4. Biodiesel

4.1 Introduction

Biodiesel is a generic name for fuels obtained by esterification of a vegetable oil. The esterification can be done either by methanol or by ethanol. Biodiesel can be used in a diesel engine without modification. By the year 2002 it is expected that there will be a European wide standard for biodiesel.

Canola is a member of the *Brassica* Family, which includes broccoli, cabbage, cauliflower, mustard, radish, and turnip. It is a variant of the crop rapeseed, with less crucic acid and glucosinolates than rapeseed. Grown for its seed, the seed is crushed for the oil contained within. After the oil is extracted, the by-product is a protein rich meal used by the intensive livestock industry.

Soybeans are a bushy, leguminous plant, *Glycine max*, native of South-East Asia that is grown for the beans, which are used widely in the food industry, for protein in cattle feed and for oil production.

Soybeans are grown predominantly in the wheat belts of Queensland and NSW and to a lesser extent in Victoria.

Tallow comes from meat rendering. This evaporates the moisture and enables the fat, known as 'tallow', to be separated from the high-protein solids, known as 'greaves'. Pure tallow is a creamy-white substance. The greaves are pressed, centrifuged or subjected to a process of solvent extraction to remove more tallow, before being ground into meat and bone meal (MBM).

Current possibilities for the processing of waste cooking oils appear to be:

- Treatment and use in stockfeed in Australia
- Export to Asia for soap or stockfeed production
- Use for production of biodiesel

It is also clear that some waste cooking oil is not collected and is disposed of in landfill or other locations. Biodiesel made from waste cooking oil has come to be known as McDiesel, because the largest source of waste cooking oil is McDonald's restaurants.

4.2 Full Fuel-Cycle Analysis of Emissions

Results are given for biodiesel made from three types of seed crops (canola, soybean, and rape), for biodiesel made from tallow and for biodiesel from waste cooking oil. In the case of these last two feedstocks, it has been assumed that tallow is a commercial product, whereas the cooking oil is a waste product. In both cases an alternative allocation (alt. allocat.) has been made that allows for the opposite situation.

4.2.1 Greenhouse gas emissions

Figure 4.1 depicts the greenhouse gas emissions estimated for biodiesel 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 basis for 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).

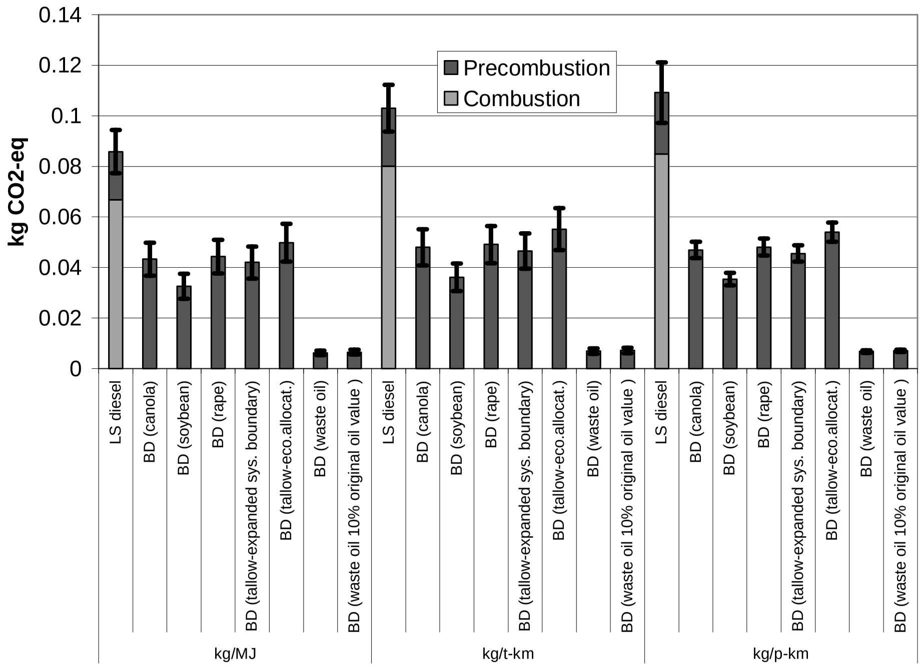

Figure 4.1
Exbodied emissions of greenhouse gases for biodiesel fuels and low sulfur diesel (LSD, the reference fuel). Tallow and cooking oil are treated both as waste and as physical inputs.

