Work Package 2

ASSESSING LOCAL SITUATIONS

Final Report

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Table of Contents

Introduction....4
1. London....5
Past, Present and Future Alternative Propulsion Initiatives....5
Policy & Regulatory Framework Relevant to Hydrogen Bus Projects....10
Management & Administrative Structures Affecting Hydrogen Bus Projects....14
General Social Framework....15
Perceptions of Hydrogen: Previous Studies....15
London - Summary and Conclusions....16
2. Luxembourg....17
Past, Present and Future Alternative Propulsion Initiatives....17
Policy & Regulatory Framework Relevant to Hydrogen Bus Projects....17
Management And Administrative Structures Affecting Hydrogen Bus Projects....20
General Social Framework....22
Luxembourg - Summary and Conclusions....22
3. Munich / Ottobrunn....23
Past, Present and Future Alternative Propulsion Initiatives....23
Policy and Regulatory Framework Relevant to Hydrogen Bus Projects....29
Management and Administrative Structures Affecting Hydrogen Bus Projects....33
General Social Framework....37
4. Perth....43
Past, Present and Future Alternative Propulsion Initiatives....43
Policy and Regulatory Framework Relevant to Hydrogen Bus Projects....47
Management and Administrative Structures Affecting Hydrogen Bus Projects....50
General Social Framework....55
5. Oakland....56
Previous Experience with FCVs and H_2....56
AC Transit - A Model Demonstration Site?....57
AC Transit's Hydrogen Fuel Cell Bus Demonstration....57
Hydrogen Station Design and Specification....59
References....62
London....62
Luxembourg....63
Munich / Ottobrunn....64
Perth....65
Oakland....66

Introduction

This report is the output of AcceptH2 work package 2, and forms the project's second deliverable.

Local situations have been assessed in each of the five cites where hydrogen buses are to be introduced in order to understand the wide variety of factors likely to affect the success of the projects.

As far as possible within the confines of the information available, the London, Luxembourg, Munich/Ottobrun and Perth sections of the report all follow a similar structure. For these four cities the main chapters of the report are as follows:

- The 'Past, Present and Future Alternative Propulsion Initiatives' chapters summarise experience to date with alternative fuel and vehicle projects relevant to each of the cities. This knowledge provides an insight into the cultures within which the projects will operate and therefore the attitudes with which the hydrogen buses are likely to be received.
- The chapters entitled 'Policy and Regulatory Framework' consider policies, legislation, taxes and subsidies that will affect the projects.
- The 'Management and Administrative Structure' chapters deal primarily with practical issues of ownership and control of the cities' public transport systems and their decision-making structures.
- The chapters entitled 'General Social Framework' consider factors such as population size and structure, income levels and distribution within each of the cities.

Less information was available about the situation in Oakland although the report still gives a useful summary of the public transport authority and its previous experience with alternative propulsion buses, its plans to introduce fuel cell buses and the hydrogen refuelling station that is being constructed to refuel them.

The report highlights experience with alternative propulsion vehicles in all five of the cities being assessed, including with hydrogen or fuel cell vehicles in London, Munich/Ottobrun, and Oakland. Overall the report presents an interesting picture of the contrasting starting points for each of the five cities, which will provide a useful resource when assessing the success and influence of each of the five hydrogen bus projects.

1. London

Past, Present and Future Alternative Propulsion Initiatives

CUTE Project, London

The three DaimlerChrysler Citaro buses that will be introduced to London as part of the Clean Urban Transport for Europe (CUTE) project will be the first hydrogen or fuel cell buses to operate in the UK. DaimlerChrysler intend to deliver the first bus to London in late October 2003 and the second and third in December 2003 or January 2004. London will be the last CUTE city to receive its FC buses as it is the only city that requires right hand drive variants and these will be constructed at the end of the 30 vehicle production run.

The fuel cell Citaro buses have an operating range of approximately200 kilometers, a maximum speed of approximately 50mph and, subject to their configuration, can carry up to 70 passengers. The buses have fuel cell units of over 200 kilowatts and are fuelled by compressed hydrogen housed on the buses' roofs at 350 bar.
http://www.daimlerchrysler.com/index_e.htm?/specials/fuelcell2002/newbuses_e.htm

FC Taxis Project, London

Between November 2000 and August 2001 Imperial College London and the University of California, Davis co-ordinated a feasibility study to assess the technical, financial and practical feasibility of introducing solid polymer fuel cell taxis into London. The project was funded by eleven partners including London Taxi International (LTI, manufacturers of London's famous black cab), Xcellsis, three London authorities, five fuel or power companies, and an investment bank.

Taxi performance and fuelling requirements were established through analysis of an existing London taxi cycle and by interviews with taxi drivers and companies. An LTI TX1 taxi with an Xcellsis fuel cell system was then modelled to ascertain whether it would meet these requirements. It was found that the FC taxis could produce the speed and acceleration rates required whether fuelled by direct hydrogen or methanol. The range of a direct hydrogen powered taxi would be considerably lower than a diesel model but would be sufficient for most drivers. Licensing requirements and potential sources of funding were also investigated and it appears that obtaining the necessary licenses to operate prototype fuel cell taxis would be straightforward.

The fuel cell taxis were not produced, however, because their estimated cost - €10m for 5 vehicles - was considered prohibitively high. [London Fuel Cell Taxi Pilot Project Feasibility Report; 2001].

City of Westminster's Fuel Cell Grounds-Vehicle, London

In December 1999 the City of Westminster purchased a 1.5 tonne hybrid battery /fuel cell van for use in maintaining Westminster's 123 parks and gardens. The base vehicle was built in California by Coval H2 Partners and incorporated a 5kW alkaline fuel cell produced by Zevco Ltd. The vehicle was claimed to have a range of 125

miles (200 km) and a top speed of 62 mph (100kmh). www.hfcletter.com/letter/january00/zevco.html

The fuel cell was powered by compressed hydrogen stored in tanks outside and on top of the cab. The fuel cell was designed to charge the vehicle's batteries, which in turn would power its 63 kW electric motor. www.hfcletter.com/letter/january00/zevco.html

The vehicle operated for several months but was beset by technical problems, principally with the fuel cell itself. This meant that during the van's short working life with Westminster it operated principally as a 'conventional' electric vehicle with its batteries charged from the mains. In late 2001 Zevco went into receivership leaving Westminster without a maintenance contract for the van. Westminster sought tenders to maintain the van from other companies but did not receive any that it considered acceptable and is now trying to sell the vehicle. [City of Westminster; April03].

Re-Engined and Retro-fitted Buses, London

London's traditional open-platform 'Routemaster' double-decker buses entered service in the 1950s and 1960s and have proved exceptionally robust in design and construction with hundreds still in daily operation. Unsurprisingly for heavy duty diesel vehicles constructed 30 years prior to Euro I legislation, these buses produce extremely high levels of emissions.

To address this problem the Government funded Energy Saving Trust (EST) runs a project that has to date 're-engined' approximately 100 Routemasters, bringing them up to well above the Euro II emissions standard. The original engines are replaced with new Cummins B5.9 diesel engines coupled to Allison MT643 automatic gearboxes. Diesel oxidation catalysts from Engine Control Systems are also fitted. [Cummins; 2001; and Energy Saving Trust; 2003]

According to tests undertaken by Millbrook Proving Ground in Bedfordshire, the re-engined Routemasters achieve a 90% reduction in HCs, 96% reduction in CO, and 30% reduction in NOx compared to the buses in their original form. The new Cummins engines are also more powerful (145hp), quieter, and more fuel efficient than the original Routemaster engines and have proved popular with drivers. [http://www.clearzones.org.uk/casestudycentrewest.htm].

Camden Community Transport, London

In 1995 Camden Community Transport (CCT) converted three Iveco Ford minibuses to electric vehicles (EVs), using lead-acid batteries and a Wavedriver controller. These minibuses operated as EVs for over a year but proved to have high maintenance costs. In 1997, therefore, CCT decided to convert them again, this time to compressed natural gas (CNG). The minibuses were technically successful in their incarnation as natural gas vehicles (NGVs), though Camden Community Transport considers that the initial capital costs of the CNG engines was high. [Transport and Travel Research; 2003]

London Borough of Merton

The London Borough of Merton (LBM) has a fleet of 19 CNG coaches and Iveco Daily minibuses that it has purchased since 1997 with financial support from the EST's Powershift programme. Although the vehicles have generally been technically successful, LBM considers their capital cost to be high and has found the weight penalty of their on-board fuel storage can be problematic. [Transport and Travel Research; 2003; and www.utopia-eu.com/reptex/rep51/rep13.htm.]

Other Alternative Fuel Bus Experience in the UK

Table 1.1 summarises experience with alternative fuel buses from other cities in the UK.

Table 1.1

Fuel	Location	Vehicles	Project	Equipment	Key findings
CNG	Southampton	6 converted and 10 dedicated CNG buses	Entrance project Southampton City Council Current	Dennis Dart midi bus	High fuel use, high capital cost, good public response
CNG	Birmingham	14 CNG buses on commercial service route	Travel West Midlands CNG demonstration Current	Volvo bus with dedicated lean-burn engine	High fuel use, high capital costs, some technical and maintenance problems
CNG	Merseyside	4 CNG buses on Park and Ride route in Southport	Jupiter-2 project Merseytravel Current	Dennis bus with dedicated gas engine	High capital and fuel costs
CNG	Northampton	6 dedicated CNG buses	CNG bus fleet Current	Volvo bus with dedicated lean burn engine	
LPG	Various (mainly operated by Arriva)	40 buses in service or as demonstrations	LPG bus fleet	Dedicated DAF SB220	
LPG	Cheshire CC	1 dedicated LPG bus for Park and Ride route in Chester	LPG demonstration 1998-2000	Dedicated DAF SB220	Technically successful, but high capital costs
Battery-electric	Bristol	2 minibuses for a Park and Ride route	Centaur	Tecnobus electric minibus	Reliable and well received by drivers and general public
Battery-electric	Merseyside	6 minibuses for Hamilton Quarter in Birkenhead	Jupiter-2 project Merseytravel Current	Tecnobus electric minibus	High capital cost, operator training and awareness needed

[Transport and Travel Research; 2003. www.utopia-eu.com/reptex/rep51/rep13.htm] Energy Saving Trust; 2003.]

Alternative Fuel Vehicles – UK Outside of London

The UK's LPG Association estimates that there are currently around 89,000 road-going **LPG vehicles** in the UK [www.lpga.co.uk/automotive_new.htm], the majority of which are after-market conversion of petrol cars to bi-fuel operation. There is considerable uncertainty over this estimate, however, because vehicle owners generally fail to inform the Driver and Vehicle Licensing Agency that their vehicles have been converted.

Almost all LPG vehicles in the UK have been purchased or converted in the last 5 years, largely in response to fuel duty (tax) incentives and Government funded vehicles purchase / conversion grants available from the Energy Saving Trust. [See Policy section]

The number of **natural gas vehicles** (NGVs) in the UK is much lower – approximately 500 [www.natural-gas-vehicles.co.uk/home/Faqs/Faqs4.html]– even though the same fuel duty and purchase incentives are available as for LPG vehicles. This is largely because the high capital cost of CNG refuelling infrastructure has made it more difficult to 'kick-start' the market.

There are currently two models of **hybrid (electric/ICE) vehicles** available in the UK – the Toyota Prius and the Honda Insight - both of which were launched in 2001. The vehicles are popular although sales have been limited by supply to several thousand of each. Two other hybrids vehicles are due to be launched in the UK in 2003: The Honda Civic in May, and the Lexus RV300 in the autumn. [EST. Pers comm. Ed Blamey, Manager Environmental Affairs Toyota (GB) Plc.]

There are only a few hundred modern **electric vehicles** in the UK, most of which are version of the Peugeot 106, the Citroen Berlingo or the Ford Think. Electric vehicles have not sold well because of their high cost, limited range, and the lack of public-access recharging points. These figures exclude electric milk delivery vehicles ("milk floats"), most of which are in the region of 30 years old and near the end of their working lives. [Energy Saving Trust; 2003; and VTT Energy; 2003]

Alternative Fuel Fuelling Stations

Hydrogen

BP will supply hydrogen for the CUTE fuel cell buses from a site that they intend to open in October 2003. BP's preferred site for the hydrogen plant is their flagship service station in Hornchurch, Essex, although planning permission for the site has not yet been granted. The Hornchurch service station is marketed as "the world's greenest service station" and has solar panels and a wind turbine installed. [www.bp.com/centres/press/hornchurch/index.asp; and BP; 2003]

Liquid hydrogen will be brought to the site by road tanker, where it will then be evaporated and compressed. The site will initially store two tonnes of liquid hydrogen, which is approximately enough for three weeks supply for the CUTE buses. BP would welcome additional hydrogen customers at the site and would expand its capacity if necessary, although all users would have to be suitably trained to use the equipment. [BP; 2003]

Other Alternative Fuels

There are currently 22 LPG refuelling stations in London, three fast-fill CNG refuelling stations (British Gas' Southward gas works, London Borough of Sutton and London Borough of Merton) and 6 public access charging points for electric vehicles (5 in local authority car parks and one in a supermarket car park).

Nationwide the number of service stations selling LPG has increased rapidly from virtually none 5 years ago to more than 1200 today, equating to nearly 10% of the UK's 12,500 petrol and diesel service stations. However there are still only around 10 public access natural gas refuelling stations in the UK and no public access EV points outside London.

Low sulphur diesel (LSD) and low sulphur petrol (LSP) have both been introduced quickly and successfully to the UK following fuel duty concessions. The concession for LSD came into effect in 1997 and by mid-2000 100% of the UK diesel market was LSD (5 years ahead of the EC deadline). [H.M. Treasury; 2003.] The duty concession for LSP came into effect in March 2001 and had an even more dramatic effect, with LSP accounting for 100% of UK petrol sales by summer 2001.

Policy & Regulatory Framework Relevant to Hydrogen Bus Projects

Transport Policy and Targets

In July 2002 the UK Government unveiled the **"Powering Future Vehicles"** strategy document that included two specific targets:

- By 2012 10% of all new car sales will emit 100g/km CO_2 or less at tailpipe.
- By 2012 600 or more buses coming into operation will be 'low carbon' – defined as 30% below 2002 average bus CO_2 emissions.

Also in July 2002 the Government announced the formation of the Low Carbon Vehicle Partnership: a multi-stakeholder forum that will meet to ascertain how best the targets can be met. [DfT, DTI, DEFRA and H.M. Treasury; 2002]

Another key transport strategy document is the Energy Saving Trust's **"Pathways to Future Vehicles",** which was published in April 2002 and contains the following targets:

- At least 10% of all new car sales in the UK to be low carbon by 2010 (defined as 100g/km CO_2 or less on a well-to-wheels calculation).
- At least 25% of all new bus registrations to be low carbon by 2010 (defined as CO_2 emissions 30% below those of the current equivalent diesel bus.)
- 5-10% of new bus registrations to run on hydrogen fuel cells by 2010.

These first two targets are similar but slightly more ambitious than the Government targets since EST uses well-to-wheel emissions rather than a tailpipe-only; targets are for 2010 as apposed to 2012; and because at current rates '25% of new bus registrations' equates to approximately 750 buses per year.

