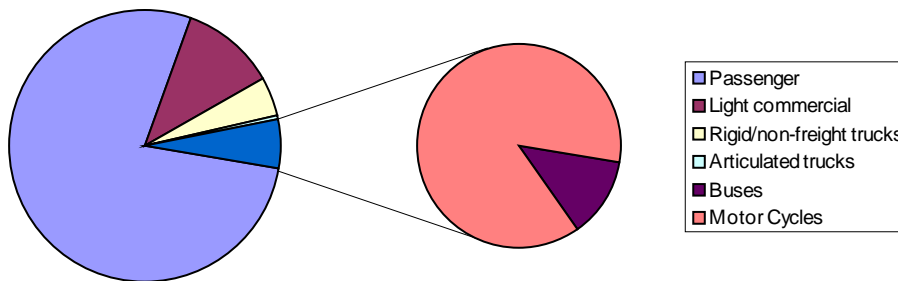


<u>6.12.3</u>	<u>Emission Sensitivity to Benzene Content in Petrol</u>	102
<u>6.12.4</u>	<u>Emission Sensitivity to Other Fuel Components</u>	103
<u>6.12.5</u>	<u>Greenhouse Gas Emissions</u>	103
<u>6.13</u>	<u>KEY FINDINGS</u>	105

1,3-butadiene (Figure 6-14) – relative emissions of 1,3-butadiene show a similar pattern to that of benzene, with passenger vehicles, light commercial vehicles and motorcycles accounting for more than 90% of total emissions for both 2000 and 2010. In 2010, motorcycles are estimated to contribute more to total emissions than light commercial vehicles, which again is a reflection of the fact that stricter emission controls on motorcycles were not modelled.

**Contribution of 1,3-Butadiene by Vehicle Type, 2000
Scenario 1**



**Contribution of 1,3-Butadiene by Vehicle Type,
2010 Scenario 4**

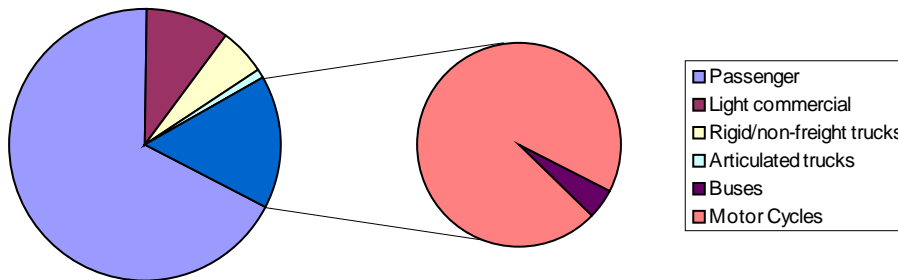
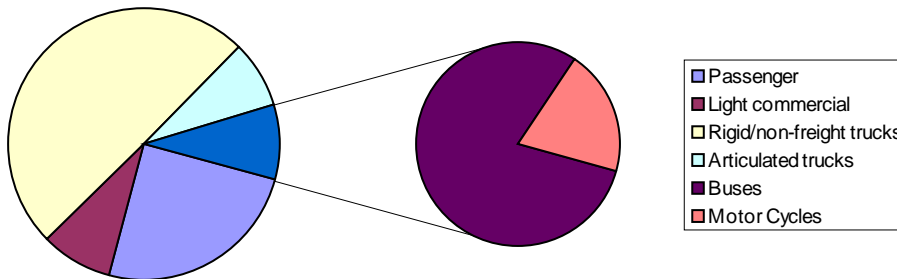


FIGURE 6-14: 1,3-BUTADIENE EMISSIONS BY VEHICLE TYPE

Formaldehyde (Figure 6-15) –diesel vehicles are the main source of formaldehyde, accounting for over 60% of emissions in both 2000 and 2010. Rigid/non-freight trucks contribute more than 50% of total emissions in both years. Passenger vehicles and light commercial vehicles collectively account for around 30% of total emissions for 1000 and 2010.

**Contribution of Formaldehyde by Vehicle Type, 2000
Scenario 1**



**Contribution of Formaldehyde by Vehicle Type,
2010 Scenario 4**

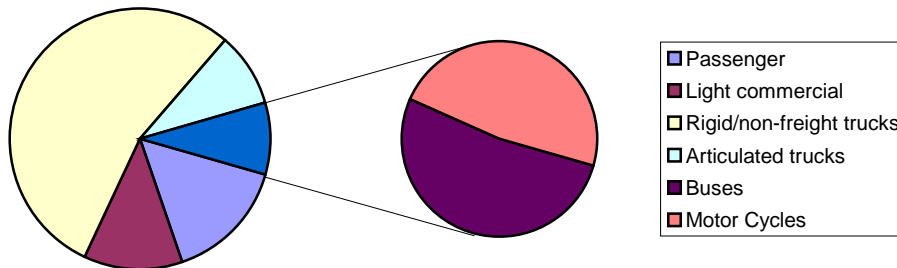
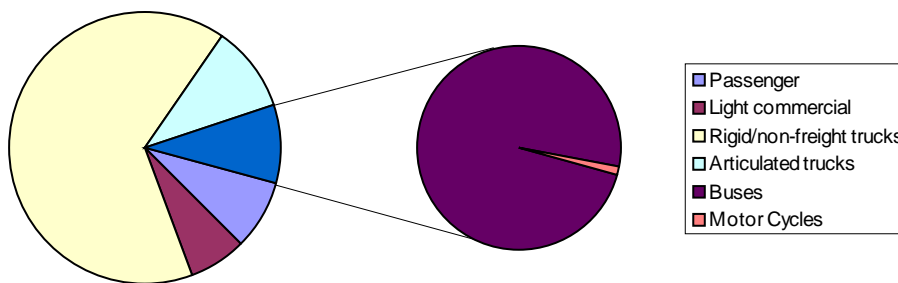


