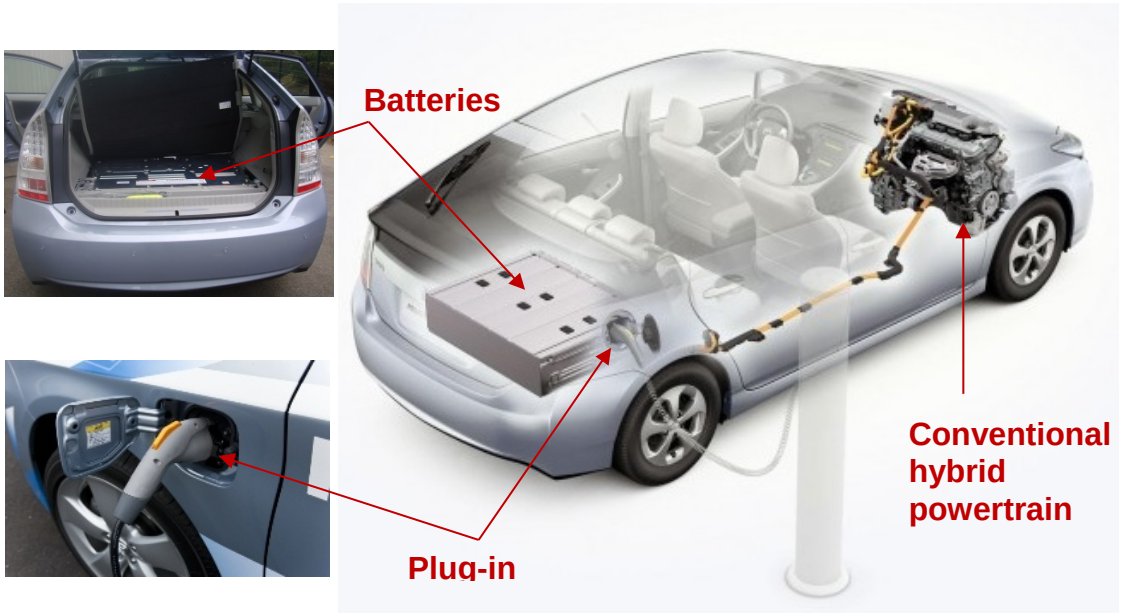
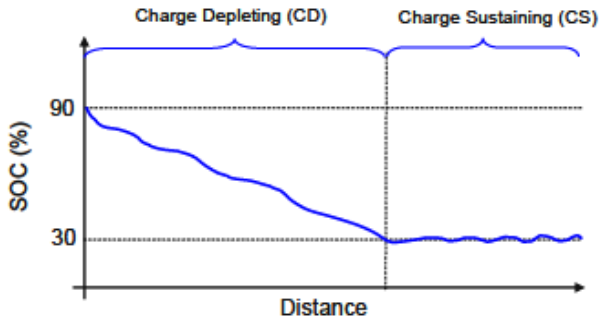
Technology Fact Sheet for Mitigation

M. Plug-in Hybrid Electric Vehicles [i]

Sector : Transport	
Subsector : Advanced powertrains for passenger cars	
Technology characteristics	
Introduction	A plug-in hybrid electric vehicle (PHEV) is a hybrid vehicle which utilizes rechargeable batteries that can be restored to full charge by connecting a plug to an external electric power source (usually a normal electric wall socket) (Figure 1). A PHEV shares the characteristics of both a conventional hybrid electric vehicle, having an electric motor and an internal combustion engine (ICE); and of an all-electric vehicle, having a plug to connect to the electrical grid. Therefore batteries of PHEVs have bigger capacities than conventional HEVs (example 1.3 kWh for the Prius HEV and 5.2 kWh for the Prius PHEV).  Figure 1. Configuration of PHEV powertrain.
Technology characteristics	**Mode of operation** Regardless of its architecture, a PHEV is capable of charge-depleting and charge-sustaining modes (Figure 2): · Charge-depleting mode allows a fully charged PHEV to operate exclusively as a Battery Electric Vehicle (BEV) in All-Electric-Range (AER) until its battery state of charge is depleted to a predetermined level. · Charge-sustaining mode is the same operating mode as conventional HEVs. Once a PHEV has exhausted its AER in charge-depleting mode, it can switch into charge-sustaining mode automatically. The key advantage of PHEV technology relative to full BEV is the fuel flexibility. PHEVs have no limitation of the driving range, and if the recharging infrastructure is spatially or temporally unavailable, it doesn't restrict the use of the vehicle.

