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Sensitivity analysis of modelling of light vehicle emission standards in Australia

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Important disclaimer

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Executive summary

The Climate Change Authority (CCA) recently released *Reducing Australia's greenhouse gas emissions – Targets and progress review draft report* and is currently in the process of finalising the review, with a final report to be released in early 2014 (CCA, 2013).

To build on the analysis of emissions reduction opportunities in the transport sector, the CCA commissioned CSIRO to examine the potential of fleet-average new light vehicle carbon dioxide emission standards for Australia ('emission standards'), as implemented in most major automotive markets in the world.

A key goal of the analysis is to quantify the emissions reduction potential of emission standards with respect to two key design features of the standard – the rate of improvement in emissions imposed and the timing of commencement of the standards. All other factors are held constant. The sensitivity analysis is modelled using the *No carbon price scenario* as the reference scenario (CCA, 2013).

This sensitivity study applies CSIRO's Energy Sector Model (ESM) to model the response of the road transport sector to the emission standards. ESM was previously applied to model the *No carbon price scenario,* together with other carbon price scenarios, in Reedman and Graham (2013) as one of several modelling inputs to CCA (2013).

The CCA have designed the emission standards sensitivity cases based around a step up in the expected improvement in new light vehicle emissions levels in the absence of standards as a low bound, and the European Union (EU) emission standards for the upper bound. The trajectories, including their timing and required rate of improvement in emissions are shown in Figure 1-1. The trajectories are forced to converge towards a likely achievable standard in 2030-2040.

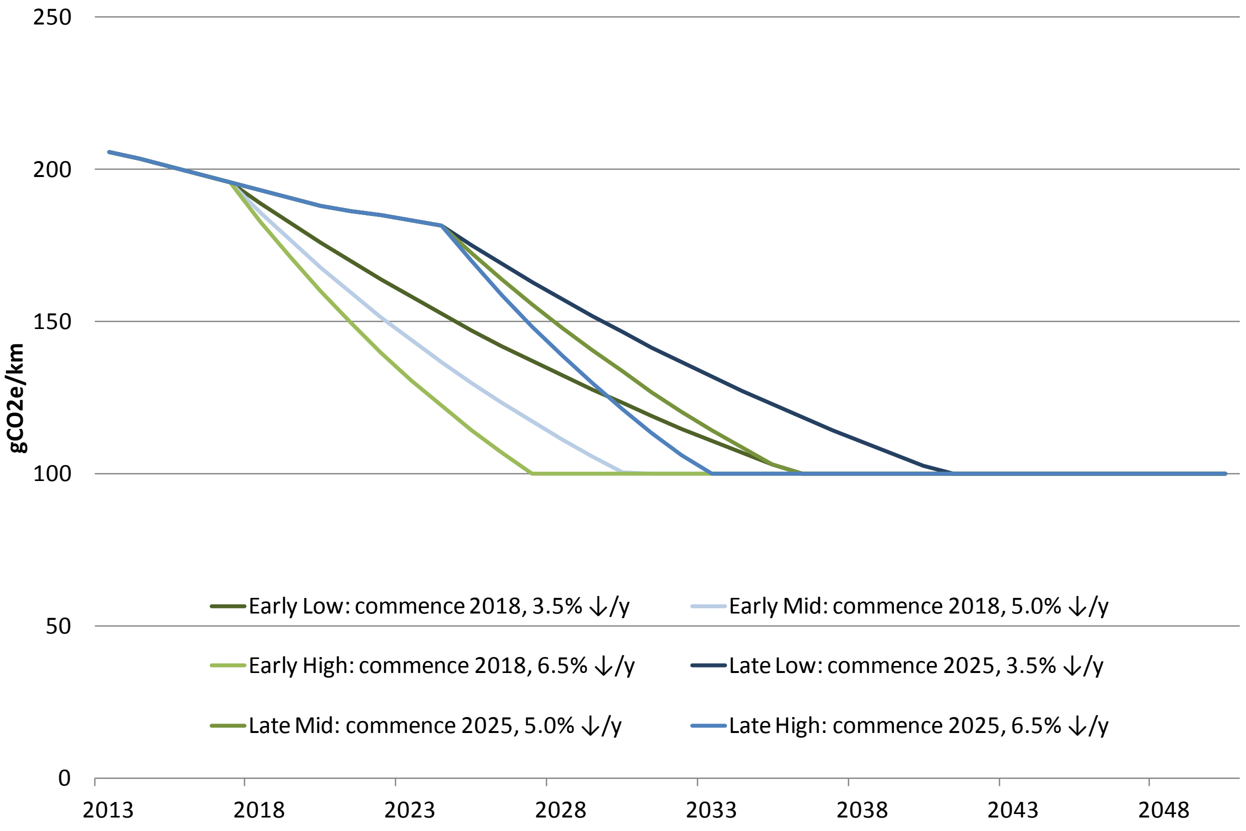

Figure 1-1: The emission standards sensitivity cases

The projected outcomes for greenhouse gas emissions from the implementation of minimum average emission standards on new light vehicles are significant reductions in transport sector greenhouse gas emissions (Figure 1-2). There are clear differences in the 'Early' and 'Late' commencement sensitivity cases followed by a degree of convergence from around 2035 onwards. By 2050, light vehicle greenhouse gas emissions are around 40 Mt for the sensitivity cases compared to 60 Mt in the No carbon price scenario reference case – a reduction of one third due to the emission standards.

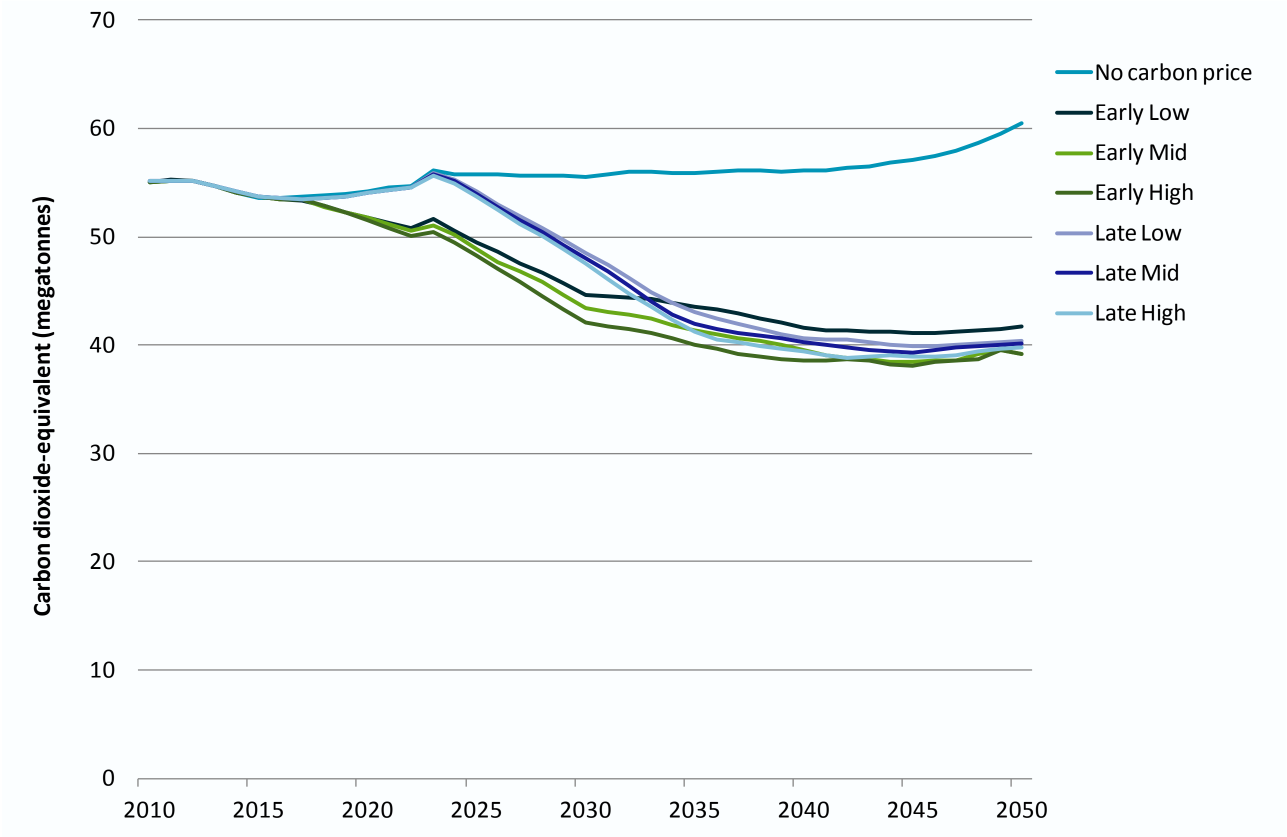

Figure 1-2: Projected light vehicle greenhouse gas emissions by sensitivity case

The modelling assumes that some vehicle changes implemented to meet the emission standards would be supplied by vehicle manufacturers at no real increase in the cost of vehicles whilst others, particularly in relation to vehicle electrification would require considerable additional cost. Under these assumptions, in the long run, the cost of travel is projected to be slightly lower, but not significantly different from the reference case as fuel savings offset assumed additional vehicle costs. No strong conclusion should be drawn from this projected change in cost, given the uncertainty in the assumptions, unless supported by other modelling evidence from Australia or similar vehicle markets.

1 Introduction

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This sensitivity study applies CSIRO's Energy Sector Model (ESM) to model the response of the road transport sector to the emission standards. ESM was previously applied to model the *No carbon price scenario,* together with other carbon price scenarios, in Reedman and Graham (2013) as one of several modelling inputs to CCA (2013).

ESM is a partial equilibrium model covering road and aviation. The ESM contains ten road vehicle categories including buses, trucks, light commercial and passenger vehicles. The ESM was developed by CSIRO and ABARE in 2006. Since that time CSIRO has continued to develop ESM. The model has an economic decision-making framework based around the cost of alternative fuels and technologies.

ESM's structure and its assumption, set out in detail in Reedman and Graham (2013), remain the same in this application with the exception of the specific assumptions applied to implement the emission standards sensitivity cases. We do not therefore repeat discussion of the assumptions in this report but recommend readers have some familiarity with the previous report.

The CCA have designed the emission standards sensitivity cases based around a step up in the expected improvement in new light vehicle emissions levels in the absence of standards as a low bound, and the European Union (EU) emission standards for the upper bound.

This report is set out in three parts including this introduction. The second part describes the emission standards sensitivity cases and methodological considerations. The third part describes the modelling results in relation to greenhouse gas emissions, fuel and technology choices, and the cost of transport.

2 Emission standards sensitivity cases and their implementation in ESM

2.1 Sensitivity cases

The Climate Change Authority has designed the emissions standards sensitivity cases to explore a range that represents an improvement over business as usual: a lenient standard with an improvement rate slightly higher than BAU (3.5 per cent), a medium standard that follows the projected US improvement rate (around 5 per cent per year), and a stringent standard that represents Australia catching up with the EU (which equates to around 6.5 per cent per year for Australia). The scenarios are modelled from 2018 and 2025, the earlier starting year reflecting a 5 year lag to introduce standards, and the later starting year to reflect later action. The sensitivity cases are set out in Table 2-1.

Recently, average new light vehicle emissions have been improving at a rate of around 2 per cent and Reedman and Graham (2013) assume this continues at a slightly diminished rate of 1.3 per cent in the *No carbon price scenario* reference case given oil price pressures have stabilised but competition between vehicle manufacturers to provide improved fuel economy for consumers remains a point of product differentiation[1].

Table 2-1: Emission standards sensitivity cases

Sensitivity	Commencement year	Annual rate of decrease in average new light vehicle emissions (%)
Early Low	2018	3.5
Early Mid		5.0
Early High		6.5
Late Low	2025	3.5
Late Mid		5.0
Late High		6.5

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[1] There two other reasons why we assume a lower than recent trends rate of fuel efficiency improvement. The first is that we want to maintain consistency with assumptions used in Graham and Reedman (2013) to maintain comparability with that study. The second is that we do not want to divorce our fuel efficiency assumptions from real achievable improvements under normal market conditions. The Graham and Reedman (2013) assumptions were designed to be compatible with the King Review (2007) which was a bottom up analysis of fuel efficiency improvements that were available, in the main, at modest additional vehicle cost. Extrapolating a trend rate indefinitely could lead to unrealistic reference case outcomes.

2.2 Implementation of sensitivity cases in ESM

2.2.1 SOURCES OF IMPROVEMENT IN GREENHOUSE GAS EMISSION INTENSITY OF LIGHT VEHICLE ROAD TRANSPORT

There are many different ways to reduce light vehicle sector emissions (e.g. cycling, walking, public transport, driver behaviour and telecommuting), however the scope of emission standards policy are those things that can be implemented by a vehicle manufacturer or importer whose is responsible for meeting the standard. This also means that biofuels are excluded, although they do have the potential to make a contribution to reducing light vehicle emissions (Reedman and Graham, 2013).

The two primary measures therefore for meeting the emission standards are fuel efficiency and vehicle downsizing. Fuel efficiency includes a wide variety of measures outlined in the King Review (2007) and other literature (Cosgrove et al., 2012) including:

- Aerodynamics
- Low rolling resistance tyres
- Engine efficiency (e.g. direct injection, turbo-/super-charging, variable valve actuation, specifying diesel compression ignition over etrol spark ignition)
- Drive-train efficiency (e.g. stop-start, regenerative breaking, partial or full electric motor application).

Vehicle downsizing generally reduces the weight and therefore the amount of energy input required to travel the required distances for a given energy efficiency of the vehicle. Cosgrove et al. (2012) outline potential savings of up to 25 per cent on light vehicle fleet emissions from vehicle downsizing. However, it can be difficult to separate downsizing from other measures as reducing weight opens up opportunities to use a smaller engine with, for example, turbo-/super-charging as well as lighter tyres.

2.2.2 DRIVING ABOVE TREND VEHICLE EMISSION IMPROVEMENTS IN ESM

All models include items which are inputs (fixed assumptions) and outputs (items endogenously determined by the model). In ESM the rate of improvement in the fuel efficiency of internal combustion engines and consumer preferences about vehicle sizes are inputs. The model determines, as outputs, the fuels consumed (and their associated spark or compression ignition engines types) and the drive-train which is either an:

- Internal combustion engine (ICE),
- Hybrid electric and internal combustion vehicle but with no plug-in capability(HYB)
- Plug-in hybrid electric vehicle (PHEV),
- Electric vehicle (EV) only, or
- Fuel cell vehicle (FCV).

Given ESM operates in this way we use the following procedure to implement the emission standards:

1. Assume no further change in vehicle size preferences relative to the *No carbon price scenario* (described below)
2. Impose an additional amount of improvement (up from 1.3 to 3.3 per cent a year) in internal combustion fuel efficiency above ESM's standard assumptions with no change to purchase price of vehicles (in real terms)
3. Allow ESM to determine the economically optimal deployment of alternative drive-trains and use of compression ignition (diesel) vehicles to achieve the remainder of the emission standard at additional cost to new vehicles available for purchase (in real terms).

Fundamentally, this approach assumes that there are a set of vehicle changes that can be implemented at no extra cost to new vehicles available for purchase and another set of changes (largely relating to alternative drive-trains) that will lead to increased vehicle cost. Supporting this approach, *King Review* (2007) lists (in Table 4.1 of that document) a number of vehicle improvements that are in the range of $150 to $1,000 per item. If deployed overall several years these may not increase the real cost of vehicles[2]. However, changes to the drive-train (to hybrid or fully electric) or the diesel (compression ignition) version of the same vehicle will generally cost several $1,000 more.

The first assumption of no change in vehicle preferences (relative to the reference case) can be justified on the basis that existing modelling by ESM does not show any major increase in the cost of travel. Improving fuel efficiencies means that rising fuel prices are offset over time. Given the cost of travel does not significantly change in the reference case there is not an obvious driver that would lead to additional changes in vehicle preferences.

While this approach can be justified it also largely reflects the limitations of how ESM deals with different drivers of change in light vehicle efficiency. The approach should not be interpreted as being the only or most likely way in which manufacturers will choose to meet the emission standards. The approach captures some of the possible costs to consumers but with significant uncertainty. It might overestimate costs if vehicle downsizing is a strong feature of how manufacturers meet the standard (smaller vehicles are cheaper in this model). It might underestimate the costs if the improved fuel efficiency or drive-train changes cost more than has been assumed here[3].

The following sections outline the reference case vehicle efficiencies and vehicle size preferences.

Vehicle size assumptions under the reference *No carbon price scenario*

The assumed changes in light vehicle size preferences are based on extrapolation of past trends. The major trend is towards smaller vehicles occupying a greater share of the road fleet (Figure 2-1). This trend has its origins in rising oil prices which began in 2004, peaking in 2008 and being largely maintained in to the present.

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[2] For example, if the rate of inflation is 2.5 per cent then if the cost of a $25,000 vehicle in the previous period increases by $625 the cost of that vehicle remains $25,000 in real terms.

[3] Table A-5 of Graham and Reedman (2013) outlines the baseline and alternative vehicle drive-train costs

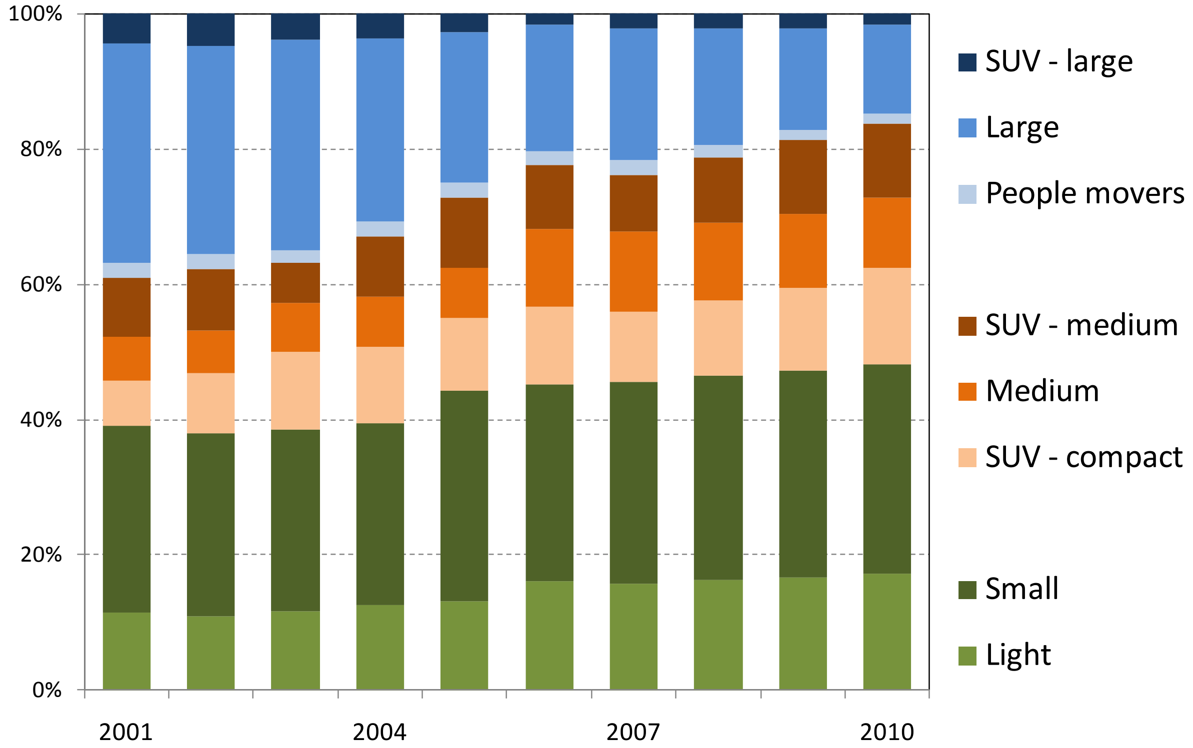

Figure 2-1: Historical changes in preferences for road vehicle types and sizes, FCAI (2011)

We assume small/light vehicles increase their share of the passenger vehicle market gradually to 50 per cent by 2050 at the expense of the large and (to a lesser extent) medium size vehicle categories. This assumption reflects that petrol and diesel prices (see Figures 4-7 and 4-8 in Reedman and Graham, 2013) are assumed to rise only gradually so that the cost of travel does not change significantly (after accounting for fuel efficiency improvements) leading to only modest change.

