6. Hydrated Ethanol

6.1 Background

Ethanol (C_2H_5OH) is an alcohol, an oxygenated organic carbon compound. It is the intoxicating component of alcoholic beverages, and is also used as a solvent (methylated spirits). By contrast, diesel is a mixture of a range of hydrocarbon compounds, none of which contains oxygen. In blended fuels, the addition to diesel of the oxygen contained in the alcohol changes a number of important fuel characteristics. These include changes in combustion properties, energy content and vaporisation potential.

Ethanol will easily blend with gasoline but not with diesel. Alcohols can be used in diesel engines by either modifying the fuel or by extensive engine adaptations. This chapter will examine hydrated ethanol produced from wheat, sugar cane, molasses and wood, and will discuss one source of ethanol from a non-renewable resource. Hydrated ethanol production is a one-stage refining process, unlike the two-stage anhydrous ethanol. However, from the viewpoint of the LCA, the upstream emissions for ethanol production will be different for every process.

Ethanol can be manufactured from:

- biomass via the fermentation of sugar derived from grain starches or sugar crops;
- biomass via the utilisation of the non-sugar lignocellulosic fractions of crops;
- petroleum and natural gas via an ethylene (C_2H_4) intermediate step (reduction or steam cracking of ethane [C_2H_6] or propane [C_3H_8] fractions).

6.2 Results

We present results for seven different scenarios. These are ethanol made from wheat using natural gas as the energy source, ethanol made from wheat using wheat straw as the energy source (wheat WS), ethanol made from wheat starch, ethanol from molasses treated as a waste product, ethanol from molasses treated on the basis of physical inputs (alt. allocation), ethanol from lignocellulosic processes (woodwaste), and ethanol via ethylene.

6.2.1 Greenhouse gas emissions

Figure 6.1 depicts the greenhouse gas emissions estimated for ethanol and diesohol. These are shown as emissions on an energy basis, as emissions on a per tonne-km basis for trucks, and on a per passenger-km basisfor buses. We have used data from Apelbaum Consulting Group (1997) for the passenger task and the freight task in Australia and taken the mean energy intensity for the Australian freight task to be 1.2 MJ/tonne-km (Apelbaum Consulting Group, 1997: p.118), and the energy intensity of buses to be 1.06 MJ/passenger-km (Apelbaum Consulting Group, 1997: p.116).

As may be expected, the use of a renewable fuel, such as ethanol considerably reduces greenhouse gas emissions because the greenhouse gas accounting rules mean that there are no tailpipe emissions from the combustion of ethanol. If ethanol is made from a fossil fuel (as in the case of ethanol via ethylene) then there are more greenhouse gas emissions involved than if diesel was used.

6.2.2 Particulate matter emissions

Figure 6.2 depicts the particulate matter (PM10) emissions estimated for ethanol. These are shown as emissions on an energy basis, as emissions on a per tonne-km basis for trucks, and on a per passenger-km basisfor buses using the same energy intensities previously noted. In all cases but one the emissions of PM10 are less from ethanol than from the reference fuel (LSD). The exception is the case where the energy to manufacture the ethanol comes from the use of wheat straw (rather than from natural gas). Combustion of the wheat straw generates higher levels of PM10 than use of natural gas or bagasse.

