SUSTAINABLE OIL AND GAS DEVELOPMENT IN LEBANON

Transport Sector

Innovative Vehicle and Bus Technologies Needed for Sustainable Mobility in Greater Beirut Area

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Current state and projection of transport energy use in Lebanon: significant growth

According to the business as usual projection of Lebanon’s energy use and emissions:

- Energy consumption and emissions expected to double by 2040 as compared to levels of 2010.
- Gasoline is the dominant fuel with 83.5%.
- Lebanon’s vulnerability to energy security will increase due to additional need to import gasoline and diesel.
- Lebanon will not be able to meet the INDC commitment to the UNFCCC to reduce its GHG emissions.

(1) Forecasted numbers are calculated using a model developed for Lebanon, based on the population and GDP growth (Source: Mansour et al. 2015, National Greenhouse Gas Inventory Report and Mitigation Analysis for the Transport Sector in Lebanon).
Current proposals for shifting to sustainable mobility

SODEL Project 2017:
**MOEW, UNDP, LPA**
Assess the use of alternative fuel-vehicle technologies

Conventional fuel vehicles

V/S

Alternative fuel vehicles

SODEL Project 2018:
**MOEW, UNDP, LPA**
Assess the use of alternative fuel-bus technologies

Revitalizing the mass transit systems
Objectives of the SODEL Study

1. What is the best way to use Lebanon’s natural gas in the transport sector?
   - Directly in passenger cars, taxis and buses?
   - Indirectly in power plants to generate electricity for electric vehicles?
   - A mix of both strategies?

2. Which other fuels can also be feasible for Lebanon’s transport sector?
   - Oil-based?
   - Natural-gas?
   - Biofuels?
   - Electricity?

3. Which vehicle and bus technologies is the cleanest and cheapest for Lebanon?
   - Gasoline and diesel vehicles?
   - Compressed natural gas (CNG) vehicles?
   - Ethanol and biodiesel vehicles?
   - Hybrid, plug-in hybrid and electric vehicles?

4. What should the government strategy be?
   - Laws and regulations?
   - Incentives and disincentives?
   - Action plan?
Project outline

I. Assessment of alternative fuel-bus and fuel-vehicle technologies

- Define the various options for the use of natural gas and other low-carbon fuels as applicable to the Lebanese transport sector.
- Identify the corresponding bus and vehicle technologies.

II. Infrastructure assessment

- Assess the existing and potential fuel-supply infrastructure relevant to the identified bus and vehicle technologies.

III. Environmental assessment

- Conduct a Well-To-Wheel energy and emissions analysis for the identified energy chain pathways.

IV. Cost-benefit analysis

- Identify the cost value of the identified bus and vehicle technologies in order to support setting a beneficial transport policy, favoring cleaner over more polluting technologies.
Study Methodology: Energy consumption and emissions at all stages of each fuel process

A well-to-wheel assessment of fuel and vehicle technologies in Lebanon is conducted. The objective is to evaluate their fuel use, environmental impacts and costs.

- **Calculation of total energy consumption for each process**
- **Calculation of total emissions for each process**
**Study Methodology: Costs**

A cost-benefit assessment is carried out to evaluate the economic impacts of the fuel-vehicle technologies on the car users, the government and the private sector, for the near- (2020), medium- (2030) and long-terms (2040). Following are the cost components considered.

<table>
<thead>
<tr>
<th>Vehicle total costs for users:</th>
<th>Infrastructure and government costs:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle ownership cost</td>
<td>Infrastructure capital cost</td>
</tr>
<tr>
<td>Vehicle purchase cost</td>
<td>Distribution infrastructure</td>
</tr>
<tr>
<td>Vehicle depreciation</td>
<td>Transportation infrastructure</td>
</tr>
<tr>
<td>Insurance fees</td>
<td>Fuel production plant</td>
</tr>
<tr>
<td>Custom and excise fees</td>
<td>Infrastructure operating cost</td>
</tr>
<tr>
<td>Registration</td>
<td>Distribution infra. O&amp;M</td>
</tr>
<tr>
<td>VAT</td>
<td>Transportation infra. O&amp;M</td>
</tr>
<tr>
<td>Road usage fees</td>
<td>Subsidy foregone revenues</td>
</tr>
<tr>
<td>Financing charges</td>
<td>Foregone fuel tax revenues</td>
</tr>
<tr>
<td>Vehicle operating cost</td>
<td></td>
</tr>
<tr>
<td>Energy consumption cost</td>
<td></td>
</tr>
<tr>
<td>Maintenance and repair costs</td>
<td></td>
</tr>
<tr>
<td>DPF and Battery costs</td>
<td></td>
</tr>
<tr>
<td>Operation subsidies</td>
<td></td>
</tr>
</tbody>
</table>

