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Ford Motor Company

Vehicle Electrification Technologies and Industry Approaches
Agenda

- Drivers for Electrification and Technology Background
- Industry Volume and Mix Projections
- Infrastructure Development
- Opportunities and Challenges
Drivers for Electrification and Technology Background
In the early 1900’s more than 27 companies were building electric cars, ~1/3 of the cars on the road were electric.

In 1912, an electric roadster sold for $1,750, while a gasoline car sold for $650.

In 1914, Henry Ford and Thomas Edison experimented with an electric car using Edison Batteries.

In 1915 the Ward Motor Vehicle Company offered an electric wagon for $875 on an one-year installment plan for the vehicle and a $10.50 month rental fee for the Edison Storage battery.
### Near Term
- Significant number of vehicles with EcoBoost engines
- Electric power steering – begin global migration
- Dual clutch and 6 speed transmissions replace 4 & 5 speeds
- Flex Fuel Vehicles
  - Add Hybrid applications
    - Increased unibody applications
    - Introduction of additional small vehicles
    - Battery management systems – begin global migration
    - Aero improvements
    - Stop/Start systems (micro hybrids) introduced
    - CNG/LPG Prep Engines available where select markets demand

### Mid Term
- EcoBoost engines available in nearly all vehicles
- Electric power steering - High volume
- Six speed transmissions - High volume
- Weight reduction of 250 – 750 lbs
- Engine displacement reduction aligned with weight save
- Additional Aero improvements
  - Increased use of Hybrid Technologies
  - Introduction of PHEV and BEV
- Vehicle capability to fully leverage available renewable fuels*
- Diesel use as market demands
- Increased application of Stop/Start

### Long Term
- Percentage of Internal combustion engines dependent on renewable fuels
  - Volume expansion of Hybrid technologies
  - Continued leverage of PHEV, BEV
- Introduction of fuel cell vehicles
- Clean electric / hydrogen fuels
- Continued weight reduction actions via advanced materials

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*2007
2011
2020
2030

**GREEN FLEET Conference 2010**

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## Electrification Technologies – Background

<table>
<thead>
<tr>
<th>Function System</th>
<th>Engine stop/start</th>
<th>Engine Assist (Downsize)</th>
<th>Regenerative Brake</th>
<th>Electric launch</th>
<th>All Electric Drive</th>
<th>Fuel Economy Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro-hybrid (14V)</td>
<td>YES (&gt; 0.3 sec)</td>
<td>Minimal (&lt; 3 kW)</td>
<td>Minimal (&lt; 3 kW)</td>
<td>NO</td>
<td>NO</td>
<td>3-6%</td>
</tr>
<tr>
<td>Mild Hybrid (42V)</td>
<td>YES</td>
<td>Modest (&lt; 9 kW)</td>
<td>Modest (&lt; 9 kW)</td>
<td>NO</td>
<td>NO</td>
<td>8%/12%</td>
</tr>
<tr>
<td>Medium Hybrid (100+V)</td>
<td>YES</td>
<td>YES</td>
<td>YES (full benefit)</td>
<td>NO</td>
<td>NO</td>
<td>40%</td>
</tr>
<tr>
<td>Full Hybrid (300V)</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>Yes</td>
<td>55%+</td>
</tr>
<tr>
<td>Plug In Hybrid (based on Blended Full)</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>Yes</td>
<td>80%+</td>
</tr>
<tr>
<td>Battery Electric Vehicle</td>
<td>YES</td>
<td>No Engine</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>Infinite</td>
</tr>
</tbody>
</table>
### Blended PHEV Hardware Commonality with HEV

<table>
<thead>
<tr>
<th>Component</th>
<th>HEV</th>
<th>PHEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Voltage Battery</td>
<td></td>
<td><strong>Power vs. Energy</strong></td>
</tr>
<tr>
<td>Traction Motor</td>
<td></td>
<td><strong>Same</strong></td>
</tr>
<tr>
<td>Generator</td>
<td></td>
<td><strong>Same</strong></td>
</tr>
<tr>
<td>Inverter(s)</td>
<td></td>
<td><strong>Same</strong></td>
</tr>
<tr>
<td>Electric AC</td>
<td></td>
<td><strong>Same</strong></td>
</tr>
<tr>
<td>DC/DC Converter</td>
<td></td>
<td><strong>Same</strong></td>
</tr>
<tr>
<td>Regen Brakes Hardware</td>
<td></td>
<td><strong>Same</strong></td>
</tr>
<tr>
<td>Transmission</td>
<td></td>
<td><strong>Same</strong></td>
</tr>
<tr>
<td>Engine</td>
<td></td>
<td><strong>Same</strong></td>
</tr>
<tr>
<td>Charger &amp; Wiring</td>
<td></td>
<td><strong>New</strong></td>
</tr>
<tr>
<td>Electric Pumps/Cooling Circuits</td>
<td></td>
<td><strong>Modified transaxle oil lubrication/cooling circuit</strong></td>
</tr>
</tbody>
</table>

- **Significant Re-use of HEV hardware to leverage scale**
Different Cells needed for different applications...
Necessary Battery Technology Evolution