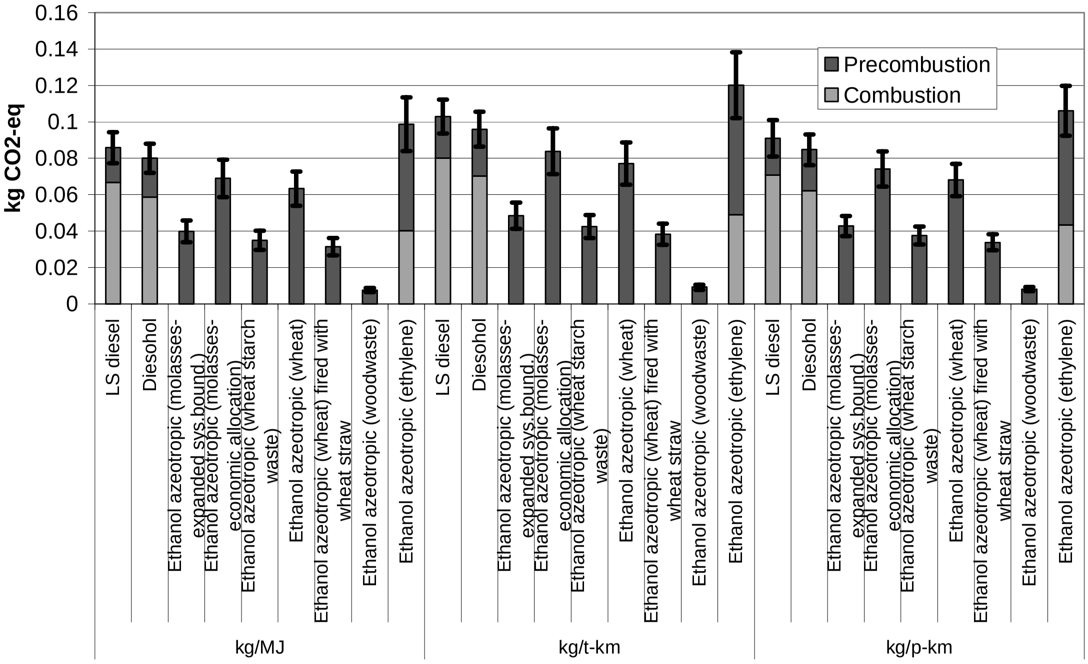

Figure 6.1
Exbodied emissions of greenhouse gases for diesohol and ethanol made from various sources.

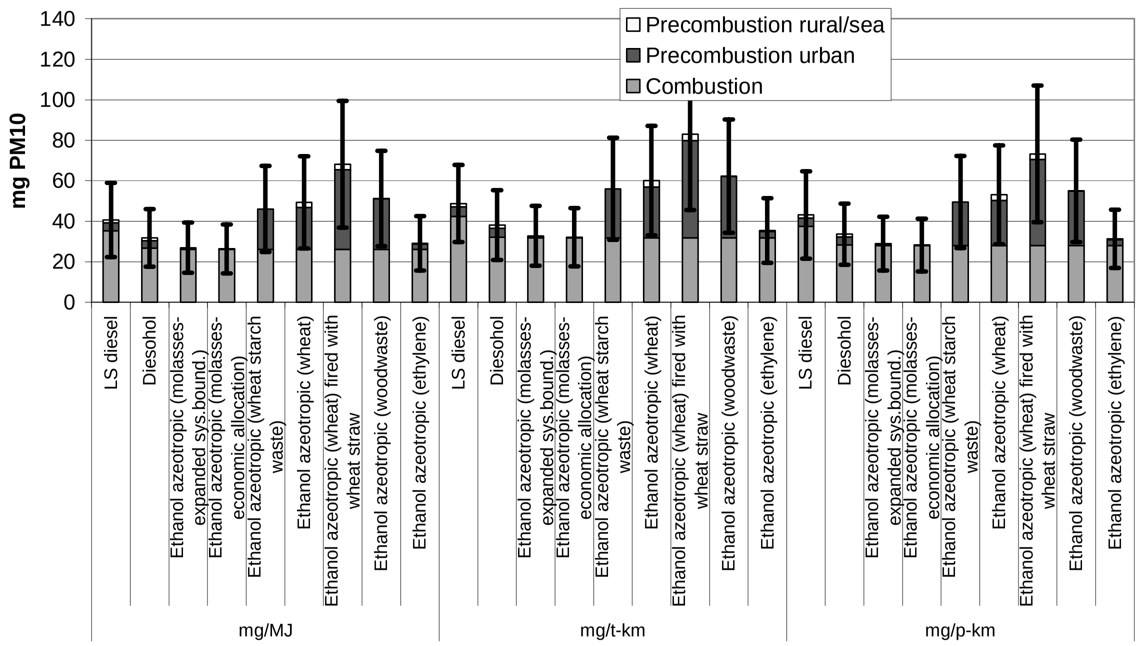

Figure 6.2
Exbodied emissions of particulate matter for diesohol and ethanol made from various sources.

6.2.3 Emissions of oxides of nitrogen

Figure 6.3 depicts the oxides of nitrogen (NOx) emissions estimated for alcohol fuels. These are shown as emissions on an energy basis, as emissions on a per tonne-km basis for trucks, and on a per passenger-km basisfor buses using the same energy intensities previously noted. As a general rule the NOx emissions from ethanol, on a full fuel cycle basis, are comparable to those of the reference fuel.

6.2.4 Emissions of hydrocarbons

Figure 6.4 depicts the non-methanic hydrocarbon (HC) emissions estimated for alcohol fuels. These are shown as emissions on an energy basis, as emissions on a per tonne-km basis for trucks, and on a per passenger-km basisfor buses using the same energy intensities previously noted.

Wheat straw and ethylene have very high precombustion emissions of hydrocarbons. Ethanol made from other sources has emissions comparable to those of the reference fuel.