Fuel efficiency assumptions in the reference *No carbon price scenario*

The *No carbon price scenario* assumed that a 15 to 25 per cent improvement in the average fleet fuel efficiency of internal combustion engines relative to 2006 occurs by 2030 under trend oil price conditions. It is part of the historical record but also generally assumed that a significant amount of the improvement occurs in the first half of the period to 2030 owing to the deployment of innovations that were sparked by the high oil prices in the mid-2000s.

Petrol vehicles are assumed to improve at the higher end of this range (25 per cent) due to their lesser state of development relative to diesel engines. Diesel engines improve at the lower rate of 15 per cent. While new LPG and natural gas vehicles are assumed to develop at a similar rate to their petrol and diesel equivalents their average fleet fuel efficiency will at times move more rapidly since they have a relatively small vehicle stock .

The efficiency improvements will occur independently of changes to vehicle drive-trains such that overall fuel efficiency improvements, if and when vehicle electrification and/or hybridisation is widely adopted will be even greater. As discussed the adoption of alternative drive-trains is endogenously determined within the model based on cost minimisation[4].

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[4] These alternative drive-trains will be selected to replace existing stock and meet new demand when their additional vehicle costs are more than offset by fuel cost savings. Vehicle cost is amortised over a five year period

In the reference *No carbon price scenario* the uptake of alternative drive-trains is low (Figure 3-3) reflecting no carbon price signal and only a gradual increase in the price of petroleum fuels. Consequently new vehicle efficiency is improving throughout the projection period but at a diminishing rate.

2.2.3 THE EMISSION STANDARDS TRAJECTORIES

The emission standards trajectories are implemented by fitting them between the assumed existing improvement in emissions (via reference case fuel efficiency and vehicle size preferences assumptions) which occur prior to the commencement of the scheme (in either 2018 or 2025) and an assumed maximum improvement end-point of average new vehicle emissions of 100gCO_2e/km. Each of the trajectories arrives at the end-point at different times due to the different commencement dates and rate of change in emission standards.

A common end-point implies that the same emission savings measures are available no matter the chosen emission standards trajectory. The policy primarily influences how quickly the measures are deployed. In reality we might in fact observe some relationship between policy and measures available as a strong emission standards policy could drive technological development and low emission vehicle costs down through economies of scale. On the other hand, given the Australian vehicle market size, it is more likely that the emission standards of a large market like the US or Europe would be a stronger driver of technological change than domestic Australian policy. Vehicle costs in Australia will generally be determined by global vehicle markets such that vehicle prices are similar across the world – with some differences due to local vehicle preferences. The United States is a closer analogy to Australia in regard to vehicle sizes than Europe.

The end-point of 100gCO_2e/km represents a 50 per cent reduction and is an achievable improvement by 2030-2040. By 2050, King Review (2007) and Cosgrove at al. (2012) projected maximum improvements of 80 and 87 per cent, respectively.

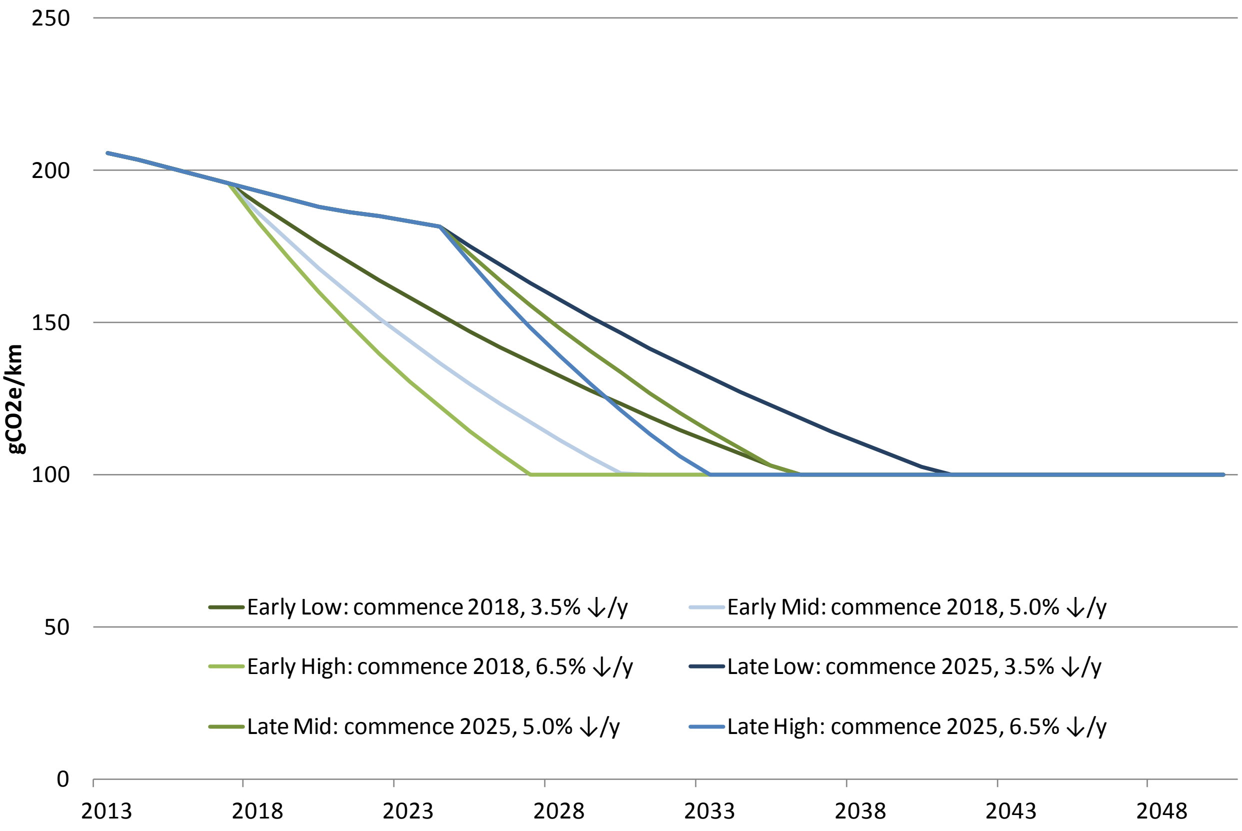

Figure 2-2: Emission standards trajectories to 2050

Graham and Reedman (2013) previously conducted a single sensitivity case of implementation of an emissions standard but in conjunction with a carbon price. We describe the outcomes of that and differences with the cases examined here in Appendix A.

3 Modelling results

3.1 The No carbon price scenario reference case

The modelling results for the No carbon price reference case was previously reported in Reedman and Graham (2013) but is repeated here because it is the reference case from which the emission standards sensitivity cases are compared. This scenario does not impose a carbon price but includes a gradual increase in oil prices. The analysis below provides additional detail not reported in Reedman and Graham (2013) with respect to the light vehicle segment (motorcycles, passenger and light commercial vehicles) of the market, which is the most important for understanding the impact of emission standards.

3.1.1 TRANSPORT FUEL MIX

Figure 3-1 shows the projected level of road transport consumption by fuel for the no carbon price scenario. It shows that there is some uptake of low emission fuels in the form of biodiesel, ethanol and electricity over the projection period[5]. The volume of fuel use grows over the projection period reflecting increased activity levels more than offsetting the assumed improvement in fuel efficiency and projected modest degree of hybridisation/electrification of the road fleet.

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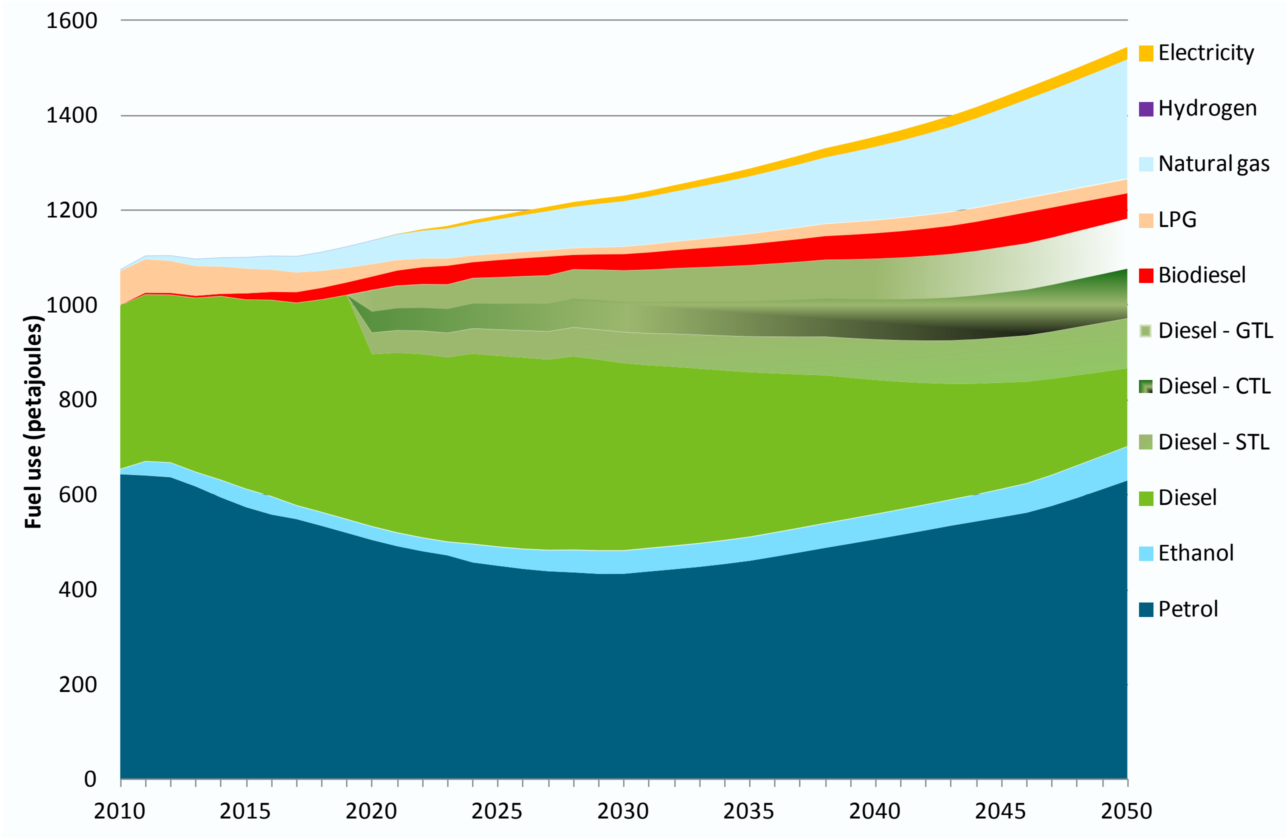
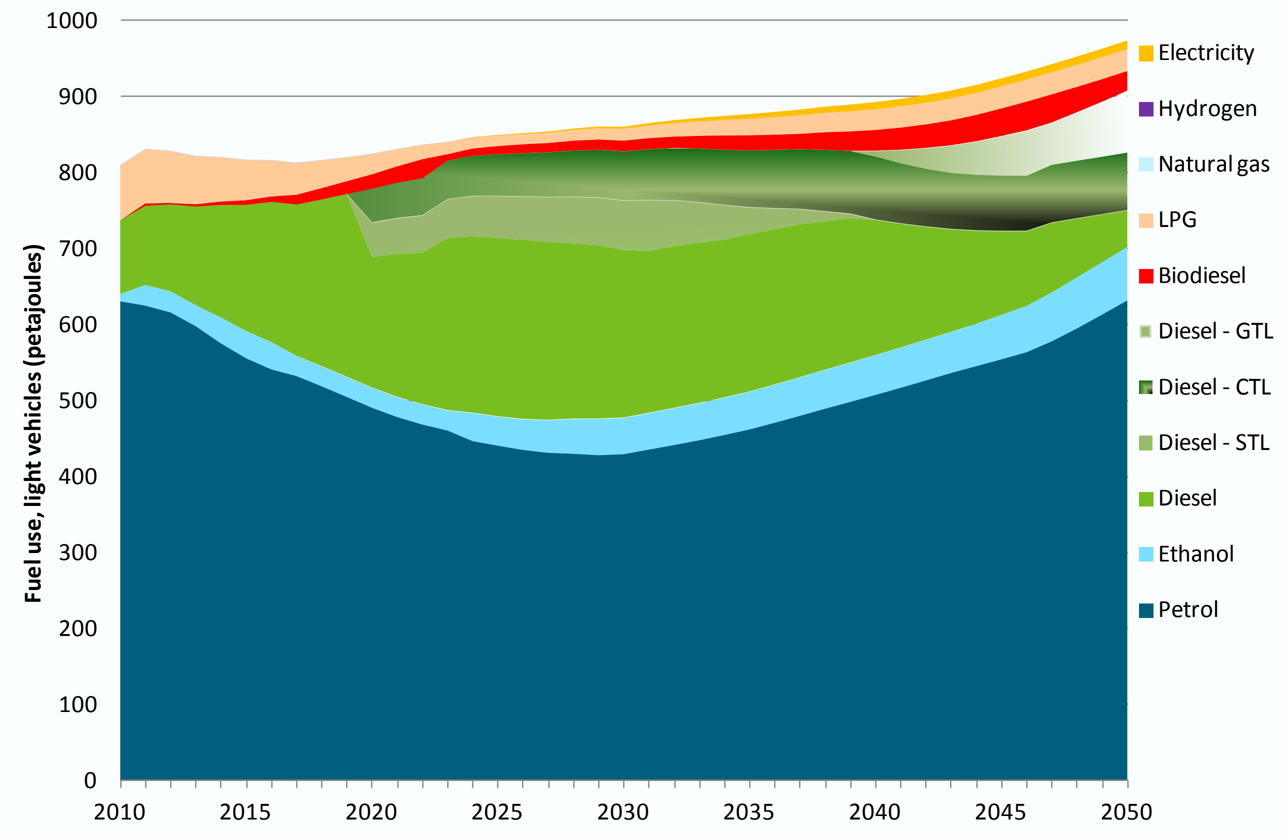
[5] It should be noted that these are considered low emissions fuels as emissions associated with their production are not ascribed to the transport sector.



LPG: Liquefied Petroleum Gas; GTL: Gas-to-liquid; CTL: Coal-to-liquid; STL: Shale-to-liquid.

Figure 3-1: Projected road transport fuel consumption by fuel under the no carbon price scenario, all vehicles



LPG: Liquefied Petroleum Gas; GTL: Gas-to-liquid; CTL: Coal-to-liquid; STL: Shale-to-liquid.

Figure 3-2: Projected road transport fuel consumption by fuel under the no carbon price scenario, light vehicles

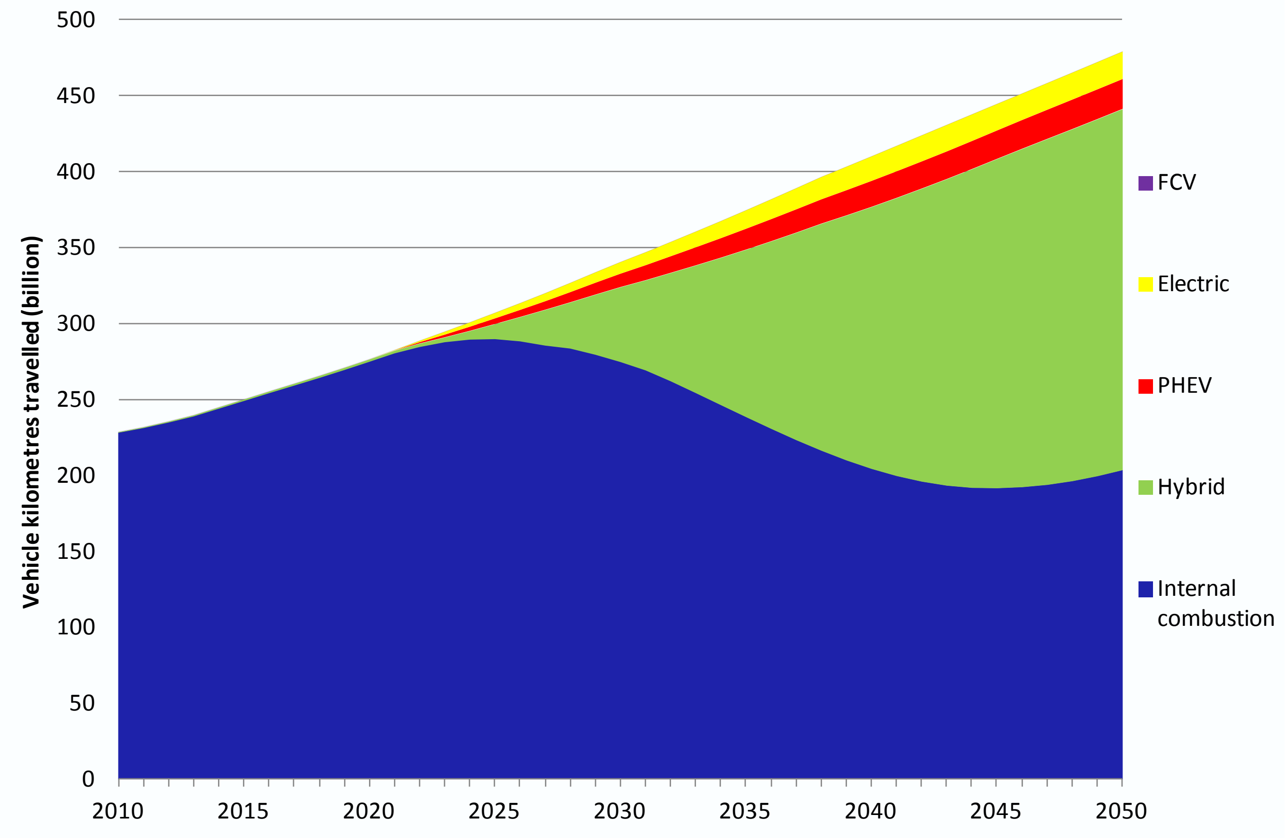
Figure 3-2 shows the projected level of road transport consumption by fuel for the no carbon price scenario by light vehicles. It shows that the uptake of diesel increases up to around 2030. This reflects an extension of the existing trend of growth in diesel in response to higher oil prices and also the availability of additional diesel sources such as biodiesel and synthetic fossil diesel, particularly in the 2020s. The growth of diesel is halted and to some extent reversed from the late 2020s because the cost of petrol hybrid vehicles falls relative to the cost of diesel vehicles providing a viable alternative to diesel as a fuel saving measure.

LPG experiences a similar trend to petrol, declining in deference to diesel and then recovering towards the end of the projection period. Ethanol experiences modest growth from the late 2020s as biofuel feedstocks expand over time and the prospects for petrol, in the form of E10, improves. Electricity uptake increases gradually from around the 2020s but remains relatively minor. However, the share of electrification is higher than indicated by this level of fuel use (electricity has a high end use efficiency as a transport fuel). The absence of uptake of natural gas reflects that the assumption is that it has been diverted to the heavy vehicle market where it is of most value to high distance travelling trucks (in this model, the lower costs of LNG compared to diesel means fuel savings are used to pay down the additional cost of LNG capable trucks).