**Environmental-to-cost performance**
In (USD/veh.km) of each fuel-vehicle technology relative to the baseline 2016 gasoline ICEV

**Government foregone revenues**
GHG abatement cost by fuel-vehicle technology in (USD/tonne CO2 eq.)

**Public sector infrastructure cost**
v/s WTW GHG emissions reduction of each fuel-vehicle technology

**Near-term 2018-2020**

**Medium-term 2018-2030**

**Long-term 2018-2040**
Results for cars: Consumption, emissions and costs of each fuel and vehicle technology

<table>
<thead>
<tr>
<th>Fuel/Technology</th>
<th>Consumption (Ml/100km)</th>
<th>GHG Emissions (g/km)</th>
<th>Vehicle Cost (USD/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline/Diesel</td>
<td>275/230</td>
<td>196/170</td>
<td>0.46/0.53</td>
</tr>
<tr>
<td>Ethanol/Biodiesel</td>
<td>255/235</td>
<td>223/175</td>
<td>0.46/0.53</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>330</td>
<td>186</td>
<td>0.49</td>
</tr>
<tr>
<td>Hybrid</td>
<td>196</td>
<td>139</td>
<td>0.30</td>
</tr>
<tr>
<td>Electric</td>
<td>129</td>
<td>0[^1]</td>
<td>0.41</td>
</tr>
</tbody>
</table>

Electric and hybrid vehicles are the best performers:

- Electric vehicles save 53% of energy consumption compared to gasoline vehicles if natural gas is used to produce clean electricity in power plants.
- Electric vehicles contribute to improve air quality in urban areas with their zero emissions.
- Hybrid vehicles save 28% of fuel consumption and emissions.
- If tax incentives are given to buy electric and hybrid vehicles, users can save 10% to 15% of total vehicle cost over the 10-year vehicle lifespan.

[^1]: 72 g/km of GHG emitted from the power plant, using natural gas as fuel.
[^2]: Vehicle cost includes vehicle ownership cost, operating cost and operation subsidy.
Results for cars: Infrastructure costs and foregone revenues

<table>
<thead>
<tr>
<th></th>
<th>Infrastructure Cost by 2040 (Million USD)</th>
<th>Foregone Revenues (Million USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>80-143</td>
<td>0</td>
</tr>
<tr>
<td>Hybrid</td>
<td>0</td>
<td>29-380</td>
</tr>
<tr>
<td>Electric</td>
<td>81-146</td>
<td>36-455</td>
</tr>
</tbody>
</table>

- Infrastructure cost for natural-gas vehicles and electric vehicles are of comparable scale (USD 80-146 M), which means it is more effective to develop an infrastructure for electric vehicles since they provide superior energy, emissions and cost savings for users, the same infrastructure investment cost.

- Natural gas vehicles are of interest only for mass transit services.

- Hybrids are the vehicle technology of choice if no infrastructure investment is to be made.

- Electric are preferred when it comes to maximizing energy and emissions savings, making them the preferred fuel-vehicle technology in the medium and long term.
Potential bus technologies as applicable for the Lebanese transport sector

- Severe congestion conditions
  
  avg. velocity: 6 km/h
  idle time: 67% of trip time

- Peak traffic conditions
  
  avg. velocity: 11 km/h
  idle time: 36%
  with frequent acceleration and deceleration

- Off-peak traffic conditions
  
  avg. velocity: 20 km/h
  idle time: 21%

- BRT service conditions
  
  avg. velocity: 36 km/h
  idle time: 23%

<table>
<thead>
<tr>
<th></th>
<th>Auxiliaries power excluding climate control auxiliaries</th>
<th>Climate control auxiliaries power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel and CNG buses</td>
<td>9,000 W</td>
<td>13,400 W</td>
</tr>
<tr>
<td>Hybrid and electric buses</td>
<td>5,250 W</td>
<td>14,000 W</td>
</tr>
</tbody>
</table>
Results for buses: Consumption

