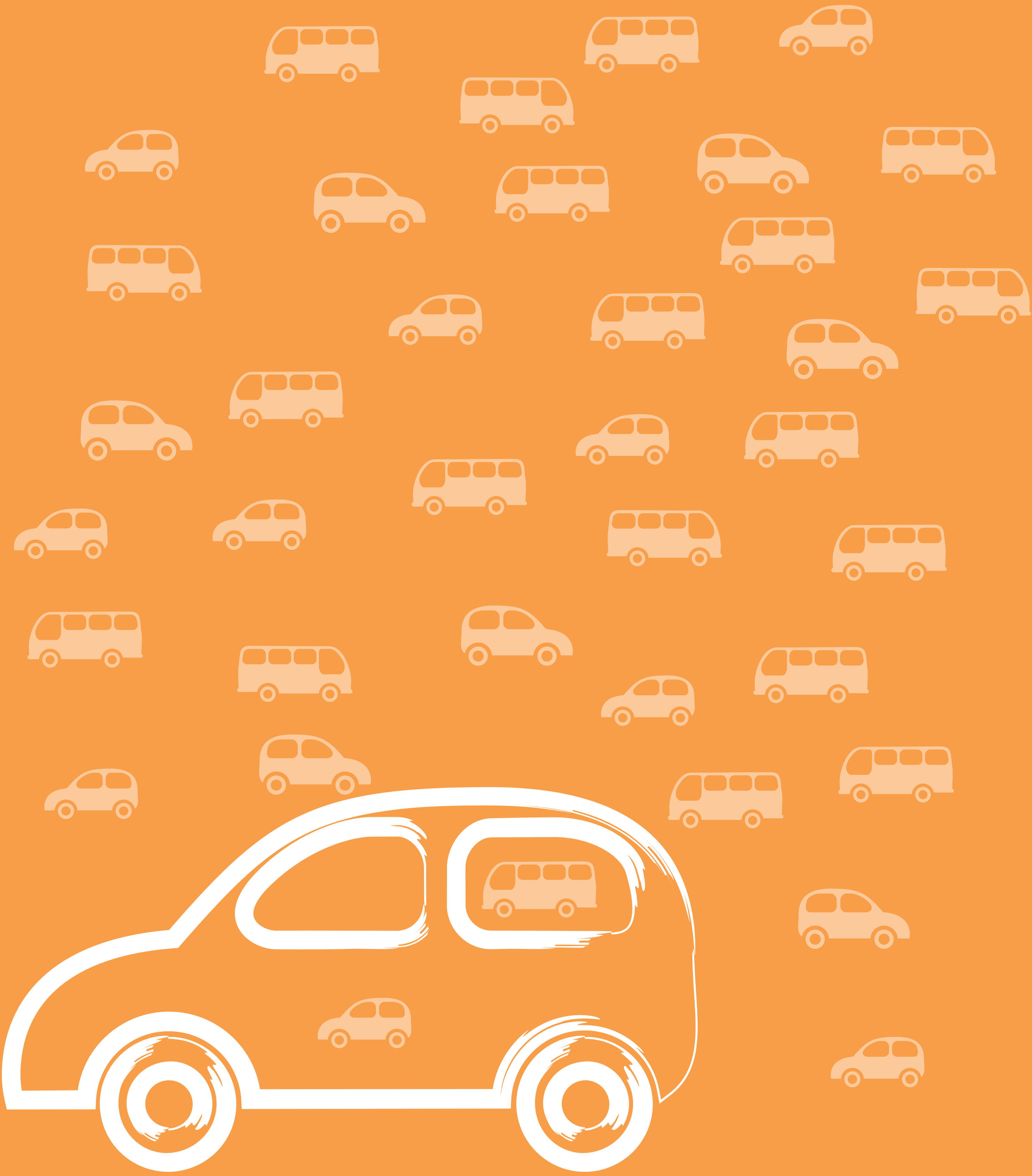
The Transport Sector



5.1 Sector overview

5.1.1 Scope of work

The scope of work in this TNA project embraces the road passenger transport sector, since it dominates all modes of transport in Lebanon and consumes the most energy produced by petroleum products. According to statistics from the International Energy Agency in 2008, the oil consumption of the road transport sector constituted more than 60% of the total oil consumption, 99.2% of which is gasoline (IEA, 2008). In terms of emissions, it accounts for nearly 21.4% of Lebanon's GHG emissions for the year 2000, and it is the main source of CO, NO_x and NMVOC emissions, with 94%, 59% and 66% respectively (MoE/UNDP/GEF, 2011).

The scope of this TNA project includes the road passengers' transport while freight, maritime and air transport are left out due to data unavailibility.

5.1.2 Road passengers' transport sector existing conditions

Reviewing past and current mobility assessments for the Lebanese road transport sector, passengers' mobility demand has experienced a real explosion since 1990, particularly in Greater Beirut Area (GBA), and the trend is strongly upward over the decade to come. This growth is mainly attributed to the raise of daily passenger trips and the increase of car ownership.

Traffic volume growth

GBA, which extends from Nahr-el-Damour south to Nahr-el-Kalb north, encloses more than 40% of the population of Lebanon, and 1.5 million of daily passenger trips estimated in 1994, expected to reach 5 million in 2015 (MoE/UNDP/GEF, 2011). Traffic conditions in GBA can be described as mostly congested, with a daily traffic volume of 230,000 passenger-car-unit crossing the north coastal highway and 85,000 the southern highway (Afif, 2012; Waked et al., 2012), and delays at some intersections ranging from 5 to 30 minutes (MoE, 2005).

Vehicle fleet overview

The current land transportation system mainly rely on vehicles, particularly private passenger cars that share in 2007 around 80% of the 1.55 million vehicles of the Lebanese car fleet, as indicated in Table 19. The rate of car ownership is estimated to be 3 persons per car in 2002, and the trend is to increase in the next decade with an annual rate of 1.5%.

Table 19 Lebanese vehicle fleet composition in 2007

Passenger cars	1,247,572
Red plate cars	47, 707
Heavy duty vehicles	183,428
2/3-wheelers	70,699
Agriculture vehicles	210
Total	1,549,616

Source:(MoE/UNDP/GEF, 2011)

The passenger cars fleet is old with an average age exceeding 13 years. 63% of the fleet is older than 20 years and 90% older than 10 years as indicated in Fig. 10. Moreover, the vehicle engine distribution shows that the fleet is mostly inefficient, since 60% of the cars have engine displacements exceeding 2.0 liters, while only 8% have engines less than 1.4 liters (Fig. 11).

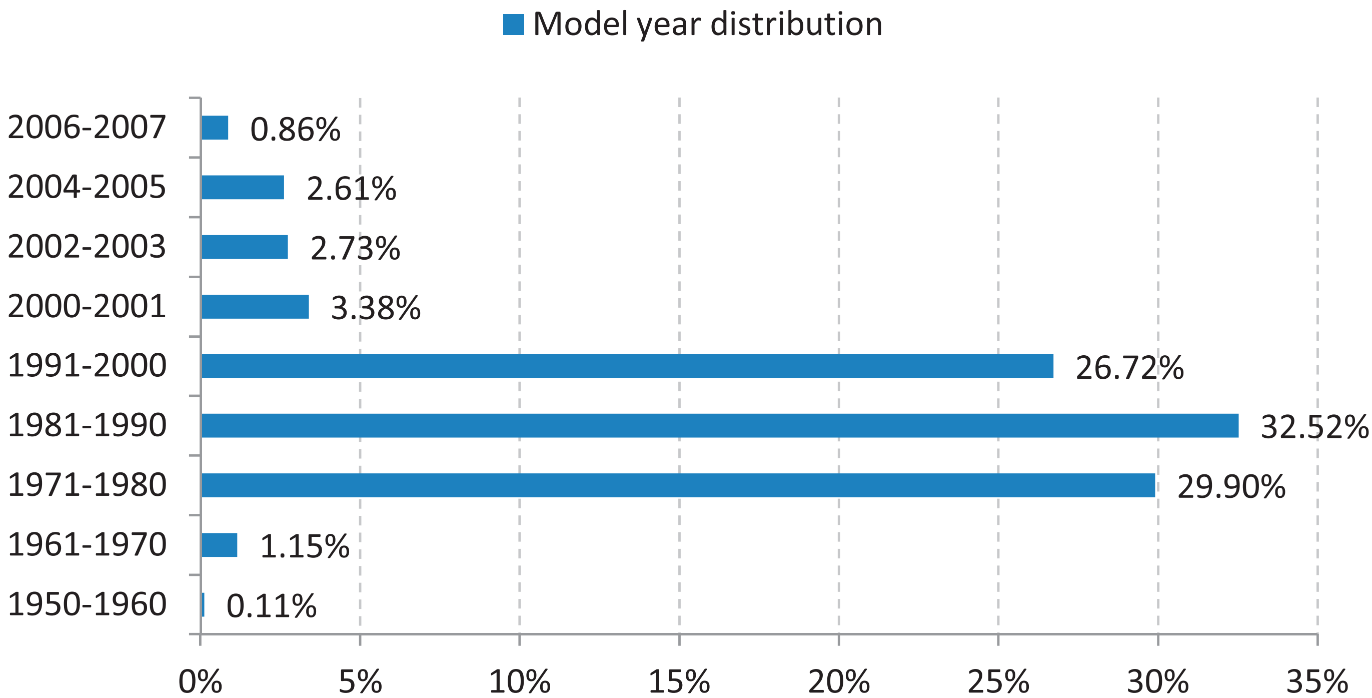


Fig. 10 - Lebanese vehicle fleet age structure in 2007.

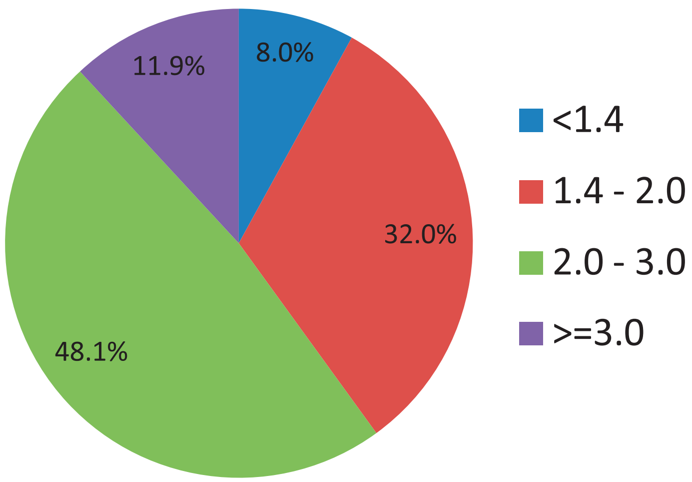


Fig. 11 - Engine displacement distribution of the Lebanese car fleet in 2007.

Public transport overview

Mass transport systems in Lebanon are generally characterized by being inefficient, unreliable and cost-ineffective. It relies on public and private buses, private vans and minibuses, and exclusive and shared ride taxis, operating without any coordination. In 2002, the mass transport market share in GBA was 31%, split between modes as illustrated in Fig. 12 (MoE, 2005). In 2007, the database of registered vehicles shows that the number of mass transport vehicles registered is 55,875, with 47,707 exclusive and shared taxis.

Contrary to the high number of mass transport vehicles, occupancy rate of mass transport systems is low, as indicated in Table 20.

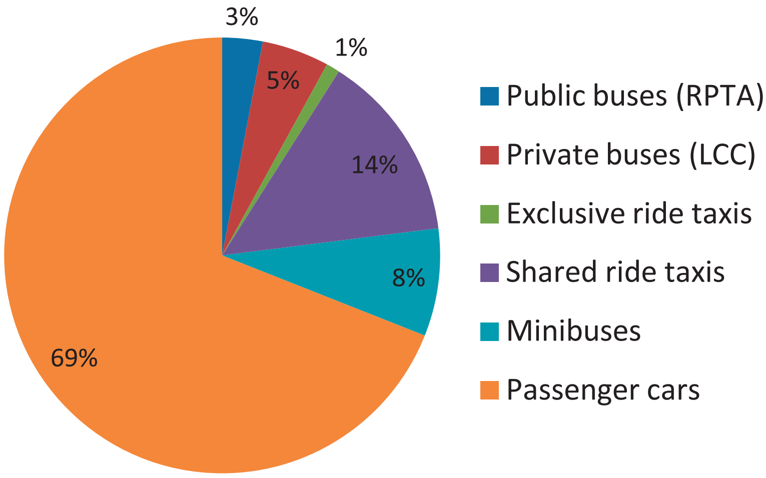


Fig. 12 - Market share of transport systems in GBA in 2002

Source: (MoE, 2005)

Table 20 - Vehicle occupancy in GBA in 2008

	Vehicle occupancy (passengers excluding driver)
RPTA buses	15.1
LCC buses	11.2
Exclusive ride taxis	1.18
Shared ride taxis	1.18
Red plate vans	5.93

Source: (Team International, 2010)

Driving conditions overview of passenger cars in GBA

Based on collected data from on-road measurements in GBA through GPS survey with different drivers, the GBA driving conditions in 2011 are characterized by the following:

- 50% of total trips have a total distance lower than 5 km and 75% lower than 12 km, with an average trip distance of 9.6 km.
- 25% of stops are below 2 seconds and 75% below 10 seconds.
- Stop time corresponds to more than 15% of travel time.

This statistical survey reflects the low driving range in GBA with high rate of congestion and high rate of short time stops. Moreover, the speed acceleration frequency distribution presented in Fig. 13 shows that the acceleration rates are significant at very low speed, which result in an inefficient operation of internal combustion engines; thus leading to a high rate of fuel consumption and pollutant emissions in conventional gasoline powered vehicles.

All these existing conditions have led the road passengers' transport sector to have a high passenger transport energy intensity in 2007, estimated at 3.08 MJ/passenger-kilometer (Fig. 14), in addition to having a high energy demand of 15.06 GJ/capita, exceeding the world average (Fig. 15).

As a result, GBA passengers are suffering from high budget required for transport, high dependence on fossil fuels, in addition to alarming pollution rates particularly in urban areas. Therefore, road passengers' transport is a key sector for reducing the total fuel consumption and emissions of Lebanon.

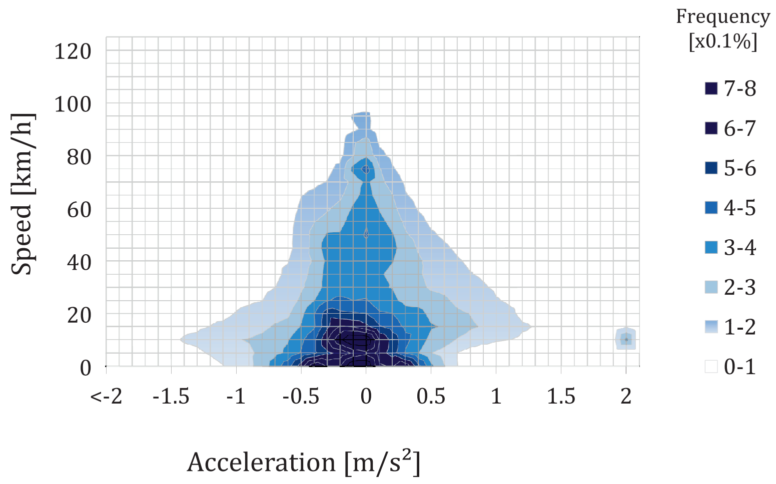


Fig. 13 - Speed-acceleration frequency distribution

Source: (Mansour and Zgheib, 2012)

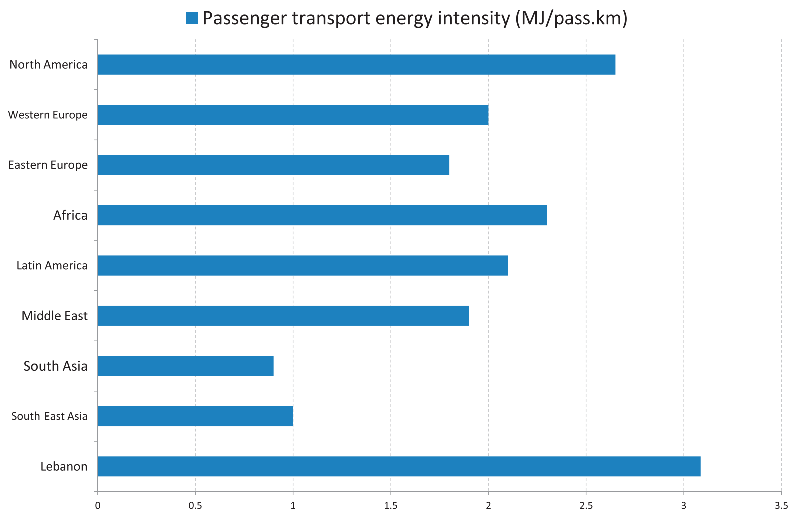


Fig. 14 - Transport energy intensity (2007 for Lebanon and 2005 for the rest of regions)

Source: (Electris et al., 2009).

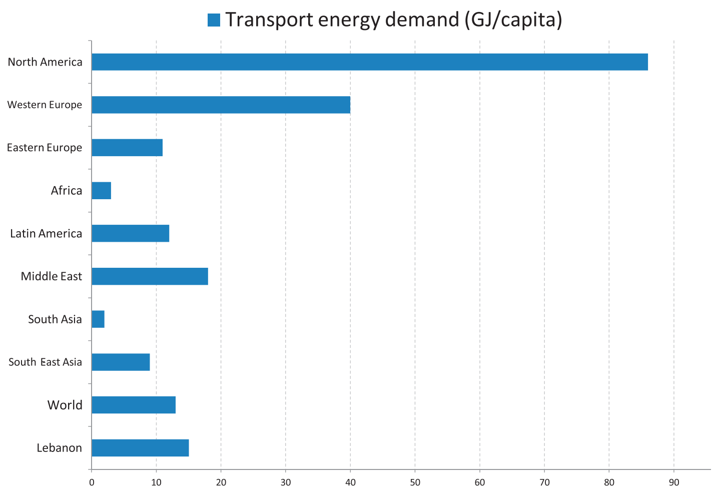


Fig. 15 - Passenger transport energy demand per capita.
(2007 for Lebanon and 2005 for the rest of regions)

Source: (Electris et al., 2009).

5.1.3 Actions at sectoral level

Existing policies and Measures

The main existing transport legislation relevant to the mitigation of GHG emissions comprises:

Rules/Policies/Regulations	Description
Decree No. 124/2003	Specifications of motorcycles and engines, and allowed time to drive, applied in all areas of Lebanon.
Decree No. 8243/2003	Mandatory Annual vehicle inspection.
Decree No. 11244/2003	Set up Traffic Management Organization (TMO) which has yet to carry out a technical traffic management role rather than just an administrative one.
Decree No. 7858/2002	• Incentives to renew the fleet such as exempting new cars, 5 years old cars, public transport cars, and buses of no more than 24 passengers from import tax, and registration, and inspection fees. • Compensate owners of private cars, public transport cars, and buses which would convert to gasoline engines with amounts ranging from 1,000,000 to 13,000,000 L.L depending on the year of manufacture. • Ban the use of private and public cars of diesel engines starting from 15/6/2002. • Ban the use of private and public transport autobuses of diesel engines starting from 15/7/2002. • Ban the use of public buses of 16 to 24 passengers of diesel engines starting from 31/10/2002. • Designate the port of Beirut and Tripoli for collecting the replaced engines until they are exported outside Lebanon.
Decree No. 8442/2002	Specifications of fuel motor vehicle; diesel oil and gasoline 92, 95 and 98 octane.
Law 341 (6/08/2001)	The law lays the legal framework for reducing air pollution from the transport sector and encouraging the use of cleaner sources of fuel. Specifically, the law bans the import of minivans operating on diesel engines, as well as old and new diesel engines for private passenger cars and minivans. The law empowered the GoL to retrieve 10,000 public license plates operating on diesel.
Council of Ministers decision 9, on 5/4/2000	The decision calls for the reform and reorganization of the Land Public Transport Sector in Lebanon and the reduction of the number of public transport vehicles from 39,761 to 27,061 vehicles.
Decree 6603 (4/4/1995)	It defines standards for operating diesel trucks and buses, as well as the implementation of a monitoring plan and permissible levels of exhaust fumes and exhaust quality (particularly for CO, NO_x ,hydrocarbons and TSP).

5.1.4 Mitigation strategies

Based on the prevailing conditions in the Lebanese road transport sector, reducing GHG and pollutant emissions from passengers' transport means (per passenger-kilometer) has become a must, which implies reducing the dependence on fossil fuels. The objective of this TNA report is to identify and prioritize technologies that contribute to mitigating emissions and fuel consumption in road passengers' transport.

Reviewing the existing conditions in the passenger transport sector, several factors need to be considered for mitigation: (1) reduce the number of passenger cars, (2) reduce the number and length of trips, (3) increase the vehicle occupancy rates, (4) increase mass transit means, (5) improve the vehicle efficiency, (6) increase the use of low carbon fuels, (7) increase urban average traffic speed.

Based on these mitigation factors, it is clear that no single measure will provide the solution and that action is needed simultaneously through different mitigation strategies. The priority strategies identified for consideration in Lebanon seek to:

- Revitalize the public transport systems
- Renew the existing car fleet through a scrappage programme
- Optimize the use of existing and planned road networks

However, the implementation of these strategies won't be successful without the adoption of enforcing strategies and policies:

- A well defined transport demand management system, based on shifting demand toward low carbon modes through pricing incentives and disincentives
- Legislative reforms regarding urban planning laws, expropriation laws, taxes and tariffs, traffic and driving laws

Fig. 16 reviews the process for reaching the objective of reducing the GHG and pollutant emission levels from transport sector.

Many ongoing projects aim at improving road networks, particularly the Urban Transport Development Plan for the city of Beirut, implemented by the Council for Development and Reconstruction (CDR). It consists of implementing a traffic management system, an on-street parking management system, a corridors improvement programme, and an establishment of the Traffic Management Organization (TMO) (MoE, 2005). Hence, the mitigation strategies to be considered in this TNA will focus on the remaining two strategies: revitalizing the public transport and renewing the existing car fleet.

The associated mitigation technologies to each of the two strategies are illustrated in Fig. 17, classified under "bus technologies for public transport", "advanced powertrains for passenger cars" and "alternative fuels for passenger cars".

5.2 Possible mitigation technology options in the transport sector and their mitigation benefits

This section highlights the characteristics of the identified mitigation technologies presented in Fig. 17, in addition to their energy consumption savings and environmental benefits comparing to Business As Usual (BAU). Two reference scenarios are considered in the analysis: the Lebanese average fuel consumption of its passenger cars fleet in 2007 under GBA driving conditions (11.16 l/100km) (Mansour et al., 2011) and the world average feul consumption of new car fleet in 2005 (8.07 l/100km) (IEA, 2011). The objectives are to identify the benefits relative to the existing conditions in GBA and its old fleet, in addition to highlighting the benefits relative to a complete new vehicle fleet with recent technologies dating 7 years.

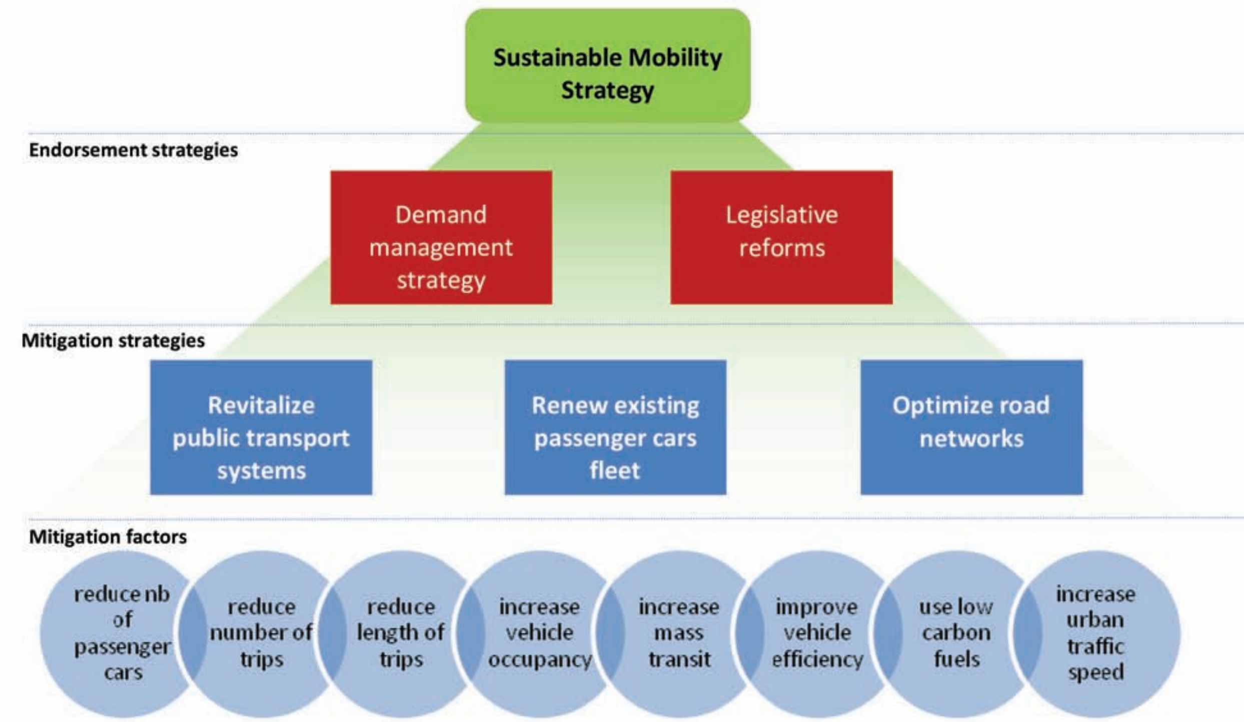


Fig. 16 - Process for reducing emissions from transport sector.