**1st Gen**
- EV Battery
  - 23 kWh
  - 225 kg
  - 125 liters

**2nd Gen**
- EV Battery
  - 23 kWh
  - 180 kg
  - 100 liters

**Future**
- EV Battery
  - 23 kWh
  - 110 kg
  - 75 liters

**Goal**
- Fuel Tank eq.
  - 23 kWh
  - 55 kg
  - 60 liters
Industry Volume and Mix Projections
Note: Volume projections are based on forecast data from the following 3rd party studies:
- Roland Berger - Powertrain 2020: China's ambition to become market leader in E-Vehicles (April, 2009)
- J.P. Morgan - Global Environmental Series Volume 3 - HEVs Potential Reconsidered in Economic Crisis (May, 2009)
- Credit Suisse - Electric Vehicles - Global Equity Research (October, 2009)
Ford Announced Electrification Projects

<table>
<thead>
<tr>
<th>BEV</th>
<th>Battery Electric Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004 CY</td>
<td>Transit Connect Electric (Global C-Platform)</td>
</tr>
<tr>
<td></td>
<td>Focus Electric (Global C-Platform)</td>
</tr>
<tr>
<td>2010 CY</td>
<td>Focus Electric (Global C-Platform)</td>
</tr>
<tr>
<td>2012 CY</td>
<td>Focus Electric (Global C-Platform)</td>
</tr>
<tr>
<td>2018+ CY</td>
<td>Focus Electric (Global C-Platform)</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>PHEV</th>
<th>Plug-in Hybrid Electric Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004 CY</td>
<td>New PHEV (Global C-Platform)</td>
</tr>
<tr>
<td>2010 CY</td>
<td>New PHEV (Global C-Platform)</td>
</tr>
<tr>
<td>2012 CY</td>
<td>New PHEV (Global C-Platform)</td>
</tr>
<tr>
<td>2018+ CY</td>
<td>New PHEV (Global C-Platform)</td>
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<tr>
<th>HEV</th>
<th>Hybrid Electric Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004 CY</td>
<td>Escape (Global C-Platform)</td>
</tr>
<tr>
<td>2010 CY</td>
<td>Next Generation HEV (Global C-Platform)</td>
</tr>
<tr>
<td>2012 CY</td>
<td>Next Generation HEV (Global C-Platform)</td>
</tr>
<tr>
<td>2018+ CY</td>
<td>Next Generation HEV (CD-Platform)</td>
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Ford Global Electrification Product Plan

- Balanced Portfolio
- Global Flexibility
- Volume will be predominantly HEV
- Plug-ins gaining acceptance

Balanced growth also provides flexibility to react to volatile external factors
Note:
- All data is from CSM Worldwide global comprehensive vehicle production and sales forecasts, 6/06/10.
- Major manufacturers are those with >40,000 electrified vehicle sales projected in 2016.
Infrastructure Development
Infrastructure: Realizing the Power of Plugging-In

Charging Customer Segments

Most Frequent

Charge at Home
Main charge spot located in garage or driveway of residence.

Charge at Depot
For fleets customers, main charge location is fleet depot where multiple chargers could be installed.

Charge at Work
Main charge location is work – allowing urban commuters/street parkers to have reliable charge. Also allows extended range for home chargers.

Charge at Public Space
For occasional trips, municipal charge locations could be viable option. If reservation system is implemented, could be used for main charge location.

Priority

Charging Infrastructure is a key enabler to Plug-in Vehicles – regardless of where consumers end up charging their vehicles.
Plug-In Vehicle Charging Options

Target overnight charging (less than 8 hours) - base assumption that Level 2 installation will be required for BEV’s, and optional for PHEV
Driver-Vehicle Interaction – Improved Efficiency

New Knowledge and Skills Needed: Customer and Engineer

New concepts required for Plug-In vehicles

- Selects recharge completion time
- Schedules daily recharge start times
- Only accepts charge at lower rates, off-peak hours

Ford’s PHEV User Interface

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Market Readiness

- Current plug-in owners on average charge at least two times per day\(^1\)
- Charge point availability is cited as the key adoption barrier to electric vehicles\(^2\)
- In an experiment, adding fast chargers at strategic city points increased electric fleet vehicle use – charge point usage did not increase but lessened range anxiety\(^3\)
- Based on announcements, current public and private Level 2 infrastructure installation rates will not keep pace with plug-in sales.

1,500 public chargers currently tracked in U.S. on www.evchargermaps.com and www.mychargepoint.net

\(^1\) Reference UC-Davis Market Survey
\(^2\) Reference EPRI Focus Group Findings May 2009
\(^3\) Reference Tokyo Electric Power Company (TEPCO) experiment
Opportunities and Challenges
Opportunities & Challenges:

- Significant New Load
- Clustering
- Information + Feedback → Change
- Communication with Utilities

Ford + Microsoft
Integrated Approach With Shared Responsibility

The development of a sustainable electrified market will be dependent on close cooperation between many key stakeholders:

- Manufacturers
- Governments
- Consumers
- Battery Suppliers
- NGO’s
- Utilities