

D5.1a TRAINING MATERIALS FOR FLEET OWNERS



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1 INTRODUCTION

Why use alternatives?

In the EU, transport is responsible for an estimated 21% of all greenhouse gas emissions that are contributing to global warming. Between 1990 and 2003, when greenhouse gas emissions in the EU saw an overall reduction, transport's share grew by about 24%. The reduction of greenhouse gas emissions from transport, therefore, could contribute significantly to meeting the EU Kyoto targets. In the EU transport sector fossil oil is the main energy source with a 98% contribution to all transport fuels. In 2002 alternative motor fuels contributed 2% and biofuels only 0.3% (Currently, 80% of EU biofuel consumption in the transport sector is biodiesel, 20% bioethanol). However, during the last few years the contribution of biofuels has increased due to the implementation of the biofuels directive in several Member States.

The EU is supporting biofuels with the aim of reducing greenhouse gas emissions, boosting the decarbonisation of transport fuels, diversifying fuel supply sources, offering new income opportunities in rural areas and developing long-term replacements for fossil fuel. In 2003 the European Parliament and the Council have adopted the Directive 2003/30/EC aiming to promote the use of biofuels for transport. This Directive requires member states in 2005 to replace 2% of their diesel and petrol with biofuels, although deviations are possible when justified.

Drivers can greatly reduce these impacts, however, by taking a few simple steps based around choosing cleaner vehicles or driving more efficiently. In most cases these measures will lead to financial savings as well as environmental benefits.

2 THE SUGRE PROJECT

SUGRE (Sustainable Green Fleets) is an accompanying measure that promotes alternative propulsion and mainly focuses on fleets. The main objective is to promote and support the conversion of fleets to alternative propulsion (ranging from bio-fuels, methane as fuel to hybrid systems comprised of combustion engines and electric propulsion systems) and the energy efficient usage of them. The project is funded by the EU with max. 50% of the total budget of 2.59 Mio. € for 27 partners.

SUGRE comprises 6 work packages:

WP1 project management will be responsible for the management of the coordination of the dissemination actions, communication and contingency management, quality assurance procedures and financial administration.

In WP2, an in-depth baseline analysis will ensure that the dissemination materials will not only contain/treat all the practical aspects and collect the best cases/show cases, but also analyse existing campaigns and their effects.

WP3 will synthesise the research into an implementation plan for the dissemination of the experiences and good practices and define the content for the three target groups (captive fleets, driving schools, teachers and other fleets).

WP4 will validate the concept and produce and assess the training materials with the help of the members who are fleet owners.

WP5 will provide training/assistance and networking amongst captive and other fleet owners and will also address individuals via supporting driving schools and teachers with materials. For the show cases, real and virtual site visits will be organised/offered.

The partners' many years of experience in networking and dissemination projects for DG TREN and others will help to offer both innovative dissemination approaches and high quality dissemination products.

WP6 will cover the general dissemination tasks (presentations, flyers, folders, newsletters, networking and internet platform) and evaluate the content and the procedures based on a discussion of the experience of the workshops with regard to technological and economical aspects.

In the website www.greenfleet.info fleet operators and citizens looking for alternatives i.e. alternative fuel or alternative propulsion will find technological primers and information about:

- Alternative fuels (production and wells to wheel balance of biofuels, biofuels, CNG, LNG, Hydrogen...)
- Usability of alternative fuels (biofuels, CNG, LNG, hydrogen...) for standard ICE internal combustion engines
- Alternative engines, power train also called drive train (Hybrid, EV, flywheels, gas turbines...)
- Refuelling facilities for alternative fuels in operational yards
- Directory of vehicle producers/retailers/repair agents with alternative propulsion
- Locator of refuelling facilities for alternative fuels guiding you to the nearest tank stop

3 ALTERNATIVE FUEL OPTIONS FOR FLEETS

This paper presents a first glance to a tool easing the decision process towards alternative fuels. The decision process has been set up in three steps:

1. The first step for the fleet owner is to select an application the fleet has to be used for. Here the most difficult task/operational scheme should be considered. In this section there is useful information to make this step easier.
2. The second level differentiates into the existing fuelling variants when deciding for a specific fuel or technology. Deciding for one technological option in the second step detailed decision will be supported if necessary by SUGRE project experts with the information summarized in this paper. For each specific fuel or technology the existing fuelling variants are explained in depth in this paper.
3. The last step comprises information to have a successful transit to the new technology. The different alternative fuel sections show recommendations for each option.

Before switching to bio-fuels the user should check engine and fuel system compliance, especially to higher blends.

The following points show the first level, the options for each operational scheme:

3.1 NEIGHBOURHOOD

For indoor passenger transfer or serving quarters only, **electric propulsion** fed from batteries is the best solution. You find low floor vehicles for goods distribution and passenger transport.

3.2 INNER CITY

For serving inner city lines, electric propulsion is on the rise. You may select trolley buses or **hybrid electric vehicles** offering you the freedom to go regional too. For clean raw gas emission **compressed natural gas** or **biogas** and low density **biofuels** like ethanol are also possible, because you may return to the refuelling stations every day. FAME/Biodiesel requires extensive exhaust gas cleaning.