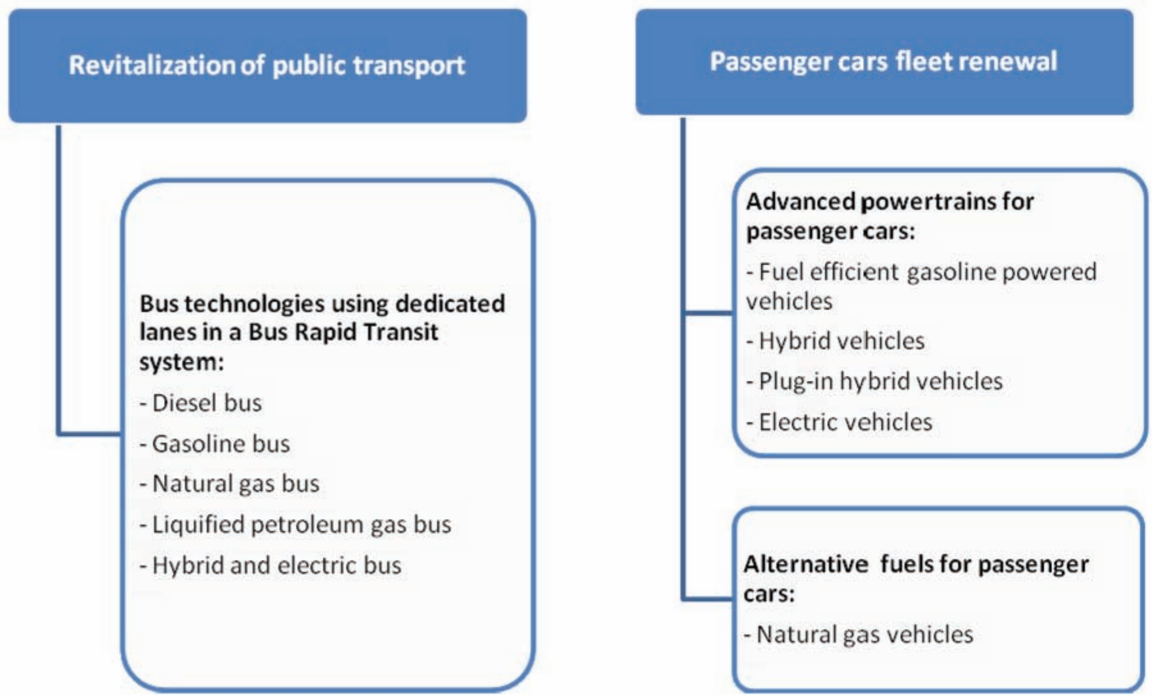


Fig. 17 - Mitigation technologies to be prioritized for each mitigation strategy.

5.2.1 Assessment methodology

In the context of assessing energy consumption and emissions savings of the identified mitigation technologies relative to the existing Lebanese road passenger transport means, results from end-of-life on-road measurements have been used, in addition to simulation results from specific powertrain simulation and life-cycle-analysis tools. These tools were used in order to bypass the complexity of real world measurements and obtain results reflecting the Lebanese existing conditions. Specific models are developed and validated for the purpose of this TNA and adapted to the existing conditions of road passengers' transport in GBA.

In fact, different variables need to be considered for assessing the consumption and emissions in real driving conditions, such as road gradient, stop duration, use of accessories, driver behavior, routes length, driving situation chronology and weather condition (Zgheib, 2009). Moreover, the variables in driving conditions are unique for every geographical area because of the variation of the road network topography, traffic congestion, car fleet composition and driving behavior in the underlying region (Andre, 2004). Accordingly, specific driving cycles emulating the Lebanese driving conditions in GBA are built for the purpose of this TNA, based on on-road measurements through GPS data logging (Mansour et al., 2011; Mansour and Zgheib, 2012).

Consumption results have served in assessing the operating costs of each of the technologies, according to its associated energy price. Other cost assessment issues such as maintenance and additional purchase costs have been determined from the literature and market review.

5.2.2 Bus technologies

Technology characteristics

Though diesel buses are still the most used bus technology worldwide, several bus technologies have made a breakthrough in public transport services, relying on different sort of fuels other than diesel. Among them are alternative fuel buses operating on CNG, LNG and LPG, and electric driven buses.

Bus public transport is a real mean to short-term solution to the environmental pollution issues in Lebanon, particularly when bus technologies are coupled to a well designed transport demand management system and dedicated lanes, like the Bus Rapid Transit (BRT) system.

Bus public transport with dedicated lanes contribute to the following aspects of sustainable developments: (1) improvement of air quality, (2) reduction of GHG emissions, (3) congestion reduction, (4) increase in energy supply security due to reduction of imported oil, (5) social equality and poverty reduction by providing affordable transport with lower operating costs than passenger cars per passenger-kilometer, (6) economic prosperity by reducing travel times and congestion. However, bus technologies not coupled to dedicated lanes and a well-defined demand management strategy lead to negative impacts on the environment and the traffic, case of the current conditions of public transport in GBA.

Fuel consumption and GHG emissions reduction potention

The passenger-kilometer efficiency of bus technologies is higher than that of the passenger cars, which is the main reason why public transport can lower the GHG and pollutant emissions of road traffic and reduce the total energy use. Nevertheless, this efficiency differs largely with the type of fuel used and the bus occupancy. Fig. 18 and Fig. 19 illustrate the passenger-kilometer efficiency and CO_2 emissions of different bus technologies as function of their occupancy. Results are compared to the average efficiency of the Lebanese car fleet in 2007, with 1, 1.5, 2 and 3 pass/veh.

In Lebanon, passenger cars occupancy is estimated to be lower than 2. Therefore, diesel, gasoline, CNG and electric driven buses would present a better efficiency and lower CO_2 emissions as their occupancy exceeds 10 to 15 pass/veh. 40.9 and 80.3% of CO_2 savings are observed with diesel buses with occupancy of 10 and 30 pass/veh respectively, comparing to Lebanese passenger cars fleet of 2007, under GBA driving conditions.

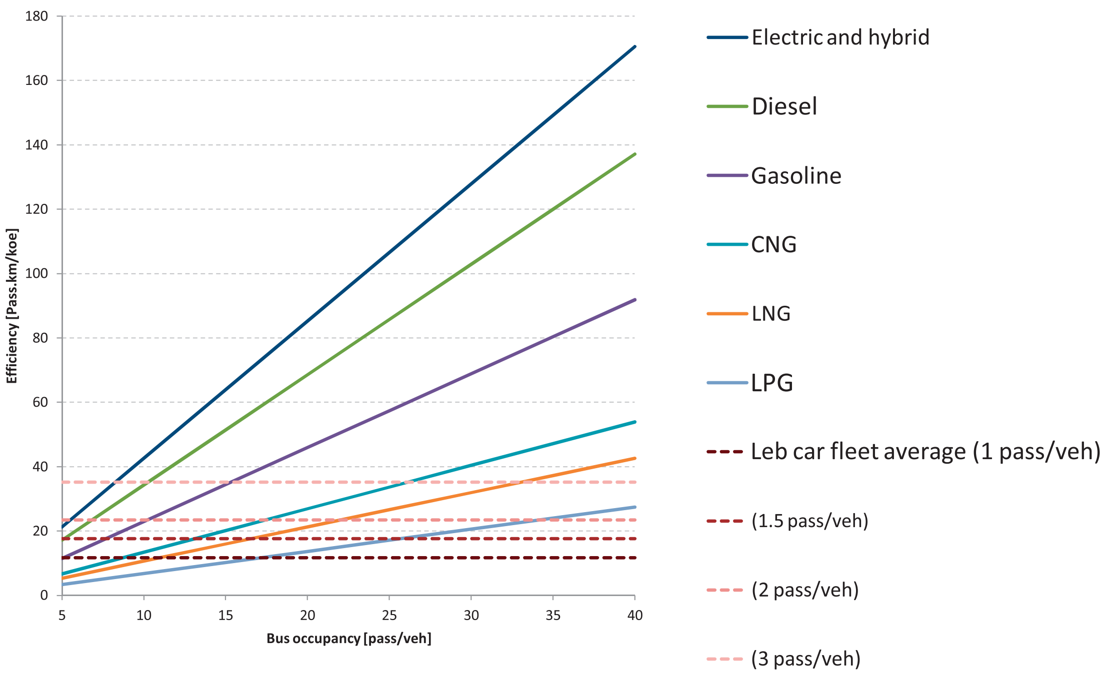


Fig. 18 - Efficiency of bus technologies as function of bus occupancy, relative to the Lebanese average passenger cars efficiency, with 1, 1.5, 2 and 3 pass/veh occupancy.

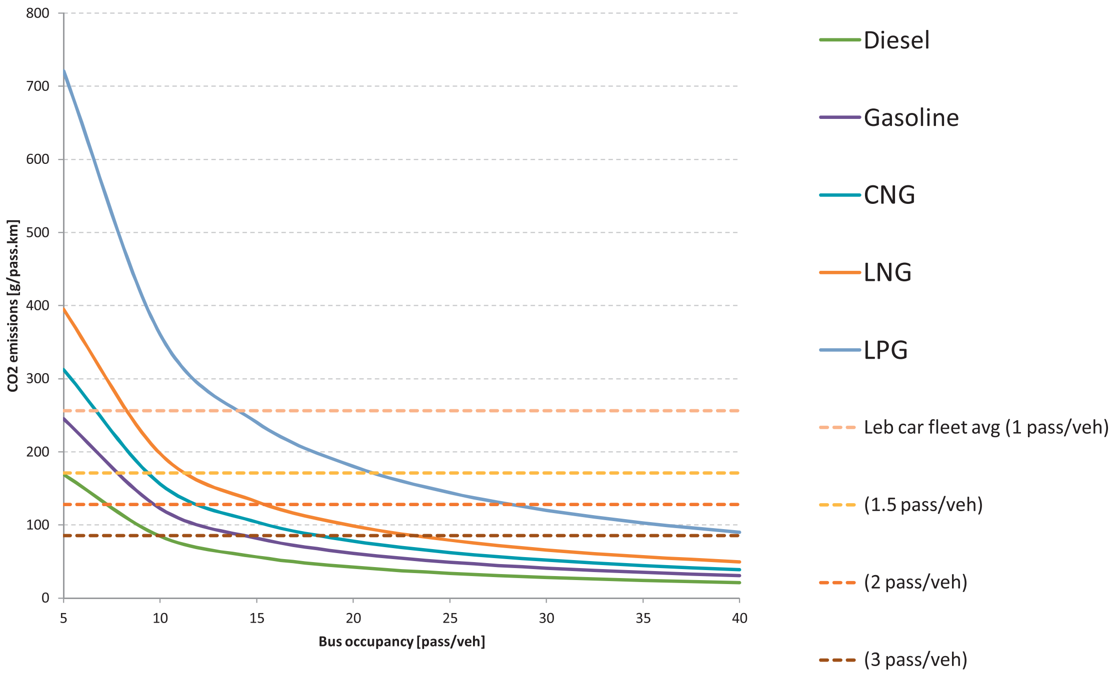


Fig. 19 - CO_2 emissions of bus technologies as function of bus occupancy, relative to the Lebanese average passenger cars CO_2 emissions, with 1, 1.5, 2 and 3 pass/veh occupancy.

5.2.3 Fuel efficient gasoline powered vehicles

Technology characteristics

Fuel efficient vehicles are commonly known by conventional gasoline powered vehicles with low consumption (estimated lower than 6.5 l/100km). These vehicles are equipped with advanced technologies and present advantages of consumption and emissions reduction comparing to similar gasoline vehicles within same vehicle segment (two-seaters, subcompact, compact, mid-size, full-size, station-wagon).

The advanced technologies are classified as passive and active systems, illustrated in Fig. 20. Passive systems have indirect impact on reducing fuel consumption, such as reducing the vehicle weight; and active systems have direct impact on consumption reduction such as engine downsizing, idle stop/start systems and continuous variable transmissions.

Fuel efficient gasoline powered vehicles are characterized by the following:

- No major modifications within the power train (similar to conventional vehicles); hence, drivers don't have to adapt their driving techniques to these new technologies.
- Technologies can be applied on the basis of modular flexibility where different combination of features (listed in Fig. 20) can be observed.
- With the addition of stop/start systems, combinations of technologies and the use of turbo charging technology to downsize the engine lead to 15-25% improvement compared to current gasoline engines.
- Additional costs are observed according to the added features, but remains cheaper than alternative technologies like hybrid vehicles.

Potential for reducing fuel consumption and GHG emissions

Considerable consumption and CO_2 emissions savings are observed with fuel efficient vehicles for all vehicle segments, as indicated in Table 21. These savings range from 10 to 50% comparing to the world average new cars fleet of 2005, and from 35 to 64% comparing to the Lebanese average consumption of the passenger cars fleet in 2007 under GBA driving conditions.

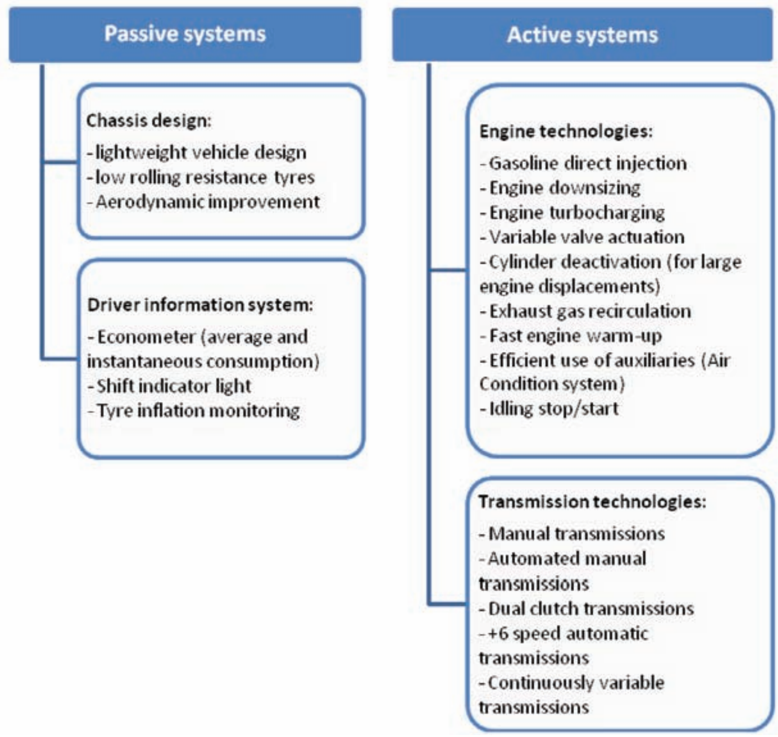


Fig. 20 - Passive and active system technologies of fuel efficient gasoline powered vehicles.

Table 21 - Fuel consumption and CO_2 emissions of fuel efficient gasoline powered vehicles, compared to Lebanese average existing cars fleet (in 2007) and to world average new cars fleet (in 2005).

Vehicle segment	Fuel efficient gasoline powered vehicles 2011	Fuel consumption on combined cycle (l/100km)	CO_2 emissions (g/km)	Fuel and CO_2 savings relative to world average 2005	Fuel and CO_2 savings relative to Lebanese fleet 2007
Two-seaters	45 kW - Manual 5spd	4.2	97	48.0%	62.7%
Mini-compact cars	63 kW - Manual 5spd	4	92	50.4%	64.7%
Sub-compact cars	74 kW - Manual 6spd	5.2	120	35.6%	53.9%
Compact cars	73 kW - Manual 6spd	5.8	135	28.1%	48.1%
Midsize cars	90 kW - Manual 6spd	6.7	155	17.0%	40.5%
Large cars	115 kW - Manual 6spd	7.3	168	9.5%	35.5%
Station-wagons	90 kW - DCT 7spd	6	139	25.7%	46.6%
Average CO_2 emissions of the Lebanese existing fleet in 2007 is estimated 260.4 g/km under GBA driving conditions. Average CO_2 emissions of the world new cars fleet in 2005 is estimated 188.3 g/km.					

Source : (ADEME, 2011; Mansour et al., 2011).

5.2.4 Hybrid electric vehicles

Technology characteristics

Hybrid electric vehicles (HEV) combine an electric motor and battery pack to the internal combustion engine (ICE) found in conventional vehicles. Three powertrain configurations are observed: parallel, series and series/parallel. HEVs are also classified as micro-hybrid, mild-hybrid, full-hybrid, plug-in hybrid and range-extender electric vehicles. They are differentiated by the fraction of electric power added onboard; consequently, the ability to achieve more hybrid functions. Note that the more electric energy is available onboard, the more fuel reduction will result, at the expense of additional control complexity and additional purchase cost.

HEVs are characterized by the following:

- More economical to run with consumption lower than 5 l/100 km in compact cars.
- High driving range of about 960 kilometers, twice that of conventional vehicles and six times that of electric vehicles.
- Fewer tailpipe pollutants because of their electric powertrains and efficiently-operated internal combustion engines.
- Downsized internal combustion engine, designed to operate efficiently when meeting average power needs because the battery intervenes when extra energy is required. In conventional vehicles, the engine is designed to meet peak power needs, thus it is oversized.
- Lower maintenance costs compared to conventional vehicles, estimated from an end-of-life study between 0.6 and 1.8 US¢/km, where the average maintenance cost for conventional vehicles from the same vehicle segment is 2.6 US¢/km (USDOE, 2011). Note that HEVs may need a battery change over the vehicle life.
- Do not require additional infrastructure investments.

Fuel consumption and GHG emissions reduction potential

Hybrid vehicles present significant fuel and CO_2 savings under current GBA existing conditions, as indicated in Table 22. 40 to 53% savings are observed with small to midsize cars. Moreover, the Table highlights the technology advancement in recent years, since 17 to 35% of savings are achievable comparing to gasoline technologies of 2005. On another note, large hybrid cars and SUVs present consumption figures above the world average, but still lower than comparable gasoline car models.

Table 22 - Fuel consumption and CO_2 emissions of end-of-life hybrid vehicles, relative to Lebanese average of 2007 existing cars fleet and to world average of 2005 new cars fleet

Vehicle segment	Fuel consumption on combined cycle	Fuel and CO_2 savings relative to world average 2005	Fuel and CO_2 savings relative to Lebanese fleet 2007
	(l/100km)		
Sub-compact cars	5.2	35.5%	53.4%
Compact cars	5.3	34.2%	52.4%
Midsize cars	6.7	17.2%	40.1%
Large cars	7.9	2.2%	29.3%
SUV	10.1	-24.6%	9.9%

Source: (USDOE, 2011).

5.2.5 Plug-in hybrid electric vehicles

Technology characteristics

A plug-in hybrid electric vehicle (PHEV) is an extended version of hybrid vehicle, which utilizes rechargeable batteries that can be restored to full charge by connecting a plug to an external electric power source. A PHEV shares the characteristics of both a conventional hybrid electric vehicle and a battery electric vehicle, having a plug to connect to the grid. Therefore batteries of PHEVs have bigger capacities than conventional HEVs.

Regardless of its architecture, a PHEV is capable of charge-depleting and charge-sustaining modes:

- Charge-depleting mode allows a fully charged PHEV to operate on electric power until its battery state of charge is depleted to a predetermined level. This mode is the vehicle's all-electric range mode (AER).
- Charge-sustaining mode is the same operating mode as conventional HEVs.

Once a PHEV has exhausted its AER in charge-depleting mode, it switches into charge-sustaining mode automatically.

PHEVs are characterized by the following:

- Less dependence on fossil fuels: PHEVs are expected to use about 40 to 60% less petroleum than conventional vehicles. The consumption of current prototypes ranges from 2.2 to 4.3 l/100km in combined driving conditions, depending on everyday charging frequency.
- Less GHG emissions: PHEVs emit less GHG than conventional vehicles, but the amount generated depends partly on the fuel used at electrical power plants. Renewable sources are highly recommended rather than the currently used in Lebanon residual-oil-burning power plants, or coal-fired power plants.
- Driving range higher than conventional vehicles, since an engine is still onboard to extend the range of the vehicle once the battery charge is depleted.
- Lower operating costs: though PHEVs will likely cost 5,700 to 7,400 USD more than comparable conventional vehicles, the consumed energy will cost less since electricity is cheaper than gasoline. Incentives will play a decisive role in promoting PHEVs.
- Lower maintenance costs: maintenance costs of PHEVs are similar to HEVs, thus lower than conventional vehicles, due to less use of the engine. However, PHEVs may need a battery change over the vehicle life.

However, serious concerns are faced by PHEVs: the recharging time lasts for 1 to 2 hours and the need of a recharging infrastructure is a prerequisite.

Fuel consumption and GHG emissions reduction potential

Fuel consumption of PHEVs depends on the everyday charging frequency. According to consumption results from on-road measurements on PHEV fleets, around 2.4 l/100km are observed for a charging frequency of 2 times/day and 4.1 l/100km for 1 time/day (Zgheib, 2012). Such results lead to fuel savings up to 78.5% under GBA driving conditions, and up to 55% comparing to their similar HEV versions, as indicated in Table 23.

In terms of CO_2 emissions, the vehicle operation emissions are lowered in the same range of the fuel consumption rates. However, the final CO_2 emission reduction depends strongly on the source of the electricity used. A larger deployment of renewable energy sources would lower the CO_2 emission of the PHEV further.

Table 23 - Fuel consumption of on-road measurement PHEV fleets in Japan and France, relative to Lebanese average of 2007 existing cars fleet and to world average of 2005 new cars fleet

Vehicle segment	Charging frequency	Fuel consumption (l/100km)	Fuel savings relative to world average 2005	Fuel savings relative to Lebanese fleet 2007	Fuel savings relative to similar HEV version
Compact car	2.1 times/day	2.2	70.3%	78.5%	55.1%
	0.9 time/day	4.3	49.2%	63.3%	23.4%

Source: (Zgheib, 2012).

5.2.6 Battery electric vehicles

Technology characteristics

Battery Electric Vehicles (BEV) are propelled by an electric motor, powered by rechargeable battery pack. They derive all the power from the battery pack and thus have no internal combustion engine.

BEV is a real mean to long-term solution to today's environmental and noise pollution issues in GBA. Technological innovations now make it possible to mass market an electric vehicle at reasonable cost. In addition, changes in vehicle use make electric cars ideal for the majority of trips in GBA, since 94% of the trips are lower than 20 km (Mansour et al., 2011).

BEVs offer several advantages compared to conventional vehicles:

- Energy efficient: its electric powertrain converts around 75% of the chemical energy from the batteries to power the wheels, where internal combustion engines only convert 20-30% of the energy stored in gasoline on highways and less than 15% in urban areas.
- Environmentally friendly: BEVs emit no tailpipe pollutants, although the power plant producing the electricity may emit them. Electricity from nuclear, hydroelectric, solar, or wind-powered plants causes no air pollutants.
- Performance benefits: Electric motors provide quiet, smooth operation and stronger acceleration and require less maintenance than ICEs (estimated to be half of an ICE).
- Reduce energy dependence.
- Lower operating costs since electricity is cheaper than gasoline. However, incentives will play a decisive role in promoting BEVs.

However, BEVs face significant battery related challenges:

- Limited driving range to 160 km in current tested vehicles.
- 4 to 8 hours battery recharging time. A "quick charge" to 80% capacity takes 30 min. Note that the concept of quick-drop in battery swap stations is under study.
- High cost of battery since lithium-ion batteries currently range between 800 and 1,000 USD/kWh. However, battery lease programmes are under study by automakers, starting from around 100 USD per month to cover a driving range of 10,000km/year (CAS, 2011).
- The need of a battery recharging infrastructure.

Fuel consumption and GHG emissions reduction potential

The energy efficiency of electric cars is very high compared to their fossil fuel counterparts, which lead theoretically to no GHG emissions. Nevertheless, the actual GHG emissions and total energy use associated with the use of BEVs depend largely on the way the required electricity has been produced. Therefore, the well-to-wheel (WTW) analysis must be considered in this assessment.

The WTW energy use improvements of BEVs comparing to WTW average consumption of the Lebanese cars fleet of 2007 are illustrated in Fig. 21. 7.2% of energy savings are achievable under the current Lebanese electricity mix; however, 33 to 42% of savings will be possible in 2030 if mitigation scenarios of electricity generation mix are adopted. These scenarios are summarized in Fig. 22.

Fig. 23 and Fig. 24 outline the WTW GHG and pollutant emissions change of a typical BEV. Note that these emissions are occurring in the Well-to-Pump (WTP) process, no emissions are observed in the vehicle operation process (Pump-To-Wheel). With the current Lebanese electricity production mix, almost no GHG savings are observed with BEV (-0.2%). However, 39.1% and 52.7% of GHG savings are observed with mitigation scenarios for 2030. In terms of pollutant emissions, BEVs can substantially contribute to improving local air quality in GBA apart from NO_x, as shown in Fig. 24.

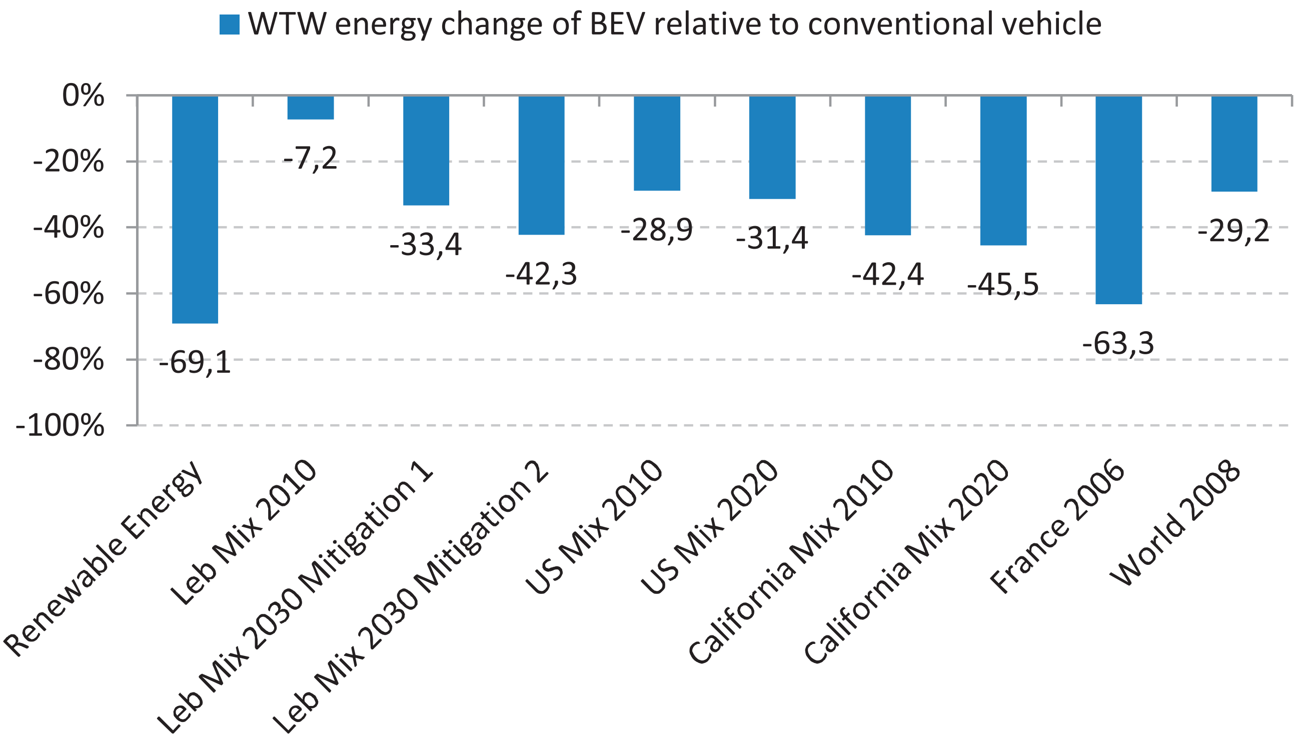


Fig. 21 - WTW energy change of BEV relative to average consumption of the Lebanese cars fleet of 2007.

