

# 12. Premium Unleaded Petrol

## 12.1 Introduction

The study brief requires an examination of premium unleaded petrol (PULP) (95 RON) meeting either the Euro2 specification for unleaded petrol or the fuel specifications for PULP proposed by the Commonwealth for implementation in 2002. It is assumed that this fuel does not contain ethanol and that it is used in light vehicles as defined in ADR 79/00 and 79/01. The emission limits specified in these ADRs may be found at:

<http://www.dotrs.gov.au/land/environment/emissionrequirements.pdf>

Our analysis is thus based on a hypothetical vehicle that satisfies Euro2 tailpipe emissions. PULP will thus be used as a reference fuel with which to compare emissions from the use of anhydrous ethanol in PULP.

## 12.2 Full Fuel-Cycle Analysis

### 12.2.1 Tailpipe emissions

We take tailpipe emissions for the hypothetical vehicle to be those of a Euro2 vehicle as given by <http://www.dotrs.gov.au/land/environment/emissionrequirements.pdf>:

CO	2.2 g/km
HC	0.28 g/km
NO <sub>x</sub>	0.22 g/km
PM	0.08 g/km,

with an additional requirement that there be less than 2 g/km evaporative emissions.

Further, we follow Louis (2001) and take these values as appropriate to a Mercedes A-class 1.6 L reference vehicle. The fuel consumption of this vehicle is 7.5 L per 100 km (13.33 km/L), which corresponds to a fuel energy use of 2.42 MJ/km. According to Louis (2001) this corresponds to 172 g/km emissions of greenhouse gases from such a vehicle when using petrol.

### 12.2.2 Upstream

#### *Production of ULP and PULP*

Petrol is manufactured using a number of refinery product streams derived from crude oil. The blending process is generally determined by three major factors: specification requirements, availability of specific process units within particular refinery configuration, and the properties of the crude oil used.

There are two grades of unleaded petrol manufactured in Australia for use in vehicles – regular unleaded (ULP) and premium unleaded (PULP). The most important parameters for both grades are summarised in Table 12.1.

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**Table 12.1**  
**Unleaded petrol specifications**

<b>Petrol grade</b>	<b>Property</b>	<b>Minimum</b>	<b>Maximum</b>
Regular	MON	82	N/a
	RON	91	93
	FVI	80	106
	Sulfur	N/a	500 ppm
Premium	MON	82	N/a
	RON	95	N/a
	FVI	80	106
	Sulfur	N/a	500 ppm

Both grades have the same requirement for motor octane number (MON). Research octane number (RON) requirement is higher for PULP. The determination of both the RON and the MON is done using standard test engines under strict conditions defined in the relevant specifications. RON test reflects anti-knock properties at lighter load, while MON is determined under conditions resembling high power demand under heavy load.

Flexible volatility index (FVI) is related to vapour pressure of petrol at various temperatures. Variations in FVI are seasonal – FVI requirement changes every month and this variation is a reflection of the average ambient temperatures within different geographic regions at different times of the year. Sulfur content is generally limited to 500 ppm (w/w), with excursions of up to 1000 ppm allowable under specific conditions.

Hydrocarbons constituting petrol can be broadly broken into three categories: paraffins, naphthenes and aromatics. Generally the octane rating of those increases with increasing chain branching, unsaturation and aromaticity. Variation of octane rating and volatility between different hydrocarbon types is the basis for the blending process. The objective is to produce petrol up to the specification while maximising efficiency of the refining process and feedstock utilisation.

An example of crude oil processing is presented in the chapter describing diesel fuel production. The first stage of crude oil processing is atmospheric pressure distillation. Fraction boiling between 90°C and 220°C, called straight run naphtha (gasoline), is the basic feedstock used in petrol production. It consists of predominantly straight chain aliphatic hydrocarbons. Its octane rating is generally below specification and needs to be adjusted by further processing. The first processing step is usually hydrotreating, which lowers sulfur contents and reduces unsaturation.

A number of processes are used to produce blending components. These typically include:

- Reforming – thermal catalytic isomerisation and aromatisation of paraffins and naphthenes, which increases octane rating.
- Isomerisation – conversion of paraffins to isoparaffins in the presence of hydrogen and the catalyst.
- Cracking – thermal catalytic breaking of heavy fractions which produces a broad range of highly aromatic fractions.
- Alkylation/polymerisation – catalytic oligomerisation of light olefines producing isoparaffins.