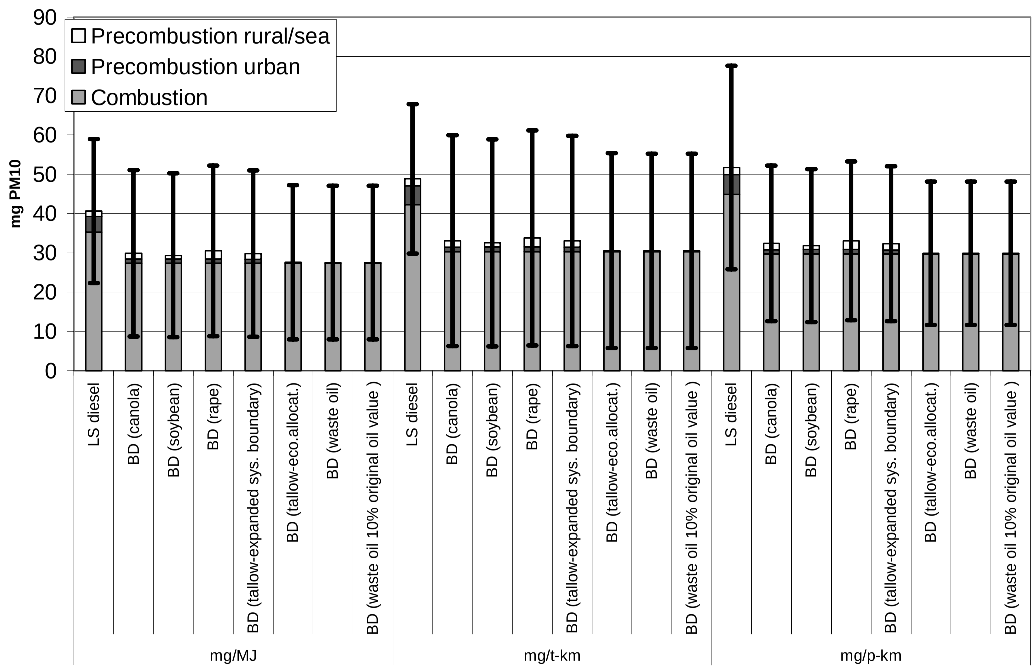

Figure 4.2
Exbodied emissions of particulate matter for biodiesel fuels and low sulfur diesel (LSD, the reference fuel). Tallow and cooking oil are treated both as waste and as physical inputs.

4.2.2 Particulate matter emissions

Figure 4.2 depicts the particulate matter (PM10) emissions estimated for diesel 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 basis for buses using the same energy intensities previously noted.

4.2.3 Emissions of oxides of nitrogen

Figure 4.3 depicts the oxides of nitrogen (NOx) emissions estimated for diesel 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 basis for buses using the same energy intensities previously noted.

4.2.4 Emissions of hydrocarbons

Figure 4.4 depicts the non-methanic hydrocarbon (HC) emissions estimated for diesel 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 basis for buses using the same energy intensities previously noted.

The variability in the results is very evident. On the basis of the data that we used for the analysis, soy biodiesel emits more hydrocarbons than the reference fuel as a result of tailpipe emissions – the upstream hydrocarbon emissions are less. Canola and rape are comparable to LSD, being higher on a per energy basis but lower on a per distance basis. Tallow and waste oil have surprisingly small hydrocarbon emissions.