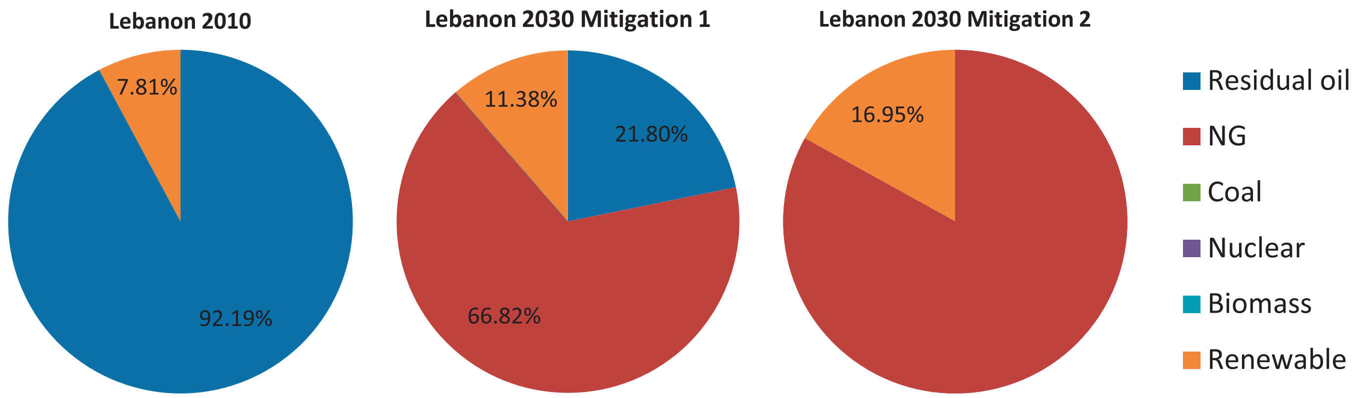


Fig. 22 - Lebanon electricity generation mix

Source: (MOE/UNDP/GEF, 2011)

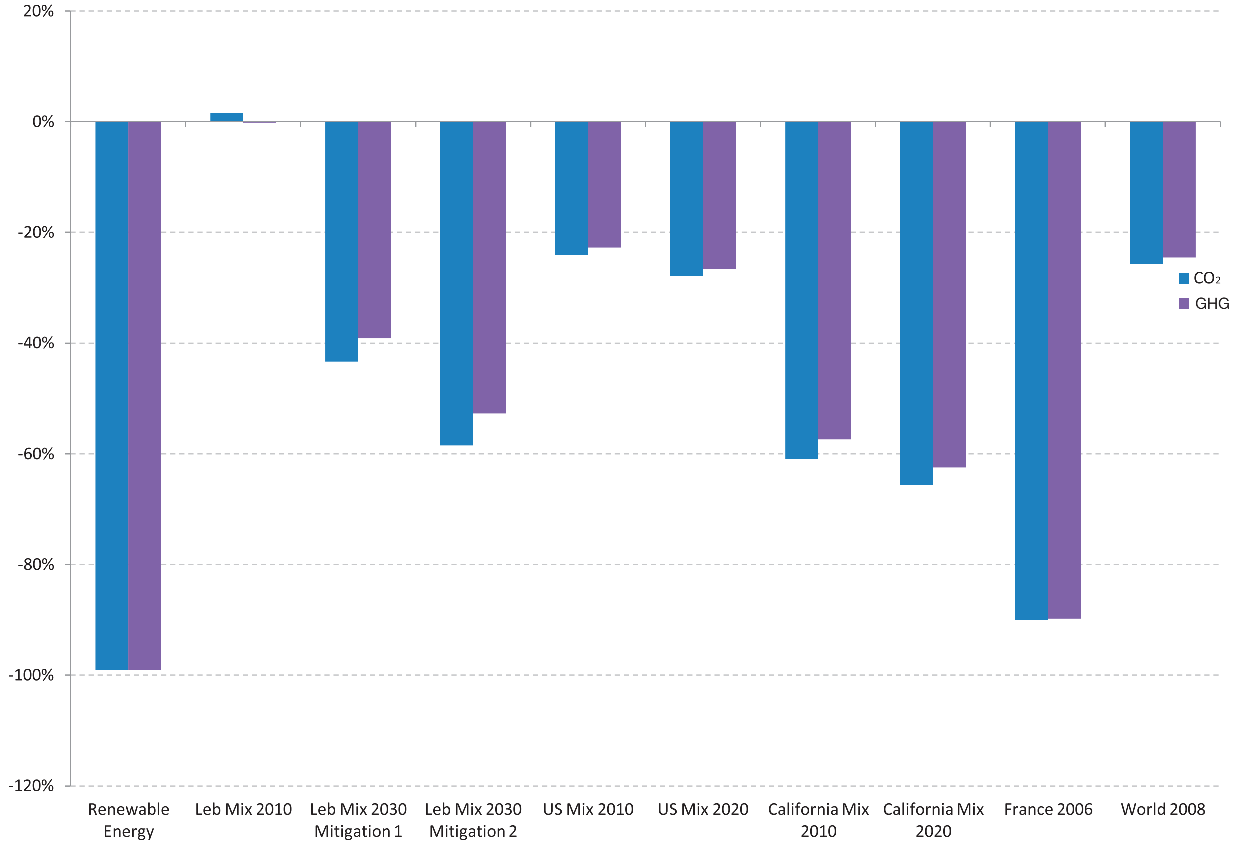


Fig. 23 - WTW GHG emissions change of BEV relative to the Lebanese cars fleet of 2007.

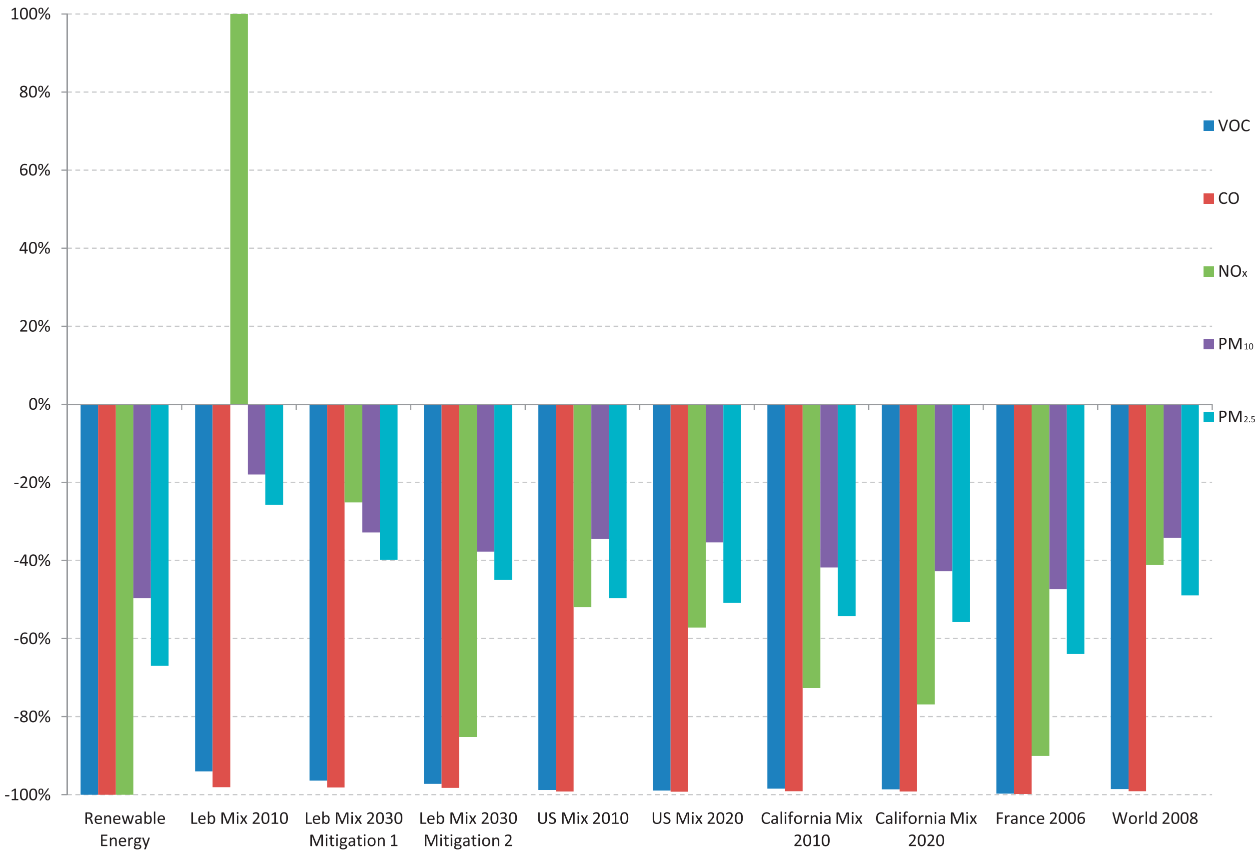


Fig. 24 - WTW pollutants change of BEV relative to the Lebanese cars fleet of 2007 under GBA driving conditions.

5.2.7 Natural gas vehicles

Technology characteristics

A natural gas vehicle (NGV) is an alternative fuel vehicle that uses compressed natural gas (CNG) or liquefied natural gas (LNG) as an alternative to gasoline and diesel. Natural gas is a fossil fuel comprised mostly of methane, and is one of the cleanest burning fuels. In most common applications, it is used in the form of compressed natural gas (CNG) to fuel passenger cars and city buses, and in the form of liquefied natural gas (LNG) to fuel heavy duty trucks. Due to high boil-off evaporative losses, LNG is not recommended for passenger cars and urban buses.

There are both dedicated NGVs which run exclusively on natural gas, and bi-fuel NGVs, which have two separate fueling systems enabling the car to run either on natural gas (CNG) or on gasoline or diesel. Most current CNG passenger cars are bi-fuel vehicles. It is possible to retrofit a gasoline powered vehicle with a natural gas tank. However, these vehicles are not as fuel efficient as OEM (Original Equipment Manufacturers) natural gas powered vehicles. In addition, retrofitted vehicles have higher emissions of NO_x and PM.

NGVs, particularly CNG passenger cars, offer several advantages compared to conventional vehicles:

- CNG vehicles have lower maintenance costs when compared with other fuel-powered vehicles, estimated around 2.1 US¢/km compared to 2.4 US¢/km for similar gasoline vehicles (USDOE, 1999).
- CNG fuel systems are sealed, which eliminates evaporation losses.
- Increased life of lubricating oils, as CNG does not contaminate the engine crankcase oil.
- CNG mixes easily with air, since it is a gaseous fuel, which leads to a clean combustion.
- CNG is less likely to auto-ignite on hot surfaces, since it has a high auto-ignition temperature, which improves the combustion efficiency.
- Less pollution as CNG emits significantly less pollutants such as unburned hydrocarbons, carbon monoxide and particulate matter, compared to conventional gasoline vehicles.

However, CNG vehicles face significant challenges: they have a higher purchase cost estimated at around USD 2,000, a lower driving range and higher gasoline equivalent consumption (110% for bi-fuel CNG and 105% for dedicated CNG and LNG vehicles) due to the inferior energy density of NG compared to gasoline, in addition to the need of an infrastructure for NG transportation and distribution. With NG, transportation is still depending on fossil fuels.

Fuel consumption and GHG emissions reduction potential

The Well-to-Wheel (WTW) energy use change of NGV, gasoline HEV and BEV comparing to the WTW average consumption of the Lebanese car fleet of 2007 is illustrated in Fig. 25. Dedicated and bi-fuel NGV technologies are considered, in addition to two different NG transportation paths: (1) the NG feedstock is transported using LNG, assumed to be the intermediate fuel to bring NG to the stations (shown in the figure under “LNG transport”); (2) the NG feedstock is transported in gaseous form.

Three conclusions are drawn from the figure:

- Dedicated CNG vehicles present better efficiency compared to bi-fuel NGV, as they are optimized to operate solely on NG rather than on two fuel types: gasoline and NG.
- Both technologies present energy consumption exceeding the Lebanese average consumption: 2% to 18% of additional energy is consumed with NGV, whereas electrified powertrains bring remarkable consumption savings, up to 28.6% with HEVs. Such result is expected since NG energy density is lower than gasoline. However, the main advantage of NGVs is expected in reducing air pollutants, due to the clean combustion occurring in the engine.
- NGVs using NG transported in liquid form present higher total energy consumption due to the double gas-liquid conversion losses and to boil-off evaporative losses when NG is transported to stations under LNG.

Fig. 26 and Fig. 27 outline the WTW GHG and pollutant emissions change of NGV, gasoline HEV and BEV comparing to the 2007 Lebanese cars fleet.

Taking into consideration the energy needed to extract and refine the fuels, the corresponding WTW CO_2 emissions of NG are lower than for gasoline. 5% to 20% of CO_2 savings are observed, depending on the powertrain technology and the path for transporting NG feedstock. Nevertheless, considering the rest of GHGs such as CH_4 and N_2O, almost no GHG emissions reductions are observed with NGVs. In contrast, HEV GHG emissions savings can reach 28.4%.

In terms of pollutant emissions, the main pollutant reductions are CO and VOC as NG (methane) has less carbon content and the CNG tanks are sealed, as illustrated in Fig. 27.

Currently, NG is imported in Lebanon from regional countries. Thus, it is convenient to compare also the vehicle operation emissions, as illustrated in Fig. 28. Bi-fuel CNG vehicles present similar CO and VOC emissions comparing to low-emission gasoline vehicles, and much lower than uncontrolled gasoline vehicles. Moreover, dedicated CNG vehicles present even further emissions reduction than low-emission gasoline. However, the uncertainty remains on the NO_x emissions level. According to the literature, NO_x emissions from bi-fuel NGVs, particularly converted CNG vehicles, may be higher or lower than comparable gasoline vehicles, depending on the engine technology. NO_x emissions from NGVs are more difficult to control using three-way catalysts.

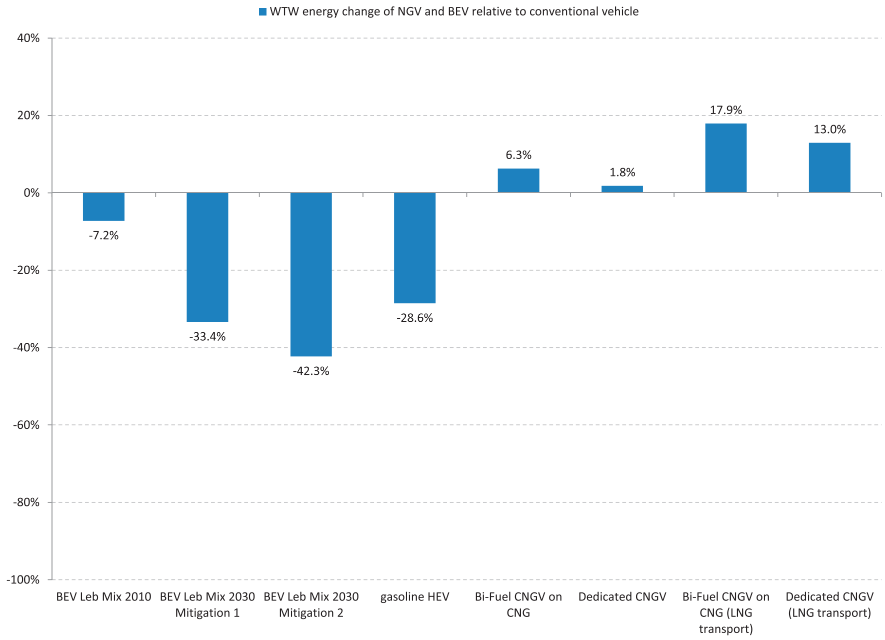


Fig. 25 - WTW energy changes of NGV, gasoline HEV and BEV relative to average consumption of the Lebanese cars fleet of 2007.

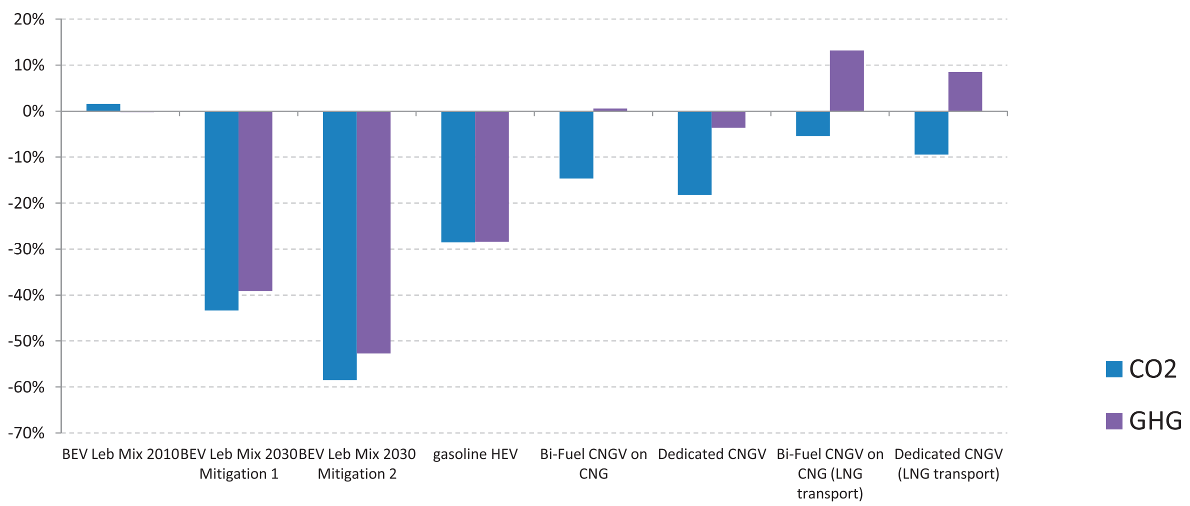


Fig. 26 - WTW GHG emissions change of NGV, gasoline HEV and BEV relative to the Lebanese cars fleet of 2007.

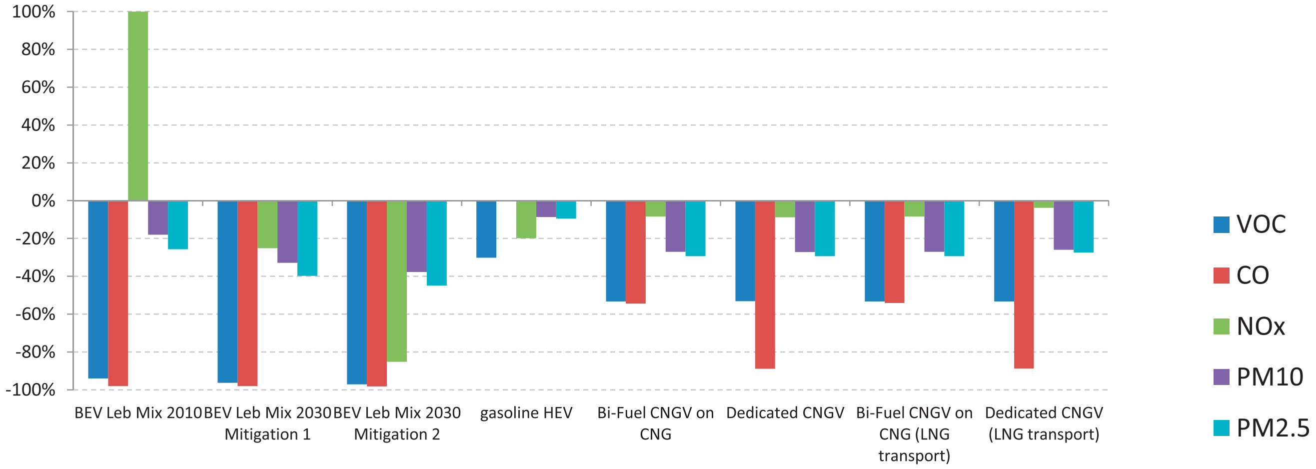


Fig. 27 - WTW pollutants change of NGV, gasoline HEV and BEV relative to the Lebanese cars fleet of 2007 under GBA driving conditions.

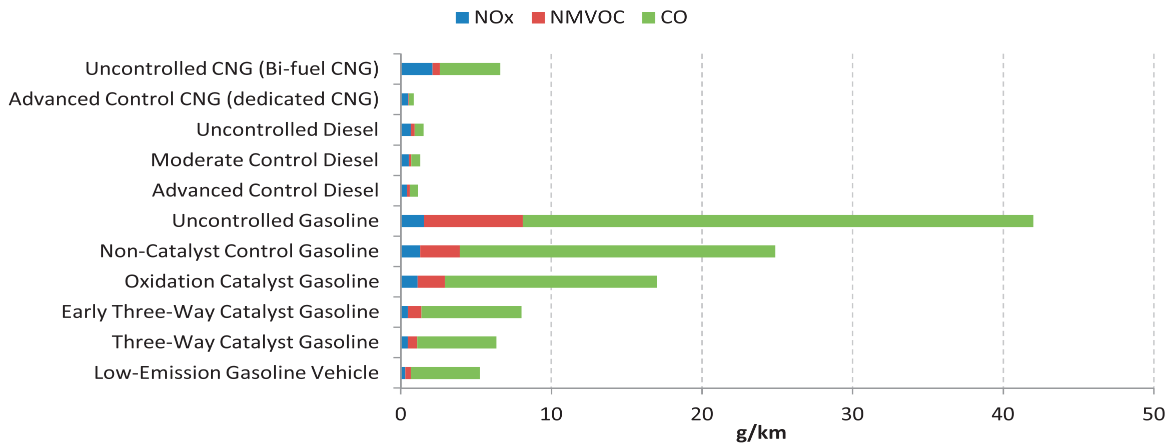


Fig. 28 - Vehicle operation emissions of CNG, diesel and gasoline technologies

Source: (IPCC, 1996).

5.2.8 Conclusions

This section brings all energy and environmental benefits of identified mitigation technologies into the same scale (Table 24), in order to compare in terms of passenger-kilometer the figures of the studied technologies.

The technologies are classified under the two studied mitigation strategies: (1) renewing the existing passenger cars fleet through a scrappage programme and (2) revitalizing the public transport systems. For passenger cars, a compact vehicle is considered for the different technologies, in order to fairly compare the energy and CO_2 emissions savings.

Note that results are obtained from end-of-life on-road measurements and simulation tools, where specific models are developed, validated and adapted to the existing conditions of road passenger transport in GBA. Therefore, obtained results are specified for the case of Lebanon, and reflect realistic driving consumption and emissions.

5.2.9 Cost analysis of mitigation technologies

Technology prioritization decisions in transport often involve tradeoffs between conflicting technology outcomes. For example, deploying the high efficient electrified vehicles may be reconsidered by stakeholders when investment costs for infrastructure implementation are included in the assessment. Hence, a global comprehensive analysis is considered in this TNA, by providing the environmental and energy benefits on one side, and the associated costs on the other side. This section provides the cost analysis of the different identified technologies in order to rationalize the prioritization decisions.

Table 24 - Energy consumption and CO_2 emissions benefits of the identified mitigation technologies.

Mitigation strategies	Renew the existing passenger cars fleet						Revitalize public transport systems	
	Fuel efficient vehicles	Hybrid electric vehicles	Plug-in hybrid vehicles		Battery electric vehicles	Natural gas vehicles	Bus technologies with dedicated lanes	
			Charge frequency				Bus occupancy	
			2 times /day	1 time /day			15 pass /veh	30 pass /veh
Fuel consumption [1] (L/100km.pass)	3.19	2.91	1.32	2.25	0.00	4.17	3.80	1.27
Total energy consumption [2] (kWh/100km.pass)	29.34	26.81	17.36	23.49	11.61	38.40	34.99	11.66
PTW CO_2 savings (%) [3]	48.10	52.00	78.49	63.26	100.00	18-25	40.86	80.29
WTW CO_2 savings (%) [4]	26.5	28.6	N/A	N/A	-1.5 (43.4-58.5% in 2030)	14.7-18.3	N/A	N/A

[1] Fuel consumption of comparable compact passenger cars, in liter gasoline equivalent. The vehicle occupancy rate considered for passenger cars is 1.82 pass/veh, observed under GBA driving conditions. Note that average fuel consumption of 2007 Lebanese car fleet is 6.13 L/100km.pass.
[2] Fuel and electricity consumption of comparable compact passenger cars, expressed in kWh.
[3] Pump-To-Wheel (Vehicle operation) CO_2 savings relative to the average CO_2 emissions of the 2007 Lebanese passenger cars fleet, estimated 260.4 g/km.
[4] Well-To-Wheel CO_2 savings relative to the average CO_2 emissions of the 2007 Lebanese passenger cars fleet.

