

# 15. Hydrogen

## 15.1 Introduction

The hydrogen energy content per unit mass is high. Compared to petrol for example, it is three times as high. On a volume basis, the energy content of hydrogen is relatively small. All mixtures of hydrogen and air with a volumetric hydrogen content between 4% and 75% are inflammable. Compared to mixtures of petrol and air, this is a wide range. Hydrogen can burn in mixtures with air from very lean (excessive air) to rich (excessive fuel).

## 15.2 Full Fuel Cycle Analysis Results

We consider only fuel-cell powered vehicles with the hydrogen derived from steam reforming of natural gas. Such hydrogen vehicles have virtually no emissions, even of NO<sub>x</sub>, because fuel cells operate at temperatures that are so much lower than internal combustion engines that NO<sub>x</sub> is not formed from the nitrogen and oxygen in the air. Theoretically, a hydrogen-fuelled fuel cell vehicle emits only water vapour.

### 15.2.1 Greenhouse gas emissions

Figure 15.1 depicts the greenhouse gas emissions estimated for the reference fuel (LSD) and hydrogen. 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).

The upstream emissions of greenhouse gases from hydrogen manufacture equates closely to the total embodied emissions of greenhouse gases from low sulfur diesel.

### 15.2.2 Particulate matter emissions

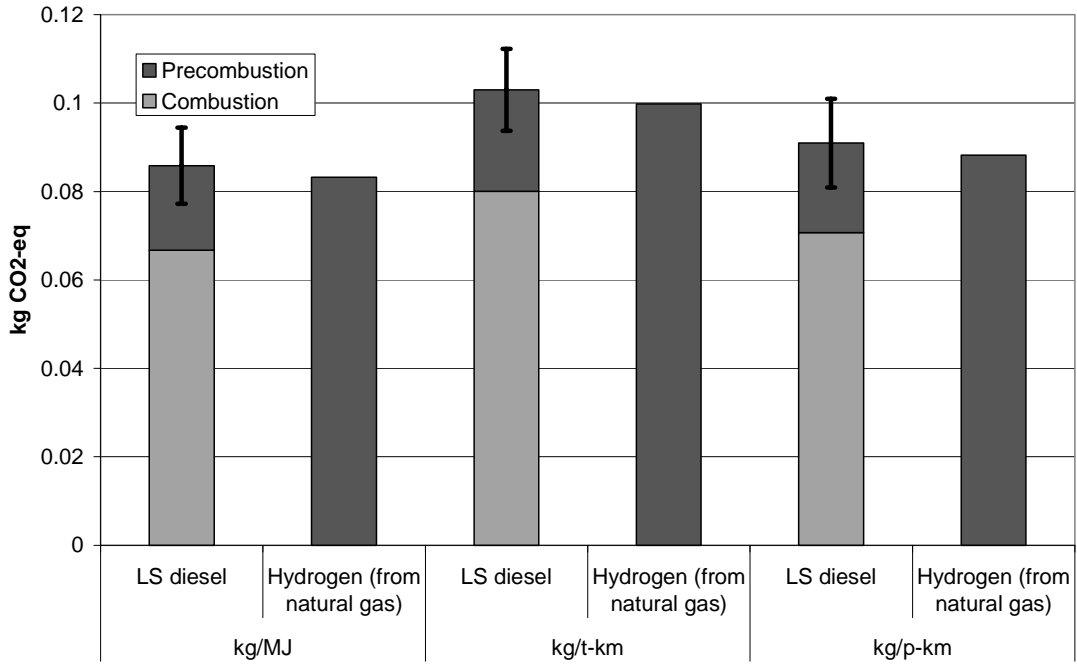
Figure 15.2 depicts the particulate matter (PM<sub>10</sub>) emissions estimated for hydrogen. These are shown as emissions on an energy basis, as emissions on a per tonne-km basis for trucks, and on a per passenger-km basis for buses using the same energy intensities previously noted. In all cases but one the emissions of PM<sub>10</sub> are less from hydrogen than from the reference fuel (LSD).

