14. Petrohol

14.1 Background

Anhydrous ethanol can be used as an additive in petrol. We use the term petrohol for a blend of 10% anhydrous ethanol in premium unleaded petrol. The symbols E10P or E10PULP are also used for this fuel, depending on whether it is necessary to specify the type of petrol (P) with which the ethanol is blended. The upstream emissions associated with anhydrous ethanol and with premium unleaded petrol have been dealt with in separate chapters. This chapter will therefore not repeat the upstream production and processing information.

14.2 Full Fuel-Cycle Emissions

There has been substantial US interest in the use of ethanol in cars. The reason for this is that the Californian Government, through their Air Resources Board, requires vehicles to use “reformulated gasoline”. Originally such reformulated gasoline could be made by blending MTBE (methyl tertiary-butyl ether) into petrol. Because of the contamination of Californian groundwater with MTBE the Californian Governor ordered the removal of MTBE from petrol and studies on the environmental and health effects of ethanol in petrol. The use of ethanol produces an oxygenated fuel that satisfies the requirements of Californian reformulated gasoline.

Oygenates are added to petrol to improve the anti-knock performance and to reduce emissions. Reuter et al (1992) studied European petrol oxygenated with MTBE, ETBE and ethanol and found that the emissions of oxygenated petrol are independent of the oxygenate that is used.

14.2.1 Tailpipe emissions

Anhydrous ethanol is rarely used as a fuel in its own right, though it is frequently used in a blend of 85% anhydrous ethanol with 15% petrol. Petrohol (petrol and ethanol blends that range from 5% to 26% ethanol) consists of a blend of anhydrous ethanol and petrol. In this chapter we will use the term petrohol (or E10PULP) to refer to 95 RON PULP with a 10% ethanol blend. Such fuel has an oxygen level of 3.5%. Table 1 gives the tailpipe emissions (in kg) over the 300,000 km life of a typical vehicle using petrol and using oxygenated petrol (Maclean, 1998; 2000). These values have been used for the tailpipe emissions in the subsequent full-fuel cycle analysis (with appropriate allowance for the fact that carbon dioxide emitted from any ethanol made from renewable fuels is not considered to be a greenhouse gas).

Table 14.1
Lifetime exhaust emissions (kg) of air pollutants and carbon dioxide from petrol and oxygenated petrol

	NMHC	CO	NOx	PM	THC	CO_2
Petrol	36	494	58	12	60	53676
Oxygenated petrol	27±11	416±248	50±20		46±15	56425±289

14.3 Results

14.3.1 Emissions per unit energy

Table 14.2
Exbodied emissions per MJ of petrohol based on ethanol from various feedstocks

Full Lifecycle	Units	PULP	PULP E10P (molasses-exp.sys. bound.)	PULP E10P (molasses-eco.allocat.)	PULP E10P (wheat starch waste)	PULP E10P (wheat)	PULP E10P (wheat WS)	PULP E10P (wood waste)	PULP E10P (ethylene)
Greenhouse	kg CO_2	0.0888	0.0895	0.0913	0.0891	0.0911	0.0889	0.0874	0.0974
HC total	g HC	0.170	0.139	0.139	0.138	0.142	0.199	0.172	0.173
HC urban	g HC	0.141	0.111	0.112	0.111	0.112	0.168	0.145	0.141
NOx total	g NOx	0.185	0.175	0.174	0.173	0.185	0.181	0.170	0.186
NOx urban	g NOx	0.129	0.121	0.122	0.121	0.123	0.119	0.118	0.132
CO total	g CO	0.930	0.820	0.830	0.786	0.834	1.014	0.902	0.790
CO urban	g CO	0.920	0.811	0.821	0.777	0.777	0.958	0.893	0.779
PM10 total	mg PM10	38.2	38.0	38.0	39.2	39.4	40.9	39.5	38.2
PM10 urban	mg PM10	36.9	36.6	36.6	37.9	38.0	39.5	38.2	36.9
Energy embodied	MJ LHV	1.14	1.10	1.10	1.10	1.11	1.12	1.23	1.28

Table 14.3
Precombustion emissions per MJ of petrohol based on ethanol from various feedstocks

