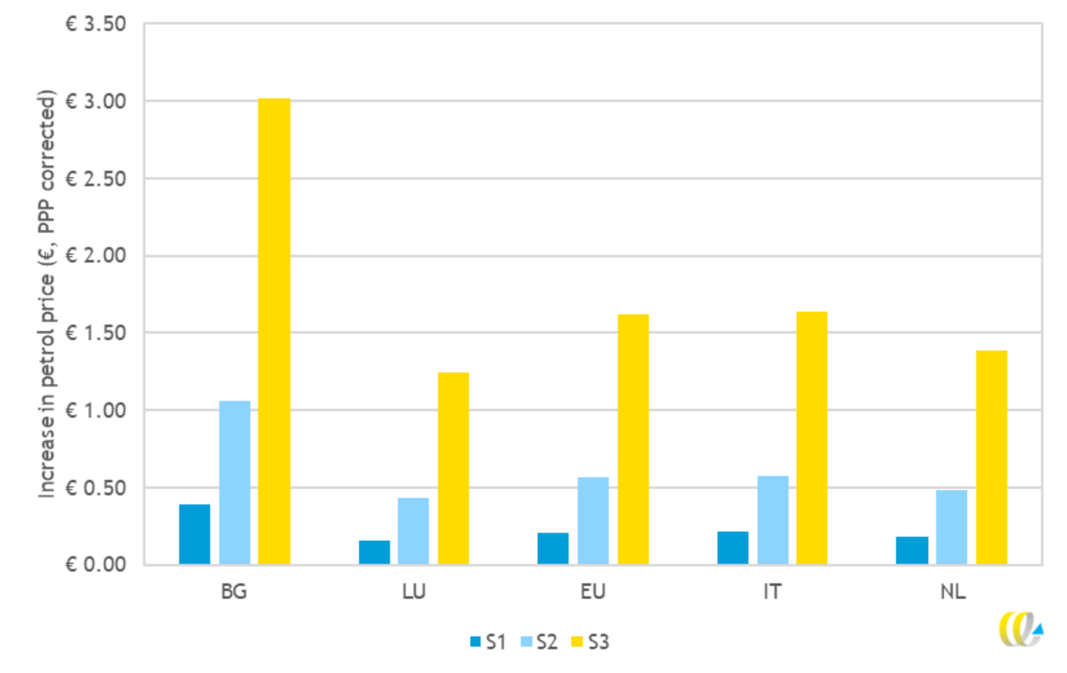
Finally, it should be noticed that comparable changes in absolute prices may have different impacts on the purchasing power across countries. This is explained in more detail in the following text box.

Impact of an ETS-RT on relative purchasing power in various countries

European countries differ with respect to price levels; e.g. prices in Bulgaria are significantly lower than in the Netherlands. This implies that a price increase of € 1 is relatively larger in Bulgaria than in the Netherlands. As an ETS-RT results in the same absolute price increase in every European country, Bulgaria is relatively harder hit than the Netherlands. This is shown by Figure 13, which shows the increase in petrol prices corrected for differences in price level between countries. This correction is conducted by using Purchasing Power Parities (PPP), which are indicators that reflect the differences in purchasing power between countries). Figure 13 shows that from the countries considered, the impact of fuel price on purchasing power of people will be much higher in Bulgaria than in the other countries considered (i.e. the impact of any given allowance price is more than twice as high in Bulgaria compared to the Netherlands).

60 In contrast to the petrol prices, we present the diesel prices without VAT. The reason for this is that the majority of the diesel in the EU is used for commercial purposes and for that reason VAT could be reclaimed by the transport user.

Figure 13 - Increase in petrol prices due to an ETS-RT, corrected for PPP (2019 price level)



5.3 Impacts on private transport users

The fuel cost increase resulting from the introduction of an ETS-RT affects the overall transport costs of households and transport companies[61]. In this section we will look into the impacts on private transport users[62]. First we discuss the general implications for the transport costs for private transport. Secondly, we discuss distributional effects as an ETS-RT might affect income groups to a different extent.

5.3.1 Transport costs

An average Dutch household spends € 4,400 per year on transport, of which about € 3,750 is spent on private road transport (CBS, 2019). About 29.5% of the total transport expenditures refer to fuel consumption. As we saw in Section 5.2, these expenditures will increase when an ETS-RT is implemented. The relative impact of this increase on the annual transport costs of an average household is shown in Table 27. These transport costs are expected to increase by 3% in S1, 9% in S2 and 27% in S3.

[61] Notice that also alternative CO_2 reduction policies that can be implemented to achieve the CO_2 reduction targets instead of an ETS-RT will result in higher transport costs. For example, tightening of CO_2 vehicle standards will lead to higher purchase prices of new vehicles.

[62] Also referred to with the general term 'consumers'.

Table 27 – Fuel and transport cost increases of an average Dutch household, based on 2019 prices

	S1	S2	S3
Fuel cost increase under ETS pricing	12%	32%	92%
Share of fuel cost in transport cost		29.5%	
Average transport cost increase	**3%**	**9%**	**27%**

5.3.2 Distributional impacts

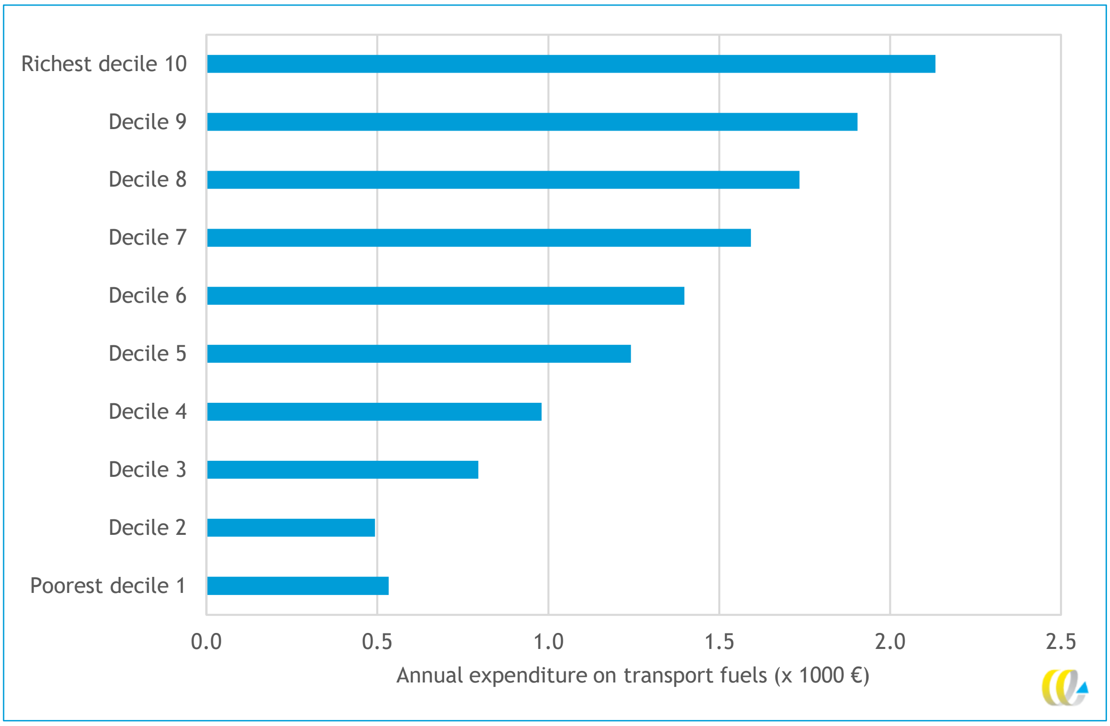
The introduction of an ETS-RT may have significant impacts on the average transport expenditures of households, as was shown in Section 5.3.1. But are there significant differences between low-income and high-income households in this respect? This question will be addressed in this section.

To assess the distributional impacts of an ETS-RT, it should be considered that the impacts of this instrument on transport expenditures occur through two mechanisms (Cambridge Econometrics, 2020):
- An ETS-RT leads to higher fuel prices and hence to higher costs of vehicle refuelling.
- Households may react to this higher fuel price by adopting reduction options like applying a more fuel efficient driving style, buying a more fuel-efficient car or travelling less (demand response). In this way they can (partly) neutralise the impact on transport expenditures following from the first mechanism.

Impact on higher fuel cost

As is shown by Figure 14, high-income households spend up to four times more on transport fuels than low-income households, reflecting their more car-intensive lifestyle (CERRE, 2020). In absolute terms therefore, an increase in the vehicle refuelling cost due to the implementation of an ETS-RT affects high-income households more than low-income households.

Figure 14 - Average annual expenditures of households on transport fuels (in 2015)

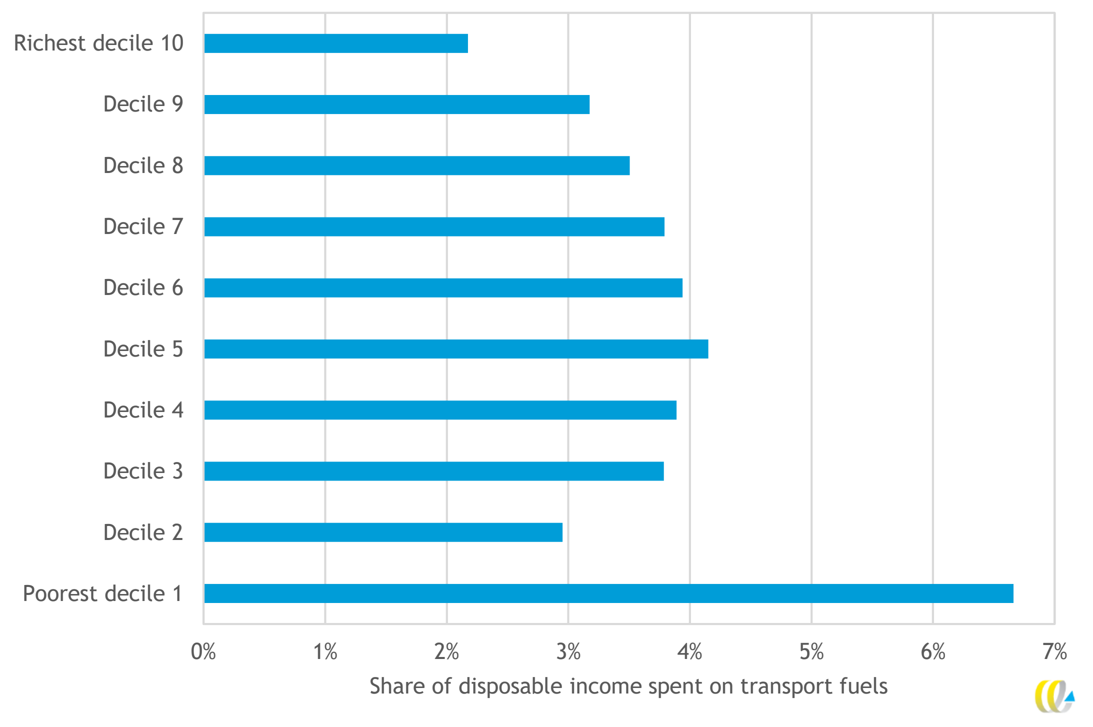


Source: CBS (2019), modified by CE Delft.