The third target equates to 150-300 fuel cell buses per year by 2010, assuming current rates of bus registration. This is ambitious but recognises that buses are the ideal vehicles to pioneer the use of fuel cells as they refuel at depots and are large enough that current gaseous hydrogen storage technology provides them with adequate range. [Energy Saving Trust; 2002].

Air Quality & Emissions Targets

Greenhouse Gas Emissions

The UK's Kyoto target is to reduce greenhouse gas emissions to 12.5% below 1990 levels by 2008-12. The UK also has a longer standing national target of reducing CO2 emissions to 20% below 1990 levels by 2010.

Air Quality Emissions

The main air quality standards in the UK are the National Air Quality Standards, which were introduced as part of the National Air Quality Strategy (NAQS) adopted by the Government in January 2000. As with other air quality standards, these are maximum concentrations of pollutants that must not be exceeded over a given period of time.

Local Authorities (LAs) play an important role in local air quality management under the UK's NAQS. Local Authorities are required to conduct periodic reviews and assessments of air quality in their area and if these assessments indicate that one or more of the air quality objectives is not likely to be met by the end of 2005, the LA must declare an Air Quality Management Area and make an action plan that will ensure targets are met. [Energy Saving Trust; 2003; and www.aeat.co.uk/netcen/airqual/dailystats/standards.html]

Local Authorities are expected to achieve the aims of local air quality management by exercising their powers on land use planning and traffic management, controlling emissions from processes they regulate, minimising emissions from their own activities, and collaborating with other organisations in reducing emissions from other sources.

Many areas of London could fail to meet the PM_{10} target [50micrograms/m^3 over a 24-hour mean] and the NO_2 target [150 micrograms/m^3 over a 24-hour mean] and are therefore establishing AQMAs. In most areas road traffic is the single biggest factor jeopardising the achievement of the air quality targets [www.defra.gov.uk/environment/airquality/index.htm and www.brent.gov.uk/ehealth]

London's Transport Authorities: Structure and Financing

Transport for London (TfL) is a functional body of the Greater London Authority, reporting to the Mayor of London. TfL is responsible for managing, providing and procuring a range of transport services and facilities, including London's local bus services, on behalf of the Mayor. TfL also manages and maintains a 550km network of London's main roads and all of London's traffic signals. http://www.londontransport.co.uk/buses/privacy.shtml

A local bus service is defined as one charging separate fares where the stopping places are less than 15 miles apart. In general terms registration rules require bus services to operate along predetermined routes to a fixed timetable. [DfT; 2002]

Fuel duty rates are particularly high in the UK and differentials in the rates are used to promote cleaner fuels. The table below shows the low sulphur petrol and diesel concessions of 3p/litre and 5p/litre respectively compared to conventional petrol and diesel and the 20p/litre concession given to biodiesel compared to LSD. The duty rate for road gas - including LPG and natural gas - is 9p/kg, which equates to approximately 15p/litre or one third of the rate applicable to low sulphur diesel and petrol. In the 2001 budget the Government committed to maintaining the duty differential between road gas and petrol and diesel until at least 2004. Budget 2002 also announced - with specific reference to hydrogen, bio-ethanol, methanol and biogas - "enabling legislation that would allow for the introduction of duty reductions or exemptions for pilot projects".

Table 1.2 UK Road Transport Fuel Duty 2003/2004

Light oils	**Pence per litre**
Ultra-low sulphur petrol (ULSP)	45.82
Unleaded petrol which is not ULSP	48.82
Heavy (gas) oils	**Pence per litre**
Ultra-low sulphur diesel (ULSD)	45.82
Heavy oil which is not ULSD (i.e. conventional diesel)	51.82
Fuel substitutes	**Pence per litre**
Biodiesel for use as a road fuel	25.82
Road fuel gases	**Pence per kg**
Gas for use as road fuel	9.00

NB: VAT is payable on these amounts as part of the retail price.
[H.M. Treasury; 2003]

For most vehicle types these duty rates have been effective in encouraging fuel and vehicle substitution, but for buses their effect is largely negated by legislation that allows bus operators to reclaim most of the fuel duty they pay. The "Bus Service Operators Grant", more commonly and hereafter referred to by its former name of the "Fuel Duty Rebate" (FDR), refunds approximately 80% of the fuel duty paid by bus operators and is worth around £300m a year in England alone. [Energy Saving Trust; 2002]

Although the principle of a direct subsidy to bus operators to help reduce costs, make services more available and lower fares is almost universally accepted, the FDR has long been criticised because it acts as barrier to the introduction of cleaner transport fuels and reduces the financial incentive for more efficient bus fleets.

In August 2002 the Department for Transport launched a consultation to consider reforming the FDR. Options being considered include replacing the FRD with either a mileage subsidy or a passenger-mile subsidy. There is a practical argument in favour of a simple mileage subsidy as this would not require the collection of any additional data as bus operators are already required to report their mileage.

The other major subsidy provided to bus operators is the Rural Bus Subsidy Grant (RBSG), which provides direct payments to operators of rural bus services. The RBSG is a temporary policy measure but has recently been extended to the 2005/6 financial year.

The Government funded Energy Saving Trust runs two programmes that provide grants for cleaner vehicles, including buses. The Powershift programme provides grants for up to 75% of the additional cost of buses that run on LPG, natural gas or electricity, and the CleanUp programme provides grants towards the cost of retrofitting existing diesel buses with cleaner engines or after-treatment technology [see section 1].

Management & Administrative Structures Affecting Hydrogen Bus Projects

Tickets & Fares

Women over 60 and men over 65 are entitled to free bus travel in London, and children under 16 qualify for reduced price tickets. The bus network is divided into four zones for calculating fares.

Single Tickets. For adult single cash fares, the London bus network is divided into two separate areas; for child single cash fares, a flat fare applies. Any adult fare including central London (Zone 1) is £1; any adult fare that does not include central London is 70p. All children's single fares are 40p. Return fares are not available.

Saver. Adult – 6 single tickets, each costing £0.65 (saving you a total of £2.10) Child – 6 single tickets, each costing £0.35 (saving you a total of 30p).

One Day Bus Passes. One day bus passes are valid for travel across the entire London bus network on the day of validity and for any journey that starts before 4.30am on the following day. Adult's day passes cost £2; children's day passes £1.

Season Bus Passes. Season tickets are available for 7 days, monthly or for any longer period up to one year. Child rate period bus passes are valid for a maximum period of 4 months.

Table 1.3 Season Ticket Rates

Zone	Adult 7 day	Child 7 Day	Adult Monthly	Child Monthly	Annual (Adult only)
2, 3 or 4	£7.50	£4.00	£28.80	N/A	300
1,2,3 and 4	£8.50	£4.00	£32.70	£15.40	340

Combined Bus and Subway Season Passes. Annual, monthly, weekly and daily tickets can also be purchased that permit travel on the subway ("the Tube") and buses. http://www.tfl.gov.uk/buses/ftt_home.shtml

General Social Framework

Population and Income Levels

The national census undertaken in 2001 recorded the population of Greater London at 7,172,091. Of these 2,766,114 live in Inner London and 4,405,977 in Outer London. http://www.statistics.gov.uk/census2001/pyramids/pages/1b.asp

The average household wage for the UK in the summer of 2001 was £26,200 www.map.hackney.gov.uk/mapgallery. No figure is available for the average household wage in London although such a figure would in any case have to be treated with caution because of the huge income inequalities in the city. The area with the highest earnings by postcode sector is South Kensington, where the average annual household income is £47,700, but in contrast several areas of London have household incomes well below the national average. www.wsws.org/wealthandinequalities/

Perceptions of Hydrogen: Previous Studies

The fuel cell taxi project co-ordinated by Imperial College London in 2001 – see section 1 – also undertook two focus groups and 100 questionnaire-based interviews to assess taxi drivers' attitudes towards FC taxis and hydrogen.

Drivers were generally positive about the vehicles and stated on average that they would be prepared to pay £2,970 per year for the use of a FC taxi, technical/breakdown support and hydrogen that equated to the same cost per mile as diesel.

Contrary to expectations, none of the taxi drivers interviewed expressed concern about the safety of hydrogen fuelled vehicles. When prompted to discuss the subject at the focus groups the general attitude was summed up by one driver who stated that "if it weren't safe it wouldn't be licensed". This unexpected lack of concern about hydrogen technologies may be partly because London taxi drivers work in a highly regulated industry in which their vehicles have to pass frequent and stringent safety tests.

London - Summary and Conclusions

The UK Government has been keen to promote cleaner vehicles and fuels in the last 5 or 6 years and through a variety of measures has achieved considerable success. Fuel duty reductions in low sulphur diesel and petrol contributed to these fuels completely replacing traditional formulations far more quickly than expected, and a combination of duty reductions and purchase incentives have led to the UK's rapidly growing LPG vehicle market. More efficient conventional fuel cars have been encouraged by reforming car and company car taxes to systems based on tailpipe CO_2 emissions and cleaner heavy-duty vehicles have been encouraged by purchase and tax incentives.

To date there has been little experience with hydrogen or fuel cell vehicles in the UK. However, last year's announcement of zero-rated fuel duty for hydrogen vehicle demonstration projects and positive statements about the vehicles in the inter-departmental Powering Future Vehicles strategy document indicate that the Government will actively promote their introduction. Furthermore, the Energy Saving Trust has already part-funded one fuel cell vehicle project – Westminster's grounds vehicle - and is likely to fund other hydrogen and fuel cell projects in the future.

There have been many trials of alternative fuel buses in the UK, mainly CNG and LPG, although in total there are only around 100 of the vehicles in operation. This low number is largely due to the Fuel Duty Rebate, which negates the effect of the lower duty on gaseous fuels and makes alternative fuel buses more expensive to run than their diesel equivalents. It appears likely, therefore, that most bus operators have trialled alternative fuel buses for environmental rather than financial reasons. This contrasts with the situation for most other vehicle types for which it is generally accepted that sales are driven mainly by the potential for financial savings.

In addition to bus operator's interest in cleaner buses, two recent developments appear to favour the introduction of alternative fuel buses: the Government's intended reform of the Fuel Duty Rebate and the Governments and EST's targets for low carbon and fuel cell buses.

Overall the outlook for the CUTE project in London is positive, with London Buses looking forward to the introduction of their three fuel cell buses and BP confident that they will have refuelling facilities in place before the vehicles arrive. Longer term the prospects for other hydrogen and fuel cell bus projects are also good given the Government's interest in fuel cell and hydrogen vehicles and in the introduction of cleaner buses.

2. Luxembourg

Past, Present and Future Alternative Propulsion Initiatives

The CUTE Project

The three DaimlerChrysler Citaro buses will be introduced to Luxembourg as part of the Clean Urban Transport for Europe (CUTE) project. They will be the first hydrogen or fuel cell buses to operate in Luxembourg. [http://www.daimlerchrysler.com/index_e.htm?/specials/fuelcell2002/newbuses_e.htm]

The buses will be delivered at the end of September and start operating in Luxembourg City after a CUTE meeting and a press conference in the third week of October.

Apart from the CUTE project, there are no established hydrogen projects in the Grand Duchy of Luxembourg. The hydrogen filling station of the CUTE project is the first one in Luxembourg.

Other Projects or Experiences with Alternative Fuel

The T.I.C.E. bus-syndicate in southern Luxembourg owns 20 natural gas buses which are refuelled at two natural gas filling stations of the TICE.

There are approximately 12 natural gas driven cars in the whole country using the T.I.C.E. filling stations.[http://www.erdgas.lu/online/news_d/FIL_2002_D.html]

In July 2003, a project with natural gas taxis is going to start. A natural gas filling station was built by SOTEG for this purpose. SOTEG offers 1000€ for the first 100 people purchasing a natural gas driven car.

The AVL (bus operator of Luxembourg City) operates about 45 bio diesel buses and three hybrid-electric buses. Bio diesel is imported and cannot be bought in public filling stations.

Policy & Regulatory Framework Relevant to Hydrogen Bus Projects

Like other European countries, Luxembourg has ratified the Kyoto protocol; hence it is a legally binding task to reduce greenhouse gas emissions. Luxembourg has committed itself to reduce greenhouse gas emissions by about 28% in 2008-2012 compared to 1990. At present, Luxembourg has one of the highest per capita emissions world-wide.

In 2001 the government published an official journal about the promotion of efficient use of energy [http://www.erdgas.lu/files/Memorial_A85_2001.pdf]. This brochure includes guidelines for the use of various different technologies. It also contains information about financial programs and about available support material for the installation of equipment increasing energy efficiency.

Funding for fuel cells is fixed at about 150 Euro per kW of installed electric capacity, with a maximum fixed at 75 000 €.

Most of the funding programs refer to residential installations and measures such as central heating, reducing electricity consumption, green electricity, heat balance etc.

A workgroup consisting of members of three ministries (Ministry Of Transport, Ministry Of The Interior, Ministry Of Environment), of the building authority, of the CFL (Chemins de Fer Luxembourgeois – Railways Of Luxembourg) and of the "Cellule Modèle de Trafic" has developed a document in May 2001 on measures in the transport sector [http://www.emweltzenter.lu/emweltzenter/meco/meenung/meenung92.pdf].

Main issues are:

- To reduce the environmental burdens caused by transport.
- To shift transport into modes protecting the environment.
- To extend public transport to all residential areas.
- Furthermore, the Ministry Of Environment decided to create plans to assist the development of ecological technologies.
- To invest in funds of eco-efficient enterprises.
- To enforce eco-management etc. [http://www.mev.etat.lu/].

Public Transportation Plans and Guidelines

The coalition agreement of 1999 of the Luxembourg government contains plans to strengthen railway in general and especially in the densely populated borderland to Lorraine, France/ Belgium.

In the past, the emphasis of mobility planning in Luxembourg has been focused on the extension of the road network. The reason for that was the sparsely populated structure of Luxembourg. The Ministry Of Transport proposes a goal of a split of 75:25 between individual and public transport. Presently, the split is 86:14 (with local differences). Luxembourg has one of the highest car densities in Europe and a strongly extended road network. As mentioned there have been plans to create a workgroup consisting of different ministries which should develop a mobility concept including road network, emissions, public transport, cargo transport etc.

At present there are activities to significantly support two concepts in transport aiming at achieving the desired modal split: park & ride (P&R) and railway (including tramway).[http://www.emweltzenter.lu/emweltzenter/meco/meenung/meenung92.pdf]

Luxembourg City expects rising numbers of cross-border commuters. Today there are 107 000 commuters per day. For the year 2020 this number is expected to increase to 170 000.

It is important for Luxembourg to handle the problems that come along with commuter traffic [http://www.dp-niederanven.lu/transport.html].

Regional Tramway and the Kirchberg-Quarter

In the last years, plans have been discussed to introduce a regional tramway in the city of Luxembourg (2-system city railway, like the "Saarbahn" in Saarbrücken). It would be restricted to one line in Luxembourg City, probably from Kirchberg to Central Station. [http://www.rail.lu/btbbulletin.html]

In 1964, the existing local tramway has been replaced by buses [http://www.rail.lu/btbbulletin.html; mobilitéit.lu – Strategiepapier zum Teilaspekt Schienenverkehr, Ministère des Transports du Grand-Duché de Luxembourg (in cooperation with CFL), January 2001].

