**Technology Fact Sheet for Mitigation**

## L. Natural Gas Vehicles [i]

| Sector : Transport | |
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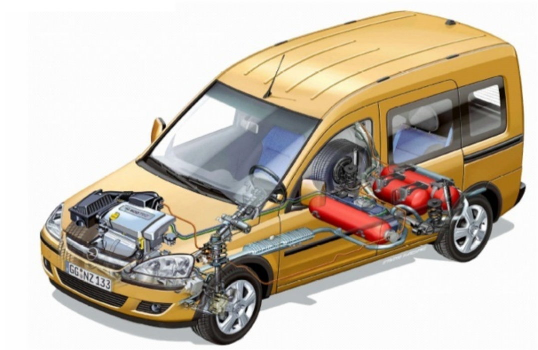
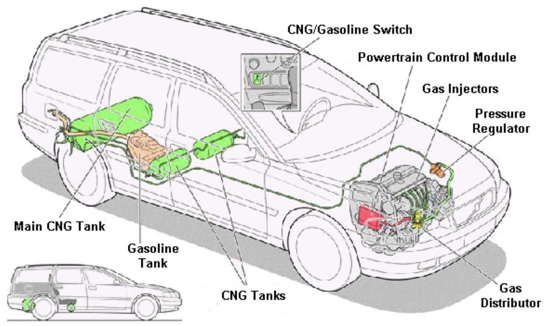
| **Subsector : Alternative fuels for passenger cars** | |
| **Technology characteristics** | |
| Introduction | A natural gas vehicle (NGV) is an alternative fuel vehicle that uses compressed natural gas (CNG) or liquefied natural gas (LNG) as an alternative to gasoline and diesel. Natural gas is a 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 used for passenger cars.<br>Worldwide, 12.7 million NGV are on the market by 2010, led by Pakistan with 2.7 million, Iran (1.95 million), Argentina (1.9 million), Brazil (1.7 million), and India (1.1 million); countries with significant own gas reserves.<br>There are both dedicated NGVs which run exclusively on natural gas (Figure 1), and bi-fuel NGVs (Figure 2), which have two separate fueling systems enabling the car to run either on natural gas (CNG) or on a conventional fuel, i.e. gasoline or diesel. Most current CNG passenger cars are bi-fuel vehicles: in the Latin American region (4.2 million vehicles) almost 90% of NGVs have bi-fuel engines.<br><br><br><br>Figure 1. Dedicated CNG powertrain. Figure 2. Bi-fuel CNG powertrain.<br>It is possible to retrofit a gasoline powered vehicle with a natural gas tank. However, these vehicles are not as fuel efficient as OEM natural gas powered vehicles. In addition, retrofitted vehicles have higher emissions of NOx and PM. CNG is also ideally suited for city buses; for example, 95% of Los Angeles city buses employ CNG.<br>Technically, natural gas vehicles function very similarly to gasoline powered vehicles with spark-ignited engines. The natural gas is stored in high-pressure fuel cylinders on board of the vehicle. |
| Technology characteristics | **Fuel characteristics**<br>· CNG is stored in gas form at high pressure (200 to 275 bar) and mainly used in passenger cars and city buses<br>· LNG is in uncompressed liquid form at the boil-off evaporative temperature (-162°C)<br>· CNG has a lower cost of production and storage compared to LNG as it does not require an expensive cooling process and cryogenic tanks |

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| | **Mileage and emissions characteristics**<br>· The driving range of CNG passenger cars is limited within the range of 350 to 450 kilometers<br>· The consumption (l/100km) ratio between NGVs and conventional gasoline powered vehicles is estimated to be 110% for bi-fuel CNG and 105% for dedicated CNG vehicles<br>**Fueling stations and operational necessities**<br>· Need of refueling infrastructure with sufficient national coverage<br>· Due to boil-off evaporative losses, the direct use of LNG is economically feasible for heavy duty trucks; thus, CNG is advised for passenger cars. |
| Operation and maintenance | · Maintenance of NGVs is similar to conventional gasoline vehicles<br>· Special technician trainings are required in order to perform adequate maintenance and repair of the NG tank and the injection system onboard<br>· Maintenance costs of CNG vehicles are in general lower than gasoline vehicles. According to a study on 10 Ford Crown Victoria realized by the USDOE in 1999, the overall total maintenance costs were slightly lower for the 5 CNG vehicles, at 0.0339 USD/mile compared to 0.0395 USD/mile for the 5 gasoline vehicles. |
| Endorsement by experts | · NGVs are endorsed by the MOEW<br>· NGVs are endorsed by some automotive manufacturers, for countries with NG resource availabilities |
| Advantages | NGVs – particularly CNG passenger cars – offer several advantages compared to conventional vehicles:<br>· Due to the absence of any lead or benzene content in CNG, the lead fouling of spark plugs is eliminated.<br>· CNG vehicles have lower maintenance costs when compared with other fuel-powered vehicles.<br>· CNG fuel systems are sealed, which prevents any spill or evaporation losses.<br>· Increased life of lubricating oils, as CNG does not contaminate and dilute the crankcase oil.<br>· CNG mixes easily and evenly in air being a gaseous fuel.<br>· CNG is less likely to auto-ignite on hot surfaces, since it has a high auto-ignition temperature (540 °C) and a narrow range (5%-15%) of flammability.<br>· Less pollution and more efficiency: CNG emits significantly less carbon dioxide ($CO_2$), unburned hydrocarbons and carbon monoxide (CO); compared to conventional gasoline vehicles.<br>· |
| Disadvantages | · Higher overall cost of NGVs comparing to comparable conventional gasoline powered vehicles<br>· Lower driving range and higher gasoline equivalent consumption due to the inferior energy density of NG compared to gasoline<br>· Limited trunk space to accommodate the NG storage cylinders<br>· Need the implementation of NG infrastructure and fueling stations<br>· With NG, transportation is still depending on fossil fuels<br>· Encourage use of private passenger cars if intelligent taxation policies are not |

