Tipping Point : Meeting Consumer Demand

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Johnson Controls Power Solutions

Center for Automotive Research – Management Briefing Seminars
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POWER SOLUTIONS IS THE INDUSTRY LEADER WITH SIGNIFICANT COMPETITIVE ADVANTAGES

15,000 TEAM MEMBERS

152M BATTERIES IN FY16

55 MANUFACTURING, RECYCLING AND DISTRIBUTION CENTERS

UNMATCHED GLOBAL CAPABILITIES

1 IN 3 CARS AROUND THE WORLD ARE POWERED BY OUR BATTERIES

SERVING CUSTOMERS IN 150+ COUNTRIES

8K BATTERIES RECYCLED PER HOUR

130+ YEAR TRADITION OF INNOVATION AND GROWTH

6 R&D FACILITIES

STRONG RECOGNIZED BRANDS
FINDING THE RIGHT BALANCE BETWEEN REGULATIONS, CONSUMER EXPECTATIONS AND COST

POLICY & REGULATORY

BALANCING ECONOMICS & COMPLIANCE

VEHICLE TECHNOLOGY

CONSUMER DEMANDS
FEATURE CONTENT WILL DRIVE MORE ELECTRICAL PERFORMANCE IN THE VEHICLE

- Emissions/CO2
- Comfort and convenience
- Safety
NOT ALL ELECTRICAL LOADS ARE CREATED EQUAL

Electrical Power Required

- Lighting Systems
- Power Seats
- Antilock Brake System
- Radar and Cameras
- V2V Comm.
- General ECUs
- Wireless Phone Charging
- Infotainment
- Stability Control System
- 120V AC Outlet
- Rear Defrost
- Electric Oil Pump
- Audio Amplifier
- Electric Assist Steering
- Electric Water Pump
- Heated Seats
- Active Steer/Brake
- Starter (ICE)
- Starter (Start-Stop)
- Electric A/C
- Cabin Preheat
- Auto Parking
- ISG (MHEV)

Electrical Energy Required

- Low
- Med
- High

- < 0.5 kW
- < 2.5 kW
- < 20 kW

[WHr]

- Low
- Medium
- High

[kW]

Emissions/CO2
Comfort and convenience
Safety
THE EVOLUTION OF ELECTRICAL LOADS

1900-1940
No significant changes until beginning of 21st century

1940-1960
6V Electric Starter

1960-1980
12V Powernet begins in earnest

1980-2000
12V Continues

2000-2020
48V/12V Dual powernet to launch

NEW HIGH POWER ELECTRICAL LOADS FOR BOTH EFFICIENCY AND FUNCTION

INCREASING ELECTRICAL POWER

VEHICLE LAUNCH YEAR
VEHICLE TYPE

**CONVENTIONAL**

**BASELINE**

- 5%

**FUEL SAVINGS**

- 20% +
- 40% +

**MARKET OPPORTUNITY**

**VEHICLE POWERTRAIN CONTINUUM**

- **Conventional Powertrain**
- **Start-Stop**
- **Hybrid Electric**
- **Plug-in Hybrid Electric**
- **Electric Vehicle**

**VEHICLE TYPE**

- **CONVENTIONAL**
- **START-STOP**

**xEVs**

- **FORD F-150**
- **HONDA ACCORD**
- **TOYOTA PRIUS**
- **CHEVROLET VOLT**
- **TESLA MODEL S**
Low voltage electrification combined with other efficiency technologies will deliver near-term improvement.

ELECTRIFICATION FOR INCREASED EFFICIENCY IS WELL DEFINED BUT STILL CHALLENGED

Delivers path to zero carbon emission transportation.
LEAD ACID BATTERIES CONTINUE TO HAVE MAJOR ADVANTAGES IN HIGH VOLUME VEHICLE APPLICATIONS

- For single battery architectures there is no perfect solution
- AGM Lead-Acid continues to lead market
- Lithium-ion entering for select applications
**JOHNSON CONTROLS ENERGY STORAGE TECHNOLOGY PAIRING – 12V SYSTEMS**

<table>
<thead>
<tr>
<th>Fuel Economy &amp; CO₂ Reduction</th>
<th>Electrification &amp; Dynamic Environment</th>
<th>Johnson Controls Recommended Battery Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Start-Stop</td>
<td>With Energy Regen Enable Emerging loads High Energy Accept &amp; Deep Cycle</td>
<td>12V Dual (Li-Ion/ AGM)</td>
</tr>
<tr>
<td>8%-+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start-Stop</td>
<td>Limited Energy Regen Existing S/S Electrical Loads Medium Cycle</td>
<td>AGM Gen. 2</td>
</tr>
<tr>
<td>5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic Start-Stop</td>
<td>No Energy Regen Minimal Electric Loads Small Engine / Shallow Cycle</td>
<td>AGM</td>
</tr>
<tr>
<td>3-5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional</td>
<td>Non Start Stop High Electrical Loads</td>
<td>AGM Gen. 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional</td>
<td>Non Start Stop Base Electrical Loads</td>
<td>AGM</td>
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</tbody>
</table>

- There is room to squeeze more fuel economy out of existing Start-Stop systems - fully utilizing AGM
- Market demand for better match between lead acid regen and alternator sizing (i.e. AGM gen 2)
- Significant increases in charge power require Li-ion chemistry
LOW-VOLTAGE POWERTRAINS WILL BE PREDOMINANT

MEGATRENDS ARE DRIVING THE POWERTRAIN MIX FOR NEW CARS

<table>
<thead>
<tr>
<th>Year</th>
<th>Conventional</th>
<th>Lithium-ion</th>
<th>Lead-acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>62%</td>
<td>34%</td>
<td>3%</td>
</tr>
<tr>
<td>2020</td>
<td>53%</td>
<td>13%</td>
<td>7%</td>
</tr>
<tr>
<td>2025</td>
<td>33%</td>
<td>60%</td>
<td>8%</td>
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</table>

LEAD-ACID BATTERIES REMAIN DOMINANT WITH START-STOP GROWING SHARE*
(Projected Original Equipment + Aftermarket battery units in millions)

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<th>Lithium-ion</th>
<th>Lead-acid</th>
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<tbody>
<tr>
<td>2016</td>
<td>60%</td>
<td>4%</td>
<td>13%</td>
</tr>
<tr>
<td>2020</td>
<td>50%</td>
<td>12%</td>
<td>6%</td>
</tr>
<tr>
<td>2025</td>
<td>30%</td>
<td>32%</td>
<td>8%</td>
</tr>
<tr>
<td>2030</td>
<td>20%</td>
<td>33%</td>
<td>7%</td>
</tr>
</tbody>
</table>

*Lithium-ion includes both >60V and 12V/48V
STAY CONNECTED

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@johnsoncontrols