Cost analysis methodology

Different transport related types of costs are included in the analysis, as indicated in Table 25 Though the list considered is not exhaustive, it provides a reasonable basis for analyzing major technologies' cost benefits.

Cost analysis of bus technologies with dedicated lanes

Cost benefits

Bus technologies present clear cost savings per passenger-kilometer comparing to passenger cars, as illustrated in Fig. 29 and Fig. 30. In average bus occupancy (15 pass/veh), Diesel and CNG buses present cost savings around 75-83%. These savings could reach 92% during rush hours (30 pass/veh). As for passenger cars, savings could be considered significant only when the car is shared by 4 passengers, as illustrated in Fig. 30.

Note that this assessment is done with different fuel prices, from Egypt, Greece, Turkey, France, Germany and USA, where NG, diesel and gasoline are used for transport, as indicated in Table 26 (NGVA, 2011).

Additional cost to implement bus technologies

According to the Transport Union for Public Transport (UITP), the initial extra capital costs compared to a 12-meter diesel bus at USD 257,000 are summarized in Table 27.

In addition to the cost of the bus technology, public transport systems operate efficiently when using dedicated lanes like in BRT systems. However, BRT requires high investment costs for its infrastructure. Depending on the required capacity, urban context and complexity of the project, BRT systems can be delivered for 1 to 15 million USD/km (IPCC, 2007), with most existing BRTs in developing countries in the lower part of this range (ITDP, 2007). These figures are substantially lower than those for rail-based systems, which cost approximately 50 million USD/km (IPCC, 2007).

Table 25 - Transport costs considered in the assessment

Cost	Description
Annual operating cost	Vehicle operating costs, including fuel price spent over one year with a driving range considered 10,000 km. These costs are computed from energy consumption simulation and end-of-life measurement results, using current gasoline and electricity tariffs in Lebanon.
Maintenance cost	Vehicle maintenance costs, including reparation fees. Accident damages are excluded.
Additional purchase cost	Additional costs requested to purchase the vehicle comparing to similar gasoline powered vehicle from same segment.
End-of-life ownership cost	The total ownership cost of the vehicle over 250,000 km, including operation, maintenance and additional purchase costs. Purchase and resale car price are excluded.
Infrastructure cost	The infrastructure cost required for bringing the technology to a commercially operable level.

Table 26 - Fuel prices of Diesel, gasoline and CNG

	Regular Gasoline (Euro/liter)	CNG price equivalent per liter gasoline	Diesel (Euro/liter)	CNG price equivalent per liter diesel	Month	Year
Egypt	0.12	0.05	0.15	0.06	December	2006
Greece	1.71	0.60	1.47	0.69	July	2011
Turkey	1.00	0.46	0.83	0.53	June	2010
France	1.52	0.57	1.34	0.65	July	2011
Germany	1.55	0.64	1.40	0.73	July	2011
U.S.A.	0.63	0.29	0.75	0.34	May	2008

Source: (NGVA, 2011).

Table 27 - Additional initial capital costs in USD.

	CNG	LPG	Diesel + CRT[(2)]	Diesel + SCRT[(3)]
Vehicle (USD) [(1)]	51,400	38,550	6,425 - 7,710	12,850
Filling station (USD)	385,500 - 771,000	282,700	-	-
Safety devices (USD)	38,550 - 1,285,000	1,285,000	-	-
Cleaning installations (USD)	-	-	32,100	32,100

[(1)]Converted from EURO at the 2012 yearly average exchange rate of 1.285.
[(2)]CRT: Continuously Regenerating Technology. It reduces HC and PM by over 90% and CO by over 70%.
[(3)]SCRT: Selective Catalytic Reduction Technology. It is a four-way emission control system that reduces CO, HC, and PM by over 90% and NO_x by 70%.

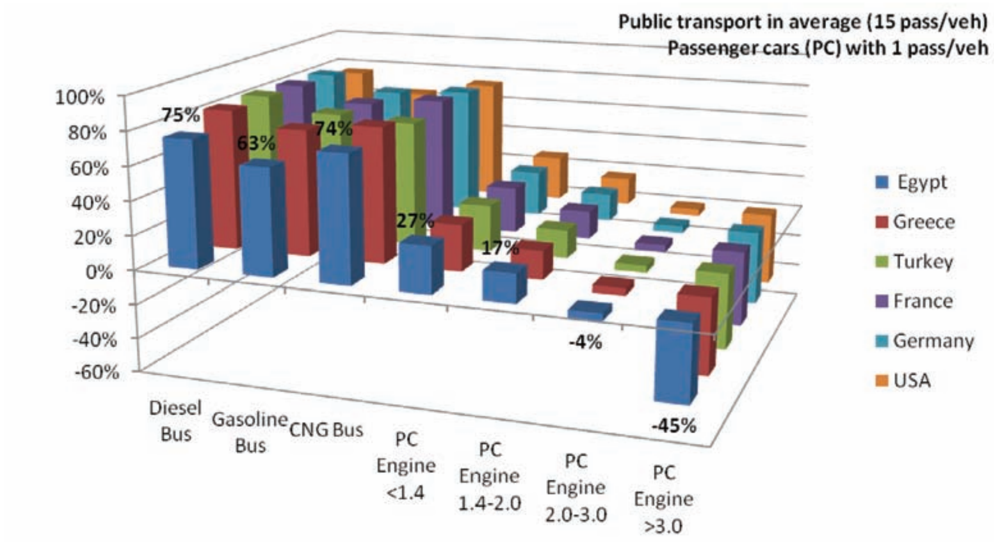


Fig. 29 - Cost savings of public transport buses in average use (15 pass/veh) and passenger cars (1 pass/Veh) relative to Lebanese car fleet average fuel cost with 1 pass/veh.

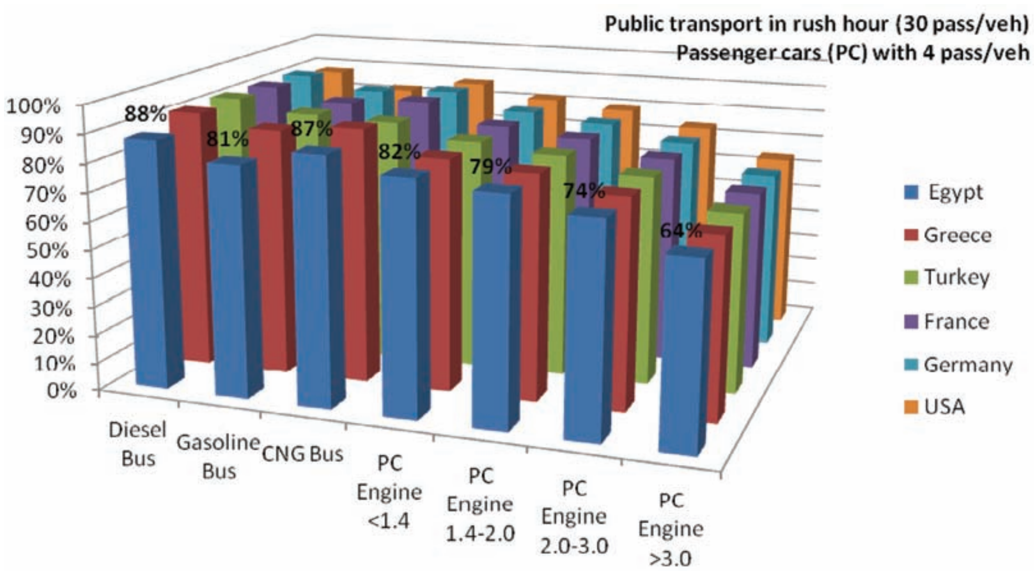


Fig. 30 - Cost savings of public transport buses in rush hours (30 pass/veh) and shared passenger cars (4 pass/veh) relative to Lebanese car fleet average fuel consumption with 1 pass/veh.

Cost analysis of mitigation passenger car technologies

In order to simplify the cost assessment done for the different passenger car technologies, Table 28 brings all results into a comparable scale. Different variables are considered for coming up with cost results coherent with the existing conditions in GBA: the energy consumption estimated under GBA driving conditions, an annual total mileage of 10,000 km and the current fuel and electricity tariffs in Lebanon, considered 1.2 USD/liter and 0.15 USD/kWh respectively.

The results are computed for a compact-size passenger car, with an average occupancy of 1.82 as estimated in GBA.

Combining environmental and energy saving results to the cost benefits, the following conclusions are drawn:

- For revitalizing the public transport systems, diesel and CNG bus technologies coupled to dedicated corridors present the highest development benefits, in terms of energy and environmental benefits, and cost savings. However, efficient pricing and optimized demand management strategy are essential to the well deployment and efficient use of these technologies.
- Under the strategy of renewing the passenger cars fleet, fuel efficient gasoline powered vehicles and self-sustaining hybrid vehicles

present significant energy, emissions and costs savings, with an acceptable additional cost if tax and legislative reforms are applied. These technologies do not require any specific infrastructure investments.

- If additional savings are aimed for, plug-in hybrid, battery electric and natural gas vehicles would be the solution, however, at the expense of higher purchase costs and the need of a costly infrastructure for refueling the vehicles. Note that NGVs may benefit from the NG pipeline network to be implemented by the MoEW for providing the coastal power plants with NG.

Table 28 - Cost analysis summary Table

Mitigation strategies	Renew the existing passenger cars fleet						Revitalize public transport	
	Fuel efficient vehicles	Hybrid electric vehicles	Plug-in hybrid vehicles		Battery electric vehicles	Natural gas vehicles	Bus technologies	
			Charge frequency				Bus occupancy	
			2 times/ day	1 time/ day			15 pass/ veh	30 pass/ veh
Operating cost savings [1] (USD/10,000 km)	640	700	910	770	965	960	75-92% savings relative to passenger car.	
Maintenance cost savings [2] (%)	0		27-77			19	-	-
Additional purchase cost (after tax reforms) (USD)	150-600	1,000-4,000	5,700-7,400		>15,000 [3]	2,000	-	-
End-of-life ownership cost savings [4] (USD)	9,450	12,750	18,000	14,500	19,375	18,700	-	-
Infrastructure cost	0	0	• 18,000 USD/public recharging station. • 1,800 USD/private recharging station.			• 500,000 USD fueling station. • pipelines cost. • NG transport 4.5 USD/ GJ.100km.	1 to 15 million USD/km for dedicated corridors.	
Timeframe	Short-term		Medium/Long			Medium	Short/Medium	

[1] Operating cost savings relative to Lebanese car fleet of 2007. Gasoline price is estimated 1.2 USD/liter and electricity tariff 0.15 USD/kWh.
[2] The maintenance cost of conventional gasoline powered compact-segment vehicle is estimated 0.026 USD/km.
[3] Leasisng option 100 USD/month.
[4] End-of-life ownership cost savings relative to Lebanese car fleet of 2007. The passenger cars end-of-life assessment is considered 250,000 km. Purchase and resale car price are excluded.

5.2.10 Criteria and process of technology prioritization

The technology prioritization process for the transport sector is carried out using a Mutli-Criteria Analysis (MCA) decision-making exercise, where transport experts and stakeholders assessed the identified mitigation technologies based on to their importance in meeting national mitigation goals. This section presents the selection process and criteria used in the prioritization exercise.

Selection process

For each identified technology, factsheets were elaborated and disseminated to a wide spectrum of researchers and experts from national and international institutions for review. These factsheets contained detailed information on technology characteristics, institutional and organization requirements, adequacy of use, capital and operational cost, advantages as well as barriers and challenges.

Based on this extensive dissemination process, an expert consultation workshop and individual consultations were conducted to ensure that the opinion and feedback of relevant institutions and experts are taken into consideration.

During the consultation workshop, the proposed weights were validated and the ranking was conducted through an open discussion among the experts and scores were attributed based on general consensus. Rankings were also completed during individual meetings.

Selection criteria

The criteria were selected based on two main objectives: minimizing the GHG and pollutant emissions for the transport sector and maximizing the environmental, social, and economic development benefits.

Accordingly, five main criteria for technologies selection were identified: (1) consistency with national policy and local context, (2) technology effectiveness, (3) technology cost-effectiveness, (4) environmental effectiveness and (5) social acceptability. Each of the criterion is attributed specific sub-criteria and assigned a weight based on its significance in meeting the two objectives, as indicated in Table 29.

The rating values attributed to each criterion were from 0 to 5, and determined by the following:

5: high relevance/ high impact

3: relevant/ moderate impact

1: less relevant/ less impact

0: not relevant/ no impact

Results of technology prioritization

Table 30 presents the final scores that were attributed to the proposed technologies of the transport sector. The main points raised during the working group session and the individual meetings revolved around:

- The need to couple the bus technologies with dedicated corridors and to optimize its operation and promote its use through proper policies and measures. Otherwise, bus public transport would bring negative impacts on the traffic, the environment and the economy, as is observed currently in GBA.
- The need to optimize the use of the existing infrastructure by adopting intelligent transport systems in demand management.
- Lebanon needs short timeframe solutions to improve its air quality rather than reduce its GHG emissions, as air pollution has daily direct impact on passengers' health, whereas Lebanon's contribution to world's GHG emissions is insignificant. As a result, it was decided to use a higher weight factor for the criterion of improving the air quality than that of reducing GHG emissions.
- Though electric mobility has proven itself as the future of transport, deployment of electrified vehicles that need to be plugged to the grid is difficult to achieve on the short and medium terms, as Lebanon is in deficit in terms of electricity generation.
- Though OEM Natural gas vehicles are safe to use, uncertified and self-retrofitted NGVs present significant safety concerns. Hence, in the lack of control policies for safety regulation, natural gas will only be considered for use in public transport buses or for electricity generation for electrified vehicles.

As a result, the MCA exercise enabled the selection of priority technologies for the transport sector in Lebanon. The top-ranked technologies are 1) Bus technologies using diesel and natural gas for revitalizing the public transport, 2) Hybrid electric vehicles and 3) Fuel efficient gasoline vehicles for renewing the passenger cars fleet.

Table 29 - Criteria and weights for the prioritization process.

Criteria	Weights	Comments
Consistency with national policy and local context:		
Relevant to existing national plans and needs	1	The technology supports the national needs for reducing GHG and pollutant emissions (particularly reducing traffic in GBA), and is aligned with national energy supply security plans.
High applicability potential	1	The technology does not have barriers with high risks hindering the deployment.
Technology effectiveness:		
Efficient technology	5	The technology ensures a low consumption of fossil fuel per passenger-kilometer.
Safe technology	2	The technology ensures safety to passengers as well to maintenance technicians. Case of accidents must be considered in the safety assessment of the technology.
Reliable technology	1	The technology is reliable and mature and can be implemented without worries.
Technology cost-effectiveness:		
Low infrastructure investment costs	4	The technology does not require high investment costs for the infrastructure, indispensable for its operation. Examples of infrastructure are land use for bus corridors, recharging stations for plug-in and electric vehicles, pipelines and compressed gas stations for natural gas vehicles, etc.
Operating and maintenance cost savings	2	The technology presents significant annual operating and maintenance cost savings comparing to conventional gasoline powered vehicles.
Affordable technology	3	The purchase cost of the technology is affordable for passengers, if accompanied with taxes and legislative reforms.
Environmental effectiveness:		
GHG emissions reduction	5	The technology reduces significantly the GHG emissions during vehicle operation. Note that well-to-wheel emissions reductions must be considered for electric and plug-in hybrid vehicles.
Improvement of air quality	5	The technology reduces significantly the pollutant emissions during vehicle operation. Note that well-to-wheel emissions reductions must be considered for electric and plug-in hybrid vehicles.
Reduction of hazardous waste	2	The technology does not generate hazardous waste.
Social benefits:		
Socio-economic benefits	1	The technology presents good impact for socio-economic development and creates job opportunities.
Short timeframe for applicability	1	The technology does not require too much time for bringing it to a commercially operable status.

Table 30 - Technology prioritization results

	Criteria	Fuel efficient vehicles	Hybrid vehicles	Plug-in hybrid vehicles	Electric vehicles	Natural gas vehicles	Bus technologies
Consistency with national plans	Relevant to existing national plans	3.7	3.7	3.0	3.0	3.7	5.0
	High applicability potential	4.0	4.0	1.7	1.7	3.7	4.0
Technology effectiveness	Efficient technology	2.7	3.3	4.3	4.3	2.7	5.0
	Safe technology	4.0	3.0	3.0	3.0	3.3	5.0
	Reliable technology	4.7	4.0	3.0	2.7	4.0	5.0
Technology cost-effectiveness	Low infrastructure investment costs	4.3	4.3	1.7	1.7	3.0	3.7
	Operating cost savings	3.0	3.3	4.0	4.0	4.0	5.0
	Affordable technology	4.3	3.7	2.7	1.7	4.0	5.0
Environmental effectiveness	GHG emissions reduction	3.0	3.3	4.3	4.3	2.7	4.7
	Improvement of air quality	3.0	3.7	4.0	4.7	3.7	4.3
	Reduction of hazardous waste	3.0	2.7	2.3	2.3	3.0	4.7
Social benefits	Socio-economic benefits	2.3	2.7	3.0	3.0	3.3	5.0
	Short timeframe for applicability	4.0	4.0	2.0	2.0	3.0	4.3
	Total /100	69.3	71.3	63.0	63.0	66.3	91.5

5.3 Barrier Analysis and Enabling Framework

5.3.1 Preliminary targets for transport technology transfer and diffusion

Reviewing the existing conditions of the transport sector and the needed mitigation actions, and in order to revitalize the public transport systems and renew existing passenger cars fleet, the preliminary targets are:

- Promote and modernise the bus mass transit system, operable on dedicated lanes in GBA.
- Create a market of hybrid electric vehicles.
- Promote fuel efficient gasoline-powered vehicles.

Beside the preliminary targets, indirect objectives are tackled and do not lack of importance:

- Contribute to a sustainable mobility sector: cleaner environment, efficient, affordable, safe and diversified transport means.
- Enhance Lebanese transport sector brand image.
- Reduce passenger per kilometre transport costs.
- Minimize on the long term the government financial and legislative burdens on the government.

The approach followed in order to set a preliminary programme design for the deployment of the prioritized transport technologies is illustrated and narrated in Fig. 31 and 32.

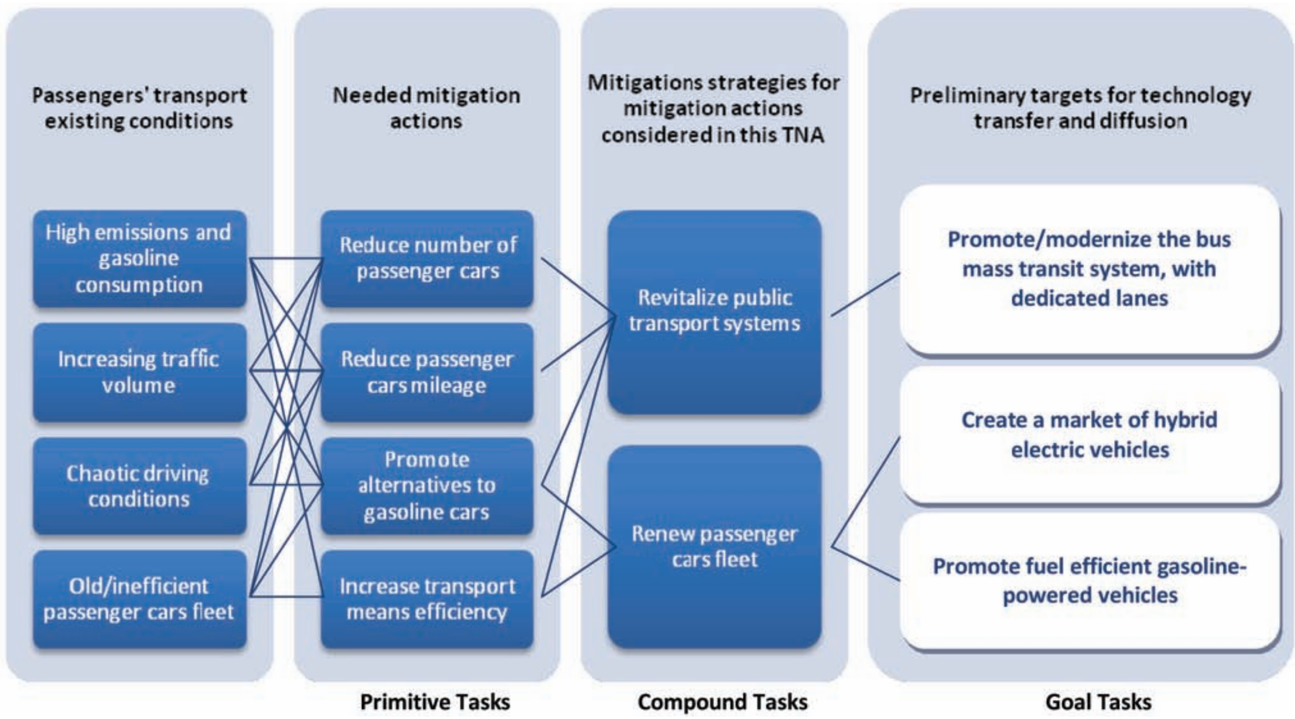


Fig. 31 - Hierarchical process for setting up preliminary targets for transport technologies transfer and diffusion.

	Description	*Tools*
Market analysis	• Identification of key stakeholders, market chain actors and the linkage between them. • Assessment of the addressable market to use mass transit buses and to swap to hybrid and fuel efficient gasoline vehicles.	Market mapping
Barrier analysis	• Identification and classification of barriers to the deployment of the prioritized technologies, including financial, policy, legal, market failures, and institutional analysis.	• Key stakeholders and expert consultations in order to identify their views and incentives to participate • Study of policy papers and case studies
Enabling framework	• Identification of measures to the deployment of the prioritized technologies. • Set up an enabling framework for the prioritized technologies based on the identified measures.	
Cost benefit analysis	• Assess the costs and benefits of the required incentives for technology deployment success, from the government and car users' perspective.	Cost benefit analysis
Technology action plan and project proposals	• Develop a Technology Action Plan (TAP) outlining the essential elements of the enabling framework, and consisting of a detailed plan of actions to implement the proposed measures and estimate the need for external assistance to cover implementation costs. • Develop project proposal for the prioritized technologies for future funding.	Technology Action Plan

Fig. 32 Approach for developing preliminary programme deployment of the prioritized transport technologies.

5.3.2 Market analysis for deployment of transit bus technologies and passenger car scrappage programme

The first step in the technology deployment approach is carrying out the market chain analysis. It serves two purposes: first, it is a framework for identifying the key stakeholders enabling the deployment process, the market chain actors and the linkage between them; second, it is a practical tool for assessing the addressable market interested in using mass transit buses and/or swapping to hybrid and fuel efficient vehicles. Market maps for mass transit buses, hybrid electric and fuel efficient gasoline vehicles are presented in annex IV. The identified stakeholders for both programmes: the mass transit system and the scrappage scheme are summarized in Table 31. They are categorized along supply, addressable market and programme enabling entities. Therefore, most of these stakeholders have been included in the consultation meetings held during the barrier analysis and enabling framework process.

Table 31 - Stakeholders and market chain actors of mass transit system and passenger cars scrappage programme.

Supply	Enabling stakeholders	Addressable market
Bus dealers. Hybrid car dealers. Fuel efficient gasoline car dealers. Association of pre-owned car importers.	Government entities: Ministry of Environment. Ministry of Finance. Ministry of Public Works and transport. Ministry of Interior and Municipalities. Central Bank of Lebanon.	Private passenger car owners. Taxi owners and taxi drivers union. Commercial car owners. Land transport union.
	Non government entities: Commercial banks. International donors.	

5.3.3 Methodology for barrier analysis

Barrier analysis can be understood as mapping out the roots to the real constraints hindering the deployment of the technologies, in order to determine the proper measures. The methodology for the barrier analysis followed in this report is outlined in Fig. 33. Each step was conducted and validated during individual consultation meetings with stakeholders identified in the market mapping technique (refer to Table 31).

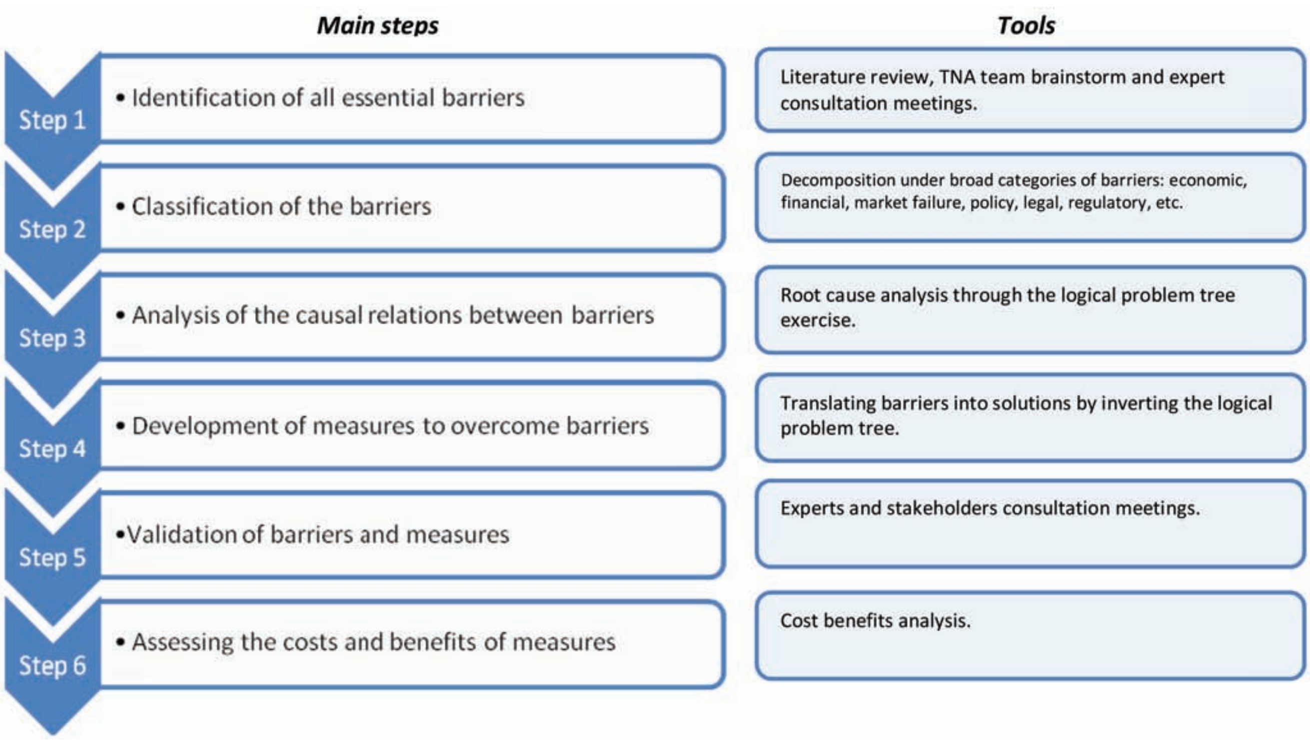


Fig. 33 - Main steps in identifying and analyzing barriers and in developing measures to overcome them.