adopted

**Capital costs**

Additional cost to implement mitigation technology, compared to "business as usual"

- 2000 USD of additional purchase cost is estimated for CNG vehicles compared to equivalent gasoline powered vehicles
- A conventional CNG fueling station where the NG is supplied by pipeline costs around 500000 USD
- Additional costs must be also considered for transporting the NG to the fueling stations (Table 1).

Table 1. Distribution costs as function of the transport distance.

| Transport distance [Km] | Transport costs [USD/GJ] | |
|---|---|---|
| | CNG | LNG |
| 100 | 4.7 | 0.6 |
| 200 | 9.0 | 1.6 |
| 400 | 18.3 | 2.3 |

**Development impacts, direct and indirect benefits**

Cost benefits

Figure 3 illustrates the operating cost savings of three equivalent Honda Civic (CNG, gasoline and HEV), compared to the world average new vehicle fleet operating cost of 2005. The total vehicle kilometers traveled per year is estimated 10000km, and the gasoline price 1.2 USD/liter. Savings are presented as function of the NG price (equivalent per liter gasoline), expressed in percentage of the gasoline price.

- As CNG price is lower than 68.3% of the gasoline price, CNG presents cost savings up to 930 USD/year. Otherwise, the hybrid is more beneficial.
- As CNG price exceeds 97%, gasoline would present better savings than CNG.

Note that additional savings are achieved by comparing to the average fuel consumption cost of the whole 2005 Lebanese car fleet, since the average consumption far exceeds the 2005 world average of 8.07 l/100km.

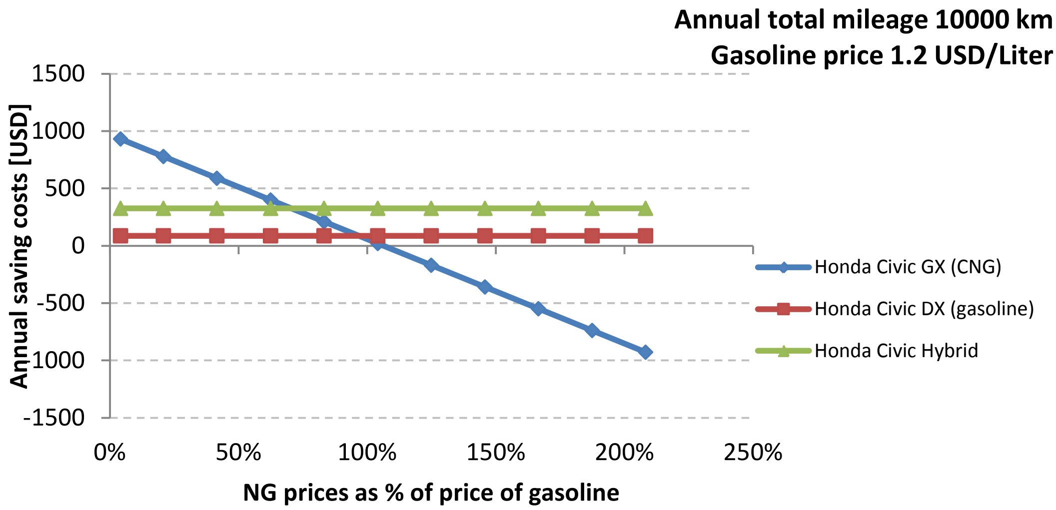


Figure 3. Annual operating saving costs of CNG, gasoline and hybrid Honda Civic comparing to 2005 new fleet world average, as function of CNG gasoline equivalent prices, with an annual mileage estimated 10000 km.

