FROST & SULLIVAN

Global Market Analysis of Plug in Hybrid Electric Vehicles

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Frost & Sullivan
4 Grosvenor Gardens
Sullivan House
London SW1W 0DH
United Kingdom

Certification

We hereby certify that the views expressed in this research service accurately reflect our views based on primary and secondary research with industry participants, industry experts, end users, regulatory organisations, financial and investment community and other related sources.

In addition to the above, our robust in-house forecast and benchmarking models along with the Frost & Sullivan Decision Support Databases have been instrumental in the completion and publishing of this research service.

We also certify that no part of our analyst compensation was, is or will be, directly or indirectly, related to the specific recommendations or view expressed in this research service.

Research Methodology

Frost & Sullivan Market Engineering Methodology

Frost & Sullivan market intelligence is based on secondary and primary information, where primary research accounts for approximately 70% to 80% of the data collection process.

The Key Regions covered for the purpose of this study include Europe (Western and Eastern), North America and Japan.

❑ Secondary Research:

Frost & Sullivan conducted an extensive review of all the **existing information** available. Some of the sources used were:

- Frost & Sullivan past publication & internal databases
  E.g.: Strategic Analysis of the European Market for Micro Mild and Full Hybrid Vehicle Technologies– Feb 2006
  E.g.: Customer Attitudes and Perceptions towards Powertrain and Hybrid Vehicle Technologies and Features– September 2006
- Trade press & associations

Review and utilise existing information

- Avoid spending time on information that is already available.
- Focus on bridging information gaps, confirm and/or challenge existing knowledge.

❑ Primary Research:

- For the purpose of this study Frost & Sullivan conducted a mix of telephone interviews with the key OEMs and suppliers across regions. The interview were targeted at Directors, Research and Development Heads, Product Development Managers, etc.

Research Methodology (Contd...)

Forecasting Methodology for the Study

- The forecast template was based on the Sales figures of each region with bottom up approach. Each model data was collected and penetration rate by model was taken into account to get the overall penetration rate by region, by OEM and by Vehicle segment.
- Each technology was separately accounted during forecasting and individual penetration rates with volumes were calculated.

A sample of sales forecasting template for Europe is shown below.

Sales Volumes and Forecast in the European Market for Key OEMs

Group	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
BMW	633,442	640,571	716,674	756,451	809,796	842,307	861,557	858,889	894,141	940,897	953,612	959,608	974,681	994,705
DaimlerChrysler	1,120,909	1,086,061	1,076,485	1,108,244	1,109,644	1,135,963	1,190,854	1,235,570	1,262,628	1,276,168	1,292,648	1,300,959	1,321,846	1,350,275
Fiat Group	1,271,264	1,169,846	1,175,309	1,045,212	998,471	1,129,879	1,156,945	1,170,411	1,203,460	1,224,872	1,241,390	1,250,527	1,272,456	1,297,305
Ford Motor Company	1,884,951	1,878,711	2,017,023	1,972,067	1,991,735	2,013,190	2,054,646	2,107,751	2,152,136	2,201,804	2,227,264	2,246,345	2,285,092	2,330,360
General Motors	1,917,748	1,919,527	2,016,915	1,798,446	1,960,161	1,911,177	1,973,521	2,103,914	2,161,298	2,196,151	2,225,128	2,242,842	2,281,189	2,327,337
Groupe Renault	2,087,764	2,129,703	2,140,830	2,445,349	2,424,155	2,435,487	2,491,544	2,562,457	2,624,380	2,677,200	2,717,217	2,743,804	2,794,165	2,852,256
PSA	2,283,417	2,239,374	2,166,903	1,976,776	2,042,470	2,105,141	2,128,849	2,164,058	2,207,087	2,246,350	2,278,342	2,300,622	2,344,781	2,386,210
Toyota Group	715,140	791,541	859,171	863,090	900,287	897,135	897,567	913,630	935,695	953,187	966,733	976,568	994,792	1,016,498
Volkswagen	2,926,337	2,879,410	2,926,290	3,049,935	3,061,483	3,172,086	3,253,523	3,308,371	3,378,739	3,437,545	3,481,533	3,510,086	3,568,406	3,637,382
Total	14,840,972	14,734,744	15,095,600	15,015,570	15,298,203	15,642,365	16,009,006	16,425,051	16,819,565	17,154,175	17,383,866	17,531,363	17,837,409	18,192,327

