Report No. [*] - GZ

Palestinian Authority

MINISTRY OF TRANSPORT

STRATEGIC ASSESSMENT ON ENERGY EFFICIENCY AND SECURITY FOR PUBLIC TRANSPORT IN THE WEST BANK

FINAL REPORT

October 2009

Sustainable Development Department

Middle East and North Africa Region

CURRENCY AND EQUIVALENT UNITS

(As of April 2009)
Currency Unit = Israeli New Shekel (NIS)
US$ 1.0 = NIS 4.0
NIS 1.0 = US$ 0.25

ABBREVIATIONS

ADEME	Agence De l'Environnement et de la Maitrise de l'Energie. French organization for Environment and Energy for the French Administration
CAN	Controller Area Network. It allows all diagnosis and show the calibration of the main parameters used for the engine and others components
CH4	Methane gas
CNG	Compressed Natural Gas (methane CH4 gas)
CO2	Carbon Dioxide
COST	European Cooperation in Science and Technology
De NOx	Generic term for the technique able to reduce the NOx such as EGR or SCR
DPF	Diesel Particles Filter
EEV	Level of performances between Euro5 and 6 (future regulation) Enhanced Environment Friendly Vehicle
EGR	Exhaust Gas Re-circulation, which allows the reduction of NOx emissions
EPA	Environment Protection Agency, a USA agency in charge of defining regulations related to the environment
EURO 0, 1, 2, 3, 4, 5	Term related to the European norm
FAP	French meaning of Diesel Particles Filter
GHGs	Greenhouse Gases
HC	Hydrocarbon (all the fuel which is not burned during the combustion)
LNG	Liquid Natural Gas (methane CH4 gas)
LPG	Liquid Petrol Gas (mixture of butane and propane)
MEA	Membrane Electrode Assembly of a fuel cell
MOT	Ministry of Transport
NOx	Nitrogen Monoxide or dioxide pollution emitted during the combustion
PAMs	Portable Acquisition Mobile. Device used with Starbus to gathers the main characteristics of a route and therefore gives all accurate data
PNA	Palestinian National Authority
PPM	particles per million
RPM	revolutions per minute; speed of the engine
SCR	Selective Catalyst Reduction of NOx
SORT	Duty cycle for buses. Standardized On Road Test Cycles STARBUS European project to choose the pathways of buses; www.starbus-tool.eu
TA	Technical Assistance
TOR	Terms of Reference
WB	World Bank
WBG	West Bank and Gaza

FISCAL YEAR (FY)

January 1 - December 31

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Contributors and Recognitions: This Report was prepared by a World Bank team led by Ibrahim Dajani and with the participation of Roger Rault, Khaled Alsahili, Lamis Aljounaidi, Gregoire Gauthier and Khalida Al-Qutob. The team is grateful for the leadership of senior officials from the Ministry of Transport, and the cooperation of the technical staff. The team is also grateful for the guidance provided by Ranjan K. Bose and John Allen Rogers for the helpful comments from peer reviewers. This work was made possible through financial assistance from the Energy Sector Management Assistance Program (ESMAP).

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1 Executive Summary

Background

The ongoing World Bank Technical Assistance (TA) is assisting the Palestinian Ministry of Transport (MOT) and the bus sector to develop a strategy for strengthening the sector, which at a minimum will require strengthening of the operators' finances to be able to afford the urgent fleet renewal. One strand of this aims at restructuring the industry sector so that it can achieve system-wide efficiencies and economies of scale. Other strands are needed to focus on practical measures to achieve technical and operational efficiencies, and help in the reduction of unit operating costs.

Since fuel is the largest expense item in the West Bank and Gaza (WBG) bus industry sector, it needs a special attention. One area of potentially radical change is to examine whether changes in fuel types would provide significant benefit. Over the last decade, some Chinese and Indian bus operators have converted their fleets to gas (Compressed Natural Gas – CNG – or Liquefied Petroleum Gas – LPG), and to a lesser extent European and North American operators have done so. At the regional level, Israeli operator Egged is exploring using CNG for its buses. There are also trends to increasing use of blended fuels, bio-fuels, and 'clean diesel'. These changes have been stimulated by expected benefits in fuel costs, security of fuel supply, fuel efficiency, and cleaner emissions.

Finally, improving the efficiency of bus operations is critical to the energy efficient and environment-friendly sustainable environmental improvement of bus transport.

Objectives

The proposed study supports the Transport Strategy (TSN) and the ongoing TA by exploring the options for the use of alternative fuels in the bus industry in West Bank and Gaza, and carrying out an initial examination of potential benefits and practicality.

Given (i) the recent high oil price rise and volatility and (ii) the weight of fuel costs within operators' operating costs, this study examines which fuel alternatives provide the best cost-effectiveness. Besides, an environmental assessment of the various pathways is carried out.

The main activities of this TA include the following: (i) general review of alternative engine pathways available for buses; (ii) description of the public transport situation in the West Bank, with a special focus of fuels availability and use for public transport; and (iii) life cycle cost comparison of 6 scenarios involving alternative fuel pathways, including CNG and LPG buses.

General review

The reviewed pathways are: diesel and its variations (water-diesel), ethanol, LPG, CNG, electric, hybrid-electric, and fuel cell engines. Within this review EURO0 to EURO5 were considered and the advantaged / drawbacks of each pathway were analyzed.

It resulted from this review to take out of the scope of the WBG analysis a few pathways. Fuel cell engines are only prototypes for the time being. With current batteries capacity, electrical engines are limited to short inner-city services. Hybrid buses are still very expensive and probably not affordable for the moment to WBG public transport operators. EURO5 buses are under recent development and are still expensive too; nevertheless, their use was analyzed and compared to EURO4 as well as to the potential of fuel options in the WBG. Ethanol and water-diesel are not present within WBG. CNG is not present either but was kept within the scope of the study, as a possible motor vehicle fuel in the future, in particular thanks to recent discovery of natural gas Gaza off-shore.

Alternative fuels use in WBG and the region

In the region, Diesel is the most commonly used fuel for public transport. Nonetheless, in Egypt, many taxis are running on CNG and there is a pilot program on CNG for buses. In Israel, CNG is not used for cars but there are about 10,000 private vehicles running on LPG. It is still unclear whether CNG or LPG is used by public transport vehicles, or not, in Israel. In Jordan, all public transport is run on Diesel.

In the West Bank, all types of fuels (diesel, gasoline, LPG) are imported and are obtained through Israel. Road transport accounts for more than half of the overall energy consumed in the Palestinian Territories. All public transport vehicles use diesel, cheaper than gasoline. CNG is banned for safety reason on behalf of Israeli – PNA agreements. LPG is not officially recognized as a motor vehicle fuel but is used by several thousand private cars in WBG.

Methodology and scenarios

The base-case (Scenario 0) is the existing conditions (EURO0 Diesel). Several other scenarios were established: EURO3 scenarios with Diesel, LPG and CNG, and EURO4 and EURO5 scenarios with Diesel, LPG and CNG. The EURO4 fuel alternatives were compared with the EURO5 engines for the same fuel alternatives. All these scenarios were compared with the existing condition (EURO0 Diesel).

A set of key assumptions was defined so that the life cycle cost, on 12 years, of each scenario could be computed with the STARBUS simulation model. The assumptions included, among others: various fuels unit prices and escalation, capital cost of each type of bus, specific capital costs needed for CNG and LPG technologies, maintenance costs of each type of buses, average kilometers per year, etc. The bus duty cycles used for the simulations are those built in the STARBUS simulation model.

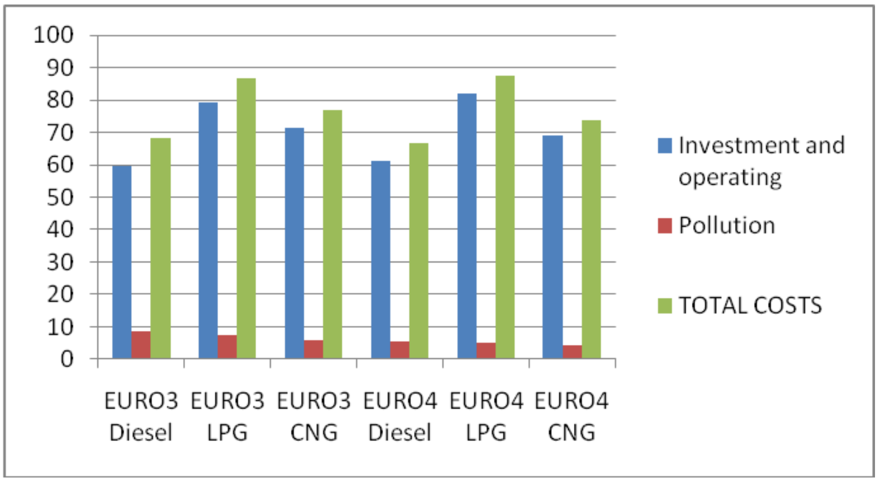
The scenario comparison is carried out on the basis of: (i) direct costs: fuel costs, maintenance costs and bus asset depreciation; and (ii) environmental monetarized costs for local pollutants (CO, HC, NOx, particles) and global pollution (CO2). EU standards were used to monetarize pollution costs.

Finally, a sensitivity analysis on key parameters was carried out to make sure of the results robustness.

Results

The main results are recapped in the following chart. The results presented are the life-cycle costs of a 40-bus fleet, over a 12-year time. Costs are shown in discounted million NIS. In addition, EURO5 diesel, LPG, and CNG alternatives were compared to same of fuel alternatives of EURO4 engine.

Tested scenarios life cycle costs comparison (Million NIS)



Among all scenarios, EURO4 diesel is the most cost-effective, with very little cost difference with EURO3 diesel. The diesel scenarios are between -10% and -25% cheaper than the other scenarios, EURO4 CNG is the third cheaper, but approximately 10% more expensive than the diesel scenarios. The LPG scenarios are much more expensive. The EURO3 Diesel scenario is the cheapest, considering only direct costs.

Regarding pollution and as expected, EURO4 scenarios are, on the whole, much better than the EURO3 ones: between -24% and -35% of emission savings when each EURO3 pathway is compared to its EURO4 counterpart. While EURO3 diesel is, by far, the worst pathway and EURO4 CNG the best, it can be stated that EURO3 CNG, EURO4 diesel and EURO4 LPG are within the same order of magnitude when it comes to pollution costs.

Among EURO5 pathways, the global pollution is reduced for the Diesel fuel whereas both LPG and CNG are best for local pollution. Nonetheless, from the operator standpoint (direct costs), again the Diesel pathway is the cheapest one. The critical point is the initial investment, which should be the barrier for the operators. The EURO5 fleet would entail an extra investment cost per bus of approximately 3-4%.

Recommendations

The recommendations are the following:

Build the case for fleet renewal. New rolling stock is critical, both for service quality to customers and for the current operators to be able to continue service and business. An estimated 200-250 bus will be needed during the next 2-3 years, and as much as 400 over the next 5 years. The current study may help the stakeholders to choose from various available options.

Decide on priorities: environment vs. minimizing costs. Better environmentally-friendly buses, such as CNG buses, will come at an extra-cost. A policy decision is to be made regarding which importance to be given to environmental issues, especially against cost constraints. However, it should be borne in mind that imposing high vehicle standards without attention to the financial sustainability of bus operations can undermine their viability with counterproductive effects.

Foster Diesel pathways. In light of the conclusions of the study, the diesel pathway should be promoted for public transport in WBG. Since the simulation results conclude that EURO3 and EURO4 technologies have direct costs in the same order of magnitude, EURO 4 should be encouraged. There is a large spectrum of bus manufacturers, which give the opportunity to buy EURO3 or EURO4 buses in good conditions. It is recommended to define a standard for all the operators in order to be able to procure for a large number of buses at the same time.

Fine-tune the results. The analysis that was carried aims at the strategic level and is preliminary. As much as possible, it is recommended to fine-tune the simulation inputs so as to get more accurate results. As the economic environment changes, three items should be of special focus: (i) the buses unit prices, (ii) the fuel unit prices, and (iii) the bus duty cycle curves really used in WBG conditions.

Fuel supply and availability. Alternative fuels, especially natural gas, supply and availability should be assessed in a more comprehensive way. The recent discovery of natural gas fields off-shore Gaza might change energy equilibrium and markets in the region.

Improve operators' financial situation. The operators financial capability is today limited. Introducing new buses is likely to, at the same time, decrease the huge maintenance costs that have to be incurred on their current worn-out buses but also increase dramatically their operating costs in terms on loan repayment and depreciation. This action is part of the public transport strengthening that is proposed through the large franchises scheme.

Improve maintenance process. The maintenance organization has to be updated. It is highly recommended to choose one or just a few kinds of buses ("standard bus"), for the various operators, so that the maintenance processes are streamlined and eased. The minimum agreement is common warehouses for the spare parts. It is also recommended that the operators consider subcontracting for specific operations that requires either heavy investments or high professional capacity. The subcontracting could be through (i) the bus manufacturer organization, (ii) through the specialization of the maintenance of the largest operators, or (iii) through a special company, as proposed in the passenger transport sector development study.

Set a regulatory framework for LPG vehicles. Light LPG vehicles (private cars) are already in use in the West Bank. Engine retrofitting is currently carried out in informal workshops. It is recommended that a regulatory framework is established to control this activity and ensure safety standards. The regulation should include: the retrofitting kits themselves, the garage which modifies the cars, the LPG stations requirements, and the periodical technical control of the cars and of the stations.

2 BACKGROUND

The Transport Sector Strategy Note (TSN) of June 26, 2007 identified several issues of concern in the transport sector. One of these issues is the problem of high operating costs which has a serious impact on the overall viability of the transport operators, and hence on their capacity to finance fleet renewal. A further issue is that the bus companies or taxi offices are often family owned and managed in a traditional way with very limited initiatives for business plan development or future planning concepts, and hence have little capacity for assessing and introducing new technologies that would improve their efficiency, capacity and/or their finances.

At present, virtually all Public Transport (PT) in WBG is provided by privately owned buses, shared taxis and personal taxis and has been regulated by a traditional system that dates back many years. There is a high level of fragmentation in both the bus and taxi sectors with many small-scale operators, most of which have just a few routes. This is compounded by the progressive shrinkage of business over the last three decades, both through a reduction of the business within the West Bank and Gaza, and the total cessation of services to destinations outside these territories. As a result, many of the former larger companies have diminished, both in scale and in technical capacity, and are surviving on the legacy of historic investments and know-how. There is currently minimal capacity to absorb complex and innovative technologies.

A recent study of the bus operator sector carried out within an ongoing Bank TA has identified that there are 76 operators in the West Bank who currently operate 594 buses on 128 registered routes, and that a further 10 companies and 26 routes are not operational. Of the 76 operators in the West Bank, all have less than 50 buses, and only 16 operators have 10 or more buses currently operational. The sentiment within the industry sector is that further contraction is likely unless there are significant changes in the operating environment. In Gaza, the general bus services have collapsed completely, with just two recognizable bus operators still providing services mainly for transport of schoolchildren and students.

The study also examined the cost structure of a number of the larger operators in the West Bank. This indicated that fuel costs accounts for about 40% of total expenditure in 2008, a significant increase in previous years. There is little prospect that fuel costs will decrease and serious concern that the costs will increase even further, and lead to closure of operators who are already in a difficult financial position having depleted their reserves and exhausted their bus assets. The bus fleet is life-expired with about 40% of the large-bus fleet being already 16 or more years of age, and only 5% of the large-bus fleet being 10 or less years old.

The ongoing TA is assisting the Ministry of Transport and the bus operator sector to develop a strategy for strengthening the sector, which at a minimum will require strengthening of the finances to be able to afford the urgent fleet renewal. One strand of this considers means of restructuring the industry sector so that it can achieve system-wide efficiencies, and economies of scale. Other strands are needed to focus on practical measures to achieve technical and operational efficiencies, and help in the reduction of unit costs.

Since fuel is the largest expense item, it needs to be a focus of special attention. Some economies can be made through network design to optimize the kilometers operated, while other measures could pay attention to the elimination of fuel-inefficient practices. One area of potentially radical change is to examine whether changes in the fuel type would provide significant benefit. Over the last decade, many Chinese and Indian bus operators have converted their fleets to gas (CNG or LPG), and to a lesser extent European and North American operators have done so. At the regional level, Israeli operator Egged has begun using CNG. There are also trends to increasing use of blended fuels, biofuels, and 'clean diesel'. These changes have been stimulated by expected benefits in fuel costs, security of fuel supply, fuel efficiency, and cleaner emissions.

This Study supports the TSN and the ongoing TA by exploring the options for the use of alternative fuels in the bus operator sector in West Bank and Gaza, and carrying out an initial examination of the potential benefits and practicality of implementation.

3 REVIEW OF ALTERNATIVE FUELS BUS PATHWAYS

3.1 INTRODUCTORY REMARKS

Energy and pollution are increasingly important; because of sky-rocketing fuel prices a few months ago and high fuel price volatility, international organizations and governments are prone to foster energy–saving programs. Local pollution has a direct impact on the health whereas global pollution - greenhouse gases, in particular CO_2 - is now one of the main challenges in terms of climate change. Therefore, most countries introduce more stringent regulations in relation with energy and pollution challenges, especially in the transport sector.

As an example, the European Commission has established pollution regulations in the transport sector for buses; USA and Japan adopted similar regulations. Other middle-income countries such as India, China and Russia have launched similar regulations; a few of these countries, such as China, adopted the European regulations.

3.1.1 LOCAL AIR POLLUTANTS: EURO NORMS

For the past 15 years, these more drastic regulations have been the main drivers for bus manufacturers to look for new alternative fuels technologies. In Europe, the second petroleum crisis (years 90') and the social impact of local pollution were the main two incentives that stimulated introducing new types of buses (EURO norms). Set by the European Commission, the EURO norms stipulate the maximum pollutant authorized in gram per KWh. The table 1 below shows the maximum emission of each pollutant (in grams per Kwh) for each EURO norm.

Table 1: Maximum Emission Limits (grams per KWh)

NORM	EURO 0	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5
YEAR	1988-92	1993-96	1996-00	2000-06	2006-09	2009 -
CO	11.2	4.5	4	2.1	1.5	1.5
NOx	14.4	8	7	5	3.5	2
HC	2.4	1.1	1.1	.66	.46	.25
PARTICLES	No limit	.36	.15	.1	.02	.02

NB: These norms are gathered with special conditions. The emissions are measured on an engine bench, with load and RPM steady conditions (different levels).