However, in relative terms, the highest income-households are least affected by the higher fuel prices. This is illustrated by Figure 15, which shows the share of disposable income spent on fuel costs[63]. This share is lowest for the households with the highest income levels, while particularly the poorest households spent a relatively large share of their disposable income on transport fuels (almost 7%). Based on Figure 15, it can be concluded that the poorest households are relatively most severely hit by a fuel price increase due to an ETS-RT (without considering any demand response yet). Furthermore, it seems that disposable incomes of medium-income households are affected more strongly, in relative terms, than the incomes of households in the second and third income deciles. This can be explained by the fact that car ownership and use are relatively higher within the middle income groups compared to the second and third income groups. Car ownership and use are expected to be low in the first decile income group. However, those who own a car spend a disproportionally high share of income on fuels. Therefore, the impact of fuel price increases of an ETS-RT will impact expenditure of this group significantly more than other income groups.

[63] Income remaining after deduction of taxes and social security charges, available to be spent or saved as one wishes.

Figure 15 - Share of disposable income spent on transport fuels per income category (in 2015)



Source: CBS (2019), modified by CE Delft.

As mentioned by CERRE (2020), the impact of higher fuel cost due to an ETS-RT on disposable income may also differ widely within income groups. This is illustrated by a study of Eliasson et al (2018), who found significant variation in transport fuel use within income octiles in Sweden, particularly between those living in rural and urban areas or between central cities and suburbs. This shows that access to substitutes for car use (e.g. public transport) and average commuting distances are important drivers of the impact an ETS-RT on disposable incomes of households (CE Delft, et al., 2014) (DIW, 2019).

Demand response

In order to (partly) mitigate the higher fuel costs due to an ETS-RT, households may adopt measures to lower their fuel consumption. It is well understood that low-income households have fewer financial means to invest in low-carbon technologies, like electric vehicles (Cambridge Econometrics, 2020) (CERRE, 2020). This is particularly the case for the short to medium term, as the costs of these low-carbon technologies are still relatively high and the volumes of second-hand electric (or other fuel-efficient) cars are rather limited. Additionally, low-income households have fewer options to reduce their transport demand as well, as the share of non-essential trips in their total number of trips is lower than for high-income households (Cambridge Econometrics, 2021). Because of these reasons, it can be concluded that low-income households have fewer opportunities to mitigate the higher financial burden resulting from an ETS-RT. For the medium-income households, there may also be some financial constraints to adopt low-carbon technologies, particularly on the short term when the costs of these technologies are still high. However, as the cost of low-carbon technologies, like electric vehicles, are expected to decrease in the future (due to learning and scale effects), these technologies will probably become affordable for the medium-income households in the long term.

Overall distributional impacts

Based on the findings presented above, it can be concluded that an ETS-RT has, in relative terms, the most severe impact on the poorest households. These households are confronted with relatively high increases in fuel costs, while at the same time they have the fewest options to mitigate these cost increases. The highest income groups are least affected by the implementation of an ETS-RT (in relative terms), as fuel costs are only a small share of their disposable incomes and as they have the financial means to invest in mitigation options. It is less clear whether the medium-income households (e.g. 5th decile) or the lower-income deciles (i.e. 2nd and 3rd decile) are more heavily affected by an ETS-RT. On the one hand, the medium-income households are affected more strongly by initial fuel cost increases, but at the same time they will probably have more options to mitigate these cost increases.

As mentioned above, the impact of an ETS-RT on disposable incomes may also differ widely within income groups, depending on factors like commuting distances and urbanisation rates.

In case (part of) the emission allowances are auctioned, the government can use the auction revenues to neutralise (some of) the distributional impacts of an ETS-RT. Cambridge Econometrics (2021) shows, however, that the design of the revenue recycling heavily affects the distributional impacts of the ETS. For example, a lump sum transfer leads to better outcomes for lower income households than a reduction in income taxes, as tax rates for these households are relatively low.

5.4 Impacts on the freight transport sector

5.4.1 Transport costs

The allowance prices increase the costs of diesel and therefore the costs of freight transport in the Netherlands. RWS and Panteia (2016) present an overview of the costs of freight transport in the Netherlands for the year 2015. These costs have been updated to current values using an index for road freight transport by CBS[64]. For 2030 we assume that the transport costs are the same in real terms as in 2021.

Table 28 provides an overview of the costs of various types of freight vehicles. The main costs for all vehicle types are the personnel costs. However, while the personnel costs are fairly similar for all vehicle types, other cost categories including fuel costs are higher for the larger vehicle types. The higher annual fuel cost for larger trucks is partly explained by higher annual mileage and partly by higher fuel consumption per kilometre.

[64] Prijsindex beroepsgoederenvervoer over de weg.

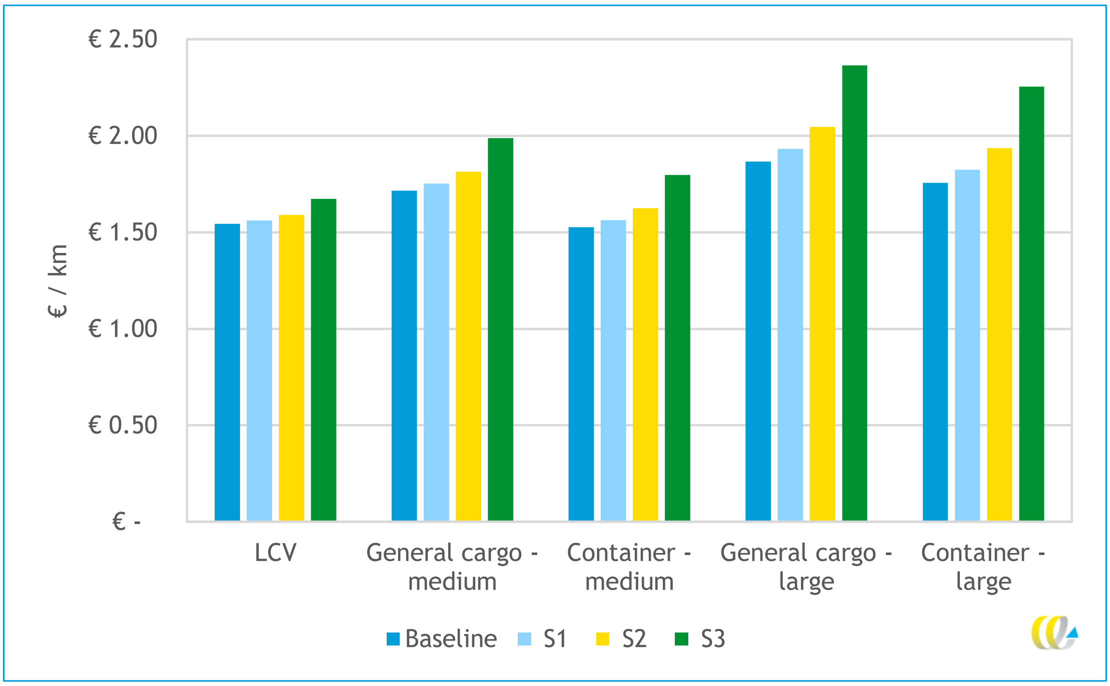
Table 28 - Costs of freight road transport in 2021

€ per year	LCV	General cargo - medium	Container - medium	Tank/bulk - large	General cargo - large	Container - large
Annual mileage (km)	70,000	85,000	105,000	125,000	130,000	135,000
Fixed costs	€ 9,134	€ 20,779	€ 22,762	€ 45,965	€ 36,513	€ 36,513
Fuel costs	€ 7,517	€ 19,269	€ 23,803	€ 52,200	€ 54,288	€ 56,376
Other variable costs (e.g. maintenance, tires)	€ 6,170	€ 10,198	€ 12,184	€ 25,220	€ 19,361	€ 20,108
Personnel	€ 71,073	€ 76,264	€ 87,003	€ 102,705	€ 102,705	€ 102,705
Other costs/general fund	€ 14,234	€ 19,398	€ 14,559	€ 31,253	€ 29,749	€ 21,405
Total costs	**€ 108,127**	**€ 145,908**	**€ 160,312**	**€ 257,344**	**€ 242,616**	**€ 237,107**

Source: RWS & Panteia (2016), modified by CE Delft.

The cost increase per kilometre resulting from the introduction of an ETS-RT is shown in Figure 16. The figure shows that the cost increase ranges between 1 and 28% depending on the vehicle type and allowance price. Because of their higher fuel consumption per kilometre, the transport costs per kilometre of larger trucks are affected most heavily by an ETS-RT.

Figure 16 - Total transport costs for freight transport in the Netherlands in 2030 in the various scenarios



As road transport is a very competitive sector where low profit margins are common, it is expected that a large share of these cost increases will be passed on to shippers. However, at the same time transport companies have an incentive to 'internalise' some of the additional costs, in order to gain some market share. Transport companies with higher fuel cost efficiency will have a greater cost efficiency compared to less efficient companies. As a consequence, transport volumes will shift towards the more efficient companies and as a result the road freight transport as a whole becomes more efficient.

5.4.2 Impacts on competitiveness

As an ETS-RT will affect the transport costs of all hauliers (both domestic and foreign ones) operating within the EU area, the competitiveness of the Dutch transport sector will not be negatively affected compared to foreign competitors. Moreover, as personnel costs are relatively high for Dutch hauliers compared to hauliers from other (particular Eastern European) countries, the ETS costs will weigh more heavily in the total costs of these foreign hauliers (Arcadis, 2019). Therefore, an ETS-RT may even (slightly) improve the relative competitiveness of the Dutch road transport sector.

The introduction of an ETS-RT does impact the competitiveness of the road freight sector compared to other modes of transport. The main alternatives for transport in mainland Europe are inland waterway transport and rail transport. In the short term, these modes of transport will benefit from a price increase of road freight transport. However, the modal shift potential to both modes is limited: for rail transport a realistic estimate is around 6% (TNO, 2017), while for inland waterway transport this will be around 8% (own estimate based on CE Delft, TNO & Connekt (2020)). Correcting for any overlap in these modal shift potentials, we end up with an overall realistic modal shift potential of road freight transport towards inland waterway and rail transport of about 10%. To fully utilize this potential is, however, not easy to achieve. Road transport has a lot of advantages compared to the other two modes of transport (e.g. flexibility, speed), making it often a more advantageous transport option for shippers, even if the costs per shipment are higher. This is illustrated by estimates of Arcadis (2019), which shows that a kilometre charge for trucks in the Netherlands of 15 €cent per kilometre (which is in the same order of magnitude as the price incentive provided in S2) will only shift 0.6% of the transport volume from road transport to rail or inland waterway transport.