**without Climate Control**

- **Severe Congestion**
  - Diesel: 149
  - CNG: 105
  - Series Hybrid: 47
  - Parallel Hybrid: 88
  - Electric: 111

- **Peak**
  - Diesel: 111
  - CNG: 72
  - Series Hybrid: 69
  - Parallel Hybrid: 31
  - Electric: 75

- **Off-Peak**
  - Diesel: 61
  - CNG: 75
  - Series Hybrid: 49
  - Parallel Hybrid: 24
  - Electric: 30

- **BRT**
  - Diesel: 30
  - CNG: 38
  - Series Hybrid: 31
  - Parallel Hybrid: 26
  - Electric: 12

**with Climate Control**

- **Severe Congestion**
  - Diesel: 204
  - CNG: 171
  - Series Hybrid: 143
  - Parallel Hybrid: 142
  - Electric: 104

- **Peak**
  - Diesel: 114
  - CNG: 104
  - Series Hybrid: 100
  - Parallel Hybrid: 74
  - Electric: 45

- **Off-Peak**
  - Diesel: 74
  - CNG: 71
  - Series Hybrid: 70
  - Parallel Hybrid: 31
  - Electric: 39

- **BRT**
  - Diesel: 39
  - CNG: 47
  - Series Hybrid: 42
  - Parallel Hybrid: 36
  - Electric: 17
Results for buses: GHG Emissions

TTW GHG emissions without use of climate control auxiliaries.

TTW GHG emissions with use of climate control auxiliaries.

WTW GHG emissions of electric bus technologies under the 2015 and 2030 electricity mixes.
Results for buses: Environmental-to-cost performance of bus technologies relative to diesel bus

SEVERE CONGESTION OPERATION

BRT OPERATION

Saved TTV GHG emissions compared to diesel bus (kg CO2 eq./bus.km)

Cost savings compared to diesel bus

Cost savings compared to diesel bus

Electric Bus (TTW)

Electric Bus (WTW)

CNG Bus

Parallel Hybrid Bus

Series Hybrid Bus

Diesel Bus
Results for buses: Costs

Total Cost Savings of Electric Bus Compared to Diesel Bus

- Severe Congestion
- Peak
- Off-Peak
- BRT operation

Bus Purchase Subsidy
Results for buses: Consumption, Emissions and Costs of each fuel and bus technology

<table>
<thead>
<tr>
<th></th>
<th>Diesel</th>
<th>Natural Gas</th>
<th>Hybrid</th>
<th>Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consumption</strong> (l/100km)</td>
<td>80</td>
<td>101</td>
<td>60</td>
<td>28</td>
</tr>
<tr>
<td><strong>GHG Emissions</strong> (g/km)</td>
<td>1,884</td>
<td>1,706</td>
<td>1,490</td>
<td>0 (1)</td>
</tr>
<tr>
<td><strong>Bus Cost</strong> (USD/km)</td>
<td>1.37</td>
<td>1.37</td>
<td>1.23</td>
<td>1.08</td>
</tr>
</tbody>
</table>

Similar to passenger cars, electric and hybrid buses are the best performers:

- Electric buses save 65% of energy consumption compared to diesel buses if natural gas is used to produce electricity in power plants.
- Electric buses contribute to improve air quality in urban areas for their zero emissions.
- Hybrid buses save 25% of fuel consumption and 21% of emissions.
- If incentives on bus purchase cost are given to bus operators, electric bus can save between 8% and 30% compared to Diesel bus over the 12-year bus service life, depending on the bus average velocity. 
  
  *(30% inside Beirut under severe congestion, 8% under BRT operation)*

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(1) 1,259 g/km of GHG emitted from the power plant, using natural gas as fuel.
**Near Term Actions:**
- Remove import taxes on hybrid cars and buses
  - No investment costs
  - Immediate, but moderate levels, of energy and emissions savings

**Medium Term Actions:**
- Convert power plants to natural gas for clean charging of electric vehicles and buses
- Build electivity charging infrastructure
- Build small-scale CNG infrastructure for mass transit
  - New investment costs
  - Additional energy and emissions savings

**Long Term Actions:**
- Expand electricity charging infrastructure
  - Additional investment costs
  - High energy and emissions savings

**Strategy Roadmap**

- **2018 – 2020**
- **2020 – 2030**
- **2030 – 2040**
Thank you for your attention