Research Methodology (Contd…)

New Segment	Revised Descriptions	Examples
A	Mini	Ford Ka, Fiat Panda, Opel Agila, Citroen C2, Peugeot 107, VW Lupo
B	Small	BMW Mini, Mercedes-Benz A-Class, Mazda2,
C	Compact	BMW 1-series, Ford Focus, Alfa Romeo 148, Citroen C4, Toyota Corolla, VW Golf
D1	Lower Medium	BMW 3-series, Mercedes-Benz C-Class, Ford Mondeo
D2	Upper Medium	Mercedes-Benz E-Class, Volvo C70, Saab 9-5, Peugeot 607
E1	Executive	Volvo S80, Lancia Thesis, Renault Vel Satis
E2	Luxury	BMW 7-series, Mercedes-Benz S-Class, Audi A8
F	Super Luxury	Rolls Royce Phantom, Bentley Arnage
Sports	Sports	BMW Z1, Mercedes-Benz CLK, Audi TT
MPV	MPV	Ford C-Max, Mazda Premacy, Fiat Ulysse
SUV	SUV	BMW X3, Mercedes-Benz M-Class, Honda CRV

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1.1.1 Market Overview for Plug in Hybrid Electric Vehicles

Plug in Hybrids

- The global market for Plug in Hybrid Electric Vehicles (PHEVs) is estimated to be 130,000 vehicles by 2015.
- North America (NA) is expected to hold a strong market for PHEVs with estimated volumes of 101,000 by 2015. Europe will also witness the introduction of plug-in hybrids by 2012 with reduction of costs but with less numbers. Japan is likely to lag behind since Japanese market is more inclined towards Fuel Cell Vehicles rather than PHEVs.
- General Motors (GM), Toyota, Ford and Daimler Chrysler are likely to be the key players in Plug in Hybrid Market. GM likely to lead the global market for plug in hybrids with a market share of over 50 percent for plug in hybrids by 2015.