Precombustion	Units	PULP	PULP E10P (molasses-exp.sys.bound.)	PULP E10P (molasses-eco.allocat.)	PULP E10P (wheat starch waste)	PULP E10P (wheat)	PULP E10P (wheat WS)	PULP E10P (wood waste)	PULP E10P (ethylene)
Greenhouse	kg CO_2	0.0177	0.0193	0.0211	0.0189	0.0209	0.0187	0.0172	0.0227
HC total	g HC	0.0543	0.0519	0.0518	0.0513	0.0554	0.112	0.0848	0.086
HC urban	g HC	0.026	0.025	0.025	0.024	0.025	0.081	0.058	0.055
NOx total	g NOx	0.094	0.096	0.096	0.094	0.107	0.103	0.092	0.108
NOx urban	g NOx	0.038	0.042	0.044	0.042	0.045	0.041	0.040	0.054
CO total	g CO	0.021	0.055	0.065	0.021	0.068	0.248	0.136	0.024
CO urban	g CO	0.011	0.045	0.055	0.011	0.012	0.192	0.127	0.014
PM10 total	mg PM10	5.19	4.93	4.9	6.19	6.38	7.89	6.49	5.19
PM10 urban	mg PM10	3.8	3.59	3.58	4.88	4.9	6.41	5.18	3.85
Energy embodied	MJ LHV	1.14	1.10	1.10	1.10	1.11	1.12	1.23	1.28

Table 14.4
Tailpipe emissions per MJ of petrohol based on ethanol from various feedstocks

Combustion	Units	PULP	PULP E10P (molasses-exp.sys.bound.)	PULP E10P (molasses-eco.allocat.)	PULP E10P (wheat starch waste)	PULP E10P (wheat)	PULP E10P (wheat WS)	PULP E10P (wood waste)	PULP E10P (ethylene)
Greenhouse	kg CO_2	0.071	0.070	0.070	0.070	0.070	0.070	0.070	0.075
HC total	g HC	0.116	0.087	0.087	0.087	0.087	0.087	0.087	0.087
HC urban	g HC	0.116	0.087	0.087	0.087	0.087	0.087	0.087	0.087
NOx total	g NOx	0.091	0.078	0.078	0.078	0.078	0.078	0.078	0.078
NOx urban	g NOx	0.091	0.078	0.078	0.078	0.078	0.078	0.078	0.078
CO total	g CO	0.909	0.766	0.766	0.766	0.766	0.766	0.766	0.766
CO urban	g CO	0.909	0.766	0.766	0.766	0.766	0.766	0.766	0.766
PM10 total	mg PM10	33.06	33.06	33.06	33.06	33.06	33.06	33.06	33.06
PM10 urban	mg PM10	33.06	33.06	33.06	33.06	33.06	33.06	33.06	33.06
Energy embodied	MJ LHV	0	0	0	0	0	0	0	0

Table 14.5
Summary of exbodied emissions per MJ of petrohol based on ethanol from various feedstocks

		PULP	PULP E10P (molasses-exp.sys.bound.)	PULP E10P (molasses-eco.allocat.)	PULP E10P (wheat starch waste)	PULP E10P (wheat)	PULP E10P (wheat WS)	PULP E10P (wood waste)	PULP E10P (ethylene)
Greenhouse	Precombustion	0.0177	0.0193	0.0211	0.0189	0.0209	0.0187	0.0172	0.0227
Greenhouse	Combustion	0.0711	0.0702	0.0702	0.0702	0.0702	0.0702	0.0702	0.0747
HC total	Precombustion	0.0543	0.0519	0.0518	0.0513	0.0554	0.1120	0.0848	0.0860
HC total	Combustion	0.1157	0.0868	0.0868	0.0868	0.0868	0.0868	0.0868	0.0868
HC urban	Precombustion	0.0257	0.0247	0.0248	0.0243	0.0248	0.0813	0.0578	0.0545
HC urban	Combustion	0.1157	0.0868	0.0868	0.0868	0.0868	0.0868	0.0868	0.0868
NOx total	Precombustion	0.0937	0.0962	0.0961	0.0944	0.1070	0.1030	0.0917	0.1080
NOx total	Combustion	0.091	0.078	0.078	0.078	0.078	0.078	0.078	0.078
NOx urban	Precombustion	0.038	0.042	0.044	0.042	0.045	0.041	0.040	0.054
NOx urban	Combustion	0.091	0.078	0.078	0.078	0.078	0.078	0.078	0.078
CO total	Precombustion	0.0212	0.0548	0.0645	0.0206	0.0680	0.2480	0.1360	0.0240
CO total	Combustion	0.9091	0.7656	0.7656	0.7656	0.7656	0.7656	0.7656	0.7656
CO urban	Precombustion	0.0113	0.0451	0.0551	0.0112	0.0116	0.1920	0.1270	0.0136
CO urban	Combustion	0.9091	0.7656	0.7656	0.7656	0.7656	0.7656	0.7656	0.7656
PM10 total	Precombustion	5.19	4.93	4.90	6.19	6.38	7.89	6.49	5.19
PM10 total	Combustion	33.06	33.06	33.06	33.06	33.06	33.06	33.06	33.06
PM10 urban	Precombustion	3.80	3.59	3.58	4.88	4.90	6.41	5.18	3.85
PM10 urban	Combustion	33.06	33.06	33.06	33.06	33.06	33.06	33.06	33.06
Energy embodied	Precombustion	1.14	1.10	1.10	1.10	1.11	1.12	1.23	1.28