For the synthetic fuels, these lower cost diesels tend to be diverted to the light vehicle market by ESM because this is the more competitive market in terms of the number and diversity of fuels that are competing for use. However, in reality it is likely these fuels will not be marketed separately from petroleum diesel and so it is not clear that they will be traded between markets in this way.

3.1.2 ROAD SECTOR ENGINE MIX

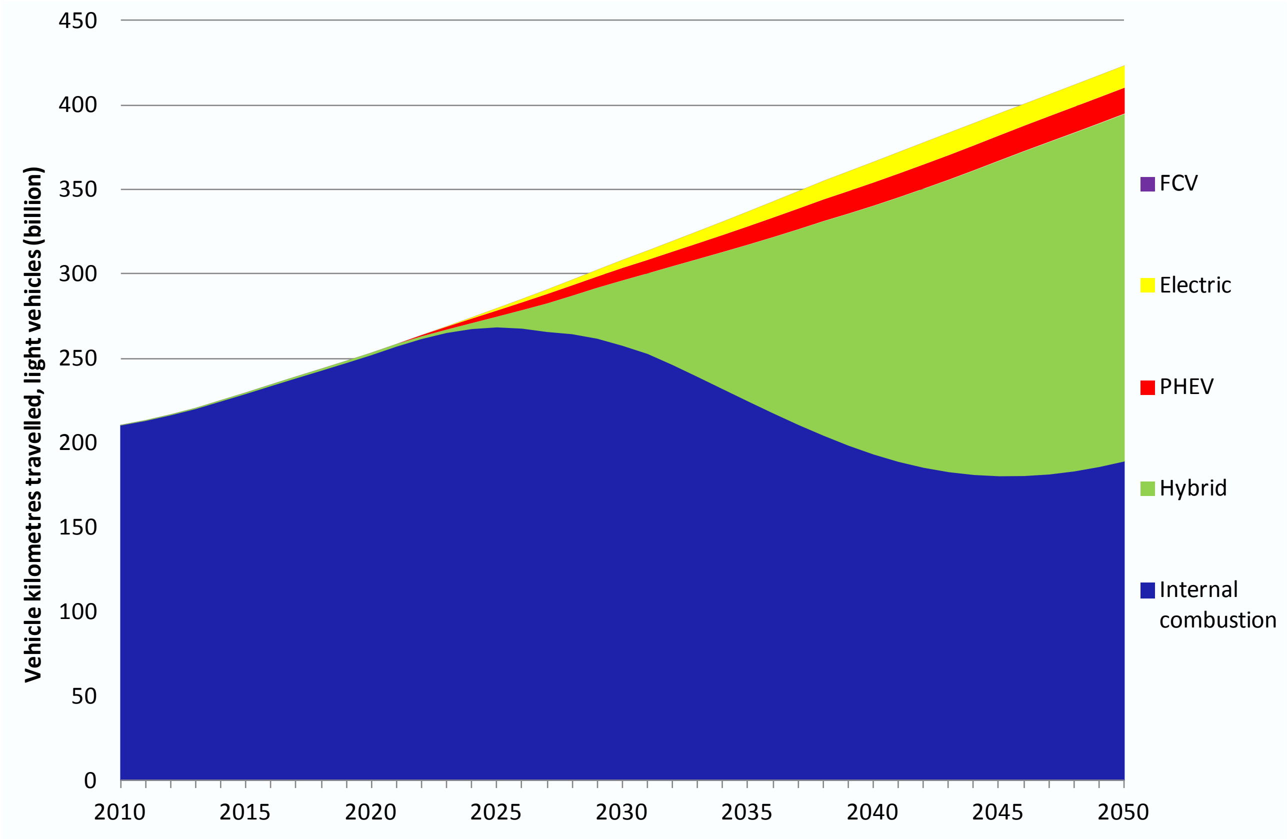
Figure 3-3 shows the engine type in road kilometres travelled for the no carbon price scenario. The uptake of alternative drive-train vehicles is mainly limited to hybrids with plug-in hybrid and fully electric vehicles unable to achieve significant market share with only the gradual oil price increase to drive change.



FCV: Fuel cell vehicle; PHEV: Plug-in hybrid electric vehicle.

Figure 3-3: Engine type in road kilometres travelled, no carbon price scenario, all vehicles

Figure 3-4 shows the engine type in road kilometres travelled for the no carbon price scenario by light vehicles. Similar dynamics are observed in the uptake of alternative drive-train vehicles to the overall road sector.

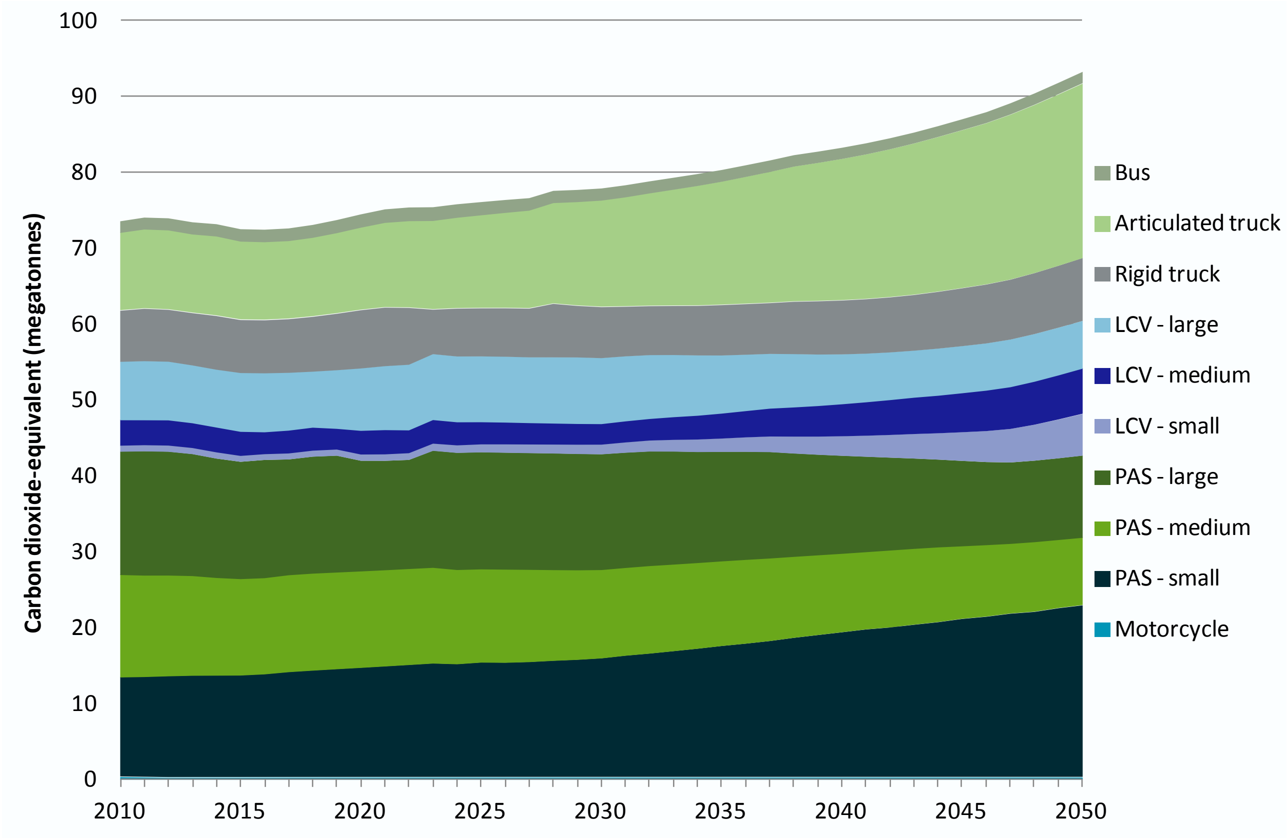


FCV: Fuel cell vehicle; PHEV: Plug-in hybrid electric vehicle.

Figure 3-4: Engine type in road kilometres travelled, no carbon price scenario, light vehicles

3.1.3 GREENHOUSE GAS EMISSIONS

Figure 3-5 shows the greenhouse gas emissions by mode for the road transport sector under the no carbon price scenario. It shows that road sector greenhouse gas emissions continue to rise from around 2015 onwards. Fuel use in the passenger vehicle segment declines over time compared to light commercial vehicles and heavy vehicles reflecting more muted activity growth, vehicle efficiency improvements of conventional vehicles, along with the mild uptake of hybrid and electric vehicles.



LCV: Light commercial vehicle; PAS: Passenger.

Figure 3-5: Road transport greenhouse gas emissions by mode under the no carbon price scenario

The net result is that road transport sector greenhouse gas emissions rise from around 74 Mt in 2010 to 93 Mt by 2050 (Figure 3-6) by 2050. Light vehicle greenhouse gas emissions initially fall to 2015 and then rise at a more subdued rate, reaching around 60 Mt by 2050 (Figure 3-7).

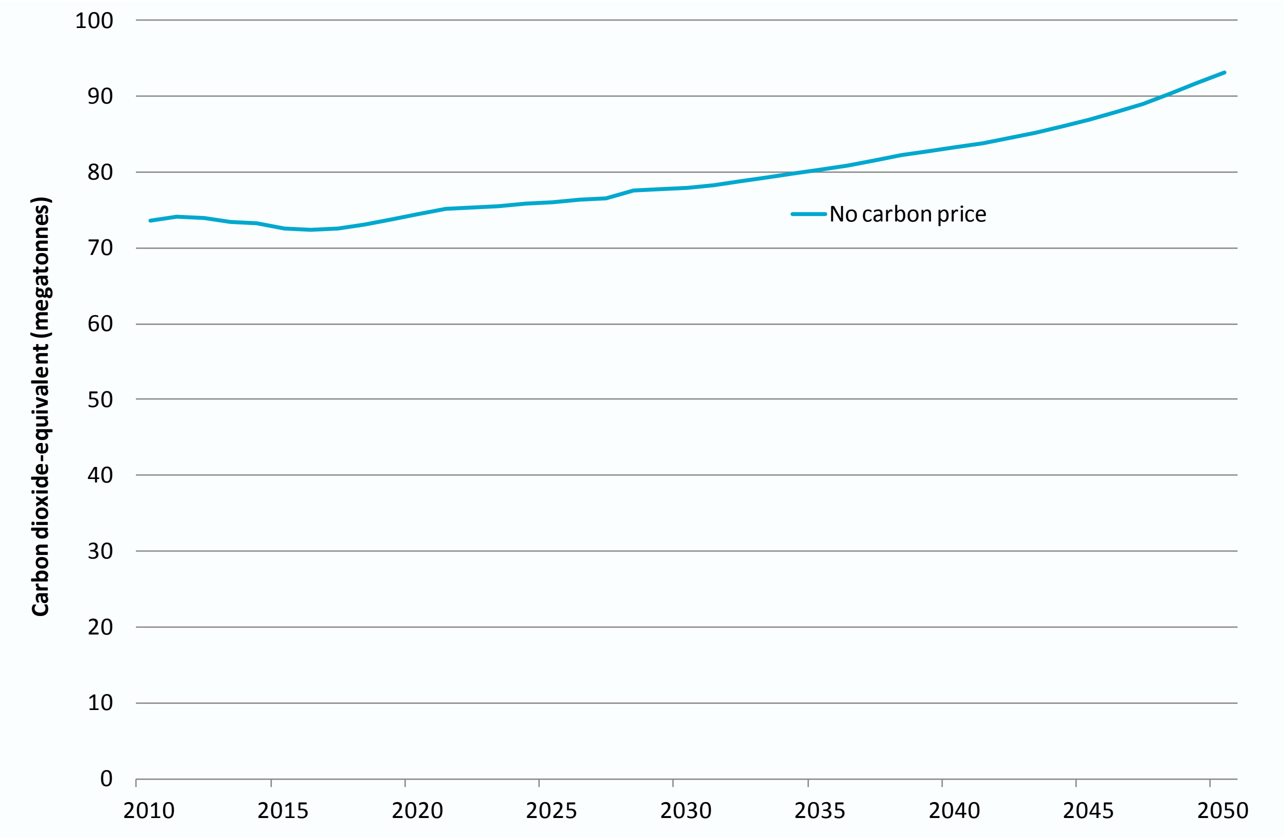


Figure 3-6: Road transport sector greenhouse gas emissions under the no carbon price scenario, all vehicles

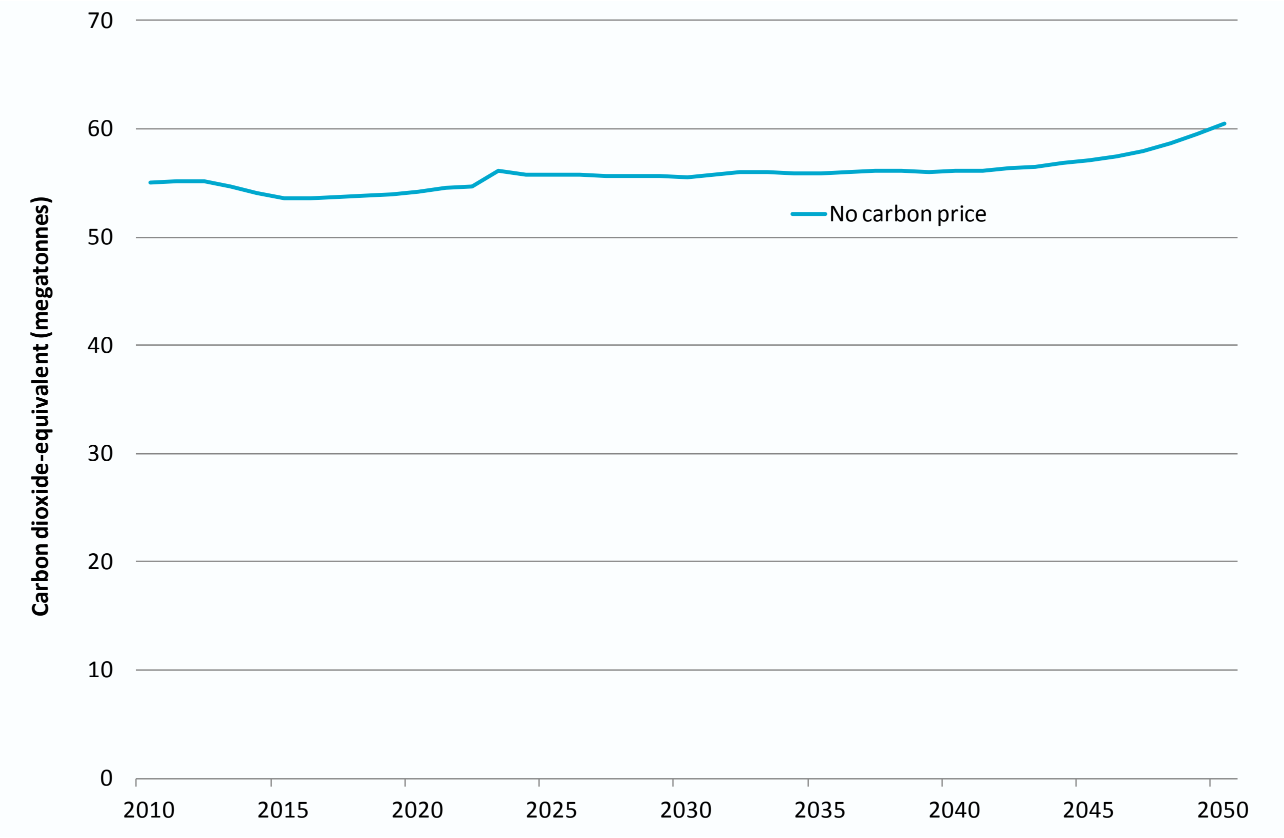


Figure 3-7: Road transport sector greenhouse gas emissions under the no carbon price scenario, light vehicles

3.2 Emission standards sensitivity cases results

This sub-section discusses the modelling results of the emission standard sensitivity cases, focussing on the main points of difference in regard to greenhouse gas emissions, fuel and technology choices, and the cost of transport relative to each other and the no carbon price scenario. All discussion focuses on the light vehicle segment (motorcycles, passenger and light commercial vehicles) of the market, the target of the emission standards.

Given their similarity, we do not describe each individual emission standards sensitivity case in detail here. However, Appendix B provides the full detailed modelling results for each sensitivity case.

3.2.1 ACTIVITY LEVELS

As discussed in Reedman and Graham (2013), growth rates in activity levels of passenger travel and freight demand for the no carbon price scenario, were provided by a general equilibrium model (MMRF) as an input into ESM. In this modelling exercise, this iterative approach between MMRF and ESM was not available. Accordingly, for the emission standard sensitivity cases, the demand trajectory from the no carbon price scenario was used as a baseline in ESM. However, a moderate degree of demand response was permitted (based on a long-run price elasticity of -0.2) to capture increases or declines in travel dependent on the impact of the standards on the cost of travel.

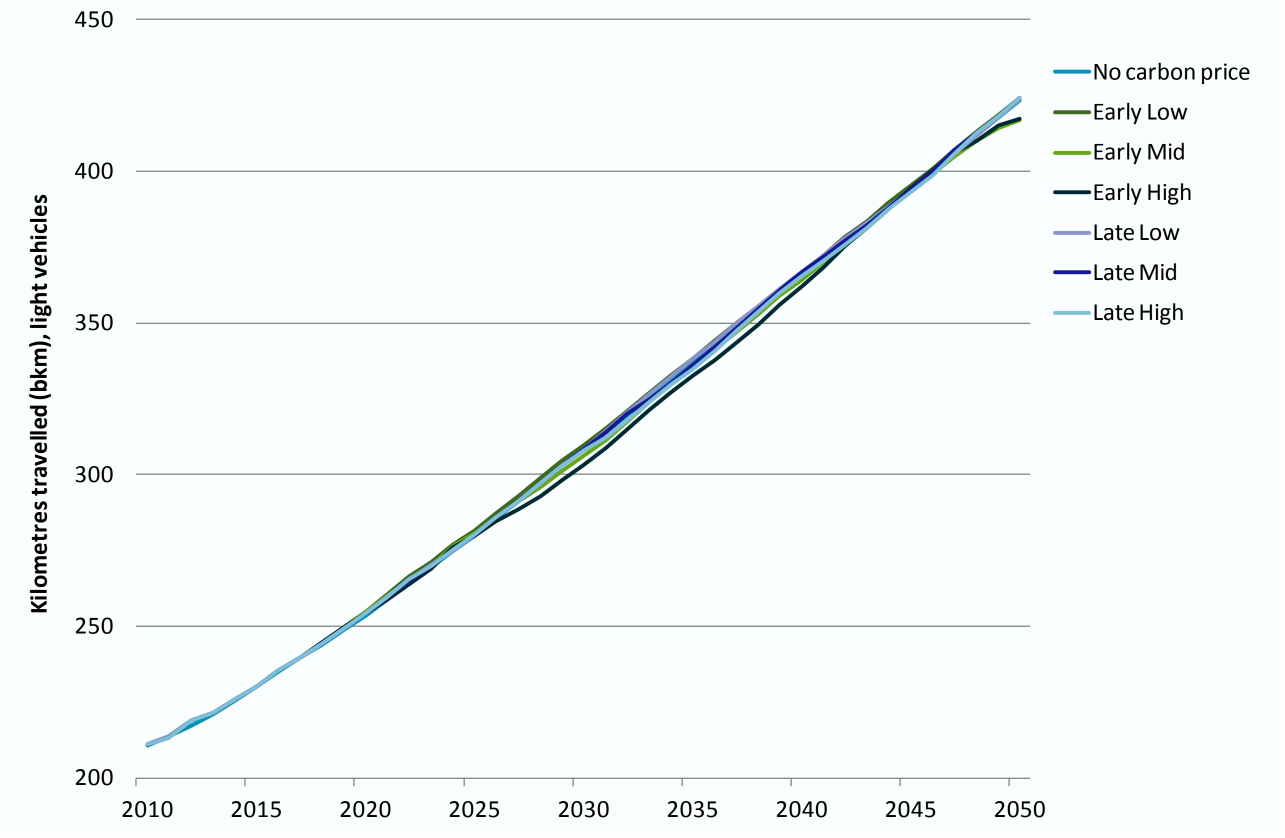


Figure 3-8: Vehicle kilometres travelled, light vehicles

Figure 3-8 shows the estimated vehicle kilometres travelled by light vehicles against the baseline demand trajectory of the no carbon price scenario. It shows that there is some demand response mainly around the period 2020-2040 and at the end of the projection period around 2050[6]. There is some reduction in travel mainly in the Early High and Early Mid cases reflecting increased purchase costs of non-conventional (hybrid, plug-in hybrid, fully electric and fuel cell) vehicles that are not completely offset by reduced fuel and operating costs. In contrast, the opposite effect occurs in the Early Late case where the net cost of travel is lower, leading to a small increase in travel. Similar dynamics are observed for the 'Late' cases.