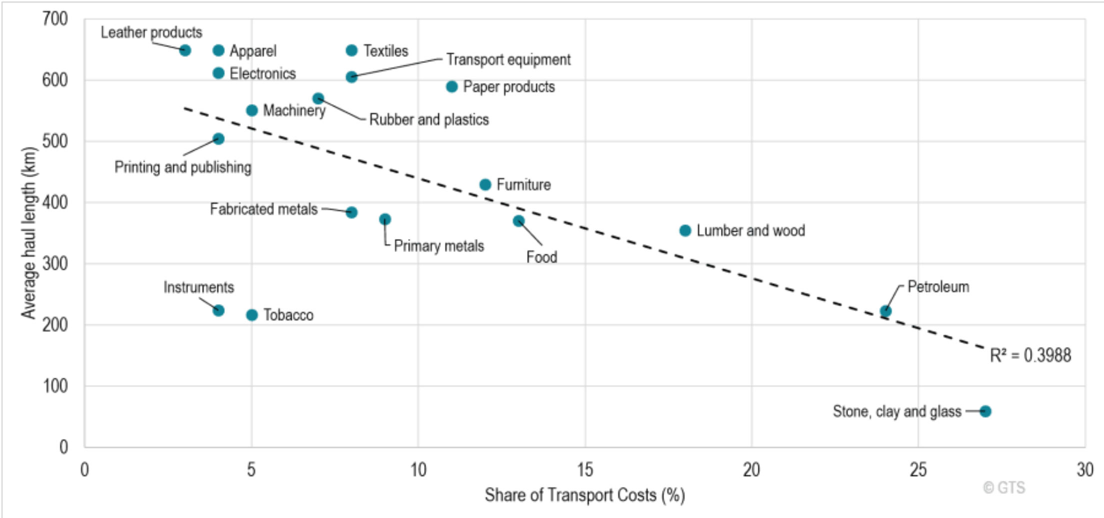
An ETS-RT may even provide a long term competitive advantage for road freight transport (compared to other transport modes) as it accelerates the uptake of innovative measures leading to a decrease in average carbon emissions. Especially inland waterway transport faces a large challenge to reduce carbon emissions due to a lack of alternatives currently available. Therefore, zero emission options will become available for road transport earlier than for inland waterway transport, which on the long run may improve the relative competitiveness of road transport compared to inland waterway transport.

Finally, the increase of freight transport costs due to an ETS-RT may theoretically affect the competitiveness of the European production sector as total production costs of goods will increase. This effect is most dominant for services and products where road transport costs take upon an important part of total production costs and for which substitutes outside the EU are available[65]. As shown by Rodrigue (2018), transport costs make up 5 to 10% of total production costs for most products. For basic materials like stone, petroleum and wood the share of transport costs in total production costs is about 20-25%. However, a significant share of these costs are from other modes of transport (mainly maritime transport). As road transport is often used for final distribution only, the share in total transport costs is limited, as is also shown by Arcadis (2019). As a result, for most products, an ETS-RT only

[65] Part of the transport of the former goods take place outside the EU and hence is not affected by an ETS-RT. Therefore, the relative impact on transport costs of those goods is lower than for goods produced within the EU, as for the latter the total transport costs are affected by an ETS-RT.

has a (very) small effect on the price and hence on the competitiveness of European producers.

Figure 17 – Share of transport costs for different types of products



Source: The geography of transport systems (2021).

5.5 Environmental impacts

5.5.1 CO_2 reduction in the Dutch road transport sector

The EU-wide CO_2 reduction in an ETS-RT is certain and determined by the ETS-RT cap set. At the national level, however, there is no certainty on the CO_2 reduction that will be achieved. The size of the CO_2 reduction in the Dutch road transport sector depends on many factors: the national reduction targets set by the various Member States, the initial allocation of allowances, differences in the MAC curves between countries and other CO_2 mitigation measures applied in the various Member States. It is out of scope to calculate the CO_2 reductions that may be expected for the various Member States (including the Netherlands).

5.5.2 Use of biofuels

As shown in Section 3.4.1, an ETS-RT will result in a significant uptake of biofuels, particularly in the more ambitious scenarios S2 and S3. In S2 about 69 Mton of CO_2 reduction is achieved in the EU by using biofuels, while in S3 this is about 150 Mton, which is the maximum available amount for road transport in Europe assumed in our assessments (see Annex B.2). Although these amounts of (sustainably produced) biofuels are expected to be available in the EU in 2030 (according to the IEA (2021) there should be sufficient sustainable biomass to reduce CO_2 emissions by the uptake of biofuels by about 300 Mton), there are some important considerations:

- Although the Renewable Energy Directive has set sustainability criteria[66] for biofuels that may be used in the EU, the strong additional demand for biofuels in case an ETS-RT is

[66] These criteria can be broken down into twelve different factors: legality; human and labour rights; local food security; GHG emissions; land rights; rural and social development; Planning, Monitoring and Continuous Improvement; Conservation; Use of Technology; Inputs and Waste Management; Water; Soil; and Air.

implemented may increase the risk that unsustainable biofuels will enter the market.
- Increased demand for biofuels from road transport may lower the availability of biofuels for other sectors, including transport sectors like aviation and maritime transport. As the availability of alternative reduction options are limited for these latter sectors, this situation may result in difficulties to reduce CO_2 emissions in these sectors.

5.5.3 Impact on the uptake of innovative reduction options

A concern with respect to an ETS-RT is that innovative reduction technologies with relatively high upfront costs (e.g. hydrogen vehicles) may not be fully incentivised by this instrument (CE Delft, et al., 2014) (CERRE, 2020). Because of consumer myopia, only fuel price incentives provided by an ETS-RT of three to five years are in general considered by consumers when buying a new vehicle. Therefore, economic instruments targeting the variable costs of vehicles (e.g. fuel costs) are less effective in stimulating innovative reduction technologies than measures targeting the upfront costs. Furthermore, the volatility in the price incentive provided by a trading scheme may act as a barrier for investors in the innovative technologies. Third, innovative solutions often require alternative regulations or infrastructure (e.g. fuelling infrastructure for hydrogen vehicles). Although the price incentives provided by ETS may contribute to the realisation of these boundary conditions of innovative vehicles (e.g. at high ETS prices there may be a positive business case for suppliers of hydrogen to invest in refuelling infrastructure), additional policy measures from governments will often be needed (PBL, 2020). These issues have been discussed in more detail in Section 4.2.4.

5.5.4 Carbon leakage

The environmental effectiveness of an ETS-RT may be reduced by carbon leakage. There are some potential types of carbon leakage that should be considered. First of all, tank tourism is a potential source of carbon leakage. Fuel price increases may incentivize transport users to fuel up their vehicles in countries outside the EU. However, there is currently already a fuel price difference and therefore an ETS-RT is expected to have a modest impact in border regions (EC, 2020b) (CE Delft, et al., 2014). At the European level, this type of carbon leakage is therefore very marginal.

A second type of carbon leakage may occur if the introduction of an ETS-RT leads to a shift of freight transport from road to inland waterway transport or diesel rail transport[67] (CE Delft, et al., 2014). As was discussed in Section 5.4.2, the potential for this modal shift is limited. Furthermore, as the carbon efficiency of these modes currently exceeds the carbon efficiency of road transport, such a shift will probably not lead to additional CO_2 emissions.

A third type of carbon leakage refers to the situation where sectors transfer production to other countries with laxer emission constraints as production costs inside the EU increase due to higher fuel costs. This is mainly the case for transport-intensive sectors where substitution between modes is not possible. As not many sectors meet these criteria, the risk on this type of carbon leakage is considered very low (CE Delft, et al., 2014).

[67] Electric rail is (indirectly) covered by the EU ETS and therefore a shift of transport volumes from road to electric rail will not result in carbon leakage.

5.6 Impact on public finance

The implementation of an ETS-RT may affect governmental revenues in the Netherlands in different ways:

- *Auctioning revenues;* in case (part of the) emission allowances are auctioned, this may lead to additional governmental income for the Netherlands. The size of these revenues depends heavily on the share of allowances that are auctioned and the approach applied to allocate the auction revenues to the Member States. In Annex C.4, the auction revenues have been estimated assuming that: 1) 100% of the allowances are auctioned, and 2) the auction revenues are allocated to Member States (MS) in a similar way as in Phase 4 of the EU ETS[68]. The resulting revenues are shown in Table 29. Resulting from the above this concerns a relatively optimistic estimate. Actual revenues will be significantly lower if the allocation of allowances will be organised in a different way.

Table 29 – Estimation of auction revenues in 2030 (billion €$_{2021}$)

	S1	S2	S3
Auctioning revenues for the Dutch government	1.4	3.3	7.9

- *Reduction in revenues from fuel excise duties*; a reduction in fuel consumption due to the ETS-RT results in lower revenues from fuel excise duties. As calculated in Annex C.2, the revenues in S1 will be reduced by about € 700 million. In S2 and S3, these reductions are higher, i.e. € 2.8 and € 4.0 billion[69]. An overview of the revenue loss figures is presented in Table 30.

Table 30 – Estimation of changes in Dutch fuel tax revenues under ETS in 2030 (billion €$_{2021}$)

	S1	S2	S3
Loss in fuel tax revenues	0.7	2.8	4.0

- *Change in revenues from VAT on transport fuels and fuel taxes;* the reduction of fuel consumption results in lower revenues from VAT on transport fuels and fuel taxes. At the same time, higher fuel prices (which increase due to the ETS-RT) result in higher VAT revenues. As is shown by Table 31, the second effect is stronger all scenarios.

Table 31 – Change in revenues from VAT on transport fuels and fuel taxes in 2030 (million €$_{2021}$)

	S1	S2	S3
Change in VAT revenues	+75	+315	+180

Note: Only VAT on petrol (taxes) is considered, as it is assumed that diesel is primarily used for commercial reasons and therefore VAT will be reclaimed.

[68] This is according to the absolute emissions of the Member States in a historic reference period/year. For our calculation, we chose 2018 as reference year, as this year is the most recent year for which emission figures are available with regard to road transport in all Member States.

[69] In this study, we assumed that fuels are taxed in accordance with their energy content and that therefore the tax rates per kilometre are equal for biofuels and their fossil fuel counterparts. Consequently, an increase in the share of biofuels in the various scenarios does not affect fuel tax revenues. Therefore, the changes in fuel tax revenues shown in Table 30 can be completely explained by the reductions in total fuel consumption because of the uptake of electric vehicles and behavioural measures.

- *Increase in electricity tax revenues;* an increase in the number of electric vehicles will result in higher electricity tax revenues. These revenues will be highest in S3, as there the most electric vehicles will have entered the Dutch vehicle fleet. Given the complicated structure of the Dutch electricity tax, no quantitative estimates of the additional revenues in the various scenarios have been made. However, it can be argued that a switch from fossil fuelled to electric vehicles will lead to considerably lower energy tax revenues, as the electricity tax level per vehicle is about 20% of the fuel tax level per vehicle (Algemene Rekenkamer, 2020).
- *Reduction in vehicle taxes;* the reduction in the number of vehicles will result in lower revenues from all types of vehicle taxes (purchase tax, ownership tax and company car taxation). Furthermore, currently all Dutch vehicle taxes are differentiated to CO_2 emissions, implying that lower CO_2 emissions per vehicle will result in lower tax revenues. However, it is unclear to what extent vehicle taxes in the Netherlands in 2030 will still be differentiated to CO_2 emissions.

The introduction of an ETS-RT on public finance may be substantial as the findings above show. The net impacts are unclear, though, as not all financial impacts have been quantified. Furthermore, the auction revenues are highly uncertain as these heavily depend on the design of the allowance auction (and particularly the initial allocation of allowances over Member States).