14.3.2 Emissions per unit distance

Table 14.6
Exbodied emissions per km of petrohol based on ethanol from various feedstocks

Full Lifecycle	Units	PULP	PULP E10P (molasses-exp.sys. bound.)	PULP E10P (molasses-eco.allocat.)	PULP E10P (wheat starch waste)	PULP E10P (wheat)	PULP E10P (wheat WS)	PULP E10P (wood waste)	PULP E10P (ethylene)
Greenhouse	kg CO_2	0.2148	0.2164	0.2209	0.2157	0.2204	0.2150	0.2114	0.2358
HC total	g HC	0.412	0.336	0.335	0.334	0.344	0.481	0.415	0.418
HC urban	g HC	0.342	0.270	0.270	0.269	0.270	0.407	0.350	0.342
NOx total	g NOx	0.447	0.423	0.423	0.418	0.449	0.440	0.412	0.453
NOx urban	g NOx	0.313	0.292	0.296	0.292	0.299	0.289	0.285	0.320
CO total	g CO	2.251	1.986	2.009	1.903	2.018	2.454	2.182	1.911
CO urban	g CO	2.227	1.962	1.986	1.880	1.881	2.317	2.159	1.886
PM10 total	mg PM10	92.5	91.9	91.8	95.0	95.4	99.1	95.7	92.6
PM10 urban	mg PM10	89.2	88.7	88.7	91.8	91.9	95.5	92.5	89.3
Energy embodied	MJ LHV	2.75	2.65	2.66	2.65	2.70	2.71	2.99	3.10

Table 14.7
Precombustion emissions per km of petrohol based on ethanol from various feedstocks

Precombustion	Units	PULP	PULP E10P (molasses-exp.sys. bound.)	PULP E10P (molasses-eco.allocat.)	PULP E10P (wheat starch waste)	PULP E10P (wheat)	PULP E10P (wheat WS)	PULP E10P (wood waste)	PULP E10P (ethylene)
Greenhouse	kg CO_2	0.0428	0.0466	0.0511	0.0459	0.0506	0.0452	0.0416	0.0550
HC total	g HC	0.132	0.126	0.125	0.124	0.134	0.271	0.205	0.208
HC urban	g HC	0.062	0.060	0.060	0.059	0.060	0.197	0.140	0.132
NOx total	g NOx	0.227	0.233	0.233	0.228	0.259	0.250	0.222	0.263
NOx urban	g NOx	0.093	0.102	0.106	0.102	0.109	0.099	0.096	0.130
CO total	g CO	0.051	0.133	0.156	0.050	0.165	0.601	0.329	0.058
CO urban	g CO	0.027	0.109	0.133	0.027	0.028	0.464	0.306	0.033
PM10 total	mg PM10	12.5	11.9	11.8	15	15.4	19.1	15.7	12.6
PM10 urban	mg PM10	9.19	8.69	8.68	11.8	11.9	15.5	12.5	9.32
Energy embodied	MJ LHV	2.75	2.65	2.66	2.65	2.7	2.71	2.99	3.1

Table 14.8
Tailpipe emissions per km of petrohol based on ethanol from various feedstocks

Combustion	Units	PULP	PULP E10P (molasses-exp.sys. bound.)	PULP E10P (molasses-eco.allocat.)	PULP E10P (wheat starch waste)	PULP E10P (wheat)	PULP E10P (wheat WS)	PULP E10P (wood waste)	PULP E10P (ethylene)
Greenhouse	kg CO_2	0.172	0.170	0.170	0.170	0.170	0.170	0.170	0.181
HC total	g HC	0.280	0.210	0.210	0.210	0.210	0.210	0.210	0.210
HC urban	g HC	0.280	0.210	0.210	0.210	0.210	0.210	0.210	0.210
NOx total	g NOx	0.220	0.190	0.190	0.190	0.190	0.190	0.190	0.190
NOx urban	g NOx	0.220	0.190	0.190	0.190	0.190	0.190	0.190	0.190
CO total	g CO	2.200	1.853	1.853	1.853	1.853	1.853	1.853	1.853
CO urban	g CO	2.200	1.853	1.853	1.853	1.853	1.853	1.853	1.853
PM10 total	mg PM10	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
PM10 urban	mg PM10	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
Energy embodied	MJ LHV	0	0	0	0	0	0	0	0