More discussion of cost will take place in Section 3.2.5.

3.2.2 TECHNOLOGY CHOICE

Given that internal combustion engine fuel efficiency changes and vehicle size preferences are imposed, the main decision the model is determining under the emission standards sensitivity cases is the timing and level of uptake of non-conventional vehicles, particularly plug-in hybrid electric vehicles (PHEV), fully electric vehicles (EV) and fuel cell vehicles (FCV).

Figure 3-9 shows that the increased deployment of non-conventional vehicles is a significant supply-side response to meet minimum emission standards, under all cases. As expected Early Low and Late Low have the most delayed uptake. Early High has the earliest and highest uptake.

While there are differences, the overall impression is a convergence in the share of non-conventional vehicle uptake by the 2040s reflecting that the convergence of the emission standards themselves. Relative to the No carbon price scenario reference case, non-conventional vehicles have an additional 25 percentage point share by 2050.

It is interesting to note that emission standards have the opposite impact on hybrid electric vehicles. As regular non-hybrid internal combustion vehicles become more efficient the incentive to take up hybrid electric vehicles is diminished. As an economic proposition, hybrids represent the opportunity to pay more up front to have lower running costs. If running costs are already lower, that proposition is less favourable. Across the emission standards sensitivity cases we generally see lower hybrid electric vehicle uptake than the No carbon price scenario reference case (see Appendix B for hybrid vehicle uptake projections).

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[6] This difference in 2050 is likely not related to the emission standards which are stable by this time but rather reflects some temporary cost changes as fuel cell vehicles enter the light vehicle market for the first time. Vehicle uptake by engine type is shown in the appendix.

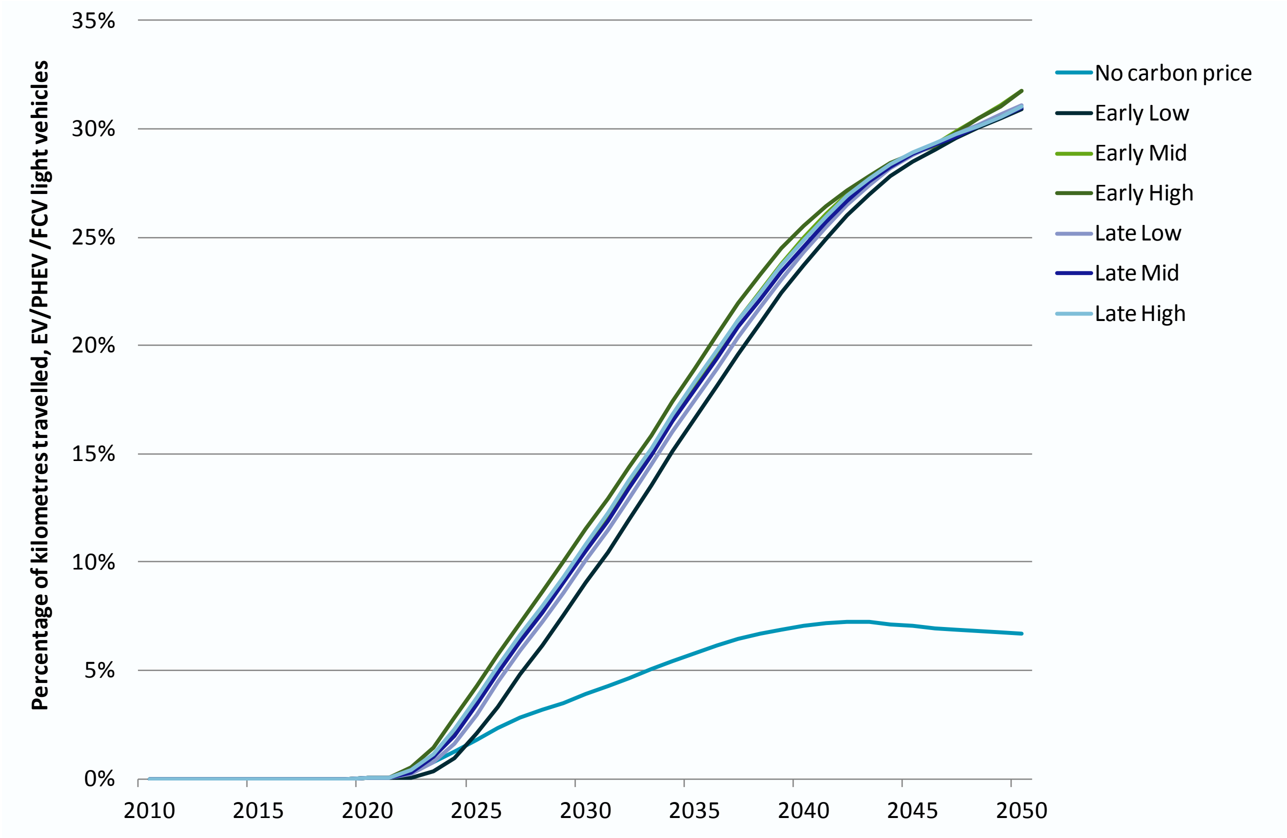

Figure 3-9: Uptake of EV, PHEV and FCV in light vehicles

3.2.3 CONTRIBUTION OF ELECTRICITY TO FUEL CONSUMPTION

Reflecting the increased uptake of non-conventional vehicles, Figure 3-10 shows that electricity use as a road fuel increases significantly. By 2050, electricity ranges between 5.7 and 6.3 per cent of fuel use compared to 1.2 per cent in the No carbon price scenario. In volume terms, electricity use in the emission standard sensitivity cases is around 11 terawatt-hours (TWh) by 2050, compared to around 3 TWh in the No carbon price scenario.

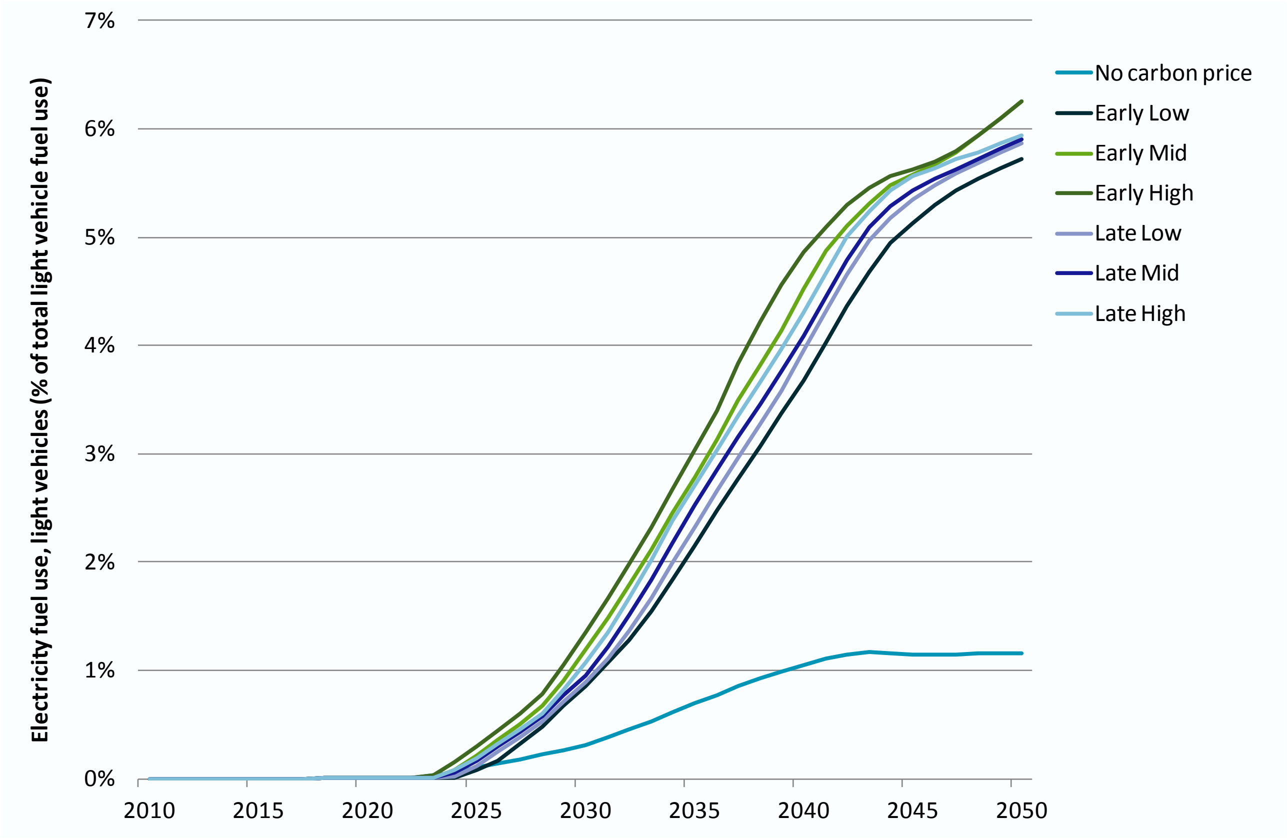

Figure 3-10: Electricity fuel use in light vehicles

3.2.4 FUEL INTENSITY

The increased use of electricity as a transport fuel and adoption of other measures for efficiency improvement means that the average fuel use per kilometre declines significantly from a current level of around 380 MJ/100km, to between 153 to 165 MJ/100km by 2050 depending on the emissions standards sensitivity case. This compares to an average consumption of around 230 MJ/100km by 2050 in the no carbon price scenario (Figure 3-11).

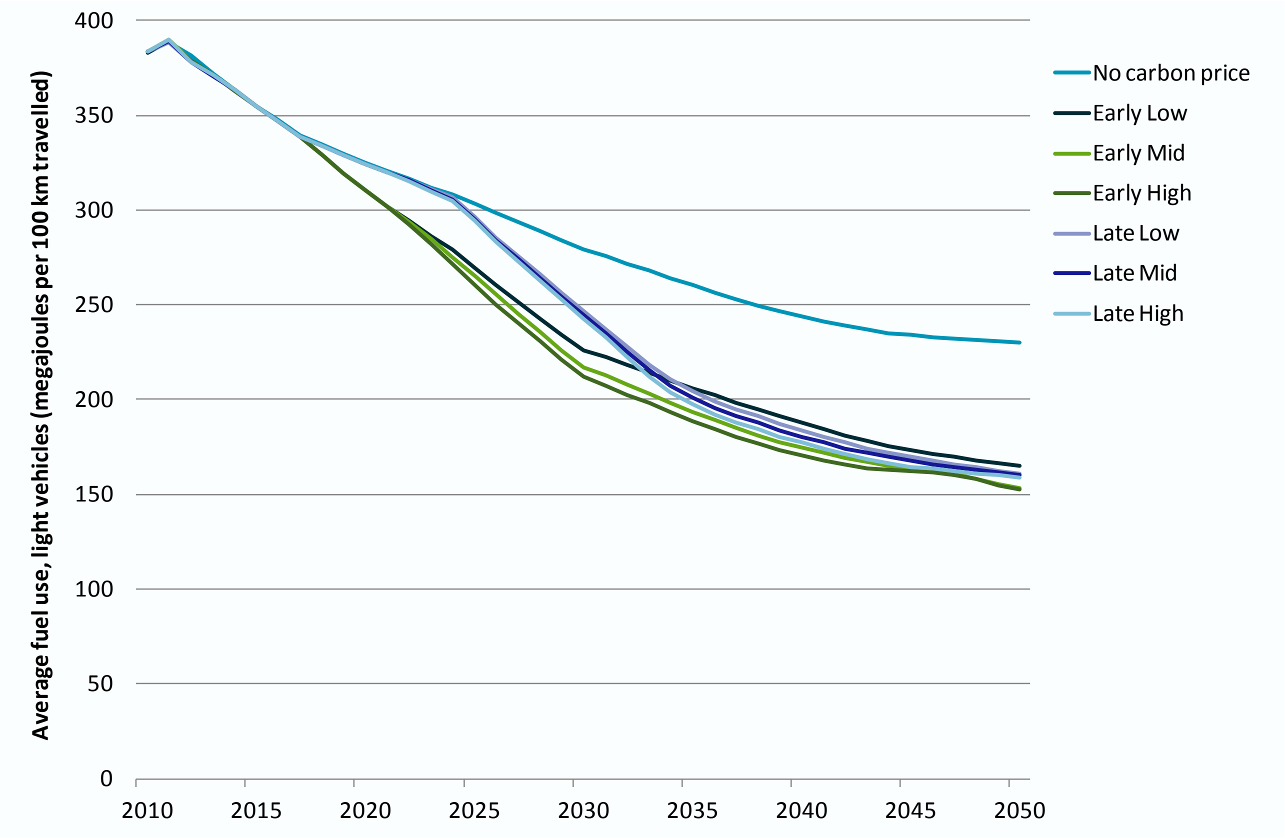

Figure 3-11: Average fuel use light vehicle fleet

3.2.5 GREENHOUSE GAS EMISSIONS

The estimated outcomes for greenhouse gas emissions from the implementation of minimum average emission standards on new light vehicles are significant reductions in transport sector greenhouse gas emissions. Figure 3-12 shows the impact of the emission standards on the emissions trajectory with clear departure points from the no carbon price scenario for both the ‘Early’ and ‘Late’ cases with a degree of convergence around 2035 onwards. By 2050, light vehicle greenhouse gas emissions are around 40 Mt for the sensitivity cases compared to 60 Mt in the No carbon price scenario.

The instability in the emission trajectory between 2020 and 2025 represents the impact of changes in the emission intensity of diesel due to the loss of some biodiesel volumes as biomass is diverted to jet fuel production. This partial loss of biomass from the road sector to the aviation sector is discussed in Reedman and Graham (2013) but is mainly driven by the lower real value of road fuel excise together with introduction of vehicle electrification, and relative high growth in aviation fuel demand diminishing the purchasing power of the road sector in regard to liquid fuels relative to the aviation sector.

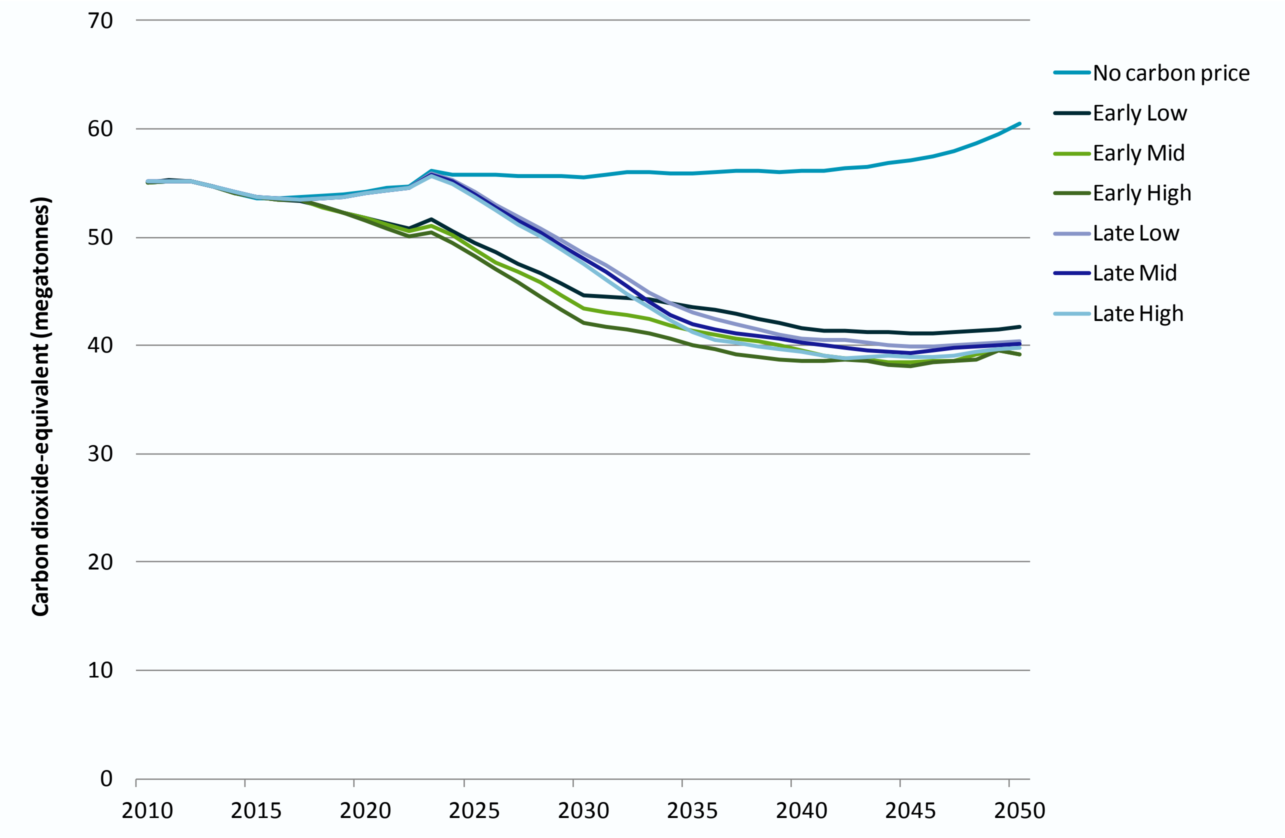

Figure 3-12: Greenhouse gas emissions light vehicles

The flow through of the minimum emission standards on new vehicles to the average of the fleet is shown in Figure 3-13. Given our standards ensure that new vehicles, on average, reach a standard of 100gCO_2e/km between 2027 and 2040, we would expect those standards to have mostly trickled through the fleet inside of 12 years given fleet losses (or 'scrapping' rates).