6 Conclusions and policy recommendations

6.1 Main conclusions

6.1.1 ETS-RT as a complementary instrument to existing policies

An ETS-RT may contribute to (cost)effective reduction of CO_2 emissions of road transport at the European level. It will strengthen the EU's control over the CO_2 reduction that will be achieved in this sector, as an ETS-RT has stronger enforcement mechanisms at the EU level compared to the Effort Sharing Regulation (ESR). This provides more certainty that the overall European CO_2 reduction targets set for road transport will be met.

At the national level, an ETS-RT may contribute to meeting the national ESR targets (and, if available, specific national reduction targets for the road transport sector) by providing an EU-wide minimum CO_2 price for road transport on top of minimum fuel tax rates prescribed by the European Taxation Directive. This will incentivise transport users to take up cost effective reduction options. It may also speed up the CO_2 reduction in countries that are currently lagging behind in meeting their reduction targets. However, an ETS-RT will not provide any certainty that national reduction targets will be met (because it is designed to enforce an average reduction target for the EU as a whole).

An ETS-RT may complement current policy instruments (e.g. CO_2 vehicle standards, RED) in different ways. First, an ETS-RT incentivises all reduction options, including the ones that are currently poorly covered by European policies (e.g. modal shift, curbing transport demand). It may in some cases also strengthen the effectiveness of current policies. For example, the price incentive provided by an ETS-RT will increase the demand for fuel-efficient vehicles, which may help vehicle manufactures to meet the CO_2 standards.

Existing European and national policies may also complement an ETS-RT, as they address market failures that are relevant in the transport sector, but will not be addressed by an ETS-RT. CO_2 vehicle standards and national CO_2 differentiated vehicle taxes, for example, address the existence of consumer myopia, i.e. the fact that consumers are not taking the life-time fuel cost (including the ETS costs) savings of low or zero emission vehicles into account, but only the savings for a small number of years. Furthermore, CO_2 vehicle standards also provide more investment security to vehicle manufacturers than an ETS-RT. Also the RED provides security for long term investments in production capacity (for biofuel producers). Furthermore, this Directive also sets conditions for the sustainability of biofuels, as the market will not ensure that sustainable fuels will be used. Finally, the Alternative Fuel Infrastructure Directive complements an ETS-RT by stimulating the deployment of an harmonised network of recharging/refuelling infrastructure throughout Europe.

Finally, there may be a risk that introducing an ETS-RT will reduce the support for maintaining and/or tightening the targets for existing (European and national) policy measures. Because of the important (complementary) role these policies have, as mentioned above, lowering their ambition levels would harm the effectiveness of the overall climate mitigation policy in the road transport sector in the EU and the individual Member States.

6.1.2 An ETS-RT will result in relatively high allowance prices

In this study an estimation of the 2030 allowance prices in an ETS-RT is made for three different ambition levels (see Table 32). Compared to the current allowance price in the EU ETS (about € 50 per tonne CO_2 in June 2021), much higher allowance prices are expected in an ETS-RT, particularly in the most ambitious scenarios. These high prices reflect that the uptake of relatively expensive reduction measures is required to meet ambitious CO_2 reduction targets in the road transport sector[70].

Although there is quite some uncertainty on the level of 2030 allowance prices (as illustrated by the bandwidths), we think the results of our analysis provide a good indication of the order of magnitude of the allowance price that may be expected.

Table 32 – Overview estimated allowance prices in 2030

	S1: 11% CO_2 reduction	S2: 30% CO_2 reduction	S3: 55% CO_2 reduction
Allowance price (€/tonne CO_2)	€ 75 (€ 65-€ 90)	€ 220 (€ 180-€ 270)	€ 690 (€ 390-€ 1,025)

Tightening the targets for other policies, such as CO_2 vehicle standards or renewable energy targets, may have a downward impact on the allowance prices by reducing the demand for allowances in the market, as part of the emission reductions required to meet the ETS-RT cap are already achieved by these other policies.

However, stricter targets for other policies will only result in lower allowance prices if these policies incentivise reduction options that are not implemented under an ETS-RT. Otherwise, the set of reduction options will be the same as in the situation without stricter targets for other policies, resulting in the same marginal costs to meet the ETS-RT cap (and hence the same allowance price)[71]. The analyses of more ambitious targets for the European CO_2 vehicle standards and the RED, as carried out in this study, illustrate this conclusion. Particularly in the high ambition reduction scenarios (S2 and S3), an ETS-RT does already stimulate the uptake of high levels of EVs and biofuels, and the introduction of stricter targets for 2030 do not result in (significantly) higher levels of these vehicles/fuels[72]. However, these policies may still complement an ETS-RT. For example, stricter RED fuel standards may be used to stimulate the uptake of biofuels in the years before 2030, as an ETS-RT will be less effective in those years. Furthermore, the investment security offered by both the CO_2 vehicle standards and the RED fuel standards will also still be complementary to an ETS-RT.

[70] Notice that the allowance price in itself does not say anything on the total cost of meeting the CO_2 reduction target, as the allowance price equals the costs of the most expensive reduction option needed to meet this target. The total cost, on the other hand, is the sum of the costs of all reduction measures applied to meet the target.

[71] If stricter targets for other policies do not result in differences in the reduction measures that are implemented, the most expensive reduction option required to meet the ETS-RT cap (the marginal reduction option) will be the same for the situation with and without stricter targets for other policies. As a consequence, the marginal costs to meet the ETS-RT cap and hence the allowance price will be the same for both situations as well.

[72] Tightening these targets well before 2030 will probably result in higher levels of these vehicles/fuels and hence will have a downward impact on the 2030 allowance price.

Finally, it should be mentioned that there is a trade-off between the ambition level set for the ETS-RT cap and the compliance costs for meeting it. An ambitious cap in 2030 will result in high abatement costs (and hence high allowance prices), but reduces the additional efforts that are required in the years after 2030. Choosing for a less ambitious 2030 cap may lower the short-term financial burden, but will require an increase in additional efforts after 2030. As the costs of reduction options in the road transport sector (e.g. zero emission vehicles, low-carbon fuels) are expected to decrease in the future (due to learning and scale impacts), it may be tempting to choose for less ambitious targets on the short term and speeding up emission reduction after 2030. However, this would postpone emission reduction and will lead to additional uncertainty on meeting the long-run reduction targets for the transport sector. Furthermore, postponing emission reduction may also increase the risk on a lock-in, e.g. people choosing to buy a new fossil-fuelled vehicle (instead of a zero emission vehicle), which will stay in the fleet for 10 to 15 additional years.

6.1.3 Impacts of an ETS-RT for the Netherlands

The high allowance prices expected to arise in an ETS-RT will result in significant increases in fuel prices and hence transport costs in the Netherlands, particularly in the more ambitious reduction scenarios (see Table 33).

Table 33 - Estimated relative increase in fuel prices and transport costs (compared to 2019 levels) due to an ETS-RT in the Netherlands in 2030

Financial impacts		S1: 11% CO_2 reduction	S2: 30% CO_2 reduction	S3: 55% CO_2 reduction
Fuel prices	Petrol	12%	32%	92%
	Diesel	15%	40%	112%
Transport costs	Private transport users	3%	9%	27%
	Freight transport sector[a]	1-4%	3-10%	8-28%

[a] The impact of an ETS-RT differs per type of truck. This is reflected by the ranges shown in this row.

The impact of an ETS-RT on the average transport costs of private transport users[73] range from 3% in S1 to 27% in S3 compared to the average transport costs in 2019[74]. This impact is expected to be most severe for the poorest households, as transport cost increases affect their disposable income the most in relative terms, while at the same time they have the fewest options to mitigate these cost increases (because of a lack of financial means, they cannot invest in low-carbon alternatives)[75]. The large financial impacts for private transport users (and particularly for low-income households) may significantly harm public support for an ETS-RT with an ambitious cap. Furthermore, the significant transport increases may also affect other markets, like the labour market or the housing market. For example, higher transport prices may reduce people's willingness to accept long commuter distances, reducing mobility in the labour market. As a consequence, unemployment may rise and/or average labour productivity may decrease. Because of these reasons, compensating private transport users to some extent for the additional costs resulting from an ETS-RT (e.g. by

[73] On average, Dutch households spend about € 4,400 per year on transport.

[74] Possible adjustment of mobility behaviour (e.g. reducing the number of kilometres travelled by car per year) incentivised by an ETS-RT and their impact on transport costs are not covered by these figures.

[75] By the same reasoning it can argued that low-income countries like Bulgaria are hit relatively harder by an ETS-RT than high-income countries. Therefore, it may be expected that the low-income countries will request for a higher share of auction revenues in order to compensate their transport users.

recycling auction revenues in a smart way) is therefore key. Although the transport costs in the freight transport sector increase by approximately the same level as for private transport users, the impacts of an ETS-RT on the freight sector are expected to be smaller. Transport companies will probably pass on the additional fuel costs to their customers, which will in the end result in higher prices of final products and services. However, as transport costs have, in general, only a minor share in the total product costs, these price increases are expected to be small[76]. As a consequence the impacts on total road transport volumes are probably limited, also because a shift to rail or inland navigation is only feasible for a small part of the transport volumes.

As for the environmental impacts, it is certain that the EU CO_2 reduction target will be met. There may, however, be concerns with respect to the high level of biofuels used to achieve the ambitious reduction targets in 2030. For example, it is estimated that with a reduction target of 55% in 2030 compared to 1990, an ETS-RT may result in a blending rate of biofuels in the order of 38%. It may be questioned whether in this situation the availability of renewable and sustainable biofuels for other transport sectors (e.g. aviation, maritime transport) is sufficient, taking into account that the availability of other reduction options is low in these sectors. Furthermore, as the costs of sustainable biofuels will increase at higher demand levels, there may be an increasing risk on the use of non-sustainable biofuels (as it becomes more profitable to use cheaper, non-sustainable biofuels).

Finally, the financial impacts of an ETS-RT for the government may be substantial. There will be significant losses in fuel tax, VAT and vehicle tax revenues. These losses may be compensated by the revenues from auctioning allowances (and additional energy tax revenues), but to what level depends heavily on which share of the auctioning revenues will be allocated to The Netherlands.

6.2 Policy recommendations

6.2.1 Balanced policy mix to mitigate CO_2 emissions of road transport

If designed appropriately, an ETS-RT is a valuable addition to (and not replacement of) the current policy mix for strengthening the effectiveness and efficiency of the overall climate policy for road transport. A right balance in the targets set for the various policies should be looked for, such that optimal use can be made of the strengths of each individual policy instrument. An integrated assessment of the entire policy mix (including an ETS-RT) would preferably be performed for this purpose in order to assess issues like:

- The overall cost effectiveness of the policy mix: what is the impact on overall cost effectiveness if targets for specific instruments are tightened or weakened?
- The design of the individual instruments in order to contribute optimally to the effectiveness of the entire policy mix (e.g. at which level are CO_2 vehicle standards effective in addressing market failures?)
- Public support for the policy mix (e.g. what level of ETS-RT prices are acceptable for transport users?).

