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Transport Greenhouse Gas Emissions Projections 2014-2050

Supplementary results for revised oil prices

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List of acronyms and abbreviations

bbl	Barrel
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CNG	Compressed Natural Gas
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTL	Coal-to-liquids diesel
DoE	Department of the Environment
DOE	Department of Energy (U.S.)
E10	A blend of 10 per cent ethanol with 90 per cent petrol
ESM	Energy Sector Model
EU	European Union
GJ	Gigajoule
GTL	Gas-to-liquids diesel
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
ML	Megalitres
Mt	Megatonnes
NSW	New South Wales
PJ	Petajoules
STL	Shale-to-liquids diesel
US	United States

Glossary

Alternative drive train – a drive train involving a power source in combination or separate from internal combustion to provide power to a vehicle

Alternative fuels – fuels other than petrol or diesel

Articulated vehicle – vehicles constructed primarily for the carriage of goods, consisting of a prime mover (having no significant load-carrying capacity) but linked, via a turntable device, to a trailer

Bio-derived jet fuel – a synthetic jet fuel manufactured via the conversion of biomass into jet fuel

Biodiesel – a diesel fuel substitute made from biomass. Those biodiesels produced using the transesterification process are often called Fatty Acid Methyl Esters (FAME) whilst those biodiesels produced using deoxyhydrogenation or Fischer-Tropsch gasification are call ‘renewable biodiesels’. Here we use the term biodiesel to cover both types.

Biomass – trees, crops, stems or other lignocellulosic or woody matters, plant oils or animal fats

Bio-SPK – synthetic paraffinic kerosene produced from tree or plant oils via the deoxyhydrogenation process

Cross-price elasticity of demand – the ratio between the proportional change in demand for a good or service divided by the proportional change in the price of another good or service (at given prices)

Deoxyhydrogenation – a refining process which removes the oxygen from vegetable oils and animal fats using various catalytic reactions at temperature and pressure. Hydrogen is a key input.

Diesel – a petroleum derived fuel suitable for use in compression ignition internal combustion engine vehicles

Drive-trains – the collection of all power transmission components in a vehicle, including the engine, which convert the fuel source into wheel propulsion

Electric vehicle – a vehicle which uses electricity stored in batteries and an electric motor in place of an internal combustion engine and a liquid petroleum fuel tank. Other elements of the conventional drive-train may also be modified or removed

Ethanol – one of several alcohol liquid fuels that can be produced from carbon based primary energy sources

First generation biofuels – Biofuels produced via one of the earlier commercialised technological pathways, including FAME biodiesel from traditional bio-oil crops and ethanol from sugars and starches.

Fischer Tropsch – a process for refining a purified syngas over a catalyst at controlled pressure and temperature into a liquid hydrocarbon. The syngas can be sourced via processing of natural gas or syngases produced from gasification of solid primary carbon fuels such as biomass and coal

Freight sector – the part of the transport sector primarily concerned with delivering non-passenger cargo

Fuel cell vehicle – a vehicle which uses a stored primary fuel such as hydrogen or natural gas, converts it to electricity via a fuel cell which is used to drive an electric motor in place of an internal combustion engine. Other elements of the conventional drive-train may also be modified or removed

Fuel efficiency – the ratio of the vehicle distance travelled per unit of fuel consumed. An alternative measure is distance a tonne is moved per unit of fuel which is more relevant for freight purposes. However, the former is more widely reported and is the preferred measure in this report.

Fuel excise – includes excise on petrol (gasoline), diesel, fuel ethanol, biodiesel, natural gas, liquefied petroleum gas, aviation gasoline, aviation kerosene, fuel oil, heating oil and kerosene. It is imposed at specific rates per unit of product.

Fuel supply chain – the collection of processes beginning from primary energy source extraction or harvesting, through transport of the energy source to a processing, refining or conversion plant, through to transport of the refined fuel the point of sale

Gasification – conversion of solid hydrocarbon fuels such as coal and biomass into a combustible gas rich in hydrogen and carbon monoxide

Greenhouse gas emissions – gaseous materials that have been classified as having a climate changing effect that have been transported into the atmosphere

Heavy duty vehicle – a vehicle with gross mass greater than 3.5 tonnes

Hybrid vehicle – an internal combustion vehicle that has been augmented with batteries and an electric motor which may store electricity generated from the internal combustion engine and then make it available at various times during the drive cycle, particularly when the electric motor is most efficient. The inclusion of an electric motor also allows regenerative breaking and for the internal combustion engine to be completely stopped rather than idled when the vehicle is stationary during a journey.

Internal combustion engine – an engine that uses the combustion of fuels via either spark or compression ignition to create wheel propulsion, usually via pistons.

Light commercial vehicle – light duty vehicle used primarily for business purposes

Light duty vehicle – a vehicle with gross mass less than 3.5 tonnes

Lignocellulosic biomass – the woody, non-food parts of crops, plants and trees

Low carbon fuels – fuels with a lower net lifecycle greenhouse gas emissions profile than petrol or diesel

Modal shift – A change in the use of one transport mode to another to achieve the same journey. For example, from passenger vehicle to bus or from aeroplane to train.

Motorcycles – two and three wheeled motor vehicles constructed primarily for the carriage of one or two persons. Included are two and three wheeled mopeds, scooters, motor tricycles and motorcycles with sidecars.

Non-road transport – aviation, marine and rail transport

Own-price elasticity of demand – the ratio between the proportional change in demand for a good or service divided by the proportional change in the price of the good or service (at a given price).

Partial Equilibrium Model – a type of economic model which finds the market equilibrium level of demand, supply and prices for a given market sector but not for the whole economy

Passenger kilometres – the number of kilometres travelled by vehicle multiplied by the number of occupants in the vehicle.

Plug-in hybrid electric vehicle – hybrid vehicles that draw electricity from the grid to charge the batteries as the primary source of power, but that also include an on-board internal combustion engine to either supplement or recharge the battery when it becomes depleted in journeys beyond the range of the battery.

Pongamia – an oil seed tree (*Millettia pinnata*) naturalised to Australia

Premium grade petrol – unleaded petrol with an octane rating of 95 or higher

Projection period – the time period from the present to the year 2050

Range anxiety – the aversion some consumers may have to owning a reduced range vehicle.

Regular grade petrol – unleaded petrol with an octane rating of 91

Rigid trucks – motor vehicles exceeding 3.5 tonnes, which do not have a pivot point to assist turning

Saccharification – the conversion of lignocelluloses into sugars

Second generation/advanced biofuels – biofuels that are produced using non-edible feedstocks of lignocellulose (such as lead, stems, wood) and tree or plant oils which are currently available but not yet used for that purpose

Switching costs – the additional cost to the consumer of purchasing and operating an alternative fuel vehicle

Synthetic fuels – Fuels that mimic the chemical composition of petroleum based fuels such as petrol, diesel and kerosene but are produced from non-petroleum energy sources

Synthetic Pariffinic Kerosene (SPK) – a jet fuel produced from the conversion of biomass via either Fischer-Tropsch gasification or deoxyhydrogenation

Tonne kilometres (tkm) – the number of kilometres travelled by a vehicle (VKT) multiplied by the mass of freight (measured in tonnes) transported.

Transport sector – the aviation, road, rail and marine sectors

Upstream CO_2 capture and storage – capturing (via a gas separation process) and storing (in a reservoir coal seam or aquifer) carbon dioxide gas that has been emitted during the process of refining a primary energy source into a transport fuel

Vehicle kilometre – a service unit which represents movement of one vehicle over one kilometre.

Vehicle kilometres travelled (VKT) – the number of kilometres travelled by a vehicle.

Executive summary

CSIRO was commissioned by the Department of Environment (DoE) to provide annual projections of emissions and fuel consumption for the transport sector to 2050 to inform *Australia's Emissions Projections 2014* and subsequently delivered a report in September 2014 (Graham and Reedman, 2014).

However, during the end of 2014 the oil price substantially declined to as low as $45/bbl which is beyond any recent experience leading many institutions to conclude that a step change had taken place in the market such that, previous projections of average oil prices in the range above $100/bbl indefinitely were now less likely.

CSIRO was subsequently commissioned to re-run all of the scenarios and sensitivity cases examined in Graham and Reedman (2014) with a new oil price range. For context the *Baseline* scenario oil price in Graham and Reedman (2014) report was A$125/bbl in 2015 rising to A$172/bbl in 2050. The scenario set includes a *Baseline* scenario, five sensitivity scenarios, two additional scenarios estimating the contribution of policy measures to greenhouse gas emissions projection outcomes and two final scenarios to determine the high and low range of emissions projections by combining various drivers in the sensitivity scenarios.

A description of each scenario is as follows:

- **Baseline scenario** – the central projection scenario including mid-range estimates of the key drivers and existing or announced policy measures.

Sensitivity scenarios:

- **Mandatory emission standards for new light vehicles** - a sensitivity scenario which assumes that, from 2018 on, mandatory CO_2 emissions standards on all new light vehicles (passenger and light commercial vehicles) apply. The average emissions intensity of new light vehicles sold in Australia must reach a target of 105g/km in 2025 (consistent with the US target in 2025) and 75g/km from 2035 onwards (which is broadly consistent with the EU 2025 target).

- **High oil prices** - a sensitivity case to gauge the impact of high oil prices. Under the *Baseline* scenario, oil prices are $97/bbl in 2020, $100/bbl in 2030, and $108/bbl in 2050. Under the *High oil price* scenario, oil prices are $140/bbl in 2020, $132/bbl in 2030 and $115/bbl in 2050 in 2013/14 Australian dollar terms.

- **Low oil prices** - a sensitivity to gauge the impact of low oil prices on the *Baseline* scenario. Under the *Baseline* scenario, oil prices are $97/bbl in 2020, $100/bbl in 2030, and $108/bbl in 2050. Under the *Low oil price* sensitivity case, oil prices are $82/bbl in 2020, $85/bbl in 2030 and $92/bbl in 2050. All prices are in 2013/14 Australian dollar terms

- **Increased supply of second generation biofuels**- a sensitivity scenario that explores the impact of a fourfold increase in the rate of expansion of second generation biofuels supply. In the *Baseline* scenario biofuels derived from lignocelluloses commence in 2036 at 1100 ML, and increase each year by an imposed maximum limit of 10 ML per annum, and biofuels derived from biologically derived oils commence at 400 ML in 2036 and increase by 10 ML per annum.

- **Delayed supply of second generation biofuels**- a sensitivity scenario that explores the impact of a 15 year delay in the availability of second generation biofuels supply which effectively means that biofuels are not available during the projection period to 2050

Measures estimates:

- **Estimate the emission impact of the NSW biofuels mandate** - modelling the *Baseline* scenario with the NSW biofuels mandate removed from 2015 in order to understand what contribution it makes to emission outcomes in the *Baseline* scenario.

- **Estimate the emissions impact of 2014-15 budget changes to fuel excise arrangements** - modelling the *Baseline* scenario with the existing fuel excise arrangements before the 2014-15 Commonwealth budget changes in order to understand what contribution they make to emission outcomes in the *Baseline* scenario.

Emission range scenarios:

- **High emission scenario** - combining the **Low oil prices** and **Delayed supply of second generation biofuels** sensitivity scenarios

- **Low emission scenario** – combining the **High oil price** and **Increased supply of second generation biofuels** sensitivity scenarios.

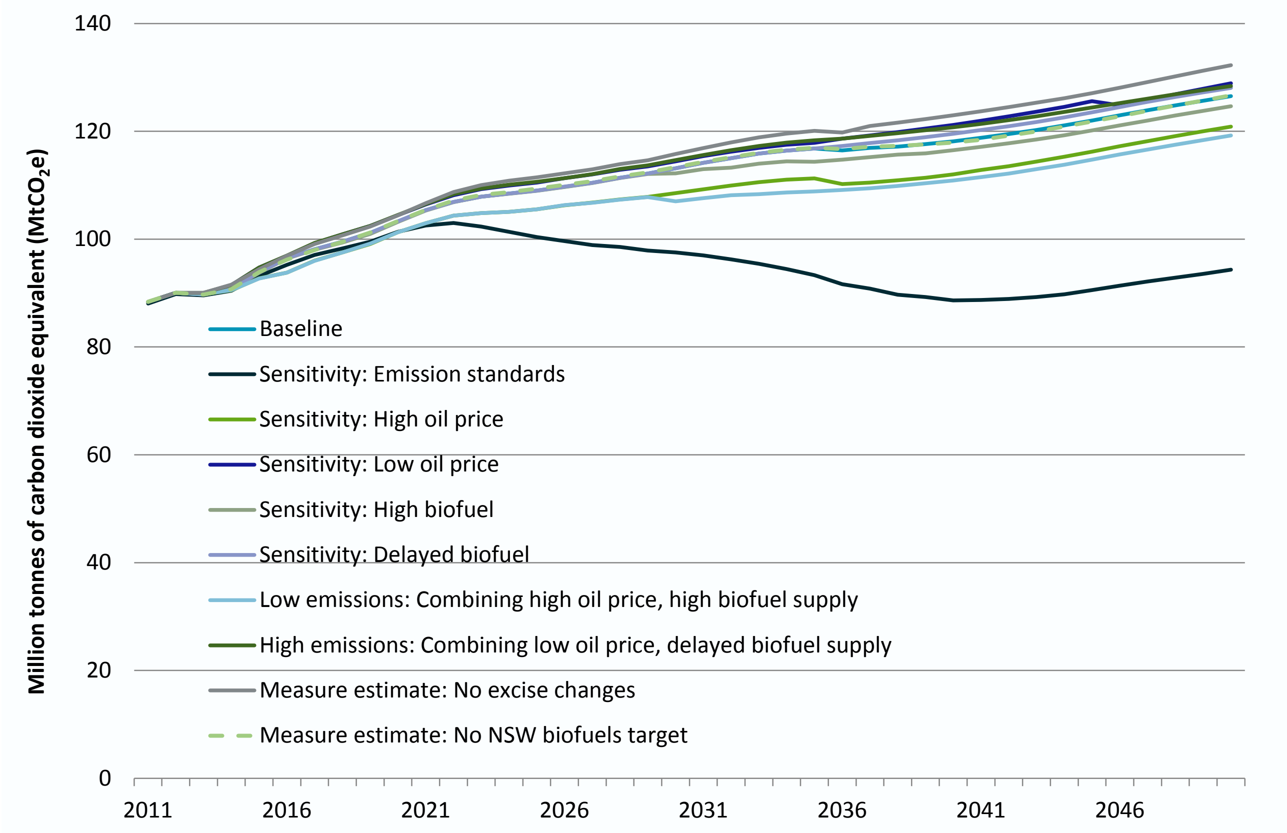

Figure E-1: Projected transport sector greenhouse gas emissions under the *Baseline* and sensitivity scenarios

The projected greenhouse gas emissions from the transport sector under these scenarios are shown in Figure E-1. Under the *Baseline* scenario, greenhouse gas emissions are projected to increase from 90.1 MtCO$_2$e in 2014 to 103.3 MtCO$_2$e in 2020, 113.1 MtCO$_2$e in 2030 and 126.5 MtCO$_2$e in 2050. This represents, from 2014, a 12.6 MtCO$_2$e increase at an average annual rate of 2.2 per cent per annum to 2020; a 22.4 MtCO$_2$e increase at an average annual rate of 1.4 per cent per annum to 2030; and a 35.8 MtCO$_2$e increase at an average annual rate of 0.9 per cent per annum to 2050.

Higher oil prices or increased supply of biofuels would moderate this increase, reducing emissions by up to 7.3 MtCO$_2$e in 2050 under the assumptions applied here in the *Low emission* scenario. Conversely, lower oil prices and delayed supply of biofuels could accelerate the growth in greenhouse gas emissions by up to 1.9 MtCO$_2$e by 2050 under the assumptions of the *High emissions* scenario.

The 2014-15 budget fuel excise changes are estimated to reduce growth in emissions by 5.7 $MtCO_2e$ by 2050 while the impact of the continuing operation of the NSW biofuel mandate is negligible by 2050 if second generation biofuels are available at a competitive price in their own right. However, cumulative savings to 2050 from the mandate are estimated at 2.0 $MtCO_2e$.

If new light duty vehicle emission standards were introduced according to the scenario assumptions outlined above then light duty road sector greenhouse gas emissions could decrease by 21.6 $MtCO_2e$ relative to 2014 to reach 34.4 $MtCO_2e$ in 2050. However, without other actions in heavy duty road transport and non-road transport, total transport sector emissions increase by 3.9 $MtCO_2e$ relative to 2014 to reach 94.3 $MtCO_2e$ in 2050.

1 Introduction

As this is a supplementary report and time to revise the modelling was limited, we do not repeat the assumptions and methodology description material provided in Graham and Reedman (2014) which remains very relevant to this report. We provide a discussion of the key differences in assumptions that were implemented to take into account the new world oil price outlook.

Discussion of the results of each scenario is somewhat shortened, focussing on the main changes and impacts relative to the *Baseline* scenario. We do not make any comparisons to the results in Graham and Reedman (2014), however the main outcome is that significantly lower oil prices mean more limited adoption of alternative fuels and vehicles and stronger demand for transport. We discuss this further in the next section.

The revised oil price range applied in this report is shown in Figure 1-1. For context the *Baseline* scenario oil price in Graham and Reedman (2014) report was A$125/bbl in 2015 rising to A$172/bbl in 2050.

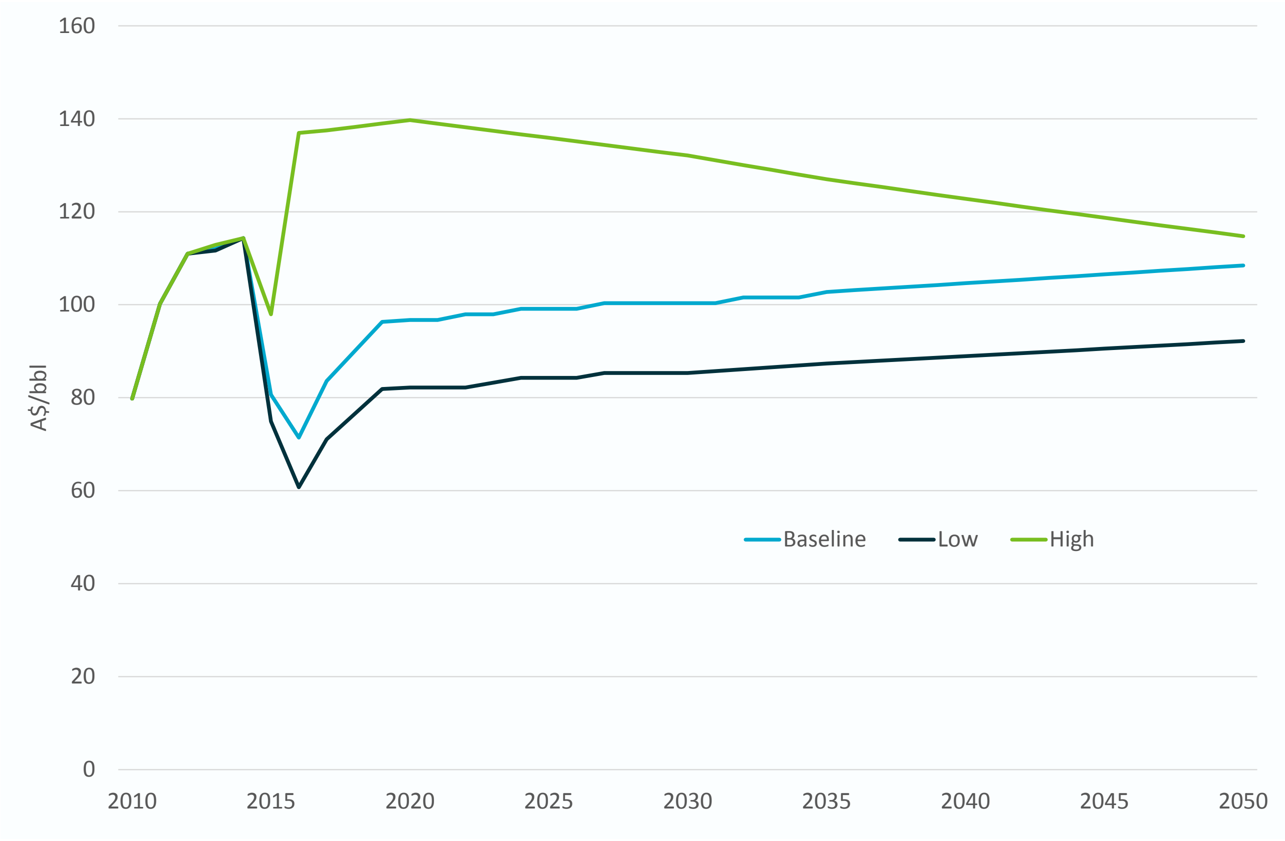

Figure 1-1: Assumed oil prices in the *Baseline*, *Low oil price sensitivity* and *High oil price sensitivity* scenarios

2 Changes in model assumptions

2.1 Background

This section outlines changes to Energy Sector Model (ESM) assumptions that will be adopted to accommodate new oil price assumptions. ESM, like all economic models, will make automatic adjustments for new price and cost data, choosing a new least cost solution to meeting transport demand. However, there are some inputs to ESM, fixed assumptions, which require manual adjustment.

The principles for modifying the user defined assumptions in ESM to take account of the lower expected oil price range are as follows:

- The global vehicle supply chain is controlled by a number of influencing factors. Australia is a vehicle importer and so changes need to be consistent with likely international responses. If USA and Europe proceed with vehicle emission standards regardless of the oil price then we would continue to see more fuel efficient vehicles in Australia together with increased global electric vehicle deployment and cost reduction.
- Upstream investment decisions will be less attractive. Sustained lower oil prices plus the uncertainty created by the recent reduction in oil prices will reduce the appetite for investment in alternative fuel production and dedicated vehicle development. However, vehicle manufacturers cannot quickly change their plans. Their current commitments to more efficient vehicles already in in progress (their typical design to on-market production cycle is five years) will still be deployed. The same cannot be said for alternative fuel production whose deployment would be more quickly halted by price changes.
- Downstream vehicle and fuel choices: Lower oil prices reduce the relative financial advantages of owning smaller vehicles and alternative fuel and engine vehicle configurations.