The Kirchberg-Quarter (in the North-East of the city) is in the focus of current strategies of public transportation. While other parts of the city reach a split of nearly 75:25 (individual to public transport), the proportion of individual traffic in the Kirchberg-Quarter is still higher than 90%. Therefore, this quarter has the greatest need and potential for development. The Kirchberg-Quarter is the quarter of businesses and international banks in Luxembourg City with about 80 000 employees and about 50 000 commuters.

Public Transportation: Structure and Financing

Trains in the Grand-Duchy of Luxembourg are operated by the governmental CFL (Chemins de Fer Luxembourgeois - Railways of Luxembourg).

The RGTR and the T.I.C.E run regional buses. The T.I.C.E (Syndicat des Tramways intercommunaux dans le canton d'Esch-sur-Alzette) operates buses in the Southwest of the Grand Duchy Luxembourg. They use 20 natural gas buses and own 2 natural gas filling stations.

Table 2-1: Public transport companies in the Grand-Duchy of Luxembourg

Company	Buses	lines	Km/year	Region
RGTR (Régime Général des Transports Routiers)	370*[1]	161	n/a	Nationwide
AVL (Autobus de la Ville de Luxembourg)	136	22*[2]	>5.300.000	Luxemburg City
T.I.C.E (Syndicat des Tramways intercommunaux dans le canton d'Esch-sur-Alzette)	50		>2.500.000	9 municipalities in the Southwest of the Grand Duchy Luxembourg

*[1] 320 buses from private enterprises and 50 of CFL
*[2] 5 of them coordinated with RGTR

[http://www.luxembourg-city.lu/vdl/html_fr/whats_new/citynight/citynightbus.htm].
[http://www.ils.nrw.de/netz/leda/

The **AVL of Luxembourg City** is completely financed by the city of Luxembourg. The AVL is a part of the municipal administration of the city and responsible for the city buses on behalf of the Mayor of Luxembourg City. 1/3 of the bus fleet is subcontracted to private companies. For the service of providing some regional busses, the Ministry Of Transport pays compensation [personal communication AVL].

Buses are usually deployed for 12 years. About 80 standard buses, about 40 articulated buses and some mini buses are operated. 45 buses are driven by bio diesel. Due to the fact that AVL is part of the city administration, all decisions are made by the municipality of Luxembourg City.

The bus line net of AVL comprises approximately 130 km on 27 bus lines. In 2000, a total of 24.418.000 passengers used AVL buses.

AVL Timetables
Buses operate every 7 to 30 minutes. In Luxembourg City there is a "night bus". Three central lines are running on Friday and Saturday nights every 30 minutes. This project intends to attract young people. On special events like concerts or festivals AVL offers gratis buses which transport people at P&R places.

Management And Administrative Structures Affecting Hydrogen Bus Projects

Tickets and Fares

The system of tariffs of the AVL-buses:

Table 2-2: Tariff Scheme

ticket/pass	conditions	tariff from 01/01/2003
a.) regular tariffs		
Kuerzstreckebilljee (short distance ticket)	the short distance ticket has a validity of one hour and is limited to one defined bus-ride	bought at bus:1.20€, booklet with 10 tickets: 9.20€
Oeko-Billjee ("eco-ticket")	the "eco-ticket" has a unlimited validity on all lines from time of first usage until the next morning 8.00 a.m.	bought at bus: 4.60€, booklet with 10 tickets: 18.50€
Kuerzstreckekaart (short distance monthly ticket)	monthly ticket for one defined line	advance sale: 20.50€
Oeko-Pass (monthly network-pass)	monthly ticket, unlimited rides on all lines	advance sale: 41.00€
L-Kaart (monthly-pass for Luxemburg City)	monthly ticket for one precise line in two defined sectors in L. City	sent by post, direct debit authorisation necessary: 10x20.50€, 12 for the price of 10
City-Kaart (monthly pass for Luxemburg City)	monthly ticket for all lines at the area of Luxembourg City	sent by post, direct debit authorisation necessary: 10x31.00€, 12 for the price of 10
b.) reduced tariffs		
Oeko-Pass (monthly network-pass)	for seniors and extended families, description see above	advance sale: 20.50€

City-Kaart (monthly pass for Luxembourg City)	for seniors and extended families, description see above	sent by post, direct debit authorisation necessary: 10x15.50€, 12 for the price of 10
Jumbo	unlimited in all lines all over the country, for persons under 20 or over 20, when they get child benefits	45.00€ by providing evidence of entitlement
F-Kaart	monthly Ticket for all lines at the area of L. City, only for functionaries, employees and workers of the City	18.50€
c.) gratis		
Certificat scolaire et titre de transport	for pupils and students under 21	n/a
Libre parcours pour économiquement faibles	for economically disadvantaged persons	n/a
Titre de transport pour invalides	for handicapped persons	n/a

Fuel Prices

As a result of lower taxation, petrol fuel and diesel can be bought much cheaper in Luxembourg than in the surrounding countries (Germany, France and Belgium). Therefore, the Grand Duchy has a lot of "tank-up-tourism". The ecological consequences of this "tourism" are intensely discussed in public.

Table 2-3: Fuel prices in Luxembourg

Fuel	**price per litre (€/l)**
Diesel	0,599
Petrol	0,754
Super Unleaded	0,757
Super Premium	0,790
Bio diesel, gas for use as road fuel	--

[http://62.146.109.25/liste.asp, prices for Luxembourg City 05/22/2003]
Note: Bio diesel is not available at regular filling stations.

Table 2-4: Fuel prices for the AVL

Fuel	**price per litre (€/l) including 15% taxes**
Diesel	0,55
Bio diesel	0,77

The costs for the bio diesel are higher than for diesel. Furthermore, the bio diesel buses need more fuel. Therefore, the AVL have trialed alternative fuel buses for environmental rather than financial reasons.

General Social Framework

Grand Duchy

The Grand Duchy of Luxembourg has a population of 448,569 (July 2002) and the following age structure:

0-14 years	18.9% (male 43,634; female 41,164)
15-64 years	67.0% (male 151,364; female 149,156)
65 years and over	14.1% (male 25,486; female 37,765)

37% of inhabitants of the Grand Duchy are foreign residents - the largest proportion in Europe. The population growth rate is 1.25% (2002) and the unemployment rate is 2.6% (2001).

In 2001 the Gross Domestic Product was 21.223 billion €, the annual average wage was 47.900 €.

Luxembourg has 3 official languages: French (especially used by government and law), German and Luxembourgish, a special German dialect, which has become the third official language in 1984.

Students at schools are taught about hydrogen and fuel cells in chemistry or physics. [www.statec.lu, http://www.emweltzenter.lu/emweltzenter/meco/meenung/meenung92.pdf].

Luxembourg City

Luxembourg City has 81,000 inhabitants and about 56,000 registered cars.

There are approximately 60,000 bus passengers per day (public transport accounts for 1/3 of daily passenger trips).

The main groups using public transport are pupils/students and elderly persons.

An important focus group for present and future plans in public transport are the commuters.

Luxembourg - Summary and Conclusions

In Luxembourg, policy generally intends to increase bus traffic and to reduce the high amount of individual traffic. To date there has been no experience with hydrogen or fuel cell vehicles in the Grand Duchy. Public buses use some alternative fuel buses (natural gas and bio-diesel). The bus operators use alternative fuel buses for environmental rather than financial reasons. Private cars are slowly beginning to use alternative fuel.

3. Munich / Ottobrunn

Past, Present and Future Alternative Propulsion Initiatives

Greenhouse gas reduction commitments

According to the Kyoto protocol greenhouse gas (GHG) reduction targets and in the framework of EU-burden-sharing, Germany committed to reduce its emissions of the six major GHGs by 21% by the year 2008 – 2012 on the basis of 1990 (CO2, CH4, N2O), respectively 1995 (HFCs, PFCs, SF6).

The German government self-committed to a CO2 reduction of 25% by the year 2005 regarding the base year 1990 – an equivalent of 1,000 million tons CO2. Nearly ¾ of this committed CO2 reduction has been realized so far. The transportation sector shall contribute a CO2 emission reduction of 1.5 – 2.0% in reference to the year 1990, or 15 – 20 million tons of CO2. Nonetheless, there are no dedicated national reduction targets concerning the public transportation sector.

Low-sulfur diesel is promoted by means of a dedicated petroleum taxation rebate [BMU 2000]. Upon request, currently 0.0614 EUR/l of the 0.15 EUR/l environmental/petroleum tax may be refunded if the fuel is consumed for public transportation purposes.

Income tax may be rebated by commuters independent of the chosen transportation mode.

Initiatives, R&D and Demonstration Projects

ARGE LH_2 City Bus Demonstration Bavaria

In the framework of the Euro-Québec Hydro Hydrogen Pilot Project (EQHHPP), an LH2 bus with internal combustion engine was developed and operated in Bavaria. Inner city and rural driving profiles were examined between 1996 and 1998 to gain performance data about the specific characteristics of an LH2 ICE bus in public service. The project partners were:

- Autobus Oberbayern GmbH, Munich, Germany
- Erlanger Stadtwerke AG, Erlangen, Germany
- Linde AG, Höllriegelskreuth, Germany
- MAN Nutzfahrzeuge AG, Nuremberg, Germany
- Stadtwerke München - Verkehrsbetriebe, Munich, Germany

The hydrogen engine and the bus were developed by MAN Nutzfahrzeuge GmbH. MAN also provided the maintenance of bus parts and the supply of spare parts, whereas Linde AG (Höllriegelskreut/Germany) was responsible for the design and manufacture of the cryogenic storage tanks and filling equipment. Autobus Oberbayern, Stadtwerke München and the Erlangener Stadtwerke operated the bus on a daily duty basis.

The hydrogen bus field trial consisted of three demonstration phases. During demonstration phase one (April 1996 to February 1997), the bus operated on city line

287 in Erlangen. The bus traveled approximately 15,500 km in this phase with 150-170 km per day and tank filling.

Figure 3.1: MAN bus powered by an internal combustion engine supplied with liquefied hydrogen [MAN]

Approx. 110-130 km per day and tank filling, respectively some 9,000 km were traveled in the course of demonstration phase II which took place in the city area of Munich between April and December 1997. During its third phase (February 1998 – end of 1998), the bus operated in the suburban Munich area.

ArgeMUC at Munich International Airport
ArgeMUC is an industrial consortium established in 1997 by major companies in the field of hydrogen technology with the purpose to develop, erect and operate a hydrogen refueling station at Munich International Airport.

Figure 3.2: CGH2 and LH2 filling station at the Munich airport [ArgeMUC]

The project aims at validating the safe and reliable handling of compressed gaseous and liquefied hydrogen. The robotized LH2 refueling outlet for passenger cars is

publicly accessible, whereas the CGH2 outlet for buses is not publicly accessible on airport premises.

Three CGH2 powered internal combustion engine buses (2 by MAN, 1 by Neoplan; all three with MAN hydrogen engines) have so far covered more than 300,000 km on the airport apron. A CGH2 fuel cell bus will be supplied to the airport by MAN this year, a second bus is foreseen, but has not yet been definitively announced. This fuel cell bus will be operated on the apron first, and in public service on a bus line serving the airport later-on.

LH2 is supplied to hydrogen ICE sedans by BMW.

The hydrogen filling station regularly receives technical visits. In June, the 10,000th visitor is expected.

Figure 3.3: MAN airport CGH2 ICE bus and BMW LH2 ICE 7'series sedan [ArgeMUC]

The airport refueling station and demonstration project comprises 15 consortium partners:

- Aral AG (LH2 filling station)
- BMW AG (LH2 system and vehicle)
- Siemens AG (safety and automation)
- MAN Nutzfahrzeuge AG (compressed gas storage, low-floor airfield buses)
- HDW – Howaldtswerke - Deutsche Werft AG (metal hydride storage)
- HEW – Hamburgische Electricitäts-Werke AG / GHW – Gesellschaft für Hochleistungs-Wasserstoffelektrolyse (Elektrolyzer)
- m-tec Gastechnologie GmbH (compressed gas filling station)
- TÜV Süddeutschland Bau und Betrieb GmbH (safety assessment)
- Grimm Aerosol Technik GmbH & Co. KG (sensor systems)
- ET – Energietechnologie GmbH (project controlling)

- Linde Gas AG (LH2 supply)
- Bayerngas GmbH (natural gas reforming)
- FMG – Flughafen München GmbH (project and demonstration infrastructure)
- E.ON Bayern AG
- Proton Motor GmbH (PEM fork lift)

Ottobrunn Hydrogen Bus on Line no. 210
It is planned to operate a hydrogen powered bus on the RVO line number 210 in the suburban area of Munich. The bus is planned to be an MAN with a compressed gas hydrogen storage. In the course of this summer the demonstration project is expecting a decision for co-funding. The operation may then be expected to commence by mid 2004.

Line 210 establishes a connection between the Munich city subway and the Munich south-east suburban area Waldperlach and Ottobrunn. It commences at the combined underground and S-Bahn station "Neuperlach Süd" in the south-east Munich city area. From there, line 210 heads south to Ottobrunn and Riemerling. The journey distance is approximately 6 km one way for which the bus takes about 15 min.

Figure 3.4 Map of the bus route which is daily serviced by line 210 with filling station (FS) in Waldbrunn

Line no. 210 is operated by RVO/RVA on the basis of §42 public transportation law (PbefG – Personenbeförderungsgesetz) and the transportation enforcement contract (Verkehrsdurchführungsvertrag) with MVV (Munich Transport and Tariff Association – Münchner Verkehrs- und Tarifverbund GmbH) and the administrative district of Munich ("Landkreis München"), respectively [RVO 2003].

Alternative Fuels Refuelling Stations Other than Hydrogen

Nationwide, there are currently 346 natural gas refuelling stations [Erdgasfahrzeuge 2003]. Thereof, seven refueling stations are located in the greater Munich area. These refuelling stations are operated by Aral (Munich), Bauer Kompressoren (Munich), Bayern Betriebshoftankstelle (Erding, Wolfratshausen), OMV (Fürstenfeldbruck), Shell (Munich), SWM Versorgungs GmbH (Munich).