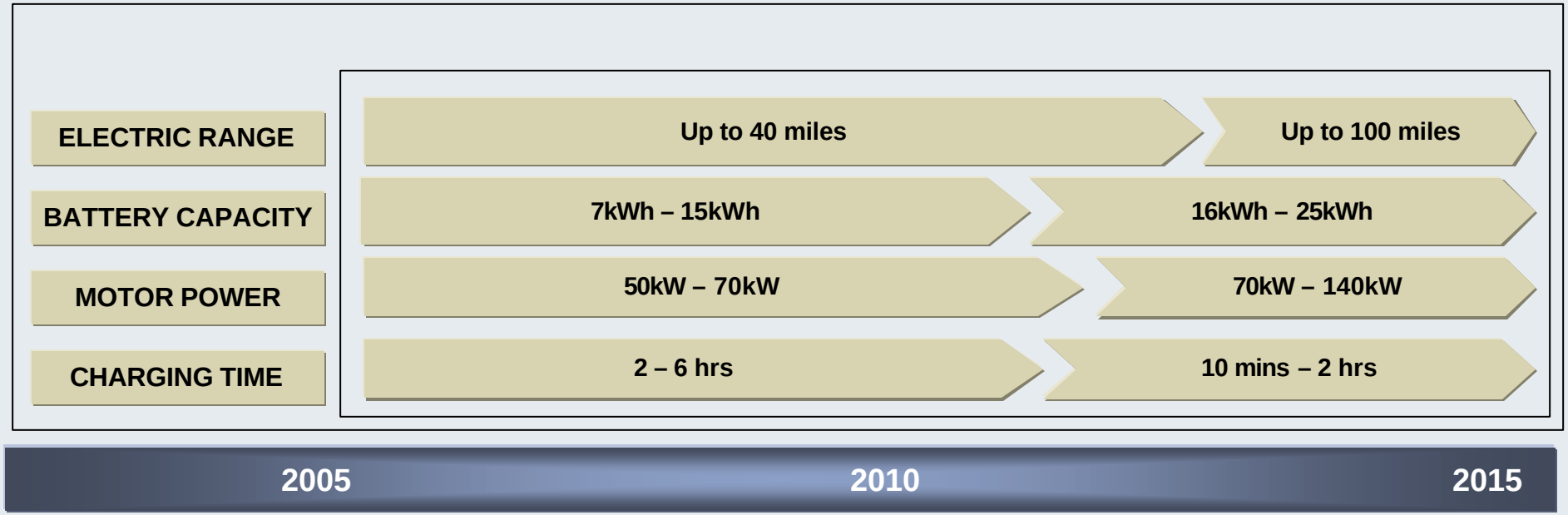
Key PHEV Models showcased

- **Chevrolet Volt (Gasoline E-Flex Architecture)**
- **Chevrolet Volt (Fuel cell E-Flex Architecture)**
- **Ford Airstream**
- **Ford Edge**

"People going into a showroom and saying I think I'll have the one with the fuel cell this time might probably be 10 years away but I'm very hopeful that the E-flex architecture and Plug-in (Chevy Volt) is the very next step. If this were to be 10 years away I will be cruelly disappointed." – General Motors

1.1.2 Technology Roadmap and Adoption Timescales

Market for Plug in Hybrid Electric Vehicles: Technology Roadmap (Global), 2005-2015



Source: Frost & Sullivan

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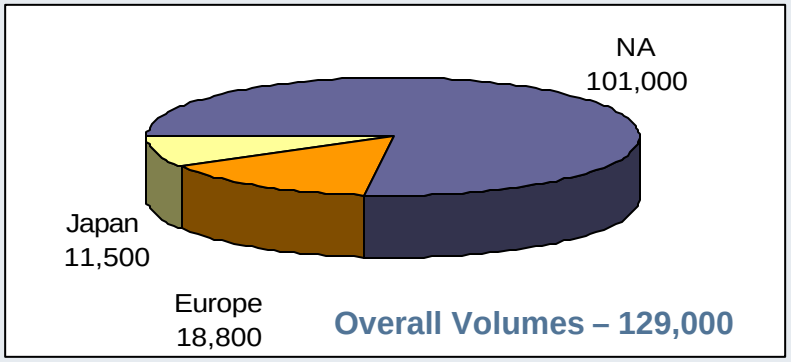
1.2.1 Market Breakdown by Region

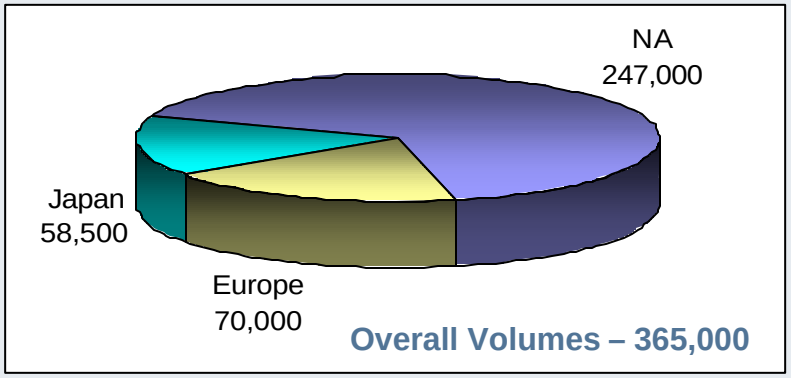
- North America perceives a better market to Plug in technology with a share of 77 percent to a very low 9 and 14 percent for Japan and Europe respectively.
- North America has better up take rates towards hybrids as witnessed from the past. The popularity and initiatives towards PHEVs is much bigger when compared to other regions.
- Frost & Sullivan estimates PHEV's to be introduced in NA by 2010 with GM leading the way. The trend in NA is likely to be monitored and accessed before introducing it in Europe and Japan.
- Europe is likely to lag behind NA by at least 4 years in terms of PHEV introduction due to a low perception of hybrid electric vehicles.
- The Plug in technology has been powered and funded by various Environmental bodies, state and local governments, utility organisations and business groups.
- Together the environmental advocates have pressurised the VM's to commercialise the technology and the repercussions were felt when three automakers GM, Toyota and Ford announced PHEV developments in the last one year.