5.4 Analysis of Technology: Deployment of transit bus technologies on dedicated lanes

5.4.1 General description of transit bus technologies

The prioritized mass transit technologies are diesel buses. The use of natural gas in buses is still at the early pre-design phase in the MoEW due to uncertainties and lack of data on the natural gas supply chain and distribution infrastructure. .

Diesel buses are still the most used bus technology worldwide, and the study presented in the TNA under GBA driving conditions showed that diesel bus public transport is a real mean to short-term solution to the environmental pollution issues in GBA, particularly when they are coupled with dedicated lanes and a well designed transport demand management system. They contribute to the different aspects of sustainable developments in GBA mainly (1) improvement of air quality, (2) reduction of GHG emissions, (3) congestion reduction, (4) increase in energy supply security due to reduction of imported oil, (5) social equality and poverty eradication by providing affordable transport with lower operating costs than passenger cars per passenger-kilometer, (6) economic prosperity by reducing travel times and congestion.

5.4.2 Identification of barriers

The barrier analysis work was carried out through a root-cause analysis presented in annex IV, summarized by a logical problem tree.

Main conclusions from the analysis are as follow:

- The starter problem of not having collective transport is the current poor market infrastructure for mass transit bus systems.
- The main barriers are:
    - The poor demand due to the mismanagement of the existing old and unmaintained fleet, the poor bus network and the long travel time.
    - The underdeveloped supply due to limited capacity of relevant institutions and insufficient number of specialized experts, particularly at the MoPWT.
    - The well-established alternatives to mass transit due to the lack of regulatory framework, from which the government is reaping benefits through tax revenues levied on fuel import and on car purchase and road usage.
- The root cause to all barriers is the absence of transport policy at the national level, providing a coherent transport demand management strategy. This lack of national policy is mainly due to having a government clash of interests and therefore limited willingness to invest.

The main economic and financial barriers are the high implementation costs of a mass transit bus systems operating on dedicated lanes, along with the inappropriate financial incentives allocated to passenger car users through loan banking facilities and easy access to pre-owned imported cars. Decomposition of barriers is summarized in Table 32.

The main non financial barriers consist of the lack of institutional capacity for planning and operation management, the absence of regulatory framework to favor mass transit buses. Decomposition of barriers is outlined in Table 33.

Table 32 - Decomposition of financial barriers to deployment of mass transit bus systems.

Economic and financial barriers		
High purchase cost of bus technologies	Inadequate government policies on purchase cost.	• High customs and excise fees (Custom and excise fees are applied similar to passenger cars). • 10% VAT on car value and duty. • For public transportation cars, car registration fees are 2% of the vehicle's estimated value.
High implementation cost	Transit bus systems need to be operated on dedicated lanes, which reduce parking areas.	• Additional costs must be considered for lanes reservation and building parking towers.
Inappropriate financial incentives and disincentives	Favorable treatment for conventional pre-owned gasoline vehicles.	• Banking loan facilities to buy pre-owned vehicles. • Large scale of pre-owned car import. • Inappropriate road-usage fees on pre-owned and brand new cars.
	Non-consideration of negative externalities in pricing transportation means using conventional gasoline vehicles.	• High urban pollution and GHG emissions due to excessive use of gasoline in old and inefficient passenger cars fleet. • Long travel time wasted due to chaotic traffic conditions in GBA.
	Tax on maintenance and repair imported spare parts.	• Custom and excise fees. • 10% VAT.
Fiscal burden on the public treasury	The current arrangement for provision of Public Transport service is fiscally unsustainable.	• The Railway and Public Transport Authority (RPTA), which maintains minimal service, requires a subsidy of USD 8.7 million per year, over twice the amount it earns from fare revenues to remain viable (in 2007). • The government subsidizes the social security obligations of the 33,000 red-plate holders estimated to be about USD 32.4 million per year (in 2007).

Table 33 - Decomposition of non-financial barriers to deployment of mass transit bus systems.

Market imperfection		
Poor market infrastructure for transit bus systems	Poor passengers demand for transit bus systems.	• Poor bus network with low frequencies (Current bus systems do not serve all boroughs, even within GBA). • Long travel time since no reserved lanes are allocated to bus. • Old and unmaintained bus fleet.
	Under-developed supply channels of transit bus system (Lack of a coherent, reliable and efficient mass transit system).	• Insufficient number of transit buses (currently no buses owned by the government are running). • No bus-stop stations. • The actual mass transit system lacks coherent organization, therefore, it does not comply with the mobility requirements and needs. • There is improper distribution of the existing public transport supply over the market. The main cities (Beirut and Tripoli) are overserved and witness severe competition among operators while other Lebanese regions suffer from a shortage of mass transit service providers. • No capability to compete with private operators of buses and minibuses which are not subject to stringent regulations, under the current institutional capacity of relevant authorities.
	Mismanaged public transport sector.	• Irregularities in bus operation, with no real-time information on the bus operation status. • Low passengers acceptance due to cleanliness and safety issues. • Poor information on existing bus tracks and network.
Market control by incumbents	Well-established alternatives to public transit systems.	• Easy access to own and use private passenger cars. • Oversupply of red plates in the marketplace: the quotas on the number of shared taxis and minibuses have not been set in relation to market demands. • Uncontrolled and unorganized shared and private taxis sector (50,000 are on the market, 17,000 are illegal, operate mostly in GBA). • Private bus operators are more competitive than public operator.
Policy, legal and regulatory		
Insufficient legal and regulatory framework	Legislation favor incumbent transport means.	• No/insufficient regulations to specify the operation maneuvers of private bus operators and taxi owners.
	Lack of implementation of legislation governing buses emissions.	• No regulation or legislation on fuel efficiency and emission standards of imported pre-owned cars (such as decree 6603/1995 relating to standards for operating diesel trucks and buses, monitoring and permissible levels of exhaust fumes and exhaust quality).
Clash of interests	Deployment of transit bus systems go against the perceived interest of the government.	Deploying transit bus might deprive the government from some revenues: • Tax revenues from customs on car purchase. • Revenues from VAT. • Revenues from registration. • Revenues from road-usage fees. • Tax revenues levied on consumed gasoline.
No enforcement to deploy transit bus systems	Missing/insufficient executive and regulatory bodies.	• Insufficient number of employees in relevant authorities to mass transit systems (particularly MoPWT).
	Insufficient willingness to enforce laws and regulations.	

Institutional and organizational capacity		
Limited institutional capacity	Limited capacity to promote and enhance market of transit bus systems.	• Limited number of employees at MoPWT, DGLMT and RPTA
	Limited number of service and maintenance specialists.	• Insufficient number of qualified bus drivers and technicians for maintenance and damage repair
	Need for specialized bodies and experts in relevant ministries and institutions at transportation planning level and operational level.	
	Fragmentation of responsibility among concerned government agencies; gap in the transport system management function with overlapping jurisdiction.	Several institutional actors deal with the field of Passenger Transportation. Each one is in a way in charge of the organization of the transport system and its functions and decisions influence the whole public transport system. These actors are: • Directorate General of Land and Maritime Transport (DGLMT) • Directorate General of Roads and Buildings which is within the MoPWT and responsible for the construction, rehabilitation and maintenance of public roads and government buildings. • Ministry of Interior and Municipalities which is in charge of vehicle registration and inspection, driver's licensing and traffic code implementation. • RPTA which is in charge of public transport operations. • Municipalities which are in charge of roads within municipal jurisdiction, and associated regulation of transport and traffic.
	Lack of technical expertise among Traffic Management Organization (TMO) staff, inhibiting it from carrying out the traffic management mandates it was conceived for.	
Human skills		
Insufficient personnel for preparing projects	Insufficient number of specialized experts in relevant ministries at planning and operational levels.	
Social, cultural and behavioral		
Consumer preferences and social biases	Lack of confidence in public transport.	• Mismanaged sector.
	Passengers prefer the easy way of using their private passenger cars.	• Passenger cars present the ultimate mean for freedom of mobility since there are no parking or access restrictions in GBA.
Information and awareness		
Lack of information	No dissemination of information on ecological and economical benefits of transit bus systems.	• No extensive efforts are needed on this point since the current traffic and economic situation in GBA serve as driving force to push travelers toward mass transit means.

5.4.3 Identification of measures

The range of measures for the deployment of a bus mass transit system in GBA, operating on dedicated lanes are presented in Table 34 and Table 35. Financial measures consists mainly of facilitating the government investments in mass transit buses. On the other side, financial disincentives cannot be imposed on other modes of transport in order to penalize them (except the road-usage fees applied to passenger cars); however, additional efforts should be made to improve the quality of service of bus mass transit systems, in order to provide a quality of service that approximates that which car drivers have been used to. As a result, dedicated lanes, wide coverage to all boroughs, real-time information, uninterrupted operation, are inevitable services.

Financial measures cannot guarantee alone the success of deployment of mass transit system. They should go along with non financial measures, summarized in Table 35. They consist mainly on deploying effective measures for improving the operation management and the infrastructure, in addition to setting up a regulatory framework that clearly manages the operation maneuvers of public bus operators, private bus operators and taxi owners.

Table 34 - Financial measures to deploy a bus mass transit system on dedicated lanes in GBA.

Economic and financial measures		
Appropriate financial incentives	Favorable treatment for mass transit buses rather than conventional pre-owned gasoline vehicles.	• Exempt mass transit buses from custom and excise fees. • Exempt from the registration fees (2% of the estimated car price).Exempt spare parts from custom and excise fees, particularly catalytic converters and filters. • Allocate concessionary fares to older people, students and disabled persons. • Use smart card ticketing schemes allowing travelling on all mass transit buses in GBA with one flexible ticket, available on daily, weekly, monthly, or yearly basis (Long term subscriptions bring additional savings to travelers).
	Encourage taxi and shared taxi owners to work in the bus mass transit system.	• Give special incentives to taxi drivers to get involved in the bus mass transit system in order to limit the number of illegal taxis (17,000 taxis) and reduce the extensive number of taxis (33,000 taxis).

Table 35 - Non financial measures to deployment of bus mass transit system on dedicated lanes in GBA.

Market development		
Develop market infrastructure	Stimulate passengers demand to use mass transit buses.	• Design of a complete bus network (bus tracks and bus stop locations) covering all boroughs within GBA
	Deploy effective infrastructure measures like an optimized land use planning.	• Reserve lanes within GBA for bus operation (reserved lanes are expected to substitute the parking spaces on both sides of the main avenues; therefore, parking spots must be constructed and managed by municipalities)
	Deploy effective operation measures like optimizing the operation management of the bus mass transit system (The objective is to provide a quality of service that approximates that which car drivers have been used to, in order to maintain a high level of mobility access in GBA with a drop in overall car usage).	• Conserve a clear and regular bus operation • Implement a real-time information system, tracking the bus operation and displaying the waiting time (information to be displayed on screens in bus stations, on mobile smartphones through special applications and on dedicated websites) • Deploy personalized travel planning tools in order to optimize and predict the travel time • Implement intelligent transport technologies like the transit signal priority in order to reduce the bus stop times on red lights • Set up stringent maintenance and cleanliness programme.
	Develop the supply channels of bus mass transit system.	• Purchase sufficient number of transit buses with the proper powertrain technology, in order to cover the designed network and avoid irregularities in operation • Construct bus stations taking into consideration the physical access to buses and stations (for example: improvements to pavements, access ramps for people with limited accessibility, timetables which can be read by those with visual impairment) • Construct relevant maintenance and repair workshops.
Manage the transport demand rather than being controlled by incumbents	Deploy a combination of access, personal travel planning and parking spots to lock the benefits from the aimed operational and infrastructural measures	
Technological development	Encourage and rely on R&D institutions in order to adopt knowledge-intensive high-tech management approaches for solving complex urban transport problems.	• Follow up on environmental and economical benefits, and to test advancement in new technologies • Favor R&D to create local spare parts manufacturer.

Policy, legal and regulatory		
Set up a regulatory framework for mass transit sector	Legislation favor mass transit transport means in general and public bus transit in particular.	• Set clear regulations specifying the operation maneuvers of private bus operations and taxi owners (such regulations must be preceded by setting up a national policy for the global mass transit sector, including the role of each of the private and public operators and the taxi owners).
	Enforce the deployment of bus transit systems.	• Create/enhance executive and regulatory bodies in charge of ensuring the design, deployment and follow up of the regulatory framework. • Restructure, empower and enhance the role of the traffic management organization (TMO).
	Implement legislation governing buses emissions.	• Update and implement decree 6603/1995 relating to standards for operating diesel trucks and buses, monitoring and permissible levels of exhaust fumes and exhaust quality • Enforce the bus inspection programme requirements and mandating the presence of catalytic converters.
	Enforce legislative reforms in urban planning laws, expropriation laws (if needed in some areas), and traffic laws.	• Redefine the use of urban road infrastructure, taking into consideration the total/partial exclusive use of lanes in mass transit buses. • Encourage municipalities to build parking spots to optimize the urban road space and allow reservation of lanes for mass transit buses. • Adopt a transit signal priority on red lights in order to reduce the bus travel time.
Institutional and organizational capacity		
Develop institutional capacity	Enhance bus transit services.	• Recruit and train bus drivers on eco-driving attitude and safety principles. • Recruit and train specialized maintenance technicians. • Recruit and train management and control staff in charge of managing and optimizing the planning and bus operation.
	Clarify and centralize responsibility among concerned government agencies in order to tackle the gap in the transport system management function.	
	Restructure, empower and enhance the role of the Traffic Management Organization (TMO).	• Develop technical expertise among TMO staff, in order to carry out the traffic management mandates it was conceived for.

Social awareness		
Dissemination of information	Aware travelers on ecological and economical benefits of transit bus systems.	• Provide information on CO_2 and fuel savings comparing to passenger cars, through the proper info display tools: mobile applications, dedicated website, media campaigns, etc.

5.4.4 Action Plan for deployment of transit bus technologies on dedicated lanes

Target for technology transfer and diffusion

The objective of the TNA for deploying mass transit buses is to highlight the benefits of bus transit system on dedicated lanes in GBA in terms of fuel savings and emissions reduction. The assessment is carried out per bus unit, and results show considerable savings. Therefore, the focus is to identify the proper strategy to revitalize the public transport and the most efficient bus technologies under the current driving conditions in GBA. Specifying the number of buses and design of the mass transit road networks need an engineering assessment study and was left for further steps with relevant authorities.

However, according to studies carried out by the MoPWT on public transport revitalization relying on bus transit, it is estimated that 507 buses will be needed in GBA, 85 in Tripoli, and 45 to serve intercity; a total of 637 buses countrywide. The total non-recurring investment in vehicles, infrastructure, terminals, depots, etc., is estimated at USD 400 million. Such revitalization target could be implemented on a 5 year basis. It is recommended that urban buses be operated on natural gas for a better air quality; however, this plan is mainly affected by the security of supply of natural gas to Lebanon, and a comprehensive feasibility study needs to be carried out to assess this option. The Technology Action Plan for transit bus technologies operating on diesel and on dedicated lanes is presented in Table 36.

Table 36 - Technology Action Plan for transit bus technologies on dedicated lanes

Measures	Priority	Objectives	Responsibilities	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)
Design a complete bus network covering all boroughs within GBA and reserve lanes for bus operation	1	Shift travel demand to efficient transport means: bus transit system.	Municipalities OCFTC DGRB CDR	Short term	Bus network on reserved lanes in GBA.	500,000 (design study of the network).
Ensure sufficient number of transit buses with the proper powertrain technology	1	Cover the designed network with sufficient number of buses and avoid irregularities in operation	MoPWT	Short term	Purchase of the required buses.	0
Exempt mass transit buses (and their spare parts) from custom and excise fees, and from registration fees	1	Decrease the cost incurred for the government on the import of the mass transit buses and give appropriate financial incentives for mass transit buses.	MoF	Short term	Law on fee exemption enacted by the government.	N/A
Create an employee package for taxi drivers (including social benefits, insurance, retirement plans, etc.)	1	- Encourage taxi and shared taxi owners to work in the bus mass transit system - Limit the number of illegal taxis (17,000 taxis) and reduce the extensive number of taxis (33,000 taxis)	MoPWT OCFTC MoF	Short/ Medium term	Package for bus drivers.	1,000 (legal services to create a package).

Measures	Priority	Objectives	Responsibilities	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)
Establish smart card ticketing schemes with appropriate reduced tariffs	2	-Stimulate passengers demand to use mass transit buses. - Shift travel demand to efficient transport means: bus transit system.	OCFTC	Medium term	Smart card ticketing schemes.	0
Optimize the operation management of the bus mass transit system: conserve a clear and regular bus operation, implement a real-time information system, deploy personalized travel planning tools, implement transit signal priority, set up stringent maintenance and cleanliness programme , construct relevant maintenance and repair workshops	2	- Provide a quality of service that approximates that which car drivers have been used to with passenger cars.	MoPWT DGLM OCFTC	Short/ Medium term	Operation management strategy.	0
Set clear regulations specifying the operation maneuvers of private bus operations and taxi owners	3	Manage the transport demand rather than being controlled by incumbents (private and public operators and the taxi owners)	MoPWT	Short term	Legislation on specifying the operation maneuvers between the various mass transit operators.	0
Draft new amended laws for increasing parking space and reserving lanes for buses	4		MoPWT	Short/ Medium term	Parking spots and reserved lanes for mass transit buses in congested urban areas.	0

Measures	Priority	Objectives	Responsibilities	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)
Develop technical expertise among TMO staff and high level management	5	- Carry out the traffic management mandates it was conceived for. - Enhance the role of the Traffic Management Organization (TMO).	MoPWT	Medium term	Well-trained TMO staff.	8,000 (technical training of 15 employees).
Provide information on CO_2, fuel and cost savings comparing to passenger cars	6	- Increase awareness of travelers on ecological and economical benefits of transit bus systems. - Shift travel demand to efficient transport means: bus transit system.	MoPWT	Short/ Medium term	info display tools on CO_2 and fuel savings: mobile. applications, dedicated website, media campaigns, etc.	50,000 (full awareness campaign).

5.5 Analysis of Technology: deployment of hybrid and fuel efficient gasoline-powered vehicles through a scrappage programme

5.5.1 General description of hybrid electric vehicles and fuel efficient gasoline-powered vehicles

Fuel efficient gasoline powered vehicles

Fuel efficient vehicles are conventional gasoline powered vehicles with low consumption, equipped with advanced technologies, reduced vehicle weight, downsized engine, idle stop/start systems and continuous variable transmissions.

Considerable consumption and CO_2 emissions savings are observed with fuel efficient vehicles from 10% to 50% comparing to the world average new cars fleet of 2005, and from 35% to 64% comparing to the Lebanese average consumption of the passenger cars fleet in 2007 under GBA driving conditions. Therefore, all these vehicle segments must be promoted through proper incentives and adequate tax policies, to substitute the current Lebanese trend of buying large inefficient cars.

Hybrid electric vehicles

Hybrid electric vehicles (HEV) combine an electric motor and battery pack to the internal combustion engine (ICE) found in conventional vehicles. They are characterised by low consumption, high driving range, reduced emissions and downsized engine. Hybrid vehicles present 40% to 53% fuel and CO_2 savings compared to small to midsize cars.

5.5.2 Identification of barriers

Barriers for deployment of fuel efficient gasoline cars are few and a fuel efficient car market is already established. However, these cars need additional measures are needed to favor their deployment over the imported pre-owned vehicles that are flooding the market.

As for hybrid cars, the market is still inexistent due to the following main barriers:

- The low demand for hybrid vehicles due to the high purchase cost of these cars, the lack of consumer or market incentives and the wrong perception of consumers regarding hybrid cars' performance.

- The high demand for pre-owned non efficient gasoline vehicles due to the low cost of these cars, the banking loan facilities, and the current inappropriate road-usage fees.
- The root cause to all barriers is similar to that for deploying mass transit buses: the inadequate current transport policy and the lack of national policy providing a coherent transport demand management strategy. Once again, this lack of national policy is mainly due to having a government clash of interests and therefore limited willingness to invest.

The main economic and financial barrier is the inappropriate financial incentives and disincentives, through a favorable treatment to conventional pre-owned gasoline vehicles, faced by lack of any incentive for fuel efficient and hybrid technologies. Decomposition of barriers for hybrid and fuel efficient vehicles is summarized respectively in Table 37.

The main root cause of non-financial barrier is the loss of revenues for the government from taxes related to the import of gasoline and gasoline vehicles. In fact, the government collects revenues from taxes levied on imported gasoline and car purchase, in addition to road-usage fees proportional to engine displacement. Moreover, private companies import the gasoline for transportation; therefore, the government does not have any interest in reducing the imported quantity, unless the assessment of the impact of the external costs resulting from the excessive dependence on gasoline (health concerns, emissions and pollution impact, etc.) is internalized. Decomposition of barriers is outlined in Table 38.

Table 37- Decomposition of financial barriers to deployment of hybrid and fuel efficient vehicles.

Economic and financial barriers		
High purchase cost particularly of hybrid vehicles	Inadequate government policies on purchase cost (MoF, 2011)	• High customs and excise fees. • Inadequate registration fees. • Inadequate road-usage fees. • 10% VAT on car's estimated value plus duty.
Financially not viable to some dwellers.	Low affordability amongst part of rural and peri-rural dwellers	• Low income (CAS, 2011).
Inappropriate financial incentives and disincentives to both hybrid and fuel efficient vehicles	Favorable treatment to conventional pre-owned gasoline vehicles	• Banking facilities to buy pre-owned vehicles • Large scale of pre-owned car import dating up to 8 years old. • Inappropriate road-usage fees on pre-owned and brand new cars.
	No market incentives to deploy hybrid and fuel efficient vehicles	• High customs and excise fees. • 10% VAT on car's estimated value plus duty.
	No consumer incentives to buy hybrid and fuel efficient vehicles	• Inadequate registration fees. • Inadequate road-usage fees at registration. • High insurance fees. • Must pay loan interest.
	Non-consideration for externalities in pricing transportation means using conventional gasoline vehicles	• High urban pollution and GHG emissions due to excessive use of gasoline in old and inefficient passenger cars fleet. • Long travel time wasted due to chaotic traffic conditions in GBA.

Table 38 - Decomposition of non financial barriers to deployment of hybrid and fuel efficient vehicles.

Market failure/imperfection		
No hybrid vehicles market	Poor demand for hybrid.	• High purchase and ownership costs. • No market incentives. • No consumer incentives. • Low consumer acceptance (resistance to change).
Underdeveloped competition	Insufficient number of hybrid vehicle suppliers	• HEV suppliers have no incentives or will to invest before any law is ratified exempting these cars from excise and custom taxes (Bejjani, 2012; Younis, 2012).
Lack of reference projects in Lebanon	The recent extensive use of sub-compact fuel efficient cars by private companies has led to promoting them, due to the positive feedback on the tangible fuel consumption savings. No such experience is available for hybrid vehicles	
Policy, legal and regulatory		
Insufficient legal and regulatory framework	Legislation favor conventional gasoline vehicles	• Lack of stringent fuel-efficiency and carbon standards on imported pre-owned and new gasoline vehicles. • Lack of implementation of legislation governing vehicle emissions (such as Decree 6603/1995). • Lack/corrupted safety control bodies on pre-owned imported cars when entering the country.
	Lack of coherent tax policies	• Higher road-usage fees on new cars which have low emission levels v/s lower road-usage fees on pre-owned old imported vehicles with unknown/high emission levels (MoF, 2011) (For example, a new 10 horsepower efficient car pays USD 216 road-usage fees, and a 50 horsepower car made before 1997 pays USD 153, 30% less).
	Hybrid and fuel efficient cars deployment goes against the perceived interest of the government	• Deploying HEV and fuel efficient cars might deprive the government from some revenues: • Tax revenues from customs on car purchase. • Revenues from VAT, consumed gasoline, registration and from road-usage fees.
Network failures		
Weak connectivity between actors favoring HEV and fuel efficient cars deployment	Insufficient coordination between relevant ministries and HEV suppliers. No cooperation between relevant ministries and R&D institutions.	
Incumbent networks of pre-owned car importers are favored	No regulation or legislation on fuel efficiency and emission standards of imported pre-owned cars.	
Lack of involvement of stakeholders in decision-making regarding transport policies	Stakeholders' consultation culture missing.	