FIGURE 6-15: FORMALDEHYDE EMISSIONS BY VEHICLE TYPE

PAH (Figure 6-16) - diesel vehicles are the main source of PAH, accounting for more than 80% of emissions in both 2000 and 2010. Rigid/non-freight trucks contribute approximately 65% of total emissions in both years. Light commercial vehicles are the second largest source of acetaldehyde in 2010 (12%), which is an indication of the increasing usage of these vehicles and an increasing proportion of diesel fuelled vehicles within this category.

Contribution of Poly-Aromatic Hydrocarbons (Semi-Volatile) by Vehicle Type, 2000 Scenario 1



Contribution of Poly-Aromatic Hydrocarbons (Semi-Volatile) by Vehicle Type, 2010 Scenario 4

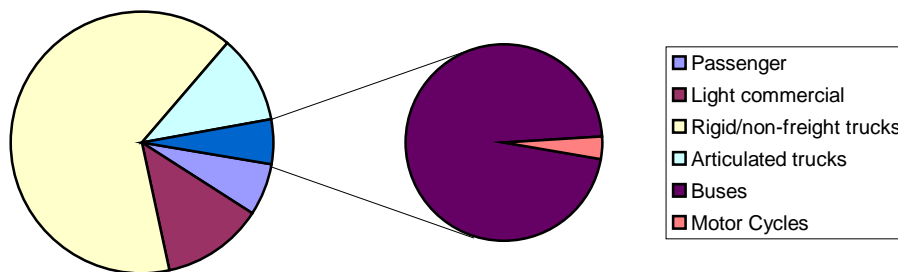


FIGURE 6-16: POLY-AROMATIC HYDROCARBONS (SEMI-VOLATILE) EMISSIONS BY VEHICLE TYPE

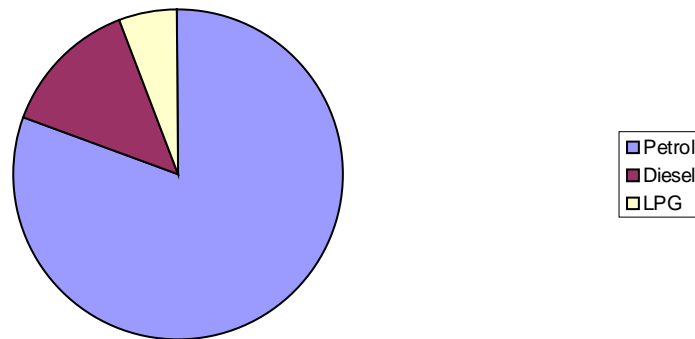
6.12.2.4 Contribution to total emissions by fuel type

For volatile emissions the following discussion applies to summer time tailpipe emissions. Emissions in winter will differ but similar percentage contributions are expected.

Evaporative emissions are relevant for volatile hydrocarbons present in fuel. The relative breakdown of tailpipe and evaporative emissions for total hydrocarbons and for benzene is discussed in Section 6.12.2.5.

Hydrocarbons (Figure 6-17) – emissions of this pollutant are dominated by petrol fuelled vehicles. Increasing activity of diesel and LPG/CNG fuelled vehicles is expected in future years, at the expense of petrol fuelled vehicles.

**Contribution of Hydrocarbons by Fuel Type, 2000
Scenario 1**



**Contribution of Hydrocarbons by Fuel Type, 2010
Scenario 4**

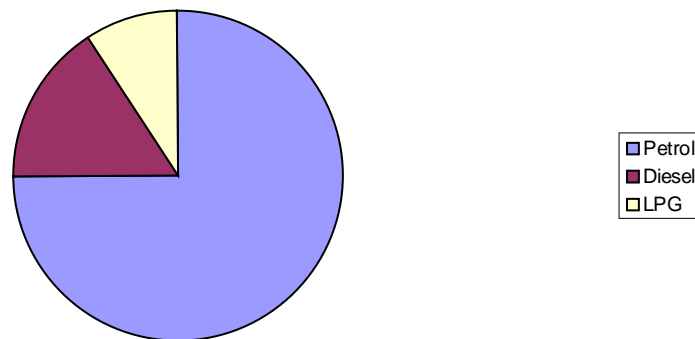
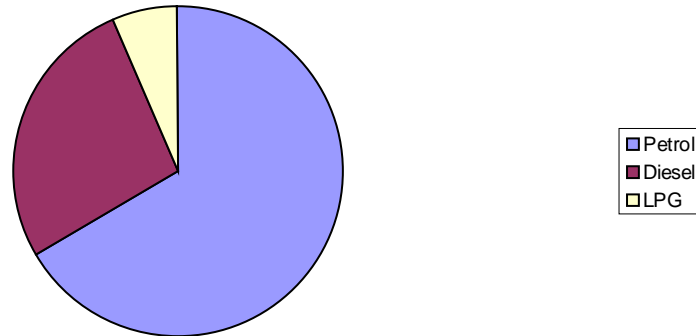


FIGURE 6-17: HYDROCARBON EMISSIONS BY FUEL TYPE

Oxides of Nitrogen (Figure 6-18) – petrol vehicles account for the majority of emissions, although diesel vehicles account for a substantial proportion. As for hydrocarbons, diesel and LPG/CNG vehicles are expected to account for an increased proportion of total emissions in future years.