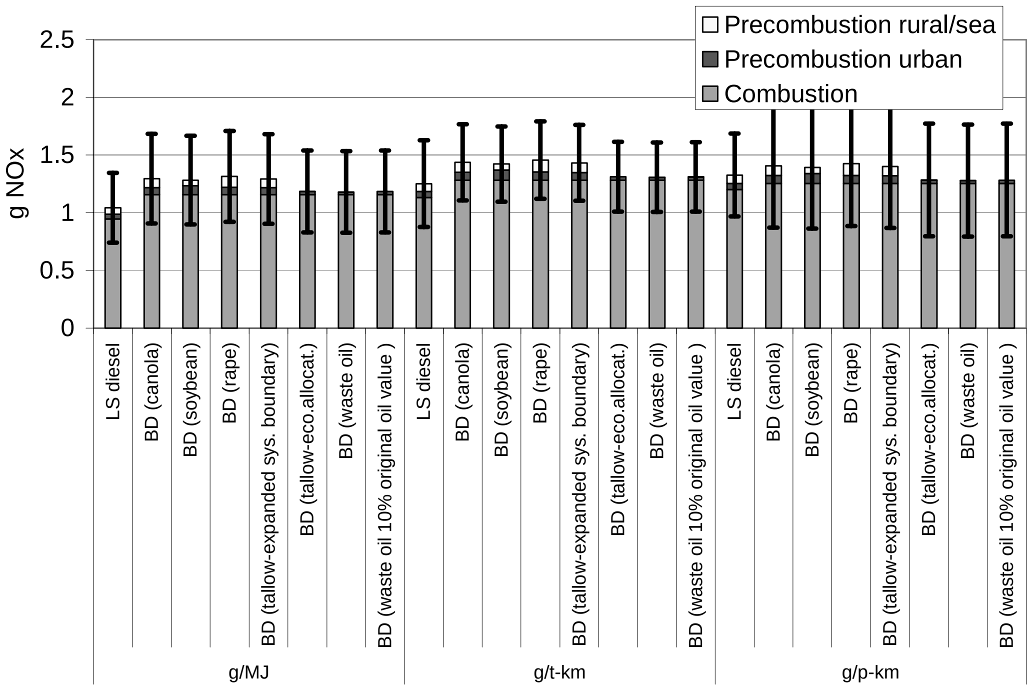

Figure 4.3
Exbodied emissions of oxides of nitrogen for biodiesel fuels and low sulfur diesel (LSD, the reference fuel). Tallow and cooking oil are treated both as waste and as physical inputs.

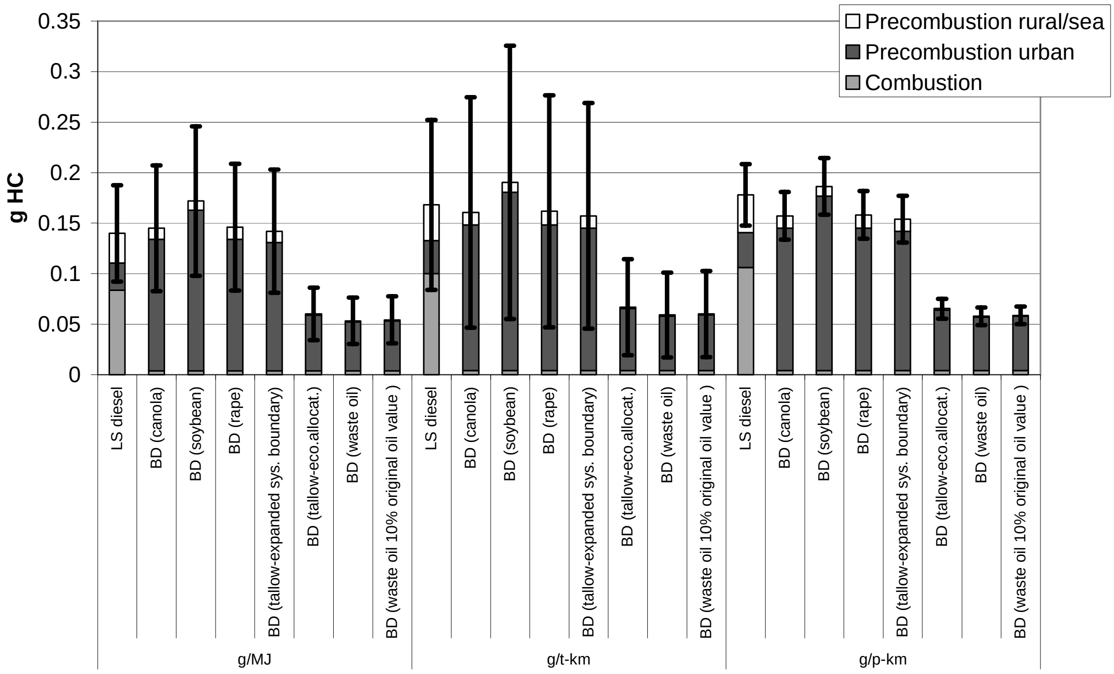

Figure 4.4
Exbodied emissions of hydrocarbons for biodiesel fuels and low sulfur diesel (LSD, the reference fuel). Tallow and cooking oil are treated both as waste and as physical inputs.