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<td>Environmental benefits</td>
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**Total energy use**

Figure 4 outlines the Well-To-Wheel (WTW) total energy use of CNG and LNG vehicles, and compares to similar gasoline HEV and BEV under different scenarios of electricity generation mix.

The total energy use of NGVs is higher than the HEV and BEV, in all its forms of NGV technologies and particularly when NG feedstock is transported to gas station using LNG. NGVs higher total energy use is due to their high vehicle operation consumption, though they have a WTP efficiency exceeding 75%.

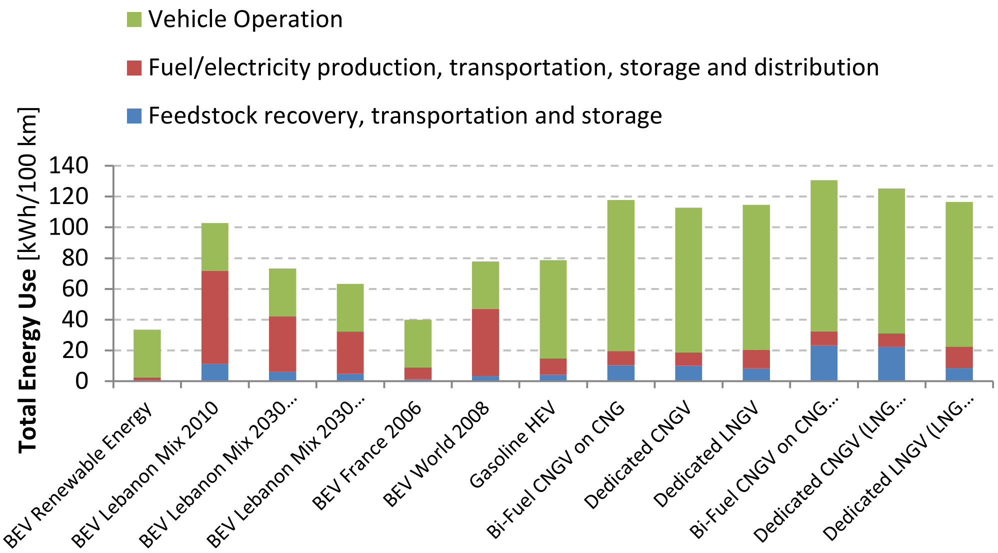


Figure 4. WTW total energy use of NGV, gasoline HEV and BEV using different electricity generation mix.

**GHG emissions reduction**

Figure 5 outlines the WTW GHG emissions change of NGV, gasoline HEV and BEV comparing to a 2005 mid-size conventional vehicle that consumes 10 l/100km.

- 5 to 20% of $CO_2$ savings are observed depending on the technology and the path for transporting NG feedstock
- considering the rest of GHGs such as $CH_4$ and $N_2O$, almost no GHG emissions reductions are observed with NGVs

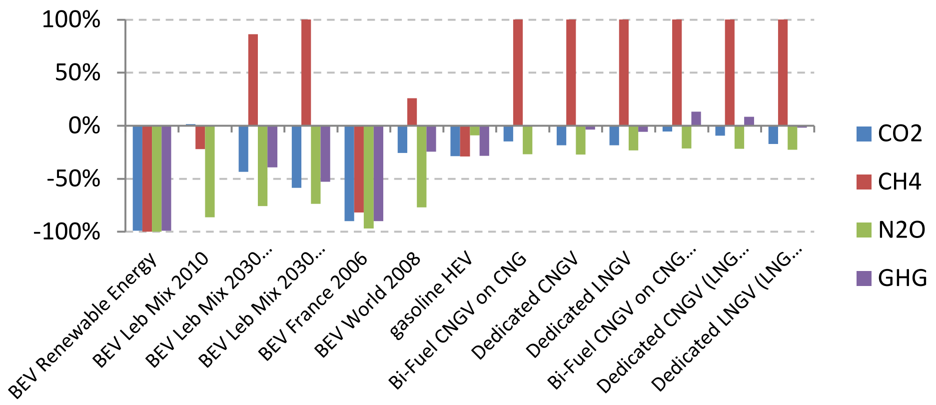


Figure 5. WTW GHG emissions change of NGV, gasoline HEV and BEV comparing to 2010 conventional vehicle.

**Pollutant emissions reduction**

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<tr><td></td><td>The main advantage of NGV is the reduction of pollutant emissions comparing to equivalent gasoline powered vehicles (Figure 6). Main pollutant reductions are CO and VOC as NG (methane) has less carbon content and the CNG tanks are sealed.