Table 14.9
Summary of exbodied emissions per km of petrohol

		PULP	PULP E10P (molasses-exp.sys. bound.)	PULP E10P (molasses-eco.allocat)	PULP E10P (wheat starch waste)	PULP E10P (wheat)	PULP E10P (wheat WS)	PULP E10P (wood waste)	PULP E10P (ethylene)
Greenhouse	Precombustion	0.0428	0.0466	0.0511	0.0459	0.0506	0.0452	0.0416	0.0550
Greenhouse	Combustion	0.1720	0.1698	0.1698	0.1698	0.1698	0.1698	0.1698	0.1808
HC total	Precombustion	0.1320	0.1260	0.1250	0.1240	0.1340	0.2710	0.2050	0.2080
HC total	Combustion	0.2800	0.2100	0.2100	0.2100	0.2100	0.2100	0.2100	0.2100
HC urban	Precombustion	0.0622	0.0599	0.0600	0.0589	0.0600	0.1970	0.1400	0.1320
HC urban	Combustion	0.2800	0.2100	0.2100	0.2100	0.2100	0.2100	0.2100	0.2100
NOx total	Precombustion	0.2270	0.2330	0.2330	0.2280	0.2590	0.2500	0.2220	0.2630
NOx total	Combustion	0.220	0.190	0.190	0.190	0.190	0.190	0.190	0.190
NOx urban	Precombustion	0.093	0.102	0.106	0.102	0.109	0.099	0.096	0.130
NOx urban	Combustion	0.220	0.190	0.190	0.190	0.190	0.190	0.190	0.190
CO total	Precombustion	0.0513	0.1330	0.1560	0.0499	0.1650	0.6010	0.3290	0.0582
CO total	Combustion	2.2000	1.8526	1.8526	1.8526	1.8526	1.8526	1.8526	1.8526
CO urban	Precombustion	0.0272	0.1090	0.1330	0.0272	0.0280	0.4640	0.3060	0.0329
CO urban	Combustion	2.2000	1.8526	1.8526	1.8526	1.8526	1.8526	1.8526	1.8526
PM10 total	Precombustion	12.50	11.90	11.80	15.00	15.40	19.10	15.70	12.60
PM10 total	Combustion	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
PM10 urban	Precombustion	9.19	8.69	8.68	11.80	11.90	15.50	12.50	9.32
PM10 urban	Combustion	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
Energy embodied	Precombustion	2.75	2.65	2.66	2.65	2.70	2.71	2.99	3.10

14.3.3 Uncertainties

In the absence of information on the variability and uncertainties associated with E10P emissions, we assume that the uncertainties are the same as those associated with diesohol (E15D).

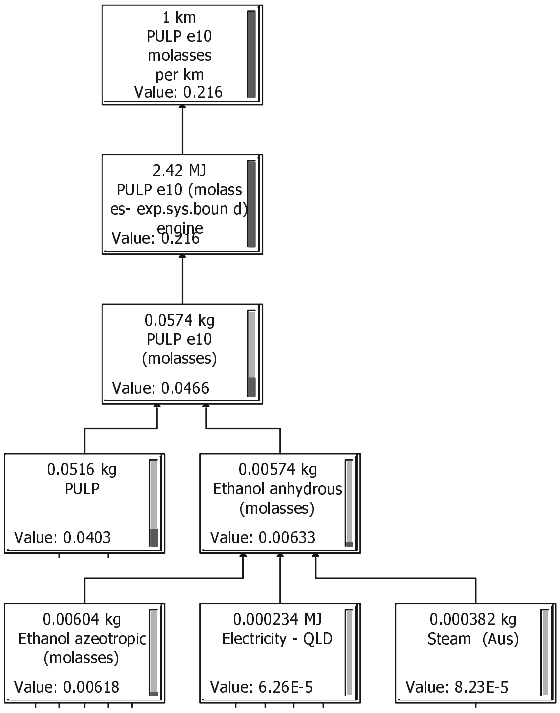

Figure 14.1
Exbodied greenhouse gases emissions (kg CO_2eq) from E10 in PULP production and processing and use in vehicle (Ethanol component is from molasses based on Sarina plant and using expanded system boundary allocation)