2.2 The change in the retail fuel price outlook

The differences in the retail fuel price outlook are evident in the following figures. Under the new baseline, petrol remains under $1.40 per litre. Under the old baseline, petrol approached $1.90 per litre in petrol equivalent terms. The LPG proportional price difference to petrol is improved under the new baseline because movements with the oil price are a larger portion of its overall pricing formula. The gap between CNG and petrol is narrower reducing the likelihood of uptake of CNG vehicles, although his was already not likely under the previous assumptions.

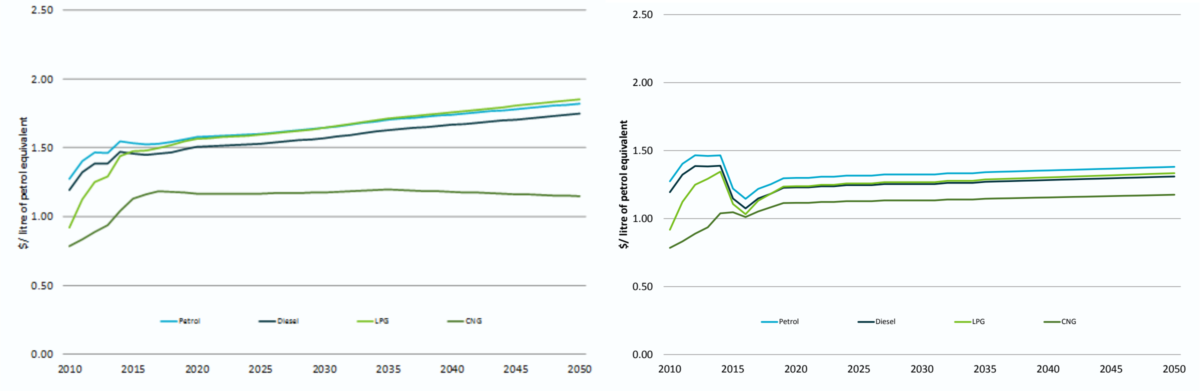

Figure 2-1: Old (left) and new (right) fuel prices to light road vehicles

Figure 2-2: Old (left) and new (right) retail prices to heavy road vehicles

For heavy vehicles we report fuel prices in diesel equivalent terms but the percentage difference is similar to petrol. For LNG the cost advantage it enjoyed over diesel disappears and in fact LNG is a more expensive fuel in energy equivalent terms for most of the projection period. This means LNG will not be adopted.

2.3 Road transport demand

We will use the same procedures we used to modify demand in some of the sensitivity cases in Graham and Reedman (2014) to recognise a likely increase in demand for road transport. The procedure involves applying a price elasticity of demand to, in this case, increase demand, to recognise a decrease in the cost of travel.

Each 1 per cent decrease in the cost of road transport will lead to a 0.2 per cent increase in demand. We will not allow for any modal switching (cross-price elastic responses) as there is not enough evidence at this stage that patrons of public transport will switch to private transport due to lower fuel prices (other threshold factors like location of public transport infrastructure, convenience and cost of buying a private vehicle are not impacted by fuel prices). However, a price reduction of this magnitude has not been observed since the late 1980s and so these assumptions could be revisited in future work as the outcomes of lower prices become more evident.

2.4 Preferences for road vehicle types and sizes

In our previous assumptions, small passenger and LCV vehicle sizes gained an additional 10 and 15 percentage points of the total share of vehicle types over the projection period, so that the proportion of medium to large vehicle types reduced over time. To reflect a lower oil price range, we now assume the additional shift into small vehicles in passenger and LCV vehicles is 5 and 7 percentage points respectively.

2.5 Road vehicle costs

To the extent that vehicle cost reductions represent both technological change and economies of scale, they should still remain achievable and driven by other factors such as subsidies, standards and other incentives in different countries. As such, while there may be a delay in the adoption due to relative price movements, no change in the rate of cost improvement is assumed.

2.6 Road vehicle fuel efficiency

2.6.1 LIGHT VEHICLES

The total technical potential for new internal combustion engine vehicle fuel efficiency improvement was identified as 30 per cent in the King Review (2007), 18 percentage points of which have already been delivered by 2014. We previously assumed 4 of the remaining 12 percentage points would be achieved by 2030 (and thereafter only minor improvements of 0.1 percentage points per annum). In the period to 2030, we now assume this amount to be 3 per cent – a minor adjustment -reflecting the view that the most efficient improvements were already in-train and will be delivered in spite of oil price changes.

2.6.2 HEAVY DUTY VEHICLES

Previous assumptions were based on the low case contained in the *DOE SuperTruck Program* report which was for a 0.2% per annum relative rate of improvement (TA Engineering, 2012). We reduce this to 0.16% per annum relative rate of improvement.

2.7 Non-road fuel choices

With reduced price incentives, technical fuel efficiency improvements and alternative fuels in the non-road sector will be pursued less vigorously. We apply the same road sector follower rule in the marine and rail sector for alternative fuels, for natural gas and biofuels. This results in some cases in no uptake of these fuels as gas prices, in particular, are unlikely to support the uptake of natural gas in road freight except in the high fuel price case.

Given fuel is such a high proportion of costs for the non-road sector, fuel efficiency improvements will still be pursued by those industries. However, it is assumed here that the final 2.5% of improvements assumed in Graham and Reedman (2014) is not economically viable under the new oil price range.

Table 2-1: Non-road transport fuel mix and efficiency assumptions

	Oil price scenario	Natural gas	Biofuels	Fuel efficiency improvement
		Follower rule	Follower rule	%
Marine	High oil price	A quarter of the road freight sector gas share	A third of the aviation biofuel sector share	20
	Baseline/low oil price			12.5
Rail	High oil price			15
	Baseline/low oil price			7.5
Aviation	High oil price	N/A	Modelled	25
	Baseline/low oil price	N/A	Modelled	17.5

2.8 Deployment of alternative fuels

The costs of alternative fuels such as biofuel and synthetic diesels from coal, gas and shale generally sit within the range of $US80 to $US110/bbl. However, given the historical volatility of the oil price and the high upfront cost of capital for alternative fuel manufacturing facilities and other parts of the supply chain, oil prices need to be at or above the high end of this cost range for a sustained period to see investment proceed. The updated baseline oil price range in 2013/14 Australian dollar terms is $71/bbl in 2016 growing to $103/bbl by 2035 (the previous baseline commenced at around $125). In light of the weakened price signal, supply of alternative fuels and vehicles will be limited. The assumptions do not directly rule out the adoption of alternative fuels, rather the economic model will do this automatically by curtailing demand where there is no financial benefit. Rather, these assumptions directly rule out any large scale investment along the supply chain in capacity which would be unlikely to be financed due to market risk. Specifically, these assumptions are as follows:

- Articulated LNG trucks – No expansion. Supply capacity fixed at current levels (1500 p.a.)
- CNG light vehicles – No expansion. Supply capacity fixed at current levels (25,000 p.a.)
- LPG – No expansion. Supply capacity fixed at 25,000 p.a.
- Biofuels – an eleven year delay in investment in capacity development to 2036 (ten years would also be appropriate but would lead to end-point discontinuity in series to 2035).
- Synthetic fuels – no expansion of GTL and STL. CTL expansion delayed to 2036
- Electric vehicles – no change to supply capacity which is generally driven by international manufacturing and international transport emission standards and incentives.

3 Baseline scenario results

This section provides the modelling results for the updated *Baseline* scenario. This scenario is central in that all other scenarios use this scenario's assumptions as their point of departure. The *Baseline* scenario features mid-range oil prices, retains the NSW biofuels target, and includes the fuel excise arrangements announced in the 2014-15 Commonwealth Budget.

3.1 Transport fuel mix

In a world where average annual oil prices are in the range from $A70 to just over $A100/bbl, alternative fuels are economically viable in theory. However, in practice, this does not provide a significant enough margin to offset the high risk for investors who are seeking a return on the infrastructure required to build new supply chains (refining, distribution and modified vehicle fuel and engine systems). As such, only the very lowest cost alternative fuels are adopted under the *Baseline* scenario. These include some types of biomass feedstocks, coal, and electricity, where cost reductions in electric drive trains are being motivated by international subsidies and incentive schemes.

From a demand point of view, adoption of alternative fuels is generally in niche markets with higher than average fuel use. For the average consumer, the cost of road travel is declining as a proportion of income (due to income growth) and so the incentives to radically alter their transport fuels and engine preferences are weak.

3.1.1 LIGHT DUTY ROAD

At the beginning of the projection period, the fuel mix (Figure 3-1) is dominated by petrol, diesel and liquefied petroleum gas (LPG) which is mainly used in light commercial vehicles such as taxis. The limited use of ethanol (blended with petrol in the form of E10) and biodiesel reflects the NSW biofuel mandate and smaller contributions from other states.

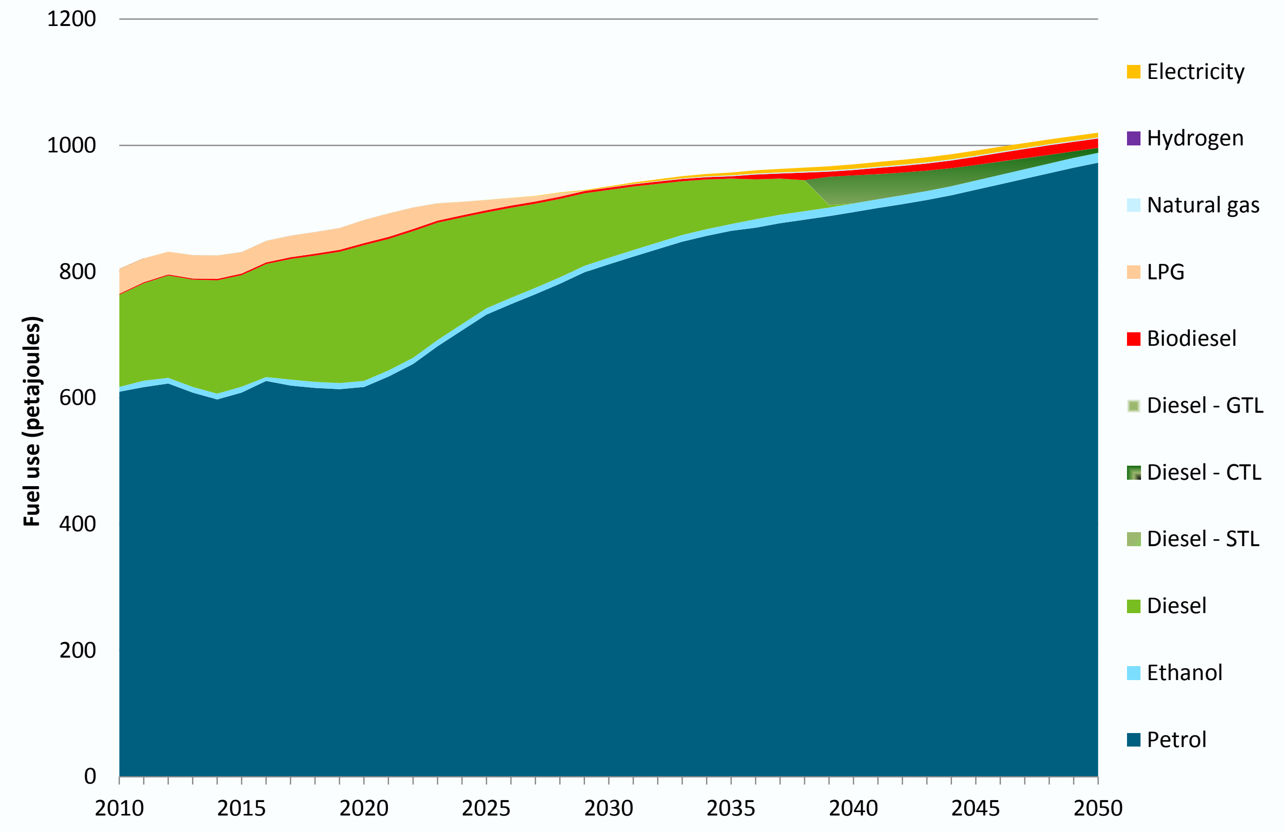

Figure 3-1: Light duty road transport fuel consumption by fuel under the *Baseline* scenario

The fuel mix volatility in the period to 2020 reflects trend growth being moderated initially by new vehicle fuel efficiency which has been improving at around 3 per cent and then this being offset by faster growth in demand due to lower fuel prices from 2015.

Diesel fuel consumption initially increases due to changes in fuel standards, the popularity of diesel in some vehicle categories and the high fuel prices that prevailed up to 2015. However, given moderate fuel prices and the adoption of hybrid electric vehicles, petrol vehicles can achieve a similar or better fuel efficiency performance than diesel, reducing the incentive to purchase diesel fuel vehicles. Accordingly, the share of petrol vehicles increases steadily from around 2020.

The availability of hybrid electric vehicles also drives the reduction in LPG fuel shares from the early to mid-2020s.

In the second half of the projection period we see three alternative fuels begin to capture a modest and declining fuel market share. Fully electric vehicles are adopted, although remain niche for those users who travel high urban kilometres. As biofuel production becomes more cost competitive, it is adopted in the form of biodiesel, because biodiesel enjoys a lower excise per energy content of fuel. However, ethanol consumption also expands due to the NSW biofuels target and increased share of petrol.

Synthetic coal to liquids diesel is also adopted from 2038, replacing conventional diesel, but is eventually squeezed out due to the reduction in diesel use generally (however the refining capacity simply switches to supply more volume to the heavy road vehicle market). These types of refineries are generally large scale, but subsequently entail more risk, hence the trend of being deployed last, though at high production volumes. Such refineries could produce petrol, however, diesel is generally the higher value market and there is ample demand in the road freight sector.

3.1.2 HEAVY DUTY ROAD

Diesel use dominates the heavy duty road fuel mix (Figure 3-2) since the fuel savings of using diesel in heavy road vehicle activities can more than pay back the extra cost of diesel engines.

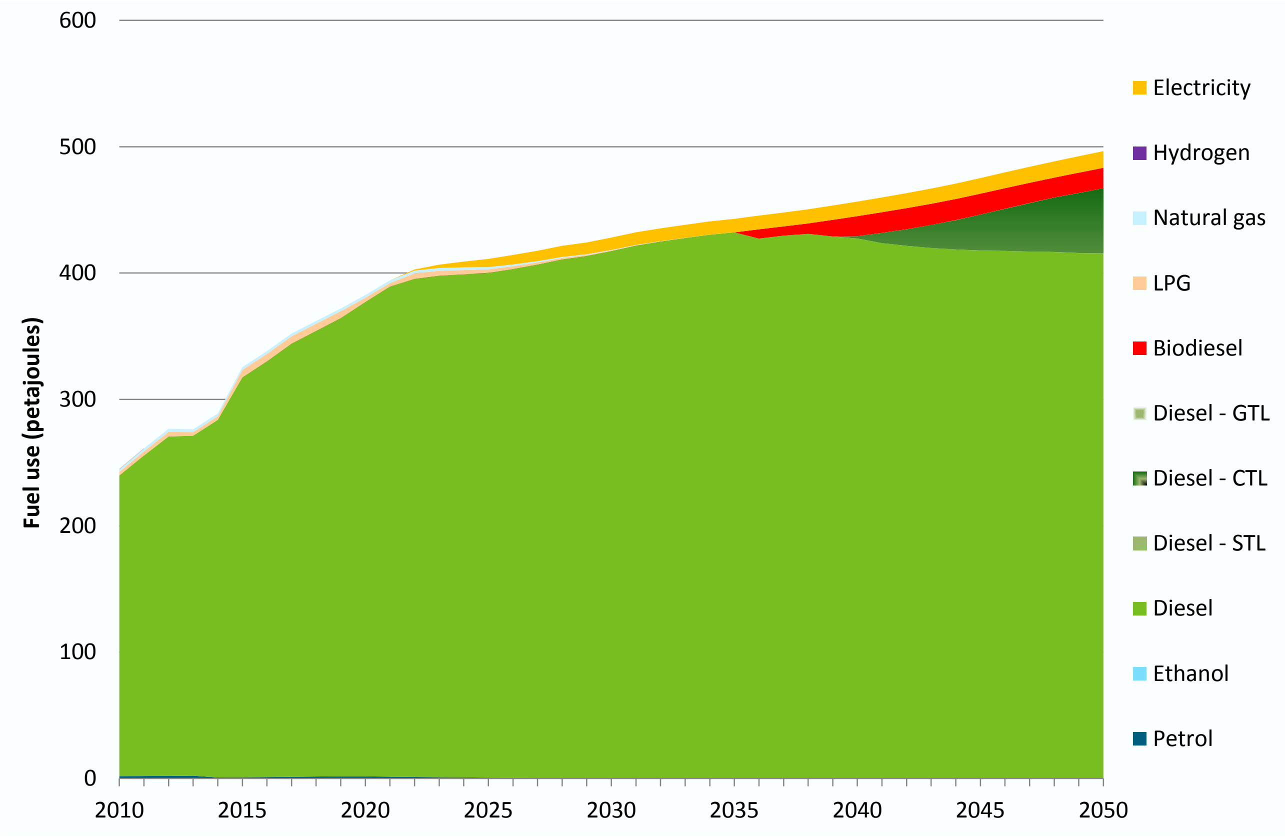

Figure 3-2: Heavy duty road transport fuel consumption by fuel under the *Baseline* scenario

Over the projection period LPG and LNG remain niche, applied predominantly in locations where the LPG or LNG supply is lower cost. At the assumed oil and gas prices, and after taking into account fuel excise increases to 2015, they do not offer any fuel cost saving advantage.

As in the light duty market, electricity, biodiesel, and synthetic diesel from coal, are the only alternative fuels that see growth, which begins in around 2020 for electricity and in the mid- to late 2030s for biodiesel and coal.

The combined fuel mix for all road vehicles is shown Figure 3-3.

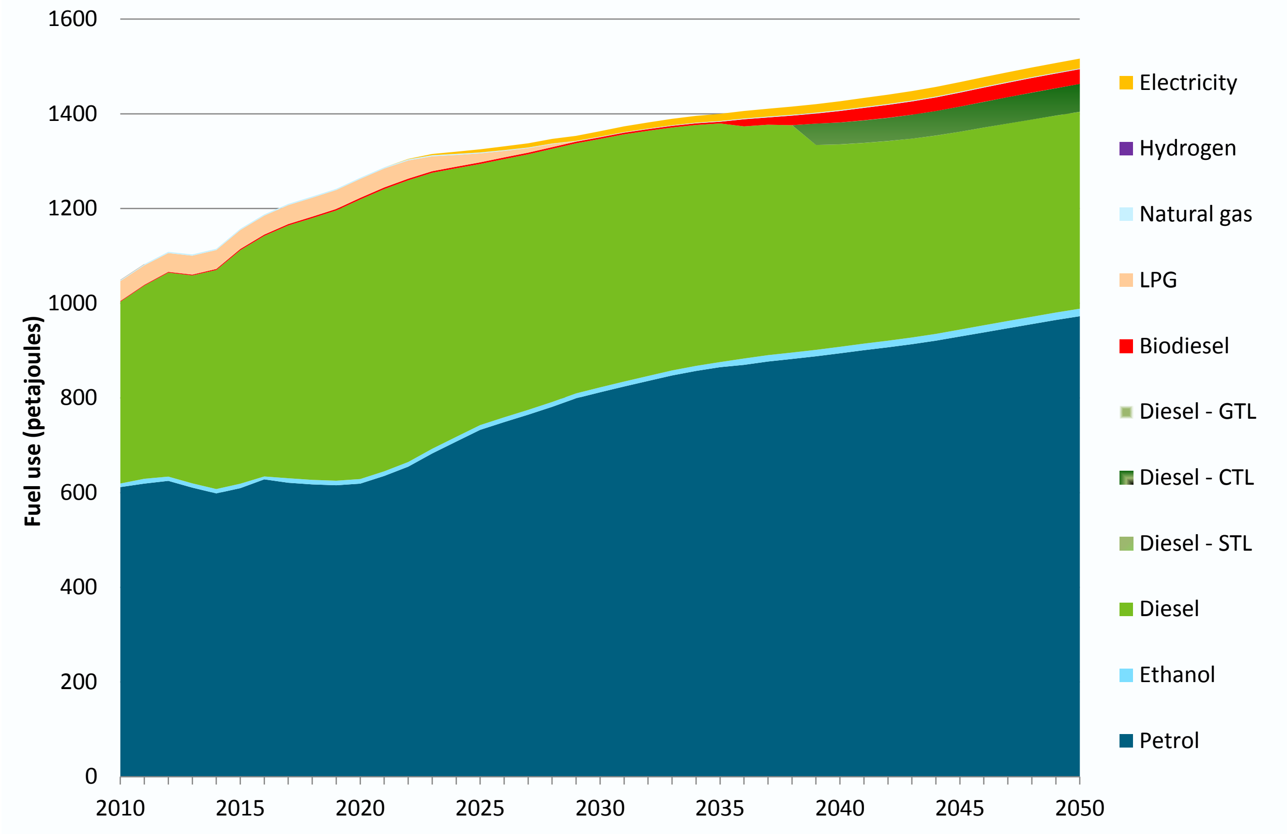

Figure 3-3: Projected total road transport fuel consumption by fuel under the *Baseline* scenario

3.1.3 NON-ROAD

Figure 3-4 shows the projected fuel consumption by non-road transport, by fuel and by mode (domestic navigation (marine), rail and domestic aviation) for the *Baseline* scenario. It shows that throughout the projection period the fuel mix is dominated by diesel, fuel oil and coal in navigation, diesel and electricity in rail, and kerosene (jet fuel) in aviation. Aviation is the largest consumer of non-road transport fuel, accounting for around half at the beginning of the projection period and increasing to 62 per cent by 2050.