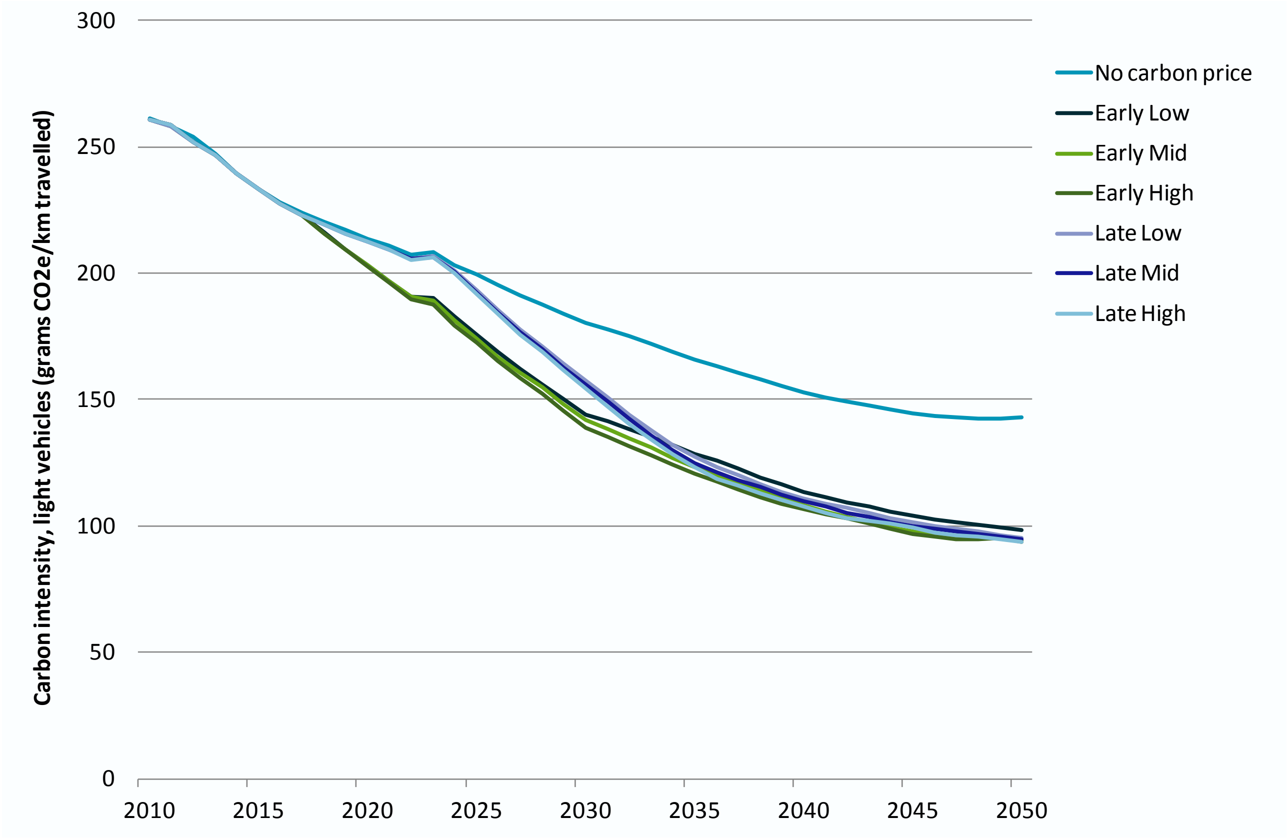

Figure 3-13: Carbon intensity, light vehicles

3.2.6 COST OF TRANSPORT

ESM projects the marginal cost of travel to meet demand in each of its road vehicle segments. Figure 3-14 shows the average of the marginal cost of travel in the passenger and light commercial vehicle market segments. The projection indicates that, the cost of travel under the emission standards sensitivity cases is not significantly different from the No carbon prices reference case. By the end of the projection period, gradually rising oil prices and some vehicle cost increases have been offset by higher fuel efficiencies so that the cost of travel is slightly lower than it is in 2013.

There are some observable differences amongst the emission standards trajectories. In the period between 2020 and 2030 the Early High and Early Mid emission standards sensitivity cases do cause the cost of travel to rise above the reference case for several years. This reflects the emission standards driving uptake of non-conventional vehicles faster in these cases - before they have reached a point where their additional costs are fully offset by fuel savings.

Even in these ‘Early’ cases, the emissions standards sensitivity cases eventually lead to lower costs of travel. This reflects our assumption that the imposition of an emission standard unlocks some ‘free’ vehicle fuel efficiency improvements that would not have otherwise been available to vehicle purchasers (and were not therefore included in the No carbon price scenario reference case). The ‘free’ efficiency improvements only get emissions so far and further improvements must be included in vehicles, at cost, to reach the standards. However, under the assumptions implemented in this study, they were more than offset by fuel savings in the long run.

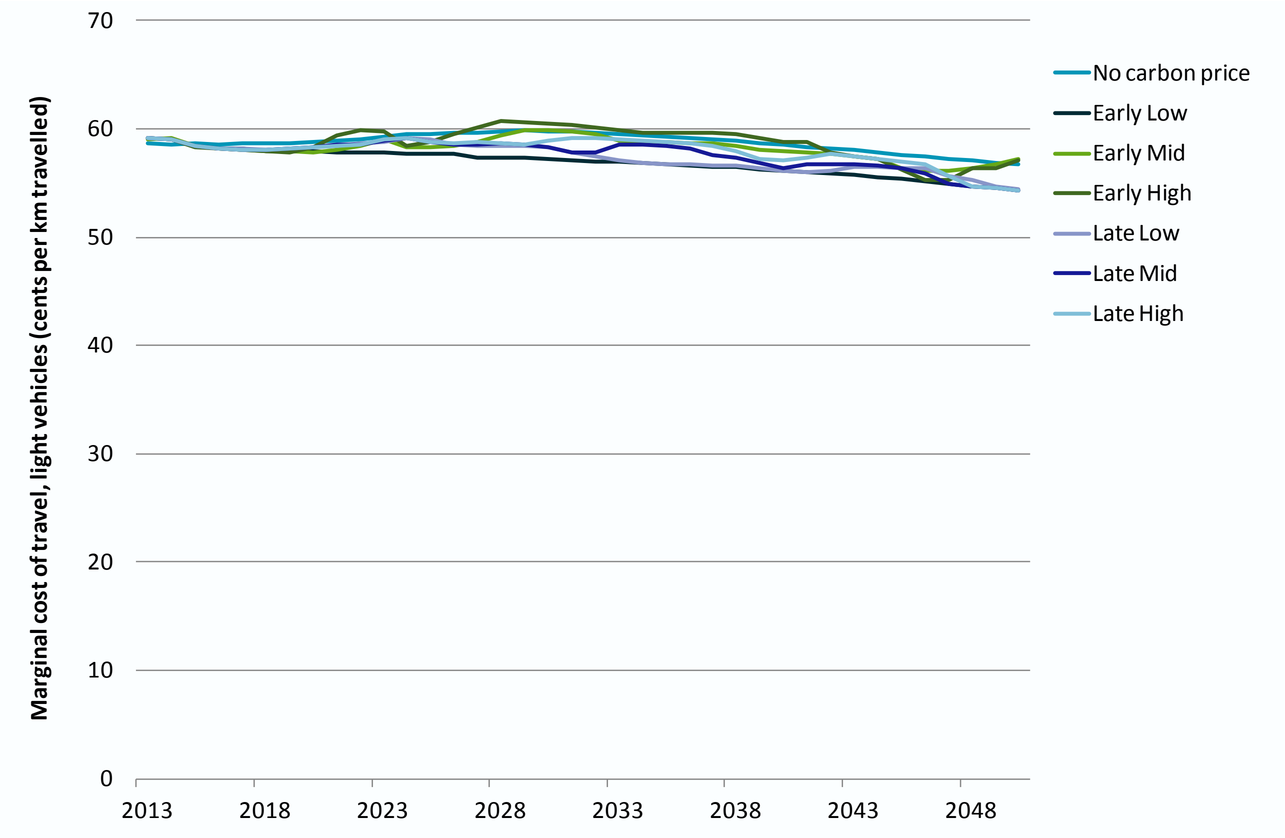

Figure 3-14: Projected marginal cost of light vehicle travel

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4 Appendix A: Previous emission standards modelling

Graham and Reedman (2013) recently modelled a single emission standards sensitivity case. Unlike the present study, that sensitivity case was modelled on a reference scenario where a carbon price is in place called the *Central policy scenario* CCA (2013). This emission standards sensitivity case assumed that mandatory average CO_2 emissions standards on all (imported and domestically produced) new light vehicles (passenger and light commercial vehicles) apply from 2015. The average emissions for new light vehicles sold in Australia in the years 2015-2020 must meet the following:

- An average CO_2 emissions target of 190g/km from 2015 onwards
- An average CO_2 emissions target of 130g/km from 2020 onwards.

Thereafter the emission standard was held, only slightly declining to 115g/km by 2050[7]. For convenience we call this previous sensitivity case modelling the '130gCO_2e case' and plot it for comparative purposes against those modelled in this report in Figure 4-1.

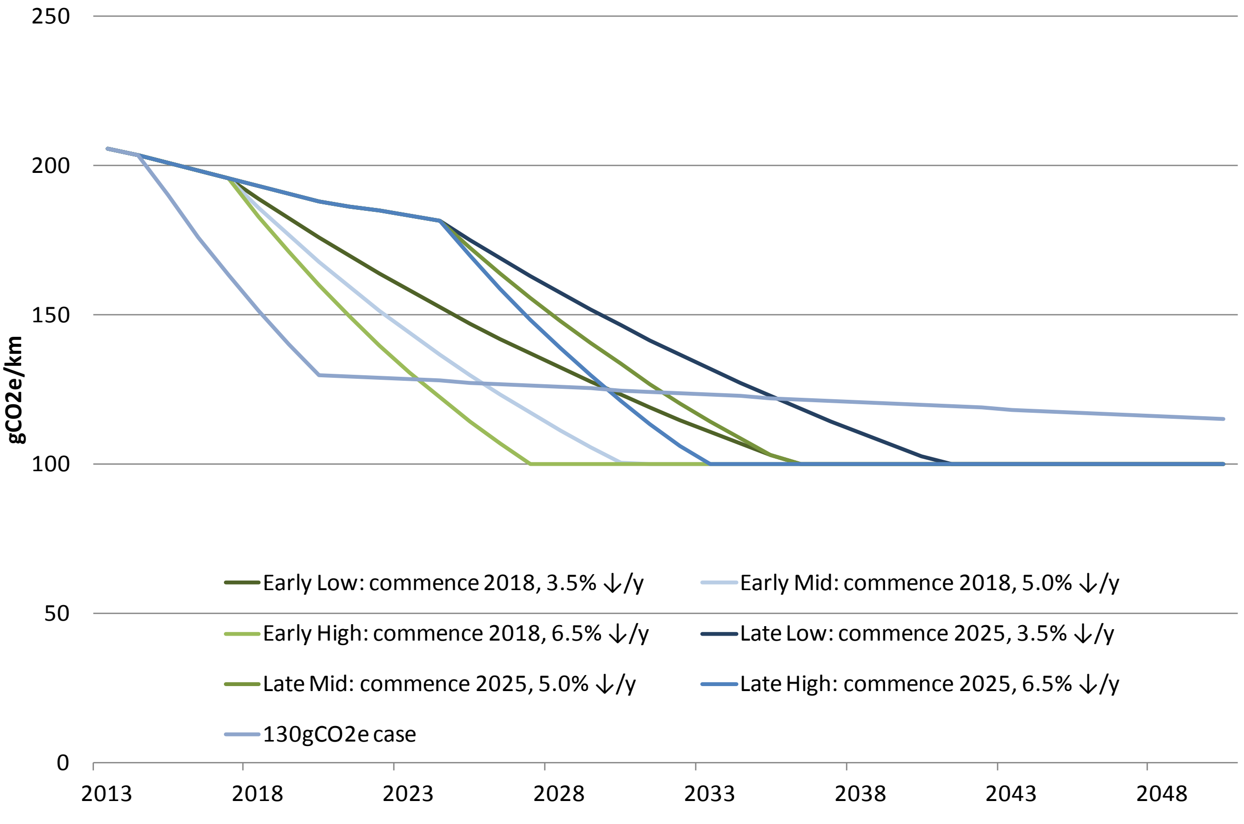

Figure 4-1: Comparison of the 130gCO_2e case and emission standards modelled in this report

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[7] This 2050 end-point was reached as a default rather than a key element of the design of the sensitivity case which was mainly focussed on the period to 2020 and keeping the policy in place afterward. A key difference between this current work and the previous analysis is more thought has been given to the long term trajectory.

The 130gCO_2e case is steeper in the early years than any of the other cases modelled in this report but on the other hand less ambitious in its end point by 2050. The impact of the 130gCO_2e case on light vehicle greenhouse gas emissions relative to the current sensitivity cases is shown in Figure 4-2.

As expected the 130gCO_2e case exhibits stronger emission reduction in the period to 2025 reflecting its steeper rate of decline in emission standards. The emission profile exhibits the same increase in emissions when the aviation sector reduces the availability of biofuels in the road sector – however this occurs a few years later. This is because a carbon price, which is active in the 130gCO_2e case, changes relative fuel costs in the road freight and aviation sectors as well as the timing and volume of biodiesel and synthetic diesel production available (which spills over into the light vehicle sector which is not subject to a carbon price).

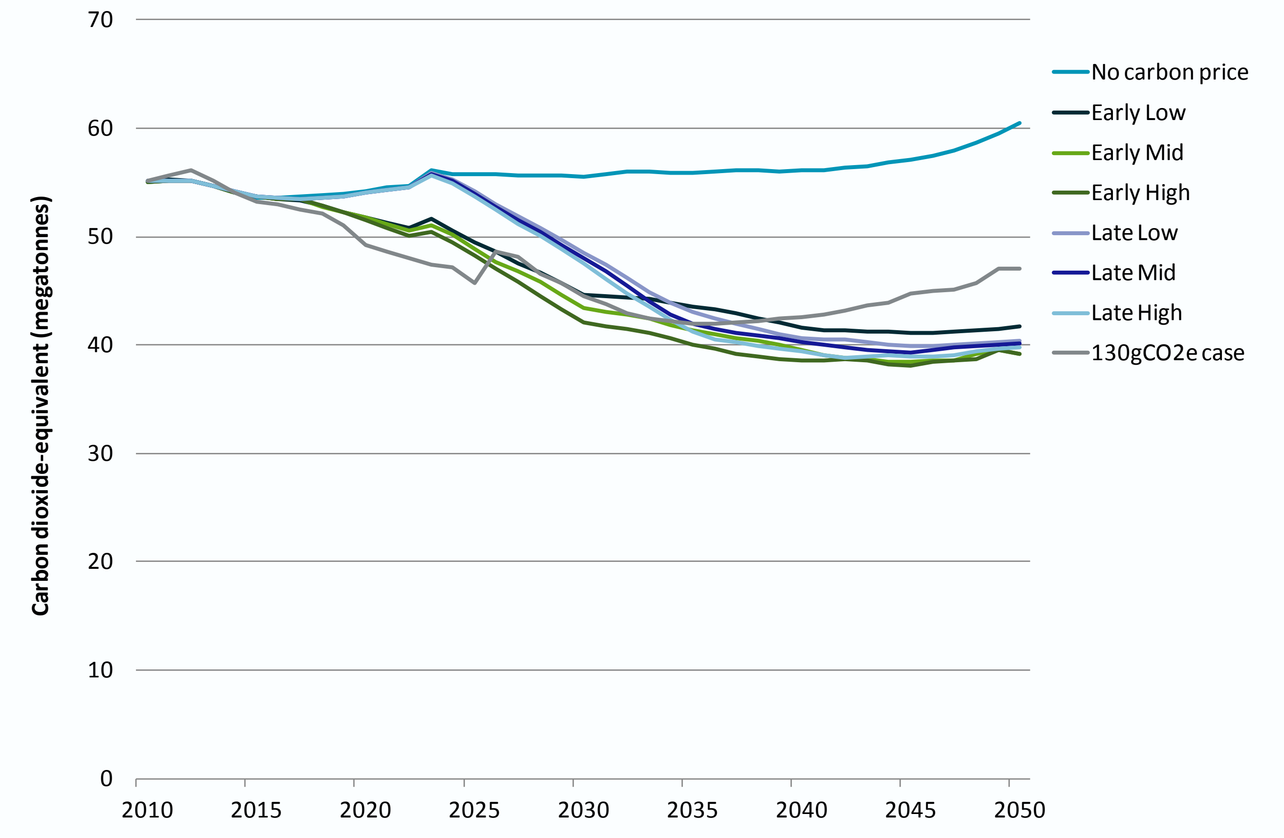

Figure 4-2: Greenhouse gas emissions, light vehicles, no carbon price scenario and minimum efficiency sensitivities

Light vehicle emissions in the 130gCO_2e case are on par with the other cases throughout 2025-2035. However for the remainder of the period to 2050 light vehicle emissions begin to rise as the relatively flat emission standards since 2020 do not force enough additional fuel efficiency improvement to offset the impact of increasing kilometres travelled on fuel consumption.

Overall the current and previous emission standards modelling complement one another. The previous modelling provides additional detail on the impact of steeper reductions. It also highlights, by comparison with the current cases, the impact of the selection of a long term target as part of the emissions standards design.

5 Appendix B: Additional modelling outputs

Given the study explores modest variations in the rate and timing of emissions standards the projected outcomes for fuel consumption, technology uptake and greenhouse gas emissions have a lot of similarities. The detailed projections are grouped here in this appendix for easy comparison purposes.

5.1 Fuel mix

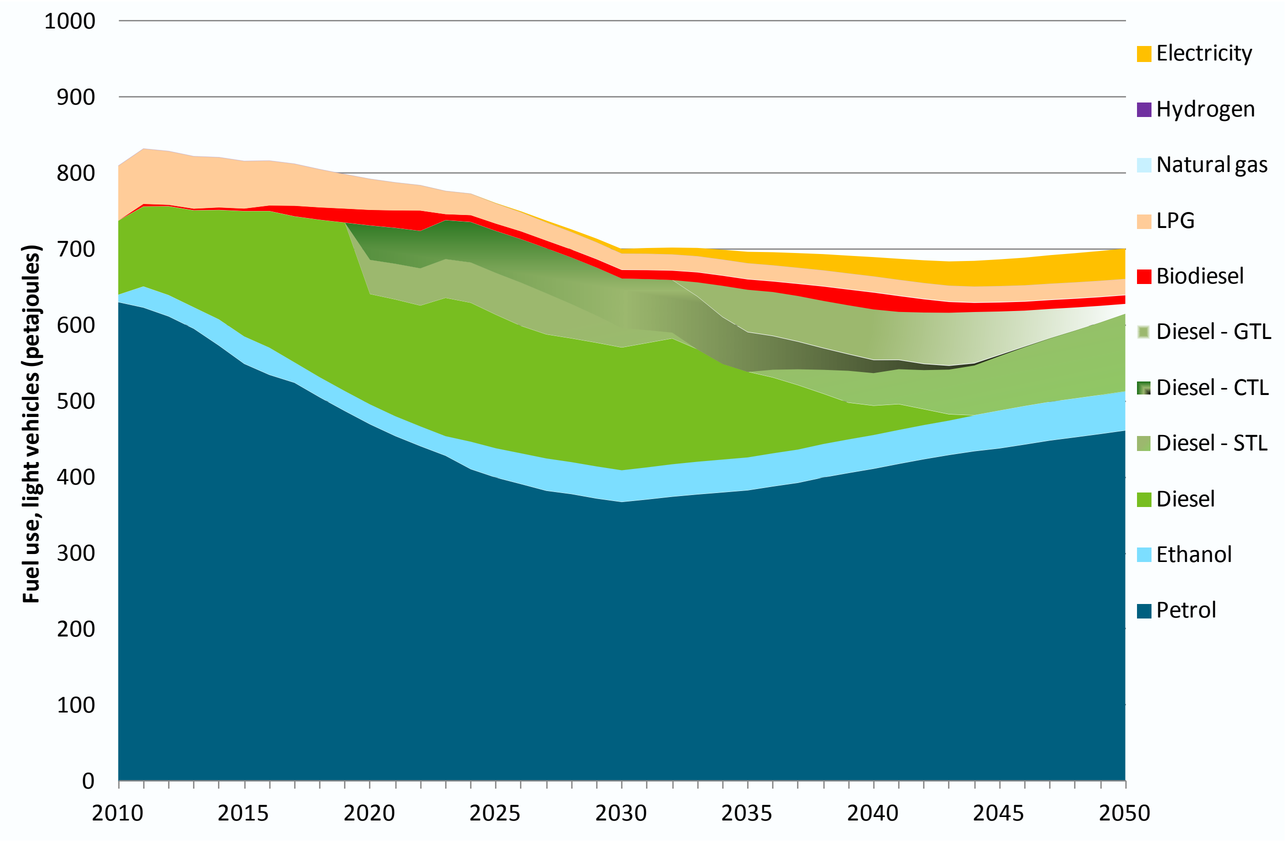

Figure 5-1: Projected road transport fuel consumption by fuel under the Early Low sensitivity case, light vehicles