The difference between ULP and PULP is determined by differences in octane rating. PULP blend typically contains a larger proportion of high octane streams, i.e those containing aromatics, isoparaffins and naphthenes.

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Upstream emissions in petrol production arise from oil recovery, transportation and processing. Further emissions derive from the distribution through the retail network.

### 12.3 Results

The upstream emissions results are based on the energies involved in typical refining operations (as evaluated for low sulfur diesel).

#### 12.3.1 Emissions per unit energy

**Table 12.2**  
**Embodied emissions per MJ for PULP**

<b>Full Lifecycle</b>	<b>Units</b>	<b>PULP</b>
Greenhouse	kg CO <sub>2</sub>	0.0888
HC total	g HC	0.170
HC urban	g HC	0.141
NOx total	g NOx	0.185
NOx urban	g NOx	0.129
CO total	g CO	0.930
CO urban	g CO	0.920
PM10 total	mg PM10	38.2
PM10 urban	mg PM10	36.9
Energy embodied	MJ LHV	1.14

**Table 12.3**  
**Precombustion emissions per MJ for PULP**

<b>Precombustion</b>	<b>Units</b>	<b>PULP</b>
Greenhouse	kg CO <sub>2</sub>	0.0177
HC total	g HC	0.0543
HC urban	g HC	0.026
NOx total	g NOx	0.094
NOx urban	g NOx	0.038
CO total	g CO	0.021
CO urban	g CO	0.011
PM10 total	mg PM10	5.19
PM10 urban	mg PM10	3.8
Energy embodied	MJ LHV	1.14

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**Table 12.4**  
**Combustion emissions per MJ for PULP**

<b>Combustion</b>	<b>Units</b>	<b>PULP</b>
Greenhouse	kg CO <sub>2</sub>	0.071
HC total	g HC	0.116
HC urban	g HC	0.116
NOx total	g NOx	0.091
NOx urban	g NOx	0.091
CO total	g CO	0.909
CO urban	g CO	0.909
PM10 total	mg PM10	33.06
PM10 urban	mg PM10	33.06
Energy embodied	MJ LHV	0

**Table 12.5**  
**Summary of embodied emissions per MJ for PULP**

		<b>PULP</b>
Greenhouse kg	Precombustion	0.0177
Greenhouse kg	Combustion	0.0711
HC total g	Precombustion	0.0543
HC total g	Combustion	0.1157
HC urban g	Precombustion	0.0257
HC urban g	Combustion	0.1157
NOx total g	Precombustion	0.0937
NOx total g	Combustion	0.091
NOx urban g	Precombustion	0.038
NOx urban g	Combustion	0.091
CO total g	Precombustion	0.0212
CO total g	Combustion	0.9091
CO urban g	Precombustion	0.0113
CO urban g	Combustion	0.9091
PM10 total mg	Precombustion	5.19
PM10 total mg	Combustion	33.06
PM10 urban mg	Precombustion	3.80
PM10 urban mg	Combustion	33.06
Energy embodied MJ	Precombustion	1.14

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### 12.3.2 Emissions per unit distance

**Table 12.6**  
**Embodied emissions per km for PULP**

<b>Full Lifecycle</b>	<b>Units</b>	<b>PULP</b>
Greenhouse	kg CO <sub>2</sub>	0.2148
HC total	g HC	0.412
HC urban	g HC	0.342
NOx total	g NOx	0.447
NOx urban	g NOx	0.313
CO total	g CO	2.251
CO urban	g CO	2.227
PM10 total	mg PM10	92.5
PM10 urban	mg PM10	89.2
Energy embodied	MJ LHV	2.75

**Table 12.7**  
**Precombustion emissions per km for PULP**

<b>Precombustion</b>	<b>Units</b>	<b>PULP</b>
Greenhouse	kg CO <sub>2</sub>	0.0428
HC total	g HC	0.132
HC urban	g HC	0.062
NOx total	g NOx	0.227
NOx urban	g NOx	0.093
CO total	g CO	0.051
CO urban	g CO	0.027
PM10 total	mg PM10	12.5
PM10 urban	mg PM10	9.19
Energy embodied	MJ LHV	2.75

**Table 12.8**  
**Tailpipe emissions per km for PULP**

<b>Combustion</b>	<b>Units</b>	<b>PULP</b>
Greenhouse	kg CO <sub>2</sub>	0.172
HC total	g HC	0.280
HC urban	g HC	0.280
NOx total	g NOx	0.220
NOx urban	g NOx	0.220
CO total	g CO	2.200
CO urban	g CO	2.200
PM10 total	mg PM10	80.00
PM10 urban	mg PM10	80.00
Energy embodied	MJ LHV	0