If an ETS-RT is implemented, it may be worthwhile to leave road transport in the ESR as well, even this combination of policy instruments may result in lower cost effectiveness of emission reduction than in the situation that road transport is taken out of the ESR.

[76] These price increases for final goods will have a negative effect on the purchasing power of households, as well. Even if these price increases are relatively small, the impacts for particularly the poorest households may be significant (without compensation).

The main reason to leave road transport in the ESR is that it ensures that at the national level policies are taken which are complementary to an ETS-RT, improving the effectiveness of the entire policy mix. Furthermore, if politicians choose to apply mechanisms (e.g. price ceilings) to address some of the (unwanted) impacts of an ETS-RT, the environmental effectiveness of the system is reduced. In this situation, the ESR may stimulate the implementation of national policies that may be needed to ensure the achievement of the required CO_2 reductions.

6.2.2 Attention for price impacts of an ETS-RT

In order to mitigate the relatively large financial impacts of an ETS-RT for transport users (and the adverse effects these impacts have on public support for this instrument), it may be recommended to partly neutralise or limit these price impacts. Recycling (part of) the auction revenues may be an option to compensate certain groups of transport users, e.g. by using revenues to lower fuel taxes, income taxes or subsidise investments in low-carbon vehicles by low-income households. The instrument that could be best applied for this purpose depends on the (set of) objectives defined for revenue recycling. Lowering fuel taxes will directly compensate transport users, but may also result in higher domestic CO_2 emissions jeopardising national reduction targets[77]. Lowering income taxes only indirectly compensates transport users for the higher fuel costs, but will contribute to an improvement of the overall efficiency of the economy by lowering distortionary taxes. Channelling revenues towards innovative reduction options will be the most effective option to optimise the environmental effectiveness of an ETS-RT, but may provide less direct compensation for the additional fuel costs.

In addition to revenue recycling, other potential options to mitigate the price impacts of an ETS-RT are:
- A *price ceiling* may (temporarily) cap the allowance price in an EST-RT. This instrument limits the increases in the allowance price, while still a carbon price is introduced in the road transport sector (i.e. minimum CO_2 price) incentivising all types of reduction options. The environmental effectiveness is harmed by a price ceiling, as there is no certainty anymore that the reduction target will be met.
- *Linking the ETS-RT to the current EU ETS*, providing regulated entities in the ETS-RT with the (temporary) option to buy some allowances in the EU ETS. This will probably lead to lower allowance prices in the ETS-RT, but it may have an upward impact on the prices in the EU ETS (increasing the risk of carbon leakage). Overall environmental effectiveness is ensured in this option, but the actual emission reductions will, for some part, take place in the current ETS sectors instead of the road transport sector.

6.2.3 Design options for an ETS-RT

This study has not considered in detail the various design options that could be applied to an ETS-RT. However, some first recommendations on this issue are:
- *Regulated entity*: tax warehouse keepers (or fuel suppliers) are the most appropriate regulated entities for an ETS-RT. At this level, monitoring and transactions costs are probably low (as use can be made of the monitoring infrastructure available for levying the fuel excise duties) and the number of entities is sufficiently high to ensure sufficient market liquidity.

[77] Notice that not all Member States have the same room to lower fuel taxes, as minimum fuel tax rates are set by the Energy Taxation Directive. Therefore, Member States with relatively high excise duties on transport fuels (like the Netherlands) have more room to lower fuel taxes to compensate transport users than Member States with tax levels just above the minimum levels (like Bulgaria).

— *Allocation of allowances:* auctioning seems to be the preferred method for the initial allocation of allowances, as this approach is more efficient/effective than allocating the allowances for free. As the risk of carbon leakage is very low in an ETS-RT, there is no reason to allocate (some of the) allowances for free.
— *Cap setting:* setting an ambitious cap top down at the EU level is expected to be easier than setting it bottom up (i.e. by summing up national reduction objectives). Also the administrative cost of a top down approach are expected to be lower. In addition, is seems most straightforward to apply a linear annual reduction factor to the cap, in line with the current approach in the EU ETS. An alternative variant would be to apply a more progressive reduction factor, reflecting the cost reductions that are expected (due to scale and learning effects) for main low carbon technologies in the road transport sector.
— *Market Stability Reserve (MSR):* in the EU ETS, the MSR and its cancellation mechanisms partly neutralise the so-called waterbed effect, i.e. the fact that additional emission reduction at the national level will result in additional emissions somewhere else in the EU[78], such that the net effect at the EU level is zero. It should be investigated whether a similar mechanism like the MSR could be applied in an ETS-RT as well to neutralise the waterbed effect.

6.3 Recommendations for further research

This study is explorative in nature, showing a first indication of the various impacts of an ETS-RT. The robustness and depth of the various assessments carried out in this study can be improved in several ways. Some relevant issues in that respect are:
— *Further improvement of the MAC curve for road transport*. A key element in the estimation of the long-term allowance price in an ETS-RT is the Marginal Abatement Cost (MAC) curve for road transport. As mentioned in Section 3.3, recent (EU-wide) MAC curves for road transport are not available in the literature and therefore we have developed our own MAC curve for this project. Although this MAC curve is suitable for the analyses done in this study, it can be improved on several aspects, including:
  - The MAC curve can be developed in more detail, distinguishing more individual reduction options. Particularly breaking down the category 'behavioural reduction options' into more individual reduction options would further improve the quality of the MAC curve.
  - There is still considerable uncertainty on the abatement costs and availability of biofuels. Improving the knowledge base on this issue would benefit the MAC curve for road transport.
  - Information on supply constraints for electric vehicles is scarce and hence this uncertainty is reflected in the current MAC curve. More research on this issue may therefore improve the quality of the MAC curve.
— *Assessment of the impacts of an ETS-RT on the long term (2035/2040)*. It would be interesting to study the impacts of an ETS-RT for the period after 2030, particularly as some of the reduction options (e.g. electric or hydrogen vehicles) will only be fully effective by then.
— *More detailed overview of the distributional impacts of an ETS-RT*. The distributional impacts of an ETS-RT may be significant as was shown in Section 5.3.2. Therefore, additional assessment on this issue is recommended, e.g. on the distributional impacts within income groups. Additionally, distributional effects between countries may be a

[78] Saving emissions at the national level will lead to freeing up emission allowances, which will be bought and used by other road transport emitters within the ETS-RT.

relevant topic for further study, particularly as this may heavily affect the political support for an ETS-RT by the various EU Member States.

- *Further study on options to recycle auction revenues*. Auction revenues may be used to soften the financial burden for specific groups of transport users or specific countries. Therefore, it is recommended to carry out a comparative analysis of several options for auction revenue recycling as input for policy development in this field.
- *Complete overview of impacts on public finance*. The current study only quantifies some of the impacts on public finance. Elaborating these analyses by covering all relevant impacts (including the impacts on revenues from electricity tax, vehicle tax and road charges) will show the net impact on public finance.
- *Assessment of the broader economic impacts;* These include, for example, the impacts on GDP and employment.
- *Further study on design and implementation issues.* Relevant issues in this respect are the design of banking and lending facilities and the relevance of a market stability reserve for an ETS-RT (to neutralise the waterbed effect). Furthermore, more knowledge on how much time it will take to implement a fully effective ETS-RT is relevant as well, particularly in order to determine which other policy actions are required in the interim period.

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A Background information on the baseline scenario

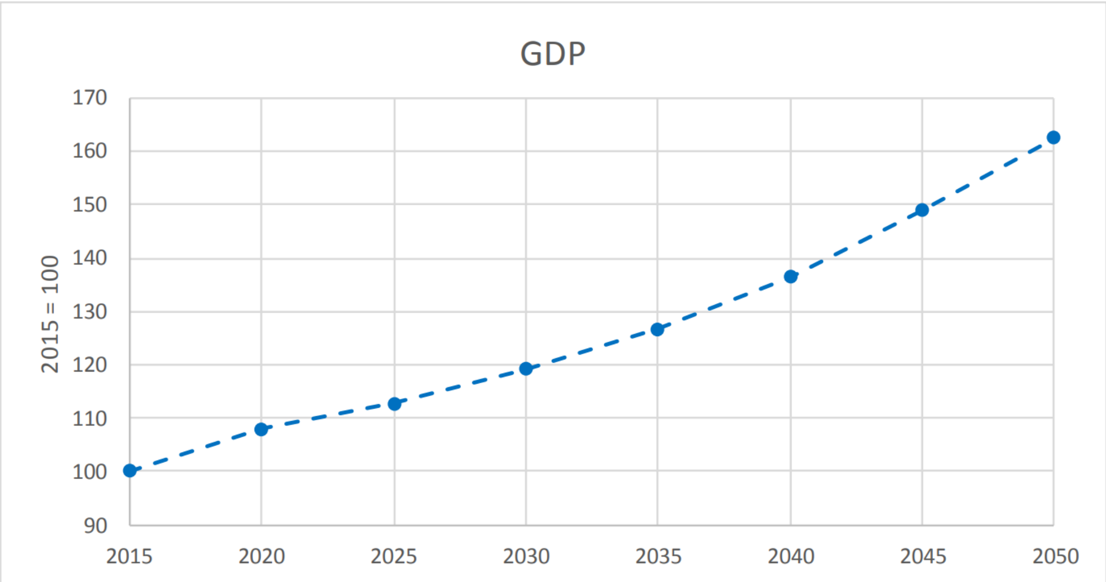
A.1 Introduction

The baseline scenario applied in this study is presented in Section 3.3.2. It has been based on the Reference scenario used by the European Commission for the impact assessment of the Green Deal. In this Annex we provide some more background information on this baseline scenario.

A.2 GDP projection

Figure 18 shows the projected EU GDP in the baseline scenario. This projection is composed by the European Commission based on socio-economic assumptions prepared before the COVID pandemic unfolded.

Figure 18 - Projected EU GDP (2015 = 100)



Source: EC (2020b).

A.3 Oil and fuel prices

Table 34 shows the projected oil prices in the baseline scenario. This projection is composed by the European Commission based on socio-economic assumptions prepared before the COVID pandemic unfolded.

Table 34 - Projected oil prices (€2015)

In €'15 per boe	2000	2005	'10	'15	'20	'25	'30	'35	'40	'45	'50
Oil	34.6	58.9	78.2	47.2	33.5	52.8	72.2	81.5	87.8	95.2	106.3
Gas (NCV)	23.4	31.7	40.6	38.7	19.7	27.9	36.2	39.7	46.6	50.5	51.2
Coal	9.9	15.0	20.6	11.6	8.9	12.3	15.6	16.9	18.0	18.9	19.7

Source: EC (2020b).

Based on the oil prices, the projected EU average fuel prices are shown in Table 35.

Table 35 - Projected fuel prices in 2030 (€2020)

Fuel prices 2030	(€/liter)
Petrol (incl. fuel tax & vat)	€ 1,43
Diesel (incl. fuel tax & vat)	€ 1,42
Diesel commercial (incl. fuel tax)	€ 1,17

B Methodology MAC curve development

B.1 Introduction

As mentioned in Section 3.3.3, three types of reduction options are considered in the MAC curve developed in this study:
— increased blending rates of biofuels;
— behavioural reduction options;
— uptake of electric vehicles.