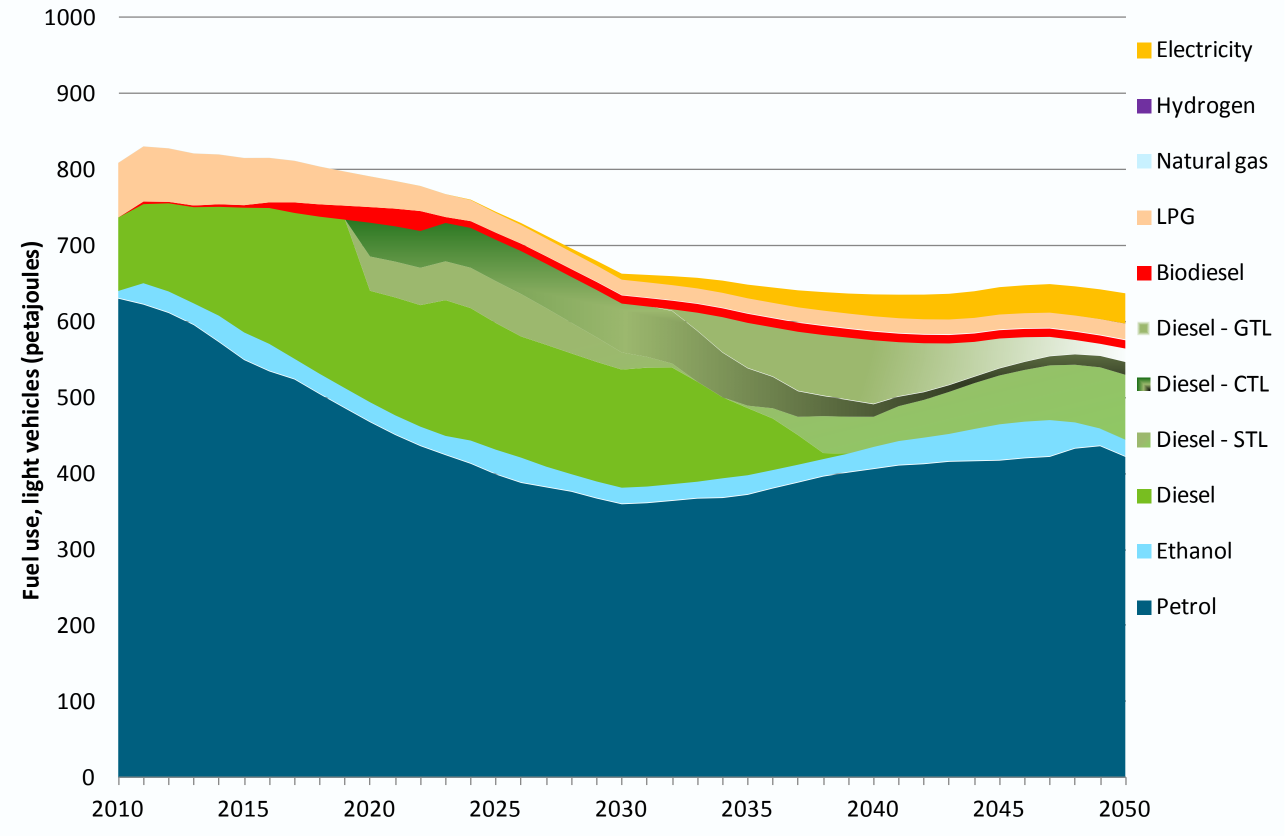

Figure 5-2: Projected road transport fuel consumption by fuel under the Early Mid sensitivity case, light vehicles

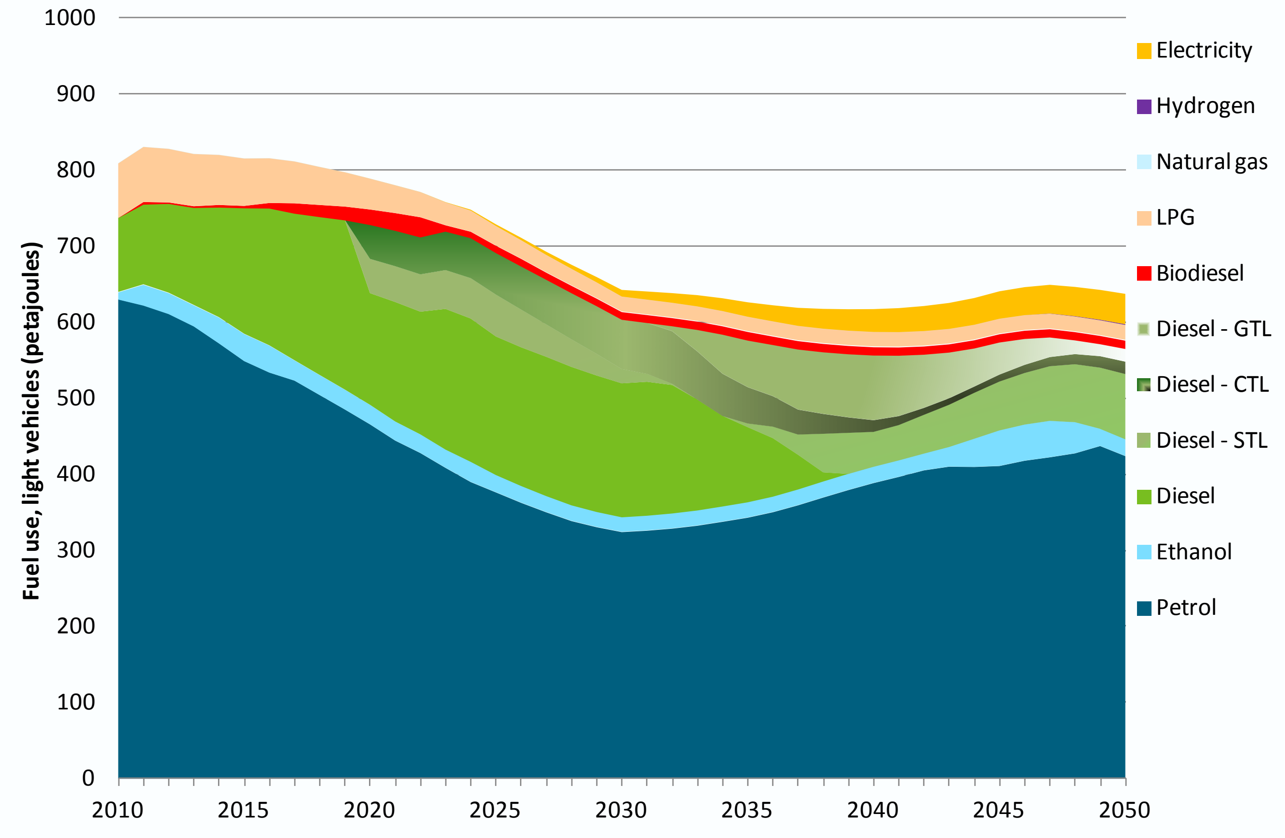

Figure 5-3: Projected road transport fuel consumption by fuel under the Early High sensitivity case, light vehicles

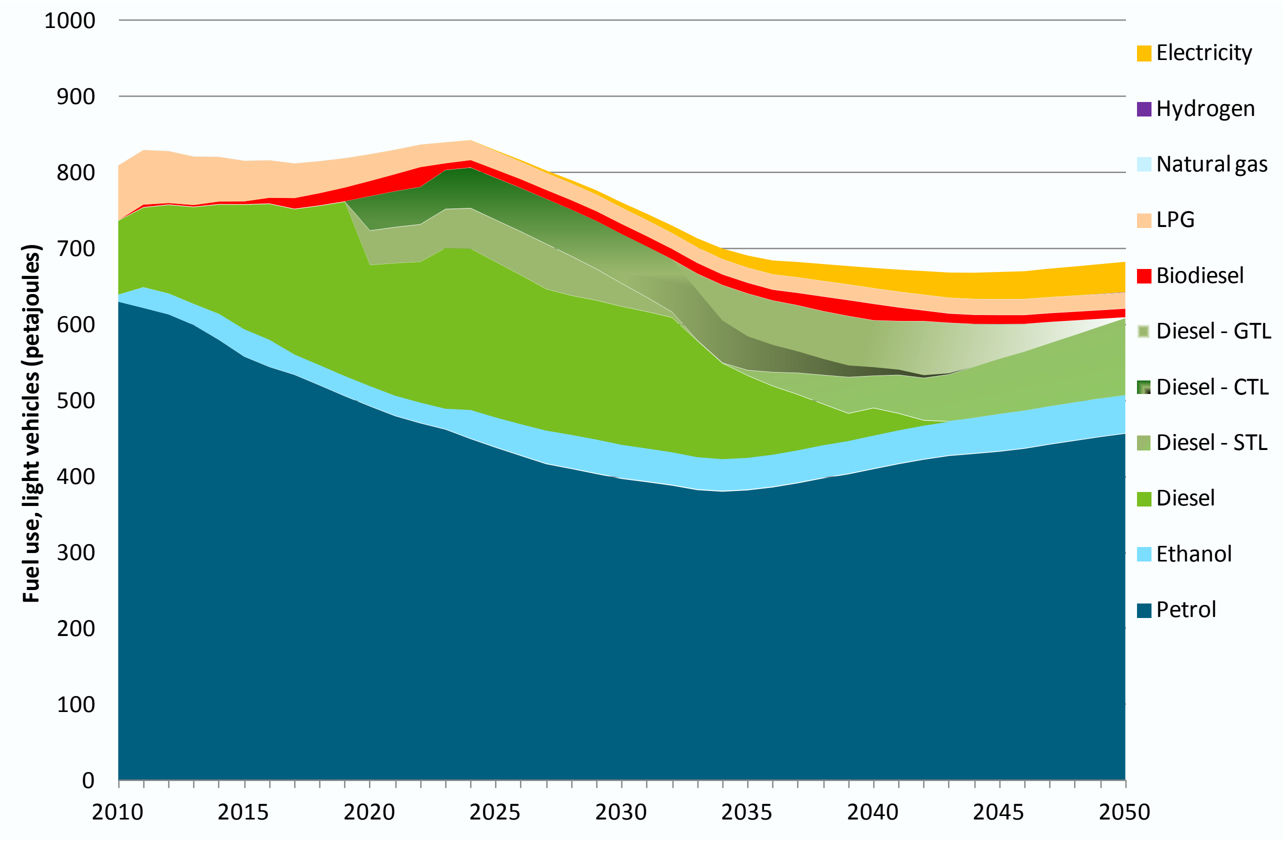

Figure 5-4: Projected road transport fuel consumption by fuel under the Late Low sensitivity case, light vehicles

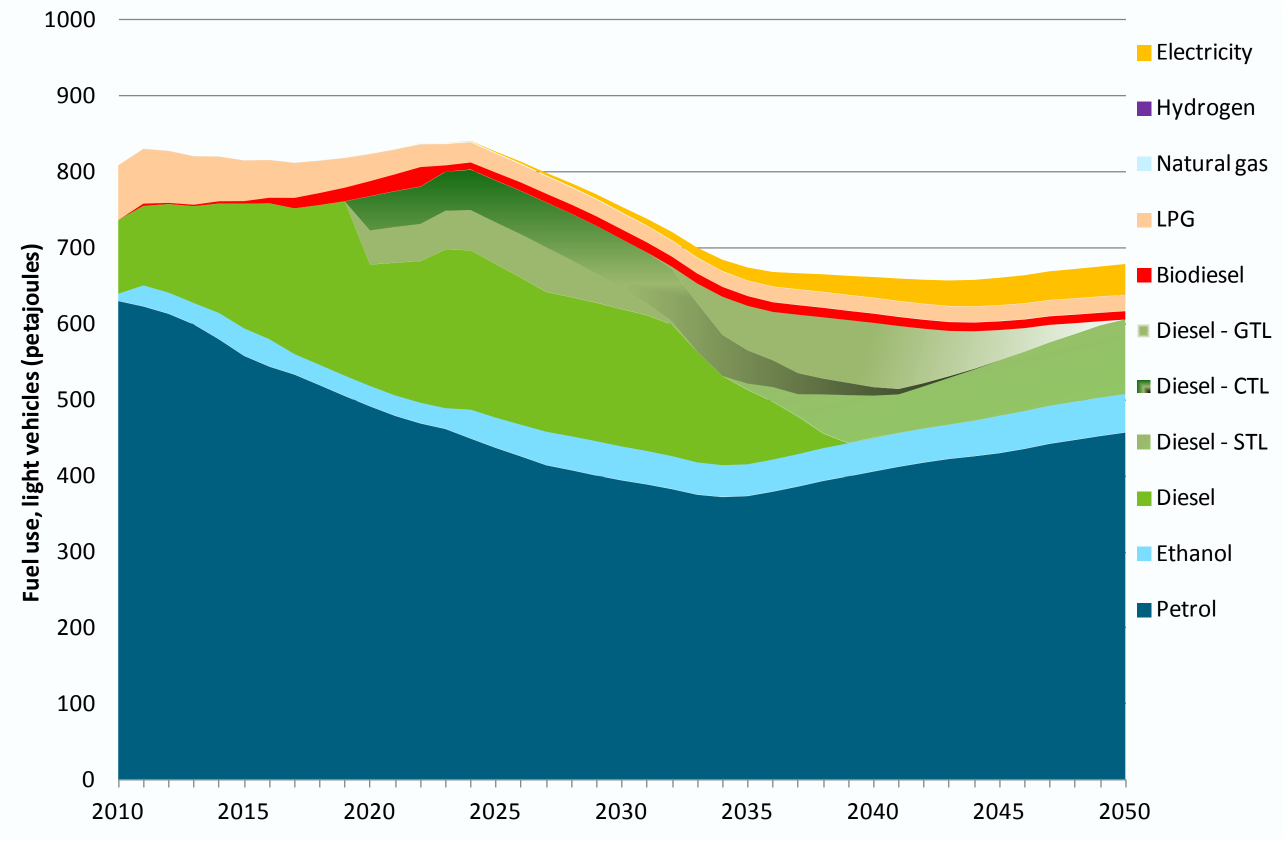

Figure 5-5: Projected road transport fuel consumption by fuel under the Late Mid sensitivity case, light vehicles

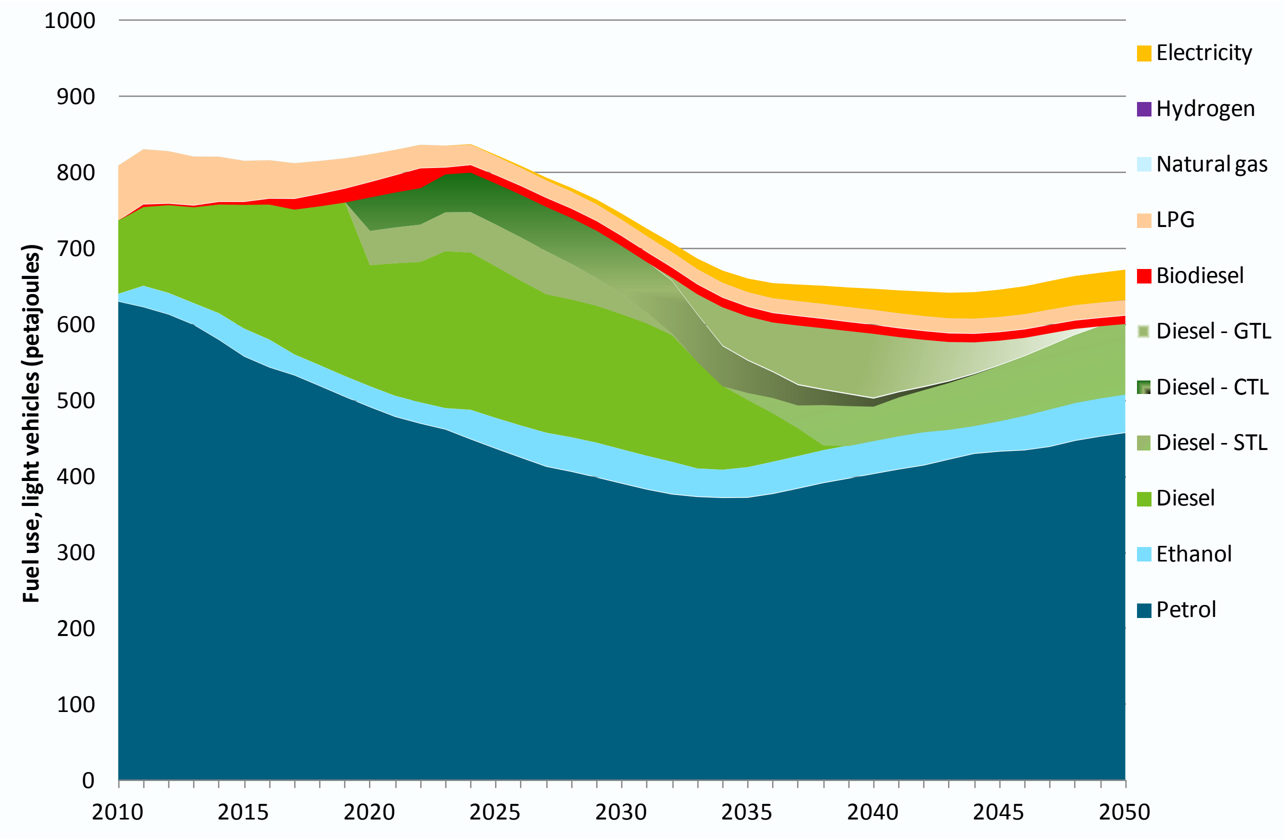

Figure 5-6: Projected road transport fuel consumption by fuel under the Late High sensitivity case, light vehicles

5.2 Engine mix

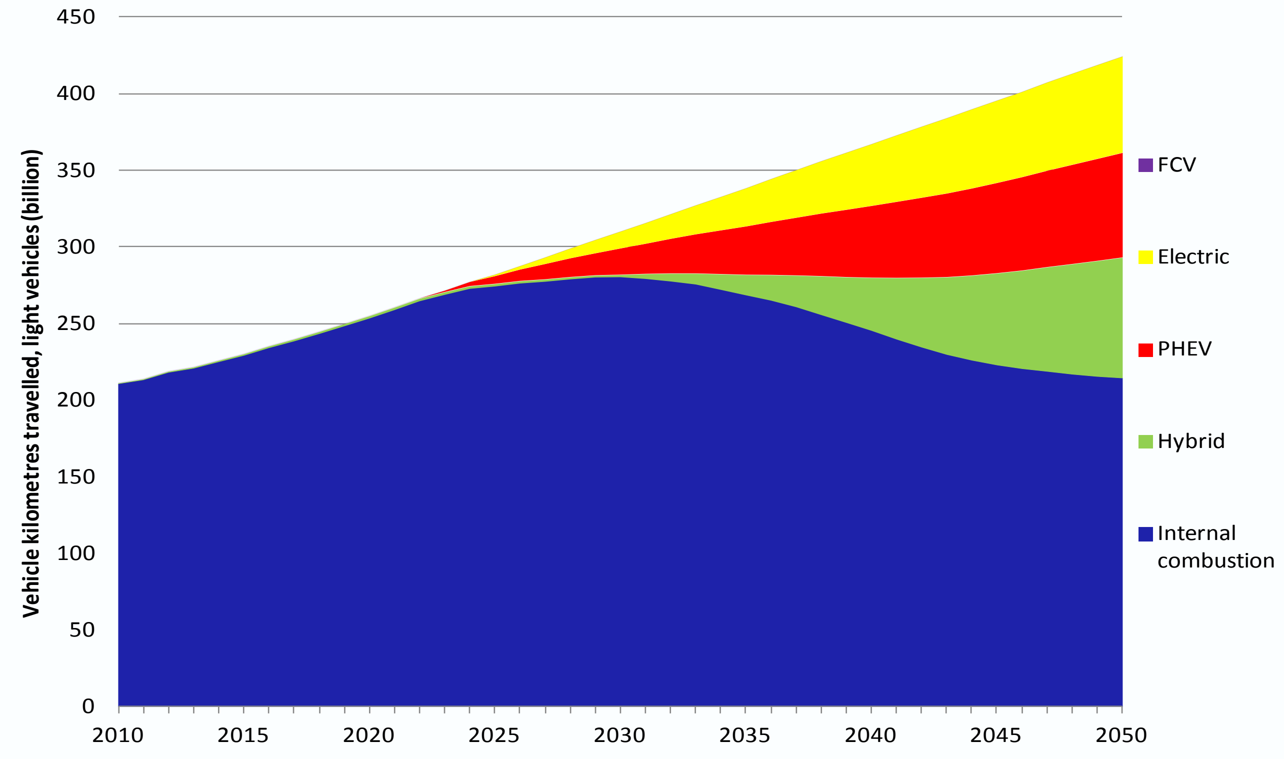

Figure 5-7: Engine type in road kilometres travelled, Early Low sensitivity case, light vehicles