There are two main changes over the projection period. First, the aviation sector adopts bio-derived jet fuel in the mid-2030s as a by-product of road biodiesel production, leading to a 0.6 per cent share by 2050. Neither rail, nor navigation is assumed to take up biofuel given their lack of purchasing power relative to the road sector where excise differences create a stronger incentive. The other main change is that coal use is slowly phased out in the navigation sector as ships using that fuel are retired.

Natural gas is not adopted owing to the cost of gas not being insufficiently low relative to diesel to support the development of that fuel supply chain in either the road or non-road sectors.

Overall the non-road transport sector experiences an average annual rate of growth of 1.8 per cent between 2014 and 2050 reflecting strong freight demand and aviation passenger demand, offset by modest fuel (litres/km) and task (t/km) efficiency improvements.

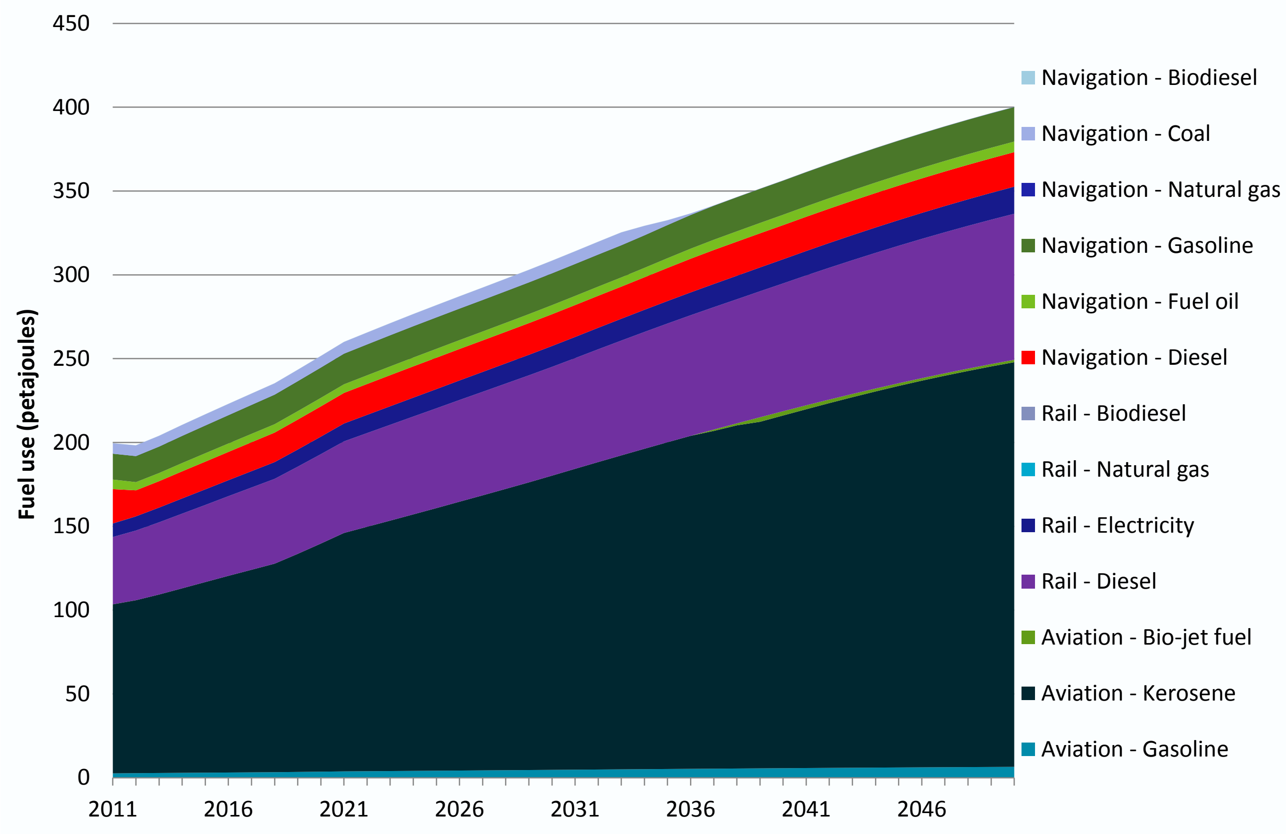

Figure 3-4: Non-road transport fuel consumption by fuel and mode under the *Baseline* scenario

3.2 Road sector engine mix

Figure 3-5 shows the share of engine type for road kilometres travelled in the *Baseline* scenario. Out to 2020, the current dominance of internal combustion vehicles is expected to continue, mainly reflecting that the cost of hybrid and electric vehicles are not yet low enough to present an economically viable alternative. Uptake in this period is only by consumers either with very long urban driving distances or who place a low weighting on financial criteria and a higher weighting on fuel and emissions saving and technological advancement.

From the early to mid-2020s, the cost of hybrid vehicles reaches a tipping point, under the model assumptions, whereby they become a financially sound choice for mainstream consumers in some vehicle size ranges. Cost is still an issue for full or plug-in hybrid electric vehicles and so their uptake is more niche. Electrification occurs in both the light duty and the smaller end of the heavy duty road sector.

Continued adoption of hybrid electric vehicles in particular means that by 2050 the share of internal combustion only vehicles in total kilometres travelled has reduced to around half.

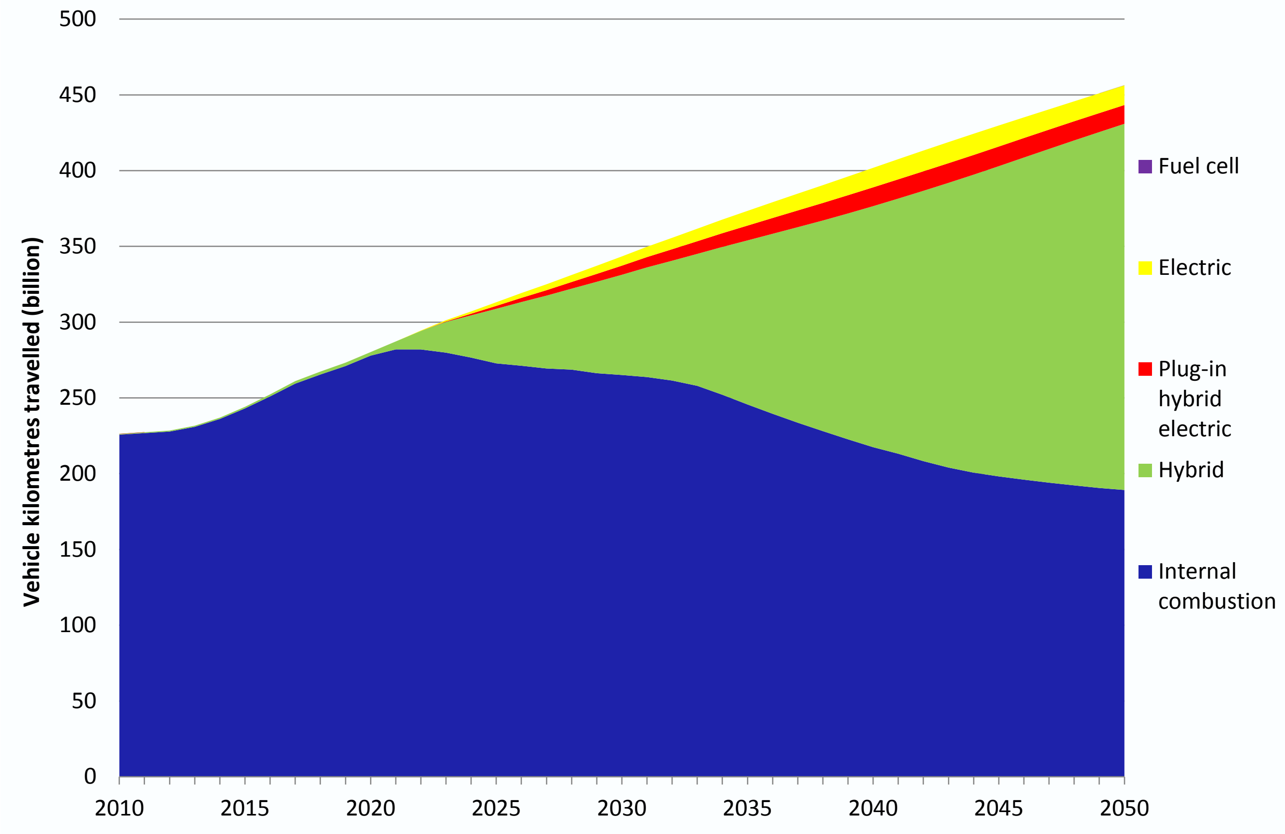

Figure 3-5: Engine type in road kilometres travelled, *Baseline* scenario

3.3 Greenhouse gas emission projections

Figure 3-6 shows the greenhouse gas emissions by mode for the road transport sector under the *Baseline* scenario. Greenhouse gas emissions rise slower than growth in road transport kilometres owing mainly to improvements in fuel efficiency, adoption of smaller vehicles, and to a lesser extent adoption of lower emission fuels such as biofuels and electricity. Biofuels have a direct zero carbon dioxide emission factor, as the emissions released during combustion are equal to the carbon dioxide absorbed as the feedstock is regrown. However, there are small amounts of non-carbon dioxide combustion emissions so the total greenhouse emissions factor is not quite zero. By convention, emissions associated with upstream biofuel production activities are not reported as transport sector emissions (neither are those emissions associated with the production of any other fuel). Electricity has no emissions associated with its use in the transport sector and so its emission factor is zero.

The distribution of emissions across the transport modes reflects the relative growth of kilometres travelled in those modes and fuel choices. The shift towards lighter vehicles is evident in the strong growth of small passenger and light commercial vehicles, and corresponding flatter trend in medium and large car sizes. Growth in articulated truck emissions reflects the strong growth in freight demand. Growth in rigid truck emissions have been moderated by electrification.

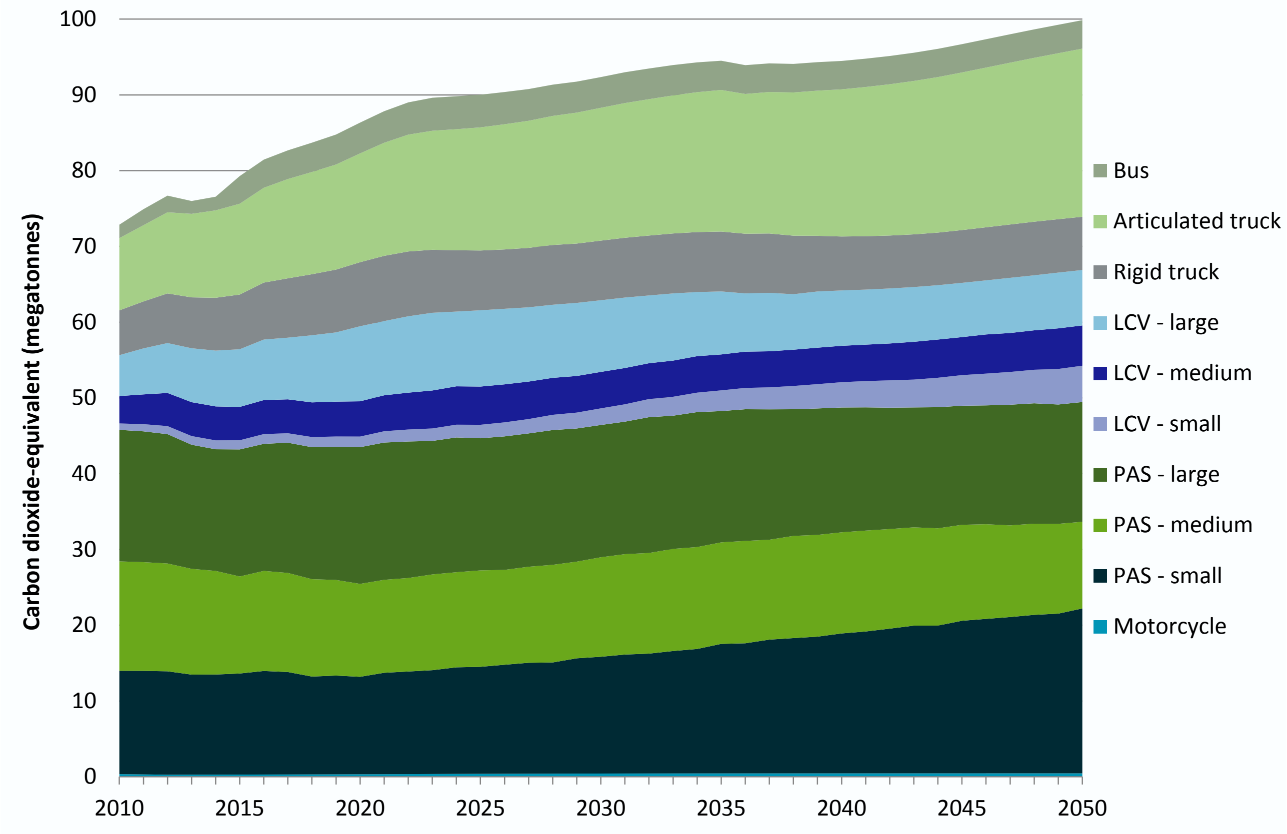

Figure 3-6: Road transport greenhouse gas emissions by mode under the *Baseline* scenario

Non-road transport emissions simply follow proportionally to non-road fuel consumption, with the exception of aviation due to a small amount of biofuels.

Projected total transport sector greenhouse gas emissions are shown in Figure 3-7. It shows that the overall trend is increasing from 90.7 $MtCO_2e$ in 2014, to 103.3 $MtCO_2e$ in 2020, 113.1 $MtCO_2e$ in 2030 and 126.5 $MtCO_2e$ in 2050.

Compared to the September 2014 report this projection is higher. The three main reasons for a higher projection of transport emissions are:

- 5.5 per cent growth in demand in response to a 30 per cent reduction in retail fuel prices
- Reduced fuel efficiency owing to reduced underlying internal combustion engine efficiency, lower adoption of diesel and lower adoption of electric drivetrains
- Reduced uptake of lower emission intensive fuels such as biofuels, electricity and natural gas due to lower conventional fuel prices.

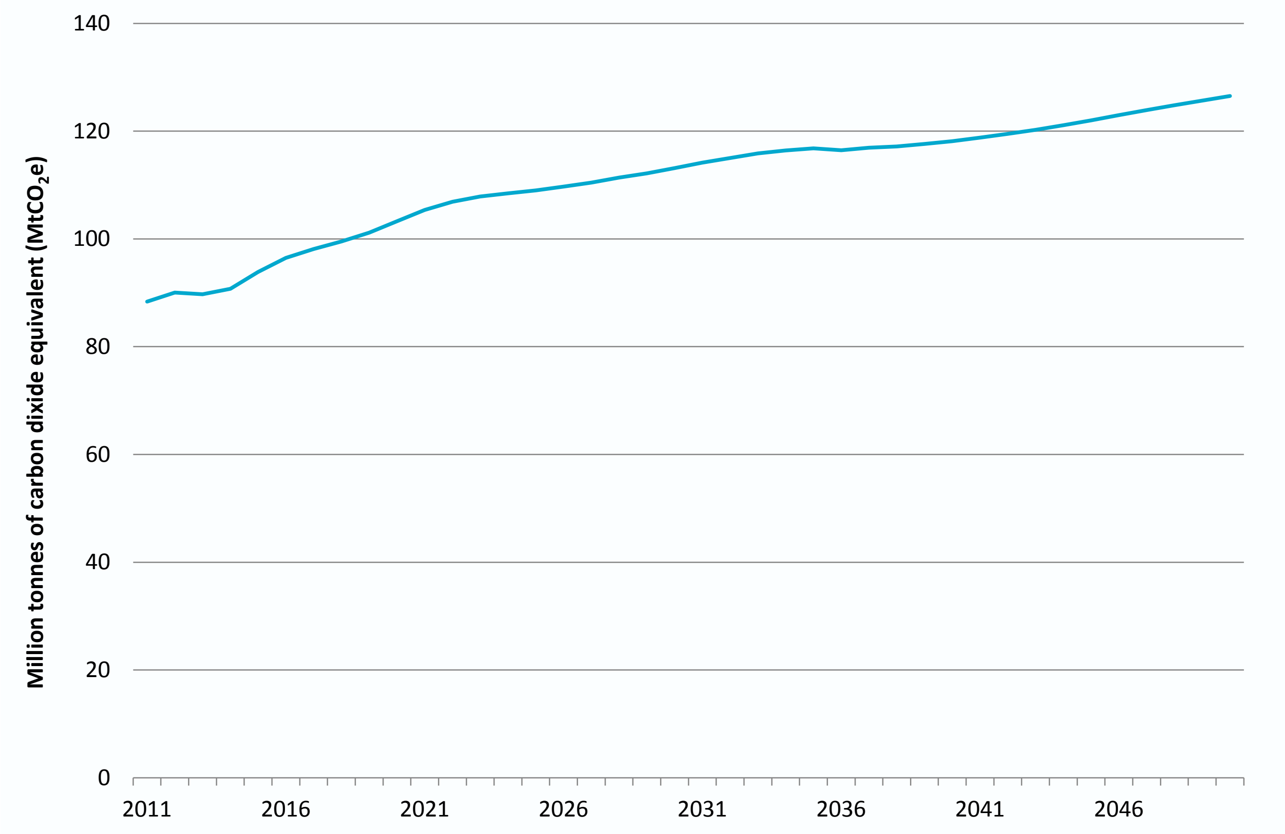

Figure 3-7: Transport sector greenhouse gas emissions under the *Baseline* scenario

4 Sensitivity scenario results

The sensitivity scenarios explore how a change in a specific driver affects the projected greenhouse gas emissions and other modelling results relative to the *Baseline* scenario. Five sensitivity scenarios are explored.

4.1 Mandatory emission standards for new light vehicles (*Emission standards*) scenario

The *Emission standards* scenario assumes that mandatory CO_2 emissions standards apply across all new light vehicles (passenger and light commercial vehicles) from 2018. This standard requires that the average emissions intensity of new light vehicles sold in Australia must reach a target of 105g/km in 2025 (consistent with the US target in 2025) and 75g/km from 2035 onwards (which is broadly consistent with the EU 2025 target). These targets are implemented in a linear manner over time so that from 2018 to 2030 the target incrementally tightens according to the slope between each two points 2018-2025 and 2025-2030.

Under this scenario we allow demand to respond to price. The impact of this assumed demand responsiveness is that total road vehicle kilometres travelled is around 4 per cent lower by 2050. The reduction in travel reflects the increased purchase costs of non-conventional vehicles that are not completely offset by reduced fuel and operating costs.

4.1.1 TRANSPORT FUEL MIX

Figure 4-1 shows the projected level of light duty road transport consumption by fuel for the *Emission standards* scenario. From 2018, fuel consumption flattens and then falls rapidly compared to the *Baseline* scenario. The reduction is achieved through a combination of internal combustion engine fuel efficiency improvements, and vehicle electrification (hybrids, electric and plug-in hybrid electric vehicles). Electricity displaces many times its own energy content of liquid fuels since the electric drive train uses less energy per kilometre - noting that (primary) energy used to generate the electricity is excluded from the accounting.

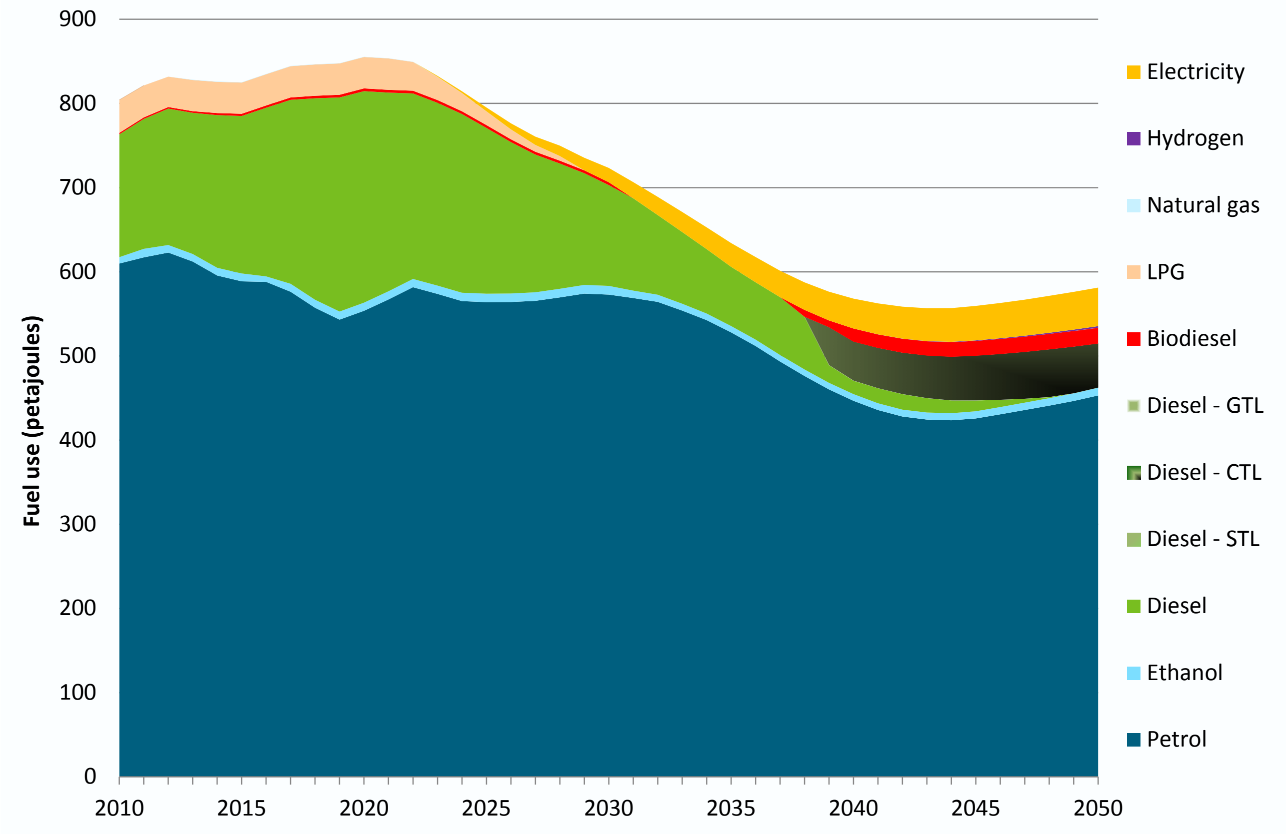

Figure 4-1: Projected light duty road transport fuel consumption by fuel under the *Emission standards* scenario

The rapid electrification of the road transport fleet in response to the emission standards policy is shown in Figure 4-2. Fuel cell vehicles, being assumed higher cost, are not taken up until the 2040s but their contribution grows from this point. Of course, alternative cost assumptions could see this occur sooner.