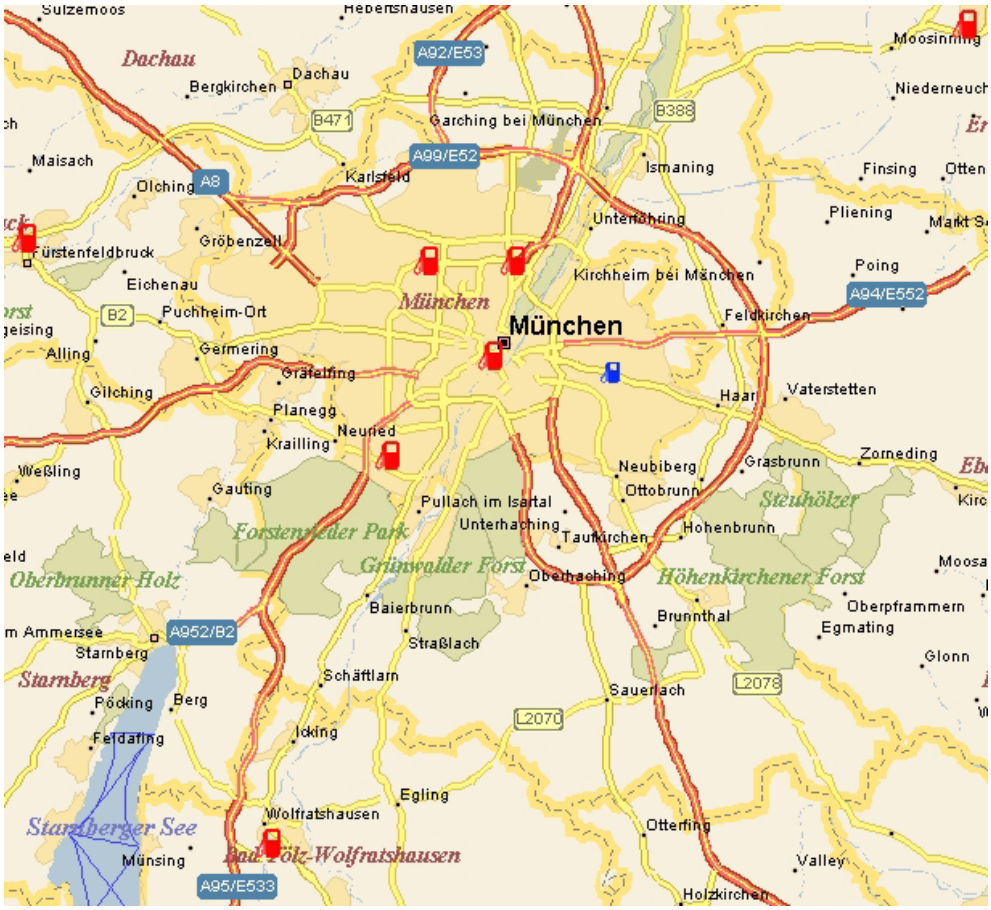


Figure 3.5: Natural gas refuelling stations in the greater Munich area (red: operational; blue: planned) [Erdgasfahrzeuge 2003]

Esso Deutschland GmbH – a subsidiary of Exxon – plans to open some 200 CNG refuelling stations within the next five years in Germany [Esso 2003]. TotalFinaElf shortly afterwards announced to add another 200 refuelling stations [TotalFinaElf 2003]. Furthermore, Aral decided to erected 250 natural gas refuelling stations by the end of 2004 [Aral 2003]. In 2002, nineteen major German gas companies established erdgas mobil GmbH, a company aimed at getting 1,000 natural gas refuelling stations operational within the next couple of years [DVGW 2002].

LPG is sold nationwide at more than 400 refuelling stations [Autogas-Forum 2003]. There are five LPG refuelling stations in the greater Munich area: Allgut (Munich), Süd Treibstoff Mergen (Munich), J. Böhm (Garching-Hochbrück), Süd-Treibstoff Tankstelle (Holzkirchen) and Tyczka GmbH & Co. KGaA (Geretsried).

Biodiesel may be bought at approx. 800 fuelling stations in Germany. There are four locations in the Munich city area: BayWa AG, Sprint-Tankstelle G. Friedl, Super wash 2000 and Gustav Eichele Kraftfahrzeuge GmbH [IWR 2003].

Policy and Regulatory Framework Relevant to Hydrogen Bus Projects

Financing the Bavarian Public Transportation Sector

According to the Bavarian law for local public transport (BayÖPNVG – Gesetz über den Öffentlichen Personennahverkehr in Bayern) the Bavarian administrative districts and non-district communities are responsible for providing buses, tram and subways for public transport purposes. The State of Bavaria is responsible for regional trains ("S-Bahn" and other).

The State of Bavaria aims at meeting public transportation demand as far as possible by means of public transport instead of individual traffic. Selected goals are [STWMVT 2002]: to offer a dense and synchronized public transport system improving service quality in terms of traveling time, reliability, punctuality, vehicle functionality and design, cleanliness of vehicles and stations, passenger information and tariff system provide an integrated public transportation system closely interacting with individual traffic.

Between 1999 and 2002 some 1,123 million EUR of investment capital were jointly spent by the German state, the State of Bavaria and local communities for this purpose in Bavaria. The financial burden is shared between the administrative bodies according to Table 3.1.

Table 3.1: Accumulated public investments in the Bavarian public transportation sector between 1999 and 2002 in million EUR [StWMVT 2002]

Infrastructure investment	Total	Bavaria	Germany	Communities	Others
Public Transportation	1,123.4	244.3	695.7	163.4	19.9
Regional train	407.5	156.3	251.2	-	-
Subway	390.1	66.5	226.0	97.7	-
Tramway	113.5	9.4	76.3	27.8	-
Bus stations, workshops, park & ride	212.3	12.2	142.2	38.0	19.9

Legal framework for the financial burden sharing are the GVFG and the "Regionalisierungsgesetz". Both laws stipulate how financial contributions from the German state are distributed among the transportation modes. Furthermore, the State of Bavaria contributes with incomes from the vehicle tax ("Kfz-Steuerverbund"). In the framework of GVFG additional allowances are granted providing the purchase of dedicated technologies, such as CNG propelled buses.

The State of Bavaria acknowledges that the local and regional public transportation sector will presumably never operate without additional public funding. In Germany, ticket sales generally cover 65 - 70% of the overall expenses. In 2001, the State of Bavaria provided 96 million EUR for new vehicle acquisition alone. Further sources

of income are communal energy suppliers. Where there are communal energy suppliers, expenses for public transportation are complemented by cross-subsidies.

The decision about which buses are bought rests with the designated public transport service operator. Public authorities may require the operator to select certain technologies or to comply with additional emission limits.

Public transportation in Munich

Public transport in Munich and the greater Munich area are unified in the Munich Transport and Tariff Association (Münchner Verkehrs- und Tarifverbund GmbH – MVV). The various transport modes are then operated by individual companies as described in further detail later-on. 5,560 million person kilometers were performed by MVV in 2001 – an increase of nearly 6% compared to 2000. At the same time annual turnover increased by 6.61% to 449.76 million EUR. In Germany, ticket income generally covers only about 65-70% of overall public transport expenses.

MVV partners are the Bavarian state, the city of Munich and administrative districts ("Landkreis") in the greater Munich area (Landkreis Bad Tölz-Wolfratshausen, Landkreis Dachau, Landkreis Ebersberg, Landkreis Erding, Landkreis Freising, Landkreis Fürstenfeldbruck, Landkreis München, Landkreis Starnberg). The three major partners with respect to the present project are described in more detail in the following sections.

S-Bahn München

Regional trains („S-Bahn“) are operated by S-Bahn München GmbH, a subsidiary of Deutsche Bahn AG, the operator of the German railways. S-Bahn operates in the region and in the city center as well. More than 720,000 passengers use the S-Bahn each day on a rail network of 420 km length.

Start of operation: April 28 1972 (for the Olympic Games)	
Growth since 1972	Number of railcars: twofold
	Number of passengers: threefold
	Personnel: 1.4 fold
Personnel	Total: 1,136
	Engine drivers: 585
	Workshop: 265
	Service: 122
	Administration: 45
	Apprentices: 63
	Operations: 56
Railcars:	ET 420: 78
	ET 423 (new regional train): 177
	VT 628 (Line A): 6
Number of stations (of which 7 in tunnel): 147	
Rail network:	442 km
Of which in mixed operation with long-distance trains: 186 km	
Number of lines:	10: S 1, S 2, S 4, S 5, S 6, S 7, S 8, S 20, S 27, Line A
Train kilometers per year (2002): 18,900,000 km/a	
Trains on workdays:	1,148
Passengers on workdays:	approx. 720,000
Saturdays:	approx. 350,000
Sundays:	approx. 240,000

MVG

In the Munich city area, Münchner Verkehrsgesellschaft mbH (MVG) operates the bus lines, the tramway lines and the underground system. Detailed data provided in 2003 are compiled in the following table:

Personnel:	3,579
Line length:	Underground 85 km
	Tramway 71 km
	Bus 412 km
Number of lines:	Underground 8
	Tramway 10
	Bus 76
Nightlines:	Tramway 4
	Bus 6
Stations:	Underground 89
	Tramway 147
	Bus 835
Average station distance:	Underground 955 m
	Tramway 484 m
	Bus 494 m
Average travel speed:	Underground 36.9 km/h
	Tramway 20.2 km/h
	Bus 19.5 km/h
Vehicles:	Underground (double headed motor coaches) 258
	Tramway 99
	Bus 257 (119 standard + 138 kneel buses)
	Bus (private partnership) 216 (208 standard + 8 kneel buses)
Vehicle capacity:	Underground
	- A/B: 98 seats and 192 standing room
	- C.1: 252 seats and 660 standing room
	Tramway
	- R.2: 97 seats and 60 standing room
	- R.3: 145 seats and 73 standing room
	Bus
	- standard bus: 37 seats and 33 standing room
	- kneel bus: 52 seats and 55 standing room
Service performance (2001):	11,056 km*capacity
	Underground 7,658 km*capacity
	Tramway 1,241 km*capacity
	Bus 2,157 km*capacity
Passengers:	440.2 million/a
	Underground 293.9 million/a
	Tramway 81.1 million/a
	Bus 160.2 million

RVO/RVA

In the Greater Munich area, RVO respectively RVA – a subsidiary of RVO – operate bus lines. Bus line 210 proposed as service route of the hydrogen buses is operated by Regionalverkehr Oberbayern GmbH (RVO). RVO is a 100% subsidiary of Deutsche Bahn AG, the main German railway operator.

	RVO	RVA (70% subsidiary of RVO)
Personnel:	622	75
Turnover:	55.0 million Euro/a	6.94 million Euro/a
Vehicle kilometers:	29.4 million km/a	3.2 million km/a

Passengers:	38.0 million/a	5.3 million/a
Vehicles:	576 (346 company owned)	69 (43 company owned)
Line length:	12,513 km	1,185 km
Number of lines:	359	48

The average age of RVO buses is slightly above six years in the suburban area and 5 years 10 months in the city area. RVO buses have a typical life-time of 10 years. Average energy consumption in 2002 was 38.6 l/100 km. The Munich branch of RVO services 23 lines with standard 12 m buses, thereof 15 lines with standard low floor buses. None of them is fitted with particulate emission traps. All RVO buses use low-sulfur diesel with a sulfur content below 10 mg/kg petroleum (10 ppm).

RVO operates 16 CNG powered buses outside of Munich, three thereof in Berchtesgaden, two in Traunstein, 9 in Weilheim and two in Tegernsee. Furthermore, there are two bio diesel (RME – rape oil methyl ester) buses operating in Berchtesgaden and one in Bad Tölz.

Some 60% of RVO/RVA buses are company owned. The complementary buses are sub-contracted. Contracts are awarded on the basis of individual negotiations. In conjunction with dedicated line and application specifications stated by RVO/RVA the purchase decision rests with the sub-contractor [RVO 2003].

Cost of Demonstration: Two Model Calculations

Case 1

Assuming the replacement of some 10 of the MVG buses operated in Munich by hydrogen fuel cell buses for a demonstration project, and further assuming these buses and the fuel to cost four times as much as conventional buses and fuel then overall investment costs increase by 6.7% and fuel costs increase by 6.3%. In Germany, personnel and administration costs account for approx. 83.5% of the overall costs of bus operation. Thus, overall bus operation costs would increase by about 1.1%.

Bus transport represents some 20% of public transport passenger kilometers operated by MVG. Considering all transport modes, overall MVG costs may increase by 0.2%. In Munich, public transport costs are covered to about 70% by ticket sales; about 30% are covered by other sources. Thus, additional costs should be covered to 70% by the tickets resulting in a 0.15% increase in ticket prices.

Case 2

Assuming the replacement of all of the MVG buses by hydrogen fuel cell buses as future scenario with fuel cell bus prices twice the amount of conventional diesel buses and hydrogen fuel to cost as much as conventional fuel per kilometer – then overall costs of MVG buses (personnel, material, fuel, investment) increase by some 11.6%.

Considering all transport modes, overall MVG costs may increase by some 2.3%. Thus, ticket prices may rise by approximately 1.6%.

Management and Administrative Structures Affecting Hydrogen Bus Projects

Timetables

The timetables of all regional train („S-Bahn“), underground („U-Bahn“), tramway and bus lines are harmonized under the auspices of the Münchner Verkehrsverbund (MVV). All timetables are compiled in a single book. An electronic database which comprises all connections can be accessed via the Internet at www.mvv-muenchen.de.

Tickets and Fares

MVV follows the idea of intermodal traffic. There is no differentiation between bus, tram, subway or regional train.

Munich city and the greater Munich area are concentrically divided into four zones which are further subdivided into 16 so-called 'rings'. A unified ticket and tariff system is applied throughout the area. Ticket prices are determined by three parameters: traveling range – such as the number of areas or rings covered –, validity period, and membership to dedicated focus groups – such as children, couples, elderly etc. Basically, the following ticket types are offered:

- Single tickets
- Stripe tickets ("Streifenkarten") allowing for several trips depending on distance
- Season passes.
-

These types of tickets are described in further detail in the subsequent chapters. There are more, dedicated tickets, such as the Green Card ("Grüne Karte"), Youth Green Card ("Grüne Jugendkarten"), apprentice cards or the seniors and retirees card ("Senioren- und Ruhestandskarten").

Single Tickets

The single fare depends on the trip length which is represented by the number of traveled zones. A reduced single fare is valid if the ticket is paid by electronic cash card ("Geldkarte").

Table 3.2: Single ticket fare 2002/2003 [MVV]

Number of zones	Cash price (incl. VAT)	Electronic payment price (incl. VAT)
1	2.00 EUR	1.80 EUR
2	4.00 EUR	3.60 EUR
3	6.00 EUR	5.40 EUR
≥ 4	8.00 EUR	7.20 EUR

Children always pay a single fare of 0.95 EUR (cash incl. VAT), resp. 0.76 EUR (electronic payment incl. VAT), resp. 1 stripe (see next chapter) independent of the traveling distance.

Stripe Ticket
Stripe tickets represent a cheaper alternative to buying single tickets. The required number of stripes depends on the traveling distance as shown in Table 3.3. Purchase prices of stripe tickets are presented in the following table.

Table 3.3: Stripe card purchase prices 2002/2003 [MVV]

User type	Number of stripes	Purchase price (incl. VAT)
Adults	10	9,00 EUR
Children	5	3,80 EUR

The purchase prices of stripe tickets listed in Table 3.3 results in travelling costs as calculated in the subsequent table.

Table 3.4: Stripe card fare 2002/2003 [MVV]

Number of zones traveled	Number of stripes required	Resulting fare price (incl. VAT)
1	2	1,80 EUR
2	4	3,60 EUR
3	6	5,40 EUR
≥ 4	8	7,20 EUR

Additionally, a short distance fare ("Kurzstrecke") may apply if the traveling distance does not exceed four stations (maximum two by U-Bahn or S-Bahn).

Season Passes
Regarding season tickets, the four MVV zones are further subdivided into 16 rings. Four rings apply for the city area (ring 1-4), 12 rings apply for the greater Munich area (ring 5-16). Seasonal passes range from tickets on a day's basis ("Tageskarten", see Table 3.5) to weekly and longer ones (dubbed "IsarCard", see Table 3.6).