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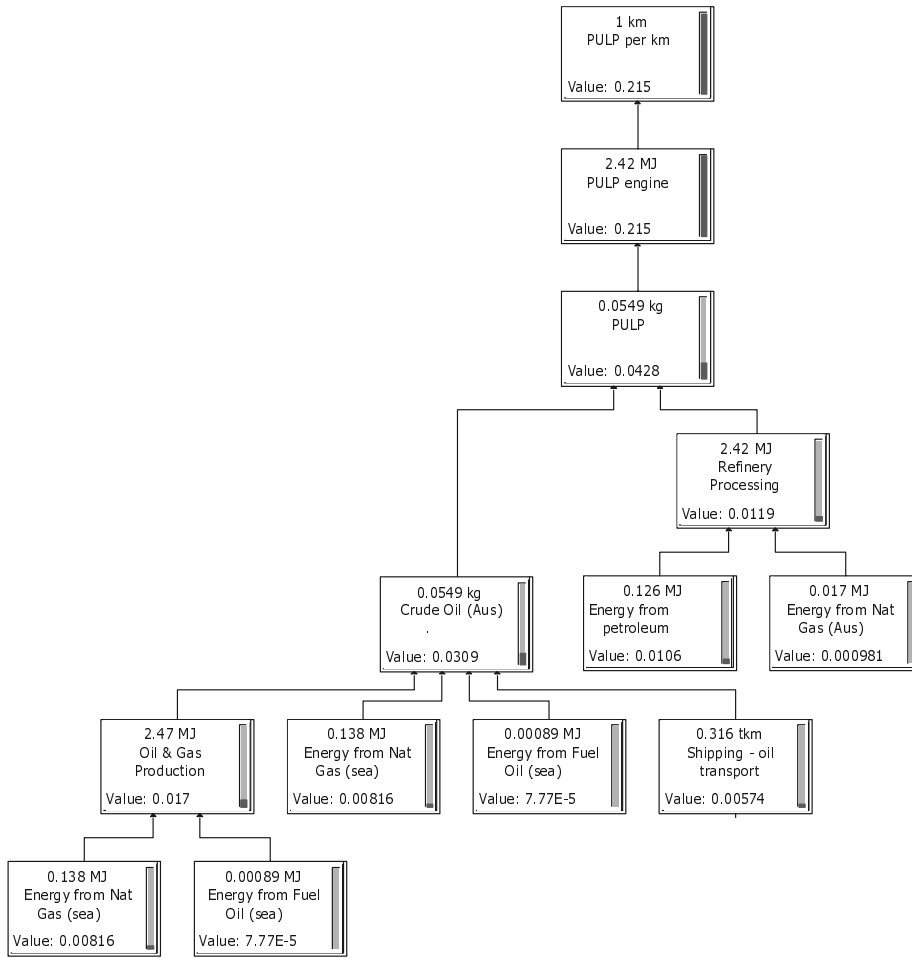
**Table 12.9**  
**Summary of embodied emissions per km for PULP**

		<b>PULP</b>
Greenhouse kg	Precombustion	0.0428
Greenhouse kg	Combustion	0.1720
HC total g	Precombustion	0.1320
HC total g	Combustion	0.2800
HC urban g	Precombustion	0.0622
HC urban g	Combustion	0.2800
NOx total g	Precombustion	0.2270
NOx total g	Combustion	0.220
NOx urban g	Precombustion	0.093
NOx urban g	Combustion	0.220
CO total g	Precombustion	0.0513
CO total g	Combustion	2.2000
CO urban g	Precombustion	0.0272
CO urban g	Combustion	2.2000
PM10 total mg	Precombustion	12.50
PM10 total mg	Combustion	80.00
PM10 urban mg	Precombustion	9.19
PM10 urban mg	Combustion	80.00
Energy embodied MJ	Precombustion	2.75
Greenhouse kg	Combustion	0