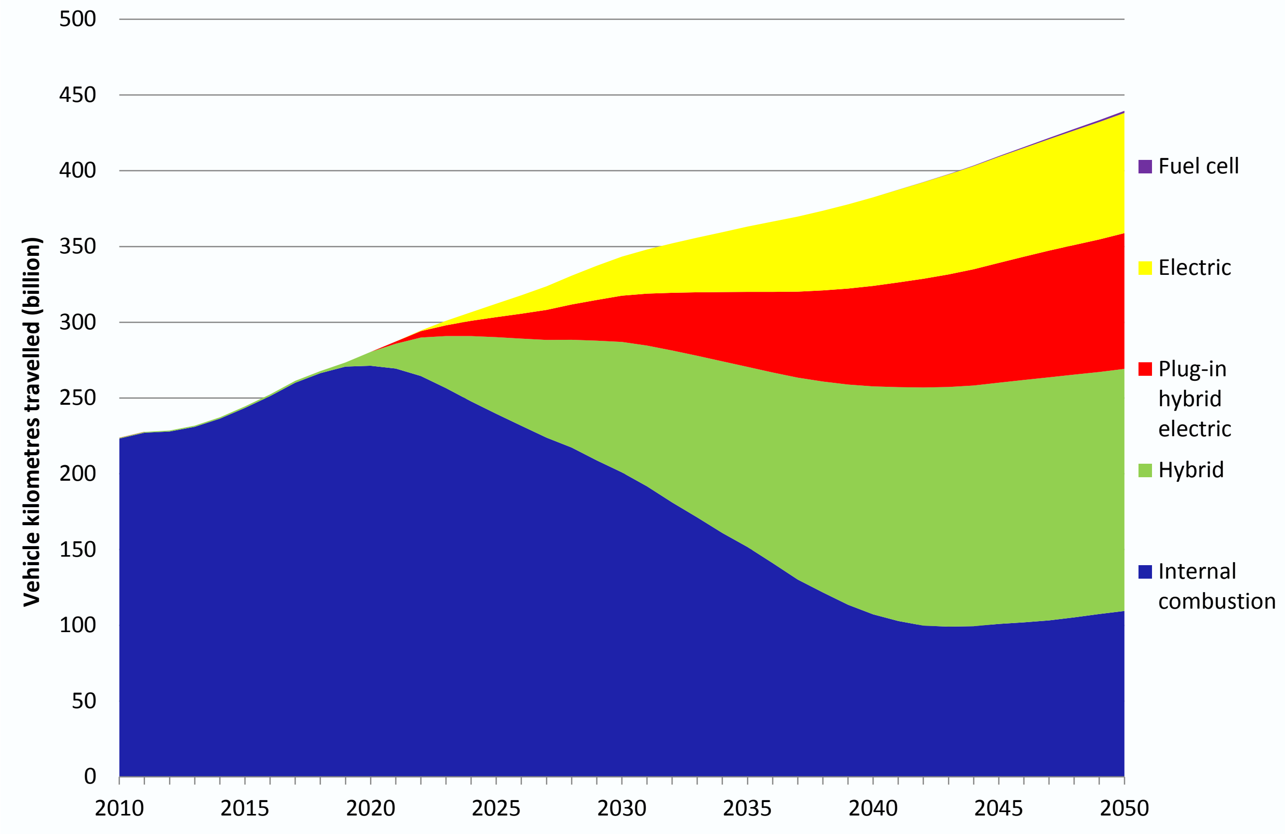

Figure 4-2: Engine type in road kilometres travelled, *Emission standards* scenario

As the emission standards are targeted at only light duty vehicles the impacts on the heavy duty sector and non-road sectors are very slight and therefore not discussed.

4.1.2 GREENHOUSE GAS EMISSION PROJECTIONS

In Figure 4-3, we show the emission profile for the light duty road sector emissions and compare them to the *Baseline* scenario. The light duty road sector modal emission profile closely follows the fuel consumption profile noting that there are near-zero emissions associated with biofuels and electricity.

Under the *Baseline* scenario, light duty road sector emissions were projected to increase by 10 $MtCO_2e$, from 56 $MtCO_2e$ in 2014 to 66 $MtCO_2e$ in 2050. Under the *Emission standards* scenario, emissions fall by 22 $MtCO_2e$ or at an average rate of 1.3 per cent per annum to reach 34 $MtCO_2e$ in 2050. Emissions in fact reach 33 $MtCO_2e$ earlier, at 2044, after which there is some slight backtracking to 34 $MtCO_2e$ because emission standards are not tightening any further from 2035 (although the fleet average still improves sometime after that due to retirement and replacement) and kilometres travelled are still rising.

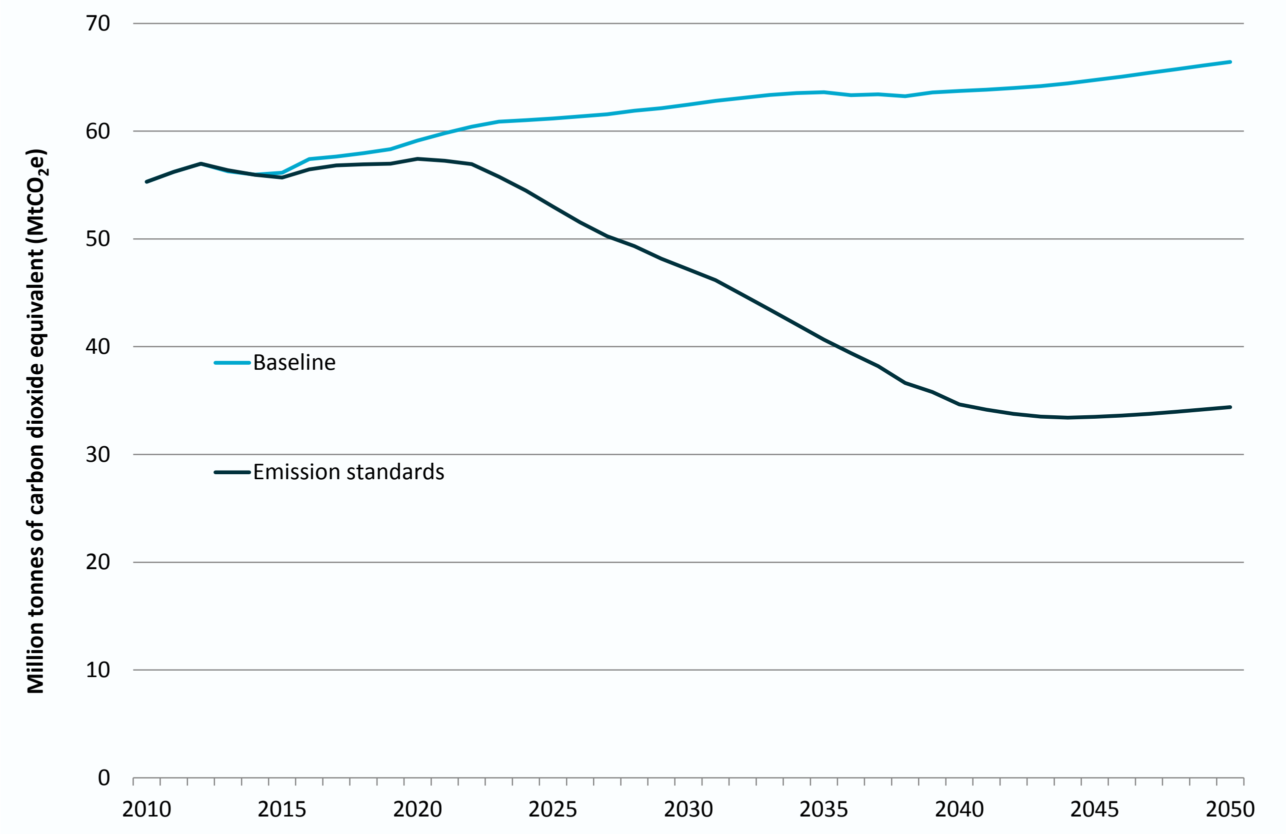

Figure 4-3: Light duty road transport sector greenhouse gas emissions under the *Baseline* and *Emission standards* scenarios (excluding motorcycles)

After adding in heavy duty road and non-road sector in Figure 4-4, the difference between the *Baseline* and *Emission standards* is not as great given there are minimal spill over impacts from the light duty vehicle standards into other transport sectors.

Overall transport sector emissions initially increase, from 90.4 MtCO$_2$e in 2014, to 101.4 MtCO$_2$e in 2020, but then decrease as the standards are implemented, to 97.5 MtCO$_2$e in 2030 and 94.3 MtCO$_2$e in 2050. This represents an average annual rate of increase of 0.1 per cent over the projection period.

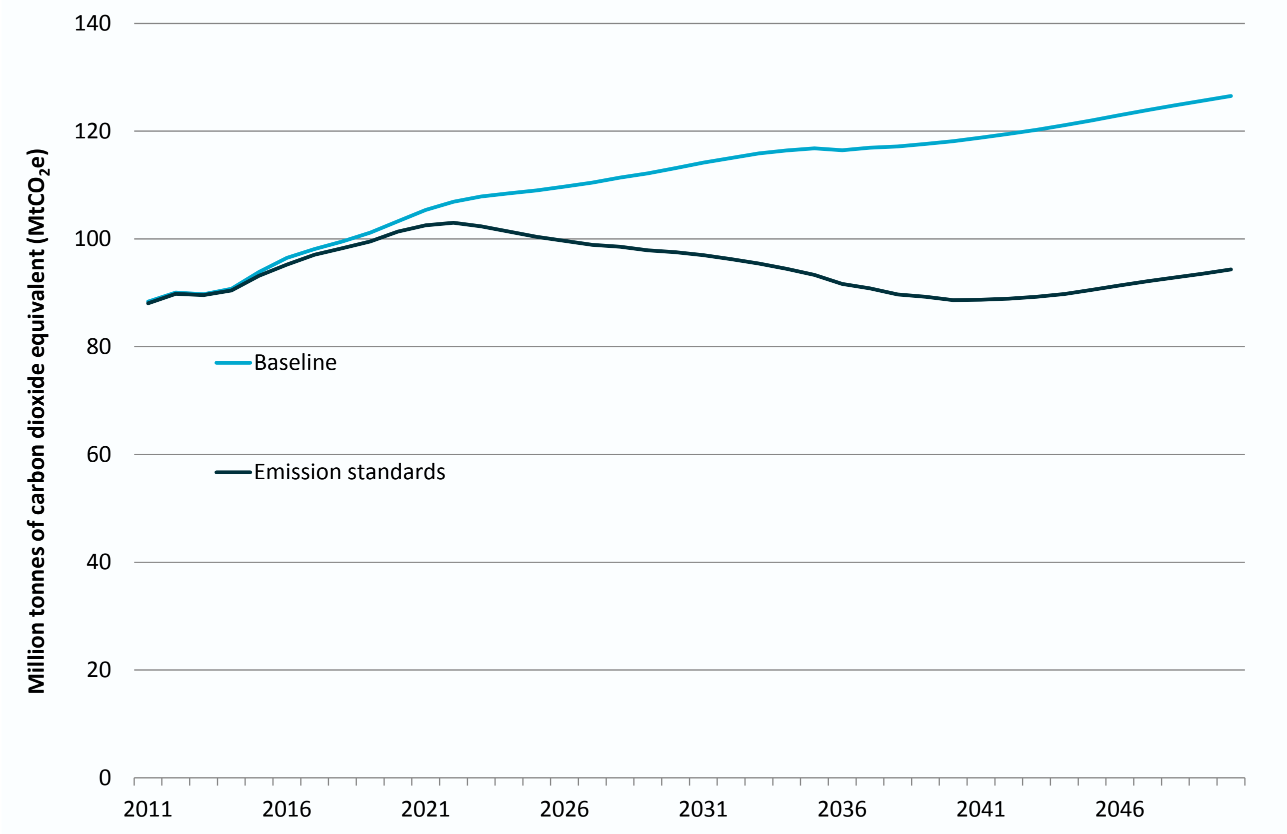

Figure 4-4: Transport sector greenhouse gas emissions under the *Baseline* and *Emission standards* scenarios

4.2 High oil price scenario

This scenario examines the impact of high oil prices. Under the *Baseline* scenario, oil prices are $97/bbl in 2020, $100/bbl in 2030, and $108/bbl in 2050. Under the *High oil price* scenario, oil prices are $140/bbl in 2020, $132/bbl in 2030 and $115/bbl in 2050 (in 2013/14 Australian dollar terms).

The impact of the own-price demand responsiveness to the higher oil prices in the *High oil price* scenario is that light duty road vehicle kilometres travelled are around 1-3 per cent lower than in the *Baseline* scenario, and are particularly low in the 2020s. However, by 2050 the difference in demand is negligible as the two oil price paths converge.

4.2.1 TRANSPORT FUEL MIX

The combined light and heavy duty road transport fuel consumption is shown in Figure 4-5. Overall, fuel consumption is around 45 petajoules (PJ) lower than the *Baseline* scenario, reflecting the modest impact of higher prices on demand and the increased use of higher efficiency electric drive trains and diesel (up to the early 2020s).

Besides expanding the use of more fuel efficient vehicles, higher oil prices encourage investors to develop alternative fuel supply chains sooner. The stronger development of biofuel and coal-derived synthetic diesel fuel supply chains has meant that some conventional diesel is displaced, beginning from the 2030s, and there is greater use of ethanol blended into petrol as E10 in the late 2030s.

Overall, the difference between the *High oil price* scenario and the *Baseline* scenario is modest reflecting that by 2050 the oil price paths converge to a similar level. However, the stronger difference in oil prices in the 2020s and 2030s allows faster and slightly higher levels of adoption of some alternative fuels – particularly electricity, biofuels and coal-derived synthetic fuels.

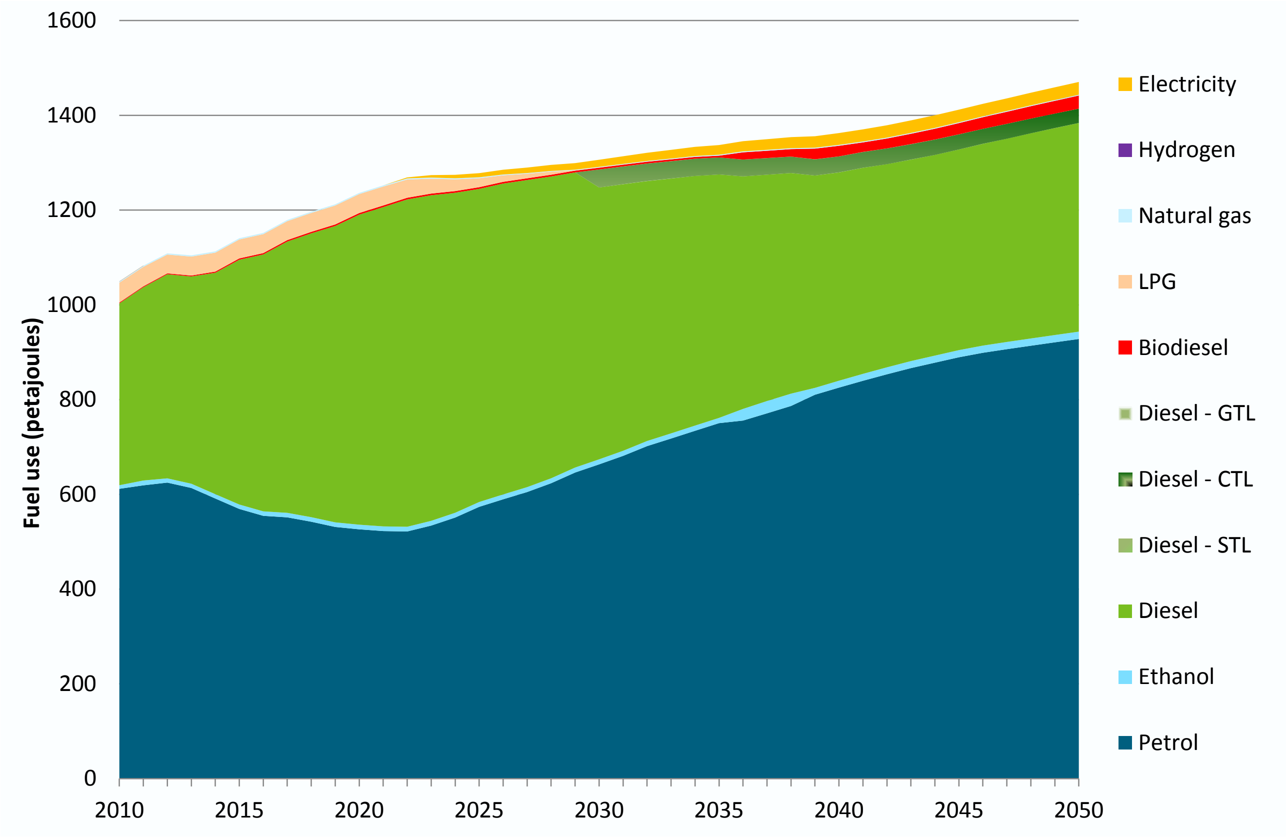

Figure 4-5: Projected road transport fuel consumption under the *High oil price* scenario

In the non-road sector, reflecting the increased availability of biofuel, there is increased uptake relative to the *Baseline* scenario. By 2050, biofuel supplies around 4 PJ of non-road fuel consumption, mainly in aviation, compared with 1.5 PJ in the *Baseline* scenario.

4.2.2 GREENHOUSE GAS EMISSIONS

Total transport sector greenhouse gas emissions are shown in Figure 4-6 and compared to the *Baseline* scenario. Under the *High oil price* scenario, total transport sector emissions track the *Baseline* scenario emissions trend fairly closely throughout but with a widening gap, increasing from 90.1 MtCO$_2$e in 2014 to 108.5 MtCO$_2$e in 2030 and to 120.1 MtCO$_2$e in 2050. While higher oil prices lead to reduced demand growth, improved fuel efficiency and adoption of some lower emission intensive fuels, this has only slowed growth in emissions relative to the *Baseline* scenario rather than supporting a declining trend. Nevertheless, this scenario does represent a 4 per cent or 5.7 MtCO$_2$e reduction in greenhouse gas emissions relative to the *Baseline* scenario by 2050.

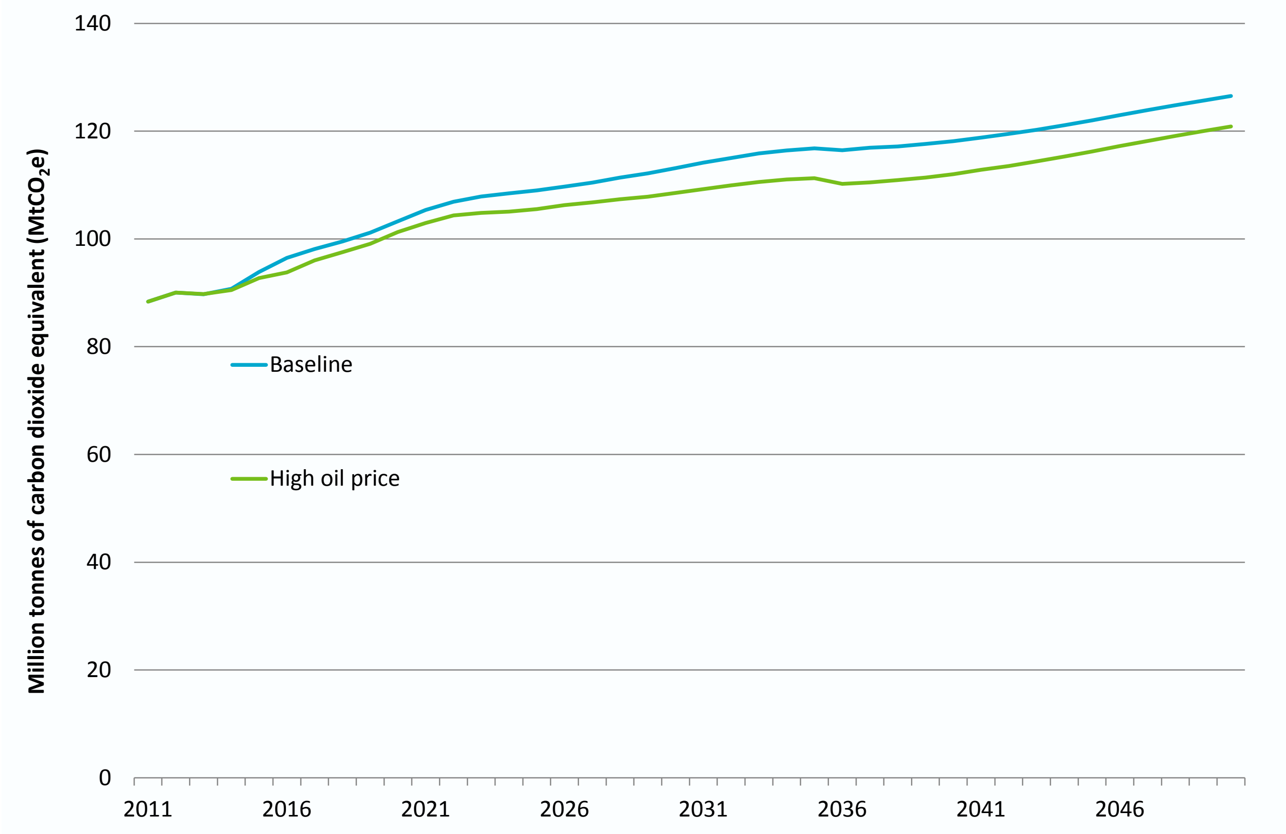

Figure 4-6: Transport sector greenhouse gas emissions under the *High oil price* and *Baseline* scenarios

4.3 Low oil price scenario

The *Low oil price* scenario examines the impact of low oil prices on the *Baseline* scenario. Under the *Baseline* scenario, oil prices are $97/bbl in 2020, $100/bbl in 2030, and $108/bbl in 2050. Under the *Low oil price* scenario, oil prices are $82/bbl in 2020, $85/bbl in 2030 and $92/bbl in 2050. All prices are in 2013/14 Australian dollar terms.