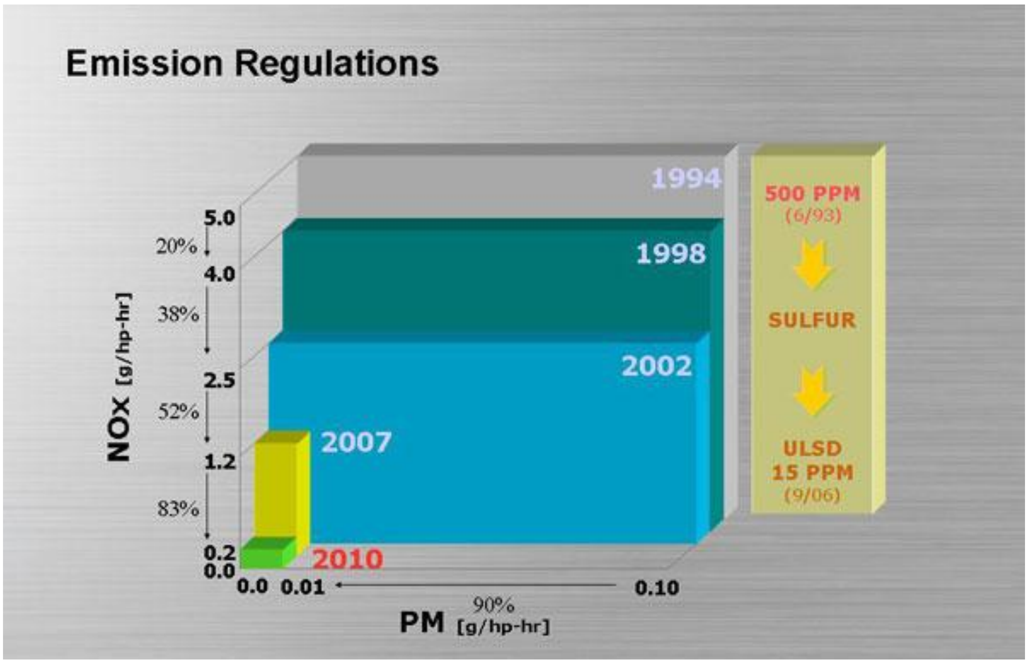
It is important to bear in mind that the EURO norms were introduced progressively; the EURO thresholds are increasingly difficult to reach and the allocated time to do so is decreasing. As an example, the delay to move from Euro0 to Euro1 was approximately 6 years and the reduction quite 'easy' to obtain. However, for the conversion from Euro3 to Euro4 and Euro5, the delay was only 5 years and the reduction was much more difficult to reach.

Table 1 above shows the emission reduction that should be obtained over 20 years with the EURO 0 to EURO 5 implementation. The reduction in fuel emissions is around 1/10 for all the regulated pollutants.

Of course, these results need new technologies within the engine and on-board devices, which are able to obtain positive results for specific pollutants. For EURO5, all the engines require the [1]De NO x systems (SCR[2] or EGR[3]) to pass the norms. Most of the European manufacturers use the SCR system, which adds some additive to reduce the NO x emissions.

In the US, the chart below (Figure 1) shows similar regulations on local pollutants from the Environment Protection Agency (EPA).

Figure1: EPA Fuel Emission Limits



3.1.2 GLOBAL POLLUTANTS

EURO norms imposed standards on local pollutants but not on global pollutants (CO_2 and CH_4 mainly) responsible for global warming and climate change. About 3 years ago, growing concern has been raised on that issue, and greenhouse gases (GHGs) were taken into account. Still, the buses are not yet

[1] De NO x techniques reduce NOx emissions, responsible for health diseases

[2] Selective Catalyst Reduction of NO x
Selective catalytic reduction (SCR) is a means of converting nitrogen oxides, also referred to as NO_x with the aid of a catalyst into diatomic nitrogen, N_2, and water, H_2O. A gaseous reductant, typically anhydrous ammonia, aqueous ammonia or urea, is added to a stream of flue or exhaust gas and is absorbed onto a catalyst. Carbon dioxide, CO_2 is a reaction product when urea is used as the reductant.

[3] Exhaust Gas Recirculation. EGR is a nitrogen oxide (NOx) emissions reduction technique used in most petrol/gasoline and diesel engines. EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders. Intermixing the incoming air with recirculated exhaust gas dilutes the mix with inert gas, lowering the adiabatic flame temperature and (in diesel engines) reducing the amount of excess oxygen. The exhaust gas also increases the specific heat capacity of the mix, lowering the peak combustion temperature. Because NOx formation progresses much faster at high temperatures, EGR serves to limit the generation of NOx. NOx is primarily formed when a mix of nitrogen and oxygen is subjected to high temperatures.

under any regulation, contrary to the commitments of car-makers to reduce GHGs emissions at an average of less than 130 grams per kilometer by 2012.

The future norms evolution is likely to be focusing also on the reduction of greenhouse gases emissions. This parameter is actually closely linked to the fuel consumption. The carbon balance is the result of the fuel consumption: fuel consumption (more precisely the carbon content of the fuel, depending of the kind of fuel) and CO_2 emission are linearly correlated.

This is the reason that some 'operating cycle' were defined so as to try to be closer to the reality. Some cycles are well-known in Europe such as SORT, ADEME, and RATP cycles. The tests are done thanks to a rolling bench to simulate the inertia of the bus for different load conditions. These methods improve a lot the process to choose the best bus related to the needs of the network.

3.2 DIESEL ENGINES

More than 70% of the European bus fleet is equipped with diesel engines. Different kinds of fuels can be used. The sub-sections below provide more information on these various kinds of fuels.

3.2.1 DIESEL

Diesel is the most common fuel used for road public transport. In Europe, all types of diesels are of low rate sulfur (almost maximum of 15 ppm). A few years ago, different diesel sulfur levels existed: more than 50 ppm, less than 50 ppm and less than 15 ppm. Special devices are needed to reduce pollutants, specially NOx and particles, are required. These devices work in a similar way as catalytic converters that trapped the lead contained in the gasoline. Sulfur and particles are trapped

For EURO5 engines, most manufacturers use the SCR technology, which needs a fuel additive to reduce NOx emission. The consumption of this additive is about 2% of the diesel liter consumption. In France, the extra-cost for the additive is approximately 1 Euro per liter.

3.2.2 WATER EMULSION DIESEL

During the last decade, different fuel suppliers introduced "water emulsion diesel". The main advantage is the reduction of the particles. Water emulsion diesel can really particles emissions so that EURO3 standards are met (for the particles); nonetheless, water emulsion diesel cannot reach EURO4 or EURO5 standards. This fuel reduces particles emissions between 5 and 30%, compared to standard diesel. The maximum reduction is actually obtained for Euro2 engines and below.

Before this fuel can be used, it is necessary to clean up all the fuel supply chain (in particular the tank of the fuel station, the replacement of the diesel filter of all the buses, and the cleaning of their tanks) so that water emulsion diesel is not mixed with standard diesel.

This system has not become really popular yet due to higher per liter price: water emulsion diesel is more expensive than standard diesel by 10 to 20%. This is mainly due to distribution constraints, with few suppliers – the distribution network mainly relies on the TOTAL-ELF and AGIP networks in Europe-; besides, there are occasionally difficulties to be supplied even from the petrol companies. Finally, the fuel consumption, in liters, is increased by 10% compared to 100% pure diesel: water emulsion diesel contains indeed 10% of water.

3.2.3 BIO DIESEL

Biodiesel is a mixture of diesel and another organic compound. “B30” is a mixture of [4]30% ethanol and 70% diesel. “Diester” is another biodiesel which contains around 30% of ester (as an example: natural oil form soybean) and 70% of diesel. Almost all standard diesel engines can work with biodiesels as experiences show that the rubber or plastic joints and seals present in diesel engines are not affected by the organic compound. Most diesels in Europe contain some bio-diesel (from1 to 5%, depending on countries]. The fuel consumption in liter is equivalent to the 100% pure diesel. Table 2 shows comparison of characteristics of the DIESTER and Diesel products.

Table 2: Comparison between Diesel and DIESTER

Characteristics	Diester	Diesel
Density (15°C)	0.88	0.83 to0.86
Flash point (°C)	188	> 55
Cetane Index	51	Around 51
Filterability limit temperature (°C)	-12 to -15	< -15
Calorific value (MJ/liter)	33.2	35.3 to 36.3
Viscosity (40°C) (mm/s)	4.5	2 to 4.5
Oxygen	11%	0

Source: web site www.partenaires-diester.fr

The bio-diesel main advantage is that the greenhouse gas effect (CO_2) is reduced thanks to the use of vegetable products, which are considered as neutral to the CO_2 emission balance.

3.2.4 ETHANOL

Ethanol can be produced from sugar cane and sugar beets, as well as from cereals and biowaste. The technology is developing continuously. Recent findings include technologies for producing ethanol from cellulose and burning the residual products in district heating or electricity generating plants. The main advantage concerns the greenhouse effect, thanks to the production of this fuel from vegetable or crops.

Current interest in ethanol mainly lies in bio-ethanol, produced from the starch or sugar in a wide variety of crops, but there has been considerable debate about how useful bio-ethanol will be in replacing fossil fuels in vehicles. Concerns relate to the large amount of arable land required for crops, as well as the energy and pollution balance of the whole cycle of ethanol production. Recent developments with cellulosic ethanol production and commercialization may allay some of these concerns.

Today, only the bus manufacturer SCANIA offers this option but the latest information is that SCANIA will stop this pathway in Europe, this information should be confirmed. The engine is based on a Diesel one with the adjunction of an ignition improver. At this moment, in Europe, the ethanol-run bus fleet is quite small (Sweden and a little Poland).

[4] B30: commercial name of a mixture of diesel and ethanol; with 5% ethanol this mixture is called DIESTER.

Stockholm Public Transport Authority introduced ethanol buses in the city bus fleet in the middle of 1980's. The Stockholm fleet has now expanded to 400 buses, the goal being to reach 50% of renewable bus fuels in 2011 and 100% in 2025. In addition, ethanol-fuelled buses are run in other Swedish cities. Since 2004, ethanol buses have been introduced in several other cities, such as: Madrid (Spain), La Spezia (Italy), Slupsk (Poland), and Sao Paolo (Brazil). New generation ethanol buses (from Scania) have been recently introduced in Oslo (Norway), Nottingham and Redding (UK), Milan (Italy), and Östersund (Sweden).

Further information about ethanol and ethanol-run engines for buses can be found on the www.ethanolbus.com website, which most of the above information stems from.

3.2.5 Facilities for Diesel engines

Diesel maintenance depot

Diesel buses are the most common standard. Therefore, virtually all bus operators, bus networks managers or bus importers have the appropriate workshops to maintain diesel buses.

Nevertheless, it is useful to point out specific equipments are required so as to keep the more technologically-advanced buses properly maintained. Additional facilities and equipment are indeed needed for Euro3 and Euro4 buses: specific diagnosis equipments to communicate with the engine through the [5]'CAN' system and others items are required. Especially, it is recommended to have at least the smoke tester and gas analyzer to check emissions on a continuous basis. The fuel injection system needs to be tuned up. These devices costs range from 15-KEuros to 50-KEuros.

Diesel fuel station

Whenever different diesel fuels are used, different specific tanks are required; this entails extra space, extra logistics management and extra costs. Bus refueling has to be carefully managed and handled so that each kind of fuel is supplied and each category of engine is fuelled with the appropriate diesel.

3.3 Otto engines

Generally speaking, "Otto engines" are engines that need to have an ignition to trigger the combustion; reversely, diesel engines need not ignition and combustion is triggered by compression. LPG, CNG and LNG engines are Otto engines.

The efficiency of Otto engines is lesser than that of diesel engines. The main reasons to use Otto engines are either to valorize oil sub-product form refineries (e.g.: Liquid Petroleum Gas), or reduce some air pollutants. In the early nineties, Otto engines appeared to suppress particles emissions and to curb NOx emissions, in comparison with Diesel uses. Two main fuels are used for Otto buses engines: (i) Liquid Petroleum Gas (LPG) which is a mixture of Butane (C_4H_{10}) and Propane (C_3H_8), and (ii) Methane (CH_4). Methane either comes from natural gas (compressed on liquefied) or from the biomass production.

[5] Controller Area Network. It allows all diagnosis and shows the calibration of the main parameters used for the engine and others components

3.3.1 LIQUID PETROLEUM GAS (LPG)

LPG is a by-product of the oil-refining process. Some countries promote LPG as a transport fuel for the cars, lorries and buses. The main market is in fact private cars, since car retrofitting for LPG is quite easy: adding a specific tank and mechanical or electronic (today 100%) fuel injections system. Almost all the cars are now considered as Bi-fuels, which means they are able to run either with gasoline or LPG.

For buses application, there is a large difference with the conversion of the cars which use Otto engine as a standard. In fact the bus manufacturer must develop Otto engines instead of diesel. This conversion cannot be done like for cars, through mechanical networks.

Compared to the Diesel the economy is in fact more related to the price difference of the fuels, than the efficiency of the engines, The LPG engine is not so efficient than the Diesel engine.

This is the main reason, that for buses, a few manufacturers (DAF and MAN) introduced LPG engines. MAN has proposed this option for buses for three years only.

Figure 2: LPG bus; tanks are located on the roof

The advantages of LPG are:

- the fuel price level is lower than the diesel (very often);
- for the Euro4 and lower, less emissions of particles and NOx;
- the engine noise is lower than diesel;
- the comfort inside the bus is improved, compared to diesel, due to a smoother engine.

At the opposite, the weaknesses are:

- the energy consumption is higher than diesel (+ 10 to 15 % to reach the same calorific power as diesel);
- more emissions of HC (due mainly to maintenance process);
- CO_2 emission is greater than diesel;
- few manufacturers offer this option in Europe.

The hurdles for the bus market are summarized below.

- acceptance of the maintenance workers (different methods; diesel, LPG);

- The specific and drastic safety rules to handle the fuel and to organize the workshop. The workshop will require specific devices such as gas extractors, inside parking places to avoid gas accumulation on the ground in case of leakage;
- the extra cost of a LPG station and, therefore, the longer investment payback time;
- The time to refuel is a little longer than for the diesel;
- The autonomy, which requires large and heavy tanks on board (the average consumption of LPG is around 80 to 100 liters per 100 kilometers). Therefore, for a range of 400 kilometers, a tank capacity of 600 liters is needed.

The economic balance between Diesel and LPG is really depending of the price of each fuel, and this parameter may show great variations from one country to another. For example, in France, the unit price of diesel is 0.8 EUR (without VAT, May 2009) per liter with a fuel consumption of 49 litres/100 km compared to LPG price of 0.4 EUR with a consumption of 90 liters /100 km. Thus, the fuel cost per 100 km is 39.2 EUR for the diesel bus and 34 EUR for the LPG bus (data from the Laval and Belfort networks – France).

There is no clear cut for the environmental comparison between LPG and diesel. Results depend on which pollutant is considered: NOx, HC, CO and greenhouse gases emissions. The table 7 in chapter 2.7.6 gives the comparison of the emissions and consumption of the different pathways.

3.3.2 Compressed Natural Gas (CNG)

"CNG" means Compressed Natural Gas (more that 90% CH_4). This technique is used to improve the energy density on board. The gas pressure inside the tank is 200 bars.

The natural gas offers several advantages, which are mainly:

- A large potential for the future, the natural gas resources are more important than the petrol.
- A clean fuel compared to the petrol related to the particles.
- The natural gas is cheaper than diesel.
- The international price is more stable thanks to many long term contracts between the producers and the international customers.

For these reasons many bus manufacturers offer CNG option for their buses. The main differences with the diesel bus are:

Replacement of the diesel tank by a CNG tanks (in fact, several bottles), which are able to support up to 250 bars. The gas is in fact compressed in order to fulfill more gas and; therefore, to have a reasonable autonomy (400 kilometers is the average). The weight of these tanks is from 400 to 1000 Kg. The tanks are very often located on the roof of the buses. The roof is consolidated to receive this over weight (see Figure 3).

Figure 3: CNG Bus

The bus refueling may be operated like the diesel is or ‘on the parking’ during off operation periods (at night).

The advantages of the CNG are:

- The price level is lower than the diesel (very often);
- For Euro5 engines and lower: less emissions of particles and NOx ;
- The engine noise is lower than diesel ;
- The comfort inside the bus is improved, compared to diesel, due to a smoother engine.

Conversely, the weaknesses are:

- The energy consumption is higher than the diesel;
- There are usually more HC emissions (mainly because of to maintenance capability). In fact the mechanicals do not pay attention that there is no smoke and they think there is no need of tune up, therefore, the calibration may deviate, and the emissions should be more important than the normal one.
- CO_2 emission is greater than diesel,
- The over weight of the bus.

The main hurdles for the bus industry:

- Possible reluctance from maintenance workers to accept CNG buses because of different methods compared to diesel;
- More drastic safety rules for the fuel and the workshop. This includes the installation of some specific devices such as gas extractors in the workshop and inside parking places to avoid (in case of leakage of gas) gas accumulation at the upper locations.
- Over costs and, therefore, longer payback time of the CNG station;
- Lower autonomy, which requires large and heavy tanks on board (800 kilograms for a 400 km range) to be made up for.

3.3.3 Liquid Natural Gas (LNG)

LNG means Liquid Natural Gas (mainly CH_4). This technique requires a cryogenic tank to keep the natural gas at a temperature range of -160°C. Liquefied natural gas takes up about 1/600th the volume of natural gas at an atmospheric condition.

Compared to the CNG, this option offers a similar autonomy to the diesel engine with a tank of 250 liter capacity (400 liter capacity of the CNG fuel to have the same autonomy).

The cost of this option is really expensive due to (i) the very particular fuel station, and (ii) the specific tanks able to keep the gas liquid (very well insulated system), for some hours of parking. In fact very few bus applications are currently in operation. With the current technology, there is not really any objective advantage to pay much more and to support a maintenance process that is more extensive than the CNG option.

We do not recommend at all this option taking into account the context of this study.

3.3.4 Biogas

The biogas could be either CNG or LNG and the consequences in terms of fuel consumption and emissions are the same as described above. The difference is that biogases derive from the valorization of the vegetable waste, and not fossil materials. Therefore, biogases are really positive for both energy independence aspect and CH_4 effect. In fact the positive impact compared to the natural gas is the CO_2 emission because most of the processes are CO_2 neutral. Actually, the CH_4 (methane) is produced from vegetable or/and waste products which through the fermentation of the products produce the gas.

The profitability is concerned through the investment of the methane production unit and the tax level of this fuel, which is conducted to the price of the gas compared to CNG/LNG.

Some countries such as Sweden, Poland and France push biogas with tax exemptions and sometimes agree to give incentive or subsidies to launch the production units.

3.3.5 Facilities for LPG engines

Safety concerns with LPG

Operating LPG requires many changes in the daily bus operation, procedures and habits. Hence, it is likely that maintenance workers will be reluctant to switch to LPG. Indeed, for safety reasons, it is forbidden to smoke in any workshop where LPG is operated. When some parts of a bus must be welded, it is important to check before welding that there is no gas leakage.

Changing these habits and procedures require time and complementary training, for instance regarding the specific maintenance procedures, different from those of a diesel engine. LPG engines specificities include: the ignition system calibration, the gas injection system and the checking of gas leakage of gas from the tank to the engine.

LPG maintenance depot

The maintenance of LPG engines requires to have at least 4 gas analyzers, an ignition control system, and to check all the safety devices needed to detect any leakage of gas. The minimum installation is therefore al the electrical plus must be 'anti –detonation', to avoid any inspection pit closed to the place where the LGP bus should be repaired, to have electrical fans to ventilate the air outside of the inner place, and at last to have a 'light _sound' alarm connected to a level gas gauge. Ideally, it is recommended to have electrical doors, which are connected with the gas sensor. The cost starts from

30K EUR to 150K EUR (150K NIS to 800K NIS) in relation with the equipments and the surface of the depot.

Figure 4: Maintenance depot from LAVAL in France

The main points to be checked in a LPG bus depot are:

- To locate all the plugs above 1.2 meter from the ground;
- To install LPG gas sensors at the interior critical points of the garage, knowing the LPG is heavier than the air at the level of the ground;
- To connect at least these sensors to an alarm which inform the persons in the garage of the excess of gas through flash lights or/and sounds;
- Ideally the sensors should be connected to some doors or/and windows to opened them when the sensors detect an excess of gas;
- For the LPG it is recommended to install some fans to blow the air closed to the ground.

Last point, it is usually forbidden to use underground inspection pits in LPG bus depots to avoid any accumulation of the LPG in the pits, in case of leakage.

LPG fuel station

The installation of the general tank has to be located outside of an area of safety (see Figure 5). Nonetheless, this regulation is specific to each country.

The refueling is easy to do, nevertheless some basic safety rules should be borne in mind while operating LPG. Staff and workers have to be trained in order to avoid any misunderstanding or incidents.