To include these three types of reduction options in the MAC curve, different methodologies have been used. In this Annex we will explain this in more detail.

B.2 Increased blending rates of biofuels

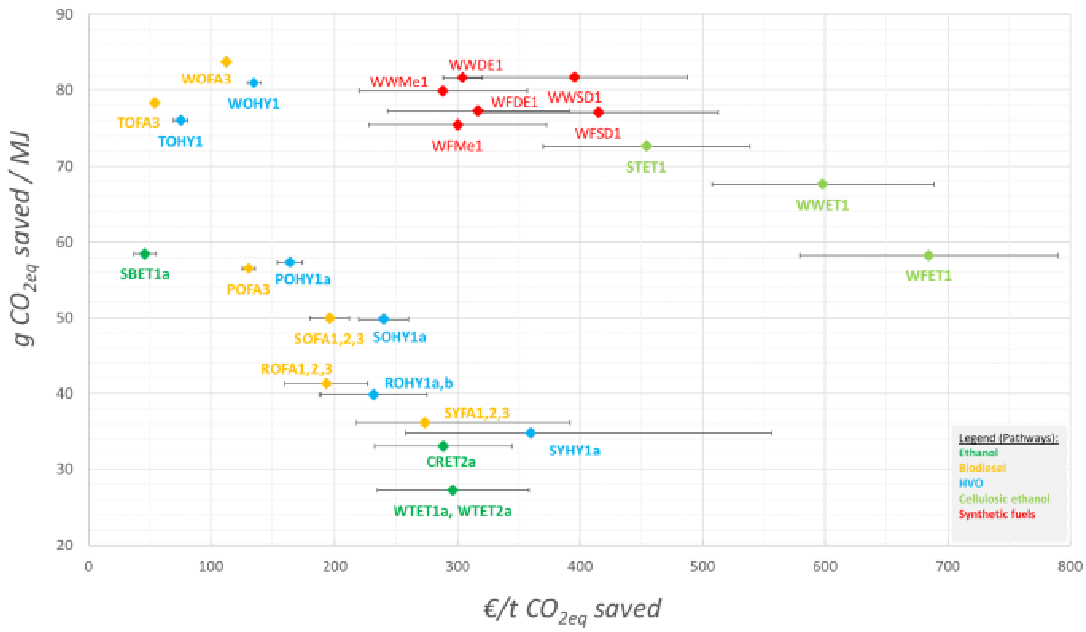
Whether fuel suppliers increase the share of biofuels in the fuel blends depends on the abatement costs of biofuels and their availability.

Abatement cost biofuels

The abatement costs of biofuels have been investigated by several studies. IEA (2020b) have analysed that currently a carbon price in the range of 50-550 €/tonne CO_2-eq. would be needed to bridge the gap in costs between biofuels and fossil-fuels. Similar figures are presented by Prussi et al. (2020), who find that in general the costs are in the range of 50–500 €/tonne. These abatement cost figures differ widely because of the various production pathways applied to produce biofuels and the uncertainty for each of these pathways on their costs. This is illustrated for a selection of pathways by Figure 19.

Abatement costs are also not fixed over time, e.g. due to learning and scaling effects. Also the development in oil price levels has a large impact on the abatement costs of biofuels over time. IEA (2020b) estimates that towards 2030 the abatement costs of all biofuels could decrease to 0-365 €/tonne CO_2-eq. Koelemeijer et al (2018) consider lower abatement costs for biofuels in 2030: 10–260 €/tonne CO_2-eq. The projected cost reduction in biofuels towards 2030 only occurs if there is significant demand for the various production pathways (in order to achieve learning and scaling effects).

Figure 19- Potential production costs of biofuels (2014-2016)



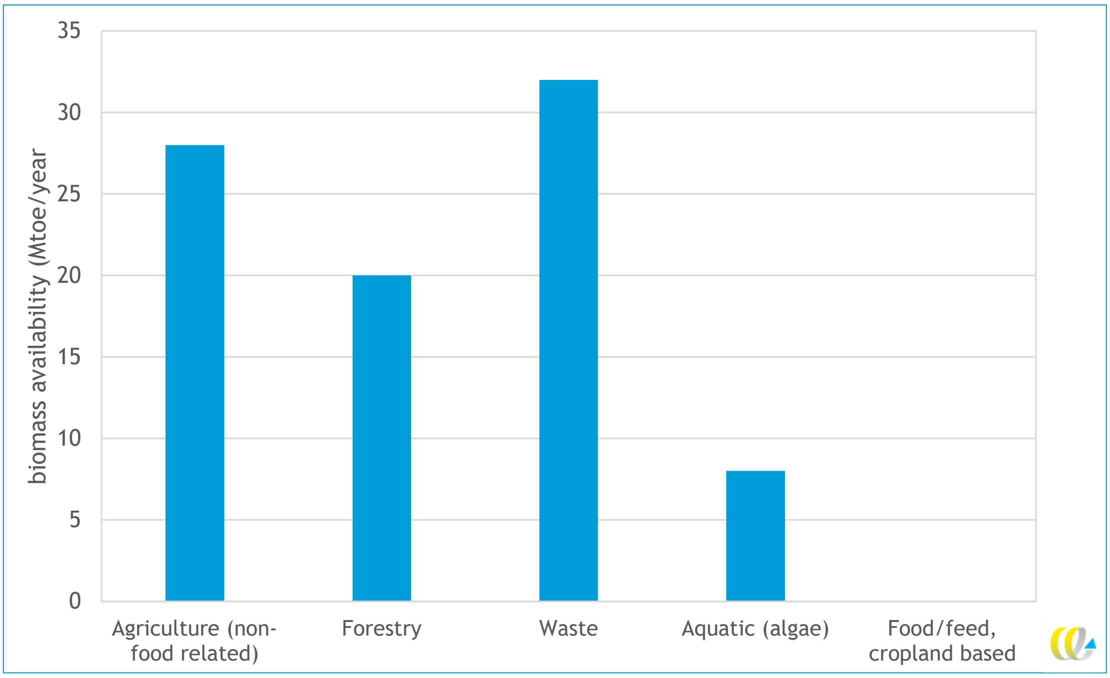
Source: Prussi et al. (2020).

Availability of biofuels

Concawe (2019) has provided an overview of the maximum (sustainable) biomass availability in 2030 in Europe, as is shown in Figure 20. The share of biomass that is available for the road transport sector (and for which production pathway) is very uncertain. Among other things, because of the (future) competition for biomass among different economic sectors (including road transport). The maximum biomass availability is about 84 toe per year[79], which would suffice for an annual CO_2 reduction of about 300 Mton compared to the baseline emission levels. This amount will, however, only become available at high allowance prices, i.e. prices in excess of € 400 per tonne CO_2.

[79] This is without the use of food/crop based biomass.

Figure 20 - European biomass availability in 2030



Source: Concawe (2019).

Main uncertainties on abatement costs and availability of biofuels

The developments in the abatement costs and availability of biofuels are rather uncertain as is the relationship between both elements. These are affected by many factors, including:

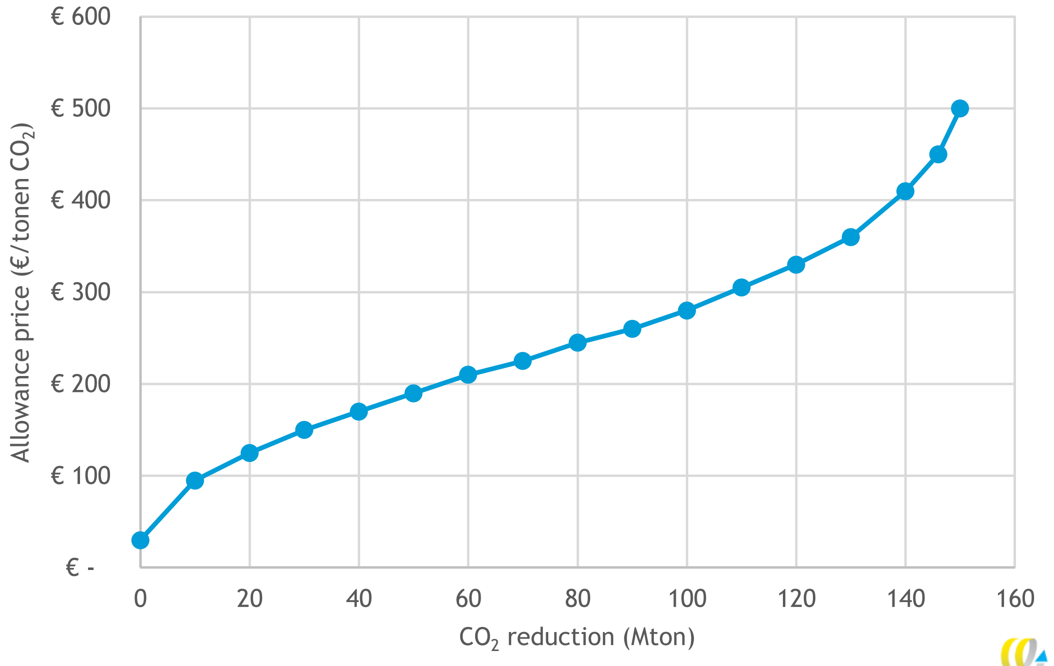
- Production capacity of each production pathway and possibly significant production cost reductions due to scale and learning effects (IEA, 2020b). It takes time to build new factories and upscale existing production pathways to produce biofuels and therefore it takes a couple of years for biofuel production to respond to (unexpected) carbon price increases. Also several production pathways have currently not reached the phase of large scale deployment. For these (advanced) biofuels it takes even longer to reach large scale production.
- The REDII regulation encourages more sustainable and discourages demand for less sustainable biofuels. As on average more sustainable biofuels are also more expensive to produce sustainability requirements put an upward pressure on prices. Notice that the current REDII targets and caps are part of the baseline scenario, and therefore their effect on additional application of biofuels (incentivised by the ETS-RT) is limited.
- The biomass used for biofuels can be used for other purposes as well. The price for biomass and biofuels could therefore increase due to higher (global) demand for biomass from other economic sectors, other transport sectors (e.g. aviation) or road transport from outside the EU.
- The tipping point for biofuels depends on the oil price, which is volatile. Lower oil prices reduce the demand for biofuels as these become relatively more expensive to their fossil counterparts. A significantly lower oil price towards 2030 could therefore reduce the cost effectiveness of biofuels.

— From a policy point of view, high quantities of biofuels used by light duty road transport may not be desirable. For other transport modes (like aviation and shipping) the range of CO_2 reduction options is rather limited and hence biofuels are probably indispensable to achieve the CO_2 reduction targets in these sectors. Furthermore, the increased demand of biofuels also reduces the biomass availability for other economic sectors, where they may be needed to achieve their CO_2 reduction targets.

Abatement cost curve

Because of the uncertainties discussed above, the development of a very detailed abatement cost curve for biofuels is complex and requires extensive research of each individual production pathway to model its production costs and capacity. As this was not possible in the scope of this study we have used a more pragmatic modelling method using the estimated production costs, and maximum reduction potential of 150 Mton CO_2. Figure 21 shows the resulting abatement cost curve for biofuels.