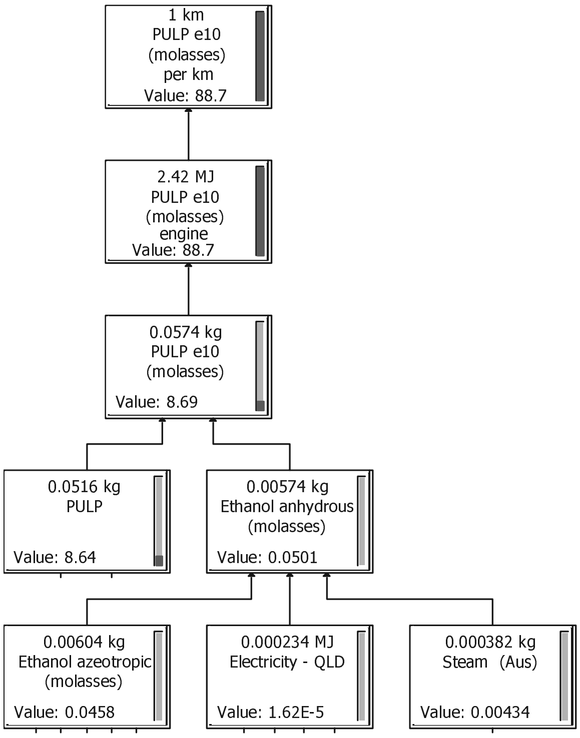

Figure 14.2
Exbodied particulate matter (mg - urban) from E10 in PULP production and processing and use in vehicle (Ethanol component is from molasses based on Sarina plant and using expanded system boundary allocation)

The exbodied greenhouse gas emissions depicted in Figure 14.1 reflect a combination of the fuel economy obtained by using petrohol, and the fact that 10% of the petrohol consists of a renewable fuel whose carbon dioxide emissions are not treated as a greenhouse gas. On the basis of the data in MacLean (1998) the emissions of CO_2 for premium unleaded petrol is 172 g/km whereas for petrohol it is 188 g/km.

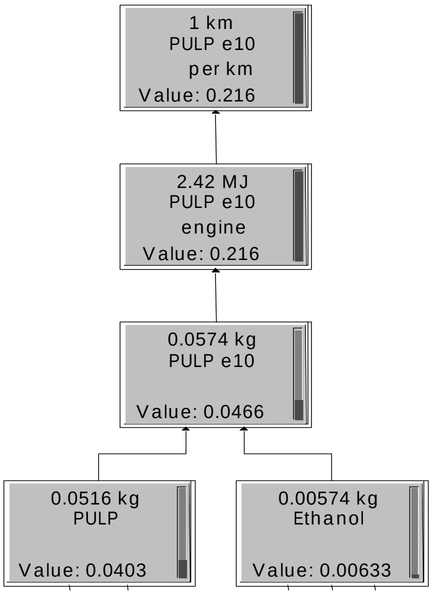

Figure 14.3
Allowing for the renewable components of petrohol means that 216 gram of exbodied greenhouse gases are emitted per kilometre.

Examining Figure 14.3 it may be noted that the tailpipe emissions of greenhouse gases from petrohol come to 170 g/km CO_2-equ. This is from 0.216 – 0.046 kg, as shown in the bottom part of the second and third boxes. The actual tailpipe emissions of CO_2 consist of 170 g/km from the petrol (being 0.9 x 188 g/km), and 11 g from combustion of 5.7 g of ethanol. This comprises 181 g/km.

The expected greenhouse gas saving of 11 g/km by using ethanol does not eventuate because of the altered fuel economy. An equivalent petrol fuelled vehicle emits 172 g/km CO_2-equ. Furthermore, the greenhouse gas benefit of 2 g/km is negated by the greater upstream processing energy in the production of ethanol so that the exbodied greenhouse gas emissions of petrol are 215 g/km whereas those of petrohol are very slightly higher at 216 g/km.

14.4 Viability and Functionality

There is considerable international experience on the use of ethanol as a blend in petrol in the United States, where it is needed under the legislation requiring the use of reformulated gasoline, and in Brazil where sugar derived ethanol is used as an automotive fuel and also as a blend (gasohol). No special engine modification or handling precautions are needed when using a 10% ethanol blend. Such widespread international experience indicates that the viability and functionality of petrohol will be much the same as of the corresponding petrol with which the ethanol is blended.
The web site (http://www.greenfuels.org/ethaques.html) of the Canadian Renewable Fuels Association answers many questions related to the viability and functionality of ethanol in the form of questions and answers. These are reproduced here.