Market for Plug in Hybrid Electric Vehicles: Market Breakdown by Region-Conservative Scenario (Global), 2015



Note: All figures are rounded. Source: Frost & Sullivan

Market for Plug in Hybrid Electric Vehicles: Market Volumes by Region for Plug in Hybrids – Optimistic Scenario (Global), 2015

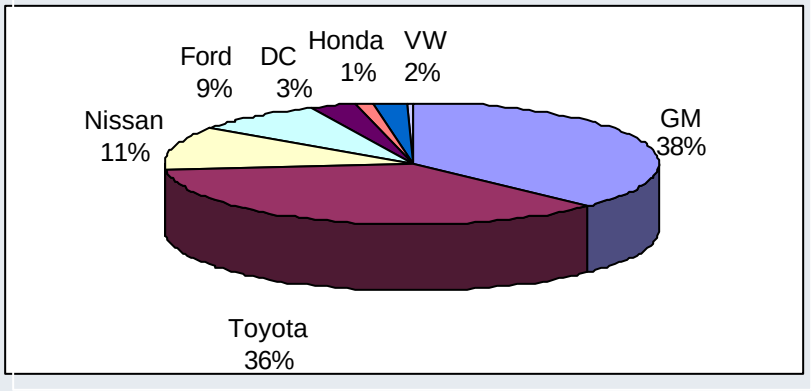


Note: All figures are rounded. Source: Frost & Sullivan

1.2.2 Market Breakdown by OEM for Plug in Hybrids

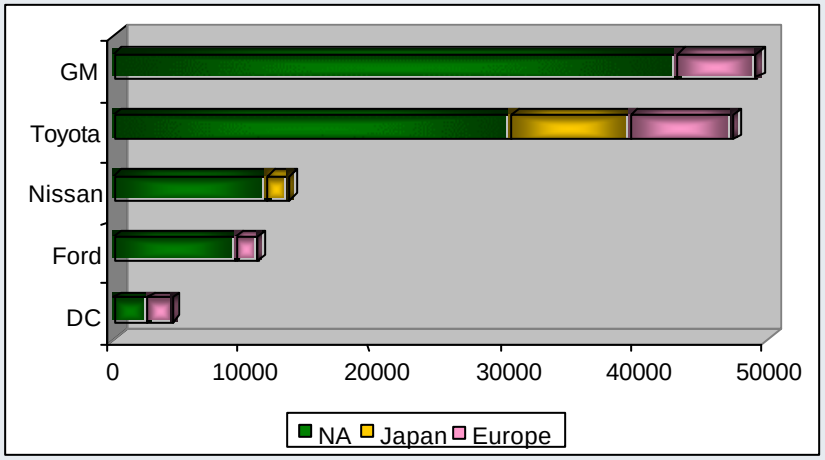
- GM's Saturn Vue Green Line SUV featuring the modified 2-mode hybrid system with plug-in capabilities is likely to be the first Plug in Vehicle to hit the NA markets followed by Volt by 2010/11. GM is expected to be a probable leader for PHEV's accounting for a global share of around 38% by 2015.
- Toyota is the only vehicle manufacturer to have introduced a full hybrid in Europe at present with Prius, Lexus RX 400h and Lexus GS450h. Toyota is tied with EDF to evaluate and test the PHEV Prius. EDF has plans to build infrastructure in France and congestion charged cities. The Japanese manufacturer is expected to account for a 36 percent share in the Global PHEV market.
- DC is the lone auto-maker investigating PHEV's through customer fleets in Europe. Germany having the largest volumes for Dodge Sprinter in Europe is expected to have around 500 PHEV units by 2015.
- Nissan has an agreement with NEC Corp. for the development of Li-ion Batteries are likely to start production of Li-Ion batteries in their hybrid cars by 2009. Nissan are to adopt PHEV capability by 2012 and likely to represent 11 percent of the market by 2015.
- Ford was the first auto giant to unveil the world's first driveable fuel cell HEV with a plug in capability with Ford Edge HySeries Drive at the Washington D.C Auto Show in January 2007. Ford is likely to occupy 9 percent of the market share by 2015. Ford is also evaluating plug ins with EDF.