<table>
<tr><td colspan="3">Institutional and organizational capacity</td></tr>
<tr><td>Lack of professional institutions</td><td colspan="2">• Need for specialized bodies in relevant ministries at transportation planning level and operational level.
• Lack of/inefficient regulatory body in the transport sector.
• Lack of institutions to support technical standards for transportation.</td></tr>
<tr><td>Limited institutional capacity</td><td>No R&D culture in transportation.</td><td>• R&D facilities are missing.
• Lack of appreciation of R&D role in mitigating transport technologies.</td></tr>
<tr><td colspan="3">Human skills</td></tr>
<tr><td>Lack of service and maintenance specialists</td><td colspan="2">Low availability of qualified technicians for HEV maintenance and damage repair except at car dealers.</td></tr>
<tr><td>Inadequate personnel for preparing projects</td><td colspan="2">Limited number of specialized experts in relevant ministries.</td></tr>
<tr><td colspan="3">Social, cultural and behavioral</td></tr>
<tr><td>Tradition and habits</td><td colspan="2">Resistance to change due to unfamiliarization and wrong perception of new technologies.</td></tr>
<tr><td>Lack of confidence in HEV</td><td>Unknown product due to inadequate information on HEV performance.</td><td>Wrong perception on hybrid vehicles’ performance.</td></tr>
<tr><td colspan="3">Information and awareness</td></tr>
<tr><td>Inadequate information</td><td colspan="2">No dissemination of information to consumers on HEV performance, environmental and economical benefits, etc.</td></tr>
<tr><td colspan="3">Technical</td></tr>
<tr><td rowspan="3">Inadequate standards, codes and certification</td><td colspan="2">Lack of initiatives to set standards on vehicle emissions and fuel efficiency.</td></tr>
<tr><td colspan="2">Standards not obligatory.</td></tr>
<tr><td colspan="2">Lack of facilities for testing vehicles and certification.</td></tr>
<tr><td colspan="3">Data and information</td></tr>
<tr><td>Lack of mobility monitoring data</td><td>Limited monitoring data to support transport studies aiming at the development of sustainable transportation strategies.</td><td>• Lack of Mobility Monitoring Indicators (MMI) framework, which serve as the basic step in setting a national sustainable mobility strategy
• The Central Administration of Statistics (CAS) publishes very basic information on transport sector status.
• Transport studies carried out by ministries and relevant authorities are not shared, neither the results nor even the information on the content (as a result, work is duplicated without reaching to a national transport strategy set up).</td></tr>
</table>

5.5.3 Identification of measures

Creating conditions for deploying green transport alternatives in general and hybrid and fuel efficient vehicles in particular requires government-mandated regulatory measures together with incentives that motivate a shift in behavior. Based on the analysis of current barriers facing that deployment, the following measures are suggested so that conditions favorable to efficient transport can be cultivated.

The range of financial measures presented in Tables 39 and 40 are intended to enable the creation of a hybrid vehicle market and to favor sales of fuel efficient vehicles, to encourage both sides of the market chain: the car suppliers to invest, and the consumer to swap old cars with hybrid or a fuel efficient car. Concurrently, disincentives should be introduced to limit the market of non-efficient and pre-owned imported vehicles. Therefore, a balance must be created through proper allocation of purchase taxes and/or road-usage fees, based on a stringent fuel-efficiency and emission standards on pre-owned vehicles, instead of allowing fees based on engine horsepower and the model year.

An example is the **French Bonus-Malus programme** applied since 2007 to new vehicle purchase. The registration or purchase tax is a one-off tax levied on vehicles related to the CO_2 rate of emission, according to a differentiated energy class system currently consisting of seven emission classes. Vehicle emitting more than 150 g/km are subject to malus and those lower than 110 g/km receives a bonus subsidy from the government (ADEME, 2011). Moreover an annual Malus of USD 205 (160 Euros) is owed by owners of vehicles emitting more than 245 g/km. Bonus-Malus scheme and programme outcomes are summarized in Fig. 34 and Fig. 35, showing the success of the programme has succeeded in favoring the sale of fuel efficient cars, reaching 56% in 2009 for the bonus classes.

Financial measures must go along with non financial actions mainly in issuing the requested legislations and setting the regulatory framework for implementing the incentives and making the relevant tax reform. Moreover, information dissemination to consumers during car purchase on consumption, emissions and money savings is of high importance in order to cope with the resistance to change of consumers and the wrong perception on hybrid car performance.

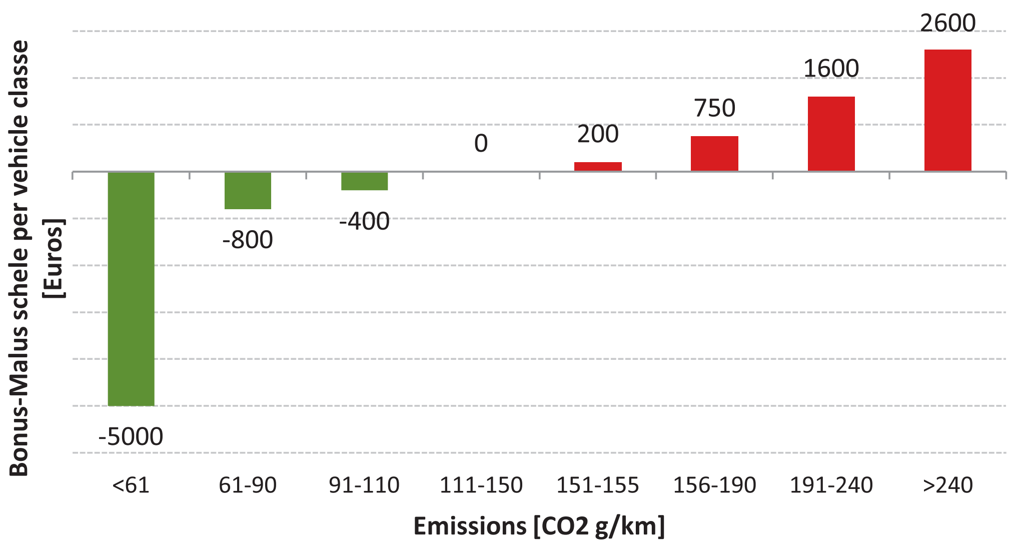


Fig. 34 - Bonus-Malus on car sales per emissions class (a negative value is a bonus).

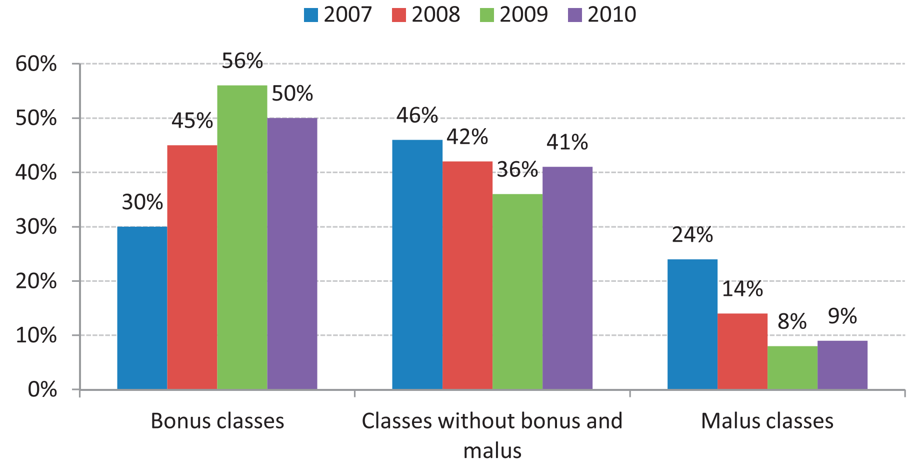


Fig. 35 - Structure of car sales according to the bonus-malus scheme.

Table 39 - Financial measures for the creation of hybrid vehicle market and favoring sale of fuel efficient vehicles.

Economic and financial measures		
Government incentives to reduce vehicle purchase and ownership costs	Market incentives	• Exemption from customs and excise fees on vehicles to favor hybrid and fuel efficient car suppliers invest. • Exemption from custom and excise fees on non conventional hybrid spare parts (battery, electric motor, etc.) in order to favor spare parts suppliers invest.
	Consumer incentives	• Exemption from registration fees. • Exemption from road-usage fee at registration. • Payment of minimum salvage value (ex. USD 2,500) as down payment for car loan. • Extension of loan period to 8 years particularly for hybrid car purchase. • Reduce loan interest and/or full subsidy of loan interests for heavy mileage drivers like taxi owners.
	Technicians incentives	• Help domestic maintenance and repair technicians to buy equipments through banking facilities (kafalat programme).
Government disincentives to import of non efficient pre-owned vehicles	Set up coherent tax policies disadvantaging the demand for high fuel consuming pre-owned vehicles	• Reduce gradually maximum age of imported pre-owned vehicles to 3 years with a mileage lower than 100,000 km, rather than 8 years as the current figure. • Road-usage fees must be reconsidered according to fuel efficiency and/or emissions rather than engine displacement as the current figure: - Increase gradually road-usage fees on old high consuming vehicles, already owned by consumers. - Increase road-usage and registration fees on imported pre-owned high consuming vehicles. - Reduce road-usage and registration fees on new and pre-owned low consuming vehicles. - Increase road-usage fees on the second owned car, for private use.
	Set up stringent fuel-efficiency and emissions standards on pre-owned imported vehicles	• Fuel-efficiency and emissions standards are intended to help setting adequate tax policies *(Bonus-Malus: polluters pay more taxes)*, in order to favor low consuming new and pre-owned vehicle rather than high consuming pre-owned vehicles.

Table 40 - Non-financial measures for the creation of hybrid vehicle market and favoring sale of fuel efficient vehicles.

Market development		
Implement a vehicle retirement programme with incentives	Create a car termination plant	• Create a plant that deals with the car termination process after the swap in the scrappage programme (interested customers in swap shall not have a grant salvage value for their old car or any incentive unless they got the certificate of car termination from the MoE or other special entity in charge). Car termination process is one of the success key of the scrappage programme; therefore, old car termination options should be clearly stated and formulated.
Policy, legal and regulatory		
Set up legal and regulatory framework to create HEV market and promote fuel efficient vehicles	Issuance of law exempting these cars from customs, registration and road-usage fees at registration in order to amend vehicle taxation system into a more balanced environmentally oriented scheme	• Exemption of new HEV from customs and excise fees, and from registration and road-usage fees at registration. • Exemption/reduction of new fuel efficient vehicles from custom and excise fees. • Payment of minimum salvage value (ex. USD 2,500) as down payment for hybrid vehicle loan. • Exemption of salvage old cars from unpaid road-usage fees in order to encourage their owners to swap their old cars (as in the law, these owners cannot sell their cars if they do not pay all due road-usage fees). • Full subsidy of loan interests over loan period for taxi drivers, students and disabled persons swapping for hybrid cars.
	Implement legislation governing vehicle emissions	• Update and implement decree like that of 6603/1995 relating to standards on permissible levels of exhaust fumes and exhaust quality. • Enforce/update the vehicle inspection programme requirements taking into consideration the special requirements for hybrid cars' inspection, in addition to mandating the presence of catalytic converters on conventional gasoline vehicles.
Set up new coherent tax policies	Issuance of law modifying the current tax figure in order to cope with the high demand for high fuel consuming pre-owned vehicles	• Adopt a Bonus-Malus tax policy where polluters pay more annual road-usage fees.
Institutional and organizational capacity		
Create professional institutions	Create institutions to support technical standards for transportation	• Set up a mechanical inspection unit at the port of Beirut in charge of checking up the emissions and safety standards of imported pre-owned cars before entering the country.
Promote technological development	Promote R&D culture in transportation in order to adopt knowledge-intensive high-tech management approaches for solving complex urban transport problems in GBA	• Encourage local industry to develop and manufacture spare parts • Give incentive to R&D institutions which play an essential role in mitigating transport technologies • Encourage universities to create engineering mobility programmes.

Social awareness		
Awareness campaign to promote hybrid and fuel efficient cars	Dissemination of information to consumers on these cars' performance, environmental and economical benefits	• Enforce new car dealers to include factsheets on all vehicles, clearly displaying information on vehicle average fuel consumption and annual fuel costs, in addition to average CO_2 emissions. • Enforce marketing campaign (billboards, TV, etc.) to include the mentioned above consumption and emissions labeling of the car. • Enforce all government vehicles to switch to HEV when buying new cars, in order to take the lead as a reference project.
	Dissemination of information to particular consumers which have high annual mileage like taxi drivers and commercial vehicle users	• Present additional financial incentives like the full subsidy of loan interests over the loan period.
Data and information		
Set up a mobility monitoring organism (with an easy and free access to data, particularly for R&D institutions)	Create Mobility Monitoring Indicators (MMI) framework to support transport studies aiming at the development of sustainable transportation strategies	• Delegate the CAS with additional experienced personnel and authority to provide on yearly basis the complete MMI set. • Enforce cooperation and communication on transport studies between relevant authorities resource savings.

5.5.4. Action Plan for deployment of hybrid and fuel efficient gasoline-powered vehicles through a scrappage programme

Target for technology transfer and diffusion

The aim from promoting and deploying hybrid and fuel efficient vehicles is not introducing additional passenger cars to the fleet (1.5 million cars are officially registered in 2010) but replacing non efficient vehicles. Therefore, the target consists of developing and implementing a complementary, integrated car scrappage programme aiming at reducing emissions from the existing fleet, where old, illegal, highly emitting, non fuel efficient vehicles would be bought by the Government and scrapped. In return, owners of scrapped cars are allocated an incentive to buy a new hybrid or fuel efficient car. Incentives can have various forms, such as custom and excise exemption, exemption from registration and road usage fees, payment of minimum salvage value (ex. USD 2,500) as down payment for new car loan, reduce loan interest and/or full subsidy of loan interests for heavy mileage drivers like taxi owners.

Such programme pursues a range of social and economic goals in addition to reducing emissions, such as preventing vehicle abandonment, lowering consumer spending on gasoline, and stimulating new vehicle sales. As a result, the vehicle turnover rate increases by incentivizing vehicle retirement.

The implementation of a car scrappage programme in Lebanon is a top priority measure that needs to be undertaken in parallel to implementing a bus mass transit system on dedicated lanes. However, car scrappage can have various forms of incentive-based applications. For heavy mileage drivers like taxi owners, where swapping to hybrid or fuel efficient vehicles have a high impact on enhancing air quality and reducing emissions, maximum incentives should be allocated. The estimated size of the taxi drivers interested by a car swap under scrappage programme is around 12,000 over 8 years, with driver age lower than 55 and car model year older than 2007. However, for private passenger car owners, estimated size depends largely on the incentives to be allocated: a well-defined programme could target a car fleet renewal between 8% and 10% by 2020.

Strict control needs to be exerted simultaneously in order to enforce the ban on old cars and therefore prevent the illegal import of such old cars that need scrapping. In parallel, strict emission standards need to be defined and enforced, in addition to amending the vehicle taxation system and registration fees into a more balanced environmentally oriented scheme. A comprehensive feasibility study needs to be carried out to assess and well-define such programme.

The technology Action plan for the deployment of hybrid and fuel efficient gasoline-powered vehicles through a scrappage programme is presented in Table 41.

Table 41 - Technology Action plan for hybrid and fuel efficient gasoline-powered vehicles through a scrappage programme

Measures	Priority	Objectives	Responsible parties	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)
Exemption from customs and excise fees, exemption from registration fees, exemption from road-usage fee at registration	1	- Create appropriate financial incentives for hybrid and fuel efficient cars. purchase - Reduce car purchase and ownership costs.	MoF	Short term	Law on tax exemption by government.	0
Payment of minimum salvage value (ex. USD 2,500) as down payment for car loan, extension of loan period to 8 years, reduce loan interest	1		MoF BDL. Commercial Banks	Short term	Car loan package and facilities for hybrid and fuel efficient cars.	2,500 per car
Reduce gradually maximum age of imported pre-owned vehicles to 3 years with a mileage lower than 100,000 km, rather than 8 years as the current figure	1	- Create disincentives for import of non efficient pre-owned cars - Limit the import of pre-owned non fuel efficient vehicles.	MoM	Short/ Medium term	Law on import of pre-owned cars.	0
Adopt a Bonus-Malus tax policy where polluters pay more annual road-usage fees, and where taxes like the road usage fees are reconsidered according to fuel efficiency and/ or emissions rather than engine displacement as the current figure	2	Set up new coherent tax policies to cope with the high demand for high fuel consuming pre-owned vehicles.	MoF	Short term	Bonus-Malus tax scheme.	10,000 (for the preparation of the bonus-malus draft policy)

Measures	Priority	Objectives	Responsible parties	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)
Create a car scrappage programme based on swapping current passenger cars with hybrid and fuel efficient cars	2	Renew the passenger car fleet Enhance the efficiency of the passenger car fleet.	MoF New cars dealers	Short term	Car scrappage program.	30,000
Create a car termination plant that deals with the car termination process after the swap in the scrappage programme	3	Implement a vehicle retirement programme to remove old cars from the fleet.	MoPWT MoIM MoE	Short/ Medium term	Car termination plant.	-
Update decree 6603/1995 relating to standards on permissible levels of exhaust fumes and exhaust quality to cover all types of vehicles	4	Improve air quality as transport sector is the main air polluter.	MoE	Short/ Medium term	Updated law 6603/1995.	0
Update the vehicle inspection programme requirements taking into consideration special requirements for hybrid cars' inspection, in addition to mandating the presence of catalytic converters on conventional gasoline vehicles	4	Improve the vehicle inspection programme.	MoE MoIM	Short/ Medium term	Updated vehicle inspection programme.	50 per trained person
Set up a mechanical inspection unit at the port of Beirut in charge of checking up the emissions and safety standards of imported pre-owned cars before entering the country	5	- Create institutions to support technical standards for transportation - Limit the import of deficient and crashed pre-owned cars.	MoPWT MoE	Short/ Medium term	Mechanical inspection unit at the port of Beirut.	-
Establish awareness campaign	6	Promote hybrid and fuel efficient cars.	MoPWT MoE	Short/ Medium term	Awareness campaign.	50,000 (full awareness campaign)
Create Mobility Monitoring Indicators (MMI) framework	7	Develop sustainable transportation strategies.	MoPWT MoE CAS	Short/ Medium term	Mobility monitoring indicator framework delegated to CAS.	0

5.6 Enabling framework for overcoming the barriers in transport sector

Fully eradicating the problems of the Lebanese transport sector in GBA is neither affordable, nor economically feasible. However, much can be done to reduce and to lessen the burden of their negative impacts on travelers and the public treasury. Hence, effectively managing this sector requires both a holistic and integrated strategy that goes beyond the visible incidence of these problems and extends to setting a national transport policy, managing all transport services as a whole.

This project has served to highlight the barriers and measures of mass transit buses, hybrid vehicles and fuel efficient gasoline vehicles: technologies highly prioritized by transport experts and stakeholders. While there are many possible measures that can be deployed, there is no single perfect solution. The following Tables propose an enabling framework for a set of measures, presented at two levels. The first level addresses the common barriers of the prioritized technologies, and the second level is technology-specific.

Table 42 provides a summary of the common measures for deploying prioritized technologies.

Table 42 - Common measures for deploying the prioritized technologies.

Economic and financial measures	Policy, legal and regulatory	Institutional and organizational capacity	Social awareness	Data and information
Amend vehicle taxation system and registration fees into a more balanced environmentally oriented scheme: • Exempt mass transit buses and hybrid vehicles from custom and excise fees, registration fees • Exempt spare. parts from custom and excise fees, particularly catalytic converters and filters and electric components for hybrids.	Issuance of laws exempting vehicles from customs, and registration fees.	Create institutions to support technical standards for transportation: • Set up a mechanical inspection unit at the port of Beirut in charge of checking up the emissions and safety standards of imported passenger cars and buses before entering the country.	Aware travelers on ecological and economical benefits of transit bus systems and hybrid and fuel efficient vehicles: • Provide information on CO_2 and fuel savings comparing to passenger cars, through the proper info display tools: mobile applications, dedicated website, media campaigns, etc.	Create Mobility Monitoring Indicators (MMI) framework to support transport studies aiming at the development of sustainable transportation strategies: • Delegate the CAS with additional experimented personnel and authority to provide on yearly basis the complete MMI set. • Enforce cooperation and communication on transport studies between relevant authorities for time, money and efforts savings.
	Implement legislation governing vehicles emissions: • Update and implement decree like that of 6603/1995 relating to standards on permissible levels of exhaust fumes and exhaust quality. • Enforce/update the vehicle inspection programme requirements.	Promote R&D culture in transportation in order to adopt knowledge-intensive high-tech management approaches for solving complex urban transport problems in GBA: • Encourage local industry to develop and manufacture spare parts. • Give incentive to R&D institutions which play an essential role in mitigating transport technologies. • Encourage universities to create engineering mobility programmes.		

Table 43 - Specific measures for deploying mass transit bus system in GBA on dedicated lanes.

Economic and financial measures	Market development	Policy, legal and regulatory	Institutional and organizational capacity
Favorable treatment for mass transit buses rather than conventional pre-owned gasoline vehicles: - Allocate concessionary fares to older people, students and disabled persons. - Use smart card ticketing schemes allowing travelling on all mass transit buses in GBA with one flexible ticket, available on daily, weekly, monthly, or yearly basis (Long term subscriptions bring additional savings to travelers).	Stimulate passengers demand to use mass transit buses: - Design of a complete bus network (bus tracks and bus stop locations) covering all boroughs within GBA.	Legislation favor mass transit transport means in general and public bus transit in particular: - Set clear regulations specifying the operation maneuvers of private bus operations and taxi owners (such regulations must be preceded by setting up a national policy for the global mass transit sector, including the role of each of the private and public operators and the taxi owners).	Develop institutional capacity to enhance bus transit services: - Recruit and train bus drivers on eco-driving attitude and safety principles. - Recruit and train specialized maintenance technicians. - Recruit and train management and control staff in charge of managing and optimizing the planning and bus operation.
Encourage taxi and shared taxi owners to work in the bus mass transit system: - Give special incentives to taxi drivers to get involved in the bus mass transit system in order to limit the number of illegal taxis (17 000 taxis) and reduce the extensive number of taxis (33 000 taxis).	Deploy effective infrastructure measures like an optimized land use planning: - Reserve lanes within GBA for bus operation (reserved lanes are expected to substitute the parking spaces on both sides of the main avenues; therefore, parking spots must be constructed and managed by municipalities).	Enforce the deployment of bus transit systems: - Create/enhance executive and regulatory bodies in charge of ensuring the design, deployment and follow up of the regulatory framework (set above). - Restructure, empower and enhance the role of the traffic management organization (TMO).	Clarify and centralize responsibility among concerned government agencies in order to tackle the gap in the transport system management function.
	Deploy a combination of access, personal travel planning and parking spots to lock the benefits from the aimed operational and infrastructural measures (set above in this Table).		

Economic and financial measures	Market development	Policy, legal and regulatory	Institutional and organizational capacity
	Deploy effective operation measures like optimizing the operation management of the bus mass transit system: - Conserve a clear and regular bus operation. - Implement a real-time information system, tracking the bus operation and displaying the waiting time (information to be displayed on screens in bus stations, on mobile smartphones through special applications and on dedicated websites). - Deploy personalized travel planning tools in order to optimize and predict the travel time. - Implement intelligent transport technologies like the transit signal priority in order to reduce the bus stop times on red lights. - Set up stringent maintenance and cleanliness program.		
	Develop the supply channels of bus mass transit system: - Purchase sufficient number of transit buses with the proper powertrain technology, in order to cover the designed network and avoid irregularities in operation. - Construct bus stations taking into consideration the physical access to buses and stations (for example: improvements to pavements, access ramps for people with limited accessibility, timetables which can be read by those with visual impairment). - Construct relevant maintenance and repair workshop.	Enforce legislative reforms in urban planning laws, expropriation laws (if needed in some areas), and traffic laws: - Redefine the use of urban road infrastructure, taking into consideration the total/partial exclusive use of lanes in mass transit buses only. - Encourage municipalities to build parking spots to optimize the urban road space and allow reservation of lanes for mass transit buses. - Adopt a transit signal priority on red lights in order to reduce the bus travel time.	Restructure, empower and enhance the role of the Traffic Management Organization (TMO): - Develop technical expertise among TMO staff, in order to carry out the traffic management mandates it was conceived for.

Table 44 - Specific measures to create a market of hybrid and fuel efficient vehicles for implementing a scrappage programme.

Economic and financial measures	Market development	Policy, legal and regulatory	Social awareness
Government incentives to consumer: - Exemption from road-usage fee at registration. - Payment of minimum salvage value (ex. 2500 USD) as down payment for car loan. - Extension of loan period to 8 years particularly for hybrid car purchase. - Reduce loan interest and/or full subsidy of loan interests for heavy mileage drivers like taxi owners.	Create a car termination plant: - Create a plant that deals with the car termination process after the swap in the scrappage programme (interested customers in swap shall not have a grant salvage value for their old car or any incentive unless they got the certificate of car termination from the MoE or other special entity in charge). (car termination process is one of the success key of the scrappage program; therefore, old car termination options should be clearly stated and formulated).	Issuance of law modifying the current tax figure in order to cope with the high demand for high fuel consuming pre-owned vehicles: - Adopt a Bonus-Malus tax policy where polluters pay more annual road-usage fees.	Dissemination of information to consumers on these cars' performance, environmental and economical benefits: - Enforce new car dealers to post up factsheets on all vehicles, clearly displaying information on vehicle average fuel consumption and annual fuel costs, in addition to average CO_2 emissions. - Enforce all marketing campaign (billboards, TV, etc.) to post up the mentioned above consumption and emissions labeling of the car. - Enforce all government vehicles to switch to HEV when buying new cars, in order to take the lead as a reference project.
Government incentives to technicians: - Help domestic maintenance and repair technicians to buy equipments through banking facilities (kafalat programme).			Dissemination of information to particular consumers which have high annual mileage like taxi drivers and commercial vehicle users: - Present additional financial incentives like the full subsidy of loan interests over the loan period.
Set up stringent fuel-efficiency and emissions standards on pre-owned imported vehicles: - Fuel-efficiency and emissions standards are intended to help setting adequate tax policies (Bonus-Malus: polluters pay more taxes), in order to favor low consuming new and pre-owned vehicle rather than high consuming pre-owned vehicles.			

Economic and financial measures	Market development	Policy, legal and regulatory	Social awareness
Government disincentives to import of non efficient pre-owned vehicles: Set up coherent tax policies disadvantaging the demand for high fuel consuming pre-owned vehicles: - Reduce gradually maximum age of imported pre-owned vehicles to 3 years with a mileage lower than 100 000 km, rather than 8 years as the current figure. - Road-usage fees must be reconsidered according to fuel efficiency and/or emissions rather than engine displacement as the current figure: Increase gradually road-usage fees on old high consuming vehicles, already owned by consumers Increase road-usage and registration fees on imported pre-owned high consuming vehicles Reduce road-usage and registration fees on new and pre-owned low consuming vehicles. - Increase road-usage fees on the second owned car, for private use.			