Table 3.5 Day ticket fares 2002/2003 [MVV]

Travel area	Adult 1 day	Child 1 day	Couple 1 day	Adult 3 days	Child 3 days
Ring 1-4 (inner area)	4.50 EUR	-	8.00 EUR	11.00 EUR	18.50 EUR
Ring 1-6 (MUC XXL)	5.50 EUR	-	9.50 EUR	-	-
Ring 5-16 (outer area)	4.50 EUR	-	8.00 EUR	-	-
Ring 1-16 (MVV area)	9.00 EUR	1.80 EUR	16.00 EUR	-	-

Table 3.6: Season ticket fares 2002/2003 [MVV]

Area covered	Adults weekly	Adults monthly	Adults annual
up to 2 rings	9.50 EUR	35.50 EUR	337.00 EUR
up to 3 rings	11.40 EUR	43.00 EUR	409.00 EUR
up to 4 rings	13.60 EUR	51.00 EUR	485.00 EUR
up to 5 rings	15.70 EUR	59.00 EUR	561.00 EUR
up to 6 rings	17.90 EUR	67.00 EUR	637.00 EUR
up to 7 rings	20.10 EUR	75.50 EUR	717.00 EUR
up to 8 rings	22.00 EUR	82.50 EUR	784.00 EUR
up to 9 rings	24.20 EUR	91.00 EUR	865.00 EUR
up to 10 rings	26.30 EUR	98.50 EUR	936.00 EUR
up to 11 rings	28.40 EUR	106.50 EUR	1,012.00 EUR
up to 12 rings	30.30 EUR	113.50 EUR	1,078.00 EUR
up to 13 rings	32.60 EUR	122.50 EUR	1,164.00 EUR
up to 14 rings	34.70 EUR	130.00 EUR	1,235.00 EUR
up to 15 rings	36.60 EUR	137.50 EUR	1,306.00 EUR
up to 16 rings	39.00 EUR	146.50 EUR	1,392.00 EUR

Fuel Costs

Diesel

As shown in Figure 3.6, the cost of DIN EN 590 diesel with a sulfur content below 10 ppm (0.0001%) ranged between 0.649 and 0.789 EUR/l between mid of May 2002 and mid of May 2003 in Munich. Delivery and petroleum tax (currently 0.15 EUR/l) is included, VAT is excluded. Prerequisite is a minimum order quantity of 30,000 l. In the course of the Ökosteuergesetz (environmental tax bill) – adopted March 3rd 1999 by the German Parliament – 0.0614 EUR/l of the environmental tax rate on diesel may be rebated upon request if the diesel is spent in public transport. The refunding is granted if the bus is operated in line service, traveling time does not exceed one hour and traveling distance is below 50 km for one trip {§25 4a) b) [MinöStG 2003]}.

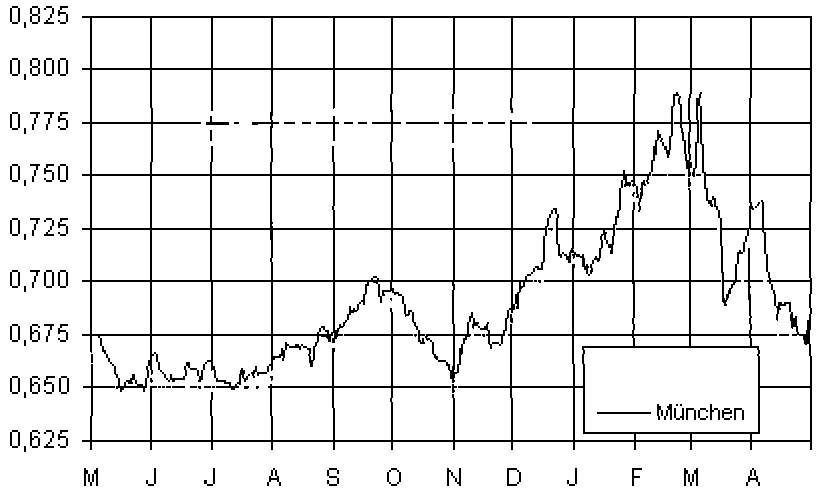


Figure 3.6: Diesel price for bulk consumers in Munich 2002 – 2003 [Dieselindex 2003]

Due to the war in Iraq, diesel prices have been highly volatile between December 2002 and end of May 2003.

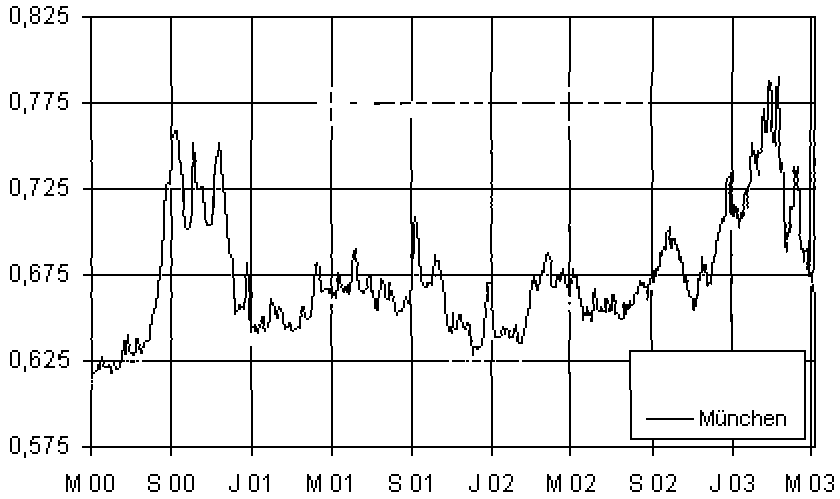


Figure 3.7: Diesel price for bulk consumers in Munich between 2000 – 2003 [Dieselindex 2003]

The triple hunch at the end of 2000 was caused by a sudden increase in US heating energy demand. As natural gas alone couldn't satisfy this demand, diesel was bought by the USA on the EU market. This effect occurs again at present and is seen as an important signal for fossil resource constraints becoming increasingly visible on international energy markets.

Natural Gas and LPG

Natural gas consumer prices ranged between 0.630 EUR/kg (January 2002) and 0.740 EUR/kg (February 2003) including petroleum tax and VAT in Munich [Gibgas 2003]. As part of the governmental environment initiative, the mineral oil tax for natural gas consumed by the transportation sector is reduced until December 31, 2020. Average natural gas and liquid petroleum gas prices in Germany are shown in Figure 3.8.

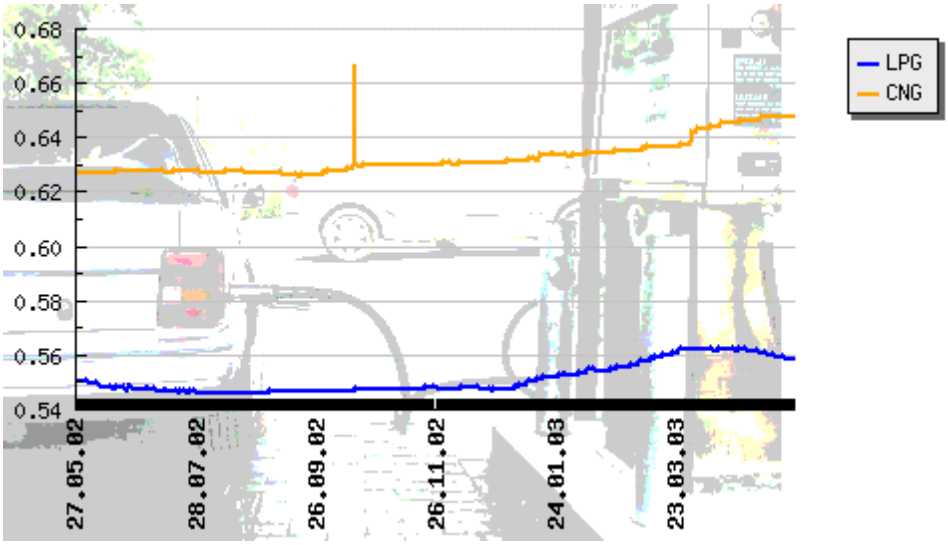


Figure 3.8: Average CNG and LPG consumer retail price in Germany 2002-2003 in EUR/kg [Gas-Tankstellen 2003]

RME ("Biodiesel")

Between 2002 and 2003 the consumer end price ranged from 0.721 – 0.834 EUR/l biodiesel [IWR 2003]. Neither mineral oil nor eco tax are due.

General Social Framework

Population, Employment and Income Levels

The area served by the MVV has an approximate diameter of 100 km roughly centered around Munich city center. In 2001, about 2.5 million people lived in the greater Munich area covering an area of 5,160 km². Thereof, 1,260,600 people live in Munich city (2001) in an area not greater than 310 km². The Munich administrative district ("Landkreis") around Munich city has a population of 301,000 people. 19,530 people live in Ottobrunn in an area of 5.24 km² (2002).

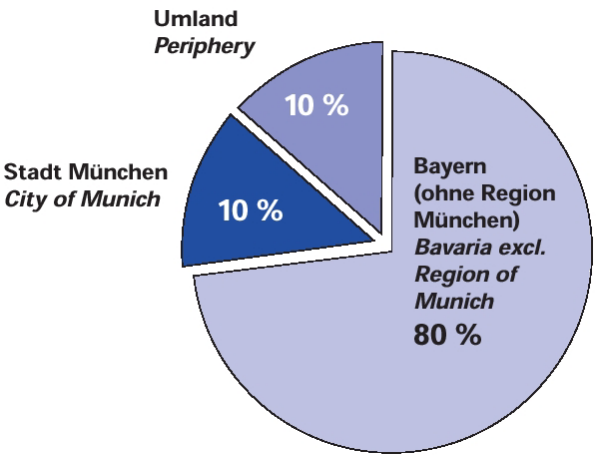
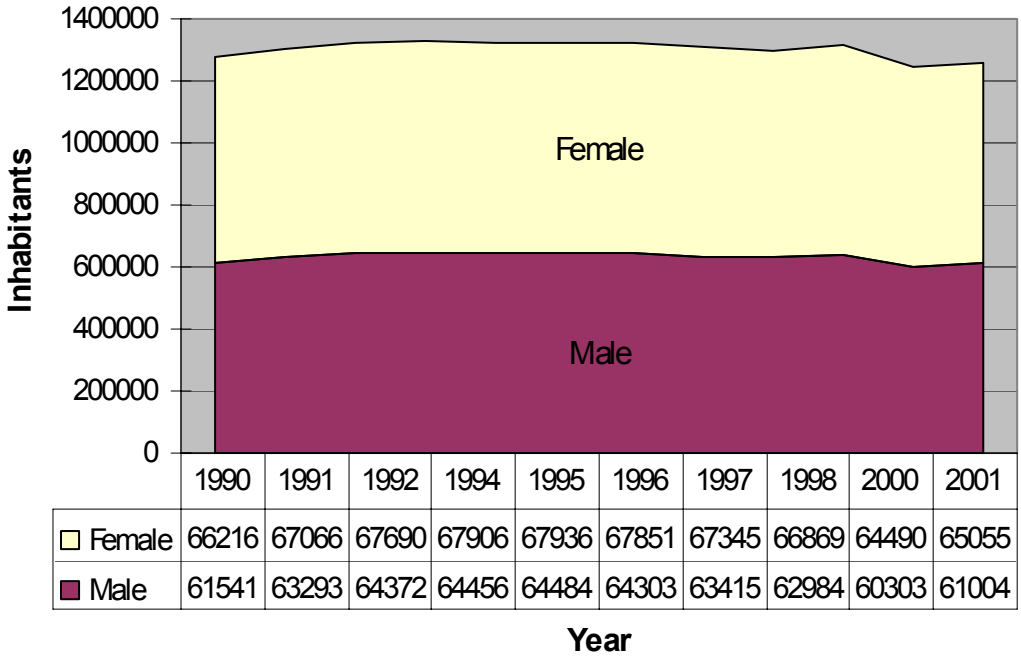


Figure 3.9: Population share of Munich and its periphery to Bavaria [RfAW 2003]



	1990	1991	1992	1994	1995	1996	1997	1998	2000	2001
Female	66216	67066	67690	67906	67936	67851	67345	66869	64490	65055
Male	61541	63293	64372	64456	64484	64303	63415	62984	60303	61004

Figure 3.10: Population development of Munich city between 1990 and 2001 [SALM 2002a]

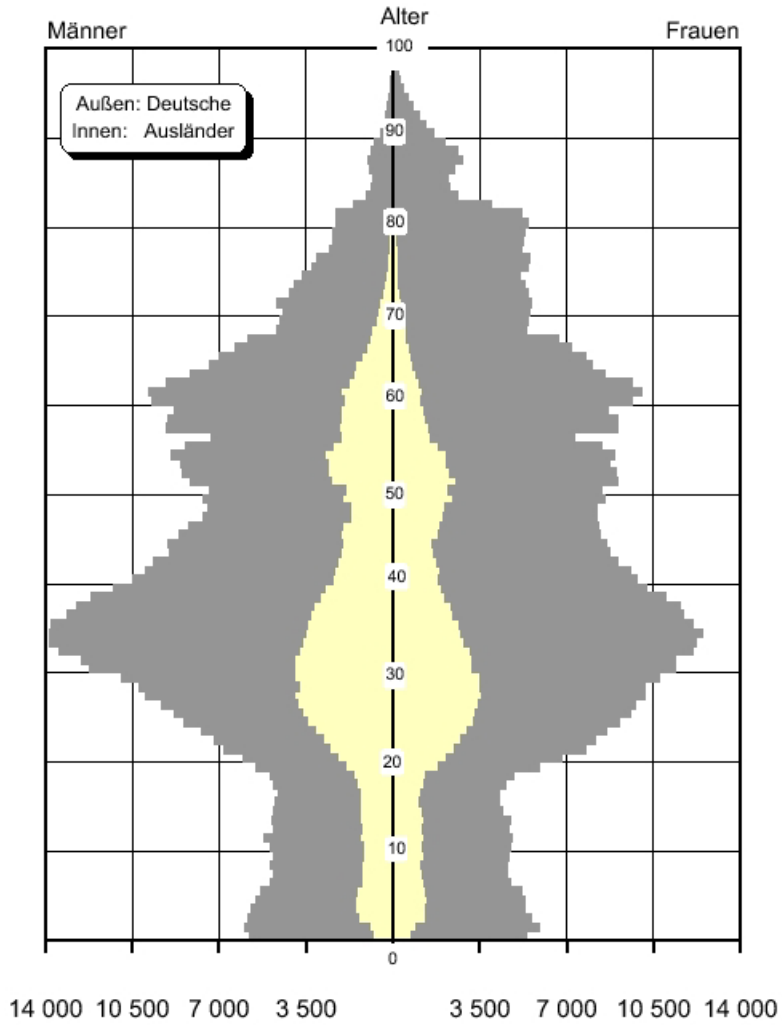


Figure 3.11: Age distribution of Munich city population in 2001/2002 [SALM 2002b]

Munich is the third biggest city and the second largest center of employment in Germany. It is one of Germany's leading centers for information and telecommunication technologies, civil and military transportation, media, life sciences and semiconductors. Major international companies in the field have their subsidiaries and/or corporate headquarters in Munich, such as BMG, BMW, EADS – European Aeronautic Defense and Space Company, GE – General Electric International Research Center, HP, IBM, Infinion, Osram etc. There is a relatively large number of companies in the greater Munich area working in the field of hydrogen, fuel cell or bus development/manufacturing, such as MAN/Neoplan, Proton Motor, Magnet Motor, Siemens etc.

