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Power Electronics

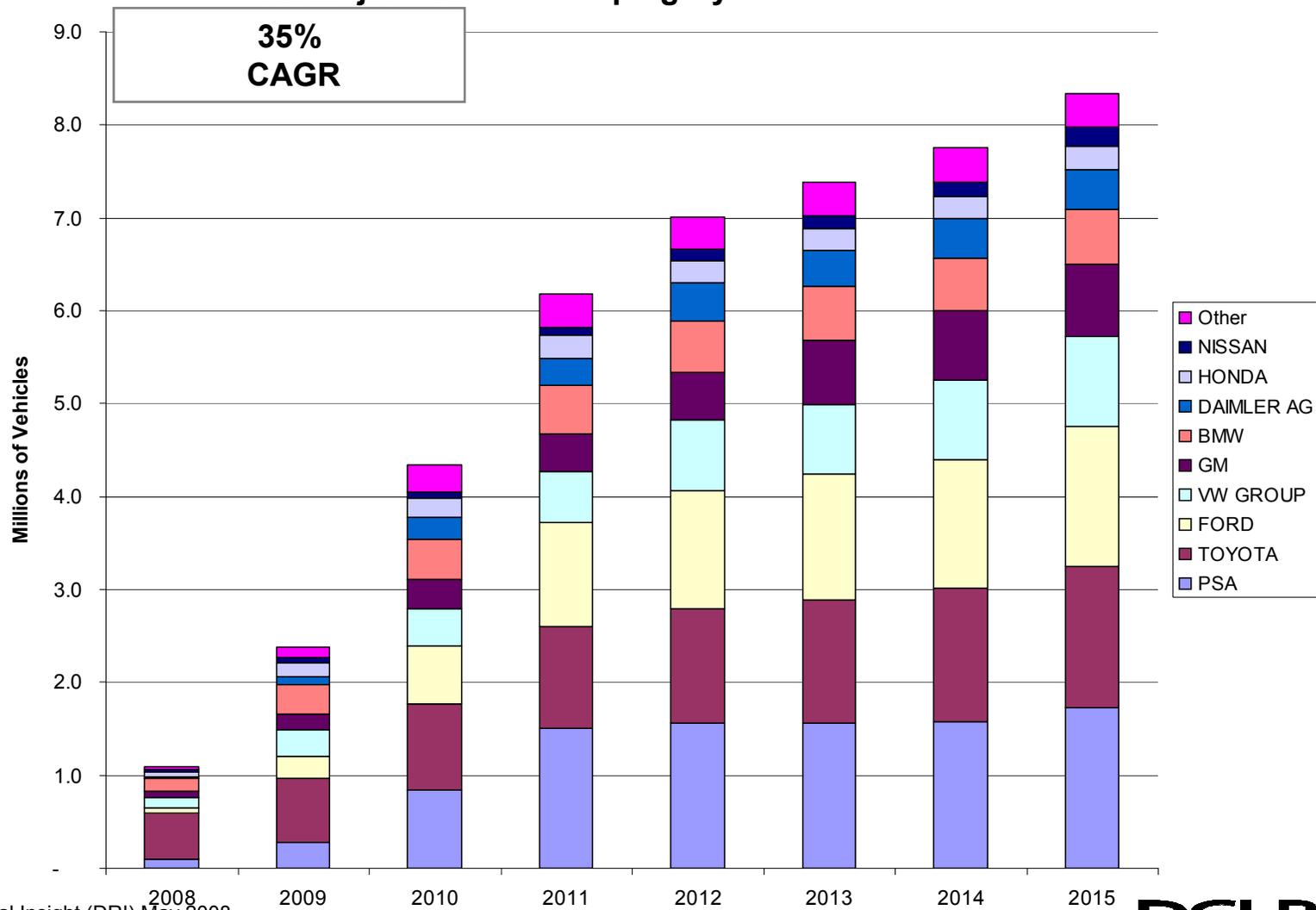
March 4, 2009

Bob Schumacher



HEV Vehicle Forecast by OEM

All Major OEMs Developing Hybrid Vehicles



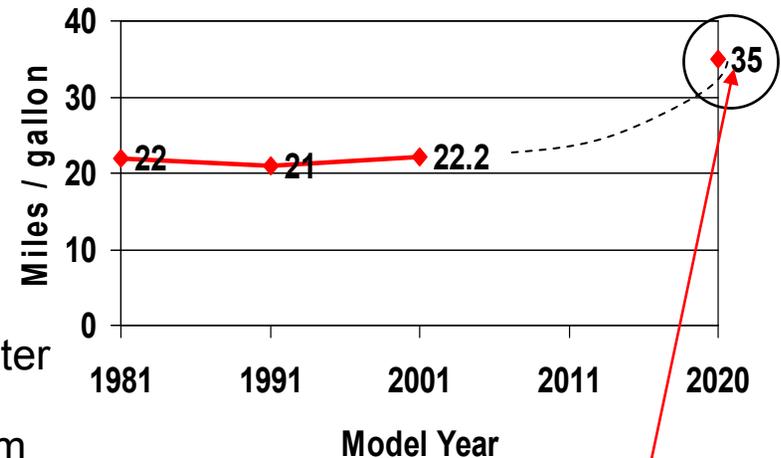
Source: Global Insight (DRI) May 2008

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U.S. CAFE and EU CO2 Requirements

- CAFE: 35 mpg for cars and trucks by 2020
 - 8 mil. trucks @ 22.2 mpg to 8m @ 30 mpg &
 - 10 mil. cars @ 25.4 mpg to 10m @ 40 mpg
 - Changes would get us to 35 mpg Avg
 - 35% improvement in Light Trucks
 - +50% improvement in cars!
- EU Standard: 130 gm/km
 - 20% improvement on 70% of the fleet results in only 14% overall