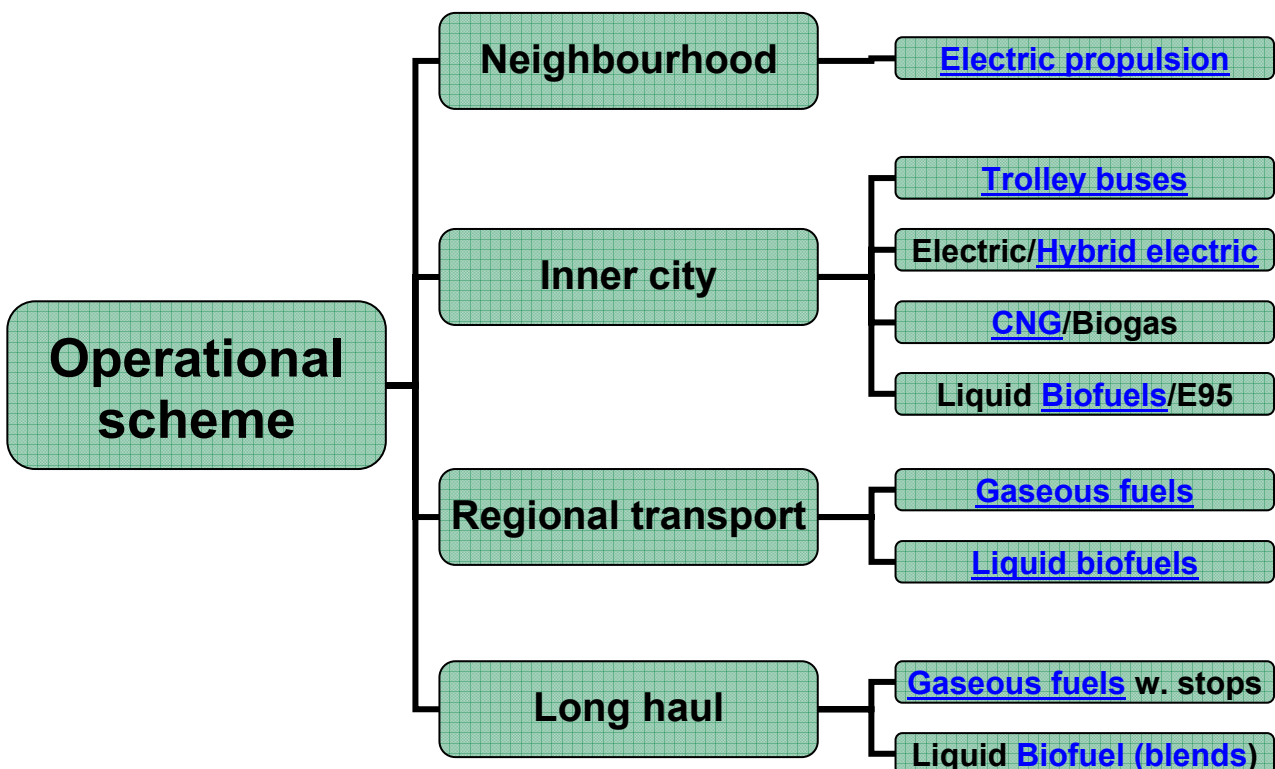
3.3 REGIONAL TRANSPORT

Liquid **biofuels** like FAME/Biodiesel or E-Diesel/E95 or lower blends are an option not compromising the passenger capacity. Gaseous fuels as **natural gas** or **biogas** fuels require tanks on the roof or embedded pressurised gas tanks which allow to use **natural gas** for regional transport without restrictions for load capacity.

3.4 LONG HAUL

Long haul operation may plan intermediate refuelling stops for gaseous fuels like **natural gas** or **biogas** (high pressure filling will save time). They also may run on higher **biofuel blends** using FAME/Biodiesel or E-Diesel/E95.

3.5 OPERATIONAL SCHEME



4 ALTERNATIVE FUELS

The term Alternative Fuel is derived from the so called biofuel directive 2003/30/EC and includes: bioethanol, biodiesel, biogas (from biomass gasification or digester), bio methanol (toxic!), biodimethylether, bio-ETBE (ethyl-tertio-butyl-ether) as additive, bio-MTBE (methyl-tertio-butyl-ether) as additive, synthetic biofuels (either gasoline or diesel type), bio hydrogen (hydrogen from renewable sources - electrolysis via power from the grid or via hydrogen reformer working on bio methanol), pure (straight) vegetable oil.

4.1 ADVANTAGES OF ALTERNATIVE FUELS

The following **objectives** for campaigning and promoting the use of alternative fuels can be distinguished:

- decreased use of fossil fuels and improvement of the security of supply of energy
- decrease of CO₂ emission
- air quality: reduction of emissions of VOC, fine dust, NO_x
- noise reduction
- improvement of traffic safety
- accessibility / reduction of congestion

The objectives mentioned above are often interrelated. Many campaigns are focussing at a reduction of the use of cars (and trucks), which leads to a number of different positive impacts: reduction of the use of energy, a decrease of the emission of CO₂ and other pollutants, noise reduction, improved safety and improvement of the accessibility by a reduction of congestion.

Campaigns that focus on the use of alternative fuels only will address a selection of the abovementioned objectives: reduction of the use of fossil fuels, decrease of CO₂-emission (for CNG to a much lesser extent) and improvement of the air quality. On the other hand, the introduction of alternative fuels can also be promoted form a different policy objective. Particularly bio-fuels are also related to policies in the agricultural sector.

More than 50 % of the conventional fleet owners will purchase clean vehicles in their next procurement which shows that alternative propulsion vehicles are considered to be of future importance if oil prices will continue to rise.

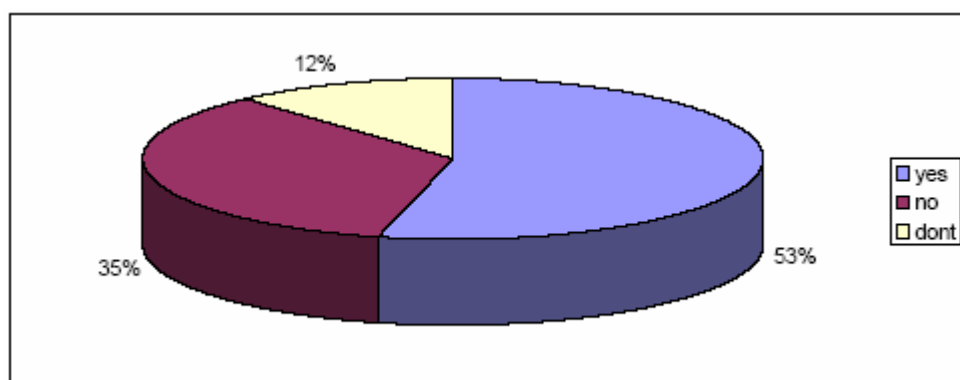


Figure 1. Are clean vehicles considered for the next purchasing phase?