Figure 5: LPG fuelling Station

For a LPG station, the investment starts from 100K EUR to 250K EUR (500K NIS to 1300K NIS) depending of the location and the engineering to be done. The capacity is mentioned for the supplying of a basis of 40 buses.

3.3.6 Facilities for CNG engines

Safety concerns with CNG

As for LPG, operating CNG requires many changes in the daily bus operation, procedures and habits. Hence, it is likely that maintenance workers will be reluctant to switch to CNG. Indeed, for safety reasons, it is forbidden to smoke in any workshop where CNG is operated. When some parts of a bus must be welded, it is important to check before welding that there is no gas leakage.

Changing these habits and procedures require time and complementary training, for instance regarding the specific maintenance procedures, different from those of a diesel engine. CNG engines specificities include: the ignition system calibration, the gas injection system and the checking of gas leakage of gas from the tank to the engine.

CNG maintenance depot

The depot requirements are similar to those needed for LPG. In addition, CNG depots and workshops should be equipped with special safety devices such as ‘sky windows’ on the roof, activated when the sensor detects CH4; CH4 is indeed lighter than the air. As for the LPG depot, the CNG depot must comply with specific design features to ensure safety with CNG.

The extra cost is similar to the LPG depot that means from 30K EUR to 150K EUR (150K NIS to 800K NIS).

CNG fuel station

The installation of the general tank is best located outside of an area of safety. Nonetheless, this regulation is specific to each country.

The refueling is easy to do even if some basic safety rules should be borne in mind while operating LPG. Staff and workers have to be trained in order to avoid any misunderstanding or incidents.

Two types of CNG fuel station are possible. The first type is similar to the LPG or Diesel (see Figure 6); refueling is done bus per bus.

Figure 6: CNG station similar to a fuel diesel station (Creteil depot – France)

The second type of fuel station is called ‘slow refueling’, and each bus (when parked) has an individual fuel connection to be plugged. This system is cheaper but its operation has to be explained properly to the staff to avoid missing the connection. The most convenient place is an ‘open space’ to avoid possible leakage and moving buses (see Figure 7).

Figure 7: “Low refueling” CNG stations (Montpellier depot)

Each bus is connected during the non-operating time to the grid and all the buses are refueled. The refueling time requires at least 5 to 6 hours. The main constraint is to have a large space to park all the CNG buses. It is recommended to have this place close to the operated routes to avoid dead trips. Details of the compression units of the CNG tanks are shown in Figure 8 below.

Figure 8: Details of the compression units and CNG tanks

The investment for a slow refueling station is around 250K EUR (1250K NIS) for 20-bus capacity. For example, the Toulouse network (France) invested 2 million EUR (10 millions NIS) for a 100-bus capacity 'slow refueling' station. The average cost for a quick refueling system for a capacity of 40 buses is around 1 million EUR (5 million NIS).

3.4 ELECTRICAL ENGINES

The power is provided through electric batteries. Main batteries technologies are :

- Lead-acid batteries are the most available and inexpensive. Electric vehicles equipped with lead-acid batteries are capable of up to 130 km per charge.
- Nickel Metal Hybrid (NiMH) batteries have higher energy density and may deliver up to 200 km of range.

- New lithium-ion battery-equipped electrical vehicles provide 320–480 km of range per charge. Lithium is also less expensive than nickel. Today this technology is only focused on car applications.
- Nickel-zinc battery is cheaper and lighter than Nickel-cadmium batteries. They are also cheaper (but not as light) as Lithium-Ion batteries.

Two kinds of batteries recharging methods are used.

In the first method, the batteries remain on board. While parked, the bus is connected for recharging to the electrical grid through plugs. This system is similar to the low fuelling CNG system and several buses can be connected at the same time.

Figure 9: Electrical plug to charge the batteries

The second method is sometimes called 'swapping system'; once discharged, the batteries rack is removed from the bus and replaced with charged batteries.

Figure 10: Pack of removable batteries

Figure 11 : Electric bus Elfo EPT model

For the moment, most buses with 100% electrical engines through batteries are small or medium buses. Very few standard buses (12 meter length) are available. All the networks operating on electrical engines are for very short trips and for inner city routes. The European fleet is concentrated in few cities where the city centers have to be pollution and noise free (tourist areas).

The weak points of the electrical engines are:

- The price of the battery related to the life time; the batteries initial cost can reach 100k EUR per bus with life-times usually comprised between 5 to 6 years.
- The supply of energy depends on electricity station and/or the battery set on board. For example the duration to fulfill the batteries should need up to 10 hours. When the batteries are part of the buses, the buses need to be plugged to the electricity grid during all this time.
- The relatively low autonomy of affordable batteries (from 80 to 150 kilometers);
- The over cost of this pathway for the mini and midi bus, compared to diesel or CNG;
- The lack of offer for standard buses;
- The maintenance of the propulsion system, which induces extra operational costs.

This pathway is very specific has not to be evaluated for the aims of this study, focusing mostly on intercity services.

3.5 Hybrid Engines

The principle of the hybrid bus is to have a small combustion engine and an electrical engine supplied through batteries. The purpose of this combination aims at reducing both fuel consumption and pollution. Saving rely on a smaller combustion engine, running if possible within better conditions of load and RPM than conventional propulsion. The additional power is provided through the electrical power.

There are different schemes of hybrid propulsion, the most offered for bus application is the "serie-hybrid". The combustion engine (e.g.: diesel) runs and, through a generator, supplies the batteries; the electrical engine is connected to the batteries and to the power train. The electrical engine also acts as an engine brake (electric retarder) and is able to regenerate energy from the deceleration.

The advantages are: (i) downsizing the combustion engine (from around 1000kg to 400kg), (ii) better running conditions (stable RPM and load) and, thus, better efficiency, and (iii) energy recovery during the deceleration and braking. When the vehicle brakes, energy which would normally be wasted is recycled and used to charge the batteries. With continuous charging of the batteries, the vehicle can achieve a larger operational range than a conventional diesel bus. Figure 12 shows the scheme of hybrid engine.

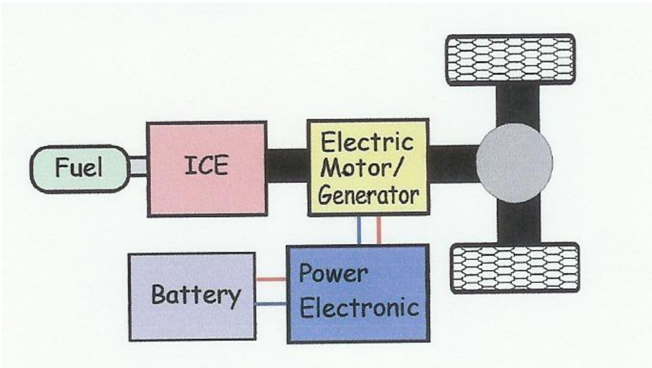


Figure 12: Scheme of hybrid bus power train

Environmental benefits

When compared with the conventional EURO4 diesel buses, hybrid buses deliver considerable environmental improvements:

- From 15 to 50 per cent reduction in oxides of nitrogen;
- From 20 to 60 per cent reduction in carbon monoxide;
- From 20 to 40 per cent reduction in carbon dioxide;
- From 15 to 30 per cent reduction in particles matter;
- From 15 to 30 per cent reduction in perceived sound levels (noise reduced from 78dB to74dB).

The results show that these buses produce fewer greenhouse gas emissions and harmful local pollutants, as well as having lower noise levels.

Energy benefits

- From 20 to 40 per cent reduction in fuel use;
- All type of fuel can be used for the thermal engine.

The present situation of these hybrid buses is mostly yet pre-series buses, even if more and more manufacturers offer hybrid technologies. At this moment the over cost of purchasing is around 60% more than the conventional bus. Moreover, the maintenance skills required are very high to afford as well the conventional, the batteries, the electronic converter and the spare parts supplying.

For the reasons mentioned above, this type of bus is not included at this moment within the study scope.

3.6 Fuel Cell engines

The fuel cell technology is quite new for the bus applications. Therefore, we first give some indications about the principles of the fuel cell.

What is a fuel cell? (Source: Documents from Fuel cell bus club.)

A fuel cell is a device that separates hydrogen electrons with a catalyst to produce electricity. After this process, the hydrogen combines with oxygen from the air to produce water and heat as by-products. In a sense, a fuel cell is like a battery, using chemical reactions -- not combustion -- to change energy stored in a fuel directly to electricity. Unlike a battery, a fuel cell can produce electricity continuously, without needing to be recharged, as long as it is supplied with hydrogen. When fuelled with pure hydrogen, a fuel cell emits no pollutants and no greenhouse gases.

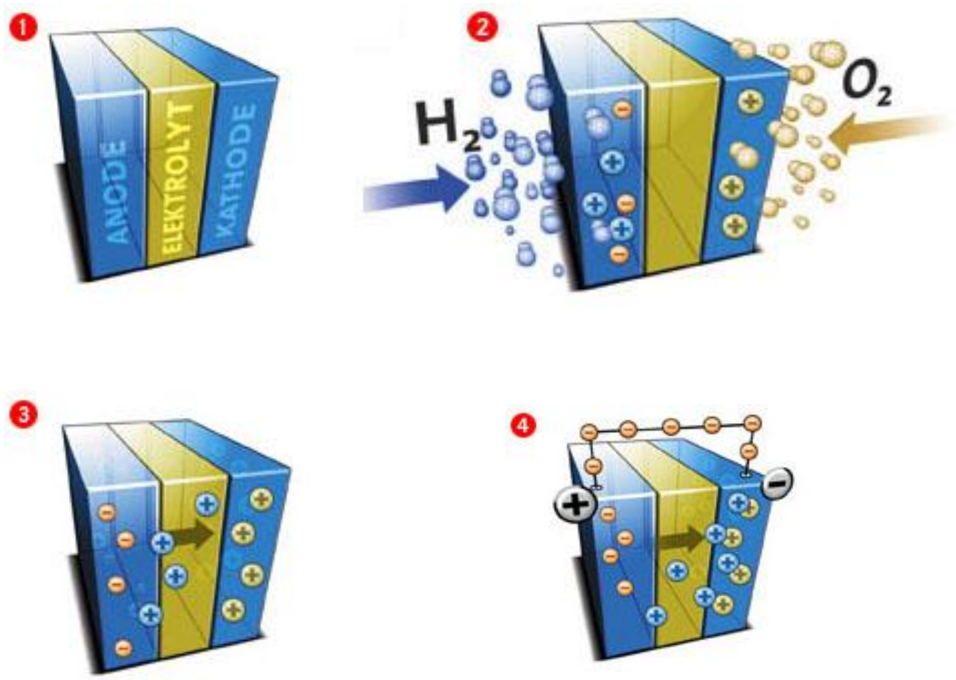
How does it work?

The basic premise of a fuel cell is as follows: hydrogen (H2) flows toward one side of a catalyst-coated plate (such as one covered with platinum). When the hydrogen comes in contact with the catalyst plate, the proton slips through a plastic membrane. The hydrogen protons come in contact with oxygen in the air to form water (H2O). The plastic membrane is too small for the hydrogen electrons to pass through. Instead, the electrons are collected on an external circuit and provide electricity. Water and heat are the only by-products of this electricity-generation if pure hydrogen is being used.

Fuel cell for buses

The main technology at this moment is the Proton Exchange Membrane fuel cell, called 'PEM'. The main advantage is the low operating temperature of around 80°Celsius and their high power density.

In the PEM fuel cell, a controlled reaction of hydrogen and oxygen supplies the current for the electric drive. The only exhaust produced by this so-called cold reaction is chemically pure water. Figure 13 shows the scheme of the PEM fuel cell.



Source: DaimlerChrysler AG

Figure 13: Scheme of the Proton Exchange Membrane fuel cell

Image 1. Fuel cell parts

Image 2. Combination of H_2 with O_2 contained in the atmosphere

Image 3. The chemical reaction of hydrogen and oxygen in the fuel cell generates electricity

Image 4. The electricity is available to supply the engine of the bus

Components of a PEM Fuel Cell

To be able to use the electric energy released in this process it is important to avoid that hydrogen and oxygen come directly in contact with each other. Therefore, they are separated by an electrolyte. In the case of the PEM fuel cell, a proton-conductive plastic foil separates the two reaction gases and serves as the electrolyte. The foil - it is only one tenth of a millimeter thick - carries a very thin layer of platinum on both surfaces. The platinum serves as a non-degrading catalyst, which accelerates the chemical process of the gases on both sides of the membrane.

In addition, the membrane is coated with an electrode of gas-permeable graphite paper. The membrane is coated with catalyst and the graphite electrodes form the so-called membrane electrode assembly (MEA).

The [6]MEA again is attached to the so-called bipolar plates. These plates usually made from solid graphite contain small channels that distribute the product gases, hydrogen and oxygen, on their respective sides of the MEA over the entire surface of the membrane.

A MEA with bipolar plates on either side constitutes an elementary fuel cell. This fuel cell is capable to supply a voltage of between 1 volt in idle mode and 0,5 volt at a maximum current of about 1 Ampere per centimetre square.

Its current capabilities can be tailored by an appropriate cross-section area. To increase the voltage of the fuel cell, several elementary fuel cells are connected in series or stacked together. Around 100 or more of these elementary fuel cells form a fuel cell stack (see Figure 14).

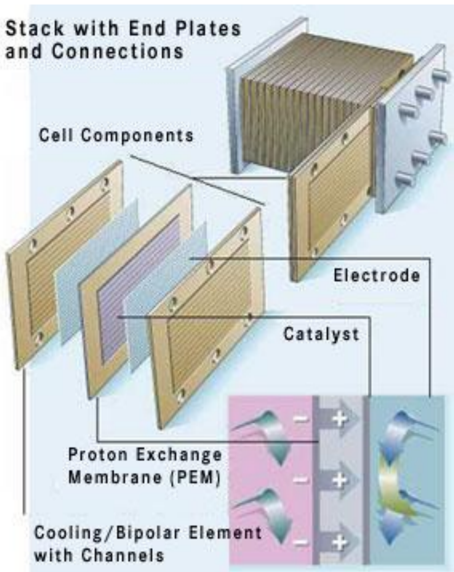


Figure 14: Fuel Cell Stack

[6] MEA Membrane Electrode Assembly

In fact the fuel cell engine is the following of the hybrid except the 'thermal' engine is a fuel cell instead of conventional engines. The fuel cell is the opposite of a cell that means from hydrogen the cell produces energy combined with oxygen. For more explanation, the website www.fuelcells.org enters more into the details.

The most well known program is CUTE and the following HyFLEET supported by the EC funding.

Several cities have implemented these buses. The approach of these programs is in fact to analyze the operational conditions, the operative costs, and the different means to supply hydrogen. The results are really very positive specially a high ratio of operative time. This is the reason of the new program, which covers not only European cities but are linked to others continents.

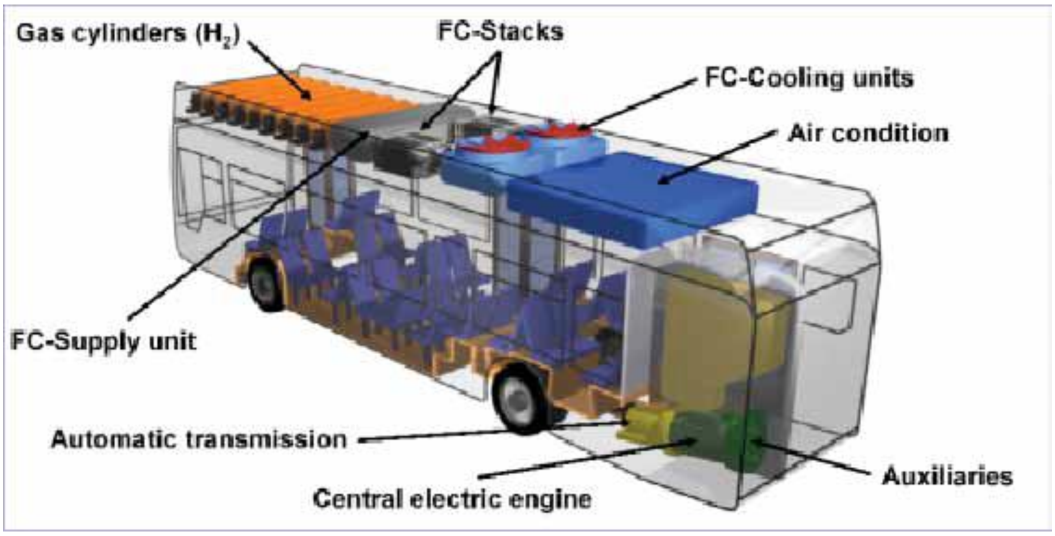


Figure 15: Bus with Fuel Cells

The results related to the pollution is obviously clear, they is no more local pollution emissions, including CO_2. More details are available in the European Commission news papers (See Annexes).

At this stage, this technique is still a prototype application; the unit cost of each bus is around 2 million EUR without the hydrogen fuel station facilities. This pathway is not considered within the scope of this study.

3.7 Comparison of the different technologies

3.7.1 Local and global emissions

From [7]STARBUS and other experiments, the following table (Table 3) presents the actual average measured pollutant emissions for several categories of buses. The emissions are given in grams per kilometer. These data stem from various networks and different manufacturers. Measurements were carried out in real conditions within the EU-funded STARBUS and COST 356 projects.

[7] See the annex for the details of this European project

Table 3: Average Emissions of Different Tests in Europe (grams/Km)*

	Euro0 Diesel	Euro1 Diesel	Euro2 Diesel	Euro3 Diesel	Euro3 LPG	Euro3 CNG	Euro4 Diesel	Euro4 LPG	Euro4 CNG	Euro5 Diesel	Euro5 LPG	Euro5 CNG
CO	5	4	3	1	5	3	0,3	3	3	0,2	2	2
HC	2	1	1	1	0,1	0,1	0,1	0,1	0,1	0	0	0
NO x	35	30	25	20	13	8	10	5	5	3	10	10
PARTICLES	1	0,5	0,3	0,1	0	0	0,1	0	0	0,02	0	0
CO^2	1600	1550	1550	1550	1900	1750	1500	2100	1550	1350	2000	1500

* 'Average' emissions for different tests in Europe from various manufacturers and different types of routes

The CO_2 is measured for 'well to wheel'; CO_2 emissions are worse for EURO5 buses than for EURO4 buses in some cases, due to fuel consumption increase from EURO4 to EURO5.

Obviously, the best results, in terms of emissions, can only be achieved if low sulfur diesel is available.

3.7.2 ENERGY EFFICIENCY

In terms of energy, Table 4 provides the energy consumption levels (in Kilos of fuel). In order to have a comparable calorific power, it is easy to change into liter or Nm^3 or other unit to be more comprehensive. The other reason is the public price of different fuels. For example in France, diesel and LPG are sold per liter, CNG is sold per Nm^3.

Table 4: Average Consumption of Different Tests in Europe*

	Euro0 Diesel	Euro1 Diesel	Euro2 Diesel	Euro3 Diesel	Euro3 LPG	Euro3 CNG	Euro4 Diesel	Euro4 LPG	Euro4 CNG	Euro5 Diesel	Euro5 LPG	Euro5 CNG
FUEL consumption in gram per km	500	485	485	485	640	620	470	709	550	425	675	530
FUEL consumption in km per gram	2.00	2.06	2.06	2.06	1.56	1.61	2.13	1.41	1.82	2.35	1.48	1.89

*'Average' consumption for different tests in Europe from various manufacturers and types of routes

These data show the average bus fuel consumption on various networks for different manufacturers. These data were measured in real conditions within the framework of the STARBUS and COST 356 projects

3.7.3 MAINTENANCE COSTS

In order to make the comparison easy, the maintenance costs of the various pathways are given on the basis of a maintenance cost index of 100 for the EURO 0 buses. The information is shown in Table 5.