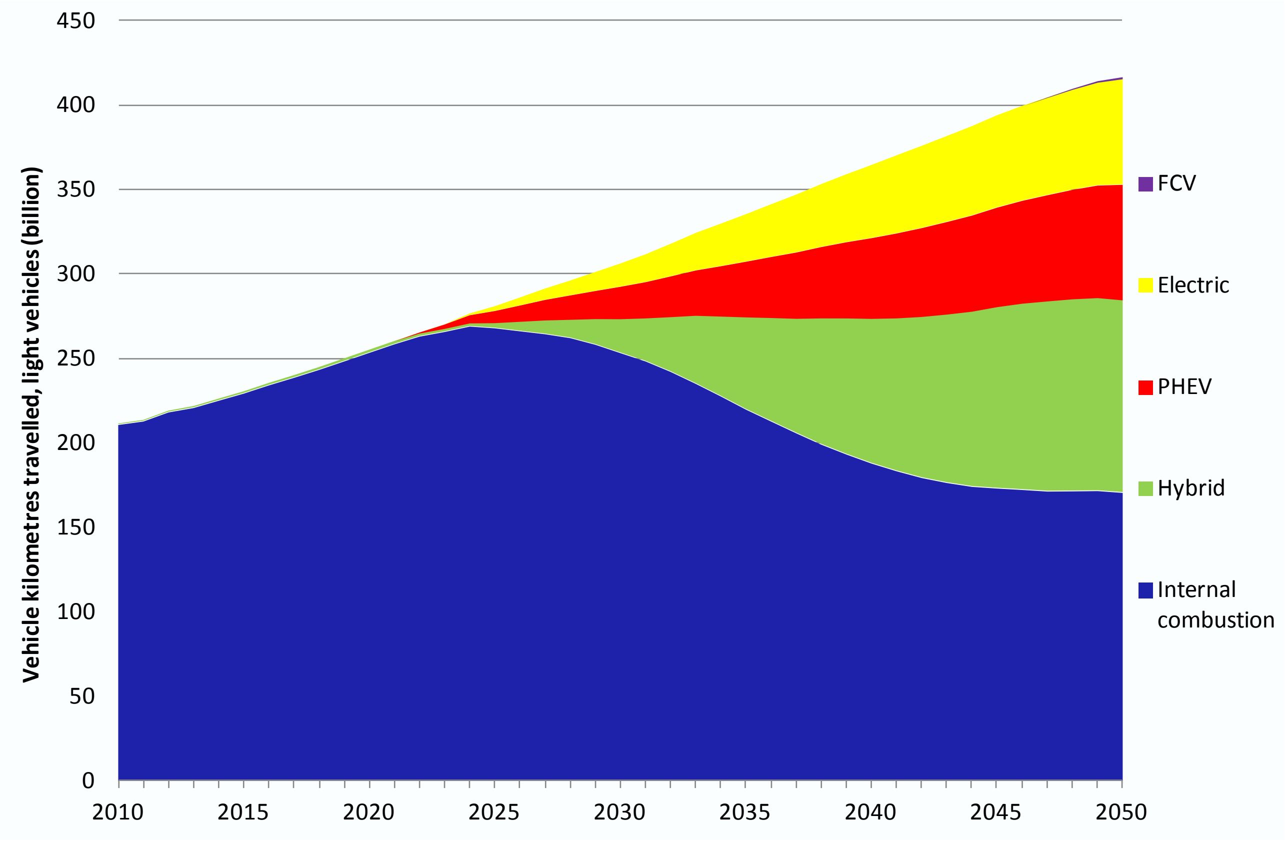

Figure 5-8: Engine type in road kilometres travelled, Early Mid sensitivity case, light vehicles

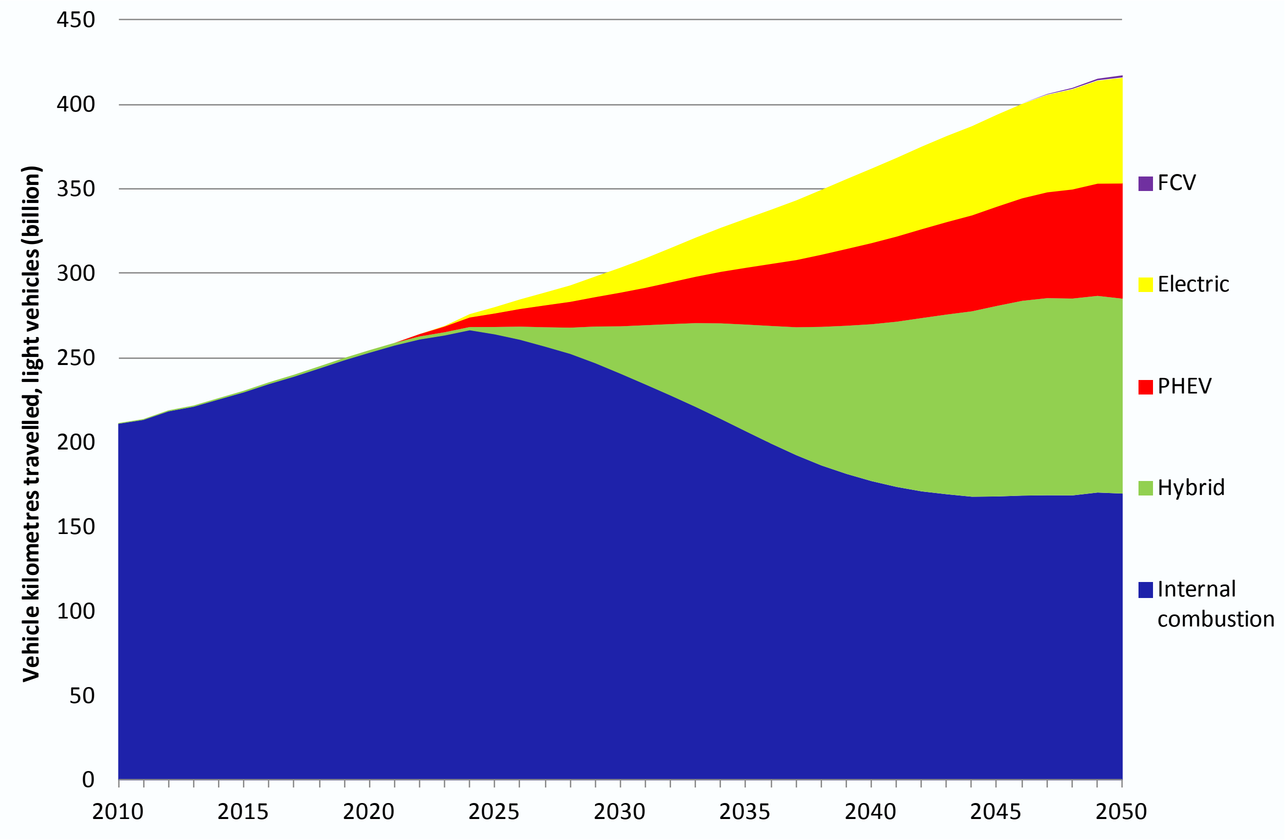

Figure 5-9: Engine type in road kilometres travelled, Early High sensitivity case, light vehicles

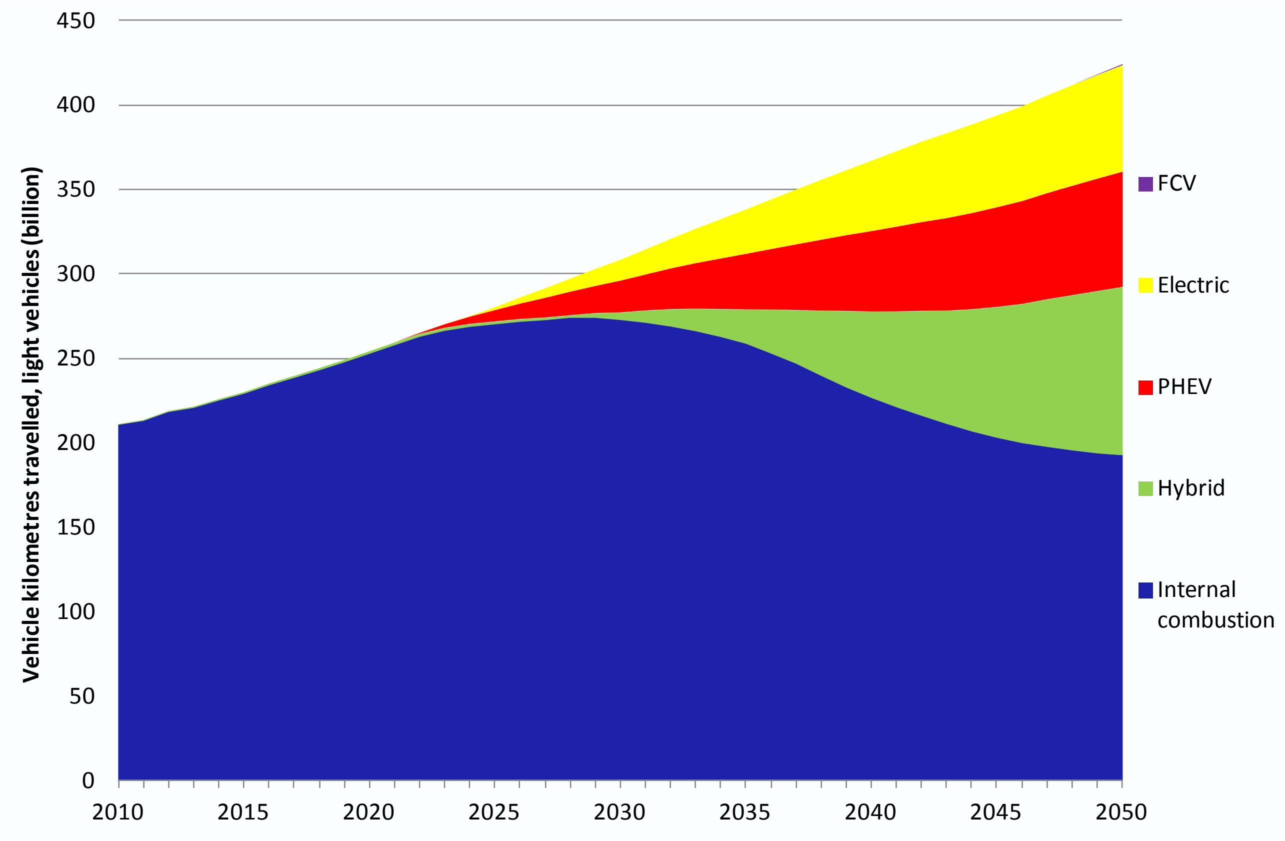

Figure 5-10: Engine type in road kilometres travelled, Late Low sensitivity case, light vehicles

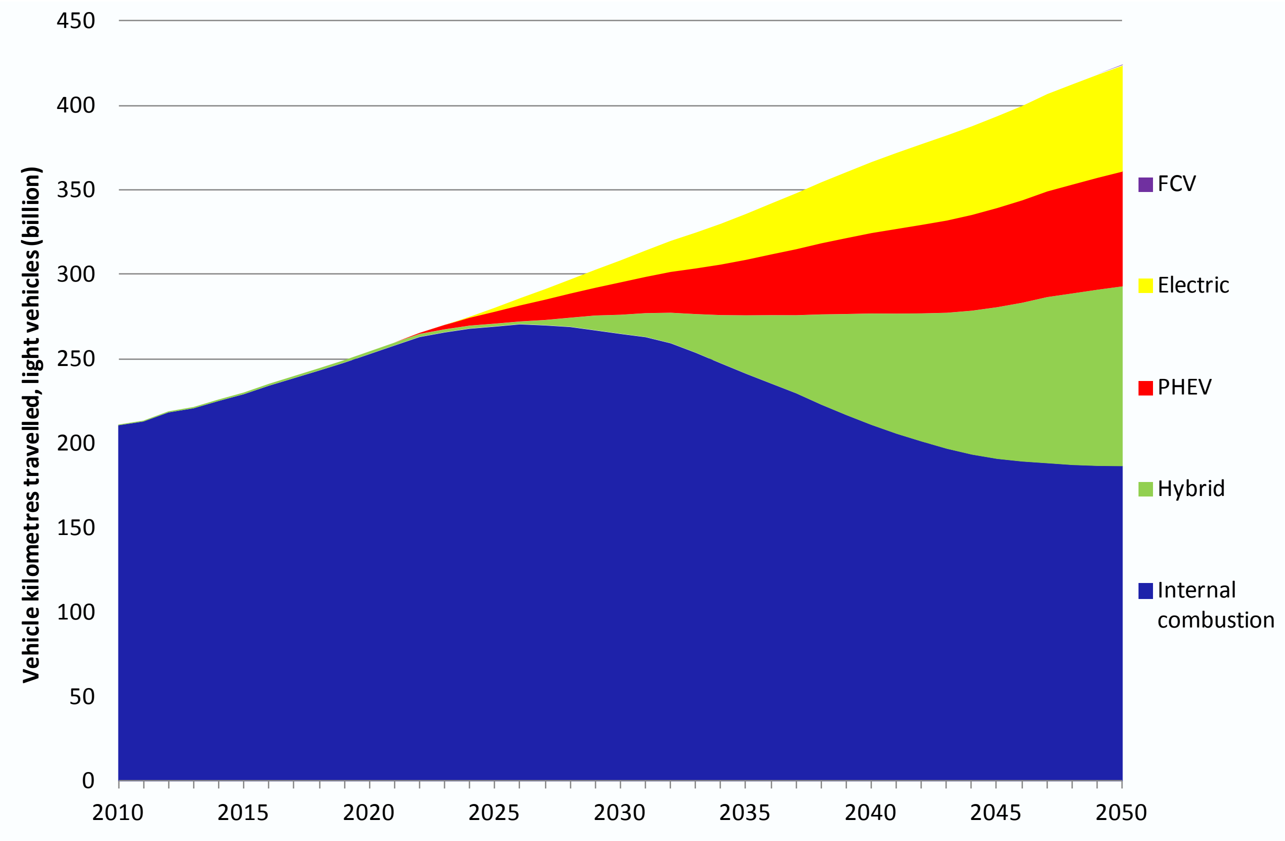

Figure 5-11: Engine type in road kilometres travelled, Late Mid sensitivity case, light vehicles

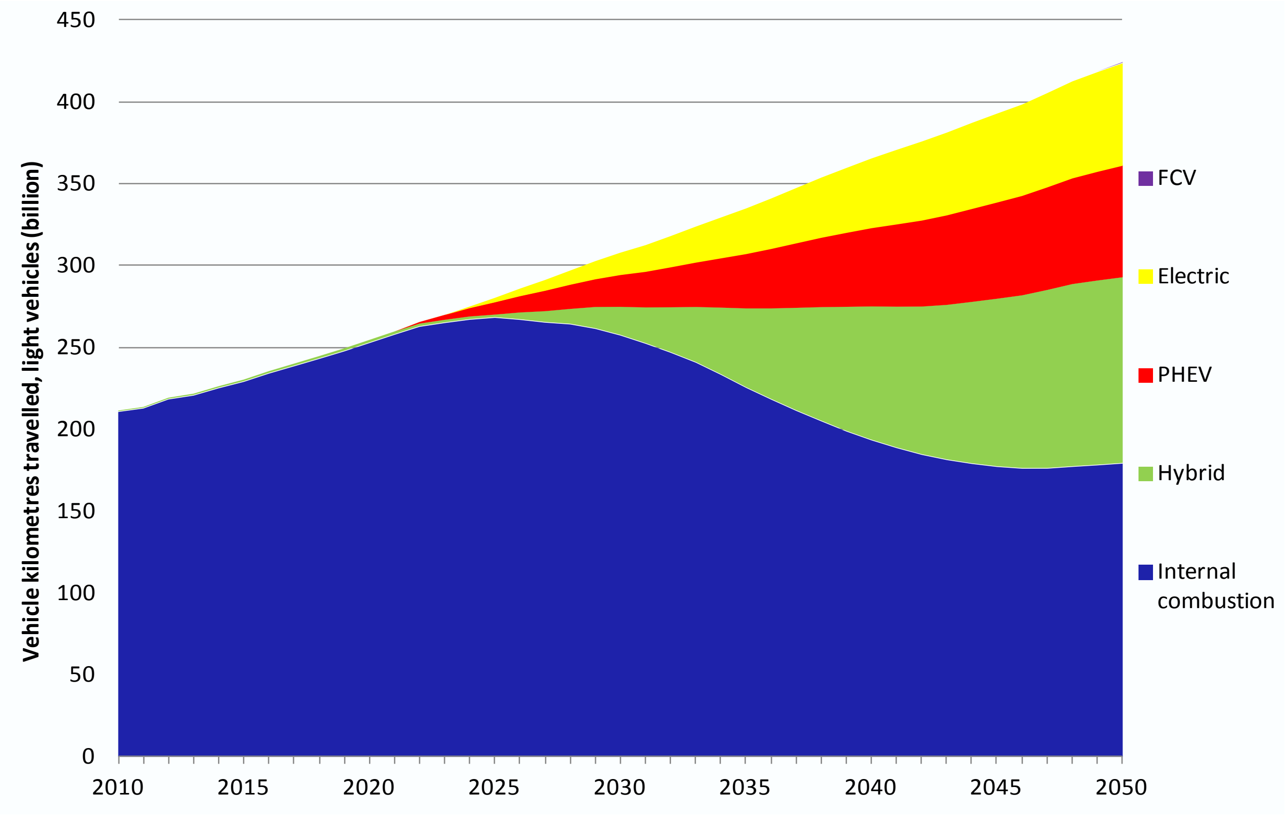

Figure 5-12: Engine type in road kilometres travelled, Late High sensitivity case, light vehicles