There are three aspects which are assessed very positively by fleet owners: ecology, image and new technological development. The environmental benefits correspond with a better image of the company which is also linked to potential advantages for inner city access.

Measures regarding the following aspects are ranged by fleet operators as very positive and important:

Regarding socio-ecological aspects:

- Company image
- General advantages for the ecology
- Curiosity towards new technology
- Support through local networks

Regarding financial and policy aspects:

- Competitive advantages
- National legislation and policy
- Local legislation and policy

Such measures could be for example inner city access for clean vehicles or financial incentives for the purchase of clean vehicles.

4.2 MEASURES REGARDING DIFFERENT FLEET OPERATORS

In the next table several measures are listed for different fleet operators. This table was filled by the SUGRE project on the basis of examples from all over Europe.

| Type of fleet | Measure |
|-------------------------|---|
| Public transport | <ul style="list-style-type: none"> • fulfilling current regulations and rules, because they are compulsory. • to improve the quality of the service offered. • to improve the public image of the fleet for the citizens. • environmental factors, to reduce pollutants, noise and save energy. • there are other European fleets developing new projects about AP and AF, showing the success of their cases. • alternative fuel costs are less compared to diesel, especially in these days of very expensive petrol. |
| Municipal fleet | <ul style="list-style-type: none"> • to improve the public image of the fleet for the citizens. • environmental factors, to reduce pollutants, noise and save energy. • alternative fuel costs are less compared to diesel, especially in these days of very expensive petrol. • the daily operational aspects do not change significantly. |

| Type of fleet | Measure |
|----------------------|---|
| Utility fleet | <ul style="list-style-type: none"> • price policies: tax exemptions, sales or road taxes. • advantages in terms of access to inner cities or parking zones. • environmental factors, to reduce pollutants, noise and save energy. • enough production: potential of biomass. • alternative fuel costs are less compared to diesel, especially in these days of very expensive petrol. • the daily operational aspects do not change significantly. |
| Taxi fleet | <ul style="list-style-type: none"> • price policies: tax exemptions, sales or road taxes. • enough production: potential of biomass. • alternative fuel costs are less compared to diesel, especially in these days of very expensive petrol. • refuelling logistic: high density of alternative fuel stations. • advantages in terms of access to inner cities or parking zones. • environmental factors, to reduce pollutants, noise and save energy. • enough production. |

Table 1. Measures regarding different fleet operators

5 LIQUID BIOFUELS (BIODIESEL, BIOETHANOL)

Biofuels are fuels which are made from a variety of sources of biomass. They can be made from plant materials, certain types of crops and from recycled or waste vegetable oils. When used as fuels for road vehicles, biofuels offer the prospect of low carbon transport, and to a large extent they are renewable and sustainable. By contrast, the conventional transport fuels petrol and diesel, and the road fuel gases such as liquefied petroleum gas and compressed natural gas, are all fossil fuels and have a finite supply.

Transport biofuels have risen to prominence in recent years. The main reasons for promoting biofuels are:

- To contribute to the **security of energy supply**;
- To contribute to the **reduction of greenhouse gas emissions**;
- To promote a greater use of **renewable energy**;
- To diversify agricultural economies into **new markets**.

Based on these considerations, the European Commission issued a Biofuels Directive in 2003, which requires Member States to set indicative targets for biofuels sales in 2005 and 2010. The Directive included “reference values” for Member States to take into account in setting their own targets – 2% by energy content in 2005 and 5.75% by 2010.

The main biofuels are biodiesel and bioethanol. Biodiesel is a diesel alternative, whilst bioethanol is a petrol additive or substitute. Biofuels can be used in all types of road vehicles – cars, vans, buses, lorries, and agricultural vehicles.

5.1 BIODIESEL

Biodiesel can replace conventional diesel entirely or it can be blended in different proportions for use in compression ignition (diesel) engines. Blending is common in many countries, with 5% blend the most common i.e. 5% biodiesel; 95% conventional diesel.

The physical and chemical properties of biodiesel are very similar to fossil diesel and conventional engines require no modification to use 5% blends. Most modern diesel engines could in fact run on blends of up to 20-30% but care must be taken as use of blends of more than 5% invalidates many manufacturers' warranties.

Producing biodiesel is still more expensive than producing diesel from crude oil. The actual costs depend on the relative costs of the biodiesel feedstock and the crude oil. With full fuel duty biodiesel is expensive to buy and a reduction in the duty rate is needed to make it competitive at the fuel pumps. Such duty reductions are common in Europe, and are used as a means of encouraging fuel suppliers to develop biofuel products and to stimulate the market.

Biodiesel production is now underway in many European countries. Biodiesel produced from waste vegetable oil or grease benefits from relatively low feedstock prices. This makes it economic to manufacture with the current duty rate incentives. However, limited supplies of waste vegetable oils and grease and fuel quality issues may limit the contribution that this type of biodiesel can make.

5.1.1 Choice of variants

The most usual biodiesel blends are B5, B30, B80 and B100:

- **B5** (5% biodiesel, 95% conventional diesel): Since B5 is part of the diesel Standard EN 590 there will be absolutely no problems – but also no big changes in CO₂ emissions. In many countries B5 is common. There are **no technical problems**, but there is **low climate protection**.
- **B30** (30% biodiesel, 70% conventional diesel): This is the **lower limit for different blends** you may choose from. You get a **guarantee** for a lot of vehicles and profit from low cold filter plugging e.g. having **no problem in winter** with gelling. It is important to blend only into the vehicle tank or in the fuel pump for fiscal reasons in a lot of countries not risking to pay levies for the biodiesel part . It is **easier to refuel** while being on tour using fossil diesel. With B30 it is easier to use feedstock for biodiesel which would cause problems when used in a pure form having to high cold filter plugging points.
- **B80** (80% biodiesel, 20% conventional diesel): This is the **upper limit for different blends** you may choose from. Even if there are some vehicles run without modifications or guarantees, you might obey **similar rules to B100 usage**. B80 requires the availability of more B100 refuelling stations to achieve the blending ration when circulating in Europe but it does not reduce your flexibility since you may use fossil diesel under all circumstances.
- **B100** (100% biodiesel): B100 is an option, if you purchase a higher amount of vehicles of the same type and are able to refuel them with a controlled FAME quality. Small changes to your processes allow reducing your contribution to global warming. You also get rid of the blending process. **Additional attention is needed**, but there is **high climate protection** and it there is **no blending effort**.