### 15.2.3 Emissions of oxides of nitrogen

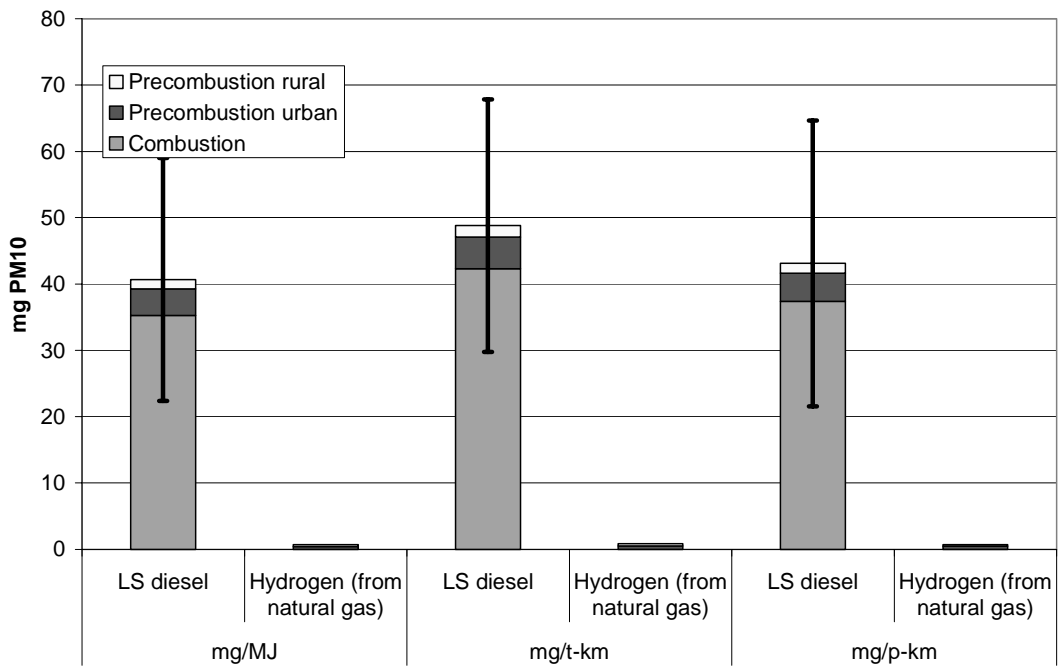
Figure 15.3 depicts the oxides of nitrogen (NO<sub>x</sub>) emissions estimated for hydrogen. These are shown as emissions on an energy basis, as emissions on a per tonne-km basis for trucks, and on a per passenger-km basis for buses using the same energy intensities previously noted. As a general rule the upstream NO<sub>x</sub> emissions from hydrogen processing are less than those of the reference fuel.