Market for Plug in Hybrid Electric Vehicles: Market Breakdown by OEM for Plug in Hybrids (Global), 2015



Note: All figures are rounded. Source: Frost & Sullivan

Market for Plug in Hybrid Electric Vehicles: Volume Breakdown by Region by OEM for Plug in Hybrids (Global), 2015



Note: All figures are rounded. Source: Frost & Sullivan

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1.3.1 Comparative Analysis of Key Vehicle Manufacturers of PHEVs

Market for Plug in Hybrid Electric Vehicles: Comparative Analysis of Key Vehicle Manufacturers on PHEVs (Global), 2015

Vehicle Manufacturer	Work on PHEVs	Market Introduction	Segments	Volume Forecast (2015)	Market Strategy	Regions
DaimlerChrysler	YES	2012	Minivan, SUV	5,500	Standard	North America, Japan
Toyota	YES	2011	Compact, Sedan, SUV	46,000	Optional (in Europe)	North America, Europe, Japan
GM	YES	2010	Compact, SUV	49,000	Standard/ Battery Lease	North America, Europe
Nissan	YES	2012	Medium	13,000	Standard	North America, Japan, Europe
Volkswagen, Audi	YES	2013	Compact, SUV	3,100	Standard	North America, Europe
Ford	YES	2012	SUV	11,000	Standard	North America, Europe
Honda	NO	2014	Sedan	1,500	Standard	North America, Japan

Source: Frost & Sullivan

1.3.2 Competitive Analysis of Key System and Component Suppliers for PHEV

Market for Plug in Hybrid Electric Vehicles: Supplier Portfolio Analysis (Global), 2007

Supplier	Electric Propulsion	Energy Storage Units	Power Electronics	Chargers
A123 Systems		●		
Brusa Chargers				●
Cobasys		●		
Continental	●	●		
Matsushita Electric		●		
Delta Q	●			●
Delphi Corporation			●	
Denso Corporation			●	
Electrovaya		●		
ETEC				●
Sanyo		●		
Hitachi	●			
Infineon Technologies			●	
Johnson Saft		●		
Panasonic		●		
Robert Bosch	●		●	
Valence Technologies		●		
Siemens VDO Auto	●	●	●	

Source: Frost & Sullivan

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1.4.1 Strategy and Opportunity Analysis of Key OEMs

GM

- GM has a handsome hybrid power train feel with AHS2 and Mild hybrids ready for market entry before year end.
- Effective strategy that GM would probably adopt is selling the car and leasing the batteries. This help them to reduce the cost of the car. They also aim at monitoring the battery performance in the hands of the customers, service it and upgrade it.
- Having seen off most of the technical obstacles, GM are looking for investment programs for cost effective supply chain. Currently GM is working on the charging structure with its battery developers.
- Initially GM plans to target the customers who have private garage parking. With no infrastructural commitments today, opportunity to associate with utilities to evaluate the energy and charging and provide infrastructure awaits.