**Contribution of Oxides of Nitrogen by Fuel Type, 2000
Scenario 1**



**Contribution of Oxides of Nitrogen by Fuel Type, 2010
Scenario 4**

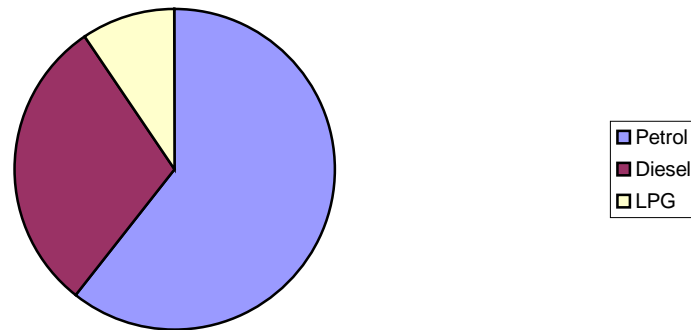
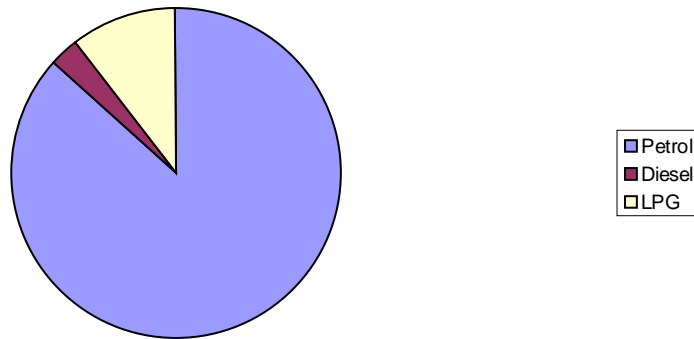


FIGURE 6-18: OXIDES OF NITROGEN EMISSIONS BY FUEL TYPE

Carbon monoxide (Figure 6-19) – petrol vehicles contribute more than 80% of emissions in 2000 and 2010. The contribution made by LPG/CNG vehicles is estimated to increase significantly between 2000 and 2010, while the contribution made by diesel vehicles remains unchanged.

**Contribution of Carbon Monoxide by Fuel Type, 2000
Scenario 1**



**Contribution of Carbon Monoxide by Fuel Type, 2010
Scenario 4**

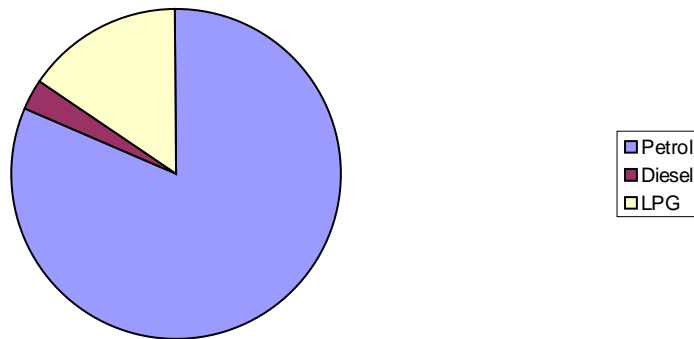
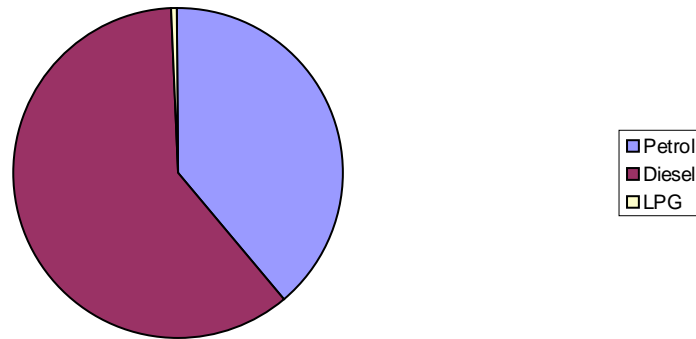


FIGURE 6-19: CARBON MONOXIDE EMISSIONS BY FUEL TYPE

Particulate Matter < 10µm (Figure 6-20) –results for 2000 indicate that diesel fuelled vehicles account for the majority of emissions. By 2010, stricter particulate emission controls for diesel vehicles indicate that petrol fuelled vehicles, which do not have stricter particulate standards, will account for the majority of particulate emissions.