### *12.3.3 Uncertainties*

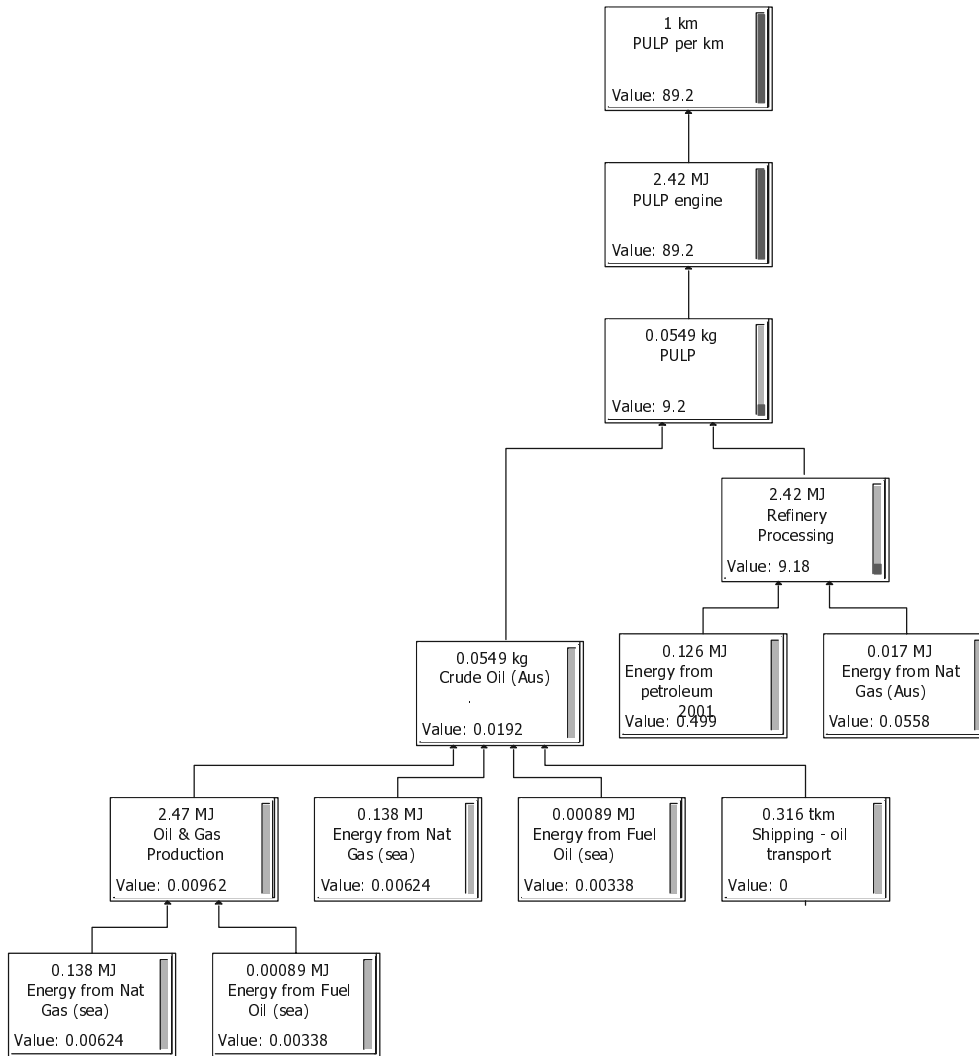
We will assume that the uncertainties are the same as those associated with low sulfur diesel.

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**Figure 12.1**  
Embodied greenhouse gases emissions (kg CO<sub>2</sub>eq) from PULP production and processing and use in vehicle

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**Figure 12.2**  
Embodied particulate matter (mg - urban) from PULP production and processing and use in vehicle

### 12.4 Viability and Functionality

Petrol is the most common automotive fuel, and unleaded petrol has been in use in Australia since 1986. Manufacturers produce premium unleaded petrol and its use does not cause warranty problems. Vehicle operational range depends on the size of the fuel tank, but typical values for a four or six cylinder car range from 400 to 600 km.

During consultation with stakeholders we were informed that there are considerable benefits arising from the widespread use of Euro4 quality RON petrol over 91 RON petrol. The improvement in fuel efficiency available for cars tuned for 95 octane is of the order of 2 to 4% over engines tuned for 91 octane. There is thus scope for smaller engines using 95 RON to have similar performance to engines tuned for 91 RON fuel.

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All forms of petrol are considered hazardous according to Worksafe Australia criteria; more so than diesel fuel. Petrol has an extreme flammability rating and extreme chronic effect rating. It has moderate toxicity and body contact ratings.

PULP properties (Louis, 2001) are a density of 749 g/L and a LHV 43.1 MJ/kg.