Toyota

- With Toyota joining the ACEA, its an opportunity to bring down the CO2 levels by means of a PHEV and retain leadership in hybrid technology.
- An established production line and supply chain for Prius, Toyota will incur minimal production costs offsetting the battery issues.
- Toyota is likely to roll out optional plug-in Prius in Europe initially as many customers lack garages or off-street parking. Thus they would target specific customers and study the sales structure.
- EDF and Toyota are developing practical solutions for commercialization of PHEV and as well evaluate energy supply distribution and trading in other parts.

1.4.1 Strategy and Opportunity Analysis of Key OEMs

Daimler Chrysler

- A PHEV will open a wide road towards green house gas reductions in North America and Europe as DC has a thin hybrid curve. A Sprinter PHEV will certainly narrow the gap of meeting the CAFÉ regulations.
- Alliance with Tesla, worlds fastest EV makers would put DC on the fast lane by producing sporty PHEVs.

Renault Nissan

- Battery Technology is the agenda for Nissan. The veterans in Li-ion technology have options to evaluate and test the technology with the consumers and agencies.

Honda

- Having made a strong entry into the Hybrid market Honda equips itself it with a close power train ready PHEV. Contrary Honda plans to strategize micro and mild hybrids to satisfy the regulations.

Ford

- Ford Airstream was the answer to GMs fuel cell E-Flex showing strong interest in PHEVs. This would make a strong impact on meeting the CAFÉ and Euro standards.
- Joint testing operations with California Edison utility makes way for a detailed evaluation with the consumers and the grid as well. Battery Technology and packaging have been of prime concern .

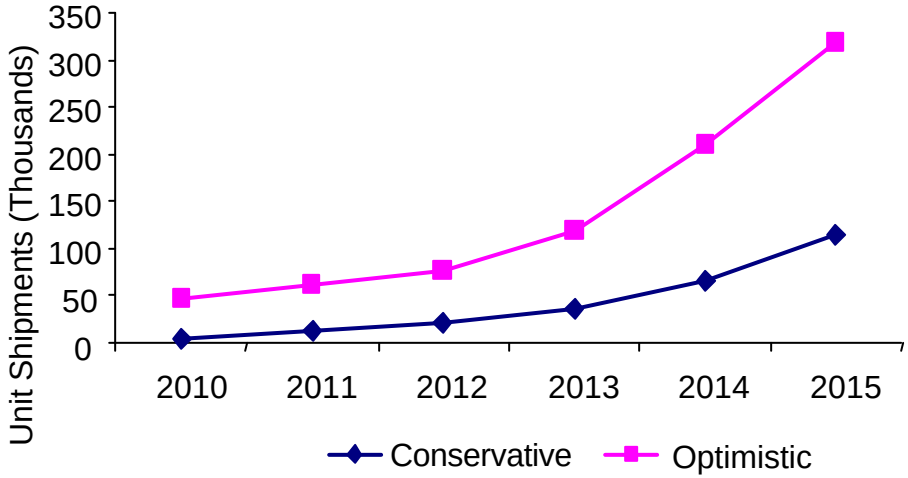
1.4.2 Scenario Analysis

Market for Plug in Hybrid Electric Vehicles: PHEV Volumes (Global), 2015

Region	Scenario 1 Conservative	Scenario 2 Optimistic
North America	101,000	250,000
Europe	19,000	42,000
Japan	12,000	30,000

Note: All figures are rounded. Source: Frost & Sullivan

Market for Plug in Hybrid Electric Vehicles: Comparison of Different Scenarios for PHEV's (Global), 2010-2015



Note: All figures are rounded. Source: Frost & Sullivan

North America would lead the Plug in race with units around a hundred thousand in a conservative scenario by 2015. With an early break through in Li-ion technology and success of early entrants like GM and Toyota, would see other EOMs entering the Plug in market early and standardization of PHEVs as well. In such an optimistic scenario, around 300,000 units has been forecasted. However a realistic estimate would cloud around the conservative curve.