Most of the employees in Munich work in the field of manufacturing (24.9%); property, rental, leasing, business services (20%); public and private services (19.4%) and commerce (13.2%) [RfAW 2003]. The qualification level is rather high. More than 18% of employees have a university degree.

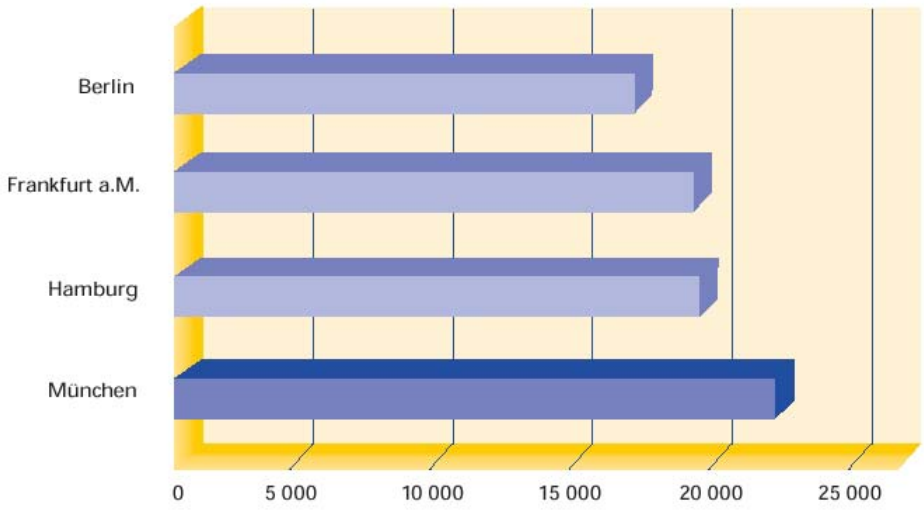


Figure 3.12: Purchasing power of selected German cities in EUR/capita in 2001 [RfAW 2003]

The average income of a Munich inhabitant is higher compared to other German cities as shown in Figure 3.12. The cost of living corresponds to the income level.

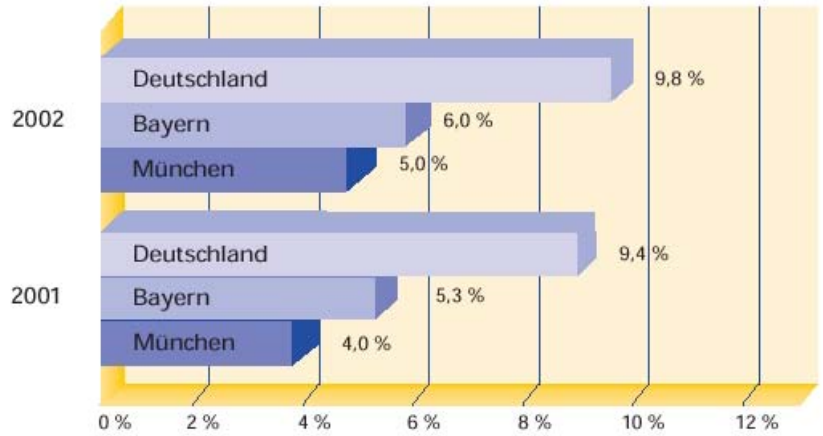


Figure 3.13: Annual average unemployment rate [RfAW 2003]

According to Figure 3.13 the unemployment rate is slightly lower than the Bavarian average, and significantly lower than the German average. Yet, unemployment has increased from 2001 to 2002 by one percentage point.

Approximately 23% of Munich's population are foreigners [RfAW 2003] in contrast to approx. 13% in the administrative district of Munich. The survey will have to be conducted in German as no single ethnic group dominates the foreign population in the Munich area.

In 2001, approx. 1.444 million cars were registered in the MVV area, thereof 683,140 in Munich city and 16,686 vehicles in Ottobrunn. There were approximately 0.54 cars per capita in Munich city, 0.85 cars per capita in the administrative district of Munich and a slightly higher 0.87 cars per capita in Ottobrunn. The Bavarian Ministry of Economic Affairs, Transport and Technology ("Bayerisches Staatsministerium für

Wirtschaft, Verkehr und Technologie") expects the public transport demand to decrease by 1.5% down to 7.2 billion person-km by the year 2015 [StMWVT 2002]. While public transport demand will stabilize in the city areas, the rural public transport demand will decrease as the number of individual vehicles is expected to increase.

Munich International Airport "Franz-Josef-Strauß" is situated about 20 km north of Munich in Erding. In terms of passenger numbers it is the second largest airport in Germany after Frankfurt a.M.. The number of passengers increased by 2.3% to 23.2 million in 2001. At the same time, the number of MVV passengers increased by 2.61% up to 561.185 million.

Attitudes and Behaviour

Between October and December 2000 a survey was conducted by MVV – Münchner Verkehrsverbund to gain information about motivation, attitudes and behavior regarding the use of the greater Munich public transport system [MVV 2002]. More than 4,500 interviews were made. The target group of interviewees were people older than 15 years and living in the MVV area at that time. Thereof, some 500 in depth interviews were led.

The main results of the MVV investigation were:

- Every fourth ride (= trips excluding walks), respectively every sixth trip (incl. walks) is done by public transport.
- Why do people move at all? 1/3 of the trips (walks included) are done for free-time activity, 26% for shopping reasons and 24% to commute between home and job. When considering rides (= trips excluding walks) commuting dominates with 34%, 28% for free-time activity and 21% for shopping reasons.
- Which modes do people prefer to move? To commute a slight majority of people living in Munich city prefers taking public transport (42%) over using their car (39%). Yet, in the rural parts of the MVV area only 20% rely on public transport compared to 58% who take their own car. When it comes to free-time activities the car is used at minimum twice as often as public transport independent of whether people live in the city or rural Munich area. For shopping reasons cars are predominantly chosen, too, except in the Munich city area where only 15% of all trips are made using the car or public transport, respectively (70% of the trips are accdomplished using other transport modes such as bikes or going by foot). In the field of educational traffic (pupils, apprentices, students etc.), public transport generally has a market share of 50% and more, no matter which geographical area is concerned.
- There is a high correlation between the parking situation at the place of work and the use of public transportation. The better the parking situation, the lower is the will to choose public transport means.
- The positive attitude towards the car is rising as people tend to "just enjoy driving". Dominating reasons for not taking public transport (multiple decisions possible) were: service frequency too low (12.2%), trip takes too long (10%), bad connections (9.8%).

- Only 5% of the surveyed people never use public transport. 30% (Munich city), or 15% (rural MVV area) are using public transport regularly on five to seven days a week.
- Approximately every second public transport trip is done even though it could be done using a car.
- The MVV passenger structure reflects the predominating population structure in the MVV area.
- The public transport image is rather positive: nearly 90% of the people questioned see positive external effects generated by public transportation. 80% say that public transportation is environmentally benign, nearly 80% appreciate the low risk of accidents, 64% enjoy using the riding time for various purposes.

4. Perth

Past, Present and Future Alternative Propulsion Initiatives

STEP (Sustainable Transport Energy for Perth) Hydrogen Fuel Cell Bus Trial

Beginning in mid 2004, Perth will be host to one of the first major hydrogen fuel cell bus trials to be undertaken around the world. The Western Australian Government, through the Department for Planning and Infrastructure, will own and operate three hydrogen fuel cell buses for two years between 2004 and 2006. The buses will be trialed on normal service routes throughout the Perth metropolitan area. This is the first hydrogen or fuel cell powered vehicle trial to be conducted in Australia and will involve the construction of Australia's first hydrogen refuelling station.

This trial is part of a series of projects initiated by DaimlerChrysler. Three DaimlerChrysler Citaro hydrogen fuel cell buses will be trialed in each of ten European cities and Perth. Buses will be trialed in Stuttgart, Hamburg, Luxembourg, Stockholm, London, Oporto, Barcelona, Madrid and Amsterdam under the CUTE (Cleaner Urban Transport for Europe) project; three buses will be trialed in Reykjavik, Iceland under the ECTOS (Ecological City Transport System) project; and three buses will be trialed in Perth under the STEP (Sustainable Transport Energy for Perth) project (see: http://www.dpi.wa.gov.au/fuelcells).

The main purpose of the STEP project is to evaluate the operation and performance of the buses within the Australian transport, industry and regulatory systems, and their potential as a future transport option in Australia. The critical technical, environmental, economic, and social factors influencing the introduction of hydrogen fuel cell buses will be investigated, and any barriers identified. The knowledge and expertise gained from the trial will be exploited to benefit the Western Australian community in any future transition to a hydrogen economy.

Other Western Australian Government Sustainable Transport Initiatives

Whilst in the past there have been limited clean fuel programs undertaken in Perth, the Western Australian Government has recently committed to a range of initiates aimed at decreasing the State's reliance on oil and the economic and environmental consequences that this entails. Some of the initiatives that the Western Australian government are currently undertaking include:

- only purchasing new buses for the public transport bus fleet which are powered by natural gas;
- expanding and investing in the Perth Urban Passenger Rail network;
- trialing biodiesel in public transport buses;
- changing the structure of the Government vehicle fleet by, where possible, replacing 6 cylinder vehicles with 4 cylinder vehicles;
- purchasing 20 hybrid cars as part of a trial of hybrid vehicles in collaboration with other governments around Australia;

- developing a Transport Energy Strategy for Western Australia (http://www.dpi.wa.gov.au/sustain).

Alternative Fuel Vehicles

Western Australia has the highest number of vehicles per head of population in Australia - 723 vehicles per 1000 people.[1] 80% of people in Perth travel to work by car. Only 9% of employed people travel to work by public transport.[2] The total number of registered vehicles in Australia in 1999 was 11,934,797 (an increase of 1.7% over the year; in Western Australia this increase was 2.7%). The average age of the vehicle fleet in 1999 was 10.6 years.[3]

In Perth, motor vehicles contribute 81% of all CO emissions, 40% of HC (VOCs), and 49% of all NOx emissions. The penetration rate of new vehicles in Australia generally means that there is a lag of 10 years before the full effect of new emission restrictions are realised.[4]

A State of the Environment report compiled in 2001 predicted that the number of vehicles and total VKT (vehicle kilometres travelled) in Australia will increase by 10% from 2001 to 2015.[5] A more recent report from the Australian Bureau of Transport and Regional Economics has predicted that the number of cars will increase by almost 20% from 2001 to 2015 and that VKT will increase by 23% over that same period.[6]

Almost 80% of trips in Perth are less than 3 km in length, and currently only about 6% of all trips are made by public transport. Under the Western Australian State Government's "Perth Metropolitan Transport Strategy" there is a target to double the percentage of trips made by public transport to 12% by 2029, and increase the proportion of morning peak periods trips made by public transport into the Perth central business district from 35% to 65%.

The number of vehicles using alternative fuels increased during 1999 at a greater rate than petrol vehicles. Diesel powered vehicles increased at a rate of 5.4% and LPG and dual fuel vehicles increased by 10.1% compared to 1.1% for petrol powered vehicles.[7]

Natural Gas

At the beginning of 2003, there were about 2500 natural gas vehicles in Australia (1250 forklifts, 900 buses, 65 trucks, 250 cars and light commercials, and 14 taxis). There are currently three CNG (compressed natural gas) refuelling stations in Western Australia and no public LNG (liquefied natural gas) refuelling outlets.[8]

[1] ABS, 2001.
[2] ABS, 2002.
[3] Ibid.
[4] SoE, 2001.
[5] Ibid.
[6] BTRE, 2002.
[7] ABS, 2000.
[8] AGA, 2003.

The Federal Government Alternative Fuels Conversion Program (AFCP), which commenced in January 2002, offers AUD$75 million over 4 years to assist the operators of heavy duty commercial vehicles and buses (weighing 3.5 tonnes gross vehicle mass or more) to convert their vehicles to either CNG or LPG or to purchase new vehicles running on these fuels.[9] The Australian Greenhouse Office (AGO) also has a CNG infrastructure program whereby AUD$7.6 million has been allocated to facilitate the establishment of a national network of CNG refuelling stations.[10]

Liquid Petroleum Gas (LPG)

There are currently over 500 000 LPG vehicles in Australia.[11] 99 000 tonnes of autogas is consumed in the Western Australian market per annum which makes up approximately 4% by energy of the Western Australian transport fuel market. This is considered to be an underdeveloped market with the national average market share of LPG fuel being 8% by energy.[12]

The Western Australia Government offers an incentive for the conversion of vehicles from petrol to LPG (or to dual-fuel). The average cost of conversion of a petrol vehicle to dual-fuel is AUD$2200. The State Government will provide a AUD$500 subsidy for the conversion of a family vehicle to a LPG vehicle or a dual-fuel petrol/LPG system and also for licensing of a new LPG vehicle to assist with this cost.[13] LPG currently doesn't attract the Federal Government fuel excise; however, under new tax reforms announced recently by the federal government, LPG will become excisable from 1 July 2008.

The light commercial vehicle sector (taxis and couriers) makes up the majority of LPG and dual-fuel vehicle sales. There is a reasonably extensive infrastructure support for LPG vehicles in Australia, particularly in urban areas. There are currently over 3500 LPG refuelling stations in Australia.[14] The State Government has a policy in place to convert 20% of the government fleet to LPG vehicles; however, there has been limited success in achieving this goal to date.

Hybrid Vehicles

Toyota and Honda both sell hybrid vehicles in Australia; however, this market is yet to become significant.

Biodiesel

There are currently very limited numbers of vehicles using biodiesel in Western Australia. Several Perth Local Government Authorities are trialing biodiesel trucks.

[9] AGO, 2003.
[10] AGO, 2003a.
[11] ALPGA, 2003.
[12] Anyon, 2002.
[13] See: http://www.transport.wa.gov.au/licensing/lpg/index.html
[14] ALPGA, 2002.

The Western Australian Public Transport Authority is currently negotiating to carry out a trial of biodiesel using 100,000 litres in 12 buses over approximately 3 months.

Australian Fuel Excise

Table 4.1: Current fuel excise rates (cents per litre)

Fuel	Excise (cents per litre)
Petrol (Unleaded)	38.143
Petrol (Leaded)	40.516
Diesel	38.143
LPG	0
CNG	NA

The government is currently reviewing the fuel tax arrangements in Australia to bring currently untaxed fuels into the excise (and customs) duty system by 1 July 2008. "Fuels that will become excisable from 1 July 2008 will include liquefied petroleum gas (LPG), liquefied natural gas (LNG) and compressed natural gas (CNG). The final excise rates to apply to fuels will be determined later this year (2003), and will take into account factors such as the energy content of fuels. The broad reform framework will be fully implemented by 1 July 2012, when all fuels used in internal combustion engines will be subject to excise (and customs) duty based on factors including energy content, providing tax neutrality between fuels."[15]

[15] Hon. P. Costello, 2003.