Contribution of Particulate Matter (< 10 µm) by Fuel Type, 2000 Scenario 1



Contribution of Particulate Matter (< 10 µm) by Fuel Type, 2010 Scenario 4

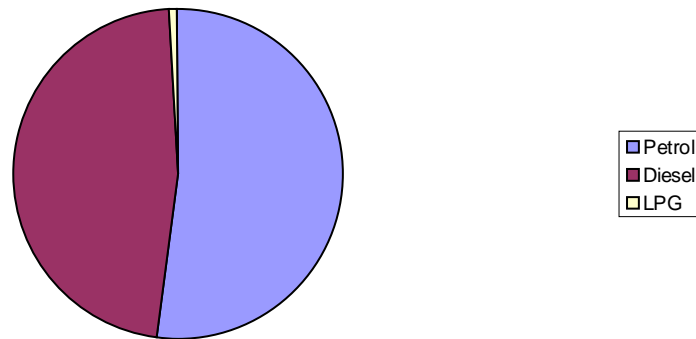
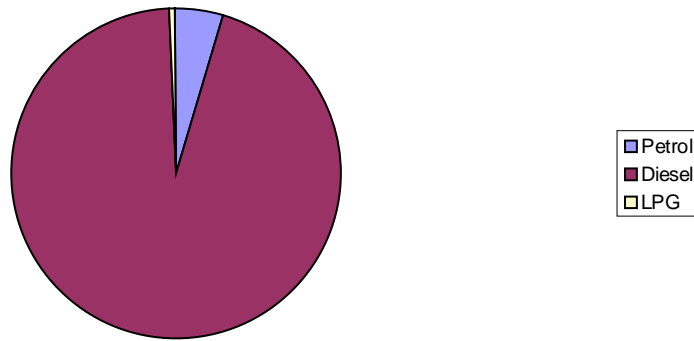


FIGURE 6-20: PARTICULATE MATTER EMISSIONS BY FUEL TYPE

Acetaldehyde, Formaldehyde (Figures 6-21 and 6-22) – emissions of these substances are dominated by diesel vehicles. The contribution made by diesel vehicles is estimated to increase in line with increasing activity levels.

**Contribution of Acetaldehyde by Fuel Type, 2000
Scenario 1**



**Contribution of Acetaldehyde by Fuel Type, 2101
Scenario 4**

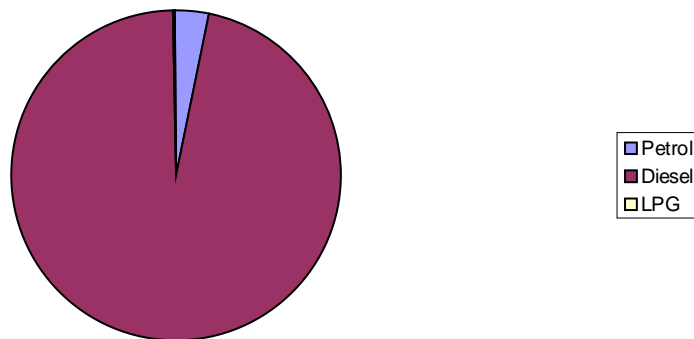
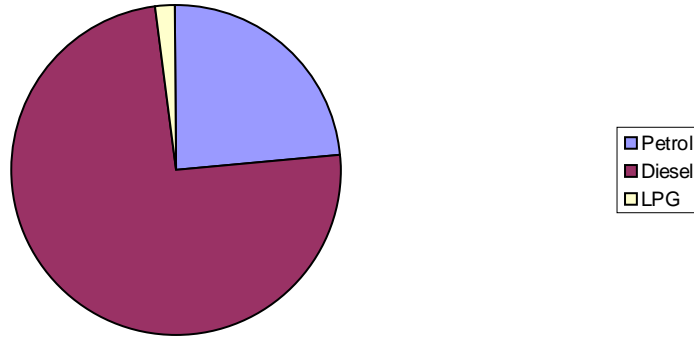


FIGURE 6-21: ACETALDEHYDE EMISSIONS BY FUEL TYPE

**Contribution of Formaldehyde by Fuel Type, 2000,
Scenario 1**



**Contribution of Formaldehyde by Fuel Type, 2010
Scenario 4**

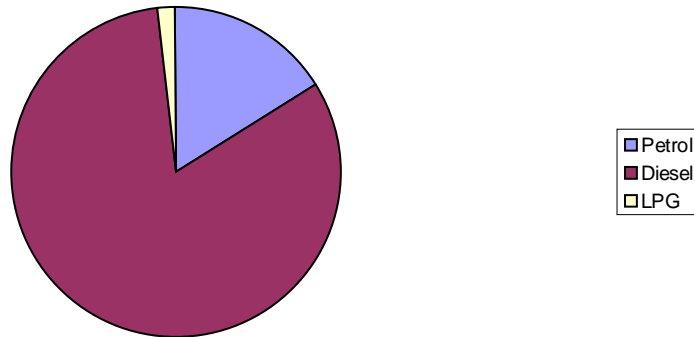
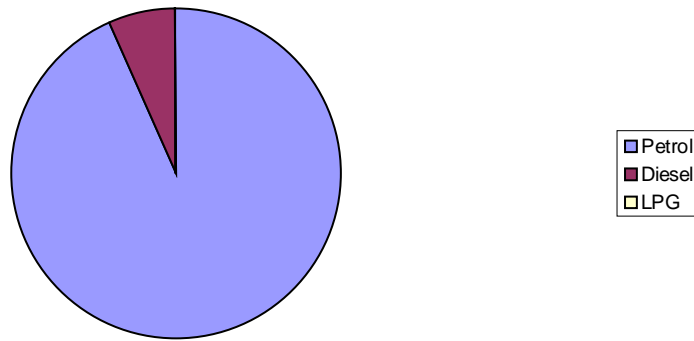