Figure 21 - Estimated reduction potential additional use of biofuels



Because of the large uncertainties in the cost and availability of biofuels, we have carried out a sensitivity analysis in order to investigate the impact of these uncertainties on the MAC curve and eventually the allowance price. This sensitivity analysis shows what the allowance price will be for different levels of biofuels availability and associated production cost levels. See Section 3.4.2 for more details.

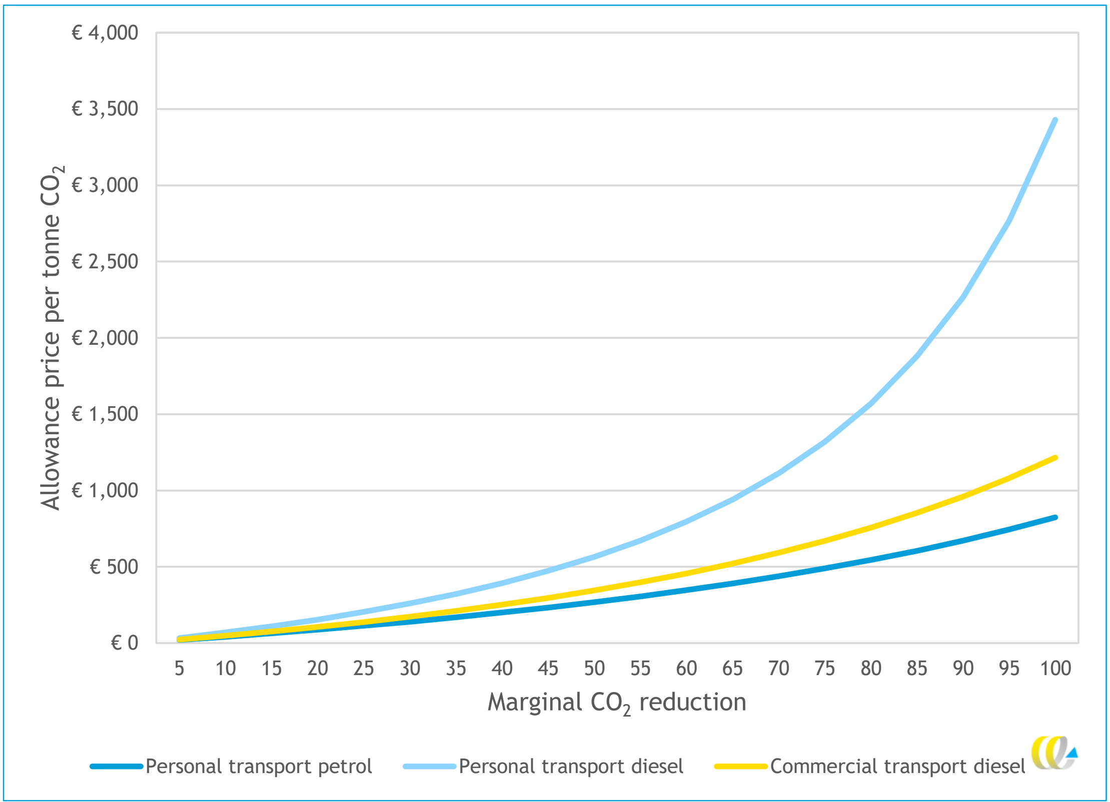
B.3 Behavioural reduction options

Behavioural reduction options encompass a large number of actions, e.g. switching from road transport to another transport mode, applying a fuel-efficient driving style, buying a more fuel-efficient (fossil-fuelled) vehicle, reduce movements, etc. As mentioned in Section 3.3.3, a fuel cost elasticity approach is used to estimate an abatement cost curve covering these reduction options. This approach consists of the following steps:

1. *Conversion of* CO_2 *prices to fuel price changes*; this has been done by using relevant figures on the carbon content of the various fuel types and the (increased) blending rates of biofuels.
2. *Estimation of the impact of* CO_2 *prices on fuel demand;* fuel cost elasticities from the literature (see Section 3.3.3 for an overview of the elasticities used) have been used to estimate the impact of the relative fuel price changes (compared to the baseline) from step 1 on the total fuel demand. Because of the direct link between CO_2 prices and fuel prices (see Step 1), this provides the relationship between CO_2 prices and total fuel demand.
3. *Estimation of the impact of* CO_2 *prices on* CO_2 *reductions;* finally, the changes in total fuel demand as estimated in Step 2 can be converted to CO_2 reductions by using the same figures on carbon content of fuels as in Step 1.

The resulting (simplified) MAC curve for the behavioural reduction options is shown in Figure 22.

Figure 22 - MAC curve for the behavioural reduction options in 2030



The elasticity approach as applied in this study has some weaknesses:
- The fuel price elasticities found in literature are based on historical changes in fuel prices. This entails that there is a limit to their application value in terms of the hypothetical price increases we need to reach the caps. For relatively small price increases the elasticities are probably fairly reliable to estimate changes in fuel consumption. For higher price increases, however, the uncertainty in the estimations with these elasticities will increase. This implies that the abatement cost curve estimated for behavioural reduction options will be most robust for lower CO_2 prices.
- In our approach, we assume that there is a linear relation between price increases and fuel consumption. In practice, non-linear relationships are possible as well (e.g. progressive relationships), however there is no empirical information on this issue that can be adopted for this exercise.

Although the elasticity approach has some weaknesses, it is still the best option to calculate abatement costs for behavioural reduction options due to absence of suitable alternatives. For the same reason, this approach has been applied in other studies on this topic as well (e.g. CE Delft (2007), Cambridge Econometrics (2014)).

B.4 Uptake of electric vehicles

The main reduction option that could be taken by transport users and that is not covered by the fuel price elasticity approach explained above is the uptake of zero-emission vehicles. Therefore, a complementary analysis has been carried out in order to integrate the uptake of full electric vehicles in the MAC curve as well.

By increasing carbon prices (e.g. due to the implementation of an ETS-RT) the demand for electric vehicles will increase. The extent to which this additional demand may result in extra electric vehicles in the fleet also depends on the supply of these vehicles. In case of supply constraints (e.g. due to a lack of production capacity), only part of the additional demand could be accommodated. In this Annex we will explain how both the demand and supply effects have been considered in study.

B.4.1 Demand for electric vehicles

A common approach to model the demand for electric vehicles is by using a total costs of ownership (TCO) model, which considers the total costs of a vehicle over its lifetime. The underlying assumption is that people will consider switching to an electric vehicle if the TCO of such a vehicle becomes comparable or even better than the TCO of a fossil-fuelled vehicle.

Uptake of electric vehicles

The uptake of electric vehicles does however happen gradually as people have individual preferences. Early adopters will switch even if the TCO of an electric vehicle is higher than a fossil-fuelled vehicle. On the other hand, there will also be consumers who keep driving fossil-fuelled vehicles even if the TCO of the electric vehicle is significantly lower. This may be because of various reasons, including consumer myopia, risk aversity, lack of charging infrastructure/range anxiety, etc. Revnext (2019) has investigated for the Dutch vehicle market the relationship between the share of consumers who switch to electric vehicles for different levels in TCO between the electric vehicle (BEV) and the fossil-fuelled vehicle

(ICEV[80]). The results for 2025 and 2030 are summarized in Table 36. Towards 2030 more people are willing to switch to electric vehicles as the quality of, and knowledge on, electric vehicles improve.

Table 36 – Percentage of new vehicle buyers who switch to EV at various TCO levels

Delta TCO (BEV-ICEV)	Percentage of switching consumers			
	Private ownership		Business ownership	
	2025	2030	2025	2030
-10%	2%	4%	3%	2%
-5%	3%	9%	10%	10%
0	6%	13%	25%	33%
5%	10%	18%	44%	61%
10%	15%	30%	60%	81%
15%	20%	45%	70%	87%
20%	27%	61%	78%	90%
25%	36%	75%	86%	93%
30%	45%	86%	92%	95%

Source: Revnext (2019).

The Netherlands is a country well suited for a switch to electric vehicles as average distances are relatively short and a rather extensive charging infrastructure is already in place. It is very likely that in the average European country lower percentages of consumers will switch to EVs. The percentages in Table 36 may be an overestimation of the number of switching consumers in Europe. However, these percentages are not stable over time. Charging infrastructure in all European countries will improve due to the Alternative Fuel Infrastructure Directive (potentially complemented by additional national or regional initiatives). Therefore, the switching rates in other countries may become more in line with the Dutch figures in the near future. As both effects contradict each other, we have applied the figures from Table 36 for the entire EU. As a sensitivity analysis we show the effect of applying significantly lower percentages (see Section 3.4.2).

The percentage of switching consumers is applied to the number of new registrations in Europe per year, as shown in Table 37. Due to the absence of reliable projections we take the registration figures from 2019 as proxy for the period until 2030. For long distance HGVs we assume that electric drivetrains are not available for large scale deployment in 2030.

Table 37 – Estimated number of new registrations in Europe per year per vehicle type for 2030

	Number of new registrations per year	Vehicle stock
Company cars	7.817.000	242,727,000
Private cars	5.212.000	46,904,000
LCV	1.750.000	28,110,951
HGV <12 ton	39.000	
HGV 12 ton-24 ton	39.000	

Source: Eurostat & T&E (2020).

80 Internal Combustion Engine Vehicle.

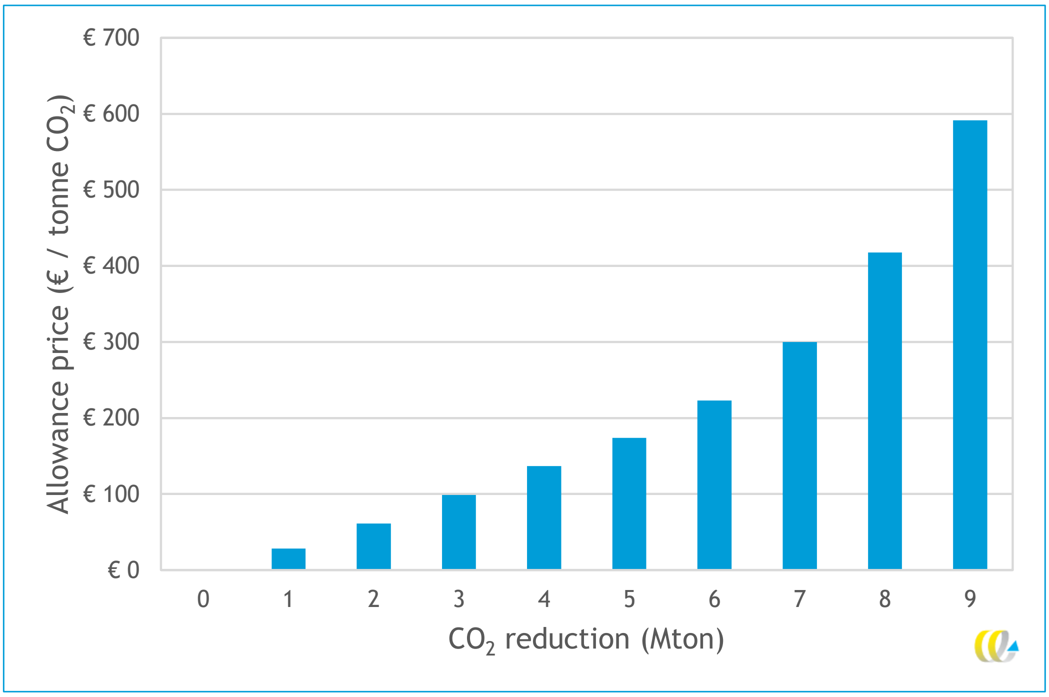
Estimation of the demand of electric vehicles