In this comparison, we focus only on the propulsion system, which differs from a pathway to another. The maintenance cost of the other bus parts, such as body parts, seats, etc., are rather the same from one pathway to another.

Table 5: Maintenance Cost for Different Bus Norms (on a Scale of 100 for Euro 0)

	Euro0 Diesel	Euro1 Diesel	Euro2 Diesel	Euro3 Diesel	Euro3 LPG	Euro3 CNG	Euro4 Diesel	Euro4 LPG	Euro4 CNG	Euro5 Diesel	Euro5 LPG	Euro5 CNG
Maintenance Cost indicator	100	100	100	110	120	120	130	140	140	140	140	140

The average cost in 2009 is estimated between 0.1 and 0.25 EUR per km for the fleet of EURO0 diesel type (including labor, for Western European countries). The maintenance cost spectrum is quite wide, as it depends on the age of the fleet, the labor costs, the operation efficiency.

The maintenance cost is higher for the LPG and CNG buses compared to the diesel buses. Two reasons are often quoted: (i) the price of the spare parts is more expensive for CNG and LPG buses compared to diesel and (ii) the need to change spark plugs and to calibrate more often the ignition system. Besides, new generation buses (EURO5, be they diesel, CNG or LPG) require more advanced skills and equipment to fine-tune and maintain the engines.

3.7.4 CAPITAL COSTS

The following table (Table 6) shows the relative capital costs for different bus standards, which are also based on indexes (values relative to EURO 0 diesel bus).

Table 6: Capital Cost for Different Bus Norms

	Euro0 Diesel	Euro1 Diesel	Euro2 Diesel	Euro3 Diesel	Euro3 LPG	Euro3 CNG	Euro4 Diesel	Euro4 LPG	Euro4 CNG	Euro5 Diesel	Euro5 LPG	Euro5 CNG
Investment of the bus	100	100	100	110	130	130	120	140	140	125	140	140

In France, today, the average cost of a standard 12-meter EURO4 bus is 200k EUR for the diesel whereas the CNG counterpart is around 250k EUR.

In addition to the rolling stock costs, the global evaluation must comprise the workshop facilities and the fuel station extra-costs.

- For a LPG station, the investment starts from 100k EUR to 250k EUR, depending of the location and the engineering to be done. The capacity is on the basis of 40 buses supply.
- For the CNG, the investment for a “slow refueling” station is around 250k EUR for 20- bus capacity. For example, the Toulouse network invested 2 million EUR for a 100-bus capacity for a ‘slow refueling' station. The average cost for a quick refueling system for a capacity of 40 buses is around 1 million EUR.

3.7.5 Operating costs

Operating costs include: the bus depreciation, the fuel cost and the maintenance cost.

Operating costs vary much among networks. Nevertheless, it can be generally stated that depreciation is lower for diesel buses compared to LPG or CNG buses, because of lower investment cost for assets that have similar life-times. Depreciation is much alike for CNG and LPG buses.

The fuel cost depends mainly on the strategy of the operators (fuel station management) and from the level competition among possible suppliers. It has been observed that, for the same supplier and a similar volume of fuel, the final price could be quite different (10 to 20% difference). The operator negotiation capabilities are success key in that regard.

In France, it has been assessed that the operating costs range between 2.8 EUR and 5.0 EUR per bus-kilometer (source GART, 2007/8).

3.7.6 Synthesis

The table 7 below provides a qualitative comparison of the different pathways.

Table 7 : advantages and drawbacks of each bus type.

Fuel Type		Local pollution				Global pollution	Economical aspects		Energy alternative	Technology maturity
		CO	HC	NOx	Part	CO_2 and CH4	Capital Costs	Maintenance Costs		
Diesel	Euro0									
Diesel	Euro1									
Diesel	Euro2									
Diesel	Euro3									
Diesel	Euro3 biodiesel									
Diesel	Euro4									
Diesel	Euro4 biodiesel									
LPG	Euro3									
LPG	Euro4									
CNG	Euro3									
CNG	Euro3 biogas									
CNG	Euro4									
CNG	Euro4 biogas									
Hybrid	Euro4									
Fuel Cell										

WORST
LOWER
NEUTRAL
BETTER
BEST

For the short and medium terms, this table shows that EURO 4 diesel buses show better local pollution results while investment and maintenance costs are moderate. This technology is available and mature. On the other hand, CNG / LPG technologies will have even lesser local emission records (and global emissions, with biofuel) but at higher capital and maintenance costs.

EURO1/2 as well as Hydrid/fuel cells are out of scope, the former because of higher pollution and the latter because of much higher costs.

4 West Bank Public Transport and Energy Context

4.1 Public transport situation

4.1.1 The bus fleet

The World Bank has already conducted various surveys that focused on the transport sector in the West Bank. The *Public transport* technical assistance (TA) to the PNA MoT (2008) assessed the current conditions of the bus industry in the West Bank and proposed a framework for the development of the public transport sector. This TA includes an assessment of the current bus fleet operated in the West Bank and some insights about the operators' financial conditions. The following tables (Tables 8 through 10) and details stem from this TA.

Table 8: Number of registered operators, routes and buses in West Bank

	Total Registered	Operating	Not operating
Registered Operators	86	76	10
Registered Routes	154	128	26
Registered Buses	723	594	129
- Large buses (>25 seats)	*355*	*284*	*71*
- Small buses (up to 25 seats)	*368*	*310*	*58*

Source: PNA Ministry of Transport (2008)

Besides, the bus fleet is rather old (see Figure 16 next page, Source: *Technical Assistance Passenger Transport Sector*. Final Report. Nov. 2008 – The World Bank), on average older than 16 years. About 30% of vehicles are older than 16 years of age and 80% are 12 years or older.

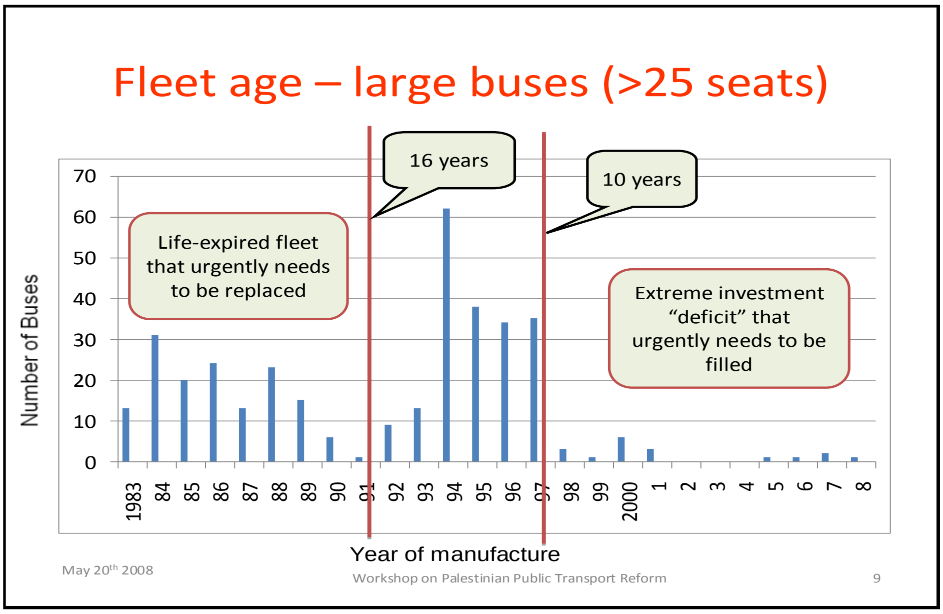


Figure 16: Age of the Bus Fleet in the West Bank

Urban operators typically replace their main fleet at 10-12 years and inter-urban operators on the main routes replace their vehicles even earlier. Even though there is residual life remaining in the vehicle, the costs of maintenance tend to increase sharply after that age. The operators can also benefit from newer technologies, better fuel efficiency, better reliability, and maintenance cost savings during the initial warranty period, and a superior quality product for their customers.

4.1.2 PUBLIC TRANSPORT INDUSTRY ORGANIZATION AND PRODUCTIVITY

Table 9 below - Source: Ministry of Transport (2008) - shows that there are currently only 6 companies operating 20 or more buses, and that the 16 companies with 10 buses or more account for 55% of the market.

Table 9: Scale of Bus Operators in West Bank

Number of Buses	Number of Operators of this size	Total Buses on Registered Routes	Cumulative total
40-49	1	42 (7%)	42 (7%)
30-39	1	37 (6%)	37 (13%)
20-29	4	107 (18%)	144 (31%)
15-19	5	82 (14%)	251 (45%)
10-14	5	56 (10%)	324 (55%)
Total 10 buses or more	**16**	**324**	**55%**
5-9	30	169 (28%)	493 (83%)
1-4	30	103 (17%)	594 (100%)
0	10	0 (0%)	594 (100%)
Grand Total	**86**	**594 (100%)**	**594 (100%)**

Specific data about Nablus and Hebron provides some insight regarding the bus operation productivity (Table 10 below).

Table 10: Productivity measures of bus operators in Nablus and Hebron

	Nablus Buses	Hebron Buses
Vehicles in daily service	60%	60%
Trips/vehicle/day	4.2	3.2
Kms/vehicle/day	61	91
Passengers/vehicle/day	113	120
Revenue/vehicle/day (NIS)	380	407
Operating speed	25	30

Source *Passenger Transport Sector Final Report* - Nov. 2008. The World Bank

NOTES:

1) Includes all services operating within, and to/from, Nablus and Hebron
2) Only routes/buses actually in operation included
3) Passengers and revenue estimated for shared taxis; includes only authorized shared-taxi services
It can be observed that:

- Bus Utilization (3-4 trips/day) and output (<100 km/day) are low by any standards;
- Passengers per vehicle (~120/day) and revenue per vehicle (NIS 280-400 (<$100)/day) are low by any standards;
- Only 60% of the registered fleet is in service (example of Nablus and Hebron);
- Buses are being withheld from service even on active routes, due to the reduced business.

Regarding operating costs, the Table 11 below provides a view of the bus operating cost structure in the West Bank, based on cases observed in Hebron and Nablus areas. The repartition does not include depreciation: all buses are completely depreciated due to their age.

Table 11: Summary of Cost Structure of Bus Operations

Expense Item	Proportion of Total Expenses
Fuel	40 – 48%
Maintenance and Parts	19 – 24%
Salaries	13 – 15%
Insurance and Fees	1.0%
Other Expenses	~ 15%

Source: West bank Bus Assessment Study“. World Bank, 2008.

Regarding bus maintenance, most large operators have their own maintenance facilities. The internal maintenance facilities are recommended for a minimum of around 50 buses, except if there are no subcontractors close to the operator.

In comparison with usual standards, the maintenance frequency is very high; usually, maintenance frequency is calibrated so that each bus is checked every 3000 kilometers, or more. This ageing bus fleet explains heavier maintenance requirements.

4.2 Energy availability and supply

All types of fuels (diesel, gasoline, LPG) are imported and are obtained through Israel. LPG and other types of fuels are transported to the Palestinian areas/central stations from Israel through semi trailer tanks; there is no pipes system. This is generally coordinated with the Palestinian Petroleum General Authority.

Road transport accounts for more than half of the overall energy consumed in the Palestinian Territories. The fuel consumption in the Palestinian Territories used for the transport sector (Gasoline and Diesel) is presented in Table 12 below.

Table 12: Average Annual Fuel Consumption (1000 litres) in the Palestinian Territories

Year	Gasoline	Diesel
2007	123662	131717
2006	116430	137193
2005	99113	172742
2004	97097	163121
2003	175387	30338
2002	147240	30111
2001	118906	40157

Source: Palestinian Central Bureau of Statistics, 2005-2009

Over the past several years, no supply shortage of diesel and gasoline had been recorded except in 2006 when the Israeli authority restricted the supply of fuel to the Palestinians as a response to the formation of a Palestinian government lead by Hamas group. As for LPG, there are times when the supply is limited during winter time when demand for gas increases for heating and other regular household usage.

4.2.1 Diesel and gasoline

Vehicle fuels that are in use in the West Bank and Gaza are Diesel and Gasoline. All public transport vehicles (buses and taxis) and freight vehicles are using (regular) Diesel fuel because it is cheaper than Gasoline (current price is 4.7 NIS/l diesel compared to 5.3 NIS/l of Gasoline). Limited number of private vehicles uses Diesel; most operate on Gasoline.

The summary of average fuel consumption for bus companies and cost of diesel is presented in Table 13.

Table 13: Yearly Average Fuel (Diesel) Consumption for Bus Companies

	Year			
	2005	2006	2007	2008
Fuel Consumption (1000 litre)	987	845	780	822
Average Price of Diesel (NIS/litre)	2.931	3.98	4.249	5.11

Source: Tamimi and Tanib Bus Companies, 2008

1 US Dollar = 4.0 NIS (on average)

4.2.2 COMPRESSED NATURAL GAS

Natural Gas is available at Gaza off-shore; however, the current agreement does not make it available to the direct Palestinian use. The British Gas (BG) Company explores the gas of Gaza and exports it to Egypt. Egypt exports gas to Israel. The PNA gets a financial share out of this agreement.

Currently, the use of CNG is restricted on the Palestinians by the agreements between Israel and the Palestinians; for the time being and due to the regulatory framework, the use of CNG for public transport is prohibited in the West Bank. However, this may change in the future. Therefore, the Ministry of Transport (MOT) indicated that this option should be considered for future scenarios.

4.2.3 LIQUEFIED PETROLEUM GAS

There are currently no regulations or standards governing the use of LPG for vehicles in the West Bank; its use is not licensed yet. Concerns over safety issues (danger of explosion of gas tanks) have impeded so far LPG to be licensed as a fuel for motor vehicles. Nonetheless, no LPG vehicle explosion has been recorded yet in the Palestinian territories.

Despite this lack of regulation, several thousand private cars in Nablus and Hebron are currently operating on LPG; nonetheless, LPG is not used for buses. Old (1980s) and new car models (2000s) have been converted from Gasoline to a dual fuel system of LPG and Gasoline. Such conversion is currently done by experienced private mechanics, though neither official nor licensed. Converted vehicles are operating well and no significant problems are reported. Conversion is limited to gasoline-fuelled vehicles.

Based on interviews with vehicle owners and LPG suppliers and mechanics, the use of LPG saves fuel cost by a range of 50-70% compared to the cost of Gasoline. Savings depend on the user driving style (harsh/smooth) and kinds of trips (urban / intercity).

There are currently several refueling LPG stations in each major city for regular house use. These stations do have the potential to provide LPG for vehicles in the future. For instance, there are 3 stations in Hebron City and its vicinity that distribute LPG to unlicensed vehicles operating on LPG.

There are times of shortage in the availability of LPG especially in winter time when there is high demand for heating. However, some local users indicated that since the vehicles can operate on dual system (gas and gasoline); the issue is not so important.

Based on field visits and observation for LPG stations in Hebron, there are no problems to fuel LPG as current gas stations provide this service with no technical difficulties. The refueling process for vehicles is simple; refueling time is slightly longer for LPG than for diesel (5-10 minutes in total for LPG while it is less than 5 minutes for Gasoline fuel).

Interviews with auto workshop owners that currently convert vehicles to LPG show that the total cost of retrofitting a car to LPG in the West Bank ranges from 3000 to 6000 NIS (US$750 – 1500), depending on the quality and source of equipment used. The most expensive type is the one with a "multi-point" system, which is the most advanced technology. In addition, the total cost of a LPG pump station is approximately $15,000.

The currently used equipments are imported from China, Turkey, Italy, etc. The equipment to be used in cars shall pass through the Israeli custom and subject to Israeli import regulations. Israel does not allow the import of any less than Euro3. Some of the equipment used in Hebron is Euro5, and they are imported from Italy (MG Company) with 3 years warrantee.

Converting Diesel engines to LPG

It is much more difficult (in terms of technical issues and needed expertise) and expensive (in terms of equipment) to convert diesel-fuelled vehicles to LPG. In fact the all engine must be removed, and therefore only very few bus manufacturers develop this type of engine. No diesel-fuelled vehicles, in particular no buses, have been converted to LPG in the Palestinian area or in Israel.

4.3 REGIONAL EXPERIENCES WITH ALTERNATIVE FUELS

4.3.1 ISRAEL

Public and private road motor vehicles in Israel regularly operate on Gasoline and Diesel, although the use of LPG is licensed.

Israel does not allow importing Euro3 engines and below. From October 2006 on, all trucks, including public transport vehicles, must be EURO 4 compliant. Current Israeli buses in operation use EURO4 type engines; they currently operate on Diesel with low sulfur. Right now, all new Israeli buses must comply with EURO5 standards and in any case before 2010 from January 2004 on, the sulfur content of diesel has been reduced from 350 ppm to 50 ppm. Information from the Israeli ministry of Environment website states that, by the beginning of 2009, the sulfur content of gasoline and diesel should go down to 10 ppm.

There are currently about 10,000 private cars operating on LPG in Israel but no public taxis. LPG is not used either for public transport. There are a few refueling stations for LPG. Israel is considering increasing taxes on vehicles operating on LPG even if, for the time being, LPG is less taxed than regular vehicle fuels (Diesel and Gasoline). Based on previous experiences, there might be times where supply of LPG is in shortage.

Major oppositions to LPG stem from safety issues. One of the current regulations concerning LPG-operated vehicles is that these vehicles should not park in closed parking; only in open lots.

Based on interviews with Israeli experts, CNG is not used in Israel. There seems to no decision regarding this. There is also a very limited experience in electric and hybrid vehicles. The use of Bio-Diesel is still debated.

On the whole, alternative fuel use is limited and there are little specific and written information about maintenance or refueling issues.

4.3.2 Jordan

Based on available information, there is no regular program of using alternative fuels on vehicles in Jordan. There are initiatives underway by private investors to introduce LPG for vehicles use.

4.3.3 Egypt

Vehicles in Egypt typically operate on Gasoline and Diesel. The largest area of growth in green vehicle technology in Egypt has been in the use of compressed natural gas (CNG) as an alternative fuel. CNG is about a third of the price of regular gas (gasoline).

The CNG technology has surged in popularity, particularly with taxi drivers, after 2008's fuel subsidy cut, which caused fuel prices to soar as much as 57 percent for the highest grade of gasoline and 35 percent for lower grades. Cairo hosts the first CNG service station in Africa and the Arab world. There, car owners can have their vehicles converted to run on natural gas for about LE 400 (US$100).

Over 100,000 vehicles in Cairo run on this technology currently, with government-owned natural gas company Egas pushing to have 300,000 by 2012. There are plans for an increase in the number of NGV fuelling stations to 390 locations around the country.

While about 70 percent of the vehicles run on natural gas are taxis, about 17 percent are privately owned vehicles. Motorcycles are also being targeted for conversion to this technology. The Egyptian Environmental Affairs Agency has partnered with Industry Canada in a $1.4 million program to convert Cairo's estimated 300,000 motorcycles to natural gas technology. There are also plans to encourage the conversion of diesel vehicles, particularly mini-buses, to CNG in the near future. The next generation of trucks, to be launched in 2010 and 2011, are going to be CNG compliant.

The Egyptian law specifies that vehicles should be Euro1 compliant, but most of cars there are expected to be Euro 2 compliant.