FIGURE 6-22: FORMALDEHYDE EMISSIONS BY FUEL TYPE

Benzene, 1,3-butadiene (Figures 6-23 and 6-24)– petrol vehicles account for approximately 90% of these substances for 2000 and 2010. The contribution made by diesel vehicles is small but increasing over this period

**Contribution of Benzene by Fuel Type,
2000 Scenario 1**



**Contribution of Benzene by Fuel Type, 2010
Scenario 4**

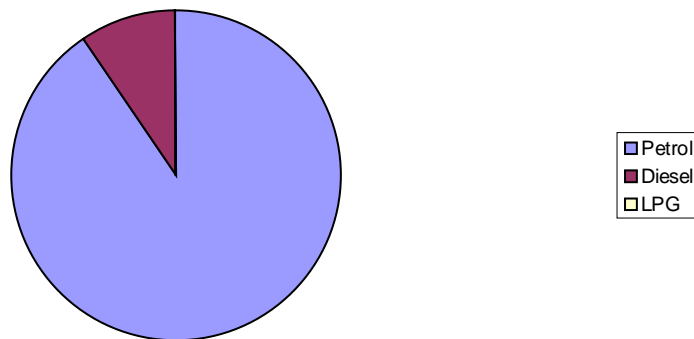
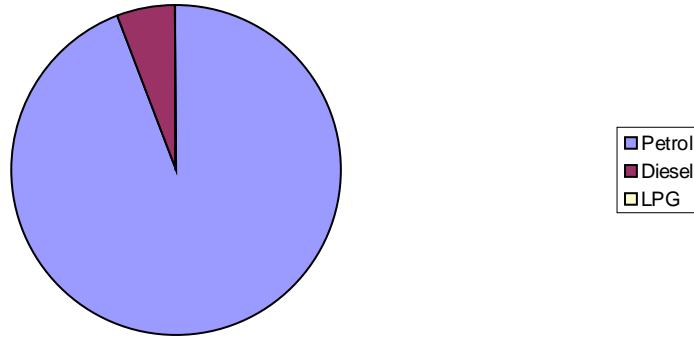


FIGURE 6-23: BENZENE EMISSIONS BY FUEL TYPE

**Contribution of 1,3-Butadiene by Fuel Type, 2000
Scenario 1**



**Contribution of 1,3-Butadiene by Fuel Type, 2010
Scenario 4**

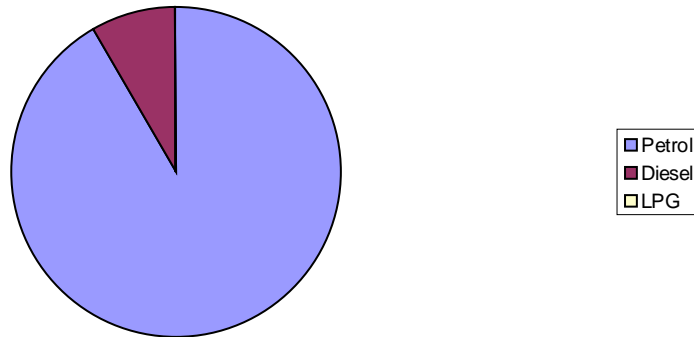
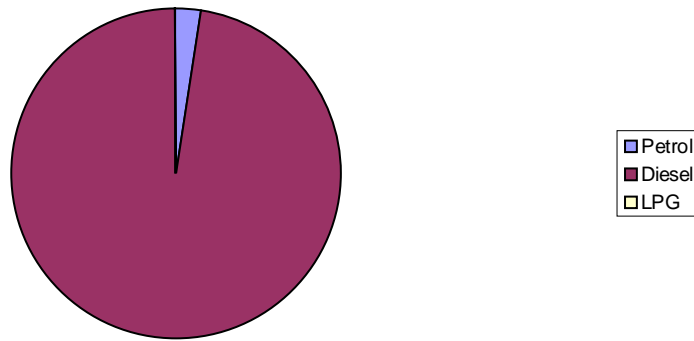


FIGURE 6-24: 1,3-BUTADIENE EMISSIONS BY FUEL TYPE

PAH (Figure 6-25) – diesel vehicles account for over 95% of emissions for 2000 and 2010, with the contribution increasing with diesel vehicle activity levels in future years.