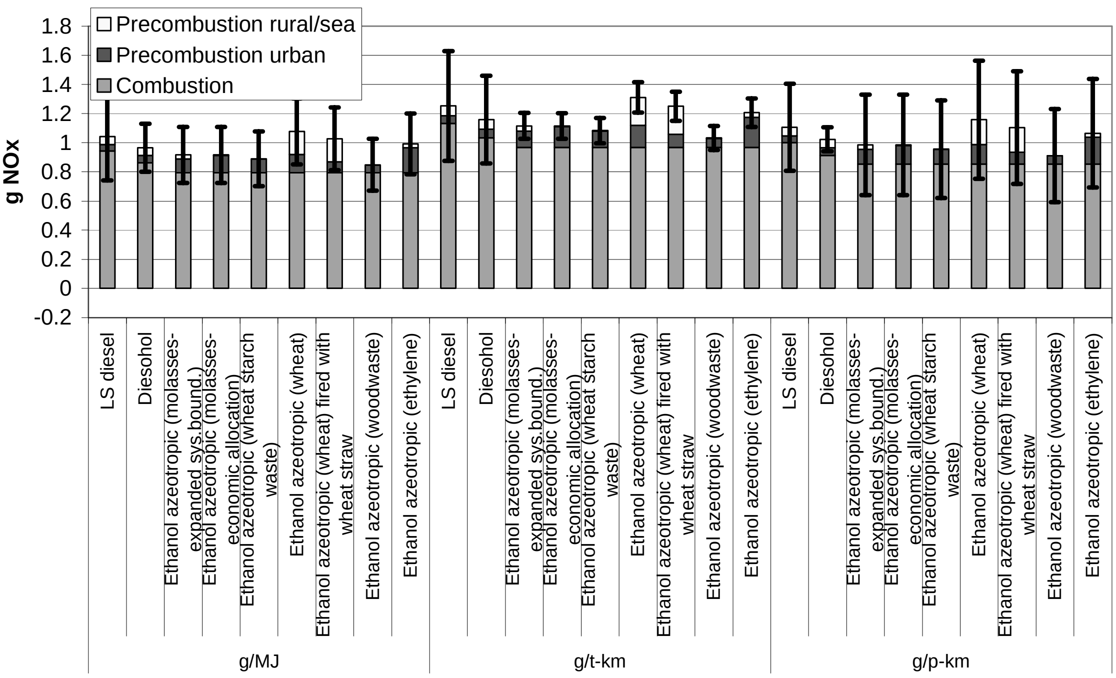

Figure 6.3
Exbodied emissions of oxides of nitrogen for diesohol and ethanol made from various sources.

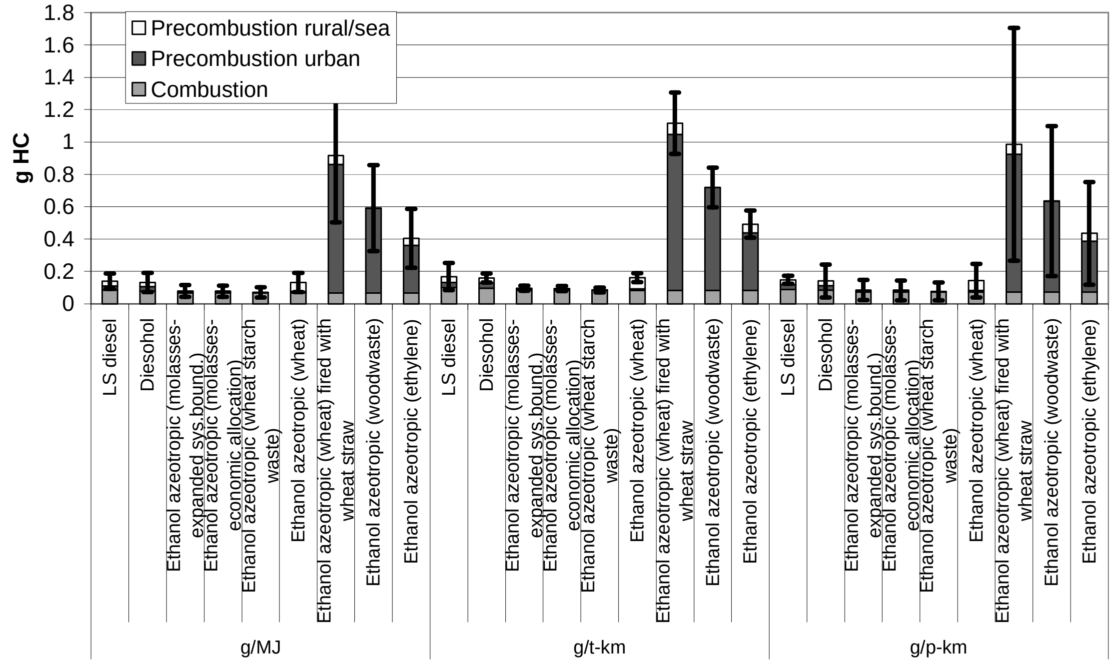

Figure 6.4
Exbodied emissions of hydrocarbons for diesohol and ethanol made from various sources.