### 15.2.4 Emissions of hydrocarbons

## Part 1 Summary of Fuels

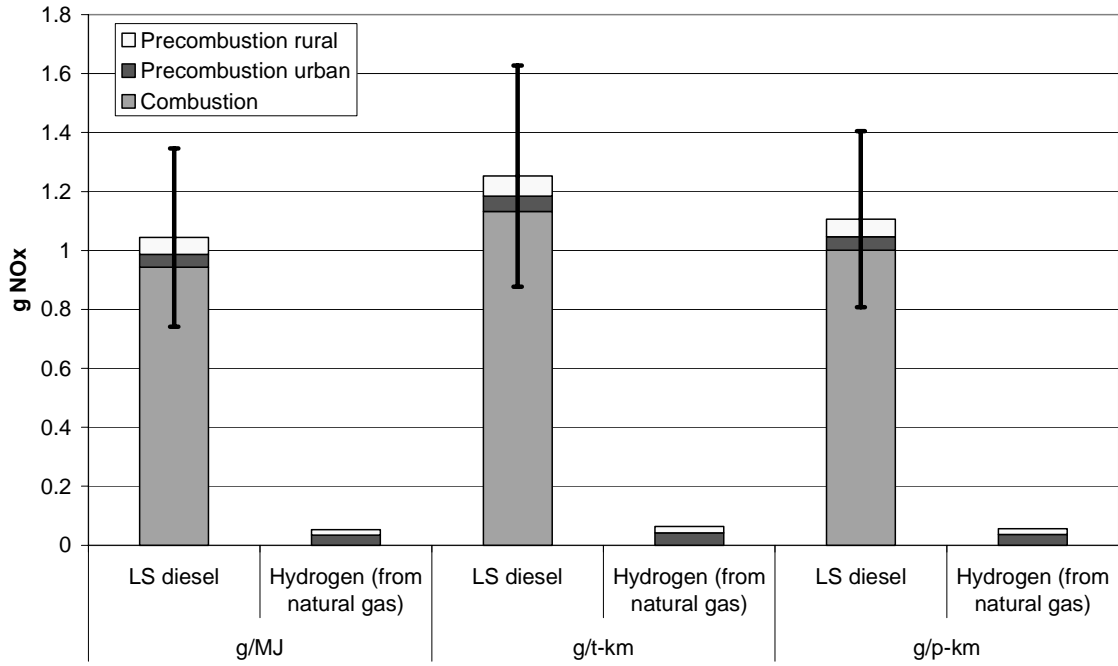


**Figure 15.1**  
Embodied emissions of greenhouse gases for low sulfur diesel and hydrogen

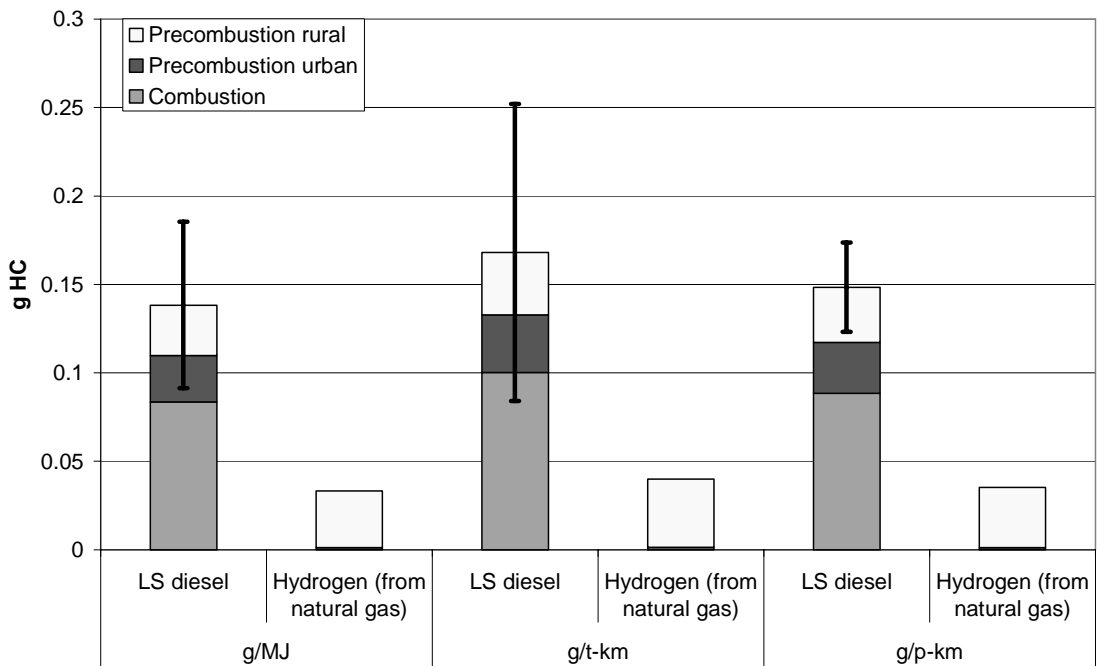


**Figure 15.2**  
Embodied emissions of particulate matter for low sulfur diesel and hydrogen

## Part 1 Summary of Fuels



**Figure 15.3**  
Embodied emissions of oxides of nitrogen for low sulfur diesel and hydrogen



**Figure 15.4**  
Embodied emissions of hydrocarbons for low sulfur diesel and hydrogen

## Part 1 Summary of Fuels

Figure 15.4 depicts the hydrocarbon (HC) emissions estimated for hydrogens. 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. Hydrogen has very low emissions of hydrocarbons compared to diesel.

### ***15.3 Viability and Functionality***

Important advantages of fuel cells are: high energy efficiency, because the efficiency is not limited to the maximum efficiency of thermal energy processes; low emissions during operation, though manufacturing of fuel cells may cause emissions as shown in Figures 15.1 to 15.4; and low noise production. However, fuel cells have some disadvantages as well. Compared to internal combustion engines, the disadvantages are: fuel cells are very expensive; and fuel cells are large and heavy per kW output.

Hydrogen rises when it is released into the open air. Its safety is then similar to that of conventional fuels. To avoid explosions, evaporating hydrogen is extracted during the refuelling process. The safety of hydrogen fuel systems is important during vehicle collisions. There is substantial testing designed to ensure leakproof hydride tanks, and to place the vehicle tank inside the safety cage of vehicles so as to reduce the risk of damage to the tank during a collision. No results from collision tests with hydrogen vehicles could be found in the literature.

The refuelling time of a hydrogen vehicle can be up to ten times the refuelling time of a petrol vehicle.

### ***15.4 Health Issues***

There are no air pollutant or greenhouse gas emissions during operation. The only emissions that may be of concern arise during precombustion.

Hydrogen upstream emissions of both particulate matter and HC are substantially less than LSD. Hydrogen has no tailpipe emissions of particulate matter or air toxics.

### ***15.5 Environmental Impact and Benefits***

#### *ESD issues*

It is difficult to see how natural gas reforming to produce hydrogen could be seen as ecologically sustainable development. It uses a fossil fuel, and considerable energy (and thus embodied greenhouse gases), to manufacture the fuel. Production of hydrogen by low pressure water electrolysis would be an ecologically sustainable method of production, provided the electricity to undertake the electrolysis is based on renewable energy.

#### *Sustainability*

Present plans are for hydrogen to be generated from steam reforming of natural gas in the Northwest Shelf. Though there are large amounts of natural gas available, this uses a fossil fuel to produce hydrogen. An innovative, sustainable scheme has been proposed based on using tidal power to dissociate hydrogen and thus run a hydrogen economy. The theoretical potential is there for great environmental benefits provided the technology can be implemented.

#### *Groundwater contamination*

Hydrogen is a gaseous fuel with no air pollutant or greenhouse gas emissions. It thus cannot contaminate soil or water.