 - Boosted, downsized DI, with stop-start for a 2 liter gas engine from 185 to 139 g/km
 - Diesel with stop-start goes from 143 to 129 g/km

US Corp. Avg. Fuel Economy



U.S. Target

European Avg (2006)

Comparison CO₂ to MPG

	Gas MPG	Diesel MPG
160 CO ₂ g/km	34.5	39.5
130 CO ₂ g/km	42.4	48.7

New Target?

• Both Targets Require Hybrid Technology as part of the Solution

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Delphi Electronics & Safety

HEV and Power Electronics



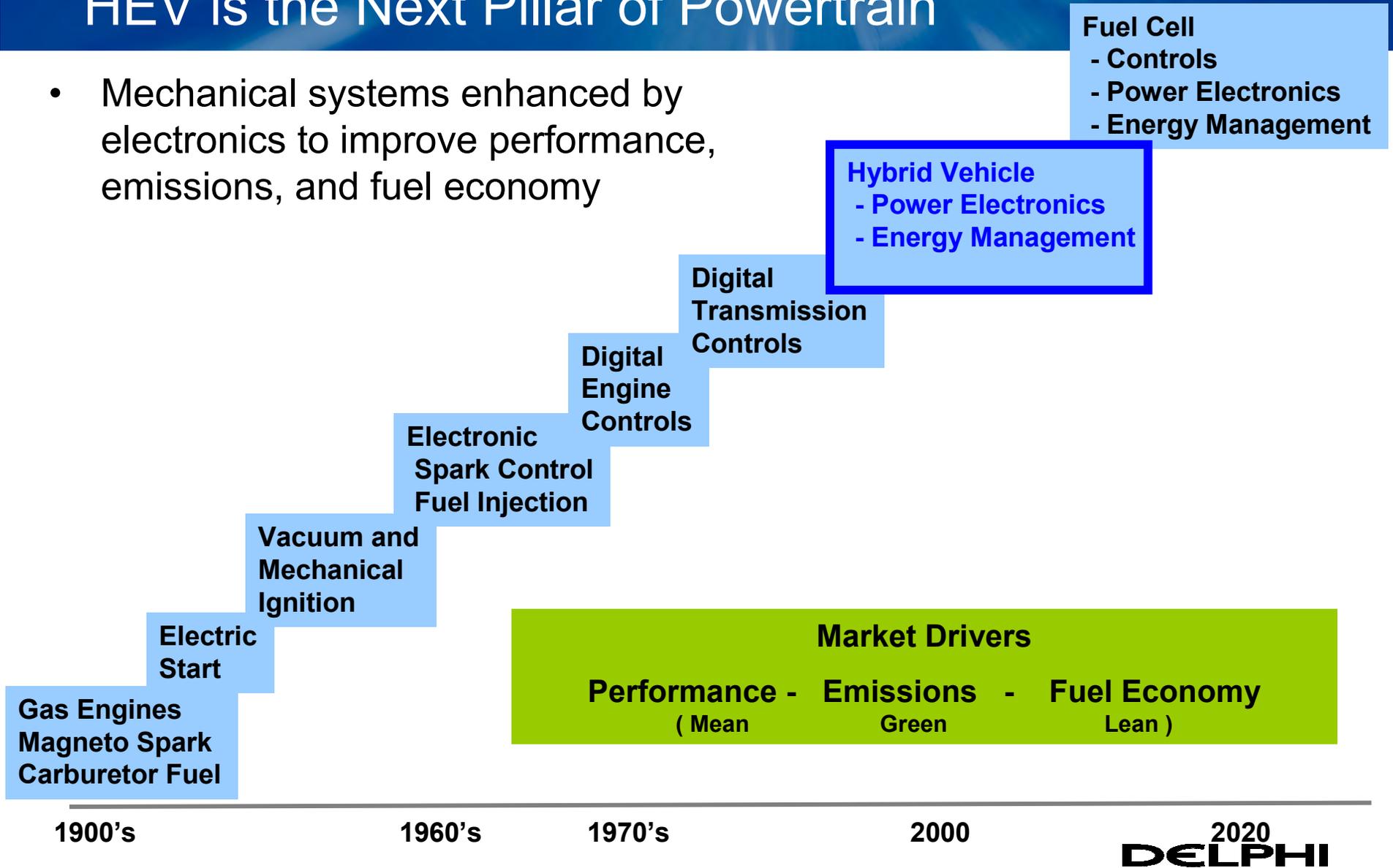
- Battery Controllers
- Hybrid and Electric Vehicle Controllers
- DC/DC Converters
- Traction Inverters
- High Voltage Battery Pack Systems
- 14V Stop/Start Systems
- Mild Hybrid Systems