5.1.2 Recommendations

Since the feedstock influences the fuel characteristics heavily, discrepancies in the findings are not unusual. Biodiesel was long regarded as unproblematic before modern injection pumps came on the market. Five things have to be observed:

- Filters must be changed a short time after switching to biodiesel
- Timing of the injection may be changed to further improve emission
- Rubber materials have to be biodiesel certified and are for most modern vehicles
- Motor oil should be checked regularly to avoid problems caused by the dilution potential of biodiesel for the motor oil; it should be chosen carefully according to manufacturers' recommendations and checked regularly. The suggested intervals for replacement of oil and filters should be observed carefully or the oil quality should be monitored.
- Injection pumps with external lubrication are preferred

Check the motor oil level regularly. In case the oil level rises, replace the oil prematurely. In addition to the items listed above, the stress on the engine has effects on oil dilution. In fact, oil dilution is at its maximum at low workloads of the engine.

When switching to biodiesel, deposits from earlier diesel fuels may be mobilised, so check and exchange fuel filters especially if you experience an engine power reduction.

Next there are some recommendations for procurement, refuelling, driving and maintenance of B100 fuelled vehicles.

Procurement

If you purchase 100+ vehicles the manufacturers will love to **guarantee B100 compliance**. For small blends you might try yourself to manage but above B30 please get a written agreement from the manufacturer –an independently assessed test run may be necessary. Exclude **fuel operated heaters** if costs escalate. Specify B100 for guarantees regarding the **exhaust aftertreatment system** (sensors, urea consumption...). **Don't accept** to frequent oil changes –agree on oil parameter monitoring instead.

Some cars may be run on B100 (100% biodiesel). However, the number has got smaller because of problems with unsuitable high pressure diesel injection pumps:

- Skoda Octavia Type 1U, Fabia Type 6Y and Superb Typ 3U (not 142 KW) may use RME rape methyl ether and thus may be used in taxi and rental fleets.
- Others like those of the Peugeot-Citroen-Group may be run only with B30 (30% biodiesel). They also announced vehicles with particle filters capable of using biodiesel.

Mercedes/EVOBUS offers a couple of models able to run with B100 (100% biodiesel):

- EVOBUS standard buses: O 405/O 407/O 408/ O405 G/O 550 with OM 447 hLA
- EVOBUS low floor: O 405 N/O 405 GN with OM 447 hLA/O 530/O530 GN with OM 906 hLA and OM 457 hLA
- Mercedes OM 457HLA/LA, OM 501/502 LA and OM 906 LA may be run with biodiesel after individual consultation with Mercedes.

Mercedes now offers B100 buses which have a particle trap.

All Scania heavy duty vehicles may be operated on Biodiesel when ordering a service contract. A regular oil check is mandatory when using Biodiesel:

- Scania Ökoline available only in Germany
- Mercedes Actros BR 500, Atego BR 900, Axor Bm 457.9

New Holland, focusing on off road, has announced that on all its present machines with CNH engines, it is possible to use up to 20 per cent blend biodiesel, providing the engines comply with European Standard EN14214.

Fendt agricultural tractors are 100% RME-fit. This is achieved by integrating the injection pumps into the motor block and applying separate oil lubrication.

Refuelling

Instead of using expensive additives you might **blend fossil diesel in winter** (B70). Don't use 3 months **old biodiesel** or biodiesel from unknown sources without certified standard **EN14214**. Don't store biodiesel in tanks cooled by ambient air **avoiding build up of water** content. Check if your existing tank and fuel hoses are **B100 compatible**. Change **diesel filter** some time after switching to B100, because B100 dissolves dirt from pervious fuels.

Driving

You will notice **no difference** if the maintenance is ok. The endurance is only some percent lower.

Maintenance

You will love that spilled fuel is no problem because it is **biologically decomposable**. PVC coated gloves and safety glasses are recommended. **Motor Oil** should be analysed, especially if you have no experience with the combination of B100 and the internal combustion engine. Pressure loss over the **fuel filter** is to be checked to avoid power loss.

5.2 BIOETHANOL

Bioethanol can be used as a 5% blend with petrol under the European quality standard EN 228 and at such a blend no engine modifications are required. Vehicle owners running their cars on bioethanol blends should adhere to the recommendations of the individual car manufacturers. Some vehicle manufacturers specify that the maximum bioethanol blend in petrol should be no more than 5% bioethanol by volume, whilst others specify a maximum bioethanol blend in petrol of 10% by volume. If the stated maximum blend is exceeded a vehicle's warranty will be invalidated (however it is hard to proof).

100% bioethanol can be used in modified, spark-ignition engines, although cold starting requires the addition of a small amount of a volatile fuel component – usually gasoline/petrol. The 5% blend of bioethanol in petrol by volume converts into 3.4% by energy content because the energy content of bioethanol is only about two-thirds that of petrol.

Producing bioethanol is still more expensive than producing petrol from crude oil depending on the relative costs of the bioethanol feedstock and the crude oil. The production costs are also influenced by the high capital cost of the production facilities for hydrolysis and fermentation.