Contribution of Poly-Aromatic Hydrocarbons (semi-volatile) by Fuel Type, 2000 Scenario 1



Contribution of Poly-Aromatic Hydrocarbons (Semi-Volatile) by Fuel Type, 2010 Scenario 4

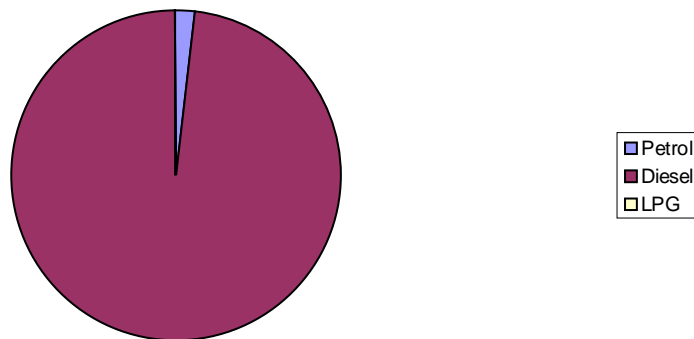
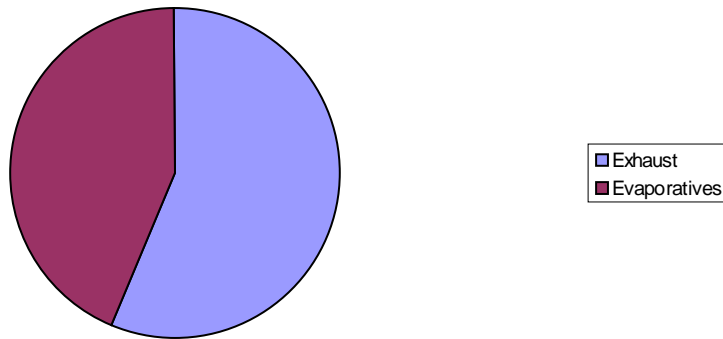


FIGURE 6-25: POLY-AROMATIC HYDROCARBON (SEMI-VOLATILE) EMISSIONS BY FUEL TYPE

6.12.2.5 Contribution of Exhaust and Evaporatives to Hydrocarbon Emissions

Total hydrocarbons (Figure 6-26) – The exhaust component of HC emissions is estimated to decrease from 56% to 24% between 2000 (Scenario 1) and 2020 (Scenario 4). This is a reflection of the fact that new emission standards do not require further reductions in evaporative emissions. The main method of controlling evaporative emissions will be through the introduction of lower volatility petrol.

Contributions of Hydrocarbons from Tailpipe Exhaust & Evaporatives, 2000 Scenario 1



Contributions of Hydrocarbons from Tailpipe Exhaust & Evaporatives, 2010 Scenario 4

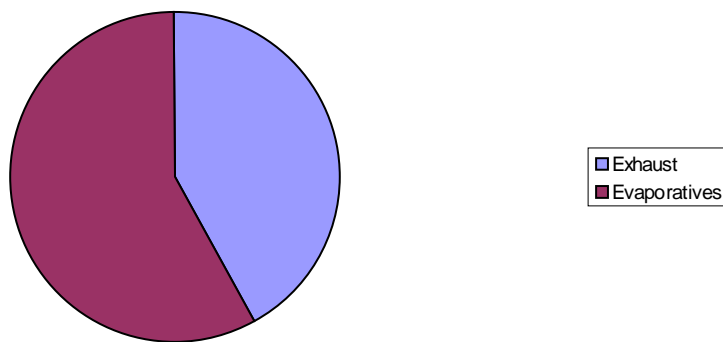
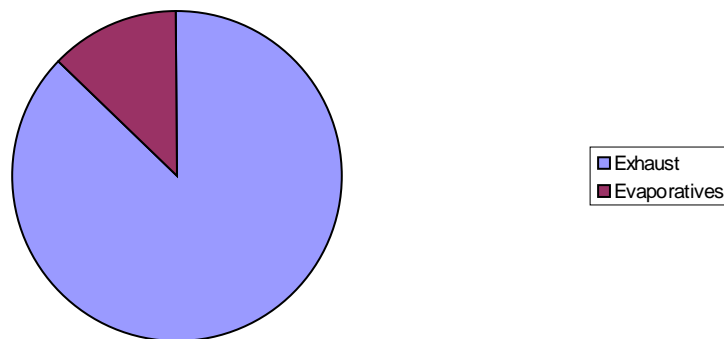


FIGURE 6-26: CONTRIBUTIONS OF HYDROCARBONS FROM TAILPIPE EXHAUST & EVAPORATIVES

Benzene (Figure 6-27) – The exhaust component of benzene emissions is estimated to be approximately 85% of the total in 2000 for Scenario 1. Under Scenario 4 conditions, this proportion is estimated to increase to around 90% by 2010 and then decrease to about 80% by 2020. There are a number of factors controlling this trend:

- exhaust benzene emissions are less sensitive to petrol benzene levels than are evaporative benzene emissions. This is because other substances in petrol can be converted to benzene during combustion.
- evaporative benzene emissions tend to be proportional to the fuel benzene level. Lower fuel benzene levels introduced before 2010 will therefore significantly reduce evaporative benzene emissions ;
- Exhaust HC emissions (and associated benzene emissions) will reduce in line with stricter emission limits specified as part of Scenario 4. Evaporative emission rates are not explicitly controlled, although they will tend to reduce over time as older vehicles with higher evaporative emissions are removed from the fleet. By 2020, exhaust emission rates have dropped significantly whereas evaporative emission rates are the same compared to 2010. This explains why the evaporative component of benzene emissions increases between 2010 and 2020.