The EEAA/USAID-sponsored the Cairo Air Improvement Program (CAIP), which focused on improving Cairo's air quality through reducing harmful emissions from lead smelters and vehicle exhausts. Part of the programme included providing 50 dedicated CNG public-transit buses to the Cairo Transit Authority (CTA) and Greater Cairo Bus Company (GCBC). The bus bodies are locally manufactured, but the CNG engines are manufactured by Cummins in the United States and the rolling chassis were supplied by a US manufacturer. Key challenges for the government have been to fund the conversion of the some 3,500 public buses operating in Cairo and change the price differential between CNG and diesel, which is heavily subsidized (source: http://www.idrc.ca/en/ev-132146-201-1-DO_TOPIC.html).

5 Alternative Pathways Comparison

5.1 Methodology

This part compares, within the West Bank context, the various bus pathways for public transport. The following alternatives are appraised:

- Scenario 0: existing fleet Euro0 (baseline scenario);
- Scenario 1: Euro3 buses diesel-powered;
- Scenario 2: Euro3 buses LPG-powered;
- Scenario 3: Euro3 buses CNG-powered;
- Scenario 4: Euro4 buses diesel-powered;
- Scenario 5: Euro4 buses LPG-powered;
- Scenario 6: Euro4 buses CNG-powered.

Other pathways (hybrid, LNG, fuel cell…) are not considered because they are not developed enough for the time being. EURO5 buses are not included either within the scope of the analysis because of the extra costs of those buses.

5.1.1 Method

The method implemented to compare the various pathways is a Cost Benefit Analysis. The appraisal takes into account:

- Direct costs (bus investment, fuel cost, maintenance cost, over-cost of specific equipments) and their escalation over time.
- External costs monetarizing local pollution (particles, NOx, CO, HC), and global pollution (CO_2, CH_4).

The unit price per ton / kilogram of each pollutant should be adjusted to the local conditions. In a first step, the calculation is based on the European standards, which, in fact, promotes the alternative fuels compared to diesel. For each of the scenario mentioned above, the 3 types of parameters defining each scenario are:

- Capital cost per new bus;
- Maintenance cost per km;
- Special costs (specific facilities for LPG...).

Many other parameters are included in the model, even if they do not appear explicitly. For instance, the model includes the emissions escalation as Euro engine types decrease, (old engines are more sensitive due to the maintenance levels) and as the total bus mileage increases (fuel consumption is a positive function of the mileage). All that kind of curves are included in the model; the data was derived from many on-site assessments across Europe, carried out through the [8]COST committee. The software STARBUS (see 4.1.3 below) is used to carry out the comparison.

All the direct and external costs are calculated for an appraisal period of 12 years, which is assumed to be the life-time of a new bus. Costs are discounted over the 12-year period, with the discount rate proposed below.

In addition to the costs mentioned above, a few qualitative parameters are also taken into account for a more comprehensive comparison; these are:

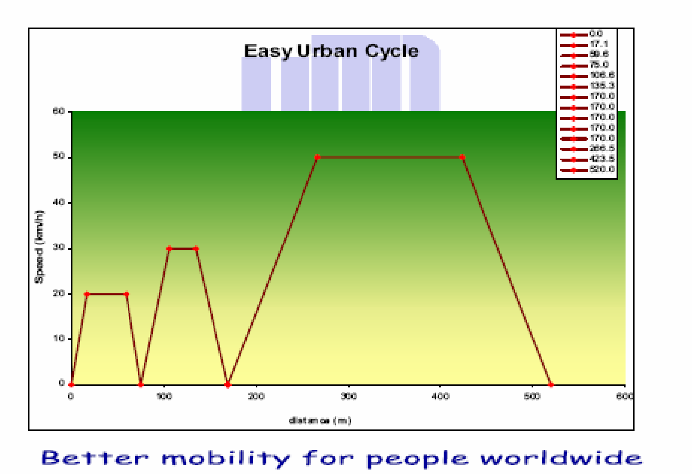
- Safety;
- Fuel availability;
- Energy independence.

For these three factors, only a qualitative assessment is provided, comparing the scenario to the diesel pathway.

5.1.2 Duty cycles used for the simulations

The computerization is based on urban duty cycles, which comes from the average fuel consumption and emission per Euro type of bus identified for every type of fuel (EURO5 and EURO6 types) and the technology options.

SORT cycle scheme (source UITP)



These data derive from **actual** duty cycles from urban bus networks; the data collected represent more than 120 types of duty cycles, and more than 40 models of buses, including diesel, CNG and LPG buses. The data was gathered through the COST committee and the major improvement, in order to have a better overview of the in situ conditions than the others evaluations even used in Europe or USA from rolling benches.

The simulation could be more accurate and better fit to the actual local conditions, if the operators are able to provide all relevant data regarding (i) actual duty cycles, (ii) fuel consumption, and (iii) emitted pollutants.

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[8] COST European Cooperation in Science and Technology

These cycles are in fact quite closer to suburban routes like in the West Bank. Moreover, very often the cycles predict a stable acceleration and deceleration which is easier than the real route concerning the emissions and the consumption.

One example is given with the SORT 'easy urban cycle' which is a part of the sort cycle test defined for the European networks.

5.1.3 Quick presentation of STARBUS

STARBUS is an EU-supported research program that started in 2006 and was completed in December 2008. The main outputs of this program are:

- A measurement and recording tool this can be used in the bus (on board) to measure a series of key operating factors, among which: speed, engine velocity, fuel consumption, pollutants emission, etc. The real conditions of operation are assessed, not bench measurements. With this tool, many data have been gathered in various networks in Europe, featuring many kinds of buses, routes, and duty cycles.
- Software to estimate all the physical quantities linked to the bus operation and monetarize all the related costs for a given route. Therefore, STARBUS can be used to assess, with simulation, (i) fleet renewal / replacement or (ii) fleet extension. This assessment can be carried out with real data measured on-site with the 'portable device', or through the 'average' conditions included in the software database. The database contains all the average emissions and consumption per type of bus (fuel _ euro type) including the versus of each type of Euro standard like of there is Diesel Particles Trap, Water Emulsion fuel, De NO x systems.

In any case all the specific characteristics such as the fuel cost and maintenance costs are provided by the operator.

Any person can use the STARBUS software.

- The input data are in fact all the parameters normally known such as the description of the fleet – number of buses per type of Euro standard, mileage-, the assumptions of the simulation, such as the number of new buses per year and the type of Euro, if there are retrofitting like Diesel Particles Traps, all the specific costs related to the maintenance and the fuel management, at last the unit price of the buses, and the financial parameters (inflation rate, loan rate, fuel price, evolution of the fuel price../..)
- The outputs of the simulations are in fact the technical data like emissions and consumption per pathway, costs of each emission and consumption parameter per pathway described, and at last the table which summarizes all these cost for the period of calculation.

pathway N°2	YEAR 0	YEAR 1	YEAR 5	YEAR 6	YEAR 15
Bus depreciation	1150815	1122508	1024835	1017374	842066
Bus Maintenance	25080	25021	22858	20385	22237
Workshop investment	3885	3772	3351	3254	0
Workshop maintenance	3000	2971	2857	2829	2592
Fuel station investment	8178	7940	7054	6849	0
Fuel station maintenance	7000	6932	6667	6602	6047
Fuel consumption cost	537342	543350	465137	338985	438710
TOTAL DIRECT COST	1735300	1712494	1532759	1396278	1311652
DIRECT COST PER KM	1,3838	1,3656	1,2223	1,135	1,046
Local pollution	238999	232476	172692	106050	136233
Retrofitting investment	0	6055	5380	0	0
Retrofitting maintenance cost	0	27	28	29	31
CO^2 cost	89037	89639	76598	55700	71911
Fuel incentives	-76500	-78750	-76577	0	0
total pollution cost	251536	249447	178121	161779	208175
pollution cost PER KM	0,201	0,199	0,142	0,129	0,166
GENERAL COST	1986836	1961941	1710880	1558057	1519827
GENERAL COST PER KM	1,584	1,565	1,364	1,264	1,212

Figure 17: Example of an output table from a STARBUS simulation

Finally, this kind of graph shows a synthetic image of each pathway.

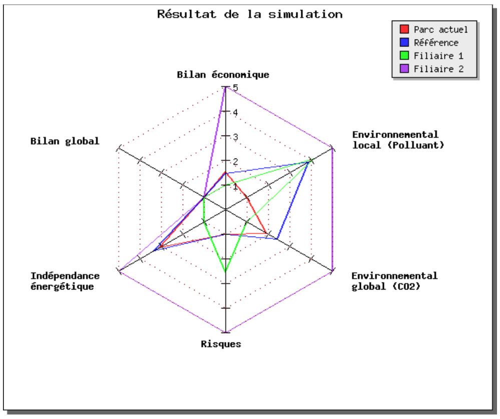


Figure 18: synthetic situation of pathways

In conclusion, STARBUS software is free of use and allows anyone to simulate any kind of situations from its network, to input different assumptions and to have the output results in order to choose or to study which pathway should be the best for the renewal of the fleet.

5.2 SCENARIOS DESCRIPTION

5.2.1 COMMON ECONOMIC AND TECHNICAL ASSUMPTIONS

For the simulation of conditions in the West Bank, some parameters are retained, which can be removed through the program translated in Excel file provided in the included CD-Rom.

Exchange rate of the NIS: (from the European Bank currency conversion rate as of May, 1 2009)

1 euro = 5.40 NIS

1 usd = 4.15 NIS

External costs:

CO	16.2	NIS per ton
HC	7560	NIS per ton
NO x	41580	NIS per ton
Particles	682020	NIS per ton
CO_2	216	NIS per ton

These unit costs are derived from the EU *Handbook on estimation of external costs in the transport sector* (2008). These could be considered higher than acceptable in the West Bank. Nevertheless, choosing high unit costs to monetarize transportation negative externalities will favor alternative fuels, compared to diesel.

Financial aspects:

Actualization rate: 12%. This is the standard actualization rate recommended by the World Bank for West Bank and Gaza.

Inflation rate: 4% per year (average in West Bank); all along the 12 years appraisal period, this rate is maintained. This rate is representative of the last past years.

Fuel prices: The price of the diesel is based on 4.25 NIS per liter and 3.75 NIS per liter for the LPG (including the last information updated April 2009). Without any price of the Natural Gas which is not available in West Bank, the assumption is a price of 3.40 NIS per Nm3 of CNG. This assumption stems from the comparison of the prices between LPG and CNG in Europe. Of course as soon as the CNG should be introduced, the simulations will be done with the prices in WBG.

Evolution of fuel prices: 5% per year for all fuels. We consider the energy cost will increase more than the inflation rate; this assumption is in fact reasonable compared to the forecasts of the energy prices estimated by some international organizations.

Maintenance cost: For the existing fleet, the average of 0.80 NIS per kilometer is retained, the focus will be on the main fleet with the larger number of buses in operation. For the new buses, ¼ of this cost for the new buses either Euro3 or Euro4 will be retained.

Evolution of maintenance costs: 5% per year, mainly taking into account labor costs and spare parts. The labor costs are more valuated than the inflation rate; this is the main reason of this rate. Moreover the spare parts after some years are more expensive; the manufacturers support the cost of the stock.

Evolution of external costs (global and local pollution): 5% per year. Many experts predict these parameters will in fact increase more than the inflation rate, due to the increasing concern about environmental issues.

Appraisal time: Twelve years is considered to be a reasonable life-time for a bus; beyond this threshold, maintenance costs increase dramatically.

Loan rate: 10%. The assumption is that a loan is taken to finance the new buses; in a first approach, it is considered that the loan maturity is 10 years and covers 100% of the initial investment.

Average kilometer per bus per year: 50000 kilometers.

Number of buses: The appraisal is carried out on a fleet of 40 buses. Forty buses is the possible number of buses allocated to a depot within the concession area framework described in the *Public transport development* TA. It is needed to have a minimum fleet to split the extra-costs generated by the implementation of a new pathway (specific costs related to the maintenance and fuel station facilities for diesel, LPG and CNG). The buses taken into account for the simulation are typical 12-meter urban / suburban buses. This assumption should obviously be refined so as to the supply fits the demand as much as possible; typically, minibuses should be used on routes where the demand is not strong enough and/or where minibuses would provide a better or more cost-effective service.

5.2.2 Reference scenario: Existing fleet Euro 0

This scenario is today's situation. There is no investment and no depreciation as the buses are worn out. The maintenance cost is derived from the previously mentioned Public transport technical assistance from the World Bank: it is estimated to be 0.80 NIS per kilometre. This high cost is directly linked to the old age of the fleet. The escalation of this cost is estimated to be 8% per year, knowing in the next future these buses will need heavier repairs to be kept in good conditions or at least able to operate.

From the simulation we retain lower fuel consumption than 'Starbus' software which is urban traffic oriented. All the emissions are also considered to be a proportional linear function of the fuel consumption. Fuel consumption is estimated at 50 litres per 100 kilometres, to take into account that the routes are suburban, and therefore the consumption is not so heavy than for inner urban routes.

For the duration of 12 years, the table summarises the main data, as well for the physical emissions and consumption, as for the value of each item.

Finally, it should be borne in mind that this reference scenario is somewhat hypothetical since the existing rolling stock is really old and little likely to endure 12 additional years of duty.

Reference scenario: Existing fleet 12 years duration calculation

	physical value in tons	Monetization in NIS	NIS per kilometer	% Direct cost	% Pollution	% total cost
Global pollution	36 912	5 685 642	0,237		13%	6%
Local Pollution		37 337 579	1,556			38%
NO x	663	19 752 904	0,823		46%	20%
Particles	36	17 256 484	0,719		40%	18%
HC	61	325 532	0,014		1%	0%
CO	236	2 658			0%	0%
Direct Cost		54 386 770	2,266			56%
Fuel Consumption	10 619	38 543 320	1,606	71%		40%
Maintenance		15 843 451	0,660	29%		16%
Depreciation				0%		
Spec maintenance		0		0%		0%
Spec fuel station		0		0%		0%
Total Cost		97 409 992	4,059			100%

The pollution of the existing fleet, based on the European external costs represents 44% of the total cost of the public transport. The main pollution costs are NO x (20%) and particles (18%) which are local emissions.

For the operators the fuel is the first component of the cost. Of course, there is no item related to the depreciation of the investments due to the old age of the buses and workshop depot facilities.

We note that the operative cost is a little less than 2.30 NIS per kilometer.

5.2.3 SCENARIO 1: EURO3 DIESEL

The maintenance cost retained for EURO3 buses is 0.20 NIS per kilometer, with a yearly cost escalation of 5%. This is a cheaper maintenance cost than the EURO 0 or 'before0' cost; the reason is that the current EURO 0 or 'before0' are really worn out and require extra maintenance. The unit price for a new EURO3 bus given is assumed to be 1 million NIS.

On the 12 years appraisal time, the table below summarizes the main output data, as well the physical emissions and consumption, as for their monetarized values.

Scenario 1: EURO3 Diesel 12 years duration calculation

	physical value in tons	Monetization in NIS	NIS per kilometer	% Direct cost	% Pollution	% total cost
Global pollution	31 727	4 882 162	0,203		28%	5%
Local Pollution		12 275 828	0,511			13%
NO x	349	10 415 518	0,434		61%	11%
Particles	4	1 758 609	0,073		10%	2%
HC	19	101 484	0,004		1%	0%
CO	19	217	0,000		0%	0%
Direct Cost		77 832 915	3,243			82%
Fuel Consumption	9 138	33 135 770	1,381	43%		35%
Maintenance		3 449 910	0,144	4%		4%
Depreciation		41 195 740	1,716	53%		43%
Spec maintenance		51 495	0,002	0%		0%
Spec fuel station		0	0,000	0%		0%
Total Cost		94 990 905	3,958			100%

The pollution of the Diesel Euro3 fleet represents 18% of the total cost of the public transport. The main pollution costs are NO x (11%) and the CO2 (5%).

For the operators, depreciation is the first component of the cost (43%). The second item is the fuel cost (36%). In total, 78% of the direct cost is composed with depreciation and fuel costs. From the operator's point of view, the direct cost will increase of 0.977 NIS per bus-kilometer, in comparison with the Scenario 0.

5.2.4 Scenario 2: EURO3 LPG

In comparison with the Euro3 Diesel scenario, the unit price of the new bus is estimated at 1.15 million NIS; the maintenance cost per kilometer is 0.25 NIS. The maintenance cost escalation retained is 6% per year to take into account the specific equipment to be checked, in particular the tanks.

On the 12 years appraisal time, the table below summarizes the main output data, as well the physical emissions and consumption, as for their monetarized values.

Scenario 2: EURO3 LPG 12 years duration calculation

	physical value in tons	Monetization in NIS	NIS per kilometer	% Direct cost	% Pollution	% total cost
Global pollution	40 623	6 251 081	0,260		42%	5%
Local Pollution		8 729 744	0,364			7%
NO x	300	8 713 148	0,363		58%	7%
Particles	0	0	0,000		0%	0%
HC	3	15 000	0,001		0%	0%
CO	144	1 597	0,000		0%	0%
Direct Cost		110 549 346	4,606			88%
Fuel Consumption	12 059	58 573 487	2,441	53%		47%
Maintenance		4 312 387	0,180	4%		3%
Depreciation		47 375 102	1,974	43%		38%
Spec maintenance		164 783	0,007	0%		0%
Spec fuel station		123 587	0,005	0%		0%
Total Cost		125 530 170	5,230			100%

The pollution is less than 12%; 5% for the global pollution and 7% for the NOx. The others pollutants are negligible. Depreciation is the first direct cost, then the fuel cost. These parameters will be the most representative of the bus-kilometer cost.

Comparison LPG Euro3 versus Diesel Euro3.

	physical value in tons	Monetization in NIS	NIS per kilometer	% total cost
Global pollution	8 896	1 368 918	0,057	28,0%
Local Pollution		-3 546 083	-0,148	-28,9%
NO x	-48	-1 702 370	-0,071	-16,3%
Particles	-4	-1 758 609	-0,073	-100,0%
HC	-16	-86 484	-0,004	-85,2%
CO	125	1 379	0,000	634,2%
Direct Cost		32 716 431	1,363	42,0%
Fuel Consumption	2 920	25 437 717	1,060	76,8%
Maintenance		862 477	0,036	25,0%
Depreciation		6 179 361	0,257	15,0%
Spec maintenance		113 288	0,005	220,0%
Spec fuel station		123 587	0,005	
Total Cost		30 539 266	1,272	32,1%

The LPG Euro3 pathway is significantly more expensive than the Diesel Euro3 pathway:

- +32.1% for the total costs
- + 42.0% for the direct costs.

LPG best advantage is the reduction of the local pollutants.

5.2.5 SCENARIO 3: EURO3 CNG

In comparison with the Euro3 Diesel, the unit price of the new bus is estimated at 1.2 million NIS, the maintenance cost per kilometer is 0.25 NIS. The maintenance cost escalation is 6% per year to take into account the specific equipment to be checked, in particular the tanks which have to be checked every 6 years (European rule).

On the 12 years appraisal time, the following table summarizes the main output data, as well the physical emissions and consumption, as for their monetarized values.

Scenario 3: EURO3 CNG 12 years duration calculation

	physical value in tons	Monetization in NIS	NIS per kilometer	% Direct cost	% Pollution	% total cost
Global pollution	39 422	6 066 215	0,253		53%	6%
Local Pollution		5 377 564	0,224			5%
NO x	185	5 361 606	0,223		47%	5%
Particles	0	0	0,000		0%	0%
HC	3	15 000	0,001		0%	0%
CO	86	958	0,000		0%	0%
Direct Cost		91 689 899	3,820			89%
Fuel Consumption	11 682	36 747 947	1,531	40%		36%
Maintenance		4 312 387	0,180	5%		4%
Depreciation		49 434 889	2,060	54%		48%
Spec maintenance		164 783	0,007	0%		0%
Spec fuel station		1 029 894	0,043	1%		1%
Total Cost		103 133 678	4,297			100%

In this scenario, pollution represents 11% (6% for the global pollution and 5% for the NOx); the others pollutants are negligible. As in the EURO3 CNG scenario, depreciation is the first expense, then the fuel cost. These parameters will be the most representative of the bus-kilometer cost.