14.4.1 Safety and handling

Is it safe to handle fuel ethanol blends?
The WHMIS Material Safety Data Sheet (MSDS) reveals that the properties of ethanol blends are substantially the same as conventional gasoline blends. Occupational health and safety risks presented

by the use of ethanol gasoline do not appear to be any different than those posed by conventional gasoline blends.

Do ethanol blends need special handling or storage?

Only in special circumstances. The gasoline marketer should pump any accumulated water from the storage tank, and add a final filter to the dispensing hose. It is wise also to check seasonally used small engines such as chainsaws and outboard motors (which are more susceptible to water contamination) for the presence of water, and drain the tank if necessary.

14.4.2 Warranty

What is the effect of using ethanol-blended fuels on the manufacturer's warranty of my vehicle?

When the use of ethanol began in 1979, most automobile manufacturers did not even address alcohol fuels. As soon as each manufacturer tested their vehicles, they approved the use of a 10% ethanol blend. Today, all manufacturers approve the use of 10% ethanol blends, and some even recommend it for environmental reasons.

14.4.3 Functionality

Is it necessary to make changes to my vehicle in order to use ethanol-blended fuels?

All cars built since the 1970s are fully compatible with up to 10% ethanol in the mixture.

Will ethanol-blended fuels work in fuel-injected engines?

Yes. It may be necessary to change the filter more frequently. Ethanol helps to clean out the fuel-injection system, and may aid in the maintenance of a cleaner engine. Since 1985, all ethanol blends and nearly all non-ethanol gasolines have contained detergent additives that are designed to prevent injector deposits. These detergents have been very effective in addressing this issue.

Does ethanol in the fuel work as an effective gas line anti-freeze?

Gas line anti-freeze contains alcohol-usually methanol, ethanol, or isopropyl, which can be used up to a 0.3% level in a car's fuel tank. All alcohols have the ability to absorb water, and therefore condensation in the fuel system is absorbed and does not have the opportunity to collect and freeze. If an ethanol blend contains 10% ethanol, it is able to absorb more water than a small bottle of isopropyl, and eliminates the need and expense of adding a gas line anti-freeze.

Will ethanol burn valves?

Ethanol will not burn engine valves. In fact, ethanol burns cooler than gasoline. Ethanol high-powered racing engines use pure alcohol for that reason.

Will using ethanol-blended fuels plug the fuel filters in my vehicle?

Ethanol can loosen contaminants and residues that have been deposited by previous gasoline fills. These can collect in the fuel filter. This problem has happened occasionally in older cars, and can easily be corrected by changing fuel filters. Symptoms of a plugged fuel filter will be hesitation, missing, and a loss of power. Once your car's fuel system is clean, you will notice improved performance.

Can I mix fuels?

Yes. All gasolines in Canada (including low-level ethanol blends) must meet the specifications of the Canadian General Standards Board (CGSB). They are all interchangeable.

Operational range

What is the effect of using ethanol-blended fuels on fuel economy?

Changes in fuel economy are minimal. While a 10% ethanol blend contains about 97% of the energy of 'pure' gasoline, this is compensated by the fact that the combustion efficiency of the ethanol-blended fuel is increased. The net result is that most consumers do not detect a difference in their fuel economy, although many people using ethanol-blended fuels have said that their fuel economy has improved.

The US National Science and Technology Council (1997) conducted a comprehensive examination of oxygenated fuels and determined that “with regard to fuel economy, the theoretical change in fuel economy as a result of the addition of oxygenates to gasoline is in the range of a 2% to 3% reduction in fuel economy.”

14.5 Health

14.5.1 Production and transport

Anhydrous ethanol can be used as an additive in petrol. The upstream emissions associated with anhydrous ethanol and with premium unleaded petrol have been dealt with in separate chapters. This chapter will therefore not repeat the upstream production and processing information.

Particulate matter
See anhydrous ethanol and PULP sections.
The LCA estimates for E10PULP urban precombustion (car) PM10 emissions are:

- Wheat: 12 mg/km
- Wheat WS: 16 mg/km
- Wheat starch waste: 12 mg/km
- Molasses (alternative allocation): 9 mg/km
- Molasses: 9 mg/km
- Woodwaste: 13 mg/km
- Ethylene: 9 mg/km

Air toxics
See anhydrous ethanol and PULP sections.
The LCA estimates for E10PULP urban precombustion (car) HC emissions are:

- Wheat: 0.060 g/km
- Wheat WS: 0.197 g/km
- Wheat starch waste: 0.059 g/km
- Molasses (alternative allocation): 0.06 g/km
- Molasses: 0.060 g/km
- Woodwaste: 0.140 g/km
- Ethylene: 0.132 g/km

14.5.2 Use

Table 14.1 gives the tailpipe emissions (in kg) over the life of a typical vehicle using petrol and using oxygenated petrol (Maclean, 1998; 2000)

Particulate matter

The estimate for PULP and E10PULP combustion (car) PM10 emissions is 80 mg/km.