	 Figure 2. State of Charge (SOC) behavior of batteries during charge depleting/charge sustaining modes in a PHEV.
Operation and maintenance	· PHEVs differ little from conventional vehicles when it comes to routine maintenance items: the systems that control the on-board storage batteries and the additional electric drive motor must be checked out regularly. · Maintenance costs of PHEVs are lower than those of conventional vehicles, due to less use of the engine; therefore, less change of oil, spark plugs, air filter, fuel filter, brake pads, etc. · PHEVs may need a battery change over the vehicle life. Battery costs range between 800 USD/kWh and 1000 USD/kWh. The long term battery costs are expected to be 300-500 USD/kWh by 2015.
Endorsement by experts	· PHEVs are endorsed by automotive manufacturers, in order to avoid paying excess emissions penalties.
Advantages	PHEVs are most feasible for use in congested cities, where the vehicle behaves mostly as BEV, thus cuts down CO2 and pollutants tailpipe emissions. They offer several advantages compared to conventional vehicles: · Less dependence on fossil fuels: PHEVs are expected to use about 40 to 60 percent less petroleum than conventional vehicles. As an example, Plug-in Prius fuel consumption is estimated at 2.6 l/100km in combined driving conditions. · Less GHG Emissions: PHEVs are expected to emit less GHG than conventional vehicles, but the amount generated depends partly on the fuel used at electrical power plants. Nuclear, renewable energy and hydroelectric power plants are highly recommended rather than coal-fired power plants. · Driving range similar to a conventional vehicle, since an ICE is still onboard to extend the range of the vehicle once the battery charge is depleted. · Lower operating costs: though PHEVs will likely cost 1000 to 7000 USD more than comparable conventional HEVs, fuel will cost less since electricity is much cheaper than gasoline, but it is unclear whether fuel savings will offset the vehicle cost when PHEVs are first introduced. Incentives will play a decisive role in promoting PHEVs. · Lower maintenance costs: maintenance costs of PHEVs are similar to HEVs, thus lower than those of conventional vehicles, due to less use of the engine. However, PHEVs may need a battery change over the vehicle life.
Disadvantages	· Recharging the battery typically takes several hours, but a "quick charge" to 80% capacity may take as little as 30 minutes. However, PHEVs don't have to be