It is important to bear in mind that this simulation results are really dependent from the CNG price assumption, since CNG is not on sale today in WBG. Further analysis will be required as soon as this fuel becomes available in WBG or Israel, as a benchmark. In particular, should the natural gas come from the Gaza offshore fields, the CNG unit liter price could be significantly lower.

Comparison CNG Euro3 versus Diesel Euro3.

	physical value in tons	Monetization in NIS	Delta NIS per kilometer	% total cost
Global pollution	3 847	592 026	0,049	24,3%
Local Pollution		-3 449 132	-0,287	-56,2%
NO x	-82	-2 526 956	-0,211	-48,5%
Particles	-2	-879 304	-0,073	-100,0%
HC	-8	-43 242	-0,004	-85,2%
CO	34	370	0,000	340,5%
Direct Cost		11 719 887	0,977	19,7%
Fuel Consumption	1 272	1 806 089	0,151	10,9%
Maintenance		531 468	0,044	30,8%
Depreciation		8 239 148	0,687	20,0%
Spec maintenance		113 288	0,009	220,0%
Spec fuel station		1 029 894	0,086	
Total Cost		8 862 781	0,739	13,0%

	physical value in tons	Monetization in NIS	NIS per kilometer	% total cost
Global pollution	7 695	1 184 052	0,049	24,3%
Local Pollution		-6 898 264	-0,287	-56,2%
NO x	-164	-5 053 912	-0,211	-48,5%
Particles	-4	-1 758 609	-0,073	-100,0%
HC	-16	-86 484	-0,004	-85,2%
CO	67	741	0,000	340,5%
Direct Cost		13 856 985	0,577	17,8%
Fuel Consumption	2 544	3 612 177	0,151	10,9%
Maintenance		862 477	0,036	25,0%
Depreciation		8 239 148	0,343	20,0%
Spec maintenance		113 288	0,005	220,0%
Spec fuel station		1 029 894	0,043	
Total Cost		8 142 774	0,339	8,6%

The CNG Euro3 pathway is more expensive than the Diesel Euro3:

- +8.6% for the total cost.
- +17.8% for the direct costs.

However, this scenario is cheaper than the LPG EURO3 scenario. Similarly to the LPG EURO3 scenario, this scenario's main advantage is the drastic reduction of local pollutants.

5.2.6 SCENARIO 4: EURO4 VERSUS EURO5 DIESEL

The bus unit price is estimated to be 1.05 million NIS; the maintenance cost per bus-kilometer is 0.20 NIS with a yearly cost escalation of 5%.

On the 12 years appraisal time, the table below summarizes the main output data, as well the physical emissions and consumption, as for their monetarized values.

Scenario 4: EURO4 Diesel 12 years duration calculation

	physical value in tons	Monetization in NIS	NIS per kilometer	% Direct cost	% Pollution	% total cost
Global pollution	30 702	4 724 389	0,197		42%	5%
Local Pollution		6 509 744	0,271			7%
NO x	188	5 581 572	0,233		50%	6%
Particles	2	917 236	0,038		8%	1%
HC	2	10 866	0,000		0%	0%
CO	6	70	0,000		0%	0%
Direct Cost		78 799 549	3,283			88%
Fuel Consumption	8 837	32 042 617	1,335	41%		36%
Maintenance		3 449 910	0,144	4%		4%
Depreciation		43 255 528	1,802	55%		48%
Spec maintenance		51 495	0,002	0%		0%
Spec fuel station		0	0,000	0%		0%
Total Cost		90 033 682	3,751			100%

Pollution now represents only 12% of the total costs. Main pollution costs are NO x (6%) and CO2 (5%).

For the operators, bus depreciation is the first component of the cost (48% of the total cost). The second item is the fuel cost (36%). From the operator's point of view, the direct cost will increase by 1.52 NIS per bus-kilometer, in comparison with the Scenario 0.

From January 2004 on, the sulfur content of diesel has been reduced from 350 ppm to 50 ppm. Information from the Israeli Ministry of Environment website states that, by the beginning of 2009, the sulfur content of gasoline and diesel should go down to 10 ppm.

For Euro5 the main differences are an initial investment which is more expensive (4%), fuel consumption less than Euro4 (7%), and emissions slightly less (10% less for CO_2, 33% less for CO, no more HC and particles, 20% less for NO x).

Scenario 4bis : EURO5 Diesel 12 years duration calculation

	physical value in tons	Monetization in NIS	NIS per kilometer	% Direct cost	% Pollution	% total cost
Global pollution	27 632	4 251 950	0,177		49%	5%
Local Pollution		4 465 304	0,186			5%
NO x	151	4 465 258	0,186		51%	5%
Particles	0	0	0,000		0%	0%
HC	0	0	0,000		0%	0%
CO	4	46	0,000		0%	0%
Direct Cost		77 318 676	3,222			90%
Fuel Consumption	7 951	28 831 523	1,201	37%		34%
Maintenance		3 449 910	0,144	4%		4%
Depreciation		44 985 749	1,874	58%		52%
Spec maintenance		51 495	0,002	0%		0%
Spec fuel station		0	0,000	0%		0%
Total Cost		86 035 930	3,585			100%

The comparison is obviously in favor of the EURO5 type.

	physical value in tons	Monetization in NIS	NIS per kilometer	% Direct cost	% Pollution	% total cost
Global pollution	-3 070	-472 439	-0,020		19%	12%
Local Pollution		-2 044 440	-0,085			51%
NO x	-38	-1 116 314	-0,047		44%	28%
Particles	-2	-917 236	-0,038		36%	23%
HC	-2	-10 866	0,000		0%	0%
CO	-2	-23	0,000		0%	0%
Direct Cost		-1 480 873	-0,062			37%
Fuel Consumption	-886	-3 211 094	-0,134	217%		80%
Maintenance	0	0	0,000	0%		0%
Depreciation	0	1 730 221	0,072	-117%		-43%
Spec maintenance	0	0	0,000	0%		0%
Spec fuel station	0	0	0,000	0%		0%
Total Cost		-3 997 751	-0,167			100%

The main difference for the operators is in fact the initial investment of the buses. This overcost is very profitable on the basis of 50000 kilometer per year.

The difference of the fuel consumption cost itself is more than the yearly depreciation including the financial cost of the investment.

On an economic and financial point of view Euro5 is better than Euro4 type.

5.2.7 Scenario 5: EURO4 versus EURO5 LPG

The bus unit price is estimated at 1.15 million NIS; the maintenance cost per kilometer is 0.25 NIS. The maintenance cost escalation is 6% per year to take into account the specific equipment to be checked, in particular the tanks.

On the 12 years appraisal time, the table below summarizes the main output data, as well the physical emissions and consumption, as for their monetarized values.

Scenario 5: EURO4 LPG 12 years duration calculation

	physical value in tons	Monetization in NIS	NIS per kilometer	% Direct cost	% Pollution	% total cost
Global pollution	44 912	6 910 982	0,288		67%	5%
Local Pollution		3 367 499	0,140			3%
NO x	115	3 351 541	0,140		33%	3%
Particles	0	0	0,000		0%	0%
HC	3	15 000	0,001		0%	0%
CO	86	958	0,000		0%	0%
Direct Cost		116 864 315	4,869			92%
Fuel Consumption	13 359	64 888 456	2,704	56%		51%
Maintenance		4 312 387	0,180	4%		3%
Depreciation		47 375 102	1,974	41%		37%
Spec maintenance		164 783	0,007	0%		0%
Spec fuel station		123 587	0,005	0%		0%
Total Cost		127 142 796	5,298			100%

Scenario 5bis: EURO5 LPG 12 years duration calculation

	physical value in tons	Monetization in NIS	NIS per kilometer	% Direct cost	% Pollution	% total cost
Global pollution	42 773	6 581 887	0,274		77%	5%
Local Pollution		2 011 564	0,084			2%
NO x	69	2 010 925	0,084		23%	2%
Particles	0	0	0,000		0%	0%
HC	0	0	0,000		0%	0%
CO	58	639	0,000		0%	0%
Direct Cost		113 752 598	4,740			93%
Fuel Consumption	12 718	61 776 739	2,574	54%		50%
Maintenance		4 312 387	0,180	4%		4%
Depreciation		47 375 102	1,974	42%		39%
Spec maintenance		164 783	0,007	0%		0%
Spec fuel station		123 587	0,005	0%		0%
Total Cost		122 346 049	5,098			100%

The comparison is in favor of Euro5 LPG type.

Differences between Euro4 and Euro5 LPG

	5.3 Physical value in tons	5.4 Monetization in NIS	5.5 NIS per kilometer	5.6 % Direct cost	5.7 % Pollution	5.8 % total cost
5.9 Global pollution	5.10 -2 139	-329 094	-0,014		20%	7%
Local Pollution		-1 355 936	-0,056			28%
NO x	-46	-1 340 617	-0,056		80%	28%
Particles	0	0	0,000		0%	0%
HC	-3	-15 000	-0,001		1%	0%
CO	-29	-319	0,000		0%	0%
Direct Cost		-3 111 717	-0,130			65%
Fuel Consumption	-641	-3 111 717	-0,130	100%		65%
Maintenance	0	0	0,000	0%		0%
Depreciation	0	0	0,000	0%		0%
Spec maintenance	0	0	0,000	0%		0%
Spec fuel station	0	0	0,000	0%		0%
Total Cost		-4 796 748	-0,200			100%

We consider the price of Euro5 LPG type is the same compared to the Euro4 LPG type. The manufacturers able to supply this type know the improvement of the Diesel Euro5 and therefore do not increase the LPG Euro5 compared to Euro4 type.

On an economic and financial point of view Euro5 is better than Euro4 type.

Comparison of LPG Euro4 versus Diesel Euro4.

	physical value in tons	Monetization in NIS	NIS per kilometer	% total cost
Global pollution	14 210	2 186 593	0,091	46,3%
Local Pollution		-3 142 244	-0,131	-48,3%
NO x	-73	-2 230 031	-0,093	-40,0%
Particles	-2	-917 236	-0,038	-100,0%
HC	1	4 134	0,000	38,0%
CO	80	888	0,000	1274,2%
Direct Cost		38 064 766	1,586	48,3%
Fuel Consumption	4 522	32 845 839	1,369	102,5%
Maintenance		862 477	0,036	25,0%
Depreciation		4 119 574	0,172	9,5%
Spec maintenance		113 288	0,005	220,0%
Spec fuel station		123 587	0,005	
Total Cost		37 109 115	1,546	41,2%

Comparison of LPG Euro5 versus Diesel Euro5.

	physical value in tons	Monetization in NIS	NIS per kilometer	% total cost
Global pollution	15 141	2 329 937	0,097	54,8%
Local Pollution	0	-2 453 741	-0,102	-55,0%
NO x	-81	-2 454 333	-0,102	-55,0%
Particles	0	0	0,000	0,0%
HC	0	0	0,000	0,0%
CO	53	592	0,000	1274,2%
Direct Cost		36 433 922	1,518	47,1%
Fuel Consumption	4 767	32 945 216	1,373	114,3%
Maintenance	0	862 477	0,036	25,0%
Depreciation	0	2 389 353	0,100	5,3%
Spec maintenance	0	113 288	0,005	220,0%
Spec fuel station	0	123 587	0,005	0,0%
Total Cost		36 310 118	1,513	42,2%

5.10.1 Scenario 6: EURO4 versus EURO5 CNG

The bus unit price is estimated to be 1.2 million NIS; the maintenance cost per kilometer is 0.25 NIS. The maintenance cost escalation is 6% per year to take into account the specific equipment to be checked, in particular the tanks.

On the 12 years appraisal time, the table below summarizes the main output data, as well the physical emissions and consumption, as for their monetarized values.

Scenario 6: EURO4 CNG 12 years duration calculation

	physical value in tons	Monetization in NIS	NIS per kilometer	% Direct cost	% Pollution	% total cost
Global pollution	34 925	5 374 307	0,224		61%	6%
Local Pollution		3 367 499	0,140			3%
NO x	115	3 351 541	0,140		38%	3%
Particles	0	0	0,000		0%	0%
HC	3	15 000	0,001		0%	0%
CO	86	958	0,000		0%	0%
Direct Cost		87 540 917	3,648			91%
Fuel Consumption	10 363	32 598 965	1,358	37%		34%
Maintenance		4 312 387	0,180	5%		4%
Depreciation		49 434 889	2,060	56%		51%
Spec maintenance		164 783	0,007	0%		0%
Spec fuel station		1 029 894	0,043	1%		1%
Total Cost		96 282 723	4,012			100%

Scenario 6bis: EURO4 CNG 12 years duration calculation

	physical value in tons	Monetization in NIS	NIS per kilometer	% Direct cost	% Pollution	% total cost
Global pollution	33 799	5 200 942	0,217		72%	6%
Local Pollution		2 011 564	0,084			2%
NO x	69	2 010 925	0,084		28%	2%
Particles	0	0	0,000		0%	0%
HC	0	0	0,000		0%	0%
CO	58	639	0,000		0%	0%
Direct Cost		86 355 500	3,598			92%
Fuel Consumption	9 986	31 413 548	1,309	36%		34%
Maintenance		4 312 387	0,180	5%		5%
Depreciation		49 434 889	2,060	57%		53%
Spec maintenance		164 783	0,007	0%		0%
Spec fuel station		1 029 894	0,043	1%		1%
Total Cost		93 568 006	3,899			100%

Difference between Euro4 and Euro5 CNG

	physical value in tons	Monetization in NIS	NIS per kilometer	% Direct cost	% Pollution	% total cost
Global pollution	-1 127	-173 365	-0,007		11%	6%
Local Pollution		-1 355 936	-0,056			50%
NO x	-46	-1 340 617	-0,056		88%	49%
Particles	0	0	0,000		0%	0%
HC	-3	-15 000	-0,001		1%	1%
CO	-29	-319	0,000		0%	0%
Direct Cost		-1 185 417	-0,049			44%
Fuel Consumption	-377	-1 185 417	-0,049	100%		44%
Maintenance	0	0	0,000	0%		0%
Depreciation	0	0	0,000	0%		0%
Spec maintenance	0	0	0,000	0%		0%
Spec fuel station	0	0	0,000	0%		0%
Total Cost		-2 714 718	-0,113			100%

The comparison shows the advantages of the Euro5 type compared to the Euro4 type.

We consider the price of Euro5 CNG type is the same compared to the Euro4 CNG type. The manufacturers able to supply this type know the improvement of the Diesel Euro5 and therefore do not increase the CNG Euro5 compared to Euro4 type.

On an economic and financial point of view Euro5 is better than Euro4 type.

Comparison between CNG Euro4 and Diesel Euro4.

	physical value in tons	Monetization in NIS	NIS per kilometer	% total cost
Global pollution	4 224	649 918	0,027	13,8%
Local Pollution		-3 142 244	-0,131	-48,3%
NO x	-73	-2 230 031	-0,093	-40,0%
Particles	-2	-917 236	-0,038	-100,0%
HC	1	4 134	0,000	38,0%
CO	80	888	0,000	1274,2%
Direct Cost		8 741 368	0,364	11,1%
Fuel Consumption	1 526	556 348	0,023	1,7%
Maintenance		862 477	0,036	25,0%
Depreciation		6 179 361	0,257	14,3%
Spec maintenance		113 288	0,005	220,0%
Spec fuel station		1 029 894	0,043	
Total Cost		6 249 042	0,260	6,9%

Comparison between CNG Euro5 and Diesel Euro5

	physical value in tons	Monetization in NIS	NIS per kilometer	% total cost
Global pollution	6 167	948 992	0,040	14,4%
Local Pollution	0	-2 453 741	-0,102	-122,0%
NO x	-81	-2 454 333	-0,102	-122,0%
Particles	0	0	0,000	0,0%
HC	0	0	0,000	0,0%
CO	53	592	0,000	92,7%
Direct Cost		9 036 824	0,377	7,9%
Fuel Consumption	2 035	2 582 025	0,108	4,2%
Maintenance	0	862 477	0,036	20,0%
Depreciation	0	4 449 140	0,185	9,4%
Spec maintenance	0	113 288	0,005	68,8%
Spec fuel station	0	1 029 894	0,043	0,0%
Total Cost		7 532 075	0,314	6,2%

5.10.2 Scenarios recap

Direct operating and investment costs

The table below compares the direct operating and investment (through depreciation) costs of the various pathways.

Recap of direct operating and depreciation costs

NIS	EURO3 Diesel	EURO3 LPG	EURO3 CNG	EURO4 Diesel	EURO4 LPG	EURO4 CNG
fuel cost	33 135 770	58 573 487	36 747 947	32 042 617	64 888 456	32 598 965
Bus depreciation and loan cost	41 195 740	47 375 102	49 434 889	43 255 528	47 375 102	49 434 889
Maintenance cost	3 449 910	4 312 387	4 312 387	3 449 910	4 312 387	4 312 387
total direct cost	77 781 420	110 260 975	90 495 223	78 748 054	116 575 945	86 346 241

Either in the EURO3 or in EURO4 category, the diesel pathway is the most cost-effective one. Diesel life cycle cost is approximately 14% cheaper than the second best (CNG) in the EURO3 category and 9% cheaper than the second best (CNG again) for EURO4. LPG is always the most expensive option.

Comparing EURO3 to EURO4, the EURO3 option is slightly cheaper; still, the order of magnitude of the difference (1%) is so little that it can be considered at this strategic assessment level, that EURO3 and EURO4 diesel have similar life cycle costs.

Obviously, these results are directly linked to a few key assumptions that were made, e.g.: unit cost of buses, fuel liter costs and maintenance costs. A sensitivity analysis is presented below.

NIS	EURO4 Diesel	EURO4 LPG	EURO4 CNG	EURO5 Diesel	EURO5 LPG	EURO5 CNG
fuel cost	32 042 617	64 888 456	32 598 965	28 831 523	61 776 739	31 413 548
Bus depreciation and loan cost	43 255 528	47 375 102	49 434 889	44 985 749	47 375 102	49 434 889
Maintenance cost	3 449 910	4 312 387	4 312 387	3 449 910	4 312 387	4 312 387
total direct cost	78 748 054	116 575 945	86 346 241	77 267 182	113 464 228	85 160 824

The option of Euro5 types shows (for 50000 kilometer per year) that it is more interesting for all any pathway chosen. The difference is approximately 1 million of NIS for Diesel and CNG, and 3 millions NIS for LPG pathway.

Pollution costs

The table below compares the physical emissions of the various pathways.

Physical emissions of the pathways

	EURO3 Diesel	EURO3 LPG	EURO3 CNG	EURO4 Diesel	EURO4 LPG	EURO4 CNG
Emissions in ton						
CO²	31 728	40 624	39 422	30 702	44 912	34 926
CO	18	144	86	6	86	86
HC	18	2	2	2	2	2
NO x	348	300	184	188	116	116
Particles	4	0	0	2	0	0
fuel consumption in ton	9 138	12 058	11 682	8 836	13 358	10 364

For CO, HC and particles, the 6 scenarios have really good results and there is not much difference between them.

For NOx, EURO4 is approximately twice as much better than EURO3, LPG and CNG being much better than diesel.

Regarding fuel consumption (and, therefore, CO2 emissions), diesel is always the best pathway, EURO4 being slightly better than EURO3. Fuel consumptions savings range between -15% and -34%, comparing diesel to the other pathways.