Contributions of Benzene from Tailpipe Exhaust & Evaporatives, 2000 Scenario 1



Contributions of Benzene from Tailpipe Exhaust & Evaporatives, 2010 Scenario 4

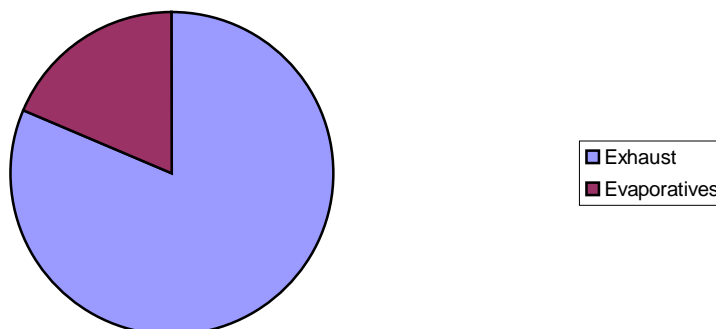


FIGURE 6-27: CONTRIBUTIONS OF BENZENE FROM TAILPIPE EXHAUST & EVAPORATIVES

6.12.3 Emission Sensitivity to Benzene Content in Petrol

The sensitivity of exhaust and evaporative emissions of benzene was assessed for selected Scenarios, using the formulae reported by USEPA (1993) as shown in Section 6.5. A modeled reduction of benzene concentration from 3% to 1% in petrol resulted in:

- Year 2000, Benzene change: exhaust -6%, evaporative -67%, total -15%;
- Year 2010, Benzene change: exhaust -20%, evaporative -67%, total -29%;
- Year 2020, Benzene change: exhaust -20%, evaporative -67%, total -35%.

Benzene exhaust emissions will reduce significantly over time as stricter hydrocarbon emission standards and fuel with lower benzene levels are introduced. Evaporative losses of benzene will be a function of fuel benzene content, as stricter limits on evaporative hydrocarbon emissions will not be introduced. As a result, the contribution of exhaust emissions of benzene will decrease in future years.

Tailpipe emissions of benzene are not highly sensitive to the benzene content of petrol. Reducing the benzene content from 3% to 1% is estimated to result in a 21% reduction of exhaust emissions of benzene, with other fuel parameters and fleet structure constant.

Reduction of the benzene level in petrol has a greater effect in controlling evaporative benzene emissions than exhaust emissions. This is because other substances in petrol can be converted to benzene during combustion. As the evaporative component of total benzene emissions becomes more significant in

later years, the reduction of benzene levels in petrol therefore becomes more important in controlling benzene emissions.

The reduction of benzene in petrol is one of several factors in controlling benzene emissions. Benzene emissions also depend on total hydrocarbon emissions and the level of aromatics in the fuel. Control of hydrocarbon emissions and lowering the aromatics level in petrol would also reduce benzene emissions. These factors, however, are secondary compared with the control of benzene levels in fuel.

6.12.4 Emission Sensitivity to Other Fuel Components

Sensitivity analyses were carried out to assess changes in emissions due to changes in the aromatics and olefins content in petrol and cetane number in diesel. The assessment was based on Scenario 4 conditions in 2010.

Under Scenario 4 conditions in 2010, an increase in the aromatic concentration from 35% to 42% in petrol is estimated to result in insignificant changes (less than 1%) in emissions of hydrocarbons, oxides of nitrogen, carbon monoxide and particulate matter. Benzene emissions, however, were estimated to increase by 4%.

Similar analyses were conducted for changes to olefins content and cetane number in fuel under Scenario 4 in 2010. An increase of olefins content from 14% to 18% in petrol is estimated to result in insignificant changes (less than 1%) in emissions of benzene, hydrocarbons, oxides of nitrogen, carbon monoxide and particulate matter. A reduction of cetane number in diesel from 55 to 51 also showed insignificant changes (less than 1%) in these emissions.

Reduction in sulfur content from 50 ppm to 30 ppm in both diesel and petrol also resulted in insignificant changes (less than 1%) in these emissions.

The results of these sensitivity analyses are consistent with results of the modelling of emissions for each scenario where (except for benzene) essentially the same level of emissions are predicted for Scenarios 3,4,5 and 6.

6.12.5 Greenhouse Gas Emissions

An assessment of national greenhouse gas emissions was made based on the modelled fuel consumption for the period 2000 to 2020 and are shown in Table 6-75.

TABLE 6-75: GREENHOUSE GAS EMISSIONS (GG OF CO₂ EQUIVALENT)

Year	Scenario 1	Scenarios 2,3 & 4	Scenarios 5 & 6
1990	54800	54800	54800
2000	67400	67400	67400
2005	73000	72500	72500
2010	78400	76400	76300
2020	85900	81100	80600

An increase in greenhouse emissions from road transport of 27% is predicted under Scenario 1 over the period 2000 to 2010. Over the same period an increase of 20% is predicted for the other scenarios. This improvement is due to the assumption that the National Average Fuel Consumption (NAFC) target of 15% improvement over business as usual would be achieved. A small improvement in greenhouse emissions for Scenarios 5 and 6 compared with Scenarios 2,3 and 4 is allowed for the improvement in fuel consumption, which would be associated with use of high octane (98 RON) fuel. The results illustrate that fuel quality has little impact of greenhouse emissions from the transport fleet and that the best prospects for improvement in greenhouse emissions will come from vehicle technology improvements.