As a result of the assumption of price responsive demand, road transport sector demand under the *Low oil price* scenario is up to 1 per cent higher in some road vehicle classes in the 2020s compared with the *Baseline* scenario, but the differences become negligible as the fuel prices converge towards 2050.

4.3.1 TRANSPORT FUEL MIX

Figure 4-7 shows total fuel consumption for the road transport sector. Although in the short term fuel consumption declines, owing to improvements in new light duty vehicle fuel consumption, the trend in fuel consumption thereafter is of steady uninterrupted growth. Compared to the *Baseline* scenario, the major features of the fuel mix are significant delay in the expansion of second generation biofuels, no fossil synthetic fuels, reduced adoption of electricity, and extended duration for LPG consumption.

Delays or reduced adoption of alternative fuels is to be expected in the *Low oil price* scenario. As coal-derived synthetic fuel refining infrastructure would be very large and capital intensive, investment does not proceed under the *Low oil price* scenario due to increased risk, even though the oil price remains above the theoretical cost of production. Biofuels are similarly impacted but, as some biofuel refining can be carried out at smaller scales, a modest amount of production proceeds after considerable delay.

Low oil prices increase the payback period for the higher upfront cost of vehicles using different types of electric drive trains and so this reduces the number of consumers willing to take up that vehicle type.

The longer phasing out period of LPG relative to the *Baseline* scenario is due to the way in which LPG is taxed. Its lower tax rate per unit of energy means that the underlying oil price is a greater proportion of its retail price. Thus, as the oil price drops, the percentage reduction in the price of LPG is greater than that of other higher taxed fuels such as petrol and diesel. Nevertheless, LPG is eventually phased out, mainly due to competition with petrol hybrid electric vehicles.

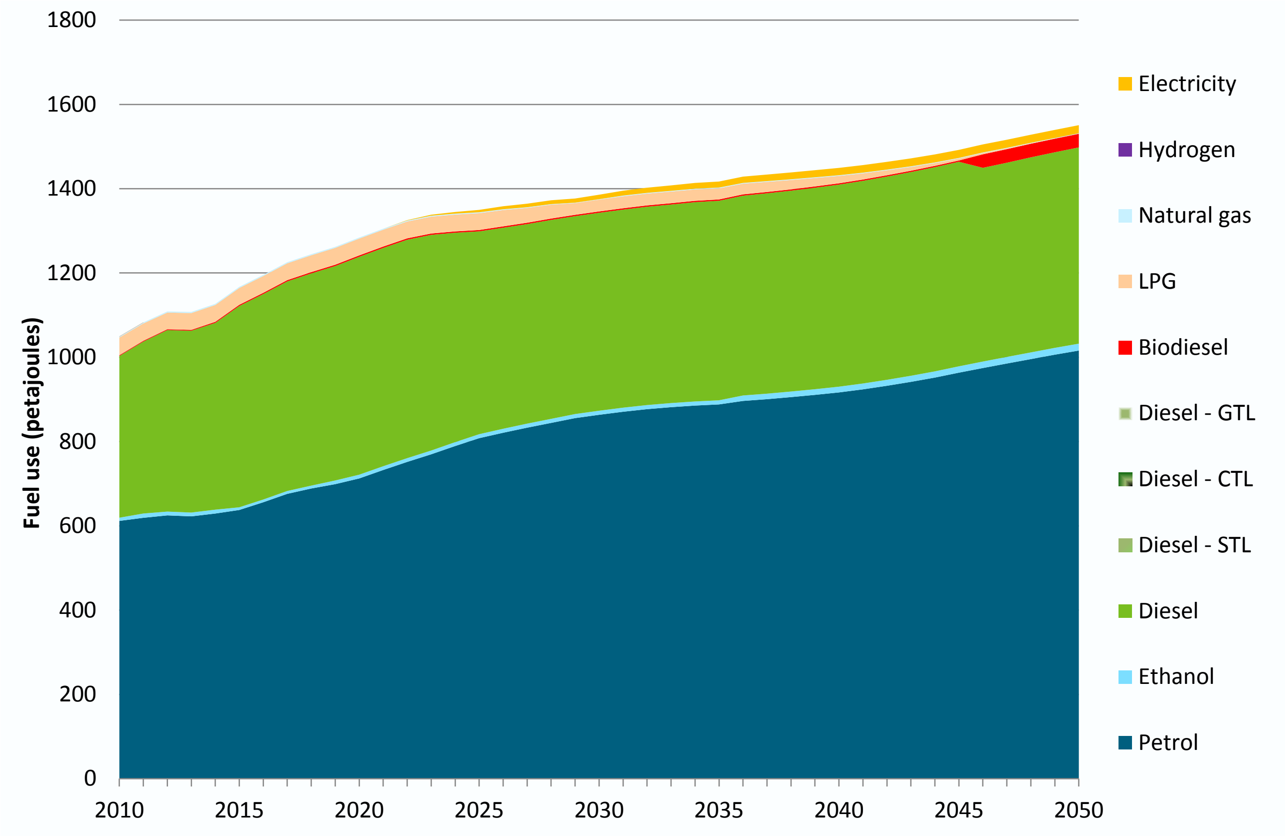

Figure 4-7: Projected road transport fuel consumption by fuel under the *Low oil price* scenario

In regard to non-road fuel consumption, compared to the *Baseline* scenario the main difference is that under the *Low oil price* scenario there is no adoption of biofuels since they prove too costly relative to the reduced cost of oil-derived fuels (whereas the road sector has access to some excise incentives and the NSW biofuel mandate which make biofuel uptake economically viable in that sector).

4.3.2 GREENHOUSE GAS EMISSIONS

Total transport sector greenhouse gas emissions are shown in Figure 4-8 and compared to the *Baseline* scenario. Under the *Low oil price* scenario total transport sector emissions increase from 90.1 $MtCO_2e$ in 2014 to 104.4 $MtCO_2e$ in 2020, 114.4 $MtCO_2e$ in 2030, and 128.9.5 $MtCO_2e$ in 2050. This represents an average annual rate of growth of 1 per cent over the projection period, only slightly higher than in the *Baseline* scenario. The declining oil prices (from 2015) mean slightly higher transport demand, slightly lower adoption of fuel efficient hybrid electric drive trains in the road sector and a delayed adoption of second generation biofuels by around 10 years to late 2040s. This scenario results in a 2 per cent or 2.4$MtCO_2e$ per annum increase in greenhouse gas emissions relative to the *Baseline* scenario.

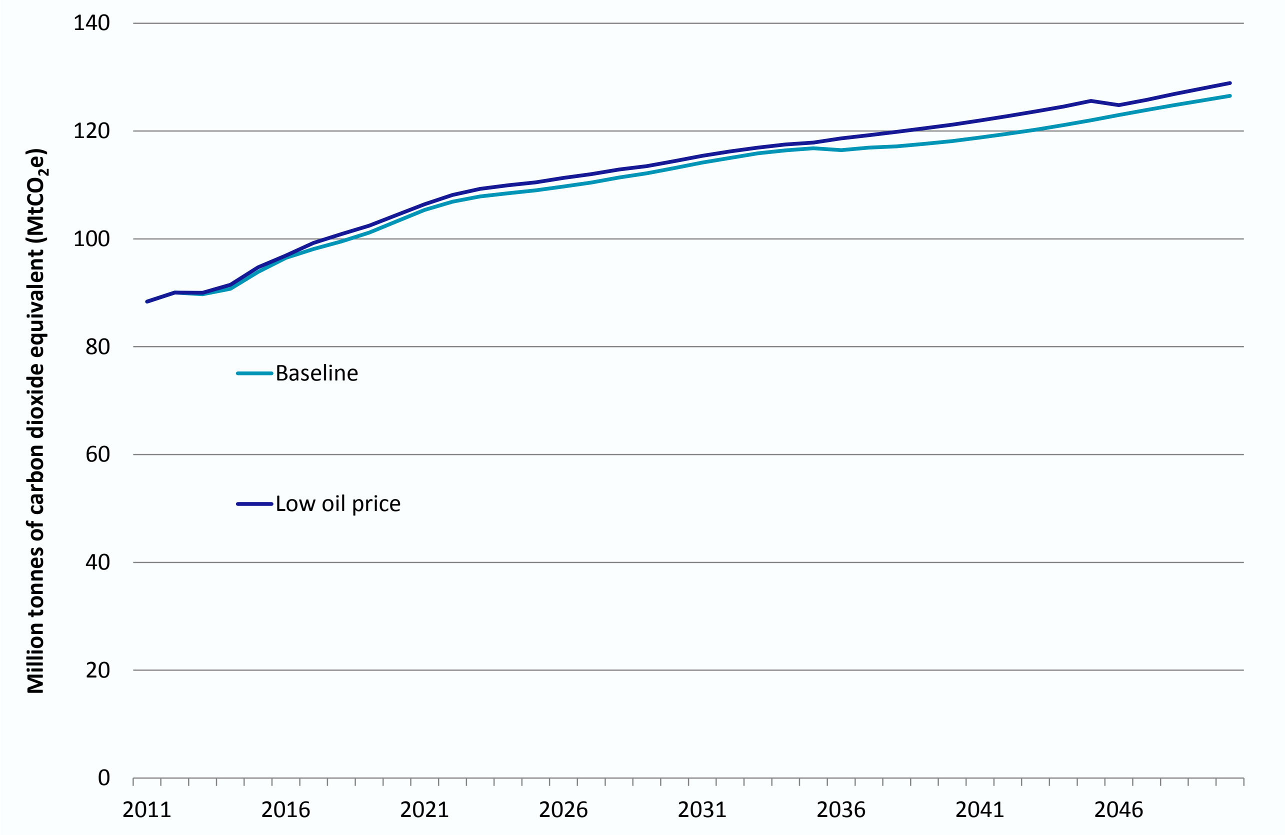

Figure 4-8: Transport sector greenhouse gas emissions under the *Low oil price* and *Baseline* scenarios

4.4 Increased supply of second generation biofuels (*High biofuels*) scenario

The *High biofuels* scenario examines the impact of a fourfold potential increase in the rate of expansion of second generation biofuels supply. In the *Baseline* scenario, biofuels derived from lignocelluloses commence in 2036 at 1100 megalitres (ML) increasing by 10 ML per annum, and biofuels derived from biologically derived oils commence at 400 ML in 2036 increasing by 10 ML per annum. In this scenario, the supply of sources of biofuels commences in 2030 and can expand each year at 40 ML per annum.

As there are no major implications for the cost of fuels, since biofuels are sold near to the prevailing conventional fuel price (in energy equivalent terms), we have not considered any particular demand responsiveness. As such, transport demand in all modes is the same in the *Baseline* scenario assumptions.

4.4.1 TRANSPORT FUEL MIX

Figure 4-9 shows total fuel consumption for the road transport sector. It indicates that increased second generation biofuels consumption commences from 2030 (as designed) with all available additional supply taken up since, by assumption, it is all cost competitive with conventional fuels. Whilst both ethanol and biodiesel consumption expand, biodiesel expansion is greater given its relatively lower excise rate on an energy content basis. The increased availability of biodiesel is initially spread across the road sector but in the long run mainly goes to heavy duty road users since the light duty market increasingly adopts petrol over time.

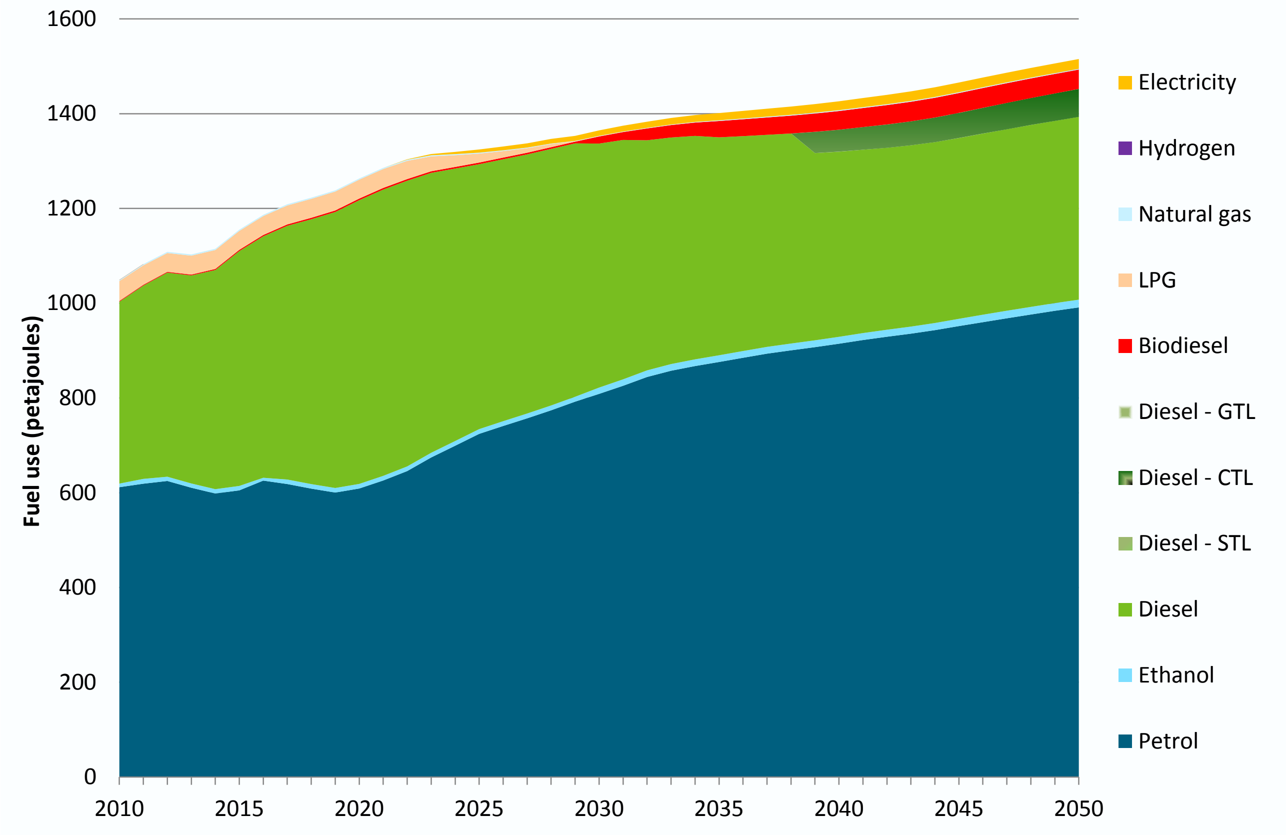

Figure 4-9: Projected road transport fuel consumption by fuel under the *High biofuel* scenario

Non-road

Figure 4-10 shows the projected level of non-road transport consumption, by fuel and mode (domestic navigation, rail and domestic aviation) for the *High biofuel* scenario. Compared to the *Baseline* scenario, the use of biofuel has increased due to the increased availability of second generation biofuel supplies. Bio-derived jet fuel adoption is much higher in the *High biofuel* scenario at 5.9 per cent of aviation fuel consumption by 2050, compared to 0.6 per cent in the *Baseline* scenario. The rail and navigation sectors follow suit and adopt a modest share of biodiesel.

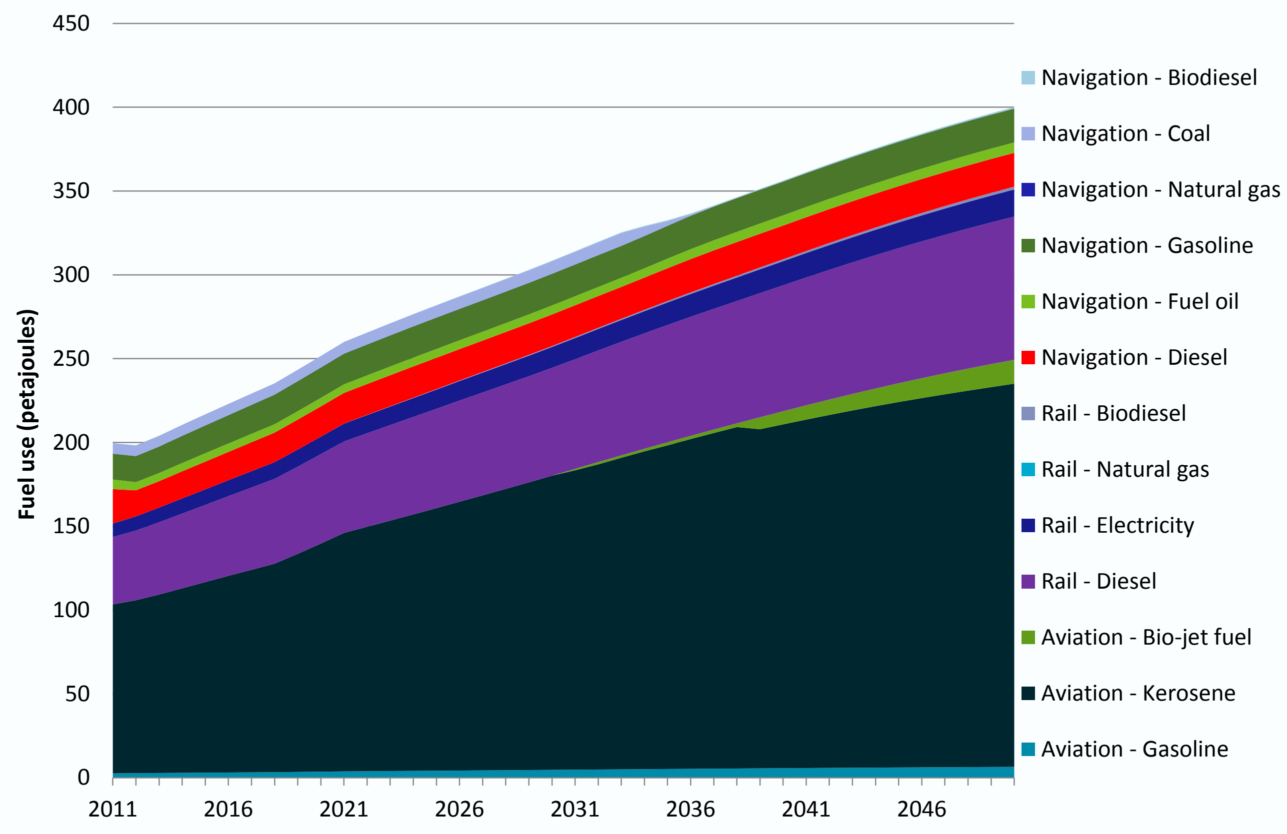

Figure 4-10: Non-road transport fuel consumption by fuel and mode under the *High biofuel* scenario

4.4.2 GREENHOUSE GAS EMISSIONS

Total transport sector greenhouse gas emissions are shown in Figure 4-11 and compared to the *Baseline* scenario. Under the *High biofuel* scenario total transport sector emissions increase from 90.1 $MtCO_2e$ in 2014 to 103.2 $MtCO_2e$ in 2020, 112.2 $MtCO_2e$ in 2030, and to 124.6 $MtCO_2e$ in 2050. This is an average annual growth rate of 0.9 per cent over the projection period. The earlier availability, and modest increase, in supply of low emission second generation biofuels from 2030 lowers the emission intensity of transport sector fuel consumption. This scenario results in a 1.5 per cent or 1.9 $MtCO_2e$ decrease in greenhouse gas emissions, relative to the *Baseline* scenario.