5.10.3	EURO4 Diesel	EURO4 LPG	EURO4 CNG	EURO5 Diesel	EURO5 LPG	EURO5 CNG
Emissions in ton						
CO^2	30 702	44 912	34 925	27 632	42 773	33 799
CO	6	86	86	4	58	58
HC	2	3	3	0	0	0
NO x	188	115	115	151	69	69
Particles	2	0	0	0	0	0
fuel consumption in ton	8 837	13 359	10 363	7 951	12 718	9 986

The Euro5 pathways are slightly better than Euro4, specifically for the NO x which is related to some health diseases. The particles for Diesel Euro5 are considered as none.

The table below compares the pollution costs, local and global (CO2) of the various pathways.

Recap of pollution costs

NIS	EURO3 Diesel	EURO3 LPG	EURO3 CNG	EURO4 Diesel	EURO4 LPG	EURO4 CNG
CO^2	4 882 162	6 251 080	6 066 214	4 724 388	6 910 982	5 374 306
CO	218	1596	958	70	958	958
HC	101 484	15 000	15 000	10 866	15 000	15 000
NO x	10 415 518	8 713 148	5 361 606	5 581 572	3 351 542	3 351 542
Particles	1 758 608	0	0	917 236	0	0
Total pollution indirect cost	17 157 990	14 980 824	11 443 780	11 234 132	10 278 482	8 741 806

As expected, EURO4 scenarios are, on the whole, much better than the EURO3 ones: between -24% and -35% of emission savings when each EURO3 pathway is compared to its EURO4 counterpart.

While EURO3 diesel is, by far, the worst pathway and EURO4 CNG the best, it can be stated that EURO3 CNG, EURO4 diesel and EURO4 LPG are within the same order of magnitude when it comes to pollution costs.

NIS	EURO4 Diesel	EURO4 LPG	EURO4 CNG	EURO5 Diesel	EURO5 LPG	EURO5 CNG
CO^2	4 724 389	6 910 982	5 374 307	4 251 950	6 581 887	5 200 942
CO	70	958	958	46	639	639
HC	10 866	15 000	15 000	0	0	0
NO x	5 581 572	3 351 541	3 351 541	4 465 258	2 010 925	2 010 925
Particles	917 236	0	0	0	0	0
total pollution indirect cost	11 234 133	10 278 481	8 741 806	8 717 254	8 593 451	7 212 506

The Euro5 pathways are better than Euro4 for the emissions global and local pollution. At least 20% is saved in NIS based on external costs hypothesis.

Total costs

The life cycle cost (including environmental costs) comparison of the various pathways is presented below:

Global comparison between the pathways

NIS	EURO3 Diesel	EURO3 LPG	EURO3 CNG	EURO4 Diesel	EURO4 LPG	EURO4 CNG
CO²	4 882 162	6 251 080	6 066 214	4 724 388	6 910 982	5 374 306
CO	218	1596	958	70	958	958
HC	101 484	15 000	15 000	10 866	15 000	15 000
NO x	10 415 518	8 713 148	5 361 606	5 581 572	3 351 542	3 351 542
Particles	1 758 608	0	0	917 236	0	0
Total pollution indirect cost	17 157 990	14 980 824	11 443 778	11 234 132	10 278 482	8 741 806
fuel cost	33 135 770	58 573 487	36 747 947	32 042 617	64 888 456	32 598 965
Bus depreciation and loan cost	41 195 740	47 375 102	49 434 889	43 255 528	47 375 102	49 434 889
Maintenance cost	3 449 910	4 312 387	4 312 387	3 449 910	4 312 387	4 312 387
total direct cost	77 781 420	110 260 975	90 495 223	78 748 054	116 575 945	86 346 241
maintenance depot	51 495	164 783	164 783	51 495	164 783	164 783
fuel station	0	123 587	1 029 894	0	123 587	1 029 894
total direct and specific costs	77 832 915	110 549 345	91 689 900	78 799 549	116 864 315	87 540 918
TOTAL COSTS	94 990 905	125 530 169	103 133 678	90 033 681	127 142 797	96 282 724

On the 6 scenarios presented, EURO4 diesel is the most cost-effective, with very little cost difference with EURO3 diesel. The diesel scenarios are between -7% and -29% cheaper than the other scenarios, EURO4 CNG is the third cheaper, but approximately 8% more expensive than the diesel scenarios. The LPG scenarios are much more expensive.

It is interesting to notice that the EURO4 Diesel scenario has the best result neither for the potion costs nor for the operating + depreciation costs. Nonetheless, this scenario is the best compromise.

Among EURO3 pathways, the Diesel EURO3 scenario is the most cost-effective. Even if we separate the specific costs to launch the LPG or the CNG fuels, Diesel offers the cheapest life cycle cost for the operators. The Diesel fuel pathway is the lowest direct cost and total cost. For the emissions, the diesel Euro3 type bus has the lowest global pollution emissions. However, for local pollutants, CNG is the best, thanks to the absence of particles (same situation for the LPG) and the NO x emission which is lower than all the others pathways.

Among EURO4 pathways, the global pollution is reduced for the Diesel fuel whereas both LPG and CNG are best for local pollution. Nonetheless, from the operator standpoint (direct costs), again the Diesel pathway is the cheapest one.

NIS	EURO4 Diesel	EURO4 LPG	EURO4 CNG	EURO5 Diesel	EURO5 LPG	EURO5 CNG
CO^2	4 724 389	6 910 982	5 374 307	4 251 950	6 581 887	5 200 942
CO	70	958	958	46	639	639
HC	10 866	15 000	15 000	0	0	0
NO x	5 581 572	3 351 541	3 351 541	4 465 258	2 010 925	2 010 925
Particles	917 236	0	0	0	0	0
total pollution indirect cost	11 234 133	10 278 481	8 741 806	8 717 254	8 593 451	7 212 506
fuel cost	32 042 617	64 888 456	32 598 965	28 831 523	61 776 739	31 413 548
Bus depreciation and loan cost	43 255 528	47 375 102	49 434 889	44 985 749	47 375 102	49 434 889
Maintenance cost	3 449 910	4 312 387	4 312 387	3 449 910	4 312 387	4 312 387
total direct cost	78 748 054	116 575 945	86 346 241	77 267 182	113 464 228	85 160 824
maintenance depot	51 495	164 783	164 783	51 495	164 783	164 783
fuel station	0	123 587	1 029 894	0	123 587	1 029 894
total direct and specific costs	78 799 549	116 864 315	87 540 917	77 318 676	113 752 598	86 355 500
total cost	90 033 682	127 142 796	96 282 723	86 035 930	122 346 049	93 568 006

Among EURO5 pathways, the global pollution is reduced for the Diesel fuel whereas both LPG and CNG are best for local pollution. Nonetheless, from the operator standpoint (direct costs), again the Diesel pathway is the cheapest one.

At last the Euro5 type is always the best for this simulation.

The critical point in fact concerns the initial investment, and therefore if the operators can afford to invest more, or to convince the banks for a loan which is upper than the Euro4 type buses.

5.11 RESULTS

5.11.1 COSTS

As stated previously, in terms of direct and operating expenses, Diesel pathways are always the cheapest solutions. The cost difference with the others alternatives ranges from -10% to -25%. LPG is always the most expensive solution, not to be promoted.

The best total cost balance is Diesel for the Euro3 type, Euro4 type, and Euro5 type.

The main direct cost items[9] are:

- Asset depreciation (investment and loan rate);

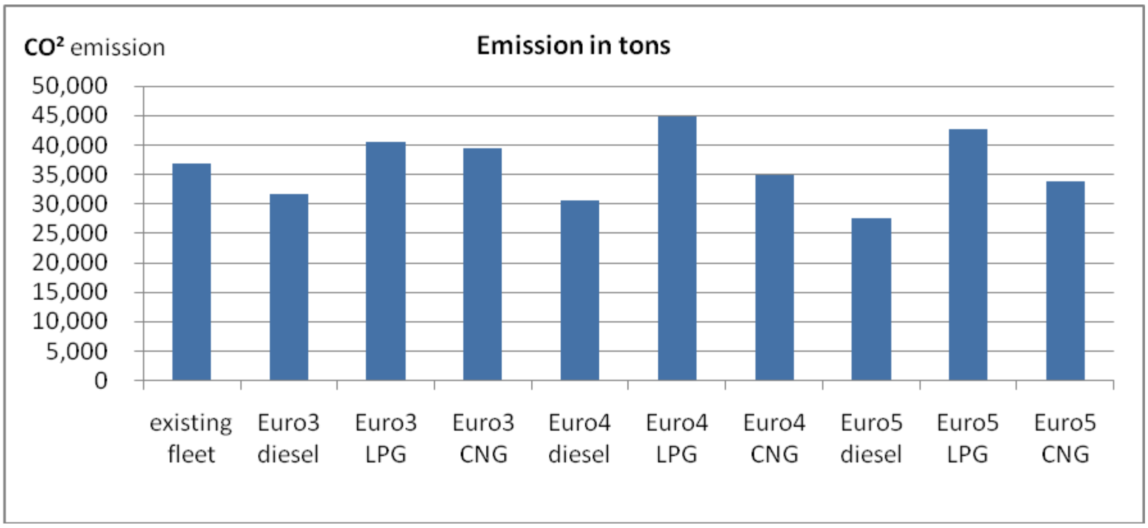
[9] Not taking into account a few operating costs, such as labour, supposed to be the same for the various pathways.

- Fuel cost.

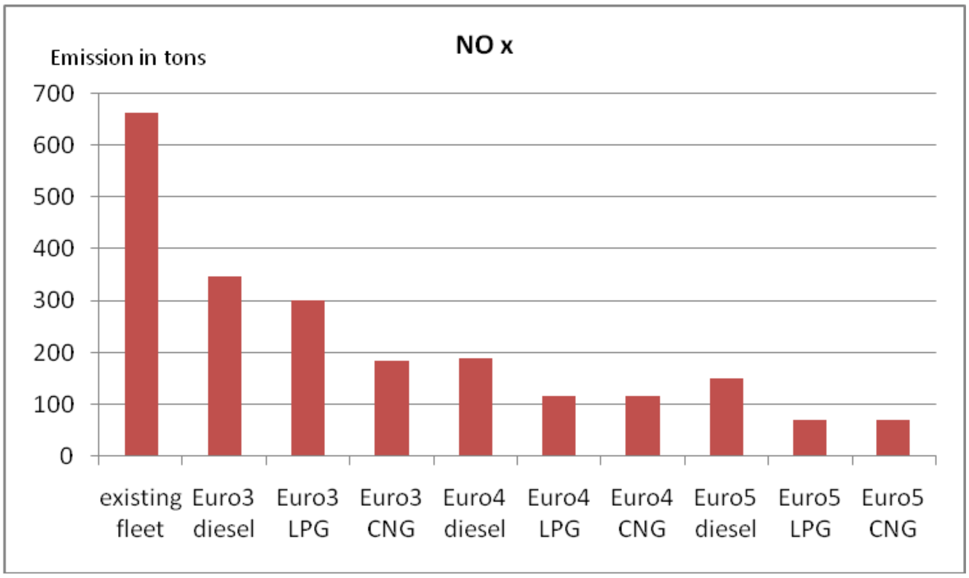
For the external costs, the main parameter is NOx for local pollution, and of course the green effect gas with the carbon dioxide. Depending of the goals of the Palestinian Authority, these 'external costs' have to be reduced to reduce the pollution.

5.11.2 Gas emissions

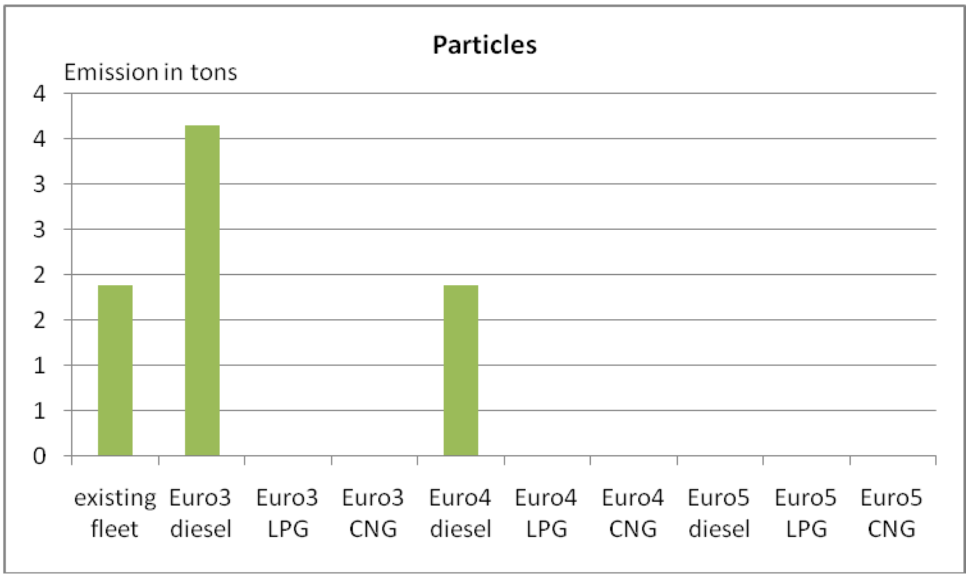
For the global pollution, the Diesel is the best solution. This is due to the efficiency of the engine, inducing lesser fuel consumption, compared to the Otto engines. CNG could be better when the natural gas comes from waste valorization. In this case, the global balance is more or less neutral, and therefore the Bio Gas is in this case the best.



NOx has to be considered seriously for the comparison and the choice of the buses. Of course the NOx emitted from the buses have to be evaluated in comparison with the other sources of pollution.



Finally, the particles emissions are drastically reduced from the existing fleet to the Euro3 choice (1/10 of emissions) and for Euro4 reaches 1/20 reduction.



5.11.3 Safety

LPG and CNG are often viewed as non secure fuels. However, these fuels are in fact very safe, and are even used for home appliances (cooking and heating), as well as in the industry.

In many countries, lots of regulations cater for LPG and CNG used. For buses, tanks must be checked in order to avoid any leakage, and safety valves have to be calibrated every three or four years. For instance, a few regulations impose that CNG tanks are checked every 8 to 10 years.

In fact the LPG / CNG alternatives really require stricter safety rules when the buses are indeed parked within the maintenance depot.

5.11.4 Fuel availability

It is really needed to check in details the supply reliability of LPG / CNG and compare it to that of diesel; the present study could not enter much into this issue. For LPG, it seems that this fuel has not been always available for cars, and the operators should negotiate with the potential suppliers that they will be supplied at any. Contrary to cars, it is very rare to have dual fuel Diesel-LPG buses. The only engine which can operate as a dual fuel is Cummins type.

For the CNG, the situation is similar to the LPG. Very few models of engine are available as Dual fuel (Diesel and Natural gas).

In fact, we consider that Diesel is the best fuel to be operated at any time. LPG and CNG fuels represent greater risks.

5.12 Sensitivity analysis

5.12.1 Method

The sensitivity analysis is carried out on the following parameters, which are the main drivers and of most importance for the operators (more than 80% of the direct costs):

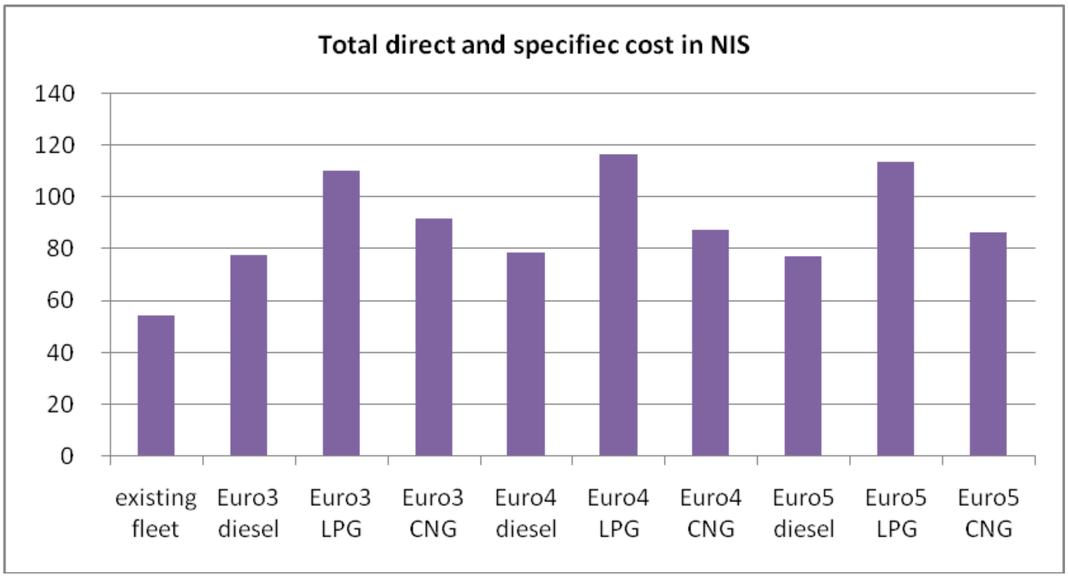
- Bus capital cost: break-even bus capital costs, for LPG and CNG, that would make these pathways as interesting as diesel;
- Diesel price escalation: break-even escalation rate that would make other pathways as cheap as the diesel pathway;
- Lower loan rate;
- Lower actualization rate.

5.12.2 RESULTS

The table below shows what the level of bus prices should be (*break-even price*) so that alternative pathways are as interesting as the Diesel EURO3 pathway. The calculation is carried out only on the direct costs (excluding pollution).

NIS	Origin Price	Break Even Price	Delta price	Delta %
Diesel Euro3	1 000 000	1 000 000	0	0,0%
Diesel Euro4	1 050 000	1 025 000	-25 000	-1,0%
LPG Euro3	1 150 000	350 000	-800 000	-69.5%
LPG Euro4	1 150 000	200 000	-950 000	-82,6%
CNG Euro3	1 200 000	860 000	-340 000	-28,3%
CNG Euro4	1 200 000	965 800	-235 000	-19,6%

The direct costs are similar for unit price of buses as follows:



In fact, this situation is very unlikely; CNG and LPG buses will always be more expensive than Diesel buses. The only solution to reach -20% to -30% discounts on CNG bus capital costs (as needed for their life cycle cost to be in line with those of diesel) is to buy second hand buses, with the assumption that these second hand buses are in very good condition. For LPG bus pathway this option is not valid at any time and any assumption.

Diesel price evolution influence

LPG and CNG prices are assumed to increase every year at a 5% rate. The table below shows what should be the diesel yearly increase rates so that alternative pathways are as cost-effective as the EURO3 diesel scenario. The calculation is carried out only on the direct costs (excluding pollution).

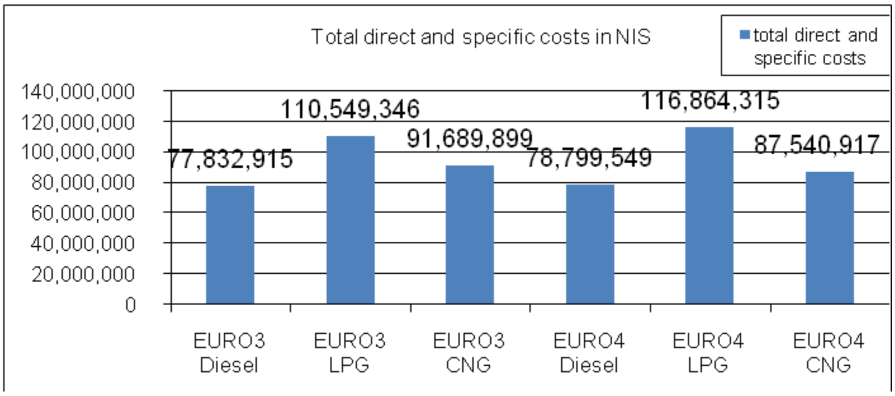
	Origin Rate	Diesel Rate for break even
Diesel Euro3	5,0%	
Diesel Euro4	5,0%	4,0%
LPG Euro3	5,0%	19,0%
LPG Euro4	5,0%	20,5%
CNG Euro3	5,0%	12,5%
CNG Euro4	5,0%	10,5%

Diesel should be increasing at least at a 10.5% yearly rate (during 12 years) so that a CNG or LPG pathway begins to be as cost-effective as the EURO3 diesel pathway. Even within a context of high oil volatility, this situation seems rather unlikely.