5.3 Greenhouse gas emissions

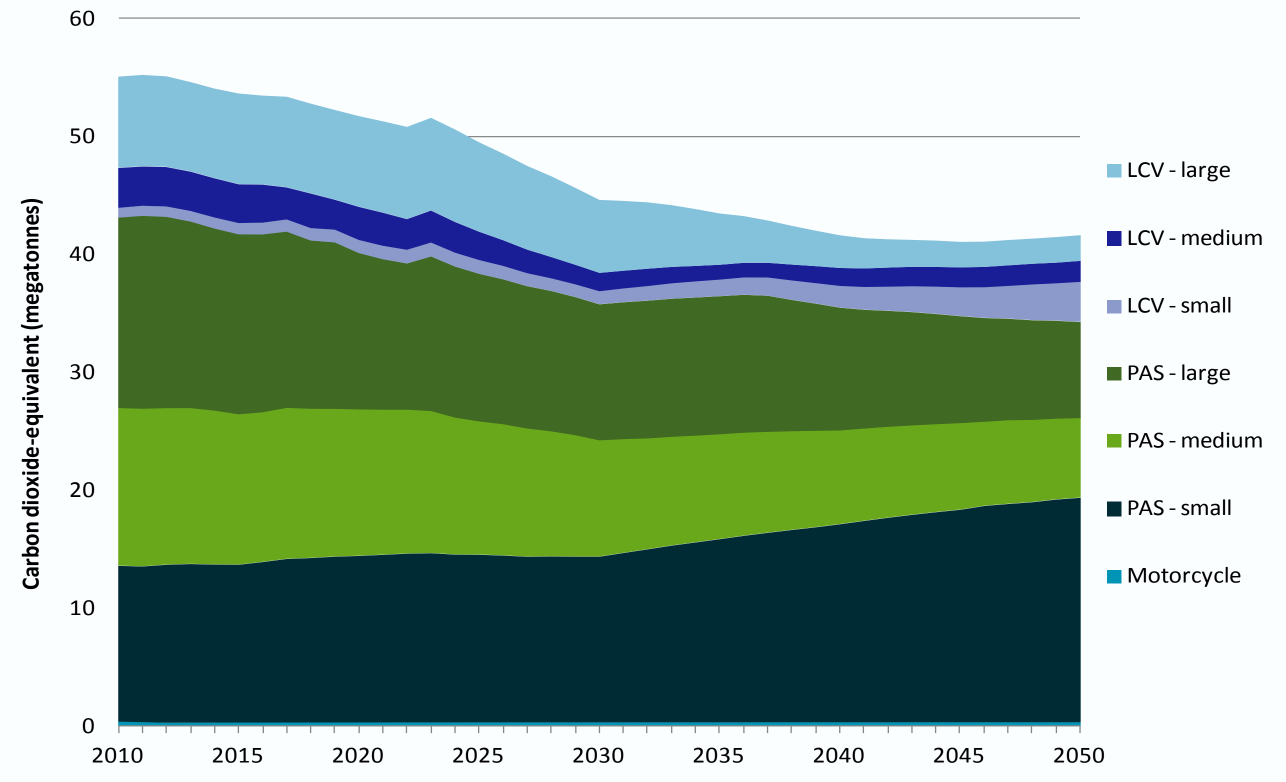

Figure 5-13: Greenhouse gas emissions by light vehicle mode, Early Low sensitivity case

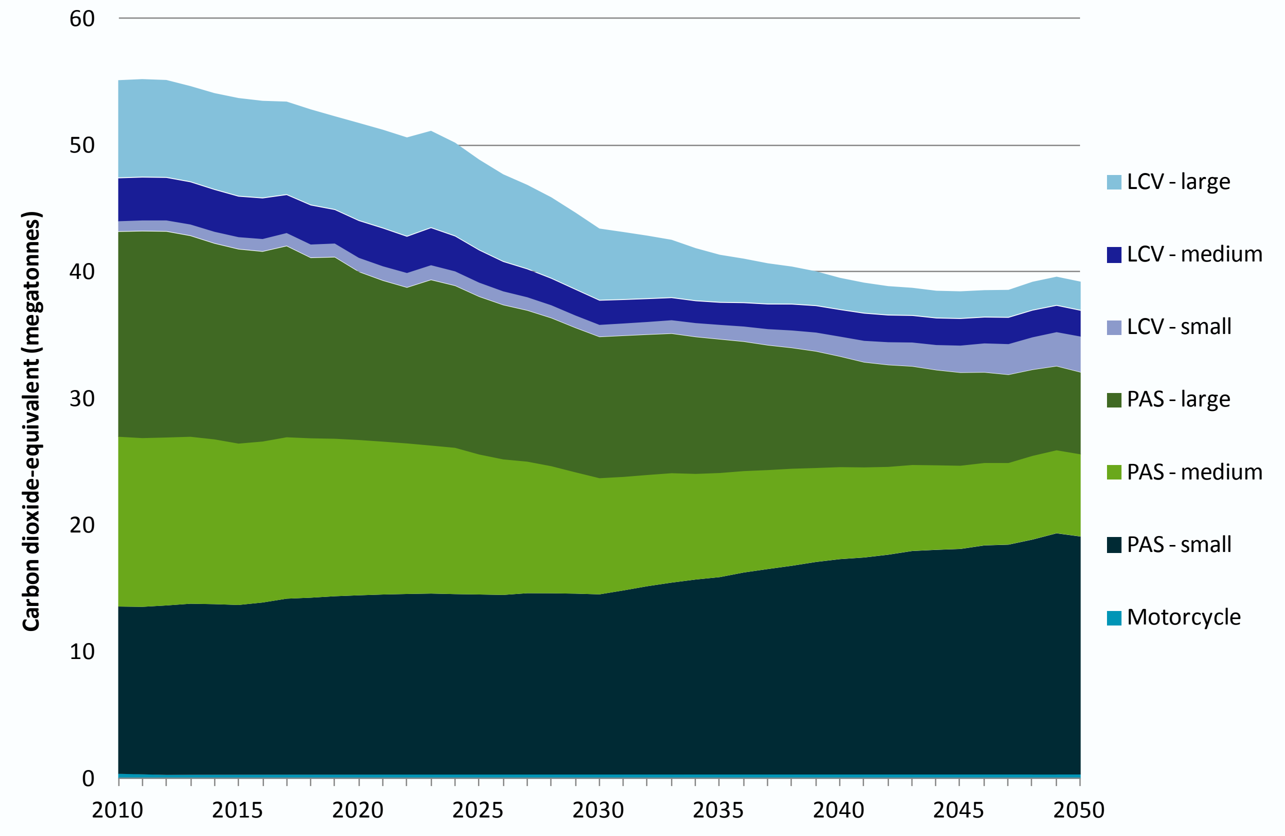

Figure 5-14: Greenhouse gas emissions by light vehicle mode, Early Mid sensitivity case

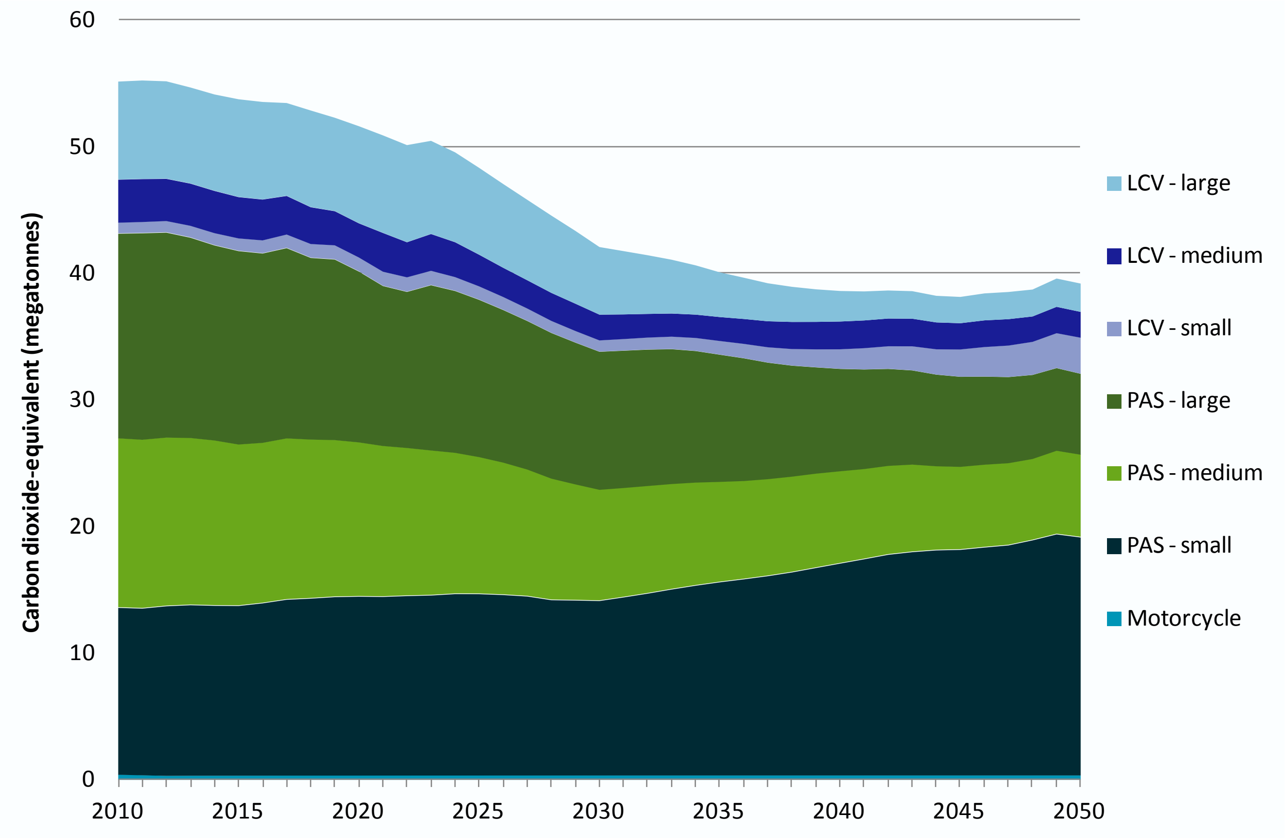

Figure 5-15: Greenhouse gas emissions by light vehicle mode, Early High sensitivity case

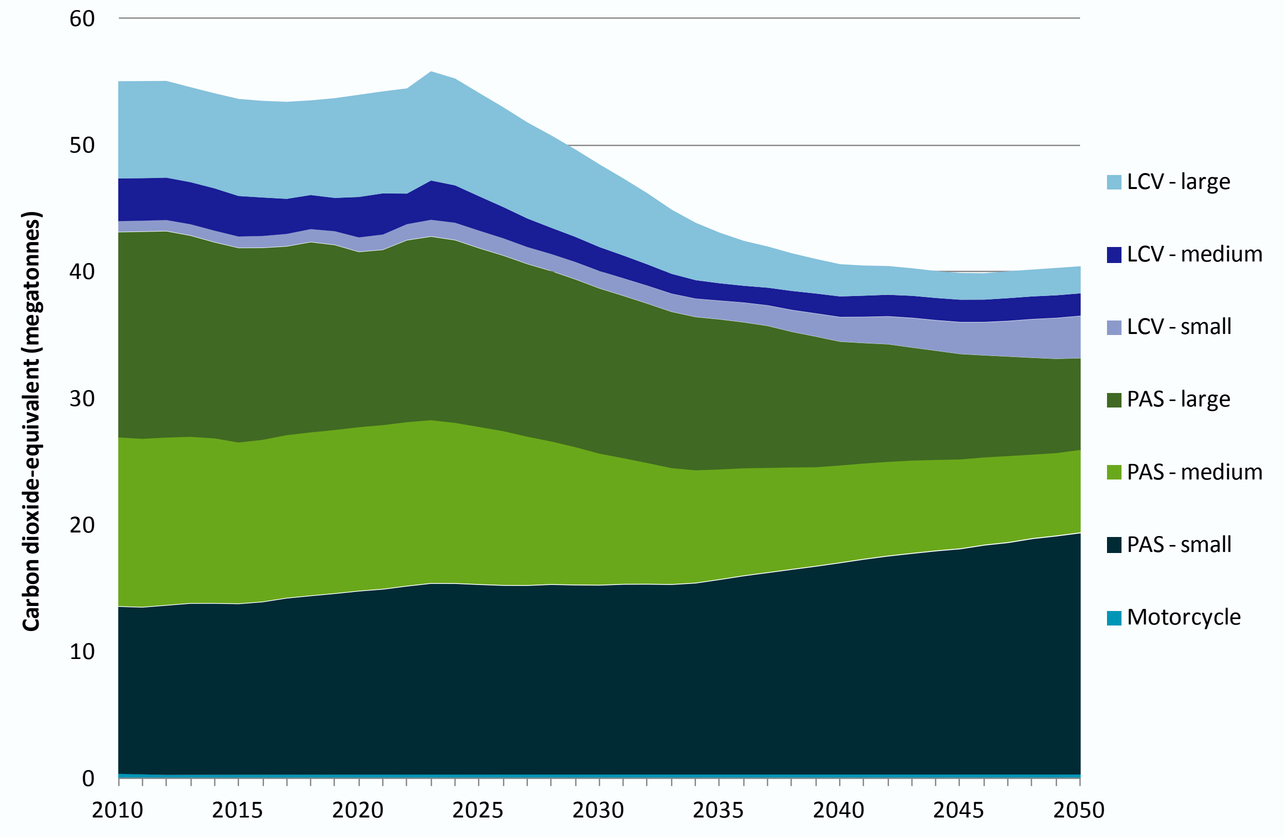

Figure 5-16: Greenhouse gas emissions by light vehicle mode, Late Low sensitivity case

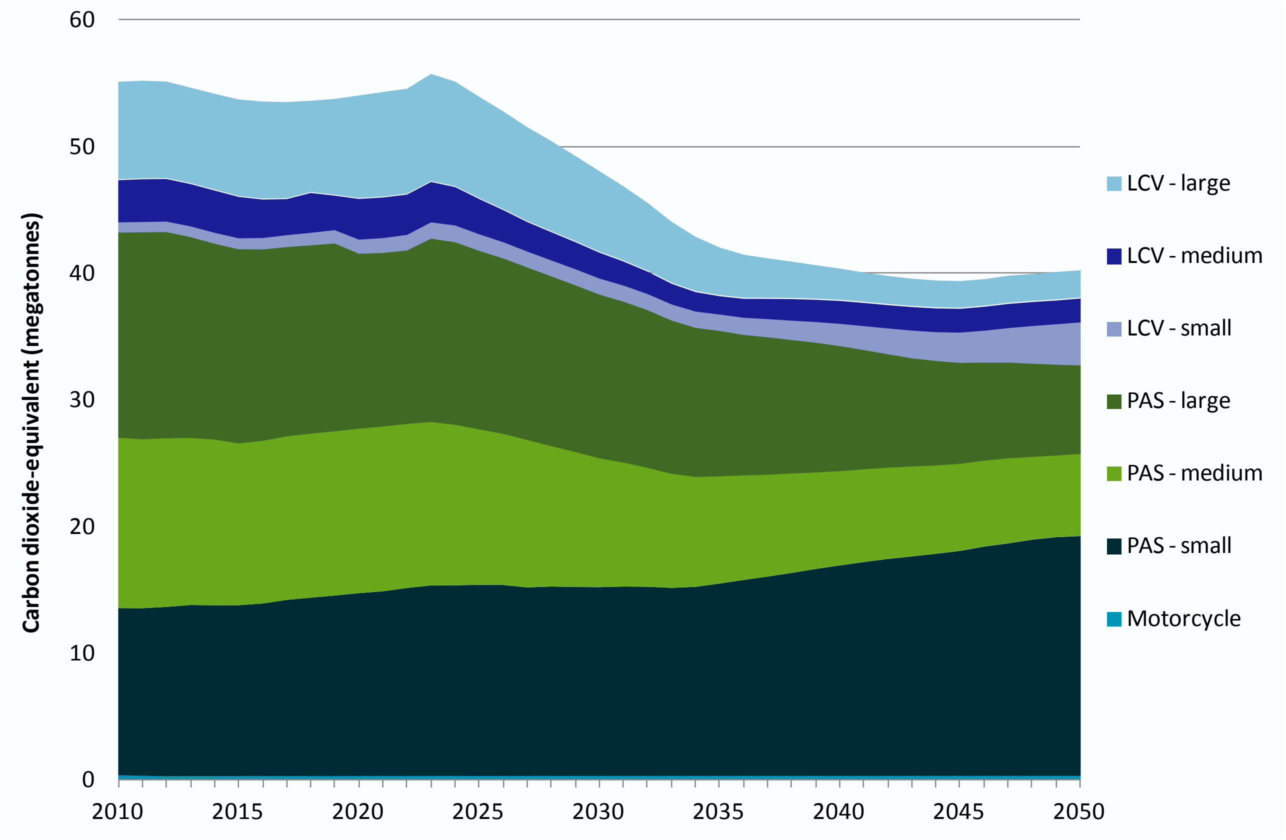

Figure 5-17: Greenhouse gas emissions by light vehicle mode, Late Mid sensitivity case

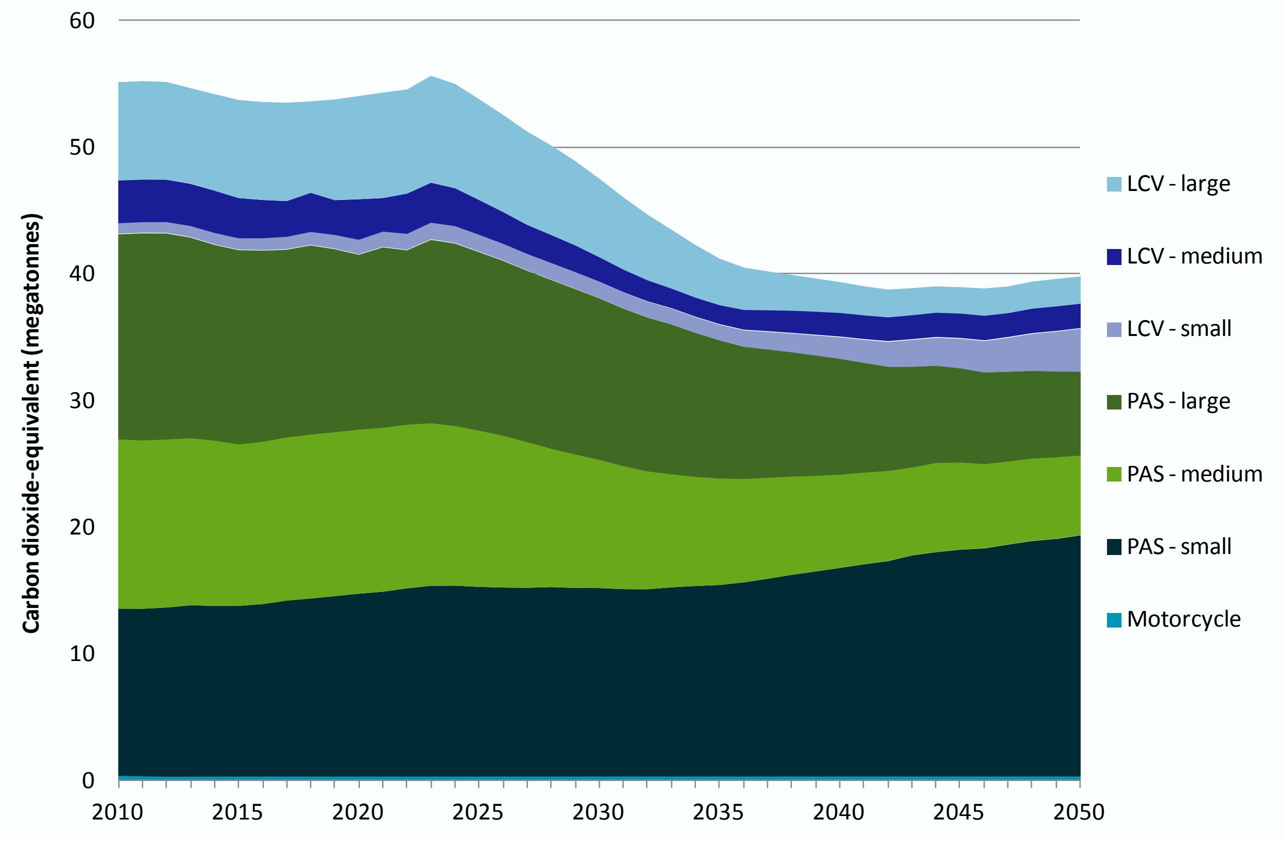

Figure 5-18: Greenhouse gas emissions by light vehicle mode, Late High sensitivity case

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