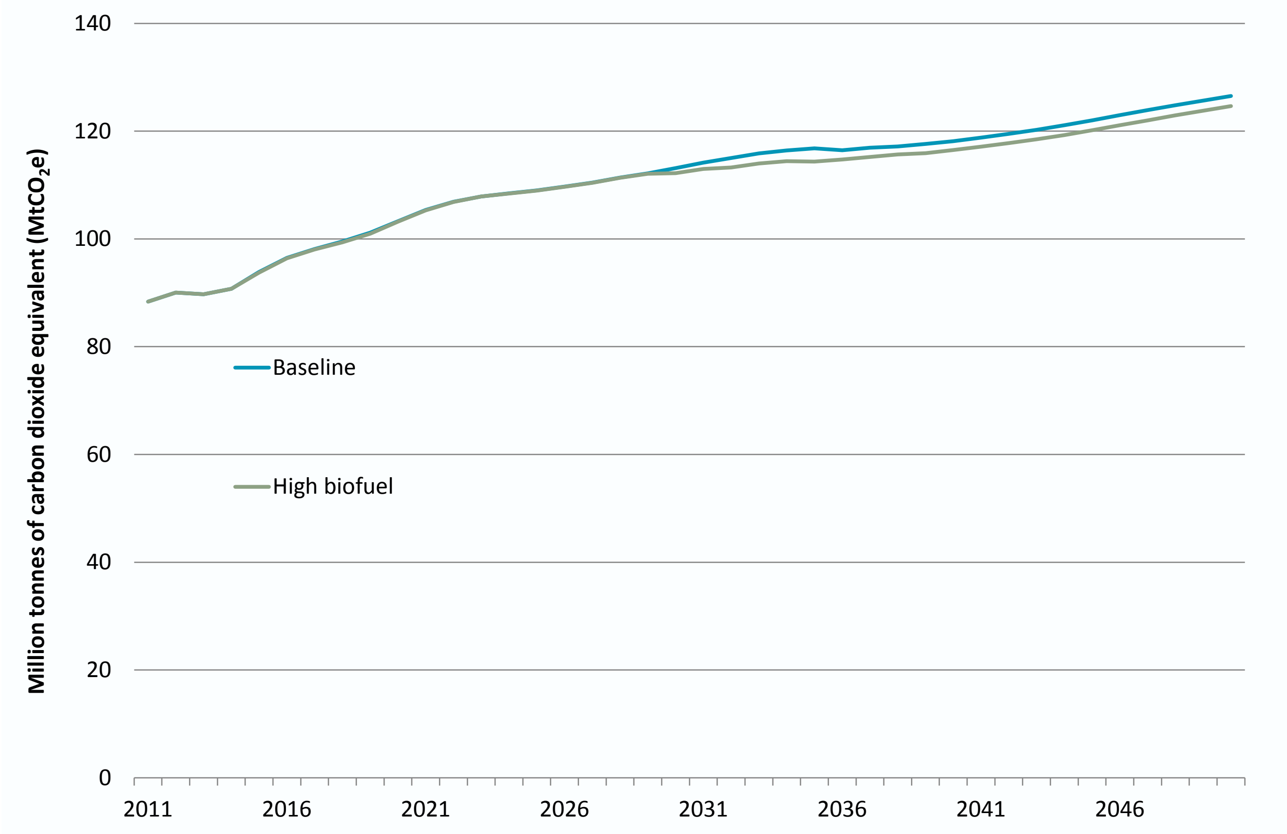

Figure 4-11: Transport sector greenhouse gas emissions under the *High biofuel* and *Baseline* scenarios

4.5 Delayed supply of second generation biofuels (*Delayed biofuel*) scenario

The *Delayed biofuel* scenario examines the impact of a 15 year delay in the availability of second generation biofuels supply relative to the *Baseline* scenario. This puts second generation biofuel production beyond the period to 2050 so that it does not significantly expand at all during the projection period.

Transport demand in all modes is the same as in the *Baseline* scenario assumptions.

4.5.1 TRANSPORT FUEL MIX

Figure 4-12 shows total fuel consumption for the road transport sector in the *Delayed biofuel* scenario. The outcome of this sensitivity scenario is straight forward in that where there was formerly an expanded second generation biofuel supply, that gap is completely filled by conventional diesel. However, current generation biofuel supply, driven by the NSW biofuel mandate, remains a feature throughout the projection period.

Biofuels are not taken up in the non-road sector at all, given that there is no existing supply to that sector and expanded volumes, via second generation supply, are not available at any time in the projection period.

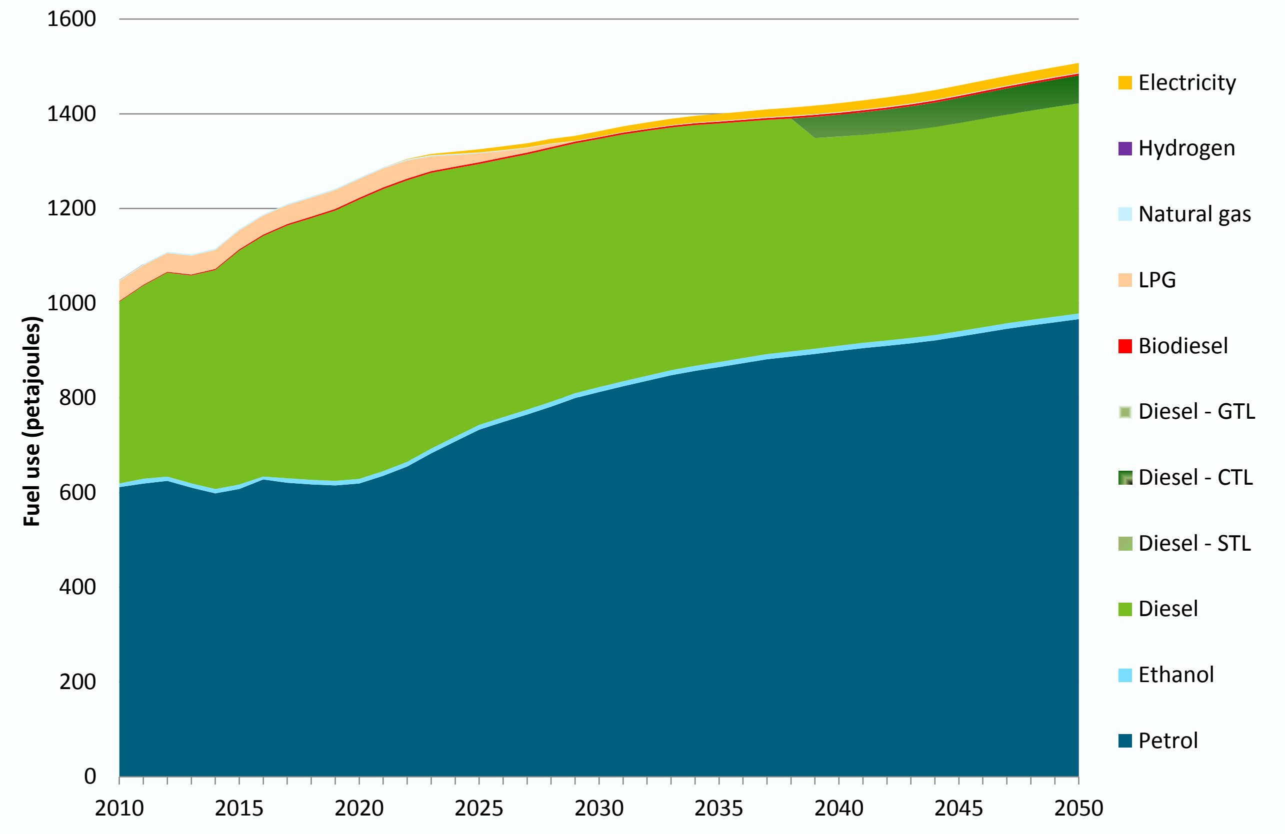

Figure 4-12: Projected road transport fuel consumption by fuel under the *Delayed biofuel* scenario

4.5.2 GREENHOUSE GAS EMISSIONS

Total transport sector greenhouse gas emissions are shown in Figure 4-11 and compared to the *Baseline* scenario. This scenario provides good insight into the contribution of second generation biofuel supply to reducing emissions in the *Baseline* scenario since its absence is the main feature of contrast.

Up to 2036 there is no difference in emissions. By 2050, annual emissions are only slightly higher than in the *Baseline* scenario. Under the *Delayed biofuel* scenario, total transport sector emissions increase from 90.1 $MtCO_2e$ in 2014 to 103.3 $MtCO_2e$ in 2020, 113.1 $MtCO_2e$ in 2030, and to 128.1 $MtCO_2e$ in 2050. This reflects an average annual growth rate of 0.6 per cent over the projection period. This is a 1.2 per cent, or 1.5 $MtCO_2e$, increase in greenhouse gas emissions relative to the *Baseline* scenario by 2050.

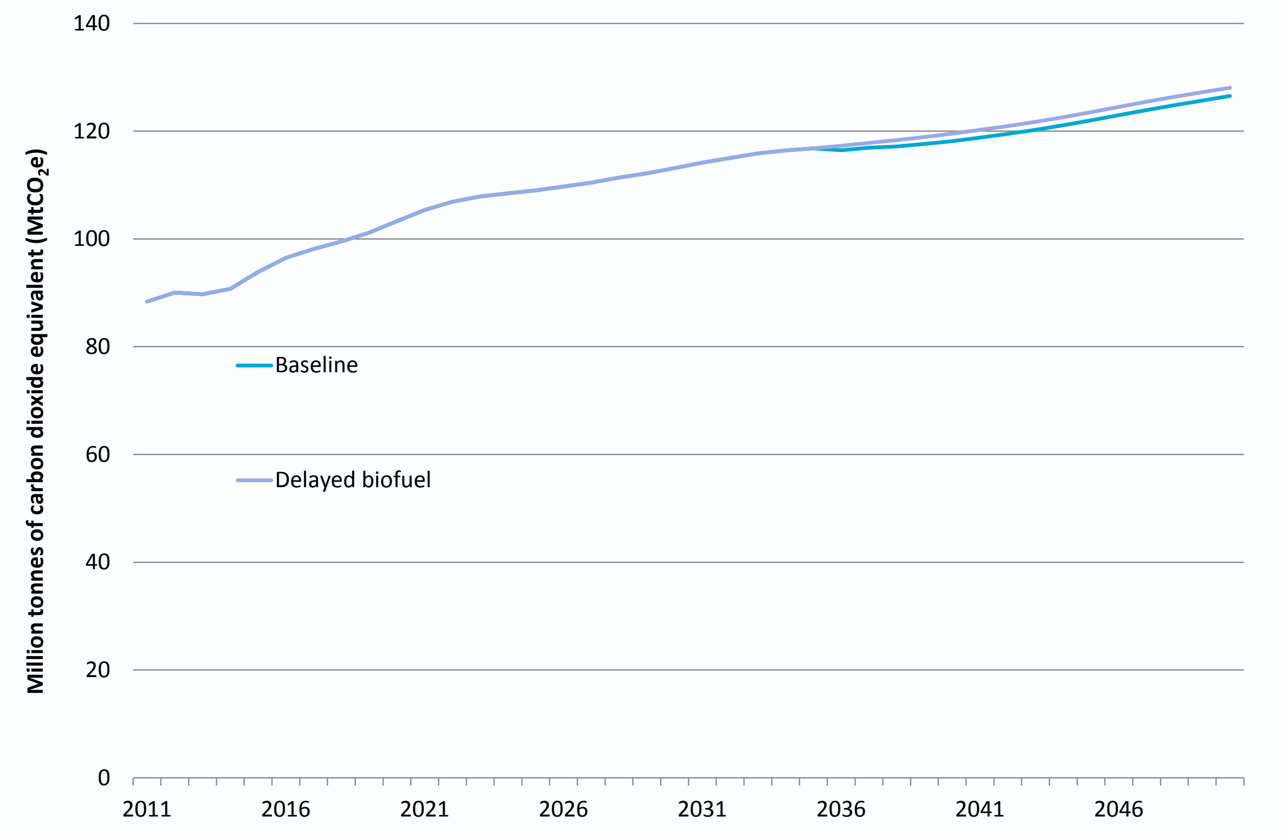

Figure 4-13: Transport sector greenhouse gas emissions under the *Delayed biofuel* and *Baseline* scenarios

5 Measure estimate scenario results

The *Baseline* scenario includes two key policy measures that have an impact on greenhouse gas emissions outcomes in the transport sector projections: the NSW biofuels mandate, and the 2014 Commonwealth Budget changes to fuel excise. The purpose of the following two scenarios is to quantify the impact of these measures on greenhouse gas emission projections.

5.1 Estimating the emission impact of the NSW biofuels mandate (*No NSW biofuels target* scenario)

The *No NSW biofuels target* scenario examines the impact on the *Baseline* scenario of including the NSW biofuels mandate as an existing policy measure, by removing this measure beginning from the year 2015. This is because the purpose here is to examine not the emission reduction benefits of the biofuels mandate from the beginning of its operation, but rather its future impact on the greenhouse gas emissions trajectory.

Given this focus, it is accepted that significant ethanol and biodiesel refining capacity already exists and the capital cost of these plants is sunk. Therefore, we do not assume that all production ceases in the absence of the policy from 2015. Where ethanol is a co-product of other agricultural value adding processes, it would be difficult to determine the marginal cost of production independently from cost-benefit analysis of other integrated processing plant products. Instead, for simplicity, we assume that if the policy were removed, NSW ethanol and biodiesel production contract only marginally. Meeting the (now removed) target does not encourage production growth, which is delayed until there are other market developments to support it. Specifically, once oil prices are high enough, and/or costs of production fall, the market reaches a point where it is financially viable to expand biofuel production without a mandate.

Transport demand in all modes is the same as the *Baseline* scenario assumptions.

5.1.1 TRANSPORT FUEL MIX

Figure 5-1 shows total transport fuel consumption for the road sector in the *No NSW biofuel target* scenario. However, at this scale of resolution it is difficult to observe any major impact.

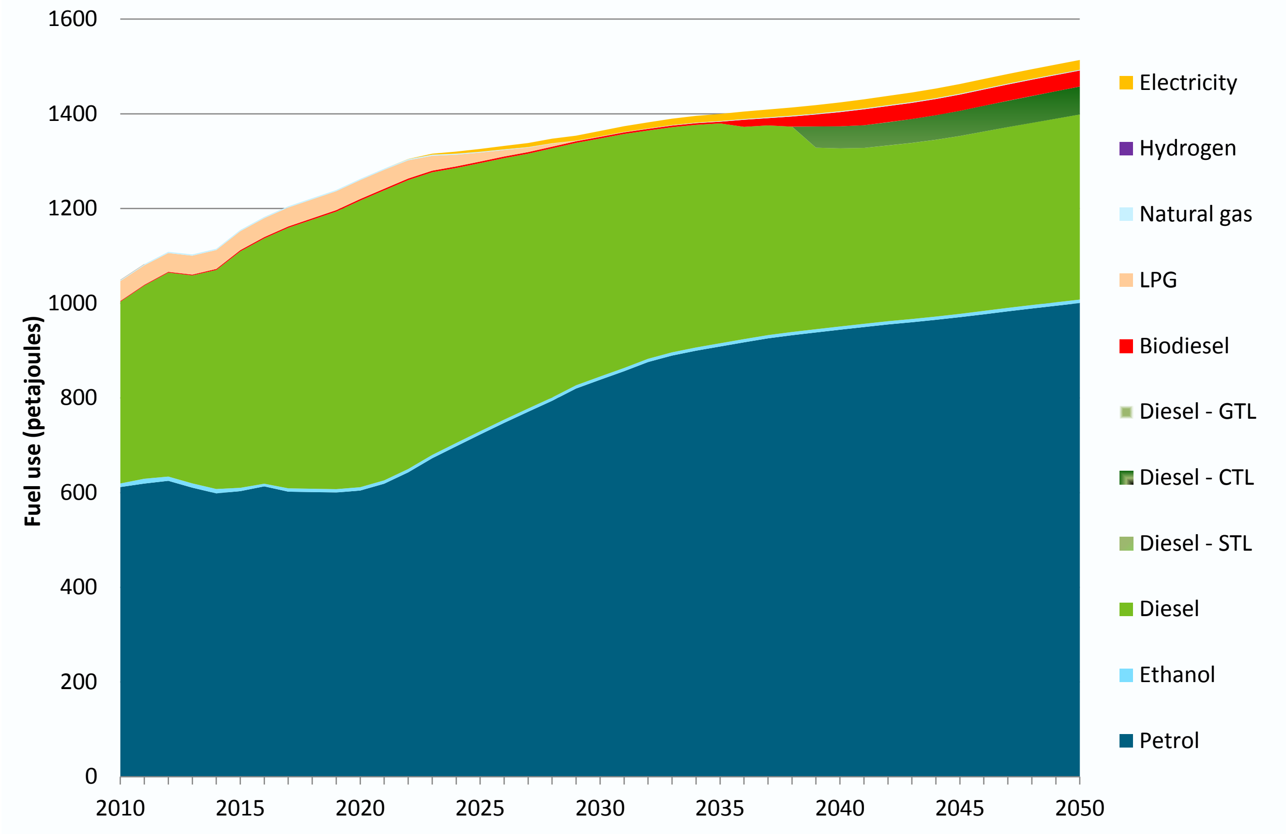

Figure 5-1: Projected road transport fuel consumption by fuel under the *No NSW biofuels target* scenario

Figure 5-2 provides greater detail, showing how biofuel consumption is impacted with and without the NSW biofuel target from 2015, comparing projections from the *Baseline* and the *No NSW biofuel target* scenarios. The impact of the removal of the policy in 2015 is somewhat interrupted by the sudden fall in oil prices in 2015 and 2016 so that initially biofuel consumption decreases in both the *Baseline* and *No NSW biofuels target* scenario. However, from 2017 the differences in the scenarios are less impacted by these price decreases.

Under the *Baseline* scenario, with a NSW biofuel target in place, ethanol sales and consumption slowly expand from 2017 to meet the target in an uninterrupted rising trend until 2036. At 2036, both ethanol and biodiesel expand given the increased supply of second generation biofuels and the dominance of petrol and diesel in the light duty and heavy duty road sectors respectively. Biodiesel expands by a greater amount reflecting the lower excise on that fuel on an energy content basis.

Under the *No NSW biofuel target* scenario, with the NSW biofuel target removed from 2015, ethanol production immediately falls back due to our assumption that most, but not all, of existing production capacity would continue to be sold because capital costs for the refining capacity are sunk. Ethanol production remains at this level, more or less.

From 2038, the loss of ethanol production is compensated for by an increase in biodiesel production relative to the *Baseline* scenario. That is, the biomass that would have been used to produce ethanol is diverted to biodiesel production, raising it above the level of biodiesel production in the *Baseline* scenario.

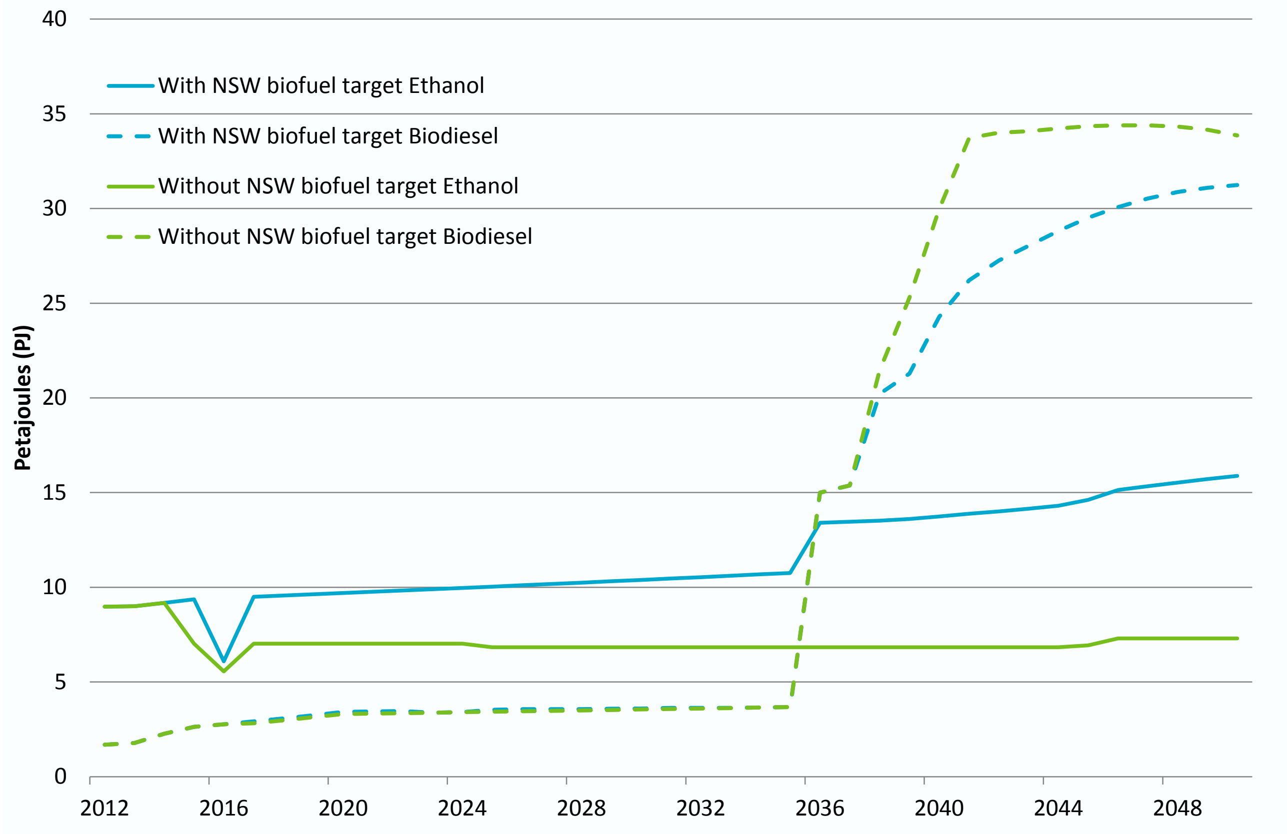

Figure 5-2: Comparison of total road transport ethanol and biodiesel consumption with and without the NSW biofuel target

These changes in the shares of ethanol and biodiesel in road transport did not impact upon the amount of biofuels taken up in the non-road sector.

5.1.2 GREENHOUSE GAS EMISSIONS

Total transport sector greenhouse gas emissions are shown in Figure 5-3 and compared to the *Baseline* scenario. The vertical axis scale is magnified to show the impact of *the No NSW biofuel target* scenario more clearly. It shows that greenhouse gas emissions are marginally higher in the *No NSW biofuel target* scenario mostly during the period 2017 to 2038. However, emissions are very similar to the *Baseline* scenario by 2050. This is because, in the absence of the ethanol target, the *No NSW biofuel target* scenario uses a higher amount of biodiesel which offsets the emission impact of reduced ethanol consumption.

However, these are all fairly subtle changes. Overall, it can be concluded that the continuation of the NSW biofuel target has a minor impact on emission projections and beyond 2025 may not have any impact at all if second generation biofuel production develops as assumed in this model. Under the assumptions applied here, the *cumulative emissions* saved by including the NSW biofuel target in the *Baseline* scenario is 2.0 $MtCO_2e$ over the projection period.