With full fuel duty bioethanol is expensive to buy and a reduction in the duty rate is needed to make it competitive at the fuel pumps (but this only depends on import of ethanol; local production needs free or at least heavily reduced tax). As with biodiesel, such duty reductions are common in Europe, and are intended to be used as a means of encouraging fuel suppliers to develop bioethanol and to stimulate the market. Bioethanol production is now underway in many European countries but hampered by the raising prices of starch and sugar products.

5.2.1 Choice of variants

Some usual bioethanol blends are E5, E20, E85 and E95:

- **E5** (5% bioethanol, 95% conventional petrol): This is the usual minimum blend in Europe. With this option adaptations are not necessary, but there is only minor reduction of the Global Warming Potential (GWP).
- **E20** (20% bioethanol, 80% conventional petrol): It is the maximum allowed blend for non Flexible Fuel Vehicles (FFV). Multi point injection copes better with E20. Adaptations are not necessary, but there is a limited reduction of the GWP. There are few pumps which offer E20, you may blend yourself into the tank
- **E85** (85% bioethanol, 15% conventional petrol): This is a standard fuel at pumps but it requires dedicated ethanol enabled vehicles (FFV). It has industrial support, but a new vehicle type is necessary with restricted supply.
- **E95** (95% bioethanol, 5% conventional petrol): It may only be used in adapted diesel engines. It has the lowest Global Warming Potential (GWP), and low emissions of NO_x and PM, and it is as energy efficient as conventional diesel engines. The engines are rarely available.

5.2.2 Recommendations

Ethanol has the potential to reach higher efficiency with internal combustion engines in the future because of its higher octane rating. This requires adaptation of the operational regime of the engines as well as changes in the lay-out. The engine may be smaller due to the higher power per volume due to a higher compression. Thus higher fuel costs may be compensated by smaller vehicles and a higher MPG (lower fuel consumption).

Ethanol production is limited (but increasing) in Europe but it is the largest biofuel produced in the world, especially in Brasil and U.S.A. 70 % of bio-ethanol goes into gasoline, of which 47 % come from ETBE. Ethyl tertiary butyl ether (ETBE) is consisting partly of ethanol (47% v/v) and isobutylene (53% v/v).

So called flexible fuel vehicles or specially ethanol enabled vehicles should be used for an ethanol share greater than 25% (they may run on all mixtures from 0% up to 85%). In the case of specially adapted vehicles no significant changes in driveability may be expected. Also few dedicated Ethanol vehicles (E95) are available (mainly buses).

But without modification there is a degradation of engine performance with ethanol fuel blends. Engine misfire frequency increases and engine stalls occur.

Other difficulties (cold start, corrosion...) will occur when fuelling conventional vehicle with ethanol (or higher ethanol blends), so the usage of flexible fuel vehicles is recommended.

Procurement

Do not overdo specification of the endurance in order not to exclude ethanol as fuel. On the other hand the FFV should meet European emission standards especially important when using retrofits or imports from Brazil.

If procuring large quantities of vehicles E-diesel/E95 is promising better fuel efficiency and producers might be willing to offer special mutations.

In Europe Flexible Fuel Vehicles (FFV) are available from:

- Ford (Focus FFV, Focus C-max FFV)
- Saab (9-5 BioPower, Saab 9-3 BioPower)
- Volvo (V50 F, S40 F, C30 F)
- Renault: Megane
- Peugeot: 307 Bioflex
- Citroën C4 BioFlex

Skoda (Octavia Flexifuel 1.6), Volkswagen (Golf, Caddy 1.6), Audi and Seat have also announced introduction of Flexi Fuel vehicles.

Ethanol buses: Scania offers Ethanol buses that run on E95. The engine is a modified diesel engine. The fuel consists of ethanol and 5 % ignition improver. The ethanol diesel engine is as energy efficient as a conventional diesel engine. 40-50 % larger volume of ethanol compared to diesel is needed because of the lower energy content in ethanol compared to diesel.

Refuelling

There is a pre-standard for E85 in Europe (prEN 15376, ASTM D 4806 in the USA), at least the following parameters shall be monitored when operating your own pump:

- Electrical conductivity (water content)
- Particulate content
- Hydrocarbon content
- Reid vapour pressure

Volatility is to be seasonally adjusted by blending 15-30% petrol. Detergents are not necessary for Ethanol to avoid foaming.

Driving

Not applicable – total endurance might be increased by switching to gasoline if no E85 pump is available.

Maintenance

Pure ethanol provides no good lubricity and is corrosive to some extent. Thus E95 operated vehicles require frequent inspections. It is not necessary if you use E85 or lower blends in a FFV.

6 GASEOUS FUELS (NATURAL GAS, BIOGAS)

6.1 NATURAL GAS

Although Natural Gas is a fossil fuel, it gains interest as an alternative fuel. This is because of the clean burning qualities of the product. Because of its gaseous form it has to be stored in a compressed state: Compressed Natural Gas (CNG) or in a liquefied state: Liquefied Natural Gas (LNG).

Natural Gas Vehicles (NGV) were characterised by higher capital costs but lower fuel costs (exise duty exemptions). But since CNG vehicles are produced on standard assembly lines and the producers give discount the vehicle prices are comparable or even lower than for diesel vehicles. Furthermore NGV refuelling stations are expensive – much more so than LPG stations - and are only commercially viable if they refuel a relatively large number of vehicles.

This means the introduction of NGVs suffers from the classic problem that fuel suppliers are reluctant to construct refuelling stations until there are sufficient numbers of NGVs and operators are unwilling to purchase the vehicles until there are sufficient refuelling stations.

According to the International Association of Natural Gas Vehicles in June 2007 there were nearly 7 million NGVs in use worldwide, of which 1.65 million were in Argentina, 1.55 million in Pakistan and 1.43 million in Brazil. Italy's fleet of 432,900 NGV is by far the biggest in Europe, followed by Ukraine with 100,000, Germany with 55,272, Bulgaria with 25,225, Sweden with 13,477 and France with 10,150.