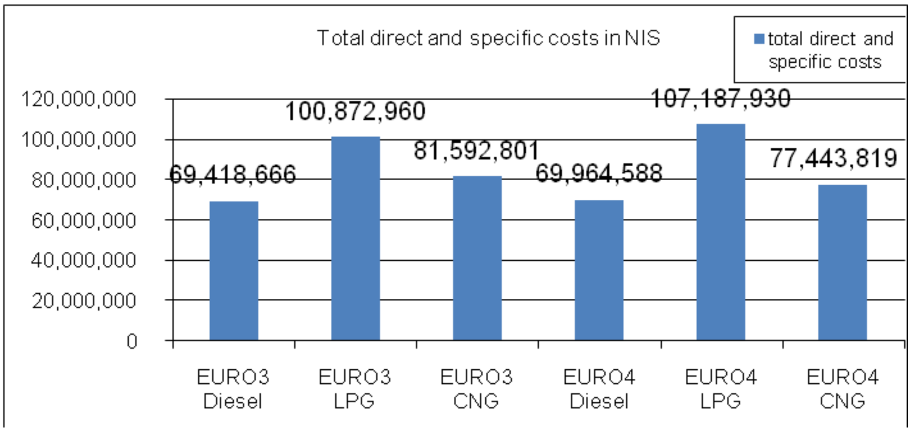
Loan rate influence

From 10% to 5% yearly rate, the ranking of the pathways is not changed. We note a decreasing of the cost of around 15% of the total direct costs (debt service).

Total direct costs Loan rate = 10% per year



Total direct costs Loan rate = 5% per year



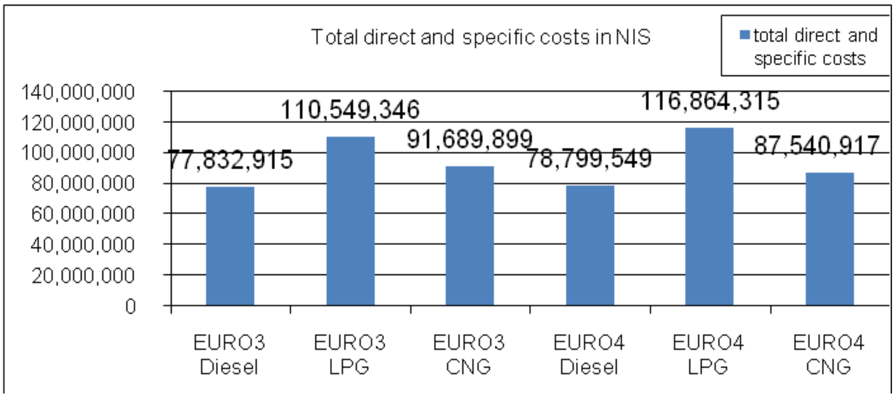
A 5% interest loan rate would be very low within the WBG situation. A higher than 10% interest rate, as in the base-case scenarios, would favour again the diesel scenarios, which entail the least capital costs.

Actualization rate influence

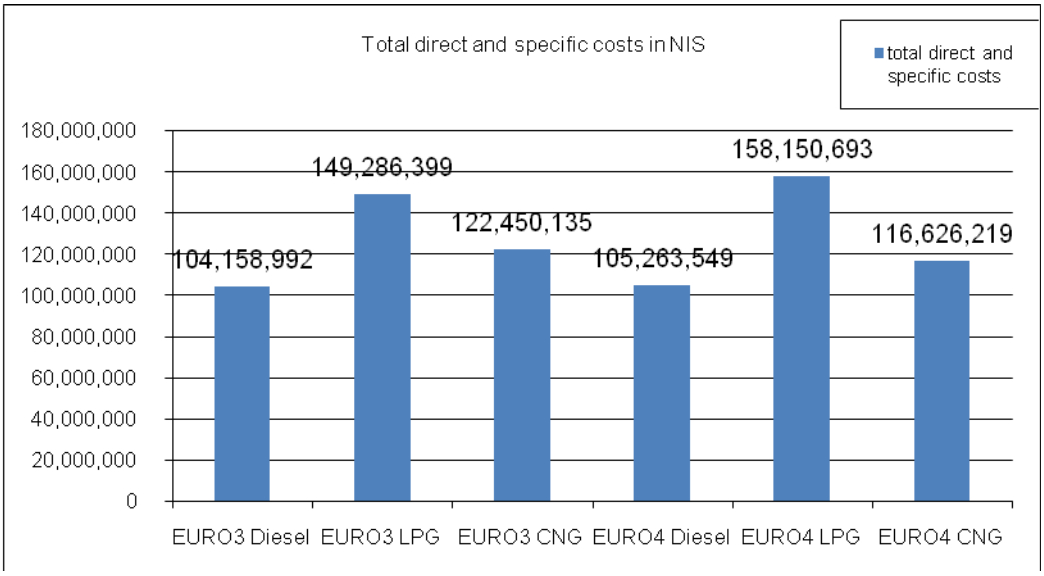
From 12% to 5% yearly rate.

In fact this parameter changes the total amount of the costs, but not the ranking; the variation is more or less the same in percentage for every pathway. The reason is the large impact of the investment.

Actualization rate 12% per year



Actualization rate 5% per year



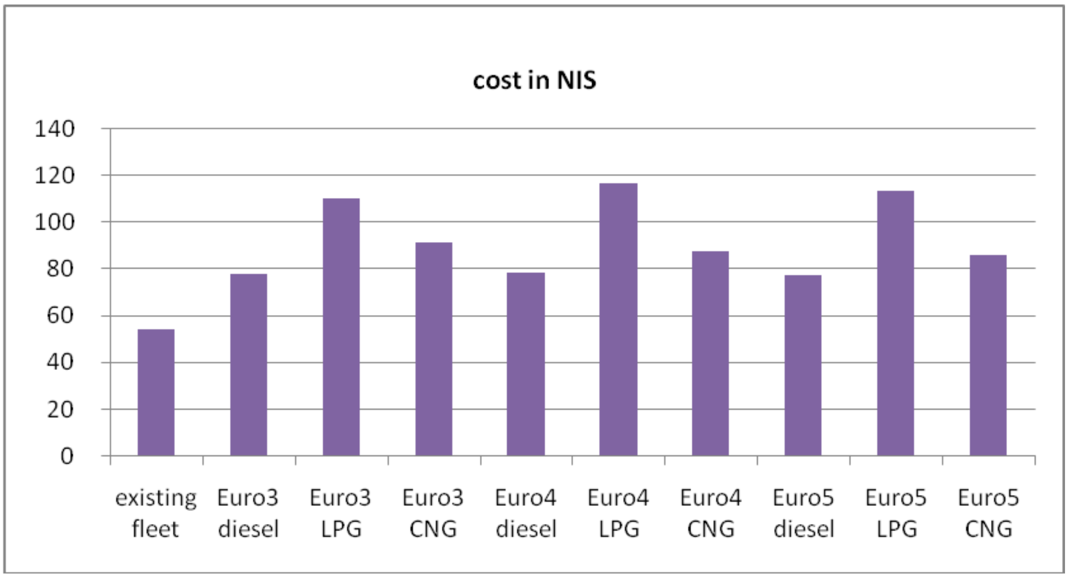
From 12% to 5% actualization rate, the difference is similar to 12 to 28 % between these two values. That shows there is not a real impact on the ranking of the different pathways and Euro type buses.

5.13 Synthesis

Investment and operating costs

The chart below compares the 6 scenarios investment and operating costs, for a fleet of 40 buses, over a 12-year period. Results are in discounted million NIS.

Direct life-cycle costs, 40 buses (million NIS)



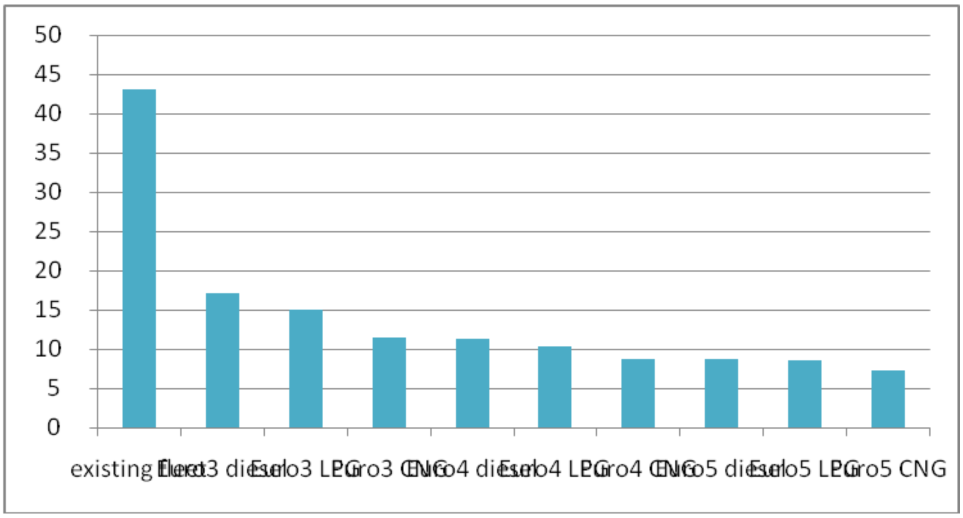
Comparing only direct costs (operating and investment costs), the diesel scenarios are between -9% and -32% cheaper than the other scenarios. EURO4 CNG is the third cheaper, but approximately 9% more expensive than the diesel scenarios. The LPG scenarios are the most expensive.

The estimated cost for the existing fleet is only based on maintenance cost, nothing for the depreciation due to the age of the fleet. Therefore the cost seems the best, which is not in fact the reality.

Pollution costs

Turning to pollution costs, the chart below compares the 6 scenarios (monetarized costs in discounted million NIS) for a fleet of 40 buses, over a 12-year period.

Monetarized pollution costs on 12 years, 40 buses (million NIS)

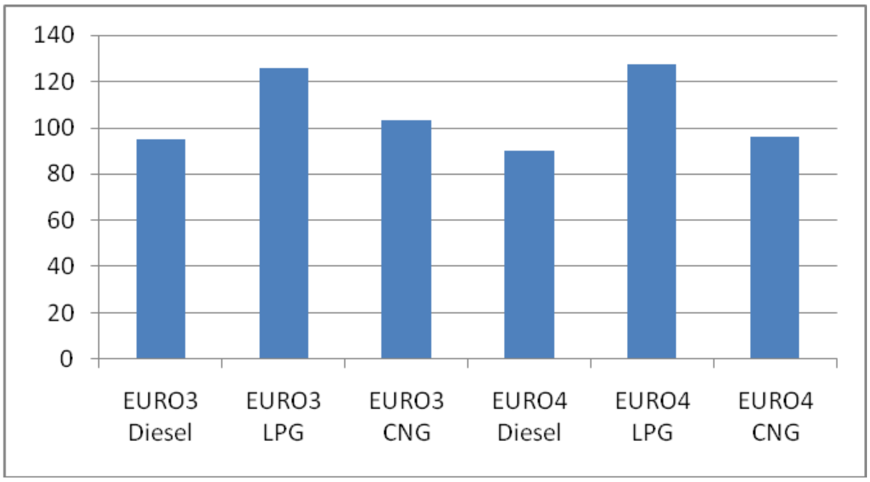


As expected, EURO 4 buses are much less polluting than EURO 3 buses, noting that EURO3 CNG is almost at the EURO4 levels. For diesel, it is interesting to note that there is a 35% pollution costs decrease between the EURO3 and EURO4 models. Euro5 are by far the best due to the more stringent regulations.

Total direct and pollution costs

The chart below compares the 6 scenarios total costs (investment, operating and pollution costs), for a fleet of 40 buses, over a 12-year period. Results are in discounted million NIS.

Total life-cycle costs, 40 buses (million NIS)



The most cost-effective pathway is Diesel, within the local conditions in West Bank. The EURO4 diesel is the most cost-effective, with very little cost difference compared to EURO3 diesel. Comparing EURO3 diesel to EURO4 diesel, the latter provides significant local emission savings, for only slighter direct costs. The diesel scenarios are between -9% and -24% cheaper than the other scenarios, direct costs (including: fuel consumption, maintenance and depreciation) and pollution costs included.

The sensitivity analysis shows the robustness of the results. Different assumptions do not change the simulation major results.

Besides, choosing the diesel pathway could also offer an opportunity to buy second hand buses, and therefore to reduce at a competitive level the direct costs for the operators. Diesel is also the more flexible and represents today the coherent choice for new buses. Finally, diesel is the pathway that requires the least maintenance reorganization in today's operators' workshops.

On this basis, EURO4 diesel buses are recommended. Within the current regulatory framework, this recommendation will still have to comply with Israeli importation regulation. Current regulation demands that imported heavy vehicles are EURO4 compliant. Should EURO5 become mandatory in the future, EURO 5 buses would be required. In that case, EURO5 fleet would entail:

- An extra investment cost per bus of approx. 3-4%;
- A fuel consumption reduction by 7%;
- Maintenance costs approximately the same**.**

The comparison shows the advantage of the Euro5 compared to Euro4, due to the mileage, and to the reduction of the fuel consumption for all pathways. The only critical point concerns the initial investment which should be the barrier for the operators. In fact they are not in a strong financial position and they should prefer the minimum of investment to renew their fleet.

6 RECOMMENDATIONS

The recommendations are the following:

Build the case for fleet renewal. New rolling stock is critical, both for service quality to customers and for the current operators to be able to continue service and business. An estimated 200-250 bus will be needed during the next 2-3 years, and as much as 400 over the next 5 years. The current study may help the stakeholders to choose from various available options.

Decide on priorities: environment vs. minimizing costs. Better environmentally-friendly buses, such as CNG buses, will come at an extra-cost. A policy decision is to be made regarding which importance to be given to environmental issues, especially against cost constraints.

Foster Diesel pathways. In light of the conclusions of the study, the diesel pathway should be promoted for public transport in WBG. Since the simulation results conclude that EURO3 and EURO4 technologies have direct costs in the same order of magnitude, EURO 4 should be encouraged. There is a large spectrum of bus manufacturers, which give the opportunity to buy EURO3 or EURO4 buses in good conditions. It is recommended to define a standard for all the operators in order to be able to procure for a large number of buses at the same time.

Fine-tune the results. The analysis that was carried aims at the strategic level and is preliminary. As much as possible, it is recommended to fine-tune the simulation inputs so as to get more accurate results. As the economic environment changes, three items should be of special focus: (i) the buses unit prices, (ii) the fuel unit prices, and (iii) the bus duty cycle curves really used in WBG conditions.

Fuel supply and availability. Alternative fuels, especially natural gas, supply and availability should be assessed in a more comprehensive way. The recent discovery of natural gas fields off-shore Gaza might change energy equilibrium and markets in the region.

Improve operators' financial situation. The operators financial capability is today limited. Introducing new buses is likely to, at the same time, decrease the huge maintenance costs that have to be incurred on their current worn-out buses but also increase dramatically their operating costs in terms on loan repayment and depreciation. This action is part of the public transport strengthening that is proposed through the large franchises scheme.

Improve maintenance process. The maintenance organization has to be updated. It is highly recommended to choose one or just a few kinds of buses ("standard bus"), for the various operators, so that the maintenance processes are streamlined and eased. The minimum agreement is common warehouses for the spare parts. It is also recommended that the operators consider subcontracting for specific operations that requires either heavy investments or high professional capacity. The subcontracting could be through (i) the bus manufacturer organization, (ii) through the specialization of the maintenance of the largest operators, or (iii) through a special company, as proposed in the passenger transport sector development study.

Set a regulatory framework for LPG vehicles. Light LPG vehicles (private cars) are already in use in the West Bank. Engine retrofitting is currently carried out in informal workshops. It is recommended that a regulatory framework is established to control this activity and ensure safety standards. The regulation should include: the retrofitting kits themselves, the garage which modifies the cars, the LPG stations requirements, and the periodical technical control of the cars and of the stations.

The kits have to be able to comply with the Euro type level needed in Israel. The LPG tanks have to be homologated related to the maximum pressure limit, and to offer the right fitting in case of car accident. The garages must be equipped with the required facilities to install the LPG kits, and the mechanics have to be certified, after proper specific training. The LPG stations must abide by all the LPG safety requirements (LPG storage, LPG distribution)

The LPG cars should be controlled every period and be checked specially the LPG tank, and the leakage diagnosis.

ANNEX 1: REFERENCES

GENERAL INFORMATION

http://ec.europa.eu/transport/sustainable/2008_external_costs_en.htm

This website presents information about direct and external cost in Europe. Besides, the European commission has a complete website including some specific topics or research and development aspects the EC promoted and financed.

http://ies.jrc.ec.europa.eu/WTW

This website focuses on well to wheel emissions for any type of vehicles.

www.civitas-initiative.org

Most comprehensive EU bus program: CIVITAS.

http://www.euractiv.com/fr/transport/acquisition-vehicules-propres-eurodeputes-soutiennent-projets-fermes-autorites-publiques/article-173633

This website is dedicated to promote clean and efficient vehicles.

BUS MANUFACTURERS

Almost all of them have a website where all the pathways they produce are described. This is a non exhaustive list of major European bus manufacturers:

- IRISBUS irisbus.com
- MAN man-mn.com
- MERCEDES evobus.com
- VOLVO Volvo.com/bus
- SCANIA scania.com/bus
- SOLARIS solarisbus.pl

ASSOCIATIONS OR SPECIFIC ORGANIZATIONS

For some techniques or topics, different associations or organizations exist, which promote or/and describe the available products.

http://www.dieselnet.com/standards/eu/hd.php

This site gathers the different regulations and emissions of the diesel engines.

www.diester.org

This website focuses on bio-diesel.

www.dieselretrofit.eu/

This website is useful regarding particulate emissions reduction on existing fleets.

www.ngvglobal.com

This website focuses on natural gas (CNG, LNG).

www.biogasmax.com

This website gathers information about a few cities in Europe which use biogas.

www.althytude.info

This site is dedicated to the HYTHANE fuel (a mixture of gas and hydrogen).

www.cleanairnet.org ; www.lpg-vehicles.co.uk

This sites focus on fuel LPG-run buses.

www.fuel-cell-bus-club.com ; www.fuelcells.org

This sites focus on fuel cell technologies.

www.ethanolbus.com

This site focuses on Ethanol-run buses.

OTHERS USEFUL WEBSITES

www.transbus.org

This is the website specialize in buses in France. It also has a lot of information about the French operators and the new introduction of buses.

www.uitp.com

This website is the public transport international association. It contains information about alternative fuels, networks and operators.

http://ec.europa.eu/energy/intelligent/implementation/reporting_en.htm

Projects such as STARBUS and others supported by the EC more precisely the Executive Agency for Competitiveness and Innovation (EACI).

http://ec.europa.eu/transport/sustainable/doc/2008_costs_handbook.pdf
For the external cost monetarization, the European Commission through the IMPACT (Internalization Measures and Policies for all Internal COSTS) survey gathers all the useful tables and external costs