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Charbel MANSOUR  charbel.mansour@lau.edu.lb
Strategy Roadmap in Detail

**Near Term Actions:**
Remove import taxes on hybrids

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Foregone Revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>No new investment</td>
<td>$29-$380 M</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Emissions</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.6%</td>
<td>29%</td>
<td>14%</td>
</tr>
</tbody>
</table>

**Medium Term Actions:**
Build electricity charging infrastructure and use NG to generate electricity.

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Foregone Revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>$25-$57 M</td>
<td>$36-$455 M</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Emissions</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>53%</td>
<td>64%</td>
<td>7.8%</td>
</tr>
</tbody>
</table>

**Long Term Actions:**
Expand electricity charging infrastructure

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Foregone Revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>$56-$89 M</td>
<td>zero</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Emissions</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>53%</td>
<td>64%</td>
<td>9.5%</td>
</tr>
</tbody>
</table>

**Build small-scale CNG infrastructure for mass transit (taxi, bus)**

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Foregone Revenues</th>
</tr>
</thead>
<tbody>
<tr>
<td>$26-57 M</td>
<td>zero</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Emissions</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20%</td>
<td>5.6%</td>
<td>3.7%</td>
</tr>
</tbody>
</table>
### Policy Recommendations

**Action plan for transition to fuel efficient passenger cars in the Lebanese Transport sector**

<table>
<thead>
<tr>
<th>Type</th>
<th>Priority sequence</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic and financial measures</strong></td>
<td></td>
<td>Exemption from custom and excise fees, registration fees, and road usage fees at registration.</td>
</tr>
<tr>
<td></td>
<td>2  Transition</td>
<td>Adopt a Bonus-Malus tax policy where polluters pay more annual road-usage fees, and where taxes are estimated based on fuel efficiency and/or emissions rather than engine displacement.</td>
</tr>
<tr>
<td></td>
<td>3  Dispose of old cars</td>
<td>Create a car termination plant that deals with the car termination process after the swap in the scrappage program.</td>
</tr>
<tr>
<td><strong>Market development</strong></td>
<td></td>
<td>Reduce gradually maximum age of imported pre-owned vehicles and maximum mileage.</td>
</tr>
<tr>
<td><strong>Policy, legal and regulatory</strong></td>
<td>4  Regulate car imports</td>
<td>Update decree 6603/1995 relating to standards on permissible levels of exhaust fumes and exhaust quality to cover all types of vehicles</td>
</tr>
<tr>
<td></td>
<td>5  Plug the leaks</td>
<td>Create an industry for recycling car parts and components.</td>
</tr>
<tr>
<td><strong>Institutional/organizational capacity</strong></td>
<td></td>
<td>Update the vehicle inspection program with special requirements for inspection of hybrid cars, and mandate catalytic converters on conventional gasoline vehicles.</td>
</tr>
<tr>
<td><strong>Social awareness</strong></td>
<td>6  Educate</td>
<td>Establish awareness campaign to educate about new technologies &amp; correct old perceptions.</td>
</tr>
<tr>
<td><strong>Initiative monitoring and validation</strong></td>
<td>7  Monitor the progress</td>
<td>Create Mobility Monitoring Indicators (MMI) framework.</td>
</tr>
</tbody>
</table>
**Policy Recommendations**

**Action plan for deployment of efficient mass transit system in the Lebanese Transport sector**

<table>
<thead>
<tr>
<th>Type</th>
<th>Priority sequence</th>
<th>Measures</th>
</tr>
</thead>
</table>
| Economic and financial measures     | 1 Develop supply chain | Design a bus network covering all boroughs within GBA and reserve lanes for bus operation  
2 Shift travel demand | Ensure sufficient number of transit buses with proper powertrain technology  
Exempt mass transit buses (and spare parts) from custom/excise fees, and registration fees  
Create employee package for taxi drivers including social benefits, insurance, retirement plans, etc. |
| Market development                  | 3 Deploy effective infrastructure | Establish smart card ticketing schemes with appropriate reduced tariffs  
Optimize the operation management of the bus transit system: conserve a clear and regular bus operation, implement real-time information system, deploy personalized travel planning tools, implement transit signal priority, set up stringent maintenance and cleanliness program, construct relevant maintenance and repair workshops |
| Policy, legal and regulatory        | 4 Set regulatory framework | Set clear regulations specifying the operation maneuvers of private bus operations and taxi owners  
Draft new amended laws for increasing parking space and reserving lanes for buses |
| Institutional/organizational capacity | 5 Manage demand   | Develop technical expertise among TMO staff and high level management |
| Social awareness                    | 6 Stimulate passengers demand     | Provide information on CO2, fuel and cost savings comparing to passenger cars |
| Project monitoring and validation   | 7 Monitor the progress              | Create Mobility Monitoring Indicators (MMI) framework |
Assessment framework for the identified fuel-vehicle technologies

