Powertrain Strategies for the 21st Century

July 12, 2011
Johnson Controls, Inc.: A global diversified multi-industrial company

**Automotive Experience**
Interior systems for cars, light trucks and vans.

**Building Efficiency**
Controls systems, services and integrated facility management for non-residential buildings.

**Power Solutions**
Lead-acid automotive batteries and advanced lithium-ion hybrid battery systems that make vehicles more energy efficient.

Johnson Controls – Saft JV Li-ion manufacturing plant on-line in Holland, MI
Applications Landscape
A Spectrum of Powertrains

Start-Stop
- Engine cranking
- Accessory loads
- Low power recuperation
- Engine-off loads and restart

Advanced Start-Stop
- Component electrification
- Engine off while coasting

Mild HEV
- Engine downsizing
- Powertrain boosting

HEV
- Short range electric drive
- High power boosting

PHEV
- Extended range electric drive

EV
- Electricity for core vehicle functions

ICE

Component electrification
Engine off while coasting

ICE

Start-Stop
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Johnson Controls
New Segment
Start-Stop Battery Market

- Expect continued movement in estimates as OE production plans change
- Europe:
  - Start-Stop rapidly growing
  - 70% of OE volume by 2015
- North America:
  - High Efficiency vehicles driving initial demand for AGM
  - OEs beginning to introduce Start-Stop
- China
  - Rapidly developing Start-Stop market
  - Following European OE standards

Start-Stop Market

Customer Orders and Third Party Data by Platform

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<tbody>
<tr>
<td>Europe</td>
<td>North America</td>
<td>China</td>
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[Graph showing projected units for Europe, North America, and China from 2011 to 2020]
Observations
A European Perspective

- Demand was driven initially by European regulations
- Rapidly gaining widespread consumer acceptance
  - Low price premium
  - Less exotic technology
  - Immediate benefit of fuel savings
  - Enhanced resale value
- OEs are rapidly converting fleets
  - Embedding Start-Stop in core marketing campaigns
  - 70% of forecasted production by 2015
- Aftermarket beginning to emerge
Advancing Technology for the Future
Unlocking the Full Potential of Start-Stop

- Maximize Start-Stop system potential with AGM technology
  - Operating temperature range, improve charge acceptance, process improvement and new manufacturing equipment
  - Number, size and placement of batteries
  - New chemistries and components

- Assess complementary and alternative technologies
  - System design alternatives
  - Capacitors and other complementary components combined with batteries
  - Low voltage Li-ion and alternate chemistries

- Collaboration to support growth of industry
  - Testing methodologies
  - Standard-setting
  - Policy making
Defining the xEVs
The Role of Energy Storage

**HEV, PHEV, EV**

Vehicle Electrification Strategies

<table>
<thead>
<tr>
<th>Platform Efficiency +</th>
<th>Engine Efficiency +</th>
<th>Transmission Efficiency +</th>
<th>Energy Storage Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerodynamic shape</td>
<td>Downsizing</td>
<td>Two sources of power</td>
<td>Power for engine boosting</td>
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<tr>
<td>Low Rolling resistance tires</td>
<td>Lean combustion cycle</td>
<td>Electric motor for boost</td>
<td>Energy for short range electric drive</td>
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<tr>
<td>Light weighting materials</td>
<td>Elimination in EV</td>
<td>Reduced complexity in EV</td>
<td>High power regenerative braking</td>
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<td>Energy for long range electric drive</td>
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The xEV Opportunity
Finding the Best Solution

Cleaner
Cost Effective
Higher Performing
Safer
Smarter
More Reliable

Demand for xEVs
Technology Landscape
Competitive Landscape
Key Technical Dimensions
Energy Storage for xEVs

Technology Landscape

Chemistry
Format
System Integration

Cleaner
Cost Effective
Higher Performing
Safer
Smarter
More Reliable

Analyst Day | June 27, 2011
Technology Landscape
Battery System Definition and Integration

- OEM Priorities
  - Understand impact of battery performance on vehicle dynamics
  - Controls and system integration to deliver reliability

- Battery Supplier Priorities
  - Define battery thermal and electrical control strategies to manage life
  - Maximize value added in system

- Cell Specialist Priorities
  - Maximize reuse of cell
  - Manage warranty
  - Reduce cost
## Competitive Landscape

### Economic Considerations for HEV

<table>
<thead>
<tr>
<th>System Cost Component</th>
<th>~$1000 per Pack</th>
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<tr>
<td>Cell Cost Component</td>
<td>~$1450 per Pack</td>
</tr>
<tr>
<td>Today's Li-ion Cost Structure</td>
<td>~$2450 per Pack</td>
</tr>
<tr>
<td>2025 Li-ion Cost Structure</td>
<td>~$900 per Pack</td>
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**Threshold for High Penetration:**
- **Today:** ~$400 per Pack
- **2025:** ~$500 per Pack
Summary
The xEV Opportunity

**Demand for xEVs**
- Retail consumers will ultimately drive large scale adoption
- Start-Stop will challenge large scale penetration in near term
- Even at low unit volume, significant revenue opportunity

**Technology Landscape**
- Nascent industry with multiple competing technology considerations
- Industry pursuing range of chemistry, format and system integration models

**Competitive Landscape**
- OE expertise and Li-Ion cost curve expertise critical
- Dynamic market with diverse participation
- Investment requirements and standardization will drive consolidation and partnerships