6.1.1 Choice of variants

The variants for methane are:

- **Monovalent:** Utilises only methane as fuel in an engine which was optimised for methane. With this option you can get higher energy efficiency, higher reduction of the (GWP) Global Warming Potential particularly when using biogas derived methane. The disadvantages are that there is no reserve tank with gasoline pushing the endurance in case no gas station available, and the number of vehicles offered which increases but is still limited.
- **Bivalent:** The additional petrol tank allows running solely on petrol. It involves higher endurance, but engine may not be optimised for a specific fuel, and there is a less reduction of GWP, especially when running on petrol.

6.1.2 Recommendations

Methane is the main component of compressed natural gas and the only one (in technical terms) in liquefied natural gas. There are two conversion systems available, mechanical (carburetted) and electronic (fuel injected) types. The fuel is mixed with the (compressed) intake air in a fuel/air mixture (carburettor). In electronic systems, injectors or control valves are used to meter the fuel flow into the intake air. Direct injection in the combustion chamber is not state of the art yet.

Mostly stoichiometric engines with three way catalysts are used for passenger cars and lean burn engines are also used with busses or truck because of the better fuel efficiency.

Procurement

Retrofitting is loosing ground with new vehicles offered having all certifications from the start. Vehicles having low floor installed tanks offer more cargo capacity. Even if not available direct high pressure gas injection allows for higher efficiency. High yearly kilometrage decreases costs per km caused by 5 yearly (depending on make and regulations) tank inspections.

In Europe the following vehicles are offered with bi- or monovalent operation:

- Citroen Berlingo and C3 bivalent
- Fiat Multipla, Punto and Doblo Natural Power
- Ford Focus C-max CNG
- Mercedes E 200 NGT
- Opel Combo 1.6 CNG and Zafira 1.6 CNG
- Peugeot Partner Premium bivalent
- Volvo V70, S60, S80 CNG
- Volkswagen Caddy, Touran, Golf Variant EcoFuel

An increasing amount of light trucks are available CNG enabled:

- Mercedes NGT Sprinter
- Ford (Transit)
- Iveco Daily
- Fiat Ducato natural power

Some CNG buses offered fall under the EEV-emission standard (Enhanced Environmentally Friendly Vehicle) and thus help the owners of captive fleets to comply to the EU directive aiming at 25% share of EEV procurements in public fleets:

- NEOMAN
- CBG Bus Breda
- Scania L94UB CB60 Low Floor – CNG
- EKOBUS CNG Buses
- Heuliez, Irisbus / Renault,
- Mercedes
- Volvo

A biogas-fuelled version of the Scania OmniLink exists for the emission standard Euro 5.

Refuelling

Refill with appropriate gas quality (in most cases H grade).

Check contaminates (carry over of oil) in the gas caused by coalescing filters in case of engine problems.

Driving

Because of an octane rating of 130 CNG has a slight efficiency advantage over gasoline. Because CNG is already in a gaseous state, NGVs have superior starting and driveability, even under severe hot and cold weather conditions. NGVs experience less knocking and no vapour locking.

Maintenance

Since temperatures in the engine are higher and the fuel has no lubricants, the engine remains clean, the focus for inspections will be on exhaust valves and the gas system.

6.2 BIOGAS

Biogas is produced at more than 4000 sites in Europe, mainly landfill and sewage plants and is normally used to power gas turbines or engines to produce electricity or combined heat. However, if it is upgraded to natural gas quality – at which point it is sometimes called Substitute Natural Gas (SNG) - it can also be used to power CNG vehicles.

Biogas has been used as a vehicle fuel in Sweden, where a national biogas fuel standard dictates that the fuel must constitute a minimum of 95% methane and more recently in Switzerland. However, numbers vehicles remain low, with probably only a few thousand vehicles fuelled by biogas worldwide.

6.2.1 Choice of variants

The same as Natural Gas.

6.2.2 Recommendations

The same as Natural Gas.

7 ELECTRIC PROPULSION

Electric vehicles (EVs) produce no emissions at the point of use, they are near-silent and are cheap to run. Since the late 1990s much interest and most research funding has been switched from pure EVs to hybrid vehicles, which combine electric motors with internal combustion engines to give more power and greater ranges.

7.1 BATTERY ELECTRIC VEHICLES

So called BEVs (Battery Electric Vehicles) are well suited for indoor, tunnels, neighbourhood vehicles etc. Because of the low endurance of the heavy battery packs (mainly NiMh or Lead Acid) a usage for private cars or for high daily milage is not possible. Latest developments like Li-Ion batteries and range extensions through fuel cells have reintroduced the concept and new application fields may be explored.

Caused by the high torque of electric motors and the easier speed control, the vehicles are easy to drive in urban environments and off-road. Pure electric vehicles may suffer from a restricted endurance. Operated at low temperatures, the capacity of the unheated batteries is much lower (depending on the battery type).

7.1.1 Choice of variants

In principle two charging method have been established

- conductive charging (plugs)
- inductive charging

The distribution of electricity is done via the ordinary grid - however for fast loading domestic fuses are not suited. Charging from the electric grid is most efficient - intermediate storage in batteries is not (in case of solar or wind power and lead acid or NiMH).

Apart from charging from the grid alternative sources like wind or solar energy may be used. However in narrow street urban areas there is not enough space to have a significant solar share. Also solar panels on the cars roof may not produce enough energy to contribute significantly to the energy used for the propulsion.

The on board energy storage may be short, medium and long term using ultracapacitors, NI-Mh batteries with high self discharge or batteries with separate electrolyte storage (so called flow batteries) with no self discharge.

7.1.2 Recommendations

Modern electric systems require no physical maintenance. Batteries might be equalised from time to time and the cooling system (if present) cleaned.

Procurement

Batteries might be leased or bought. When comparing offers, the replacement of batteries is an important cost factor to be considered.