Feedstock-related activities:
- Feedstock recovery, processing, storage and transportation

Fuel-related activities:
- Fuel production, transportation, storage and distribution

Vehicle-related activities:
- Refueling and operation

Pollutants emissions
- (g/MJ of fuel)
- (g/t.km)
- (g/km)

GHG emissions
- (CO2 eq. g/MJ of fuel)
- (CO2 eq. g/t.km)
- (CO2 eq. g/km)

Energy intensity of used resources
- (MJ/t.km)
- (MJ/km)

Consumption of total energy resources
- (oil, electricity, renewable, etc.)
- (MJ/MJ of fuel)

Vehicle energy consumption
- (gasoline, diesel, NG, etc.)
- (MJ/km)

Evaluated GHG emissions: CO2, CH4 and N2O

Evaluated pollutants emissions: VOCs, CO, NOx, PM10, PM2.5, SOx
CO2 emissions versus energy use of the assessed fuel-vehicle technologies

More CO2 emitting

More energy consuming

WTW CO2 Emissions (kg/100km)

WTW Energy Use (MJ/100km)
Costs and benefits from the car users’ perspective:
Environmental-to-cost performance of fuel-vehicle technologies relative to gasoline ICEV for yearly mileage of 12,000 km
Costs and benefits from the car users’ perspective:

Environmental-to-cost performance of fuel-vehicle technologies relative to gasoline ICEV for yearly mileage of 30,000 km.

- Gasoline: 1 USD/liter
- NG: 0.5 USD/lge
- Electricity: 23 USC/kWh

Cost savings compared to gasoline ICEV.
Government foregone revenues and saved WTW GHG emissions over the near, medium and long-terms

**Low market penetration of alternative fuel vehicles**

- HEV: 29.3 M USD, 58,500 tonnes/year
- PHEV20: 34 M USD, 74,000 tonnes/year
- PHEV60: 39.3 M USD, 95,000 tonnes/year
- EV: 36.2 M USD, 129,000 tonnes/year

**High market penetration of alternative fuel vehicles**

- HEV: 381 M USD, 105,500 tonnes/year
- PHEV20: 442 M USD, 132,500 tonnes/year
- PHEV60: 511 M USD, 167,000 tonnes/year
- EV: 455 M USD, 230,000 tonnes/year
Infrastructure investment costs and saved WTW GHG emissions over the near, medium and long-terms

**Low market penetration of alternative fuel vehicles**

- **CNG**:
  - Investment: $80.1 M USD
  - Saved emissions: 11,000 tonnes/year
- **L-CNG**:
  - Investment: $98 M USD
  - Saved emissions: 11,000 tonnes/year
- **LPG**:
  - Investment: $19.6 M USD
  - No needed investment
- **HEV**:
  - Investment: $81.3 M USD
  - Saved emissions: 58,500 tonnes/year
- **PHEV**:
  - Investment: $81.3 M USD
  - Saved emissions: 74,000-95,000 tonnes/year
- **EV**:
  - Investment: $81.3 M USD
  - Saved emissions: 129,000 tonnes/year

**High market penetration of alternative fuel vehicles**

- **CNG**:
  - Investment: $143 M USD
  - Saved emissions: 19,500 tonnes/year
- **L-CNG**:
  - Investment: $174 M USD
  - Saved emissions: 19,500 tonnes/year
- **LPG**:
  - Investment: $35 M USD
  - No needed investment
- **HEV**:
  - Investment: $145 M USD
  - Saved emissions: 105,500 tonnes/year
- **PHEV**:
  - Investment: $145 M USD
  - Saved emissions: 132,000-167,000 tonnes/year
- **EV**:
  - Investment: $145 M USD
  - Saved emissions: 230,000 tonnes/year