### 12.5 Health Issues

Petrol is flammable, carcinogenic, and potentially addictive when inhaled (petrol sniffing). A typical material data safety sheet notes that unleaded petrol is:

- Highly flammable.
- Harmful by inhalation, in contact with skin and if swallowed.
- May cause cancer.
- Danger of serious damage to health by prolonged exposure.
- Harmful-petrol may cause lung damage if swallowed.
- May produce discomfort of the eyes and respiratory tract\*.
- Repeated exposure potentially causes skin dryness and cracking\*.
- Vapours potentially cause drowsiness and dizziness\*.

**Table 12.10**  
Summary of air toxics emissions of PULP per km

Substance	Unit	PULP
Benzene (tailpipe)	mg	0.0768
Benzene (sea)	µg	0.268
Formaldehyde	mg	0.0148
Formaldehyde (sea)	µg	9.6
PAH (total)	µg	0.511
PAH (sea)	µg	0.0948
PAH (tailpipe)	µg	0.0071
Toluene (total)	mg	0.386
toluene (sea)	µg	0.467
Xylenes (total)	mg	0.153

#### 12.5.1 Production and transport

##### Particulate matter

The LCA estimate for PULP urban precombustion (car) PM10 emissions is 9 mg/km.

##### Air toxics

The LCA estimate for PULP urban precombustion (car) HC emissions is 0.062 g/km. The public health effects of air toxics will be mainly associated with combustion emissions in large urban centres. An accompanying disk to this report provides details of air toxic emissions from upstream activities.

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\* There is limited evidence for these effects

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### 12.5.2 Use

#### *Particulate matter*

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

#### *Air toxics*

The LCA estimate for PULP combustion (car) HC emissions is 0.280 g/km.

## 12.6 OHS Issues

The OHS issues in the lifecycle of PULP are well known and covered by a range of State and Commonwealth occupational health and safety provisions.

## 12.7 Vapour Pressure Issues

Evaporative emissions are a considerably more important issue for petrol or gasoline fuelled vehicles, than for diesel vehicles. There is evidence (see for example NRC, 1991) that evaporative emissions have been consistently under-estimated, and recent studies have continued to demonstrate the importance of evaporative emissions.

At a 1999 US workshop sponsored by the Coordinating Research Council (CRC) on On-Road Vehicle Emissions, (a summary is available at:

<http://www.crao.com/crcwebpage/reports/recent%20studies/9onroad%20workshop%20summary.pdf>

Bob Gorse of the Ford Motor Company summarised results from several CRC and the Auto/Oil Air Quality Improvement Research Program vehicle evaporative emissions studies. Hot-soak, diurnal, and running loss emissions were evaluated using in-use passenger cars and light trucks captured at I/M lanes in Phoenix, using tank fuels during summer periods. The hot-soak study tested 300 1983-1993 model year vehicles; the diurnal study tested 150 1971-1991 model year vehicles, and the running loss study tested 151 1971-1991 model year vehicles. A new vehicle evaporative emissions program tested 50 1992- 1997 model year vehicles for hot-soak, diurnal and running loss emissions. The combined results from these studies of in-use vehicles by model year groups suggest that evaporative emissions may be equal in mass emission rates to those from exhaust emissions, and concludes that further emphasis should be placed on evaporative emissions studies in the future.

The CRC/Auto-oil study considers three sources of evaporative losses from vehicles: diurnal, hot-soak and running loss emissions. Running loss emissions have not been extensively characterised, but there is evidence (see, for example, Duffy *et al*, 1999) that diurnal emissions are enriched in the more volatile components of the fuel, and that hot-soak emissions have a composition close to that of the parent gasoline. This suggests that hot soak losses are a consequence of essentially complete evaporation of the fuel, whereas diurnal losses arise from vaporisation of the lighter, more volatile components.

## 12.8 Environmental Impact and Benefits

Ecologically sustainable development (ESD) is based on the principles of equity, efficiency and ecological integrity. The modern western economy is based on petroleum products, of which petrol, unleaded petrol, and premium unleaded petrol are examples. Though substantial arguments can be advanced that such an economy is not sustainable, in the sense that fossil fuels constitute a non-renewable resource, over the past three decades exploration activity has continually discovered new hydrocarbon reserves. In addition, the current concern over

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climate change has highlighted the burning of fossil fuels as one of the main causes. Thus even if one argues that the fossil fuel economy is economically efficient, it is more difficult to argue that it encourages equity or ecological integrity.

Petrol is refined from crude oil. Spills of crude oil, especially during transport in oil tankers at sea, pose an environmental hazard that contaminates marine life and bird life. Environmental damage from petrol itself can also occur, especially from leaks, at service stations and refuelling depots, which have been known to contaminate groundwater supplies.

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