Full size electric vehicles for road usage are not sold via retailers. Few full sized vehicles are still on the market:

- Citroen Berlingo 500E Electrique
- Veturi Vetish, Ariana Ev IEV 797
- Mega City (2-seater)
- G-Wiz (2+2 seater)

Apart from vehicles for operation on yards (also called neighbourhood vehicles), some utility vehicles are sold (YDEA electric Micro Vett, Piaggio Porter Van).

A couple of electric buses for quartier operation are available:

- Battery Mini Bus Breda
- Gepebus
- IVECO Europolis
- Micro Vett Schoolbus based on IVECO DAILY

The following small sized battery electric vehicles may be used in yards or in historic city centres:

- Graf Carello Transporter
- Aixam Mega City branded NICE
- Alke' ATX
- Tasso Domino
- H2 Truck, a small utility vehicle suitable for transport applications at hospitals and airports
- Italcarr

Two companies have now launched vehicles into the truck market in the UK:

- Modec
- Smith Electric Vehicles

Refuelling

Charging regime is to be adapted to the battery chemistry. With on board power conversion a range extension is possible.

Driving

The electric drive increases the torque with low RPM.

Maintenance

With sealed batteries or gelled electrolyte controlling the acid or electrolyte level is not an issue. With active cell balancing rectifying batteries is not necessary. If not available cell equalising from time to time helps to avoid premature failure of single cells.

7.2 GRID CONNECTED VEHICLES

Electric vehicles produce zero emissions at the point of use, which makes them a particularly attractive environmental proposition for busy urban areas where poor air quality often leads to health problems.

7.2.1 Choice of variants

There are basically two methods in operation. The catenary type and the ground level power supply. Both get their energy from the grid but may be decoupled partially by using capacitors or batteries but also internal combustion engine energy generators. Trolley busses have to use two catenaries -one for trams. The installation may be using lighting masts but has to be erected separately in most cases. The pantograph for trolley busses is using catenary switches similar to track switches. The pantograph is secured with a rope and may be pulled down with it in case of derailments.

7.2.2 Recommendations

Modern electric systems require no physical maintenance.

Refuelling

The system is bound to the catenary system unless hybridized.

Driving

The electric drive increases the torque with low RPM. The driving characteristics of electric vehicles are very good. Good acceleration and sufficient power is available. For the passenger of a trolley bus a tram like feeling is given because of the absence of most of the noise and vibrations of an internal combustion engine.

Maintenance

With battery electric or hybrid vehicles, when off-grid and with discharged energy storage no safety issues arise. Less maintenance is expected compared to internal combustion engines.

8 HYBRIDS

A hybrid car combines an electric motor with an internal combustion engine. Hybrids are sold at a premium compared to their non-hybrid equivalents but can bring large fuel cost savings in stop and go operation (city traffic). In most EU countries– as well as many US states and cities– hybrids qualify for purchase grants and/or reduced taxes. For high mileage users they can make sense in economic terms.

From the manufacturers' perspective the economics of hybrids seems unclear. Many experts believe the manufacturers make a loss on each vehicle sold. However, production costs are of course expected to fall as volumes increase and the increased brand image pays those costs by selling other vehicles well.

Sales of hybrids now are relatively small compared to conventional vehicles but are limited by supply rather than demand. Consequently there are waiting lists for most hybrid models in the US and European markets.

Toyota has sold more than 1,25 million of Prius since the first generation of the vehicle was launched in Japan in 1997, making it by far the world's best-selling hybrid.

The development of plug-in hybrids are supported in the U.S.A. by campaigns, offering an even bigger fuel saving.

8.1 CHOICE OF VARIANTS

Hybrid Electric Vehicles are produced in three variants:

- **serial** having no mechanical connection of the ICE to the wheels
- **parallel** adding torque from electric motor and ICE
- **combined** allowing to load the batteries while contributing to the propulsion

Serial concepts are better for stop&go operation only. Parallel hybrids require sophisticated control algorithms but have better efficiencies at full load operation (in terms of investments in machinery). With non serial concepts called microhybrid or start'n stop automatic it is possible to hide very small electric traction power and energy storages under the shining hybrid label. So called mild hybrids are not more than improved start/stop concepts without the ability to drive electrically. Plug-in hybrids try to improve those concepts allowing longer electric only operation.

Very simple but fuel ineffective concepts have four wheel drive with one axle ICE-driven and one axle electric driven.

You can choose from several variants which are summarized in the next table:

| Type | Passenger car | Light duty | Heavy duty |
|----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| Stop'n Go (50km/day) | Battery electric Serial Hybrid | Battery Electric Serial Hybrid | Serial hybrid |
| Mixed operation | Serial Hybrid Parallel Hybrid | | Parallel hybrid |
| Long distance (500km/day) | Light hybrid | Light Hybrid | Electric energy from exhaust heat |

Table 2. Variants for Hybrid Electric Vehicles

- Strong Parallel Hybrids especially Plug In Hybrids are versatile concepts, and battery size may be scaled according to the duty cycle.
- The decision towards battery electric depends on the ability to recharge frequently to allow flat cycles and i.e. a long battery service life.

8.2 RECOMMENDATIONS

Modern electric systems require no physical maintenance. Batteries might be equalised from time to time and the cooling system if present cleaned.

Procurement

Batteries might be leased or bought. When comparing offers, the replacement of batteries is an important cost factor to be considered. With HEVs, shallow cycling allows long service life without replacements.

Hybrid Electric Vehicles (HEV) are available from:

- Honda (Civic IMA)
- Toyota (Prius).
- Lexus (RX400h, GS450h)

Citroen and Peugeot will be using a parallel concept with diesel engine in future. Others licensing Toyotas Synergy Drive System like Nissan will follow. Furthermore, almost all important manufacturers intend to have hybrid models on sale in Europe next years – Daimler Chrysler, General Motors, BMW, Volkswagen, Audi, Porsche, etc.

In the public transport sector in Europe hybrid electric minibuses may be ordered based on IVECO Daily or Mercedes Sprinter Chassis. Also Solaris Poland offers buses with the US fabricated parallel hybrid system from Allison. Wrightbus is providing hybrid electric buses for Transport for London. Hess is testing doubly articulated buses called light tram in daily operation.