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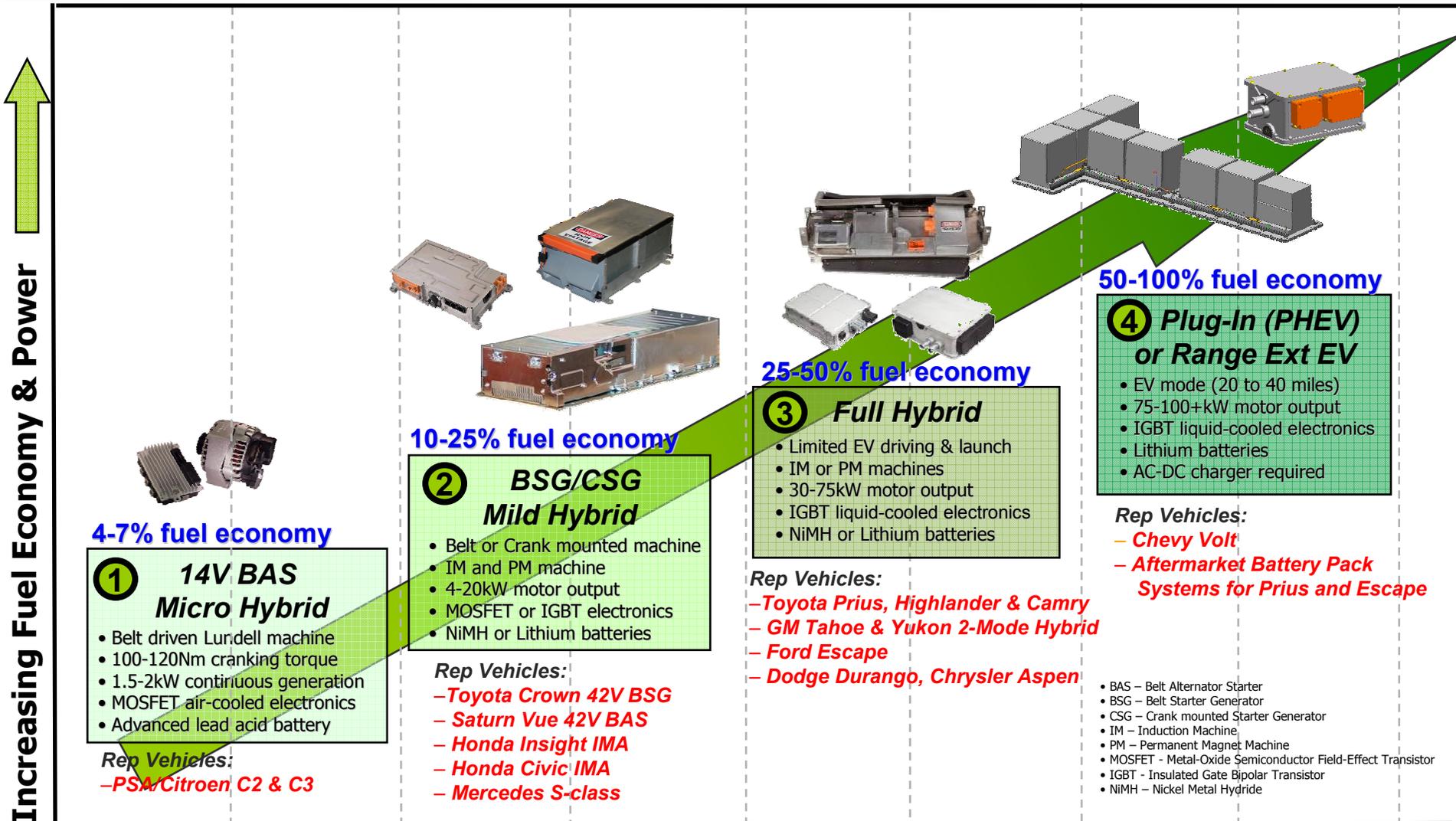
Powertrain Electrification Megatrend