Table 6-76 presents the assessment of increase on greenhouse emissions as a result of changes to refinery operation required to deliver improved fuel quality. The assessment is based on information regarding energy requirements and hydrogen production needs compared with the base case (Scenario 1). The emissions estimates are consistent with extrapolation of greenhouse gas estimates for the period 1990 to 1997 produced by the National Greenhouse Gas Inventory.

TABLE 6-76: REFINERY GREENHOUSE EMISSIONS INCREASES (Gg CO₂ Equivalent)

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
2000	0	0	0	0	0	0
2005	0	200	200	700	700	2100
2010	0	1100	1600	2100	2100	2100
2020	0	1600	1600	2100	2100	2100

Note: The greenhouse emissions for 2010 and 2020 for Scenarios 5 and 6 do not take account of production of a high proportion of 98RON petrol as the refineries have indicated that this is not practicable.

The assessment of incremental refinery emissions shows significant greenhouse emissions associated with the production of improved fuel quality.

6.13 KEY FINDINGS

The key findings of the motor vehicle emissions analysis are:

Substantial reduction in air pollutant emissions are predicted over the next ten years for hydrocarbons, carbon monoxide, oxides of nitrogen, particulate matter and air toxics including benzene.

In general, emissions are relatively insensitive to changes in fuel quality. Improvements in the emission rates of future vehicle fleets will be due primarily to advances in pollution control technology. This is illustrated by the results of the emissions modelling, which show a relatively small difference in total emissions for Scenarios 3 to 6. The major impact of cleaner fuels is to allow new pollution control technologies to be implemented.

Emissions of some pollutants tend to vary in direct proportion with the fuel content of the pollutant in questions or related substances. These include sulfur and lead. Such substances in fuel may undergo little or no transformation during the combustion process before being emitted. Fuel quality, therefore, tends to have a more direct effect on emissions for these substances.

Evaporative hydrocarbon emissions are expected to contribute an increasing proportion of total hydrocarbon emissions over the period studied, and are estimated to account for the majority of annual emissions by 2010 (under Scenario 4 conditions). This is because stricter limits on evaporative emissions are not part of the new exhaust emission standards to be introduced. It is important to note, however, that the modelling of evaporative emissions undertaken in this study has some uncertainties, particularly with regard to the magnitude of running and resting losses for Australian vehicles.

Emissions of benzene show significant variation between the scenarios, which is an indication of the fuel benzene level specified for each scenario. The exhaust component of benzene is estimated to account for the majority of emissions over the period studied, although the evaporative component will gradually become more important. As for total hydrocarbons, the reason for this change is that stricter limits on evaporative emissions are not part of the new exhaust emission standards to be introduced, meaning that future evaporative emissions of benzene will depend upon fuel benzene levels.

The Business As Usual travel activity estimates adopted for this study show significant increases in vehicle Kilometres Travelled over the period studied. For most of the pollutants considered, however, total emissions are expected to decrease for all scenarios modelled. Exceptions to this are Scenario 1 (base case) emissions of particulate matter, polycyclic aromatics and acetaldehyde,

which are primarily diesel related. Emissions of these substances are estimated to stabilise or increase after 2010 under Scenario 1 conditions. This is a reflection of increasing diesel vehicle usage expected for future years.

Particulate matter emissions are estimated to significantly reduce under Scenarios 2 to 6 compared with the base case. The extent of reduction is similar for these scenarios, which is an indication that the main influence of cleaner fuels is to allow the introduction of vehicles with improved emissions performance. Petrol vehicles are expected to contribute the majority of particulate emissions by 2010, which reflects the fact that particulate emission rates of these vehicles are not explicitly controlled as part of new emission standards.

The emissions sensitivity of emissions on aromatics/olefins content in petrol and sulfur content/cetane number in diesel was investigated. For petrol vehicles, the results indicate that benzene is sensitive to the level of aromatics, whereas other pollutants are relatively insensitive. Changes to olefin content did not impact significantly on emissions. For diesel vehicles, reduction of sulfur levels in diesel fuel from current levels to Euro 4 levels is expected to reduce particulate matter emissions. Emissions were found to be relatively insensitive to cetane number.

Fuel quality has little impact of greenhouse emissions from the transport fleet and the best prospects for improvement in greenhouse emissions will come from vehicle technology advancements that allow improvements in fuel economy. Fuel quality improvements are required to enable technologies which control air pollutant emissions associated with engine efficiency improvement. (For example lean burn technology offers the promise of improved fuel efficiency at the cost of higher emissions of oxides of nitrogen from the engine. Low sulfur levels in fuel are required to support de-NO_x catalysts to address these emissions).

Projected greenhouse gas emissions for the Australian transport fleet are projected to substantially exceed the target of an 8% increase from 1990 to 2010 agreed for Australian under the Kyoto Protocol.

Uncertainties

The emissions projections presented provide a reasonable basis for assessment of transport emissions to 2010 for the nominated scenario. The projections contain uncertainties in relation to the application of emissions sensitivity factors from international experience (predominately Europe and United states). Predictions of emissions to 2020 must be considered somewhat speculative as new vehicle technologies, such as fuel cell engines and hybrid vehicles, may change the nature of the motor vehicle fleet within that time frame.