5.7 Cost benefit analysis for identified measures in transport sector

Specific transportation costs evaluated

Cost Benefit Analisys is carried out in this study in order to evaluate the economic impacts of the prioritized technologies on the government and the car users. The economic evaluation considered comes under the objective of maximizing the cost reduction of daily passengers' trips. It involves quantifying the cost of market resources like the ownership and operation costs, and non-market resources like the travel time, the crash impact and environmental quality. The specific transportation costs evaluated are summarized in Table 45.

Table 45 - Specific transportation costs assessed in the CBA.

Specific cost	Description	Cost category[1]	Market/Non market
Vehicle ownership	Cost for owning a vehicle, including the vehicle purchase cost (minus its salvage value by the end of the vehicle life estimated 10 years), insurance fees, custom and excise fees, registration fees, road-usage fees and financing charges.	Internal-fixed	Market
Vehicle operation	Vehicle operation costs including the cost of consumed fuel, maintenance and tires costs.	Internal-variable	Market
Travel time	The cost of the time used during the travel.	Internal-variable	Non-market
Congestion	The external costs a vehicle imposes on other travelers.	External	Non-market
Parking	Parking fees borne directly by the car users or the government.	Internal-fixed	Market
Internal crash	Damage costs of vehicle accidents borne directly by travelers.	Internal-variable	Non-market
External crash	Damage costs a traveler imposes on others during vehicle accidents.	External	Non-market
Air pollution	Costs of air pollution emissions from vehicle exhaust.	External	Non-market
GHG emissions	Cost of reducing GHG emissions or removing GHGs from the atmosphere through carbon dioxide sequestration	External	Non-market
Operation subsidies	Financial subsidies for implementing the required measures.	External	Market
Fuel tax revenues	Revenues to the government from tax on consumed fuel of passenger cars.	External (from the government perspective) Internal-variable (from car user perspective)	Market

[1] Cost categories are: internal/external, fixed/variable. Internal costs are directly borne by the car user; external costs are borne by others. Variable costs are related to the external variable factors like the fuel consumption or the mileage; fixed costs are not affected by these external variable factors.

Transport modes and travel conditions evaluated

Table 46 summarizes the transport technologies evaluated in this CBA that was prioritized in an early stage of the TNA. The specific cost estimates of Table 45 are computed for each of the considered technologies under three travel conditions (urban-peak, urban off-peak and rural). These estimates are based on extensive research of the real Lebanese driving conditions in GBA through simulation and on-road measurements (Mansour et al., 2011; Mansour and Zgheib, 2012), in addition to assessing the Lebanese vehicle market (Mansour et al., 2011; MoF, 2011; MoE/UNDP/GEF, 2011; Team, 2010).

Methodology for computing the net benefits

Transportation is undoubtedly one of the most complicated economic sectors. It exhibits a number of specific features that renders a common economic wisdom in considering only the relevant peculiarities in the assessment of the sectors' costs and benefits (refer to Table 45). Transportation costs and benefits tend to have a mirror-image relationship: benefits are considered as a reduction in costs, and costs are considered a reduction in benefits. Accordingly, benefits of the identified measures are computed as a reduction in transport costs of the prioritized technologies comparing to BAU. Two BAU technologies are considered, the transport costs of a typical average Lebanese car and those of a typical non-fuel efficient gasoline car. For example, the mass transit bus system benefits are calculated based on the reduction of its total costs (internal and external) per passenger-kilometer compared to the total costs obtained with BAU technologies. As a result, this CBA starts in next section by quantifying the internal and external costs of each of the studied technologies.

Table 46 - Transport technologies evaluated.

Technology[(1)]	Description
Average gasoline car	Mid-size passenger car emulating the average consumption of the Lebanese car fleet. Purchase cost: USD 30,000. Fuel consumption (urban peak/ urban off-peak/ rural): 15.8/ 11.2/ 9.1 l/100km.
Non fuel efficient gasoline car	Large passenger car or SUV emulating the non fuel efficient vehicles observed in the Lebanese fleet. Purchase cost: USD 50,000. Fuel consumption (urban peak/ urban off-peak/ rural): 23.6/ 16.6/ 13.5 l/100km.
Sub-compact fuel efficient car	Small passenger car from the sub-compact segment. Purchase cost: USD 13,000. Fuel consumption (urban peak/ urban off-peak/ rural): 9.5/ 6.7/ 5.4 l/100km.
Compact fuel efficient car	Mid-size passenger car from the compact segment with fuel efficient powertrain. Purchase cost: USD 25,000. Fuel consumption (urban peak/ urban off-peak/ rural): 11.4/ 8.0/ 6.5 l/100km.
Micro hybrid electric vehicle	Sub-compact hybrid passenger car equipped only with stop/start hybrid functionality. Purchase cost: USD 15,000[(2)]. Fuel consumption (urban peak/ urban off-peak/ rural): 6.4/ 5.8/ 4.7 l/100km.
Full hybrid electric vehicle	Compact hybrid passenger car with maximum hybrid functionalities: stop/start, brake energy recovery, electric boost, electric drive mode. Purchase cost: USD 35,000[(2)]. Fuel consumption (urban peak/ urban off-peak/ rural): 5.4/ 5.3/ 4.9 l/100km.
Diesel bus	12-meter diesel bus operating on dedicated lanes in GBA. Purchase cost: USD 300,000 (borne by the government). Fuel consumption (urban peak/ urban off-peak/ rural): 33.4/ 33.4/ 27.2 l/100km.

[(1)] The estimated average annual mileage for all passenger cars is 15 000 km. The vehicle life is considered 10 years for passenger cars and 20 years for buses.
[(2)] Considered purchase cost of hybrid vehicles is exempted from custom/excise fees and registration fees.

Cost Benefit Analysis

This section describes and estimates the specific transport costs presented in Table 45 for the following technologies: (1) mass transit bus technologies, (2) hybrid vehicles and (3) fuel efficient gasoline-powered vehicles. These monetized cost estimates are provided for urban peak, urban off-peak and rural driving conditions in GBA, then average savings are computed on the base that urban peak constitute 51.1% of the total travel time, 31.2% for urban off-peak and 17.7% under rural. This travel distribution is determined from an extensive GPS survey of GBA driving conditions (Mansour and Zgheib, 2012). They represent GBA average costs, except where noted otherwise due to lack of data.

Methodology and estimates of specific transport costs under GBA driving conditions

- *Vehicle ownership and operating costs*

The direct user expenses to own and use transport technologies are computed in this section under the vehicle ownership costs and the vehicle operating costs. These costs permit to determine savings that result from alternative and fuel-efficient transport means with respect to the BAU, considered in this study the average gasoline passenger car. Table 47 and Table 49 summarize the vehicle operating and ownership costs of the considered technologies in USD/veh.km and in USD/pass.km, assuming that the vehicle occupancy in GBA estimated at 1.2 pass/veh for passenger cars and 25 pass/veh for buses, under urban peak driving conditions. Similar exercise for operating costs is applied for GBA off-peak and rural driving conditions, summarized in Table 48.

Table 47 - Vehicle operating costs of the studied transport technologies under GBA peak driving conditions.

	Average car	Non fuel-efficient car	Sub-compact fuel efficient car	Compact fuel efficient car	HEV Stop/Start	HEV Full Hybrid	Diesel bus
Fuel consumption[(1)] (USD/veh.km)	0.1900	0.2826	0.1135	0.1362	0.0965	0.0648	0.2896
Maintenance[(2)] (USD/veh.km)	0.0275	0.0311	0.0262	0.0262	0.0262	0.0112[(3)]	0.2858[(4)]
Tires[(5)] (USD/veh. km)	0.0060	0.0124	0.0060	0.0060	0.0060	0.0060	0.0400[(6)]
Operating costs (USD/veh.km)	0.2234	0.3261	0.1457	0.1683	0.1286	0.0819	0.6154
Operating costs[(7)] (USD/pass.km)	0.186	0.272	0.121	0.140	0.107	0.068	0.025

(1) computed from the vehicle fuel consumption under GBA driving conditions (l/100km) (Annex V, Table 1), the annual mileage (estimated at 15000 km) and the fuel cost (1.2 USD/liter of gasoline and 0.867 USD/liter of diesel).
(2) estimated from the American Automobile Association in 2010 as no local data is available (AAA, 2010).
(3) estimated from end-of-life accelerated on-road vehicle testing, on 6 full-hybrid electric vehicles (USDOE, 2011).
(4) estimated from the Environmental and Energy Study Institute (EESI, 2009).
(5) average tire costs in the Lebanese market are 120 USD/tire for compact passenger cars and 250 USD/tire for large passenger cars and SUV. The total mileage considered before changing tires is 50 000 km.
(6) estimated from maintenance results over 12-month period on New York city transit buses (Barnitt, 2006).
(7) vehicle occupancy in GBA is estimated 1.2 pass/veh for passenger cars 25 pass/veh for buses under urban peak driving conditions.

Table 48 - Vehicle operating costs of the studied transport technologies under GBA off-peak and rural driving conditions.

	Average car	Non fuel-efficient car	Sub-compact fuel efficient car	Compact fuel efficient car	HEV Stop/ Start	HEV Full Hybrid	Diesel bus
Operating costs under GBA off-peak[(1)] (USD/pass.km)	0.139	0.202	0.093	0.107	0.087	0.067	0.025
Operating costs under rural[(2)] (USD/pass.km)	0.119	0.171	0.081	0.092	0.080	0.063	0.022

[(1)] Vehicle occupancy off-peak driving conditions is estimated 1.2 pass/veh for passenger cars and 10 pass/veh for buses.
[(2)] Vehicle occupancy under rural driving conditions is estimated 1.2 pass/veh for passenger cars and 15 pass/veh for buses.

Table 49 - Vehicle ownership costs of the studied transport technologies.

	Average car	Non fuel-efficient car	Sub-compact fuel efficient car	Compact fuel efficient car	HEV Stop/ Start	HEV Full Hybrid
Vehicle purchase[(1)] (USD)	30000	50000	13000	25000	15000	35000
Salvage value[(2)] (USD)	7600	12660	3290	6330	3800	8860
Insurance[(3)] (USD/year)	510	800	263.5	437.5	292.5	582.5
Custom/Excise[(4)] (USD)	10666.7	20666.7	2283.3	8166.7	3166.7	13166.7
Registration[(5)] (USD)	1200	2000	520	1000	600	1400
Registration (USD)	1200	2000	520	1000	600	1400
Road-usage fees[(6)] (USD)	810	2286.7	810	810	810	810
Financing charges[(7)] (USD/year)	597.5	995.8	258.9	497.9	298.7	697.1
Ownership costs (USD/year)	3549	5959	1626	2983	1852	4114
Ownership costs (USD/veh.km)	0.2366	0.3972	0.1084	0.1989	0.1235	0.2743
Ownership costs (USD/pass.km)	0.1972	0.3310	0.0903	0.1657	0.1029	0.2286

[(1)] Estimated from Lebanese market survey and personal communication with BUMC (Toyota dealer) (Bejjani, 2012)
[(2)] Vehicle depreciation is estimated 20% for the first year and 12% for the following years. Vehicle life is estimated 10 years.
[(3)] Insurance fees are computed according to the following formula: 14.5% of the vehicle purchase cost during the loan period (5 years), in addition to 150 USD/year after loan period for the last 5 years. The total insurance sum is divided over the 10 years of the vehicle life.
[(4)] Refer to (MoF, 2011) for details of the custom and excise fees.
[(5)] Car registration fees are 4% of the vehicle's estimated value, considered in this study similar to the vehicle purchase cost (MoF, 2011).
[(6)] Road-usage fees are locally known by "road-usage fees". New cars are exempted from this fee for the first 3 years (Informs, 2012). Refer to (MoF, 2011) for details on the road-usage fees. All vehicles are considered in the 11-20 horsepower category, except the non fuel efficient car 31-40 horsepower. The estimated values are computed over the vehicle life (10 years).
[(7)] Financing charges are the bank loan interest over the 5 years car loan.

Therefore, the total vehicle costs (which stand for the ownership and the operation costs) per vehicle-kilometers and per passenger-kilometers are illustrated in Fig. 36. Note that these costs are borne by the user and not the government. Moreover, the subsidy measures intended for hybrid and fuel efficient car buyers has not been included in this section (refer to section operation subsidies by Lebanese government).

- *Travel time*

The cost of travel time refers to the cost of time spent on transport, including waiting as well as actual travel. It is the product of time spent traveling (measured in hr/veh.km) multiplied by unit costs (measured in USD/hr). The traveling time is estimated from the vehicle average speed (Annex V, Table 2), and the unit cost is estimated at 5 USD/hr, for an average wage rate of 800 USD/month (CAS, 2011).

Travel time costs vary significantly, depending on various factors. For example, time spent in discomfort has higher unit costs than time spent in comfortable conditions. Hence, for this evaluation, travel is divided into four categories, with different cost values, as summarized in the Table 50 (Litman, 2011a).

Travel time cost results are summarized in Table 51, under urban peak driving conditions. Two different scenarios are considered for the bus transit system: (1) bus transit operating on dedicated lanes in GBA and (2) bus transit not operating on dedicated lanes. Results for off-peak and rural driving conditions are summarized in Table 52.

Fig. 36 - Total vehicle costs of the studied transport technologies under GBA peak driving conditions.

Table 50 - Travel time cost categories used in the CBA.

Category	Description	Cost value	Portion of travel time
Paid	Travel by employees when being paid, including business people traveling to meetings, and workers traveling between job sites.	150% wage rates	5% commercial travel
Personal, high cost	Personal travel during which travelers experience significant discomfort or frustration, such as driving in congestion or pedestrians and transit passengers in uncomfortable conditions.	50% wage rates for drivers, 35% of wages for passengers	20% Typical for urban-peak commute that occurs under congested or unpleasant conditions
Personal, medium cost	Personal travel during which travelers experience no discomfort.	25% wage rates for adults	50% Typical of errand trips under uncongested conditions
Zero-cost travel time	Travel that users enjoy and so would pay nothing to reduce their travel time.	No cost	25% Typical for recreational travel and some personal travel

Table 51 - Travel time cost under GBA peak driving conditions in US¢/pass.km.

	Passenger cars	Bus system not operating on reserved lanes	Bus system operating on reserved lanes
Paid	2.1	2.6	1.9
Personal, high cost	2.8	3.4	2.5
Personal, medium cost	3.6	4.3	3.1
Zero-cost travel time	0	0	0
Travel time cost (US¢/pass.km)	8.5	10.2	7.5

Table 52 - Travel time cost under GBA off-peak and rural driving conditions in US¢/pass.km.

	Passenger cars	Bus system not operating on reserved lanes	Bus system operating on reserved lanes
Travel time cost under GBA peak driving conditions (US¢/pass.km)	3.8	4.6	4.3
Travel time cost under rural driving conditions (US¢/pass.km)	2.9	3.5	2.9

- *Congestion*

Congestion costs consist of both internal and external costs that result from the interference among vehicles during traffic, particularly as traffic volumes approach the maximum road's capacity. These costs are the incremental delay during traffic, the additional fuel consumption, the vehicle components wear, the pollution emissions and the cost of the passengers' discomfort (Hau, 1992).

To prevent double counting, internal congestion costs that are borne by the drivers are not considered in this section since they have been accounted for under the travel time cost, the emissions cost, the crash cost and the vehicle operating cost. Therefore, Table 53 presents the external congestion costs a vehicle imposes on other travelers.

- *Crash costs*

The crash costs assessed in this study is the monetized value of damages caused by vehicle accidents. They include the damages to the individual traveling by a particular vehicle (internal costs), and the damages imposed by an individual on other travelers (external costs).

Due to lack of data availability on crash costs in Lebanon, data are borrowed from the literature. The internal crash costs are estimated at 5.2, 5.8 and 0.25 US¢/pass.km for average car, compact car and diesel bus respectively; and the external crash cost at 3.4, 3.3 and 16.5 US¢/veh.km respectively (Litman, 2011c).

- *Air pollution*

Air pollution costs refer to motor vehicle air pollutant damages, including human health, ecological and esthetic degradation. The scope of pollutant emissions analysis in this study is narrowed to considering only emissions from vehicle exhaust pipes. Therefore, air pollution cost estimates are based on reflecting only exhaust emissions during vehicle operation (CO, NO_x, PM, VOC, SO_2). It excludes upstream emissions that occur during fuel production and distribution, and the pollution associated with vehicle manufacturing, as these costs are not borne by the Lebanese government.

Literature provides extremely divergent estimates of air pollution costs (Delucchi, 2004; Litman, 2002; Holland et al., 2002; Wang et al., 1995). Average estimates are considered in this analysis, and air pollution estimates are summarized in Table 54, in US¢/pass.km (Litman, 2011d).

- *GHG emissions*

The greenhouse gas emission values are based on the mitigation cost estimates, which is the cost of reducing GHG emissions from the atmosphere through carbon dioxide sequestration, and therefore reducing future climate change damages. Several studies suggest that GHG mitigation costs will remain 20-50 USD/tonne of CO_2 equivalent for some time, although this may increase to achieve larger emission reductions (Litman, 2012). A value of 35 USD/tonne is used in this analysis as the default value.

To calculate the per kilometer cost of GHG emissions, the Tank-to-Wheel GHG emissions from the analyzed transportation technologies (in g/km) are multiplied by the considered GHG mitigation cost. Results are summarized in Table 55.

- *Operation subsidies by Lebanese government*

Reviewing the identified measures to deploy hybrid and fuel-efficient gasoline vehicles, market and consumer incentives are inevitable. The incentives mainly intend to reduce the vehicle purchase and ownership costs, through:

- exemption from customs and excise fees on vehicle and spare parts to favor suppliers invest
- exemption from registration fees and from road-usage fee at registration
- payment of minimum salvage value as down payment for the car loan
- banking facilities through loan extension up to 8 years
- reduce loan interest and/or full subsidy of loan interests over loan period

Table 56 summarizes the government subsidy assuming an average annual mileage of 15,000 km per vehicle and an average occupancy of 1.2 passengers per vehicle.

- *Fuel excise*

The government collects indirect revenues from car usage through a tax levied on imported liters of gasoline. Excise on gasoline is not an added value tax, it a specific tax levied as function of volume. It is estimated around 400 LBP/liter of gasoline (0.267 USD/liter). Table 57 highlights the gasoline excise revenues of the government on the evaluated transport technologies.

Table 53 - Congestion costs considered in the analysis in US¢/pass.km.

	Passenger car	Diesel bus operating on dedicated lanes	Diesel bus not operating on dedicated lanes
Urban peak	6.73	0.1	0.67
Urban off-peak	1.04	0.25	0.25
Rural	0	0	0

Table 54 - Air pollution costs in US¢/pass.km, including exhaust emissions only.

	Urban Peak	Urban Off-peak	Rural
Gasoline average car	3.23	2.71	1.35
Sub-compact gasoline fuel efficient car	2.39	2.01	1.00
Compact gasoline fuel efficient car	2.66	2.23	1.11
Stop/start hybrid electric vehicle	2.51	2.11	1.05
Full hybrid electric vehicle	1.20	1.01	0.50
Diesel bus not operating on dedicated lanes	0.46	1.00	0.05
Diesel bus operating on dedicated lanes	0.40	1.00	0.05

Table 55 - GHG emission costs in US¢/pass.km.

	urban peak	urban off-peak	rural
Gasoline non efficient car	1.60	1.13	0.91
Gasoline average car	1.07	0.76	0.61
Sub-compact fuel efficient car	0.64	0.45	0.37
Compact fuel efficient car	0.77	0.54	0.44
Stop/Start hybrid electric vehicle	0.43	0.39	0.32
Full hybrid electric vehicle	0.36	0.36	0.33
Diesel bus	0.12	0.30	0.20

Table 56 - Government subsidy for full hybrid HEV, stop/start HEV and fuel efficient gasoline vehicles (US¢/pass.km).

	Sub-compact fuel efficient gasoline car	Compact fuel-efficient gasoline vehicles	Stop/start hybrid electric vehicle	Full hybrid electric vehicle
Customs/Excises[(1)]	1.27	4.53	1.76	7.31
Registration[(2)]	0	0	0.33	0.78
Road-usage fees[(3)]	0	0	0	0
Salvage/Return on salvage[(4)]	0	0	0	0
Subsidy of loan interest[(5)]	0	0	0	0
Total subsidy	1.27	4.53	2.09	8.09

[(1)] Refer to (MoF, 2011) for details of the custom and excise fees. The vehicle costs are estimated at USD 13,000, 25,000, 15,000 and 35,000 for the sub-compact, compact, stop/start and full hybrid vehicles respectively.
[(2)] Car registration fees are 4% of the vehicle's estimated value, considered in this study similar to the vehicle purchase cost (MoF, 2011).
[(3)] Road-usage fees are locally known by "road-usage fees". New cars are exempted from this fee for the first 3 years (Informs, 2012).
[(4)] This value is the difference between the salvage value of the swapped old car, borne by the government, and the return on salvage value. An efficient car termination programme of swapped cars should bring this value to zero.
[(5)] The government full subsidy of loan interest over loan period is not considered in this analysis. Taxi drivers, students and disabled persons are only eligible for this incentive.

Table 57 - Gasoline excise on the evaluated transport technologies in US¢/veh.km.

	Average gasoline car	Non fuel efficient gasoline car	Sub-compact fuel efficient car	Compact fuel efficient car	Stop/start hybrid electric vehicle	Full hybrid electric vehicle
Urban peak	4.2	6.3	2.5	3.0	1.7	1.4
Urban off-peak	3.0	4.4	1.8	2.1	1.7	1.4
Rural	2.4	3.6	1.5	1.7	1.3	1.3

Cost benefit analysis results

The objective of the CBA is to identify the cost value of the prioritized measures and technologies in order to support setting a beneficial transport policy, favoring lower-cost transport technologies over higher-cost transport technologies. Thus, it is of great interest to presents the costs and benefits results from two perspectives: the passenger car users' perspective and the government's perspective.

- *Costs and benefits from the passenger car users' perspective*

Considerable savings are observed, particularly when car users swap from non efficient cars to buses or fuel efficient cars (Fig. 37 and Fig. 38). Such swap becomes feasible if the car purchase loan is spread to over an 8-year loan period, as illustrated in the net cash flow of car users (Fig. 40 and Fig. 41). The net cash flow calculation is based on both revenues and mandatory charges. Therefore, the benefits depend on the income activity of the car user (Fig. 39).

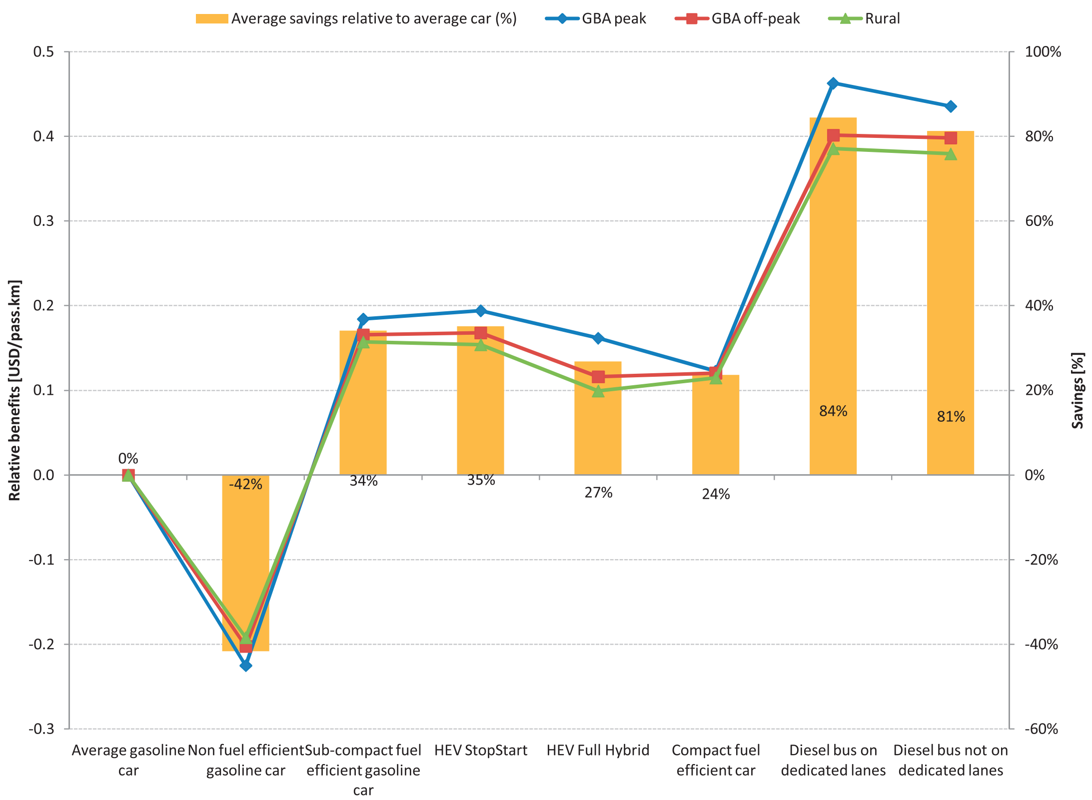


Fig. 37 - Car users benefits of transport technologies relative to average car under GBA driving conditions.