	plugged in to be driven. They can be fueled solely with gasoline but will not achieve maximum range or fuel economy without charging, since they will be operated as conventional HEVs. · It is assumed that plug-in recharging will take place overnight at home. However, residents of cities, apartments, dormitories, and townhouses do not have garages or driveways with available power outlets, and they might be less likely to buy plug-ins unless recharging infrastructure is developed. Electrical outlets or charging stations near their places of residence, or in commercial or public parking lots or streets or workplaces are required for these potential users to gain the full advantage of PHEVs. Even house dwellers might need to charge at the office or to take advantage of opportunity charging at shopping centers. However, this infrastructure is not in place today and it will require investments by both the private and public sectors.
Capital costs	
Additional cost to implement mitigation technology, compared to "business as usual"	Additional costs must be considered at two levels: · PHEVs require a bigger battery which adds extra to the costs. The price of the battery system is about 1700 USD for a 15 kilometer AER and about 3400 USD for a 60 kilometer AER. This brings the additional cost of a PHEV to 5700-7400 USD compared to similar conventional gasoline powered vehicle. · In addition to the battery extra costs, there is a need for investment into the recharging infrastructure: – a simple recharging point at a private house or at an office costs about 1800 USD – a public recharging station, with the necessary electronics to make contact with the bank costs about 18000 USD
Development impacts, direct and indirect benefits	
Cost benefits	Figure 3 illustrates the operating cost savings of Prius and Escape PHEVs and their equivalent HEV versions, compared to the average new vehicle fleet operating cost of 2005. The total vehicle kilometers traveled per year is estimated 10000km, and the electricity tariff 0.15 USD/kWh. · With the current fuel price trend (~1.2 USD/liter), savings of plug-in Priuses range between 450 and 500 USD/year, comparing to the average fuel consumption cost of the 2005 world new car fleet. However, HEV Prius savings are around 330 USD/year. Therefore, 120 to 170 USD savings are achievable comparing to HEV. · Though Ford Escape is a SUV, the Escape PHEV saves 150 USD/year for 1.2 USD/liter of gasoline. However, the Escape hybrid has an additional operating cost of 75 USD/year comparing to the 2005 world average. 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 world average of 8.07 l/100km. Figure 4 highlights the influence of electricity tariff increase with a fuel price estimated at 1.2 USD/liter and 10000 km/year. As electricity tariff increases, operating cost saving of PHEVs are lowered, and HEVs becoming more beneficial. As an example, HEV Prius presents better cost savings than plug-in Prius as electricity tariff exceeds 0.4 USD/kWh.

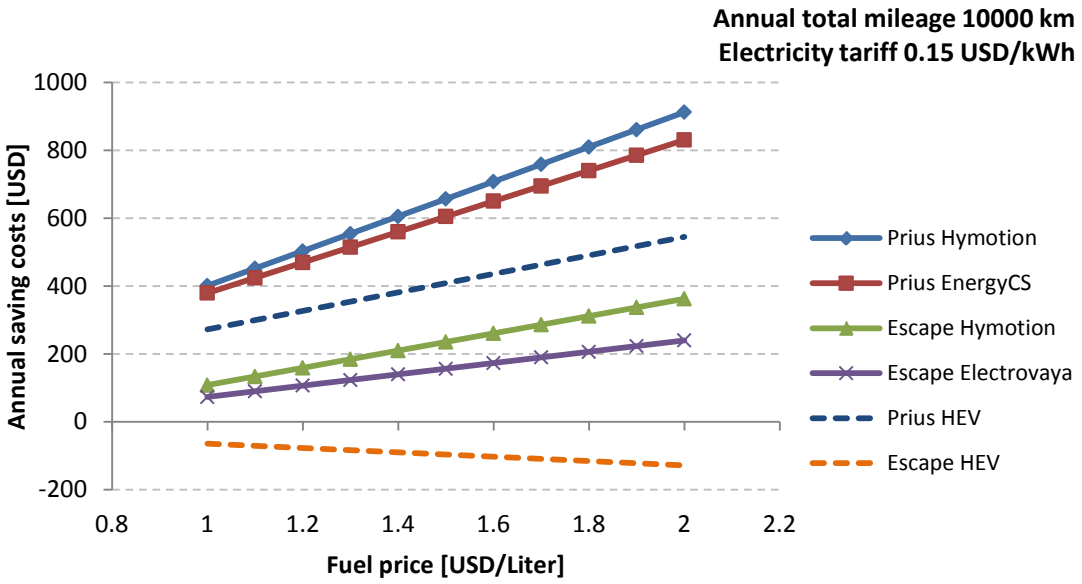


Figure 3. Annual operating saving costs of PHEVs and their similar HEVs comparing to 2005 new fleet world average, as function of fuel price, with an annual mileage estimated 10000 km and electricity tariff of 0.15 USD/kWh.

