What Will Ford’s HEV Provide?

- **Improved Fuel Economy:** 52 - 56% fuel economy improvement over a conventional powertrain.
- **CO₂ Reduction Potential:** Up to 36%.
- **Increased Range:** 500 miles or more between fuel stops.
- **Better Acceleration:** Performance like a V6 from an I4.
- **Reduced Emissions:** Achieve strict SULEV standard (7.5 times cleaner than LEV).
How do HEVs Work?

A Hybrid Electric Vehicle combines:

- A chemically fueled (gasoline, diesel, or alternative) internal combustion (IC) engine
- Electric motor(s)
- An energy storage device (battery)
- Regenerative braking

The combined system improves the overall vehicle efficiency to increase fuel economy and reduce tailpipe emissions.
### Essential Hybrid Operations

- **Engine Downsize:**
  Performance is retained by supplementing the power of the IC engine with the electric motor.

- **Regenerative Braking:**
  Recharges the batteries thus recovering energy that would otherwise be lost as heat.

- **Electric Launch & Drive**
  Propels the vehicle without turning on the IC engine.

<table>
<thead>
<tr>
<th>HEVs</th>
<th>Engine Shutdown &amp; Restart</th>
<th>Engine Downsize</th>
<th>Regenerative Braking</th>
<th>Electric Launch</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEVs</td>
<td>Engine with Electric Accessories</td>
<td>Light Blue</td>
<td>Red</td>
<td>Light Blue</td>
</tr>
<tr>
<td>HEVs</td>
<td>Engine with Integrated Starter/Alternator</td>
<td>Yellow</td>
<td>Orange</td>
<td>Yellow</td>
</tr>
<tr>
<td>HEVs</td>
<td>Full Hybrid Powertrain</td>
<td>Orange</td>
<td>Orange</td>
<td>Orange</td>
</tr>
</tbody>
</table>
Hybrid Solutions

Fuel Economy Hybrids

- Conventional-type vehicles with at least one electric motor added for energy recapture, performance boost, and engine starting
- Small battery pack reduces weight penalty, improving performance
- Range is equal to or better than conventional vehicles
Hybrid Solutions

Range Extender Hybrids (Series Hybrid)

- Electric-type vehicles with a small engine/generator device added as insurance in case vehicle is driven beyond the range capability of the battery
- Large battery pack allows for significant engine-off, zero emissions range, ideal for polluted city centers
- The small generator set is not capable of meeting the average power requirement, so battery charge typically drops over time, requiring a plug-in recharge
Series Hybrid System

- Electric drive motor integral with transaxle
- IC engine operates generator to provide electricity to the motor and to recharge the battery pack
- Gasoline engine can be modified to run Atkinson cycle to improve efficiency
- High technology battery storage for high energy density
Parallel Hybrid Architecture

- Both the engine and motor are connected to the drivetrain
- Electric motor can be packaged within transmission bell housing
- Disconnect clutch between the engine and transmission to allow electric launch without starting the engine
- Advanced battery energy storage for high power density
What Do Customers Want?

• An environmentally friendly, competitively priced vehicle

• A combination of:
  – Exciting performance
  – High fuel economy
  – Superior quality
  – Low emissions
  – High recycleability
  – An uncompromised package

• Convenient operation:
  – Extended range
  – No special fuel or daily plug-in
## HEV Functional Targets (Versus Conventional Escape)

<table>
<thead>
<tr>
<th></th>
<th>Conventional Escape 4x2</th>
<th>HEV Escape 4x2</th>
<th>Full Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.0 I4 MT</td>
<td>3.0 V6 AT</td>
<td></td>
</tr>
<tr>
<td>Performance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 0-60 mph (sec)</td>
<td>~11.9</td>
<td>10.4</td>
<td>10.4-10.7</td>
</tr>
<tr>
<td>- Trailer Tow (lbs)</td>
<td>1,000</td>
<td>3,500</td>
<td>1,000</td>
</tr>
<tr>
<td>Fuel Economy 1/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Metro Highway (mpg)</td>
<td>29.1</td>
<td>25.0</td>
<td>38-39</td>
</tr>
<tr>
<td>- % &gt; base</td>
<td>16%</td>
<td>BASE</td>
<td>52-56%</td>
</tr>
<tr>
<td>Emissions</td>
<td>LEV</td>
<td>LEV</td>
<td>SULEV</td>
</tr>
<tr>
<td>Refueling Interval (miles)</td>
<td>400</td>
<td>370</td>
<td>500 or more</td>
</tr>
</tbody>
</table>

1/ Metro Highway. HEV Fuel Economy numbers are directional estimates.
Battery

- Sanyo is the exclusive battery supplier
- 300 Volt nickel-metal hydride traction battery pack
- Runs the vehicle in pure electric mode and provides engine boost
- Packaged in the rear with no loss of usable space
- Designed with safety as a top priority
HEV Powertrain

- Efficient I4 engine with Atkinson cycle
- Transaxle integrates planetary gears with two motor/generators
- Provides efficiency and the smooth power flow functionality of an electric CVT
- Operates in a series, parallel or compound mode
Regenerative Braking – Parallel vs. Series

Parallel Regen Brakes

Series Regen Brakes

%Pedal Effort

%Brake Response

Electric Regeneration

Base Brakes
HEV System Controller

• Highest level control in the logical hierarchy Controls:
  – PCM (engine)
  – TMU (Transmission/motor)
  – Battery and Braking System

• Provides optimal balance among performance, FE and emissions.

• Hierarchical, modular design with built in robustness and diagnostics.

• Optimized through the use of modern control theory and development tools.
Public Website

www.hybridford.com
HEV Service Challenges

• 300 volt electrical system versus 12 volt conventional
• Complex/new system interactions
• Unique Components
  – PowerSplit Transmission
  – Traction Battery
  – Control Modules
    • Traction Inverter
    • Series Regeneration Brakes
    • Vehicle System Controller
  – DC - DC Converter
End of Presentation