Under the *No NSW biofuel target* scenario, total transport sector emissions increase by 35.9 $MtCO_2e$ or at an average annual rate of 0.5 per cent from 90.1 $MtCO_2e$ in 2014 to 126.6 $MtCO_2e$ in 2050. This is a 0.1 per cent or 0.1 $MtCO_2e$ increase in greenhouse gas emissions by 2050 relative to the *Baseline* scenario.

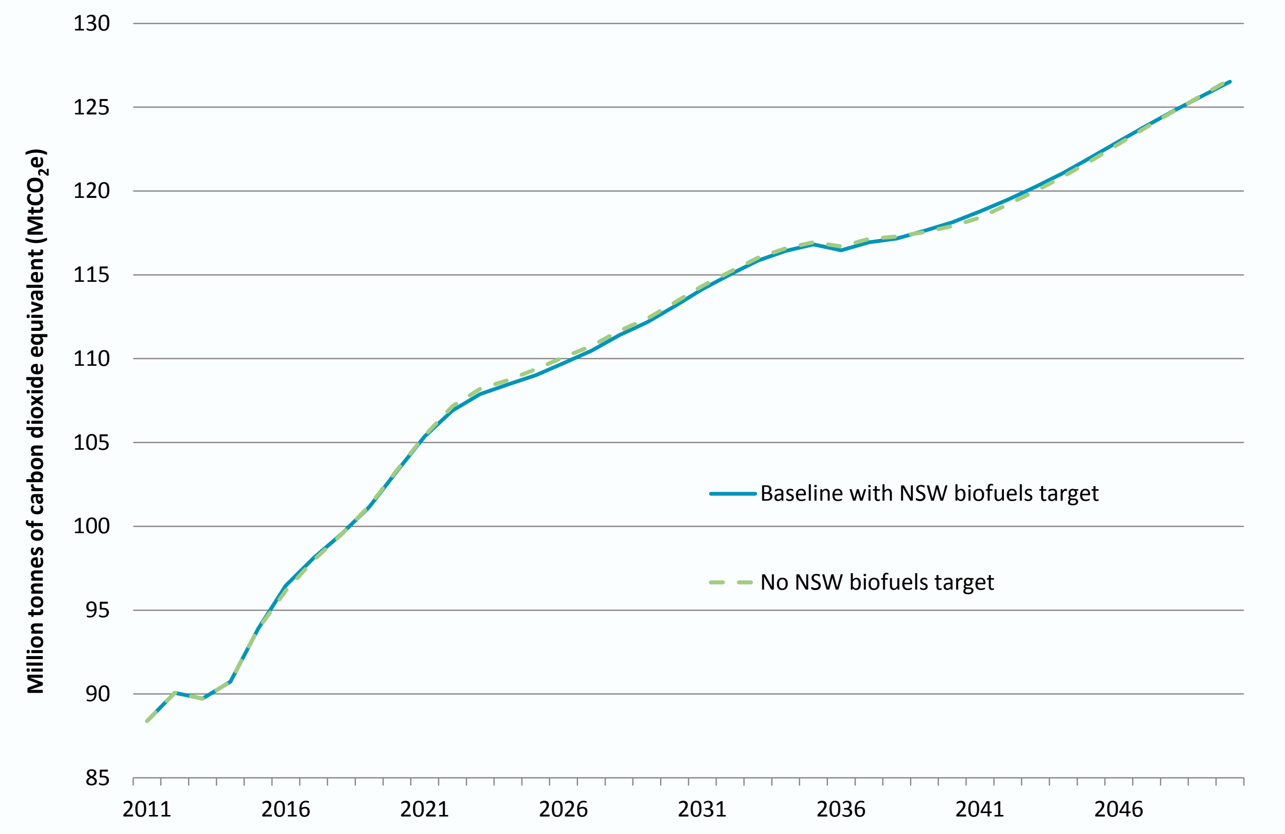

Figure 5-3: Transport sector greenhouse gas emissions under the *No NSW biofuels target* and *Baseline* scenarios

5.2 Estimating the emissions impact of 2014-15 budget changes to fuel excise arrangements (*No excise changes* scenario)

The *No excise changes scenario* estimates the emissions impact of 2014-15 Commonwealth budget changes to fuel excise arrangements - modelling the *Baseline* scenario with the existing fuel excise arrangements before the 2014-15 budget changes in order to understand what contribution they make to emission outcomes in the *Baseline* scenario.

In the 2014-15 budget, the government signalled its intent to change the excise treatment of fuels. The changes impact primarily light duty vehicles and are as follows:

- Indexation of fuel excise other than aviation will be re-introduced in 2014-15 based on consumer price inflation.
- The government will reduce grants made under the Cleaner Fuels Grant Scheme to zero, and will reduce the excise on biodiesel to zero from 1 July 2015. From 1 July 2016, the excise rate for biodiesel will be increased for five years until it reaches 50 per cent of the energy content equivalent tax rate.
- The government will cease the Ethanol Production Grants Programme on 30 June 2015. The fuel excise on domestically produced ethanol will be reduced to zero from 1 July 2015, and then increased by 2.5 cents per litre per year for five years from 1 July 2016 until it reaches 12.5 cents per litre, which represents 50 per cent of the energy content equivalent rate that is applied to petrol.

The impact of these changes relative to existing excise arrangements is shown in Table 5-1. In general, the changes increase the real cost of fuel in 2020 (all else being equal) by 12c/L for petrol and diesel, 4c/L for LPG, 8c/kg for natural gas and 12.5c/L for ethanol and biodiesel.

It is interesting to note that, while biofuels are now subject to an effective excise rate, the difference between the biofuels and petrol/diesel excise is around 26c/L by 2020 under both the existing and new arrangements. However, under the new changes the excise difference will remain constant indefinitely, while under the previous arrangements the excise difference would perpetually narrow as inflation eroded the real value of the petrol and diesel excise. This means that under the new excise arrangements, all else being equal, biofuels are more attractive in the light duty market from 2020 onwards. Of the biofuels, biodiesel is the most attractive, all else being equal, because it has the same excise but a higher energy content.

There are no other individual changes in the relative attractiveness of alternative fuels. However, given that under the new excise arrangements the real value of petrol and diesel excise, and therefore total fuel costs, are higher under the new excise arrangements, this makes all alternative fuels more attractive in the *Baseline* scenario. Therefore, we would expect in the *No excise changes* scenario that alternative fuel uptake is slightly moderated relative to the *Baseline* scenario.

Table 5-1: Comparison of real effective fuel excise rates in 2015 and 2020 prior to and after 2014-15 budget changes assuming a constant 2.5 per cent consumer price index (2015 dollars)

Fuel	Unit	Prior to budget changes		Under 2014-15 budget changes	
		July 2015	July 2020	July 2015	July 2020
Petrol	$/L	0.38143	0.26336	0.38143	0.38143
Diesel	$/L	0.38143	0.26336	0.38143	0.38143
Liquefied petroleum gas	$/L	0.125	0.08631	0.125	0.125
Natural gas	$/Kg	0.26122	0.18036	0.26122	0.26122
Ethanol	$/L	0	0	0	0.125
Biodiesel	$/L	0	0	0	0.125

Heavy road vehicles use primarily diesel fuel and pay an excise of 38.143 cents on each litre. However, they receive a fuel tax credit of 12.003 cents per litre so that their effective (net) fuel tax rate is equivalent to the road user charge of 26.14 cents per litre (this was the rate set in July 2013 and maintained at that level in 2014-15) under both the *Baseline* and *No excise changes* scenario.

Under this scenario we allow road transport demand to respond to price so that changes in the excise may impact demand. The impact of this assumed demand responsiveness is that total road vehicle kilometres travelled is up to 0.2 per cent higher in the road sector as a whole through the projection period.

5.2.1 TRANSPORT FUEL MIX

Figure 5-4 shows total fuel consumption for the road transport sector in the *No excise changes* scenario. It shows that the main impact of the scenario is there is a stronger preference for ethanol instead of biodiesel due to a more equal tax treatment of the two in the *No excise changes* scenario. The lower excise also decreases the uptake of more efficient engines in the light duty road sector such as diesel and electric drive chains although these impacts are slight.

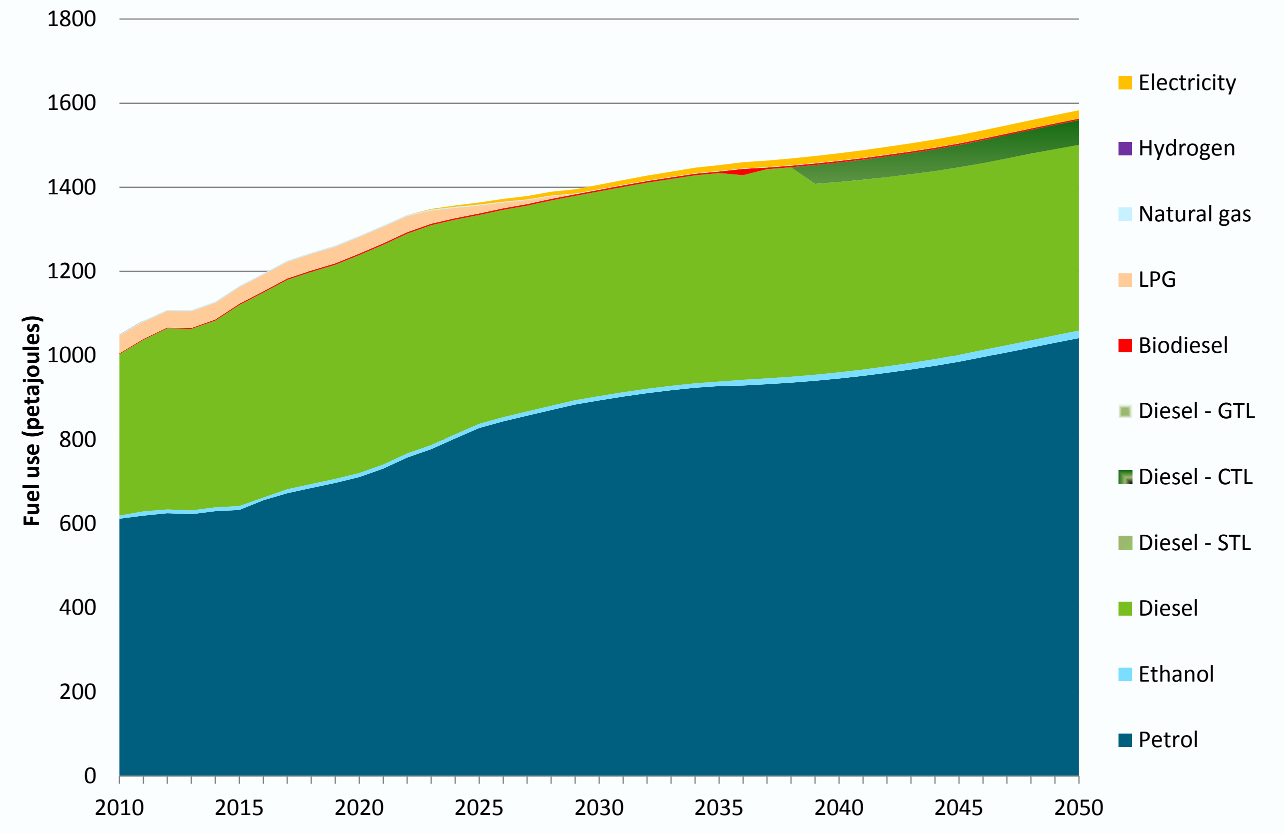

Figure 5-4: Projected road transport fuel consumption by fuel under the *No excise changes* scenario

Another outcome is that, because the premium the light duty road sector can offer for biofuels is declining in real terms each year under the *No Excise change* scenario, the aviation sector has better access to biomass supplies to refine bio-derived jet fuel. Under the *No Excise change* scenario the share of bio-derived jet fuel is projected to be 5 per cent by 2050 compared to 0.6 per cent under the *Baseline* scenario. Rail and navigation use of biofuels is also assumed to increase relative to the *Baseline* scenario.

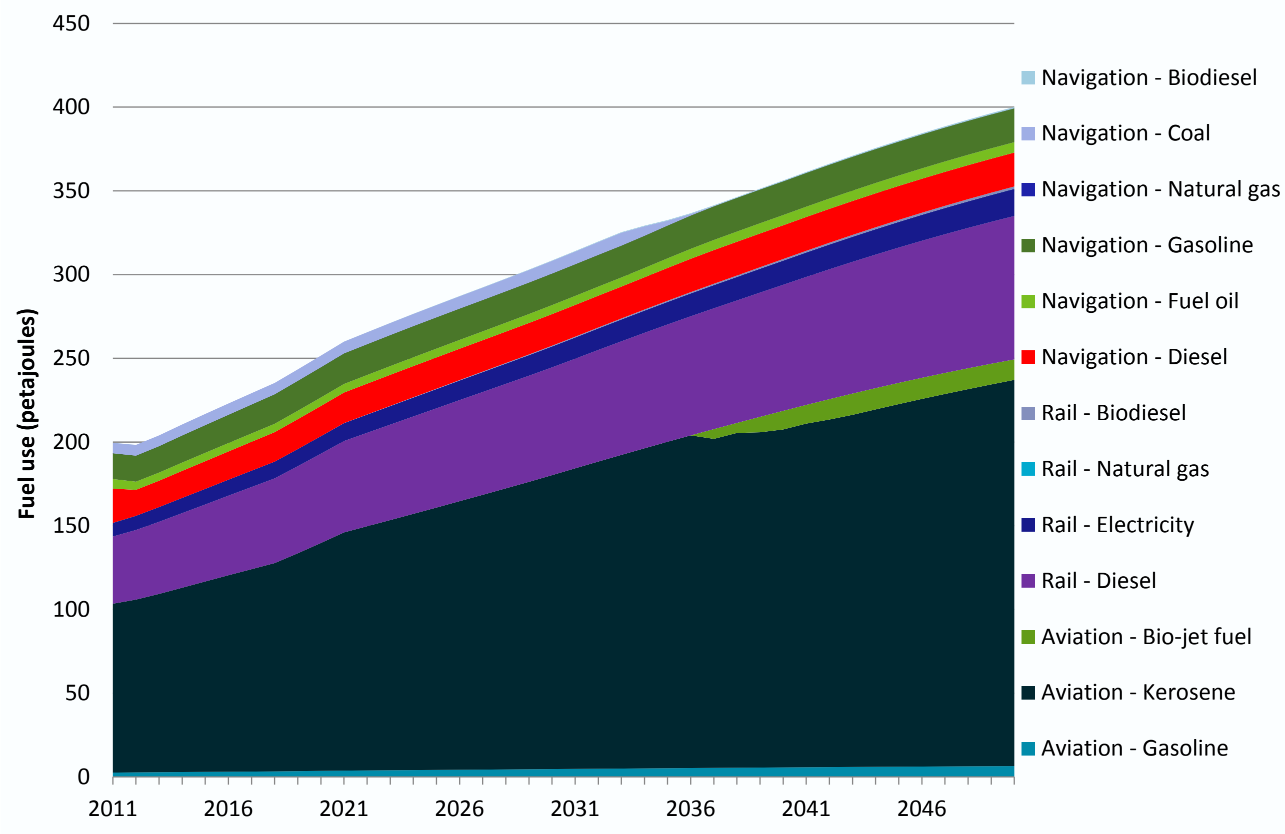

Figure 5-5: Non-road transport fuel consumption by fuel and mode under the *No excise changes* scenario

5.2.2 GREENHOUSE GAS EMISSIONS

Total transport sector greenhouse gas emissions are shown in Figure 5-6 and compared to the *Baseline* scenario. Not implementing the 2014-15 budget excise changes lowers the real cost of fuels in light duty road transport, changes the relative energy equivalent prices of ethanol and biodiesel and the premium the road sector can pay for biofuels relative to non-road. As a consequence, there is lower uptake of fuel saving measures and biofuels, leading to higher greenhouse gas emissions.

Under the *No excise changes* scenario, total transport sector emissions increase from 91 $MtCO_2e$ in 2014 to 104.4 $MtCO_2e$ in 2020, 115.9 $MtCO_2e$ in 2030, and to 131.9 $MtCO_2e$ in 2050. This is a 4.3 per cent or 5.4 $MtCO_2e$ increase in greenhouse gas emissions by 2050 relative to the *Baseline* scenario.

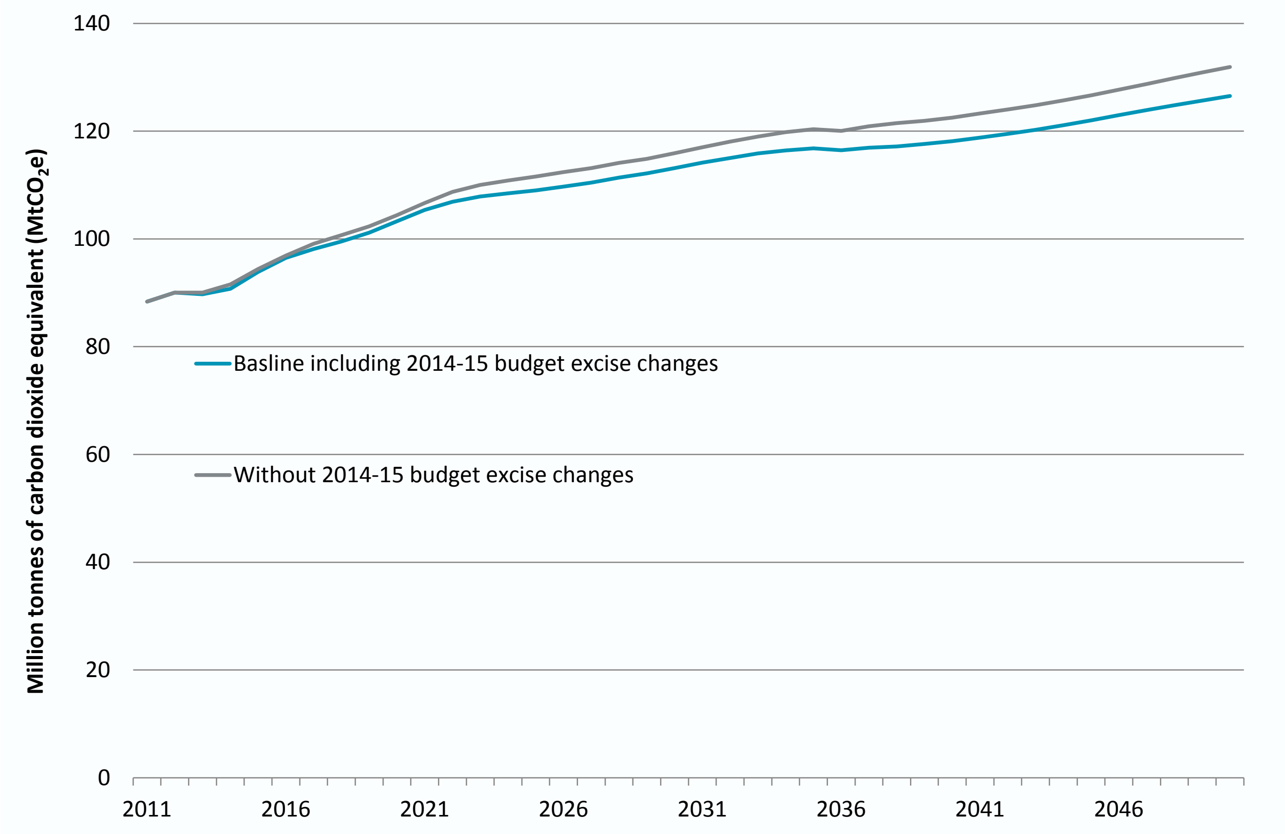

Figure 5-6: Transport sector greenhouse gas emissions under the *No excise changes* and *Baseline* scenarios

6 Emission range scenario results

The sensitivity scenarios highlight a number of alternative assumptions, which, if included in the *Baseline* scenario, would have led to higher or lower greenhouse gas emission projections. The purpose here is to use the results of those sensitivity scenarios to construct scenarios that combine the drivers that lead to high or low range emissions. We exclude the *Emission standards* scenario but combine the high or low oil prices and various alternative conditions for the biofuels supply drivers in the remaining four sensitivity scenarios to construct our ranges.

Combining scenario drivers does not necessarily lead to additive impacts on greenhouse gas emission projections. The total impact of two drivers can lead to either greater than or less than their individual impacts, depending on what their interaction results in according to the logic of the model and any other assumptions.

6.1 High emission scenario

The *High emission* scenario combines the modelling assumptions of the *Low oil prices* and *Delayed biofuel* scenarios to create a scenario which indicates the high end of the range of emissions from the drivers explored.

We calculate a demand response from lower fuel prices by implementing an assumed price elasticity of demand as in the *Low oil prices* scenario. As a consequence, road transport sector demand under the *High emission* scenario is up to 1 per cent higher in some road vehicle classes in the 2020s compared with the *Baseline* scenario, although the differences become negligible as the fuel prices converge towards 2050.

6.1.1 TRANSPORT FUEL MIX

Figure 6-1 shows total transport fuel consumption for the road sector in the *High emissions* scenario. The projection shows a relatively static fuel mix with the only major change being the gradual substitution of LPG for hybrid electric vehicles over time. The extended phasing out of LPG compared to its more rapid phasing out in the *Baseline* scenario is because of its lower tax rate (and subsequent higher proportion of oil driving the retail price) which was discussed in the *Low oil price* scenario. The absence of any major expansion of biofuels is by scenario design, whilst the lack of synthetic fuels is because the high upfront costs of that infrastructure makes it too risky for investment under prevailing low oil prices. Following the lead of the road sector (as by assumption), the non-road sector also has a static fuel mix over time under this scenario.