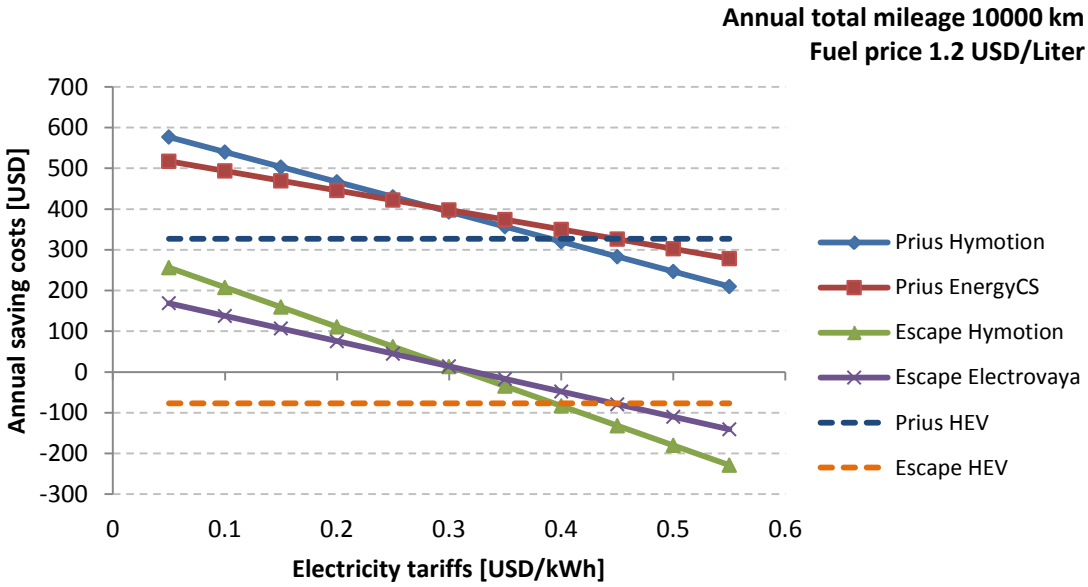


Figure 4. Annual operating saving costs of PHEVs and their similar HEVs comparing to 2005 new fleet world average, as function of electricity tariffs, with an annual mileage estimated 10000 km and fuel price of 1.2 USD/liter.

Environmental benefits	According to results of an on-road accelerated testing measurements on two plug-in Prius and two plug-in Ford Escape, done by the USDOE (the office of Energy Efficiency and Renewable Energy), consumption savings range between 56 and 63% for the Prius and 20 to 30% for the Escape. Both PHEVs present 26 to 45% of savings comparing to their similar HEV versions. Reducing fuel consumption implies reducing emissions. However, the final CO2 emission reduction depends strongly on the source of the electricity used. A larger

	deployment of renewable energy sources would lower the CO2 emission of the PHEV further.
Local context	
Status	No PHEVs are available in the Lebanese car fleet. The only commercialized PHEVs are the BYD F3DM (China 2008, US 2010), the Chevy Volt (December 2010 for US market only) and the Prius Plug-in (US market only by using aftermarket kits). Therefore, all three models cannot be imported to the Lebanese market. Some models are expected to be commercialized worldwide soon, particularly the official Prius plug-in and the Chevy Volt/Opel Ampera. It is expected that more and more car manufactures will bring plug in vehicles to the market in the coming years: Fisker Karma, Ford Escape Plug-in Hybrid, Volvo V70 Plug-in Hybrid, Suzuki Swift Plug-in, Ford C-Max Energi and others.
Timeframe	**Medium term implementation** PHEVs' implementation could not start immediately. A specific recharging infrastructure is requested. Many efforts are invested toward creating universal safe standard recharging stations. Different pilot projects are ongoing worldwide to ensure the well-operation of the PHEV concept, and learn lessons from drivers behaviors, charging time, charging frequency, charging location, daily driving mileage, mileage between charging events, and other influencing parameters. One of these projects is undertaken in France by Toyota and EDF (Electricité De France), where Toyota is proposing a fleet of 100 Prius Plug-in for lease and EDF is implementing the recharging infrastructure in residential and public parking. Results are expected to be published in 2012. PHEV concept is expected to become a mature expandable technology on the short to medium terms.

[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/**