The following steps have been carried out to estimate the demand of electric vehicles (and hence the CO_2 reduction potential) as function of the CO_2 price:

1. *Estimate the TCO excluding taxes for all vehicle and propulsion types*. We have used the TCO model COSTREAM for this task, which contains up-to-date cost data for all different types of vehicles. We have estimated EU-average TCO figures, assuming no differences in cost data for the various countries. This is done for each year between 2025 and 2030, taking the impacts of learning and scale effects on abatement costs of electric vehicles into account.
2. *Analyse the impact of a carbon price on the TCO;* in this second step, the impact of a carbon price on the TCO of the various vehicle types (and propulsion types) is calculated. Notice that this carbon price consists of two parts: the fuel tax (incl. VAT) and the ETS-RT allowance price (in case an ETS-RT is implemented). The current EU average fuel tax (incl. VAT) already results in an implicit carbon tax of about € 250 per tonne CO_2. Again, we have performed this analysis for each year between 2025 and 2030.
3. *Estimate the uptake of electric vehicles based on the TCO;* using the figures from Table 36 and Table 37 and the results of Step 2, the number of consumers switching annually from a fossil-fuelled vehicle to an electric vehicle is estimated. By assuming that the annual mileage will stay the same, the CO_2 reduction potential is estimated.
4. *Calibration of the modelling results;* the results from Step 3 have been calibrated against the baseline projections for the vehicle stocks (EC, 2020b), as well as the predicted 30% passenger car EV sale in 2030 (TNO, 2018). In this way, we have been able to estimate (and add) the average EU fiscal stimulation (in addition to fuel taxes) of electric vehicles.

For illustrative purposes the MAC curve for newly sold electric passenger cars in 2030 is presented in Figure 23.

Figure 23 - MAC curve for electric vehicles for 2030



B.4.2 Supply constraints

The shift towards electric vehicles has a large impact on the automotive supply chain. The demand for combustion engine parts will decline rapidly, while at the same time the demand for batteries and electronics increases. Current shortages of semiconductors already show that the production of vehicles can halt due supply chain issues. Especially the supply of the raw materials for batteries, mainly lithium and cobalt, may become problematic (McKinsey&Company, 2018). This is further discussed in the following text box. Production capacity of electric vehicles seems less of a problem. Deloitte (2019) estimated that global production capacity of electric vehicles will largely exceed the demand for these vehicles in the baseline scenario (about 40%).

Battery shortages at the global level due to scarcity of minerals do not necessarily limit the EV supply to Europe, as countries and regions compete with each other for scarce supply of electric vehicles[81]. In practice, supply of electric vehicles will flow to the regions with the highest price level, which is pushed by local policies. This disproportionate supply is currently exemplified by the large number of EVs going to Norway and the Netherlands, countries with a high level of EV tax benefits. Also the introduction of the standard of 95 grams CO_2 per kilometre for 95% of the new passenger cars in 2020 has already greatly accelerated the uptake of electric vehicles in Europe[82]. As a result Europe has become the market leader for electric vehicles in 2020 with a market share increase form 20% (in 2019) to 45% (IEA, 2021). The supply of electric vehicles in 2025 and 2030 will thus depend on the global level of electric vehicle uptake and the ambition of European policies compared to other countries and regions.

Although there is a risk of constrained supply of electric vehicles to the European market, no evidence is available to quantity this risk and the level of constraints. In this study, we therefore assume that there are no limitations for the supply of electric vehicles in Europe towards 2030.

Scarcity of minerals for batteries

IEA (2021) has investigated the role of critical minerals in the clean energy transition, including the expected large-scale market uptake of electric vehicles. Suppliers of essential minerals for the production of batteries for EVs like cobalt and lithium are facing significant challenges in ensuring adequate supply to fulfil (predicted) demand in the future. Today's mineral supply and investment (plans) of mining companies fall short of the needed production capacity for the short- and long-term demand for these minerals for the application in EVs. This may lead to delayed and a more expensive energy transition in the long-term. More specifically, the demand for EVs in scenarios that will achieve the current climate goals[83]is on such a level that the expected supply from current and future mining projects is predicted to meet only half of the projected lithium and cobalt needs by 2030 (IEA, 2021). Also McKinsey & Company states a strong demand increase for these minerals as global battery demand (EVs, electronics, stationary storage and machinery) is expected to increase at 32% per annum up until 2030 (Campagnol, et al., 2018).

[81] And hence, EV supply to Europe may be sufficient, although this will result in a shortage of EV supply in other parts of the world.

[82] https://theicct.org/blog/staff/snapshot-eu-new-pv-markets-jan2020

[83] Demand can be expected to rise especially in case a carbon price on road transport fuels is implemented.

C Estimation of fuel tax and auctioning revenues

C.1 Introduction

In this Annex we explain how the revenues from fuel taxes, VAT and auctioning of emission allowances for the Netherlands have been estimated.

C.2 Impact of ETS-RT on fuel taxes revenue

In this section we give an estimation of the revenue loss from fuel sales for the Dutch state due to lower fuel demand in 2030 as a consequence of the presence of an ETS-RT. For the baseline, we estimated the fuel sales (broken down to petrol and diesel) based on the projections provided by the Climate and Energy Outlook 2020 (PBL, 2020). Assuming that the fuel tax rates are constant between 2021 and 2030 in real terms, the baseline revenues are estimated at about € 8.0 billion in 2030.

In order to estimate the Dutch fuel tax revenues in the three ETS-RT Cap scenarios, we first calculated the reduction in fuel consumption based on the CO_2 reduction determined for each scenario for road transport in the Netherlands. The resulting fuel consumption has been multiplied by the Dutch fuel tax rates[84] to estimate the revenues (see Table 38).

Table 38 – Dutch fuel excise duty revenue in 2030 in the three ETS-RT Cap scenarios (billion $€_{2021}$)

	Baseline	S1	S2	S3
Revenue under ETS-RT	8.0	7.3	5.2	4.0

C.3 Impact of ETS-RT on revenues from VAT on transport fuels and fuel taxes

The introduction of an ETS-RT affects the revenues from VAT on transport fuels and fuel taxes in two ways:
- As allowance prices are incorporated in fuel prices, the fuel prices (excluding taxes) will increase and hence the VAT revenues per litre fuel sold will be higher.
- The reduction in fuel consumption will result in lower revenues from VAT on transport fuels and fuel taxes.

In our calculations we have only considered the VAT on petrol (and fuel taxes on petrol), as we assume that the majority of the VAT on diesel is used for commercial purposes and hence can be reclaimed. The VAT revenues in the baseline scenario and the three ETS-RT Cap scenarios are shown in Table 39. These revenues increase by implementing an ETS-RT, which is due to the upward effect of the ETS on fuel prices.

[84] We assumed that for biofuels tax rates are applied that correct for the lower energy content of these fuels (compared to their fossil fuel counterparts). As a consequence, an increase in the biofuel share in the various scenarios does not affect fuel tax revenues. Therefore, the changes in fuel tax revenues shown in Table 38 can be completely explained by the reductions in fuel consumption because of the uptake of electric vehicles and behavioural measures.

Table 39 - VAT revenues in 2030 in the three ETS-RT Cap scenarios (billion €$_{2021}$)

	Baseline	S1	S2	S3
Revenue from VAT on petrol	1.5	1.6	1.8	1.7

C.4 Auctioning revenue

In this Section, we estimate the expected revenues from ETS allowance auctioning for the Dutch state in 2030. We assume the ETS prices per tonne CO_2 as presented in Table 7 to be constant, so we ignore short-term price fluctuations which might occur during the year. Therefore, the presented figures are only an indication of the situation under these assumptions (and those stated in the scenarios). The total number of allowances is equal to the Cap set in the respective scenario. Comparable to the current EU ETS, we assume 90% of the allowances are proportionally distributed among the Member States, according to their share of road transport emissions in a reference year. We use the share of road transport CO_2 emissions in the Netherlands in the reference year 2018, which is 3.85% of the total emissions from road transport in the EU. In Table 40, we present the indicative revenue for the Dutch state from the auctioning of ETS-RT allowances in the year 2030.

Table 40 - ETS-RT auctioning income for the Dutch state in 2030

	S1	S2	S3
ETS price per scenario	€ 75	€ 220	€ 690
Emission CAP (Mt)	551.9	434.0	331.0
Number of Dutch allowances (millions)	19.1	15.1	11.5
Income for Dutch state (billion €)	€ 1.4	3.3	7.9

The revenue from auctioning ETS-RT allowances under the assumed allowances allocation ranges from € 1.4 billion in S1 to € 8 billion in S3. In practice, the design of the allowance allocation might be according to a different method. For example, the share of allowances allocated directly to Member States with fewer options or financial capacity to invest in emission reduction options may be larger than 10%, in which case the share for the Netherlands will probably be smaller (and hence so will be the auctioning income). Also, in line with the regulation of the EU ETS, we assumed that all allowances will be auctioned in 2030[85]. This is also a political issue and increasing the share of free allowances will negatively impact the revenues from the ETS-RT allowances. Therefore, the estimated auctioning revenues should be perceived as a higher end indication of these revenues.

[85] See https://ec.europa.eu/clima/policies/ets/ for distribution of EU ETS rights in 2021-2030 and the effort sharing mechanism.

D Overview tables of fuel prices under ETS-RT scenarios

D.1 Real petrol prices under ETS-RT

The estimated petrol prices in the baseline and the various ETS-RT scenarios in 2030 are presented in Table 41 for a selection of EU Member States.

Table 41 - Real petrol prices in the baseline and under ETS scenarios in 2030, per litre (incl. VAT)

Country	Baseline	S1	S2	S3
Bulgaria	€ 1.21	€ 1.42	€ 1.84	€ 2.39
Luxembourg	€ 1.30	€ 1.52	€ 1.92	€ 2.46
EU average	€ 1.45	€ 1.67	€ 2.09	€ 2.65
Italy	€ 1.67	€ 1.89	€ 2.32	€ 2.88
The Netherlands	€ 1.77	€ 1.99	€ 2.41	€ 2.97

D.2 Real diesel prices under ETS

The estimated diesel prices in the baseline and the various ETS-RT scenarios in 2030 are presented in Table 42 for a selection of EU Member States.

Table 42 - Real diesel prices in the baseline and under ETS scenarios in 2030, per litre (incl. VAT)

Country	Baseline	S1	S2	S3
Bulgaria	€ 1.09	€ 1.29	€ 1.67	€ 2.17
Luxembourg	€ 1.11	€ 1.31	€ 1.70	€ 2.20
EU average	€ 1.19	€ 1.40	€ 1.78	€ 2.25
Italy	€ 1.38	€ 1.58	€ 1.96	€ 2.46
The Netherlands	€ 1.30	€ 1.50	€ 1.88	€ 2.38