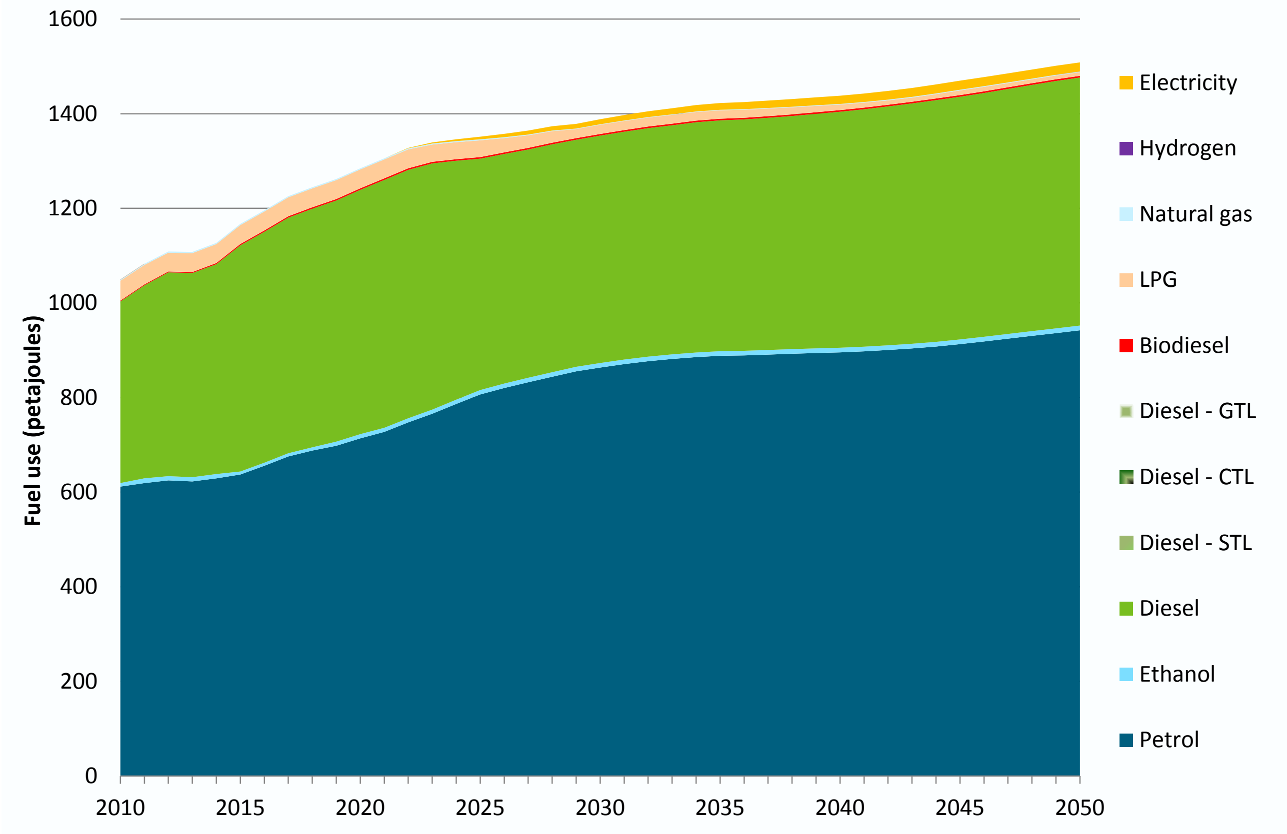

Figure 6-1: Projected road transport fuel consumption by fuel under the *High emission* scenario

6.1.2 GREENHOUSE GAS EMISSIONS

Total transport sector greenhouse gas emissions are shown in Figure 6-2 and compared to the *Baseline* scenario. Low fuel prices and the delayed introduction of biofuels beyond the projection period lead to lower uptake of low emission fuels, lower adoption of fuel saving measures, and higher road transport demand relative to the *Baseline* scenario.

Under the *High emissions* scenario, total transport sector emissions increase from 91.0 $MtCO_2e$ in 2014 to 104.5 $MtCO_2e$ in 2020, 114.7 $MtCO_2e$ in 2030, and to 128.4 $MtCO_2e$ in 2050. This is a 1.4 per cent or 1.9 $MtCO_2e$ increase in greenhouse gas emissions by 2050 relative to the *Baseline* scenario.

The *Low oil price* and *Delayed biofuel* scenarios lead to an additional 2.4 and 1.5 $MtCO_2e$ respectively or combined 3.9 $MtCO_2e$ increase on emissions in the *Baseline* scenario by 2050. As such, combining the drivers from both scenarios in the *High emission* scenario has led to a less than additive outcome. This is likely because lower oil prices independently reduce the uptake of biofuels (even without a biofuels delay in addition) and this effect on emissions cannot be double counted in our modelling framework.

Indeed, by 2050 the *Low oil price* scenario arrives at a higher level of emissions than the *High emission* scenario. This is because the *Low oil price* scenario has access to biofuels in the last five years of the projection period and this supports higher volumes of travel because while they price-follow the petroleum fuels we assume they are sold at a slight discount. However, the *High emission* scenario is the higher emission scenario in the period up to 2036.

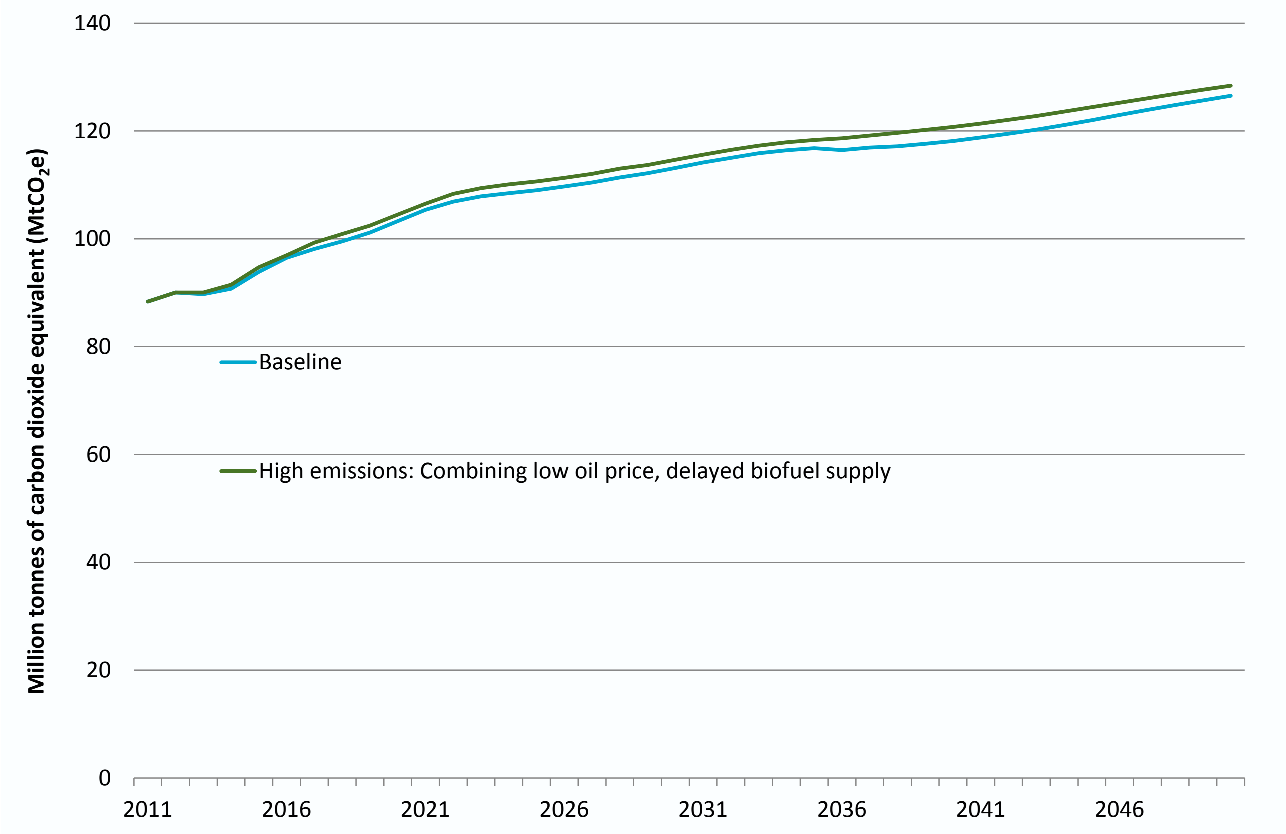

Figure 6-2: Transport sector greenhouse gas emissions under the *High emission* and *Baseline* scenarios

6.2 Low emission scenario

The *Low emission* scenario combines the modelling assumptions of the *High oil price* and *High biofuel* scenarios to create a scenario indicative of the low end of the range of emissions from the drivers explored. Note that one of the modelling assumptions of the *High oil price* scenario is that all alternative fuel supply chain resources are increased in proportion to the ratio of the *High oil* and *Baseline* scenario fuel price paths. As a consequence, biofuels receive a double boost in supply volume in this implementation.

As for the *High oil price* scenario, we allow ESM to calculate a demand response from higher fuel prices by implementing an assumed price elasticity of demand. The outcome is that in this scenario, road transport kilometres travelled are up to 3 per cent lower for some time periods and transport modes, than under the *Baseline* scenario.

6.2.1 TRANSPORT FUEL MIX

Figure 6-3 shows total transport fuel consumption for the road sector, in the *Low emissions* scenario. The projection shows that the adoption of more efficient diesel vehicles expands up to the early 2020s, after which the fuel consumption trend moves back to petrol reflecting the beginning of stronger uptake of petrol based hybrid electric vehicles. Beyond the 2020s the other main feature is the adoption of biofuels and coal-derived synthetic diesel from 2030. E10, biodiesel and coal-derived synthetic diesel all expand in relatively equal measure by 2050.

Relative to the *Baseline* scenario, growth in total fuel consumption is reduced by the adoption of fuel saving hybrid electric or fully electric drive trains, as well as the reduction in transport kilometres due to the assumed price responsiveness of demand.

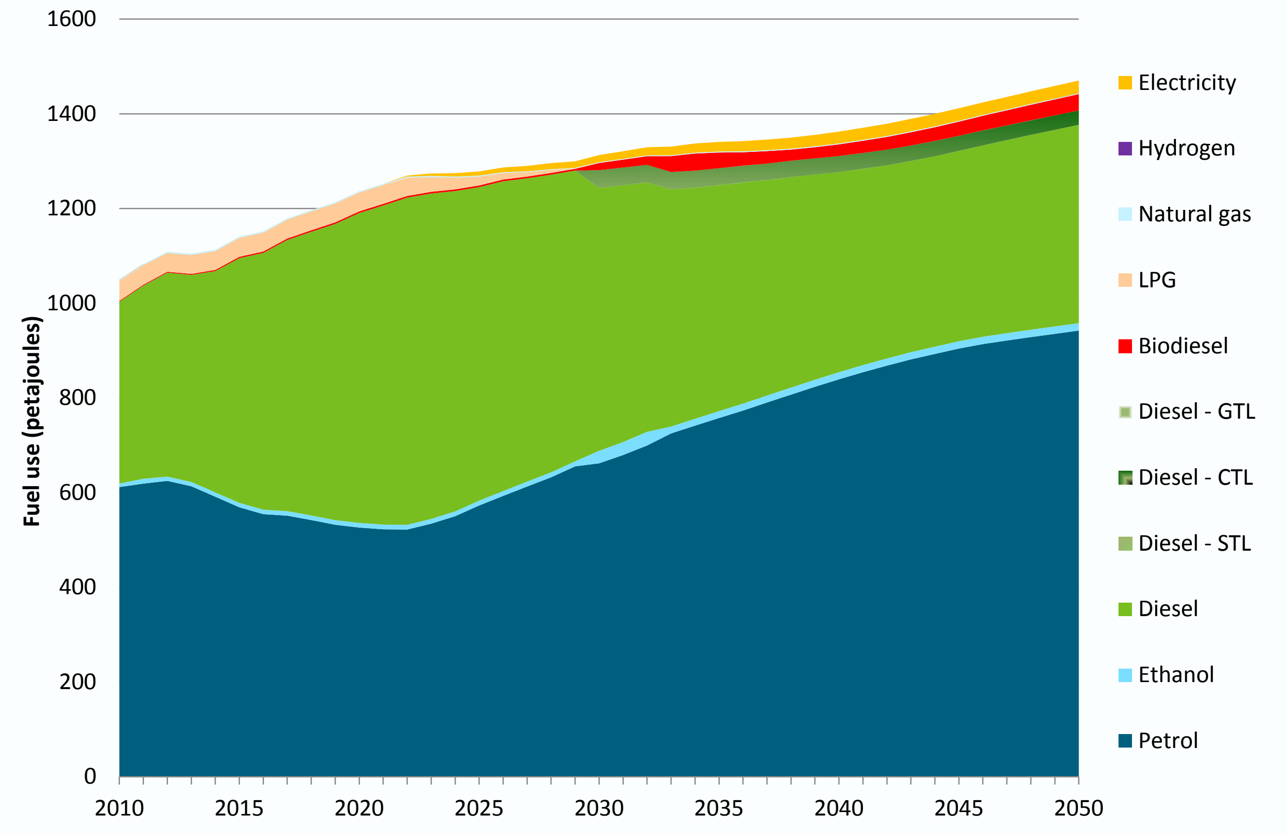

Figure 6-3: Projected road transport fuel consumption by fuel under the *Low emission* scenario

Figure 6-4 shows the projected quantity of non-road transport fuel consumption by fuel type and transport mode (domestic navigation, rail and domestic aviation) for the *Low emissions* scenario. Relative to the Baseline scenario, the key difference is much greater uptake of bio-derived jet fuel, owing to the greater biofuel production capacity, which reaches a share of 7.5 per cent of aviation fuel consumption by 2050. The navigation and rail sectors follow their lead but with more modest biofuel shares of 2.5 per cent by 2050.

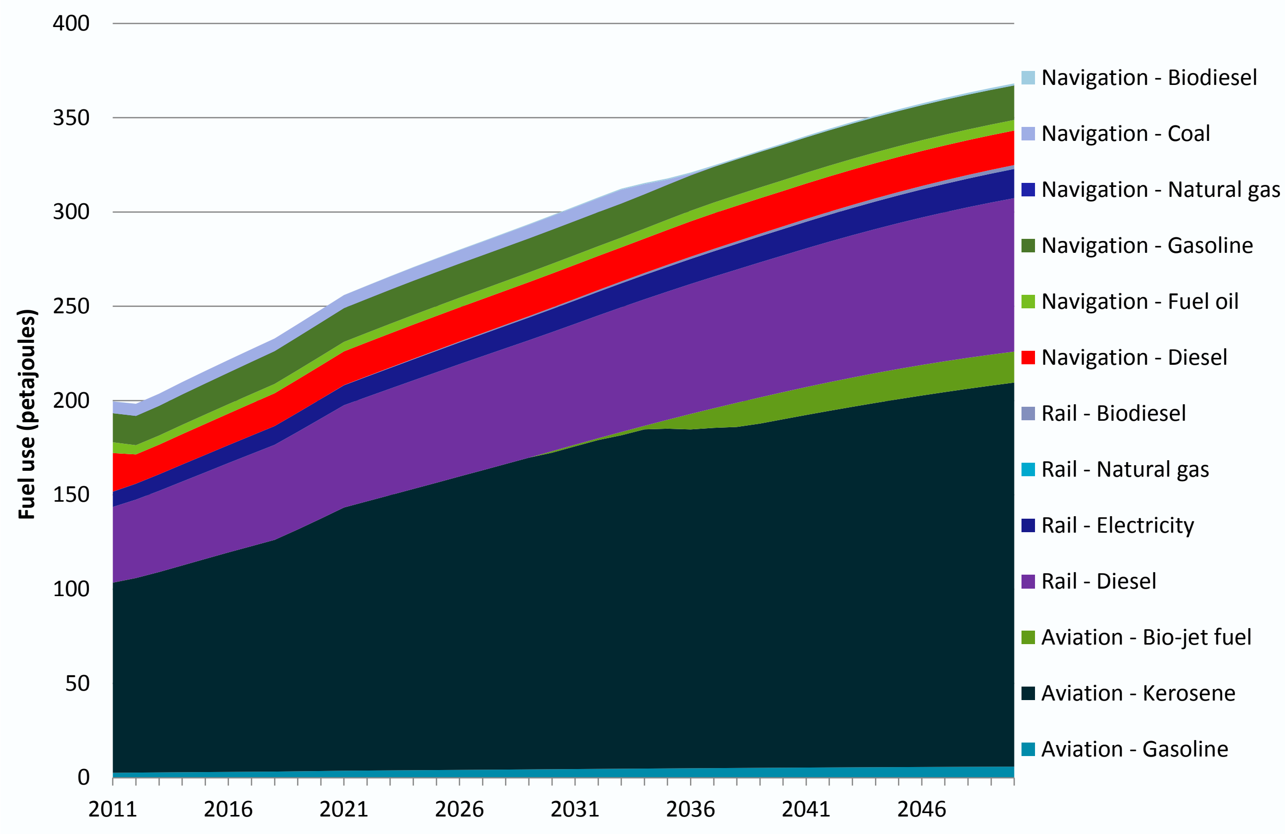

Figure 6-4: Non-road transport fuel consumption by fuel and mode under the *Low emission* scenario

6.2.2 GREENHOUSE GAS EMISSIONS

Total transport sector greenhouse gas emissions are shown in Figure 6-5 and compared to the *Baseline* scenario. High fuel prices, and increased supply of biofuels and other alternative fuels, leads to higher uptake of low emission fuels, higher adoption of fuel saving measures, and lower road transport demand relative to the *Baseline* scenario.

Under the *Low emissions* scenario, total transport sector emissions increase from 90.1 $MtCO_2e$ in 2014 to 101.3 $MtCO_2e$ in 2020, 107.0 $MtCO_2e$ in 2030, and to 119.2 $MtCO_2e$ in 2050. This is a 5.7 per cent or 7.3 $MtCO_2e$ decrease in greenhouse gas emissions by 2050 relative to the *Baseline* scenario.

The *High oil price* and *High biofuel* scenarios lead to a reduction of 5.7 and 1.9 $MtCO_2e$ each on emissions in the *Baseline* scenario, which sum together as a 7.6 $MtCO_2e$ decrease. However, combining the drivers from both scenarios in the *Low emission* scenario leads to a less than completely additive outcome. This is because higher oil prices already independently expand the supply of biofuels (even without further expansion due to the high biofuel availability assumption) and this effect on emissions cannot be double counted in our modelling framework.

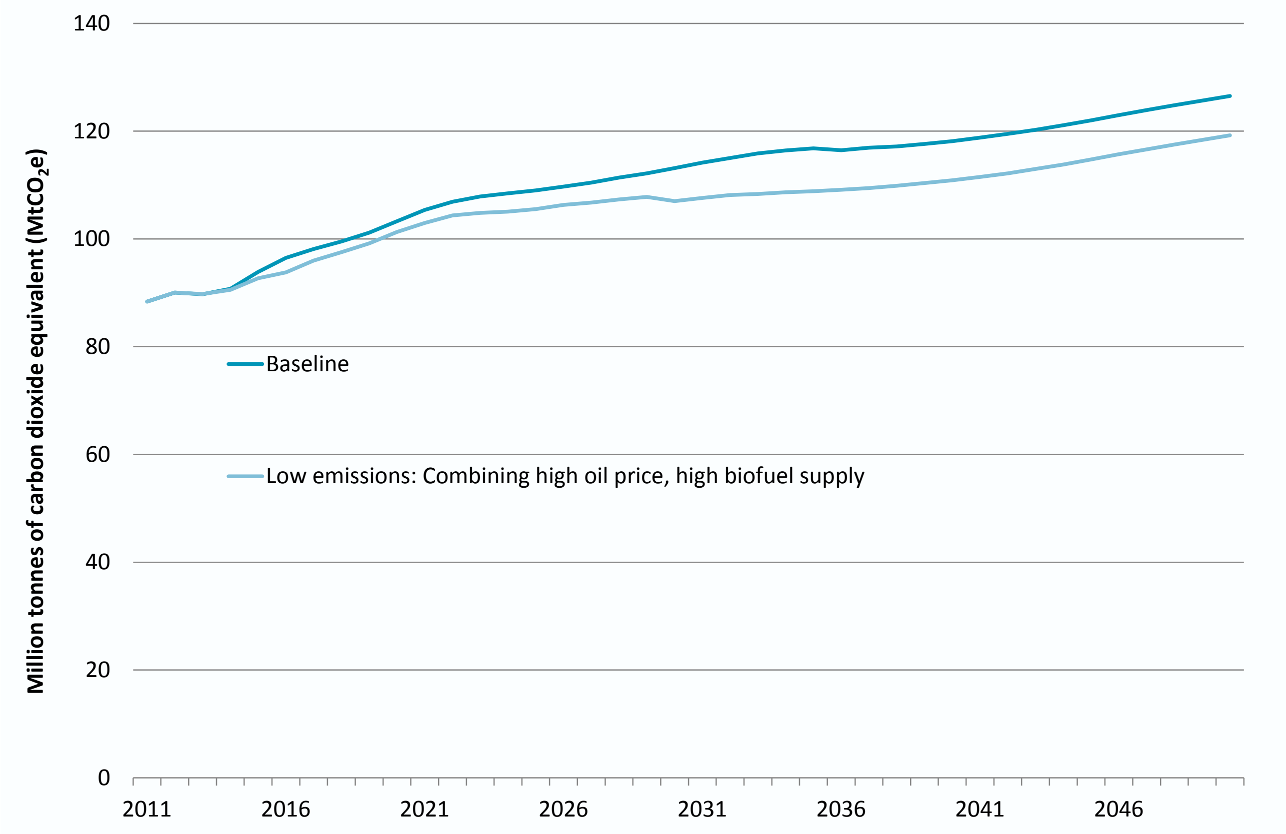

Figure 6-5: Transport sector greenhouse gas emissions under the *Low emission* and *Baseline* scenarios

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