HEV is the Next Pillar of Powertrain

- Mechanical systems enhanced by electronics to improve performance, emissions, and fuel economy



The Continuum of Hybrid Vehicle FE and Power



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Delphi HEV and Power Electronics Products

Hybrid Products:

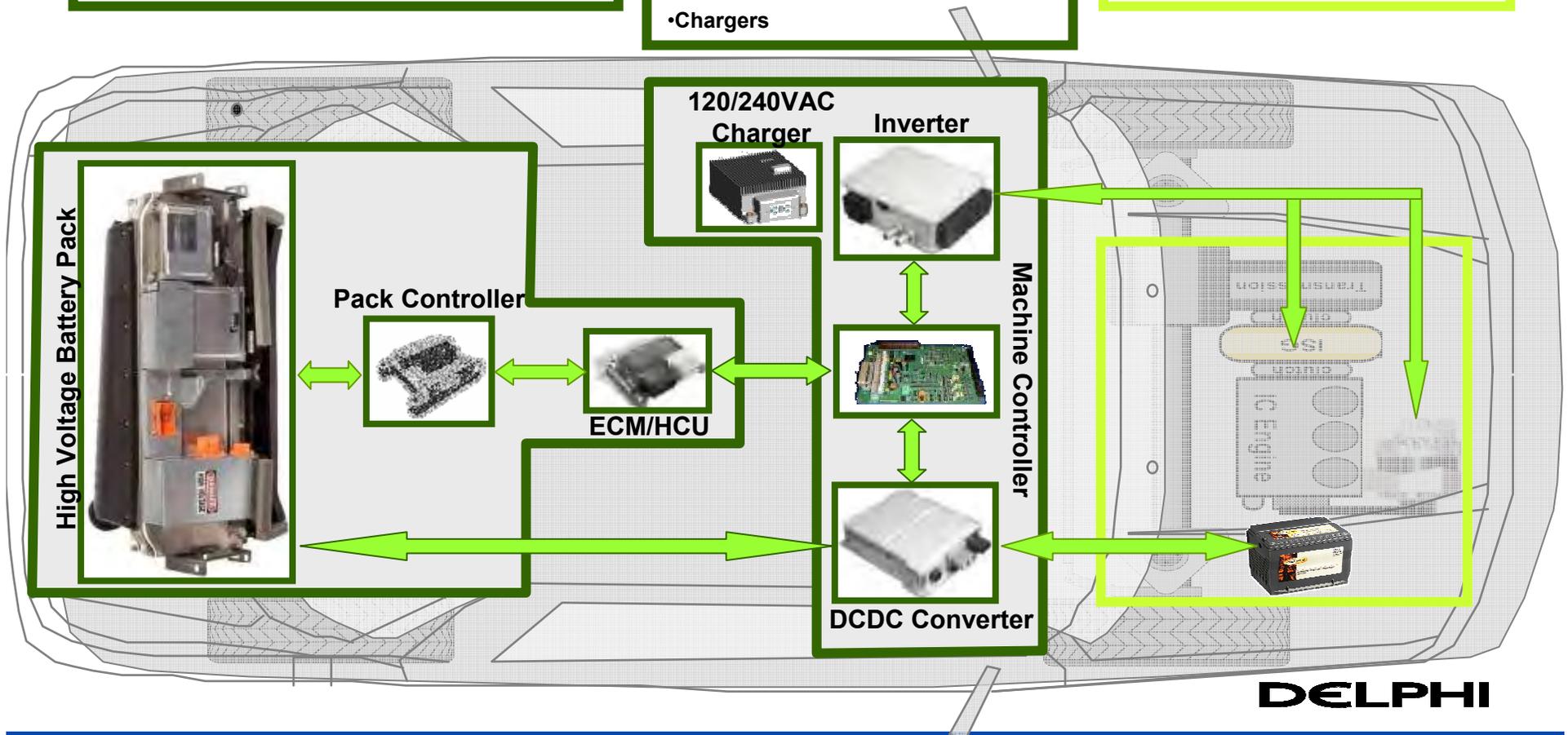
- Battery Pack
- Battery Pack Controller
- HEV Controller