6.3 Viability and Functionality

The third generation fleet of ethanol buses runs with oxidation catalysts. In general, ethanol buses have enlarged holes for the fuel injector, modified injection timing, and increased fuel pump capacity. Gaskets and filters need to be alcohol-resistant. In addition, because ethanol has a tendency to dissolve the oil film on greased metal surfaces, castor oil needs to be used for fuel pump lubrication. US transit authorities experienced high rates of engine failure and poor engine reliability with the earlier generation of ethanol buses.

6.4 Health and OH&S

Ethanol upstream emissions of particulate matter and HC range from lower to higher than LSD emissions depending on the feedstock. Ethanol tailpipe emissions of particulate matter and HC for all feedstocks are marginally less than LSD. Limited tailpipe emissions data indicate that ethanol is likely to reduce benzene and 1,3 butadiene emissions compared with LSD, formaldehyde emissions would be similar, while acetaldehyde emissions would increase substantially.

Ethanol in solution is hazardous according to Worksafe Australia, with high flammability, moderate toxicity, and a moderate irritant.

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 compared with LSD, no OHS issues unique to the production and distribution of ethanol have been identified.

Diesel fuel has very low vapour pressure, but the addition of alcohol to diesel (for example diesohol) creates a fuel with a vapour pressure similar to that of ethanol. While modern gasoline vehicles have some evaporative emission control measures, diesel vehicles do not. Evaporative emissions may be a significant problem from unmodified vehicles using ethanol based fuels, but this needs to be tested.

To contain evaporative emissions from vehicles using alcohol fuel, measures may need to be implemented to control fuel vapour pressure.

6.5 Environmental Issues

ESD issues

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. Provided that the source of ethanol is not fossil fuels then it satisfies ESD principles.

In particular, we draw attention to the fact that appropriate disposal of the refinery waste-products is crucial to environmental impacts or benefits. Dunder application is often criticised as being the cause of poor waste quality in Queensland, though there is little evidence of this (www.sunfish.org.au/fishkills/fishkills.htm). Conversely, appropriate and careful disposal of dunder means that many farmers in the district near Sarina now use it as a fertiliser and soil condition - even though it was once considered a poison.

Sustainability
Ethanol from sugar or wheat is liable to be a niche fuel and thus there are no sustainability issues associated with it. Large-scale usage of ethanol will require ligno-cellulosic production to be economical.

Foran and Mardon (1999) contains details of ethanol and methanol production technology and supply constraints, and of the environmental consequences of both crop and fuel production processes. They claim that if ligno-cellulosic ethanol production is used then it would be possible to establish biomass plantations over the next 50 years that meet 90% of Australia’s oil requirements, and specifically to supply all transportation fuels. To do this using ethanol requires biomass production to cover up to 19 million hectares of Australia’s croplands and high rainfall pasture zones. Their modelling approach envisages substantial environmental benefit. In addition to the reduction in greenhouse gas emissions (up to 300 million tonnes by the year 2050), the large-scale planting of tree and shrub crops as ethanol feedstock would help to control dryland salinity and associated problems.

Groundwater
We are not aware of any issues related to groundwater contamination except to note that in the US the replacement of methyl tertiary butyl ether (MTBE) by ethanol in oxygenated fuels was specifically done to reduce groundwater contamination.

We also note ethanol when used as a heavy vehicle fuel may contain 2.3% MTBE. This additive was extensively examined in the US where 15% MTBE (or 7.5% ethanol) was added to petrol to achieve the 2.7% oxygen content required under the Clean Air Act. The use of MTBE is no longer permitted because of concerns in relation to health as a result of groundwater, and hence drinking water, contamination by MTBE.

6.6 Expected Future Emissions

Ethanol can be expected to meet all future Australian Design Rules for all pollutants except hydrocarbon which may be slightly above Euro3 and Euro4 standards.

6.7 Summary

6.7.1 Advantages

- As a renewable fuel, ethanol produces less fossil CO_2 than conventional fuels.
- Particulate emissions are lower with ethanol than with conventional fuels.
- 1,3 butadiene and benzene levels decrease as the ethanol concentration increases.
- Ethanol contains less sulfur than conventional fuels.

6.7.2 Disadvantages

- The chemical emulsifiers and ignition improvers used to blend ethanol may contain harmful chemicals.
- There are higher emissions of formaldehyde and acetaldehyde from ethanol vehicles than from diesel vehicles.
- There may be an odour problem.