Air toxics

Table 14.10 gives the exhaust emissions of air toxics given by MacLean (1988) that may also be found in the supporting documentation of MacLean and Lave (2000). The air toxics emissions are given in terms of mass emitted per vehicle lifetime, but are also given in terms of weighted emissions in terms of sulfuric acid equivalents. In both cases, petrohol produces a marked decline in the emissions of air toxics. For comparison, the weighted emissions for diesel exhaust are estimated to range from 37,000 to 80,000 grams sulfuric acid equivalent per lifetime.

Table 14.10
Lifetime exhaust emissions (g) of air toxics from petrol and oxygenated petrol, along with CMU-ET[1] weighted toxic emissions (grams sulfuric acid equivalent)

	Benzene	1,3-butadiene	Form-aldehyde	Acet-aldehyde	Aggregate toxics
Petrol	1820	210	350	126	2506
CMU-ET weighted	1138	48	389	0.4	1575
Oxygenated petrol	840	126	336	84	1386
CMU-ET weighted	525	29	373	0.2	927

Motor vehicle emissions data indicates that the use of ethanol results in substantial reductions in air toxics emissions. According to the USEPA (1993) substantial reduction in benzene, 1,3 butadiene, refuelling vapours and particulate matter occur, while formaldehyde would be emitted at levels similar to gasoline vehicles. They claim that acetaldehyde emissions may increase substantially, though Table 14.10 does not support this contention.

Oxygenated fuels perform better than conventional fuels in terms of lower emissions of air toxics. Armstrong (2000) reviews the health effects of ethanol vapours coming from ethanol blended petrol and finds no evidence of any health effects. The Californian Office of Environmental Health Hazard Assessment (1999) found similar results. The main thrust of this latter report was to compare ethanol in relation to MTBE as a fuel oxygenate. They concluded that “the direct effects of ethanol (if any public exposure were to occur) would be substantially less severe than the effects of MTBE.”

14.5.3 Summary

E10PULP tailpipe particulate and HC emissions are lower than PULP emissions irrespective of the feedstock. E10PULP tailpipe emissions of benzene, 1,3 butadiene, are substantially less than petrol vehicles, while formaldehyde emissions are similar. There is contradictory information about the emissions of acetaldehyde tailpipe emissions with some studies showing and increase while other show a decrease compared with petrol. More research is required to clarify this issue.

14.6 OHS Issues

Ethanol in solution is hazardous according to Worksafe Australia, with high flammability, moderate toxicity, and is a moderate irritant. The flash point of the fuel emulsion becomes that of alcohol when the alcohol content exceeds 5% of the volume.

Ethanol fuels increase permeation of elastomers that have been used in automotive applications (eg: rubber hoses, plastic fuels tanks). Research is required to quantify the permeation impacts of ethanol. (Harold Haskew & Associates, 2001).

The OHS issues in the lifecycle of ethanol are covered by a range of State and Commonwealth occupational health and safety provisions. While there will be different OHS issues involved in the production process associated with ethanol based fuels compared with LSD, no OHS issues unique to the production and distribution of ethanol have been identified.

14.7 Vapour Pressure Issues

There is contradictory information about evaporative emissions from ethanol added fuels. Some studies indicate that the use of ethanol results in substantial reductions in refuelling vapours. Others state that to contain evaporative emissions from vehicles using alcohol fuel, measures may need to be implemented to control fuel vapour pressure, and control evaporative emissions from diesel fuel vehicles.

[1] Carnegie Mellon University Equivalent Toxicity

The higher vapour pressure of ethanol/gasoline blends compared to neat gasoline is a concern in their use. The effects of ethanol addition to PULP do not appear to have been specifically studied, but other studies with ethanol/gasoline blends provide useful guides to the magnitude of the effects.

Effects of ethanol addition on Reid vapour pressure have been summarised in a National Research Council report (NRC, 1999) produced for the USEPA, as follows:

> Studies indicate that fuel RVP increases as ethanol is initially added. The greatest RVP increase occurs with an ethanol content of about 5 vol % and is about 1 psi (~ 6.9 kPa). For ethanol concentrations greater than 5 vol %, the RVP slowly decreases

There are comprehensive studies of ethanol blends (CARB, 1998), which show that adding 10% ethanol to gasoline, resulting in an increase of RVP from 48 kPa to 55 kPa, increases the evaporative hydrocarbon emissions by an estimated 40%. The impacts of these increases on ozone-forming potential are discussed below.