Policy and Regulatory Framework Relevant to Hydrogen Bus Projects

Vehicle Standards

Australia first adopted comprehensive petrol vehicle emission standards for passenger cars in 1974. Initially the ECE (Economic Commission for Europe) approach was used, then in 1976 a switch was made to using US standards and test methods. Since this time, as concern over air pollution has increased and technology has advanced, emission standards have gradually become more stringent. In recent years, there has been a transition back from the use of US standards to United Nations Economic Commission for Europe (UN ECE) standards or '*Euro'* standards. Some standards for heavy-duty diesel, LPG and NG vehicles are still adopted from US standards as many of these engines are imported from the US. The Australian Design Rules (ADRs) reflect the Euro and US standards (but in some cases come into effect at a later date) and are enforced under the Commonwealth *Motor Vehicle Standards Act 1989*. [16]

Table 4.2: Australia Design Rules for Vehicle Emissions (2002- 2007)[17]

Light Vehicles			Heavy Vehicles		
ADR	Petrol, LPG & NG	Diesel	ADR	Petrol*	Diesel, LPG & NG
79/00	2003-04 (*Euro 2)*	2002-03 (*Euro 2)*	80/00	2003-04 (US EPA 96)	2002-03 (*Euro 3* or US EPA 98)**
79/01	2005-06 (*Euro 3)*	2006-07 (*Euro 4)*	80/01	2005-06 (US EPA 98)	2006-07 (*Euro 4* or US EPA 04)

* US standards are adopted for heavy petrol vehicles, as such engines are not covered by the UN ECE standards

** US 98 is base standard, plus additional requirements applicable to model year 2000 engines

Fuel Standards

The Commonwealth *Fuel Quality Standards Act 2000* provides the framework for Australia's national fuel standards. The first set of standards for petrol and diesel were introduced in 2002. By 2006, these standards should broadly reflect *Euro 3* standards, although *Euro 4* for sulphur in diesel. Standards are currently being developed for LPG (liquefied petroleum gas) and biodiesel. CNG (compressed natural gas) standards will likely also be developed in the near future.[18]

Fuel standards in Western Australia set earlier than the national standards under the Environmental Protection (Diesel and Petrol) Regulations 1999, are stricter than the national standards and override the national standards. See table 4.2.

[16] MVEC, 2003.
[17] Ibid.
[18] MVEC, 2003.

Table 4.3: Specifications for Petrol Supplies in Perth in 2001[19]

	Substance	Maximum
Hydrocarbons	Aromatics	43.0% v/v
	Benzene	1.0% v/v
	Olefins	18.0% v/v
Oxygenates	Methyl tertiary-butyl ether (MTBE)	0.10% v/v
	Lead	5 mg/L
	Sulphur	150 mg/kg

Australian Air Quality Standards

Formed in 1998, the National Environmental Protection Measure for Ambient Air Quality (Air NEPM) sets national standards for six air pollutants – carbon monoxide, nitrogen dioxide, photochemical oxidants (as ozone), sulfur dioxide, lead, particles as PM_{10} (see table 4.3). These standards are periodically reviewed by the National Environmental Protection Council (NEPC). A National Environmental Protection Measure for Air Toxics (focussing on benzene, formaldehyde, polycyclic aromatic hydrocarbons, toluene and xylene) is also currently being developed.

Table 4.4: Air National Environmental Protection Measure Standards[20]

Criteria Pollutant	Averaging Period	Maximum (ambient) Concentration	Goal by 2008 (maximum allowable exceedences)
Carbon Monoxide	8 hours	9.0ppm	1 day a year
Nitrogen Dioxide	1 hour	0.12ppm	1 day a year
	1 year	0.03ppm	None
Photochemical oxidants (as ozone)	1 hour	0.10ppm	1 day a year
	4 hours	0.08ppm	1 day a year
Sulphur Dioxide	1 hour	0.20ppm	1 day a year
	1 day	0.08ppm	1 day a year
	1 year	0.02ppm	None
Lead	1 year	0.50 μg/m3	None
Particles as PM_{10}	1 day	50 μg/m3	5 days a year

Greenhouse

The contribution of transport to Australia's greenhouse gas emissions in 2000 was estimated to be 14%.[21] Road transport is responsible for about 85% of those

[19] Government of Western Australia, 1999
[20] Adapted from MVEC, 2003.
[21] AGO, 2002.

emissions.[22] Based on a business as usual scenario, greenhouse gas emissions from transport are predicted to be 47% higher than 1990 levels by 2010.[23]

Australia has not ratified the Kyoto Protocol relating to greenhouse gas emission targets. However, the Federal Government of Australia has nonetheless committed to achieving the target for Australia set out under the Protocol. To meet this target would require limiting greenhouse gas emissions to an 8% increase over 1990 levels.

The AGO (Australian Greenhouse Office) has implemented an Environmental Strategy for the Motor Vehicle Industry including a fuel consumption guide and label for new cars (as of 2001 this label became mandatory for all new vehicles).[24]

[22] BTRE, 2002a.
[23] BTRE, 2002a.
[24] See: http://www.greenhouse.gov.au/fuellabel/index.html

Management and Administrative Structures Affecting Hydrogen Bus Projects

Public Transport Authority

The Public Transport Authority (PTA) is responsible for the following transport services in Western Australia:

- rail, bus and ferry services in the Perth metropolitan area;
- public transport services in some regional centres;
- bus and rail passenger services in regional areas; and
- school buses.

The Public Transport Authority (PTA) was formed under the Public Transport Authority Act 2003 and brings together the services of Transperth, Transwa and the school bus system. It replaces the WA Government Railways Commission.[25]

- Transperth manages the overall coordination of Perth's metropolitan bus services.
- Transperth Train Operations operates metropolitan train services in Perth.
- Transwa provides regional rail and coach services
- SchoolBus Services provides metropolitan and regional school bus services.

The annual Transperth patronage in Perth is approximately 55.3 million passengers. Transperth is fully controlled and financed by the Government of Western Australia. The government owns a majority of infrastructure including buses, trains, depots and interchange facilities; however, all bus services in Perth are contracted out to private operators. There are three bus operators – Path Transit, Swan Transit, and Southern Coast Transit. All modes represent and carry the Transperth brand, and accept the same ticket irrespective of the service used.[26]

As at 1 January 2003, there were 997 vehicles of various age, make and model in the Transperth bus fleet. This includes 99 CNG (compressed natural gas) buses and 2 LPG (liquid petroleum gas) buses. The majority of buses in the current fleet are diesel buses. However, under the policy of the present Western Australian government, all future bus purchases in the state will be CNG; there will be no further diesel purchases. By 2010, all Transperth buses will meet the minimum Euro 2 emissions standard. Existing Euro 2 standard diesel buses all operate on low sulphur diesel (500ppm). From 1 July 2003, the majority of diesel sold in Western Australia, and hence used by Transperth buses, will contain only 50ppm sulphur. Transperth also operates 48 two car train sets and manages two ferries. [27]

The bus fleet is distributed between 20 bus depots which are run by the three different private operators. Path Transit operate over 330 buses from 5 depots and have over 550 employees. Swan Transit operate 235 buses and employ 350 staff over 11 depots. Southern Coast Transit operate 405 buses over 4 depots.

[25] PTA, 2003.
[26] Transperth, 2003.
[27] Transperth, 2003.

Path Transit will be responsible for housing the hydrogen fuel cell buses for the STEP trial. Path Transit employees will be trained to carry out the maintenance and operation of the hydrogen fuel cell buses. The compressed hydrogen refueling station will be situated at the Path Transit Morley Depot. The Hydrogen will be produced at the BP oil refinery in Kwinana. BOC will be responsible for refining the Hydrogen and maintaining the fuel infrastructure. The hydrogen will be trucked from Kwinana to the refueling station as a compressed gas.

Tickets and Pricing

The current system of ticketing in Perth requires the purchase of a single trip cash ticket or the purchase of a 'MultiRider' card which stores a number of rides and works by a magnetic stripe system. By the end of 2004, a fully-integrated smartcard ticketing system will be introduced.[28]

Cash tickets can be purchased from the bus or ferry driver or from the coin-operated ticket vending machines at train stations. The cost of each ticket is partially subsidised by the Government of Western Australia. Revenue from tickets does not cover the cost of the public transport system.

The MultiRider 10 stores 10 trips at a saving of 15% on normal cash fares. The MultiRider 40 stores 40 trips at a saving of 25% on normal cash fares. They can be purchased as either a standard or concession ticket. The ticket cost is determined by the number of zones to be travelled.

The FamilyRider ticket allows unlimited all day travel for seven people anywhere on the Transperth system on weekends and public holidays. The seven people can include up to two full fare paying adults and five concessions, or up to seven concession holders. Adults and children can qualify as concession holders. Valid concession cards are Seniors Cards, Health Care Cards, Pensioner Concession Cards and Student Cards. On weekdays, FamilyRiders can be used during the following times - after 6pm Monday to Thursday; after 3pm on Friday; and during school holidays from 9am on weekdays. During school holidays the FamilyRider cash ticket is valid for unlimited all day travel. It is available for purchase from 8.30am within zones 5-8 and from 9am within zones 1-4.

The DayRider ticket offers unlimited all day travel on all Transperth services after 9.00am on weekdays and all day on weekends and public holidays. It is available as standard or concession; however, the concession tickets are also permitted to be used before 7.15am on weekdays except in zones 5-8 where it can be purchased after 8.30am.

Free services operate on specific routes within the central business districts of Perth and Fremantle to transport people around the city. Specialised CAT (central area transit) buses operate these routes. Travel is also free on buses within the FTZ (free transit zone). The free transit zone is within the Perth central business district boundaries; any trip that starts and finishes within the zone is free.

[28] Ibid.

Table 4.5: Transperth Fares (AUD) effective from July 7, 2003.[29]

	Cash		Multirider 10		Multirider 40	
	Standard	Concession	Standard	Concession	Standard	Concession
2 Section	$1.30	$0.50	$11.05	$4.25	$39.00	$15.00
1 Zone	$2.00	$0.80	$17.00	$6.80	$60.00	$24.00
2 Zones	$3.00	$1.30	$25.50	$11.05	$90.00	$39.00
3 Zones	$3.80	$1.60	$32.30	$13.60	$114.00	$48.00
4 Zones	$4.50	$1.90	$38.25	$16.15	$135.00	$57.00
5 Zones	$5.50	$2.10	$46.75	$17.85	$165.00	$63.00
6 Zones	$6.40	$2.40	$54.40	$20.40	$192.00	$72.00
7 Zones	$7.30	$2.80	$62.05	$23.80	$219.00	$84.00
8 Zones	$8.00	$3.10	$68.00	$26.35	$240.00	$93.00
Day Rider	$7.50	$3.00	NA	$25.50	NA	$90.00
Family Rider	$7.50	NA	NA	NA	NA	NA

Attitudes to Public Transport in Perth

Annual Passenger Satisfaction monitor, 2002

Since 1990, an annual Passenger Satisfaction Monitor has been conducted across the Bus and Rail elements of the metropolitan Public Transport System. In 2002, a total of 2589 bus passengers were surveyed through face-to-face interviews. Patron satisfaction levels with the Bus System overall increased marginally in 2002, with 82% of respondents indicating satisfaction with the bus service overall (32% 'very satisfied' and 50% 'satisfied') – a five percentage point increase from 2001. Levels of dissatisfaction continued to decrease in 2002 to 10% (9% 'dissatisfied' and 1% 'very dissatisfied'), representing a eight percentage point decrease since 1999. The remaining 8% of respondents were 'neither satisfied nor dissatisfied'.[30]

Amongst the 10% of respondents expressing dissatisfaction overall, the most frequently nominated reasons for dissatisfaction with the Bus system were:

- 'Infrequent buses / buses too far apart / need more peak time buses' (40%);
- 'No buses/ poor service outside of normal times – weekends / evening / public holidays' (26%)
- 'Buses never on time / unreliable / poor bus to bus or train to bus connection' (23%)

In terms of *Cost of Fare* 'value' perceptions, a little over two thirds of all respondents (68%) indicated fares to be 'excellent/ good value' for money (a significant increase from 59% in 2001). 8% of respondents felt that fares were 'quite/ very expensive'.[31]

The ten most important Bus Service Characteristics, determined by respondents from a list of 30, were as below in Figure 4.2.

[29] Adapted from: Transperth, 2003.
[30] NFO Donovan Research, 2002.
[31] Ibid.

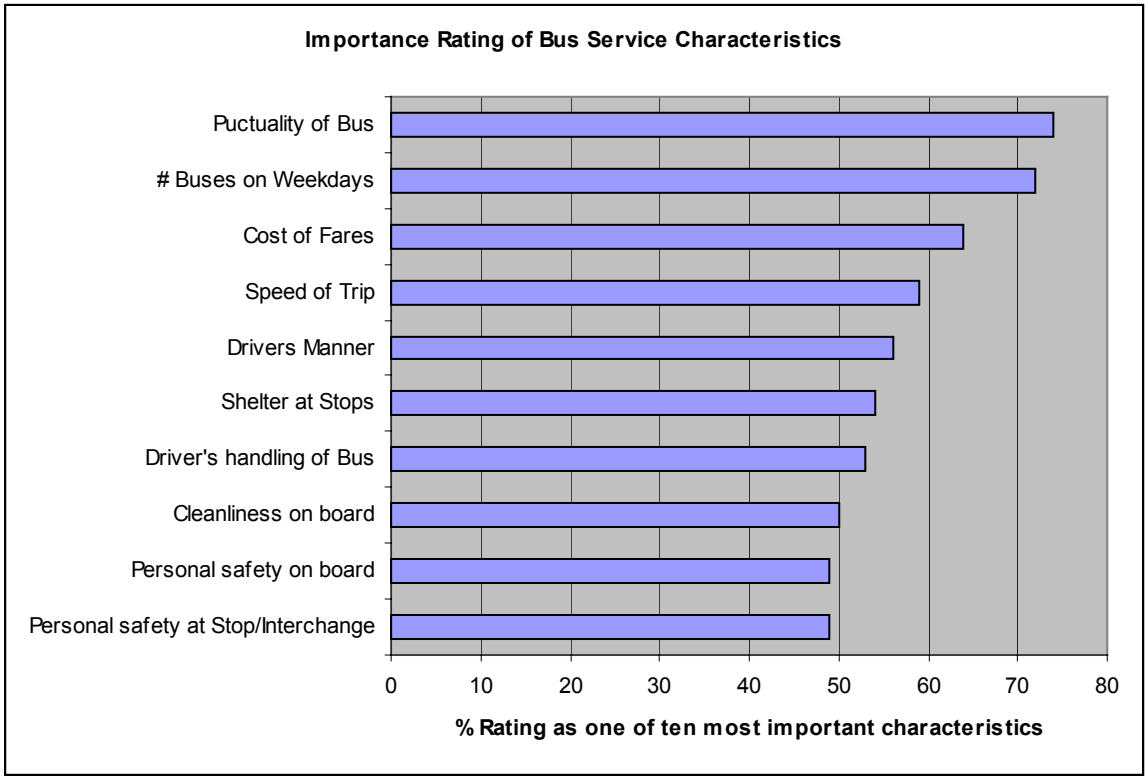


Figure 4.1: Importance Ratings of Bus Service Characteristics[32]

Survey "Profiling the Market for Transport in Perth" 2001

In April 2001, a telephone survey was conducted on behalf of Transperth to obtain strategic information on how to:

- Get existing users to use public transport more frequently, and to continue to use public transport throughout their lives;
- Get lapsed users to switch back to using public transport;
- Get non-users to trial public transport as an alternative to their existing travel choices.