Key Elements that would influence and shape the curves:

- Li-ion Battery Technology
- Standardization and Market Entry
- GM and Toyota

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1.5.1 Strategic Conclusions and Recommendations (1/2)

- **Breakthrough in the Lithium Ion battery technology is decisive and will highly influence the market for Plug in Hybrid Electric Vehicles**

Vehicle Manufacturers have agreed that Lithium Ion battery technology is the most viable technology for performance of PHEVs in the market. Size of the battery, temperature management, reliability, durability, material and production costs have been important issues that comes as a caveat in Lithium Ion technology implementation. Innovative research and development is required to be nurtured by the suppliers in order to achieve the technical demands for such a technology. Frost & Sullivan recommends the suppliers and the VMs to work in association to meet the specifications.

- **Conversion of full hybrids into a plug in capability is beneficial to vehicle manufacturers**

PHEVs are looked ahead as the next step of full hybridisation with an additional capability of plugging into a standard electric outlet for recharging the battery. The other drive train components such as electric motors, ECU and electronics remains identical to that of a full hybrid. The only investment made is on the larger capacity battery, battery monitoring and charging systems. Therefore the vehicle manufacturers should concentrate more on upgrading the full hybrids sooner rather than expending energy developing a PHEV from scratch.

- **Vehicle manufactures should join hands with promotional organisations to push for governmental incentives to assist ramping up the commercialisation**

Environmental organisations and utilities are offering tax credits and incentives for plug in hybrid technology, especially in California and Texas. However this is insufficient, rather incentives should be encouraged irrespective of the region or state for mass commercialisation. Various promotional organisations are pushing the local governments for incentives but it becomes more visible if vehicle manufacturers join hands and parade the benefits of fuel economy, partial zero emission range and energy savings as justification.

1.5.1 Strategic Conclusions and Recommendations (2/2)

- **Generate greater awareness of Plug in Hybrid Electric Vehicles among the consumers**

One of the biggest hurdles is to ensure acceptance of plug in hybrid electric vehicle in the market. The market indicates that PHEVs are being marketed on the pure electric vehicle mandate. Rather than a development of pure electric vehicle, which they invariably are, PHEVs should be marketed as a full hybrid propulsion system. This is because the repercussions of the failure of pure electric vehicles such as EV1 and RAV4 still persists among the consumers. On the other hand the European customer market is characterised by poor understanding of hybrid technology. European automakers are suggested to invest more into promotion of hybrid technology to increase the take up rates and the consumers are to be educated that the benefits of PHEVs do overweigh barriers.

- **Vehicle manufactures, Energy Utilities and Suppliers are required to work closely to develop and integrate the Plug in Hybrid technology**

The battery manufacturers are engineering the Li-Ion battery technology to meet the specifications of a PHEV. Such a technology opens up new supplier avenues for battery charging and monitoring systems and high power electronics. OEMs should again team up with the energy utilities to evaluate and standardise the logistics involved in charging. It will be beneficial in integrating the intelligence if the automakers, utilities and the suppliers work in close association.

- **The existing electricity infrastructure is sufficient to fuel enough electricity into the PHEV**

It has been perceived by some VM's that usage of coal for production of electricity influences the consumers in refusing the fact that PHEVs promote green revolution. Since the batteries are to be charged mostly during the night (off-peak hours), the base load is more than sufficient for re-charging all the batteries for the forecasted number of PHEVs and even beyond that in almost all the regions. It is also to be educated that PHEVs are beneficiary when they provide energy back to the grid during peak demand periods. However the concept of charging from the grid is to positively impact in regions where bulk of the electricity is generated by nuclear and renewable resources.