Evaporative emission system technologies designed to reduce evaporative emissions from vehicles using gasoline and gasoline blended with 10 percent ethanol have also been examined (Louis Browning of ARCADIS Geraghty & Miller, reported in CRC (1999)). When using ethanol in gasoline, evaporative emissions are almost twice as high as when using gasoline without ethanol due to much higher permeation rates. This study also showed that by using low permeation materials, evaporative emissions could be substantially reduced from both fuels.

Effects of ethanol blends on ozone forming potential

CARB (1998) report overall increases of 40% in evaporative emissions in a 10% ethanol/gasoline blend using multi-day test procedures. As a consequence of this increase in evaporative emissions CARB estimate that use of a 10% ethanol blend would result in an overall increase of about 17% in ozone forming potential for the ethanol blend compared to a fully complying (RVP less than 7 psi or 48 kPa) gasoline. On this basis they have recommended against the use of 10% ethanol blends.

Similarly the NRC (1999) concludes that the use of an ethanol-containing fuel with a 1 psi higher RVP is likely to produce a negative air quality impact.

By contrast, the USEPA have recently (USEPA, 2000) proposed an adjustment to the reformulated gasoline VOC standard to encourage the use of ethanol blends given the beneficial impacts of ethanol on CO emissions in particular. It should be noted, however, that this increased use is associated with strict controls on the volatility of the gasoline with which the ethanol is blended, and hence requires changes to refinery practice and co-operation between refiners and ethanol manufacturers.

In any case evaporative emissions are a critical issue in the use of ethanol blends, and need to be evaluated with direct reference to Australian conditions, including emissions performance of the Australian fleet and current refinery practice.

14.8 Environmental Issues

Environmental and ESD issues associated with ethanol are discussed in Chapter 6.

Ethanol is not persistent in the environment. Virtually any environment supporting bacterial populations is believed to be capable of biodegrading ethanol. Atmospheric degradation is also expected to be rapid.

The tailpipe greenhouse gas emissions from petrohol (from renewable sources) are lower than those of petrol because of the use of a renewable fuel in the blend, but this advantage is offset by reduced fuel economy. On a life-cycle basis the source of the ethanol is crucial in determining whether it is, or is not, climate friendly. Only petrohol made from wood waste has lower exbodied greenhouse gas emissions than premium unleaded petrol. Provided that ethylene is not used as the feedstock, then the exbodied emissions of air toxics are lower from petrohol than from petrol. The increased evaporative emissions from petrohol indicate the possibility of increased emissions of ozone pre-cursors.

14.9 Expected Future Emissions

Arcoumanis (2000) developed a model that examines a given alternative fuel relative to the reference diesel engine (Euro2) in terms of a specific regulated pollutant. A value of 1 implies identical performance to the low sulfur diesel/Euro2 combination. A value greater than 1 implies inferior performance, whereas a value less than 1 indicates superior performance.

Table 14.11 lists the estimated emissions factors for oxygenated petrol. The columns in bold represent the standards relative to the Euro2 standard. The adjacent column gives the expected performance of petrohol. The estimates of Arcoumanis (2000) indicate that petrohol can be expected to meet all future Australian Design Rules for all pollutants.

Table 14.11
Estimated emission factors for petrohol under future technologies (PM is unregulated)

Technology	CO	CO	THC	THC	NOx	NOx	CO_2	LCA CO_2
Euro2	**1.0**	0.9	**1.0**	0.9	**1.0**	1.0	**1.0**	0.9
Euro3	**1.05**	0.6	**0.59**	0.5	**0.6**	0.6	**1.0**	0.85
Euro4	**0.45**	0.3	**0.29**	0.3	**0.32**	0.3	**1.0**	0.8

14.10 Summary

14.10.1 Advantages

- As a renewable fuel it should produce less fossil CO_2 than conventional fuels, but the decrease in energy content of the ethanol means that more fuel has to be burnt. This increased fuel consumption, combined with the greater processing energy of the ethanol, means that exbodied greenhouse gases generally increase (albeit very slightly), the only exception being the case of ethanol made from wood waste.
- Tailpipe emissions of CO and HC appear to be lower on average.
- Air toxic levels decrease as the ethanol concentration increases.

14.10.2 Disadvantages

- There are high hydrocarbon evaporative emissions that require adjustment of the vapour pressure of the base petrol to which ethanol is added.
- There are problems of phase stability in the petrol mixture if water is present.