The survey consisted of 632 telephone interviews averaging 15 minutes in length, comprising some 200 interviews with each of the three groups:

- 232 surveys with Current Users (those currently travelling on public transport on a consistent or regular basis);
- 200 surveys with Lapsed Users, (those who used to but no longer use public transport on a consistent or regular basis);
- 200 surveys with Non-Users, (those who have never used public transport on a consistent or regular basis).

The findings of the survey included the key motivations and barriers to the use of public transport in Perth, see table 4.5 and 4.6.[33]

[32] Adapted from: NFO Donovan Research, 2002.
[33] Right Marketing Australia, 2001.

Table 4.6: Key motivations for the use of public transport in Perth (unprompted)[34]

	Current Users %	Lapsed Users %	Non Users %
Not having to find/pay for parking	62	45	53
Cheaper than driving/save money	51	42	33
Less stressful/ more relaxed than driving	46	29	24
Reduced air pollution	23	25	22
Less wear on car	18	22	22
Reduced traffic congestion	17	17	18
Being chauffeured/ not having to drive	17	17	10

Table 4.7: Key barriers for the use of public transport in Perth (unprompted)[35]

	Current Users %	Lapsed Users %	Non Users %
Too long a wait at bus stop/ service too infrequent	62	47	39
Personal security	27	18	23
Loss of freedom to travel where and when you like/ inconvenience	25	35	41
Takes longer than car	17	29	24
Crowded	16	11	10
Carrying shopping/ gear etc.	16	9	11
Bus stops inconveniently located	12	22	24

Table 4.8: Major reasons for Lapsed Users ceasing to use public transport[36]

Reason	% respondents
Buying a car	55%
Moving house	21%
Moving jobs	12%
Completing course/degree/school etc.	10%

[34] Adapted from: Right Marketing Australia, 2001.
[35] Adapted from: Right Marketing Australia, 2001.

[36] Adapted from: Right Marketing Australia, 2001.

General Social Framework

In the National census undertaken on 7th August 2001, the population of Perth was determined to be 1339,993 people (656,798 males and 683,195 females). The population of Western Australia was 1851,242 people.[37]

The median individual income for people in the 2001 census was $300-$399. The median household income was $800-$999. The average household size was 2.6 persons.[38]

The median age of people in the 2001 census was 34 years. 0-14 years (20.7%); 15-24 years (15.1%); 25-44 years (29.9%); 45-64 years (23.1%); 65 years and over (11.3%).[39]

The unemployment rate for Western Australian in 2001 was 7.4%. In 2001, there was a continued fall in the proportion of full-time workers. In 2001, full-time workers represented 58.1% of the labour force compared to 61.2% in 1996. In the period 1996 to 2001, the number of persons employed part-time increased by 19.8%.[40]

[37] ABS, 2001.
[38] ABS, 2001.
[39] Ibid.
[40] ABS, 2003.

5. Oakland

Previous Experience with FCVs and H_2

In late 1999, AC Transit had the opportunity to test the Xcellsis ZEBus with its P4 prototype fuel cell engine. The District was impressed with its operating performance. The bus carried a standing load of passengers up 12% grades, ran at speeds in excess of 105 km/hr (65 mph), and easily handled boardings and alightings on its 51-Line between Oakland and Berkeley, which carries in excess of 20,000 riders per day. The District subsequently ran tests of the Mercedes-Benz NeBus in 2000 and received a very favorable reaction from riders and the public at large, because of its modern look and ultra-quiet, hub-motor drive system.

Figure 5.1 Xcellsis (Ballard) ZEbus

Figure 5.2: Mercedes-Benz NeBus

Following its initial test of the ZEbus, AC Transit staff recognized the potential of fuel cells and the importance of taking a leadership role in developing the technology. The District's Board of Directors subsequently adopted a policy to pursue the development of the technology by seeking membership in the California Fuel Cell Partnership and applying for multiple grants to fund its program. In January 2000, AC Transit was invited to become a member of the Partnership, along with SunLine Transit Agency in Thousand Palms, California. Later, the Valley Transportation Authority in San Jose, California joined the Partnership as a third member transit agency. From the beginning, AC Transit's role in pursing the commercialization goals of the Partnership has been a commitment to prove the technology's worthiness in large fleet applications, operating a fleet of three or more buses under a variety of conditions common to most transit systems worldwide.

The District is suitably qualified to be this test site for five primary reasons:

- A strong belief in the potential of this technology and the commitment of its entire staff, from board members to mechanics and drivers, to the demonstration program.
- An industry reputation for a well-managed fleet, achieving performance standards of from 12,698 km (8,000 miles) between maintenance road calls (KBR) and 15,873 KBR (10,000 MBR). The industry standard is 6,349 KBR (4,000 MBR).
- A large fleet of 779 buses, with a division size of at least 240 buses.
- An urban service area with lines that carry in excess of 20,000 passengers per day
- A diversity of terrain and services, including many hilly routes on grades in excess of 10%, freeway express routes, and service in densely populated areas

Additionally, AC Transit is committed to an extensive training and education program for its 2,480 employees, covering a range of topics including: hydrogen and its specific properties; the extensive use of hydrogen for industrial and research applications; safety concerns and dispelling myths associated with the Hindenberg and the Hydrogen bomb; and the District's fuel cell development program and the leadership role it will play in helping to commercialize the technology.

AC Transit - A Model Demonstration Site?

AC Transit (District) is California's third largest transit agency and the third largest bus-only operator in the United States. With a fleet of 779 buses, AC Transit carries 70.6 million passengers annually (236,000 passengers each weekday), serving 13 cities, including Berkeley and Oakland, in the East Bay region of the San Francisco Bay Area.

The District maintains a route structure of more than 150 lines, of which 36 operate between the East Bay and San Francisco via the San Francisco-Oakland Bay Bridge. Its fleet of buses is maintained at four operating depots and one Central Maintenance Facility. The latter is devoted entirely to heavy-duty maintenance and repair, including the manufacture and repair of specialty parts, body fabrication and repair, body painting, rebuilding engines and transmissions, re-powering older buses with new engines, and maintaining a centralized parts inventory. The largest operating division has a fleet of approximately 250 buses, which is the optimal maximum size for a bus division. This compares favorably to much larger transit operators, like the RATP in Paris, France, which has a fleet of 4,000 buses and approximately 23 operating divisions, each with no more than 250 buses.

Table 5.1: AC Transit Area Statistics

Service Area Size	932 sq km (360 sq mi)
Service Area Population	1.5 million
Areas Served	13 cities and the unincorporated areas of two counties
Ridership	70.6 million boardings per year
Ridership Growth	7% increase since 1999
Market Share	12% of all work trips in service areas
Lines (Routes)	150 (36 Transbay Lines to San Francisco)
Fleet Size	779 revenue vehicles
Employees	2,480 (1,410 drivers)
FY 2001/2002 Budget	$244 million USD (Operating and Capital)

AC Transit's Hydrogen Fuel Cell Bus Demonstration

The main components of AC Transit's development program include the procurement of buses, construction of a fueling and maintenance center, development of additional fueling stations at other operating divisions, extensive training and education, public outreach, and a comprehensive evaluation program.

Originally the District had planned for an initial procurement of as many as eight buses by the middle of 2003, with an expansion of its fleet to 12 buses as funding became available. Escalating costs and difficulties in finding a bus manufacturer have

delayed the expected arrival of buses until mid- or late 2004 and restricted the number of vehicles the District will be able to purchase to no more than four or five.

The effect that these four or five buses have on public perceptions of hydrogen and fuel cells will be assessed as part of the AcceptH2 project.

Funding

AC Transit has received nearly $14 million in grants from state, regional, and federal agencies, enabling it to launch an aggressive demonstration program.

Table 5.2: Revenue Sources for AC Transit's Fuel Cell Development Program

Revenue Sources	Amount
State of California Traffic Congestion Relief Plan	$8,000,000
California Air Resources Board	$2,500,000
Bay Area Air Quality Management District	$1,000,000
California Energy Commission	$1,000,000
Federal Transit Fund	$1,000,000
U. S. Department of Energy Clean Cities Program	$300,000
AC Transit matching funds	$1,100,000
TOTAL	**$14,900,000**

All but $1.3 million came from state and local sources as a result of strong support from local officials, state legislators, and the California Governor's office. Mayors from all 13 cities in AC Transit's service area, and many environmental organizations, wrote letters of support to state and federal officials, strongly endorsing the District's proposal. Although AC Transit has raised significant levels of funding, fuel cells are cutting edge technology and will require more financial resources to achieve the performance standards and production economies of a commercialized product. Existing grants and revenues will enable a credible program to begin, but sustaining a well-managed program over many years is critically important to realizing the ultimate goal of commercialization. Additional resources from federal agencies, including the U.S. Departments of Transportation and Energy, will be needed to support this endeavor and to ensure a continuity of effort and long-term sustainability. Also key to this effort will be an extensive public outreach campaign, directed at educating the public on the advantages and benefits of hydrogen and fuel cells and generating strong community support. The District will pursue a number of key strategies, including:

- Using the buses as "educational tools" while in service. Each bus will be traveling billboards on the outside and information centers on the inside. The District will make every effort to circulate these buses throughout its entire service area, without compromising research and evaluation objectives.
- Launching an extensive outreach effort, featuring educational videos, a speaker's bureau, cable T.V. commercials, and new editions of AC Transit's *Environmental Leadership Report.*

- Developing an online educational curriculum for middle- and high-school students, working in conjunction with a new $80 million regional space and science center in Oakland and local schools.
- Converting a custom-made, electric mini-bus into a fuel cell bus for promotional and educational purposes at community events and schools.

Hydrogen Station Design and Specification

History

The Richmond Hydrogen Refuelling Station opened for fuelling on October 30, 2002, and was the product of a joint collaboration between Stuart Energy Systems and AC Transit as an in-kind contribution to the California Fuel Cell Partnership. Stuart Energy designed and built the station, providing both equipment and project management. AC Transit provided the site, and managed site issues including neighbourhood relations and permitting. The station has limited public access, and will be used by the automotive members of the CaFCP, namely Daimler-Chrysler, Ford, Honda, Hyundai, GM, Nissan, Toyota, and Volkswagen.

Station Design

The station produces hydrogen by the process of electrolysis. The oxygen is vented into the atmosphere, and the hydrogen is compressed, purified, and stored in high-pressure storage vessels. These storage vessels deliver the hydrogen to the dispenser, and into the vehicle during refuelling.

Electrolyser

The station's electrolyser, the Stuart Community Fuel Appliance 450 (CFA 450) is the most complex part of the station. The following is a list of the electrolyser's equipment divided by system:

- **Water Purification**: de-mineraliser cartridges, carbon filter
- **Gas Generation System and Seals/KOH Handling**: conductivity sensor, leak detector, feed water bowl, feed pumps, cell stacks with temperature and water level control, ventilation blower, seal/mist eliminator, hydrogen blow-down tank, hydrogen gas analyzer, gas membrane separator.
- **Hydrogen Compression System:** four-stage, air-cooled, oil-lubricated hydrogen compressor (5000 psi), 10-hp compressor motors, non-return valves, pneumatic valves, after-cooler.
- **Hydrogen Purification:** coalescing filters, carbon adsorbtion filters, and intercooler.
- **Dryer System:** two gas-dryer columns (they must take turns adsorbing moisture to allow for regeneration).
- **High-Pressure System:** pressure transmitter, pressure relief valves.
- **Condensate Collection Systems:** condensate collector, oil-water separator, solenoid valves.
- **Hydrogen Leak Detector System:** combustible gas transmitter.
- **Cooling Water System:** water/ethylene glycol mixture, centrifugal pump, heater, heat-exchanger, motor-driven fan, temperature transmitter, expansion chamber.
- **Instrument Air System (for pneumatic valve control):** air compressor.
- **Electrical System:** main breaker, AC-to-DC rectifier, 4 transformers, solid-state relays, controller, data acquisition equipment

The electrolyser produces hydrogen at the following specifications:

Table 5.3

Hydrogen	Capacity:	450 SCFH / 12.74 NCMH
	Pressure	5000 Psig / 345 bar
	Dew Point:	- 60°C / -78°F
	Purity:	> 99.998 wt %
Oxygen	Capacity:	225 SCFH / 6.37 NCMH
	Pressure	1.5 Psig / 0.1 bar
	Purity:	99.5 wt %
	Dew Point	Saturated @ 40°C / 104°F

Storage Module

The station stores the hydrogen produced from the CFA 450 in a storage module provided by Dynetek, which contains:

- 3 bank cascade, 4 tank per bank, 150 liters per tank for a total of 1800 Liters, ~49.3 kg @ 6000 psi
- Type III storage tanks (Aluminum w/ carbon overwrap)
- Valves and plumbing
- 3 Pressure Relief Devices

Dispenser

The dispenser has two separate hoses using Sherex nozzles which dispense at either 3,600 psi or 5,000 psi. The display on the dispenser indicates pressure in the tank, as well as the monetary value (in dollars) of the hydrogen dispensed.

Refuelling

To refuel a vehicle at this station, one first slides their Stuart refueling card in the card reader and enters their personal pin number to identify the user and the vehicle being fueled. The user may connect a communications cable from the station to the car if the car has this feature. This feature enables communication between the car and station about fill rate, tank temperature and tank pressure. The vehicle is grounded to the station automatically through the hose and piping, though an auxiliary ground connection can be provided using a standard jumper cable.

Once the vehicle is ready to be refueled, one connects the Sherex nozzle to the vehicle's fueling port, and tightens the seal (this is done by turning the handle 90 degrees). The station will automatically begin refueling and continue until the pressure reaches the 3,600 psi or 5,000 psi (depending on the vehicle's storage tanks), or the refueling is prematurely terminated by loosening the seal on the Sherex nozzle.

A Type 3 (3,600 psi) fill has flow limitation of 2 kg/minute restricted by pressure regulator (varies by pressure – slows as storage pressure increases). A Type 2 (5,000 psi) fill is limited to 1 kg/min.

Codes and Standards

The Richmond station was designed to conform to industrial gaseous hydrogen customer-site system standards outlined in NFPA 50 A. The compressed hydrogen vessels were designed, fabricated, and tested consistent with the ASME Boiler and Pressure Vessel code. The design and installation of the station mechanical and electrical components conform to other applicable codes and standards such as the National Electric Code and Uniform Fire Code.

The station meets the following codes:

- ASME Code for vessels
- NFPA 50A as applicable
- CNG Code NFPA52 (as applicable)
- National Electric Code (NEC) NFPA72

For the break-away connector, CNG code B108 has defined force requirement for breakaway = 25 lbs minimum, 50 lbs maximum

Safety

The station is equipped with the following safety features:

- Pressure Relief Devices to vent hydrogen in case pressures inside the storage vessels exceed established limits
- A chain-link fence surrounding and enclosing all station components except the dispensers
- "Turnpike-style" concrete barriers surrounding the station to protect it from vehicle traffic and bus traffic ("enough to protect from bus traffic at 10 mph").
- The station has a break-away hose connection to interrupt flow and shut off fill sequence. The breakaway force to set at 25 lbs.
- Hydrogen Leak Detection at the dispenser and inside the electrolyzer (20% LEL alarm, 40% LEL shut-down)

To ensure the safety of the users of this station, local emergency responders were brought together and trained on the facility. They were given Emergency Response Guides to clearly spell out the potential hazards of the station and the fuel cell vehicles that refuel at this site.

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