Refuelling

Charging regime is to be adapted to the battery chemistry. With on board power conversion a range extension is possible. With HEVs, no difference to the operation of the conventional vehicle is expected. HEVs may be refuelled like ICE-powered vehicles or recharging to some extent from the grid.

Driving

The electric drive increases the torque with low RPM. Caused by the high torque of electric motors, the vehicles are easy to drive in urban environments and off-road.

Due to the "phlegmatised" internal combustion engine (for efficiency reasons), the power follows later than expected if no electric assistance is available (at higher speeds and low state of charge). When accelerating from stand still the electric drive adds more torque compared to ICE-only vehicles.

Maintenance

With sealed batteries or gelled electrolyte controlling the acid level is not an issue. With active cell balancing rectifying batteries is not necessary. If not available cell equalising helps to avoid premature failure of single cells.

9 FUEL CELLS AND HYDROGEN

A fuel cell is an electrochemical device that combines hydrogen (H₂) and oxygen to produce only water, heat and electricity. The fuel cell is a very promising technology that is expected to provide a clean and efficient source of power for many applications, including transport. Almost all vehicle manufacturers are involved with major fuel cell research programmes but most believe fuel cell vehicles (FCVs) are unlikely to become commonplace within the next 10 years. The economic viability of FCVs is dependent on greatly reducing fuel cell production costs and on developing a

commercially viable refuelling infrastructure.

H₂ can also be burned in internal combustion engines (ICE) that are very similar to petrol engines, but which produce zero emissions of tailpipe CO₂, CO and HC (except for very small quantities deriving from engine lubricants and small amounts of NO_x). Hydrogen ICEs bring some of the advantages of FCVs but in a technology that is already well-proven and accepted by consumers. Some vehicle manufactures believe H₂ ICE vehicles will help bridge a gap towards a longer term FCV future by creating demand for H₂ as a fuel, thereby leading to the development of a H₂ refuelling infrastructure that will fuel FCVs in the longer term.

9.1 CHOICE OF VARIANTS

Hydrogen can be used in Fuel Cells, which consist of a stack which converts hydrogen from an onboard hydrogen tank or fuel reformer and oxygen from the air or from tanks to water generating electricity. H₂ can also be burned in internal combustion engines (ICE).

9.2 RECOMMENDATIONS

Procurement

Fuel cell vehicles are not sold but leased. There are three passenger cars offered by

- Honda (FCX)
- Daimler Chrysler (Mercedes F-cell) and
- Ford (FWD)

The Honda FCX has only super capacitors and no batteries on board and the biggest range with 210km. Two FCV from Ford are methanol fuelled (Focus FC5, Mazda Premacy FV-RV).

Refuelling

Hydrogen is a very light gas; therefore the energy flow through a defined hole is smaller compared to natural gas. But filling requires very high pressure and transport of liquefied hydrogen is more efficient, compared to compressed hydrogen. Solid hydrogen storage may be playing a big role in the future plans but only small quantities are stored in prototypes.

Hydrogen refuelling stations may use remotely produced hydrogen, but also produce hydrogen from natural gas/Methanol/LPG reformation or proton exchange membrane electrolysis on site. The stations may be equipped with low and high pressure dispensers to accommodate vehicles with onboard metal hydride storage (solid) or onboard compressed or liquefied gas cylinders. A cooling apparatus allows for a rapid fill of 10 minutes.

Driving

Caused by the high torque of electric motors, the FC-vehicles are easy to drive in urban environments and off-road. Endurance depends on the amount of Hydrogen stored on board, restricted endurance may be the case. If energy is stored in batteries the driveability is acceptable.

Maintenance

Modern electric systems require no physical maintenance. Batteries might be equalised from time to time and the cooling system if present cleaned. With FC external air moistening systems may be drained and cleaned from time to time.

10 SHOW CASES

Here you find compilation of some alternative propelled vehicles used in public transport.

| Fuel/technology | Cases in the database | Success factors | Remarks |
|---------------------------------|---|--|--|
| Ethanol (E95) | Stockholm 127 (400) buses Madrid 5 buses | Lower Global warming potential GWP, higher efficiency with E-diesel | 2nd generation of buses in 2007 |
| FAME | Madrid 209 buses B30 Graz 131 buses B100 Paris 72 busses B30 | Lower fuel cost, very small vehicle adaptations | fuel qualities differentiation summer/winter helps to exploit cheaper feedstocks |
| SVO/PPO | Hasselt 70 Leeuwarden 22 buses | Lowest fuel cost | Fuelling system has to be adapted entirely |
| HEV (Excluding Diesel Electric) | London 6 buses Dresden 1 bus Aalborg 5 buses Jena 1 bus | Lower fuel cost and lower emission | Test with parallel and serial hybrids, no market prices yet |
| Catenaries | Landskrona 3 buses combined with BEV Athens 193 buses | Zero emission | Proven tram technology makes trolleys costly |
| CNG | Athens 416 busses Torino 223 buses Madrid 202 buses Malmö 180 buses Paris 90 busses | Lower fuel costs, Lower emission | 3rd generation of vehicles is available |
| Bio-CNG | Lille 100 buses, Linköping 5 buses | Lower fuel costs, Lower emission, lower GWP | low blending of lower qualities into CNG saves costs |
| Hydrogen | Reykjavik 3 buses, in Europe 27 buses | Zero emission (lower GWP if renewable) | Pilots only, service life has improved |
| BEV | Rome 51 buses Paris 12 busses | Zero emission, recharging logistics, low battery costs for lead acid batteries | Operation in historic city centres mainly, battery characteristics may change with new types of battery. |

Table 3. Buses show cases

Although the number of hydrogen cases is high and implementations prominent, it may not be compared with CNG, E95, B100 or Biogas implementations where hundreds of buses are running per case. Also with other fuels more buses are in operation in each case compared to the number of buses running in hydrogen projects.