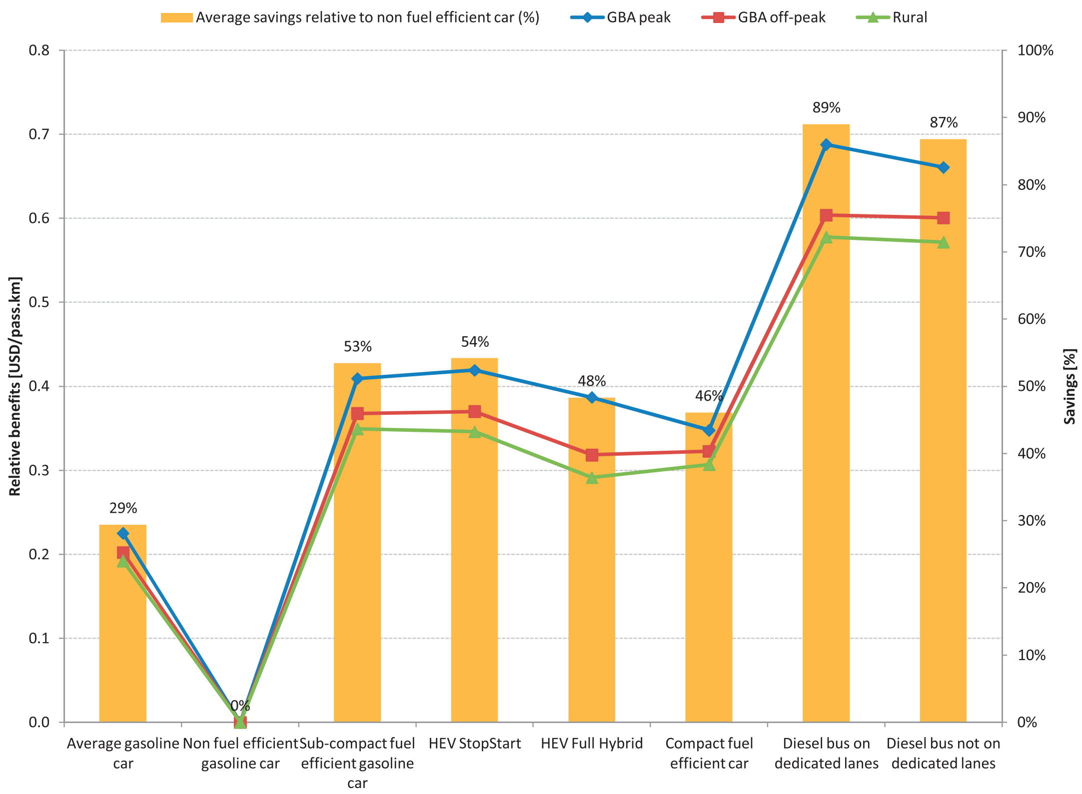


Fig. 38 - Car users benefits of transport technologies relative to non fuel efficient car under GBA driving conditions.

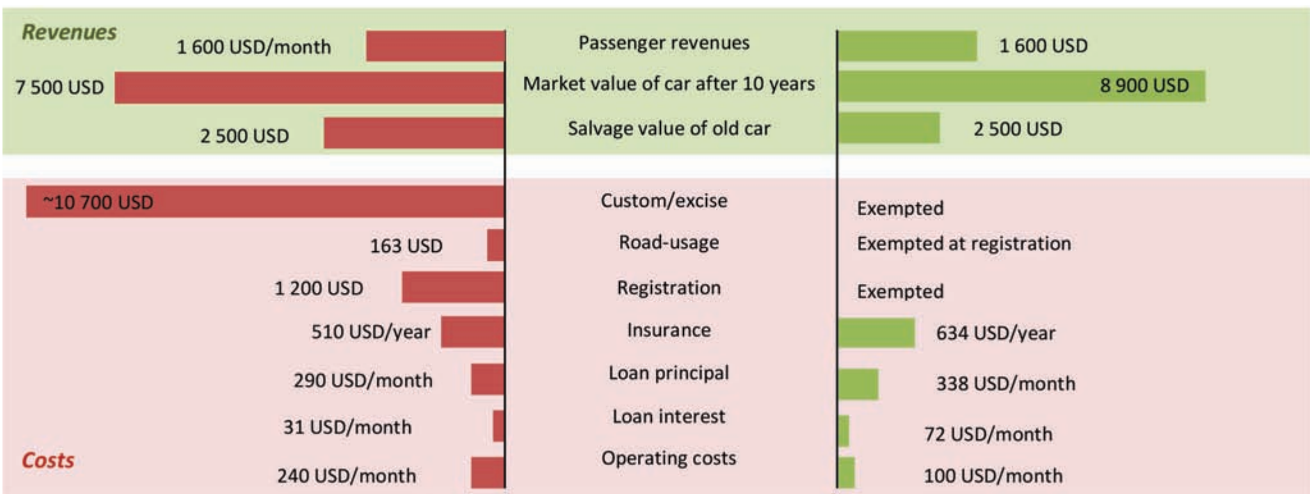


Fig. 39 - Revenues and costs of an average car versus a full hybrid car.

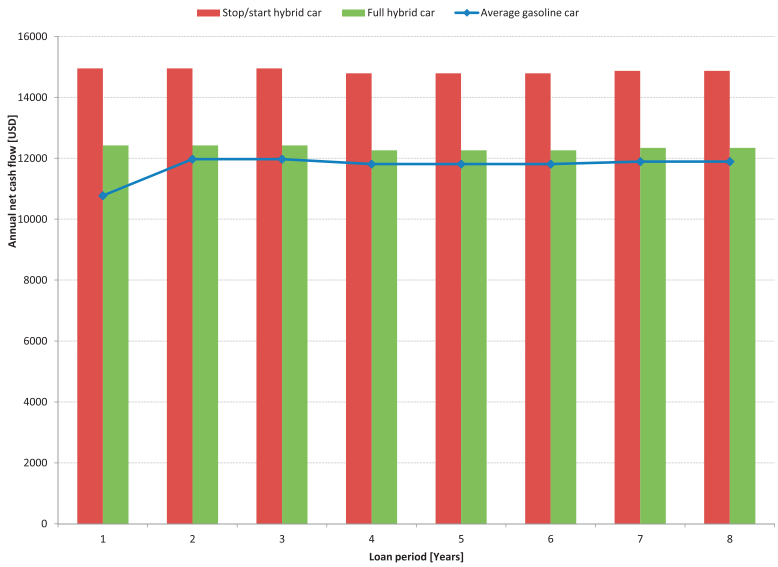


Fig. 40 - Annual net cash flow for a stop/start and full hybrid car user over an 8-year loan period.

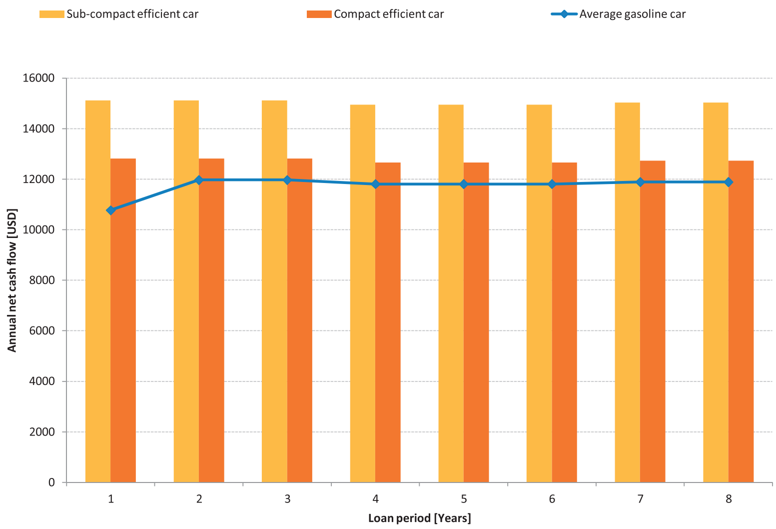


Fig. 41 - Annual net cash flow for a sub-compact and compact fuel efficient car user over an 8-year loan period.

At this stage, it is interesting to identify the specific key parameters that maximize the car users' benefits. For passenger cars, full hybrid cars serve as a good example. It costs nearly 0.4 USD/pass.km: 27% and 48% more beneficial than the average and the non fuel efficient cars respectively. The largest benefit examined come from the vehicle operation cost reduction due to the higher efficiency of the hybrid powertrain, as illustrated in Fig. 42 and Fig. 43. As a result, including energy efficiency as decision-making criteria for buying a car is a key parameter for achieving considerable benefits. Thus, energy efficiency indicators must imperatively be communicated to car buyers, through appropriate standards and regulations imposed by the government.

Similar analysis shows that the diesel bus operating on dedicated lanes in GBA brings additional benefits to travelers, 84% and 89% more beneficial than the average and the non fuel efficient cars respectively. Benefits come mainly from reducing the vehicle ownership cost, the vehicle operation cost in addition to reducing the crash and parking costs, and no operation subsidy has to be borne by the government, as illustrated in Fig. 43.

Therefore, maximizing the transport benefits from the car users' perspective implies selectively eliminating the worst energy efficient vehicle technologies in the fleet and stimulating replacement by the best performing vehicles (including mass transit buses) with the highest energy efficiency per passenger-kilometer.

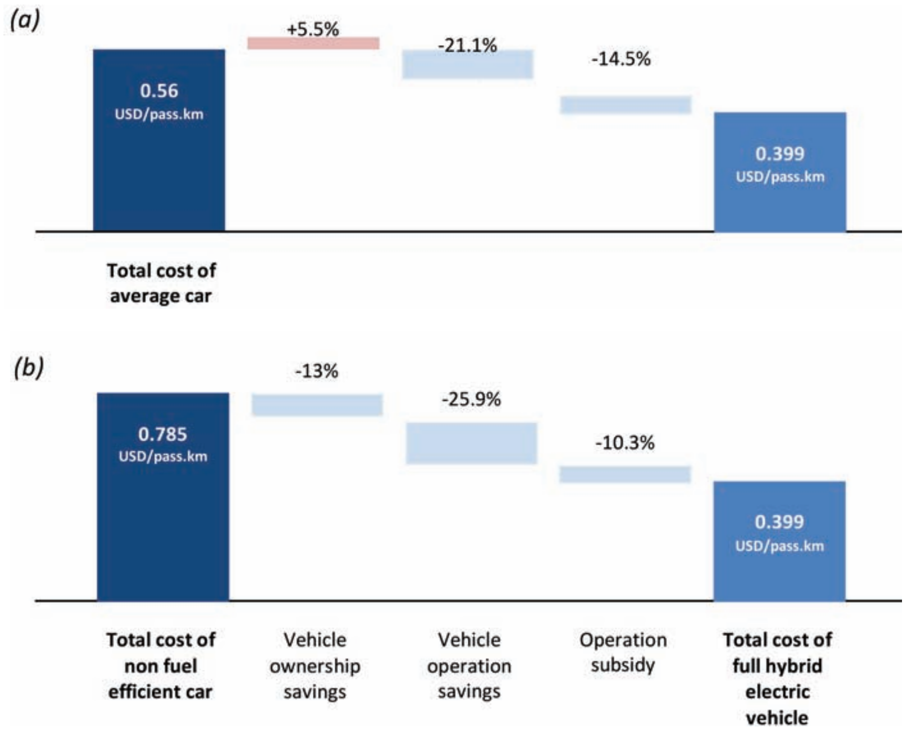


Fig. 42 - Cost savings breakdown of hybrid electric vehicle users under GBA peak driving conditions: (a) relative to average car, (b) relative to non fuel efficient car.

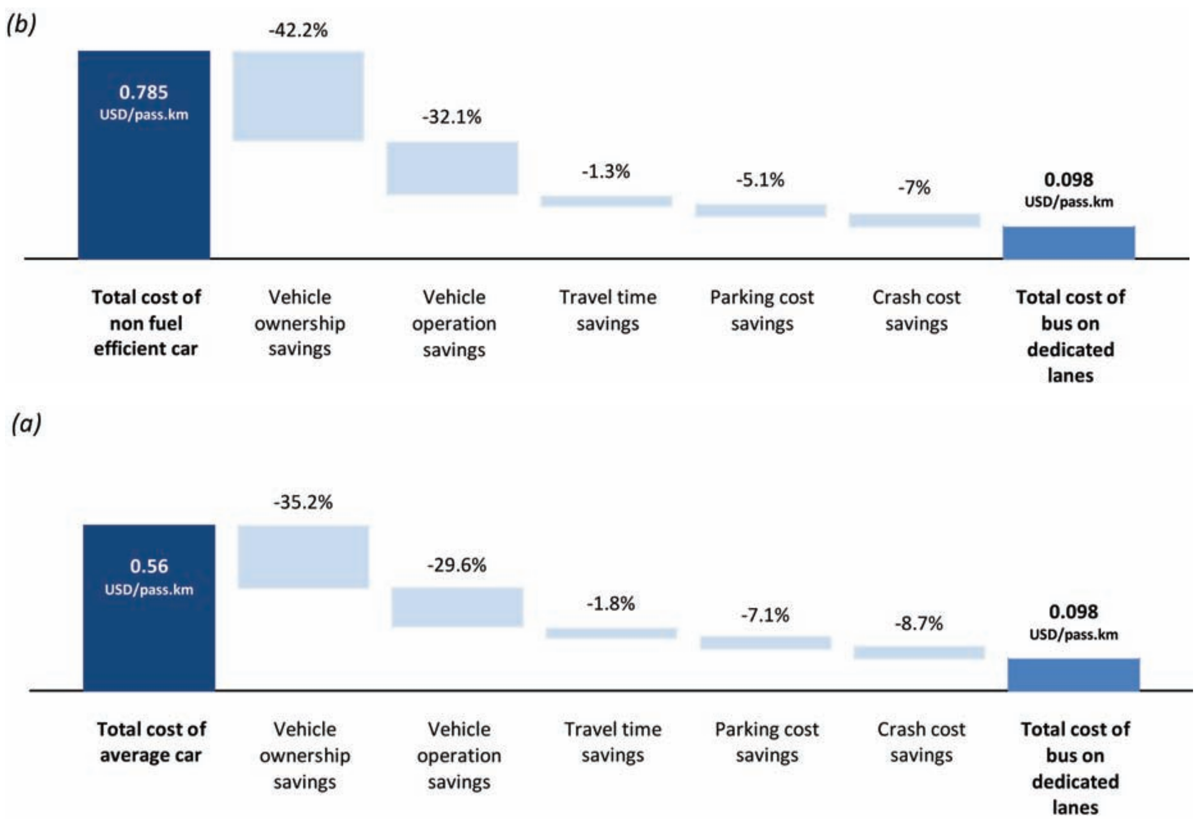


Fig. 43 - Cost savings breakdown of bus users on dedicated lanes, under GBA peak driving conditions: (a) relative to average car, (b) relative to non fuel efficient car.

- *Costs and benefits from the government's perspective*

Several scrappage and fleet renewal schemes have been implemented worldwide in order to improve air quality, reduce dependence on imported fuels, reduce CO_2 emissions and support the automotive industry (ECMT, 1999; ITF, 2011). Among the well designed fleet renewal schemes: the United States CARS programme, the German Umweltprämie and in France the Prime à la Casse programme in 2009. All the 3 programmes did not succeed in recovering the total government costs. Only 80% of the US government costs were recovered through societal benefits like fuel savings, pollutant and CO_2 emissions savings, traffic casualties and serious injuries avoided. The German and French programmes were even poorer with 25% and 46% of cost recovery respectively (ITF, 2011). Therefore, objectives of scrappage and fleet renewal programmes are not designed to bring benefits to the government rather than for economic stimulus and environmental and health protection. Fleet renewal programmes are designed for their economic stimulus, environmental and health protection rather than cash benefits to the government.

Similar figures are observed in this CBA exercise from the Lebanese government perspective. Scrappage scheme by swapping average cars with hybrid and fuel efficient cars would allow the government to recover between 44% and 90% of the government costs (Fig. 44). Only bus systems would bring benefits. However, it is worth mentioning that the current trend of massive market submerge with non fuel efficient cars also do not allow cost recovery for the government: 33% of losses are observed comparing to an average car. Therefore, a well designed scrappage programme would be beneficial if mainly targeting on eliminating non fuel efficient cars, as illustrated in Fig. 45.

Note that, observed results derive from the current figures of tax levied on fuel imports in Lebanon, from road-usage fees, from custom duties excise tax, and VAT from cars at import. However, a well designed and effective scrappage programme should be implemented in parallel with a tax reform, at least at the road-usage fees, where high-polluters should be penalized and low-polluters recompensated. With such reform, the government will be able to optimize more efficiently its revenues from the scrappage programme.

- *Upper purchase cost limit of the hybrid electric and fuel efficient cars*

Since not all hybrid and fuel efficient cars allow total recovery of the government costs, as illustrated in Fig. 45, there is an upper purchase cost limit of these cars for having 100% recovery. The maximum purchase cost is estimated at USD 23,000, as illustrated in Fig. 46. Therefore, all fuel efficient and hybrid electric vehicles with lower purchase cost should be subsidized without any loss to be borne by the government.

Table 58 summarizes the government foregone revenues and the car users' benefits over the vehicle life (estimated 10 years), under the scrappage programme. The societal and economical benefits to car users' are 2.5 to 5 times the foregone revenues borne by the government during the programme. Therefore, such programme implies an important economical stimulus to car users.

- *Peak shift savings*

An additional interesting issue to consider in the CBA is improving the level of service of GBA roads, and therefore, switching from urban peak to off-peak driving. From both the government and the car users' perspectives, maximizing benefits is obtained from shifting transport demand to bus mass transit operating on dedicated lanes, as illustrated in Fig. 47 and Fig. 48. As a consequence, the new thinking approach in establishing a sustainable transport policy in GBA is (1) to shift transport demand massively to mass transit systems, (2) to swap non efficient technologies with efficient technologies through well designed scrappage scheme, and (3) to switch from peak to off-peak driving conditions by avoiding unnecessary trips and shifting demand to mass transit.

The CBA has considered the different technologies under the mitigation strategies proposed in the TNA. Internal and external costs have been computed from both perspectives: passenger car users and the government, under the current Lebanese driving conditions.

Considerable savings are observed from car users' perspective in both cases: swapping to fuel efficient vehicles or shifting to bus transit system. The benefits examined come from reducing the vehicle operation cost reduction due to the higher efficiency of the buses and the hybrid car technologies investigated.

Fig. 44 - Government benefits of transport technologies relative to average car under GBA driving conditions.

Fig. 45 - Government benefits of transport technologies relative to non fuel efficient car under GBA driving conditions.

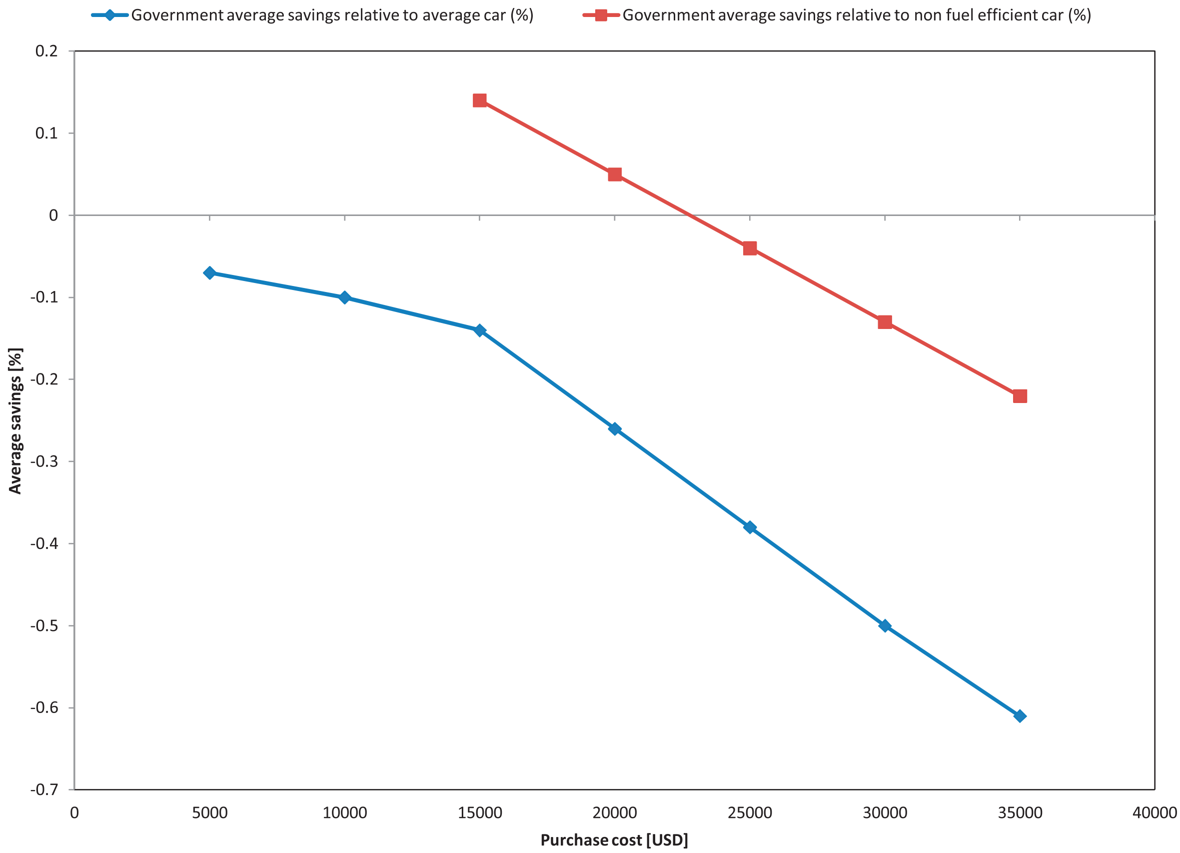


Fig. 46 - Upper purchase cost limit of hybrid and fuel efficient cars.

Table 58 - Government foregone revenues and car users' benefits over 10 years for the upper purchase cost limit of hybrid and compact fuel efficient cars.

	Hybrid electric vehicle at USD 23,000	Compact fuel efficient car at USD 23,000
Government foregone revenues relative to average car(1)	Car tax exemption at purchase: USD 8,000 Foregone gasoline excise fees due to fuel savings: USD 4,175 Total: USD 12,175	Car tax exemption at purchase: USD 7,100 Foregone gasoline excise fees due to fuel savings: USD 1,800 Total: USD 8,900
Car users' benefits relative to average car(2)	USD 31,770 /veh	USD 22,140 /veh

Government foregone revenues relative to non fuel efficient car(1)	Car tax exemption at purchase: USD 8,000 Foregone gasoline excise fees due to fuel savings: USD 7,275 Total: USD 15,275	Car tax exemption at purchase: USD 7,100 Foregone gasoline excise fees due to fuel savings: USD 4,900 Total: USD 12,000
Car users' benefits relative to non fuel efficient cars(2)	USD 70,000 /veh	USD 60,350 /veh

(1) The government forgone revenues are the operation subsidies in addition to the forgone gasoline excise fees due to fuel savings.
(2) The car users' benefits considered include car ownership savings, operating cost savings, travel time reduction, parking and crash savings and the operation subsidies received from the government.

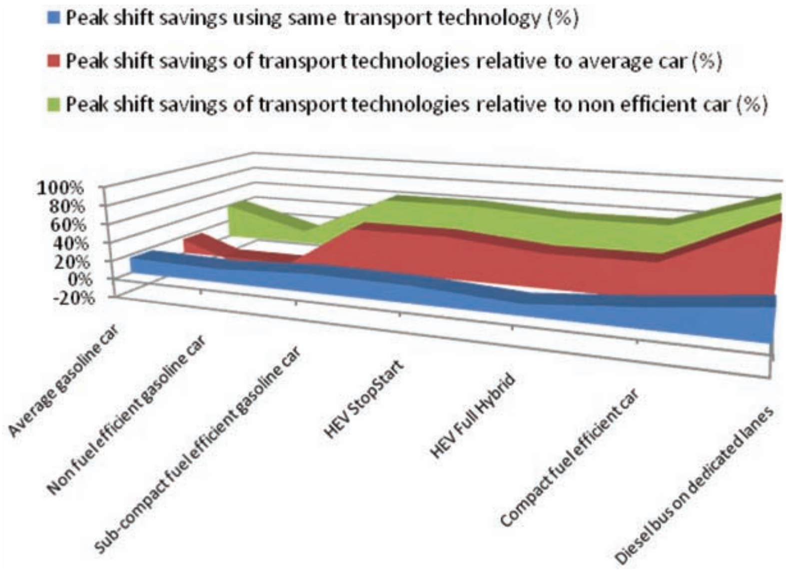


Fig. 47 - Peak shift savings from the car users' perspective.

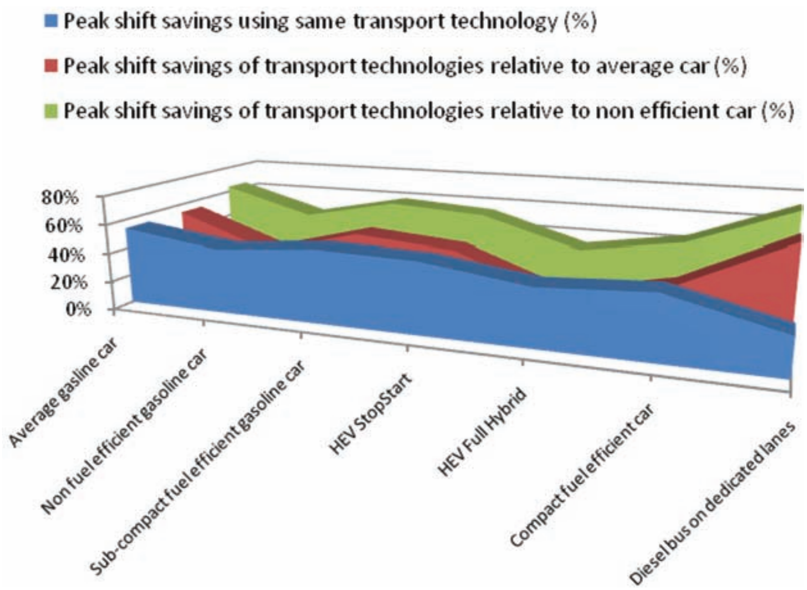


Fig. 48 - Peak shift savings from the government perspective.

Similar benefit figures are observed in this CBA exercise from the Lebanese government perspective, particularly adopting bus transit system on dedicated lanes in GBA. Scrappage scheme as defined in this CBA would allow the government to partially recover its investment costs. However, the current trend of massive market submergence with non fuel efficient cars also implies considerable cost (losses) on the government.

As a result, according to this CBA, the development of transport sector within the transition to a sustainable mobility and a green economy would be well served for both the Lebanese government and the car users by the adoption of the following specific actions:

- Shifting travel demand in GBA to the most efficient mode: bus transit on dedicated lanes, as benefits are considerable for both the car users and the government.
- Eliminating the least energy efficient vehicle technologies in the fleet and stimulating replacement by the best performing vehicles, through implementing a well designed scrappage programme.
- Adopting in parallel to the scrappage programme a tax reform scheme, at least at the road-usage fees, where high-polluters are penalized and low-polluters recompensed. With such reform, the government will be able to optimize more efficiently its revenues from the scrappage programme.