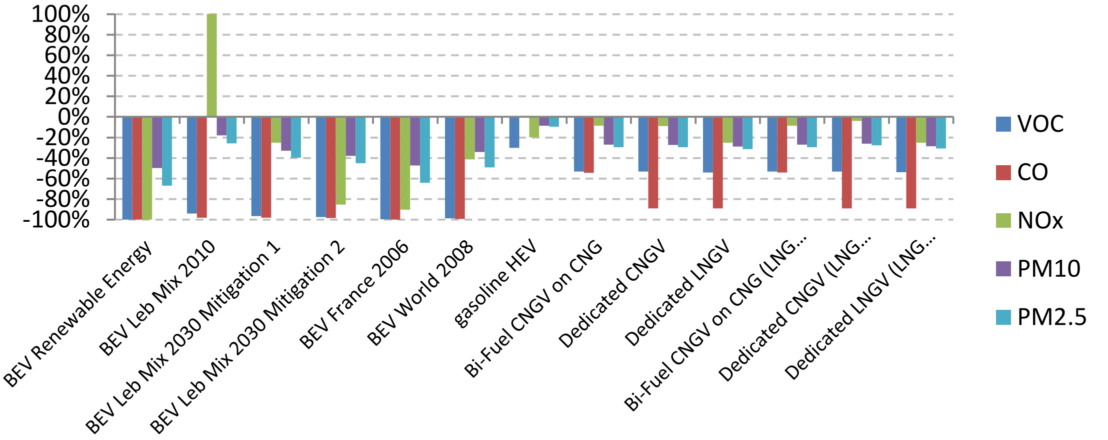


Figure 6. WTW pollutants change of NGV, gasoline HEV and BEV comparing to 2005 conventional vehicle under urban driving conditions.

For the case of Lebanon, NG is imported from regional countries. It is convenient to compare the vehicle operation emissions (Figure 7). Bi-fuel CNG vehicles present similar CO and VOC emissions comparing to low-emission gasoline vehicles, and much lower than uncontrolled gasoline vehicles. Moreover, advanced control CNG like dedicated CNG vehicles present even much lower emissions than low-emission gasoline. However, the uncertainty remains on the NOx emissions level. According to the literature, NOx emissions from bi-fuel NGVs may be higher or lower than comparable gasoline vehicles, depending on the engine technology. NOx emissions from NGVs are more difficult to control using three-way catalysts.

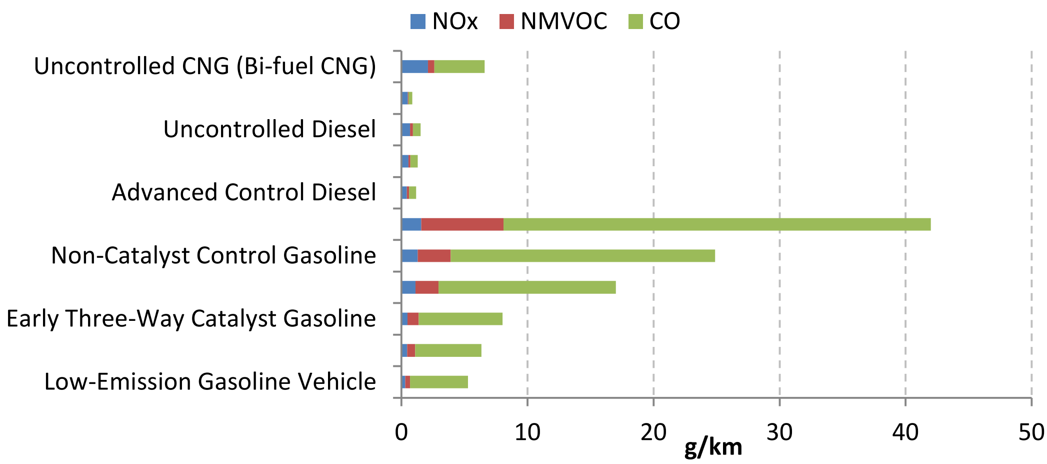


Figure 7. Vehicle operation emissions of CNG, diesel and gasoline technologies.</td></tr>
<tr><td colspan="2">Local context</td></tr>
<tr><td>Status</td><td>No NGVs are officially registered in the car registration office. However, the MOEW is studying the possibility to introduce NGVs to the Lebanese market on the medium term.</td></tr>
<tr><td>Timeframe</td><td>Medium term implementation<br>NGVs' implementation could not start immediately. A specific fueling and NG transportation infrastructure is requested. Though NGV concept is a mature</td></tr>
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| | technology, its implementation is not expected on the short term. |

[i] **This fact sheet has been extracted from TNA Report – Technology Needs Assessment Reports For Climate Change Mitigation – Lebanon. You can access the complete report from the TNA project website http://tech-action.org/**