Global Market Analysis of Plug in Hybrid Electric Vehicles

M12D–18

December 2007

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Sullivan House
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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.
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

<table>
<thead>
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<td>1,250,527</td>
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<td>2,278,342</td>
<td>2,300,622</td>
<td>2,344,781</td>
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<td>Toyota Group</td>
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<td>791,541</td>
<td>858,171</td>
<td>863,090</td>
<td>900,257</td>
<td>897,135</td>
<td>897,567</td>
<td>913,530</td>
<td>935,525</td>
<td>953,157</td>
<td>986,733</td>
<td>976,588</td>
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<td>1,016,498</td>
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<td>15,095,600</td>
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<td>15,298,203</td>
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## Research Methodology (Contd…)

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

<table>
<thead>
<tr>
<th>Feature</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
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<tr>
<td>Electric Range</td>
<td>Up to 40 miles</td>
<td>Up to 100 miles</td>
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<tr>
<td>Battery Capacity</td>
<td>7kWh – 15kWh</td>
<td>16kWh – 25kWh</td>
<td></td>
</tr>
<tr>
<td>Motor Power</td>
<td>50kW – 70kW</td>
<td>70kW – 140kW</td>
<td></td>
</tr>
<tr>
<td>Charging Time</td>
<td>2 – 6 hrs</td>
<td>10 mins – 2 hrs</td>
<td></td>
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</tbody>
</table>

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

Overall Volumes – 129,000

<table>
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<th>Region</th>
<th>Volume</th>
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<tbody>
<tr>
<td>NA</td>
<td>101,000</td>
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<td>Europe</td>
<td>18,800</td>
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<td>Japan</td>
<td>11,500</td>
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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

Overall Volumes – 365,000

<table>
<thead>
<tr>
<th>Region</th>
<th>Volume</th>
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<td>NA</td>
<td>247,000</td>
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<tr>
<td>Europe</td>
<td>70,000</td>
</tr>
<tr>
<td>Japan</td>
<td>58,500</td>
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</tbody>
</table>

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.
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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

<table>
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<tbody>
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<td>Daimler Chrysler</td>
<td>YES</td>
<td>2012</td>
<td>Minivan, SUV</td>
<td>5,500</td>
<td>Standard</td>
<td>North America, Japan</td>
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<td>Toyota</td>
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<td>2011</td>
<td>Compact, Sedan, SUV</td>
<td>46,000</td>
<td>Optional (in Europe)</td>
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<td>Nissan</td>
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<td>3,100</td>
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<td>Ford</td>
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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

<table>
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<tr>
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<th>Energy Storage Units</th>
<th>Power Electronics</th>
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<td>Delphi Corporation</td>
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<td>Valence Technologies</td>
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<td>Siemens VDO Auto</td>
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</table>

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.

**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.

**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.

**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

<table>
<thead>
<tr>
<th>Region</th>
<th>Scenario 1 Conservative</th>
<th>Scenario 2 Optimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>101,000</td>
<td>250,000</td>
</tr>
<tr>
<td>Europe</td>
<td>19,000</td>
<td>42,000</td>
</tr>
<tr>
<td>Japan</td>
<td>12,000</td>
<td>30,000</td>
</tr>
</tbody>
</table>

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.

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

Key Elements that would influence and shape the curves:
• Li-ion Battery Technology
• Standardization and Market Entry
• GM and Toyota

Note: All figures are rounded. Source: Frost & Sullivan
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   1.5 Strategic Conclusions and Recommendations  
      1.5.1 Strategic Conclusions and Recommendations  

2 Global Market for Plug in Hybrid Electric Vehicles  

3 Vehicle Manufacturer Profiles
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.