4.3 Viability, Functionality and Health Issues

There appear to be no health risks of air toxic emissions from biodiesel with respect to mortality, toxicity, fertility or teratology. All air toxic emissions from biodiesel are lower than equivalent diesel emissions except for acrolein. Though highly toxic, the slight increase in acrolein is offset by the decrease in the equally toxic aldehydes.

The National Biodiesel Board web site also points out that biodiesel over time will soften and degrade certain types of elastomers and natural rubber compounds. Precautions are needed when using high percent blends to ensure that the existing fueling system, primarily fuel hoses and fuel pump seals, do not contain elastomer compounds incompatible with biodiesel.

Cummins will warranty only biodiesel blends, though Caterpillar will warranty biodiesel in certain of their engines. In contrast to the cautious attitude of the manufacturers, the "truck in the park" project and other road-test projects found no difference in engine viability and functionality between diesel and biodiesel.

4.4 Environmental Issues

ESD issues
Biodiesel is made from agricultural crops and is thus more environmentally friendly and ecologically sustainable than fossil fuels. Our results confirm that, on a life-cycle basis, biodiesel is more climate-friendly than diesel. The carbon emissions caused by agricultural production and fertiliser production are less than the exbodied emissions from diesel made from fossil fuels.

Sustainability issues

Biodiesel is made from either crops or from animal product. Its feedstock is thus a renewable resource. Biodiesel will be a niche fuel, albeit a very useful one, because there is not sufficient area to grow the plants needed to convert all of Australia's diesel fuel usage to biodiesel.

Groundwater contamination

Not an issue with biodiesel, except for the possible use of i) pesticides or fertiliser during the growth of the crop from which the biodiesel is made, and ii) runoff from cattle feedlots (for biodiesel made from tallow).

4.5 ADR Compliance

100% biodiesel can be expected to meet all future Australian Design Rules for all pollutants except oxides of nitrogen which may be slightly above Euro3 and Euro4 standards, and possibly the particulate matter standard for Euro3. Arcoumanis notes that there is limited data for 100% biodiesel on which to make this judgement. He also indicates that a blend of 20% - 30% biodiesel with diesel in heavy vehicles is expected to meet all Euro 4 standards.

4.6 Summary

The advantages of biodiesel are:

- It is a renewable bio-based fuel and, as such, has lower life cycle CO_2 emissions than diesel derived from mineral oils.
- Neat biodiesel contains almost no sulfur and no aromatics. In a properly tuned engine this is expected to lead to lower particulate exhaust emissions.
- The material is bio-degradable and non-toxic.
- As an oxygenated compound, it reduces the non-soluble fraction of the particles.
- The PAH content of exhaust particles is reduced.
- In a mixture with low-sulfur diesel, biodiesel can act as a lubricity improver (Arcoumanis, 2000).
- The absence of sulfur allows more efficient use of oxidation catalysts.

The disadvantages of biodiesel are:

- Constraints on the availability of agricultural feedstock impose limits on the possible contribution of biodiesels to transport.
- The kinematic viscosity is higher than diesel fuel. This affects fuel atomisation during injection and requires modified fuel injection systems.
- Due to the high oxygen content, it produces relatively high NOx levels during combustion.
- Oxidation stability is lower than that of diesel so that under extended storage conditions it is possible to produce oxidation products that may be harmful to the vehicle components.
- Biodiesel is hygroscopic. Contact with humid air must be avoided.
- Production of biodiesel is not sufficiently standardised. Biodiesel that is outside European or US standards can cause corrosion, fuel system blockage, seal failures, filter clogging and deposits at injection pumps.
- The lower volumetric energy density of biodiesel means that more fuel needs to be transported for the same distance travelled.
- It can cause dilution of engine lubricant oil, requiring more frequent oil change than in standard diesel-fuelled engines.
- A modified refuelling infrastructure is needed to handle biodiesels, which adds to their total cost.

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