Power Electronics Products:

- DC/DC Converters
- DC/AC Inverters
- Motor Controller
- Chargers

Partner/Supplier Products:

- Battery/Cells
- Electric Machines
- Transmission



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Hybrid Vehicle Control Unit (HCU-1)

HCU-1 Hybrid Control Unit

Description

The HCU-1 Hybrid Control Unit is based on the Delphi Electronics & Safety MT-Series family of controllers. These modules are designed to provide intelligent control to any hybrid electric vehicle application. They are able to make measurements of multiple instantaneous events to enable “real-time” adjustment of inverter and converter setpoints, electric machine and battery management system operating points, and they are capable of managing vehicle level HEV safety algorithms. MT-Series controllers are flexible enough to be used on a wide variety of vehicle applications and across multiple HEV architectures.

Delphi designs and manufactures intelligent controllers that enable hybrid vehicles to function more efficiently, reliably, and economically.

OEM Benefits

- ◆ Based on high volume, low cost Delphi powertrain controller
- ◆ Readily configurable microprocessor and software to meet customer specific functions
- ◆ Flash programming provides for in-vehicle memory updates
- ◆ Up-integrated design reduces weight and wiring
- ◆ Mounting flexibility: Underhood or passenger compartment



Features

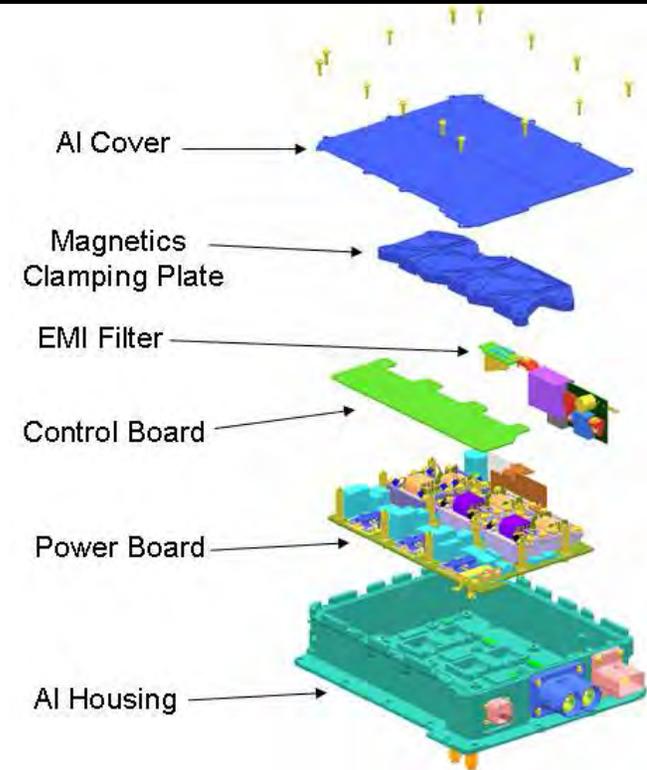
- ◆ Microprocessor: 32-Bit, 66MHz, 1MB Flash Memory
- ◆ Communication: CAN (2 Channels) , KW2000
- ◆ Instrumentation: CCP, ETAS
- ◆ Analog Input: 32 Channels
- ◆ Digital Input: 18 Channels
- ◆ Digital Output: 23 Channels (2 HSD, 16 LSD, 5 Relay)
- ◆ PWM Output: 3 Channels
- ◆ Frequency Input: 8 Channels
- ◆ Memory: 56kB RAM, 16kB x 2 non-volatile ROM
- ◆ Environment: Underhood, -40°C – 105°C

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In Production (since Fall 2007)

300V/14V & 42V DC/DC Converter

- Multi-output, Bi-directional 3.2kW DC/DC Converter
- Input voltage range
 - 216 to 390Vdc operation
- 300Vdc to 14Vdc, bi-directional DC/DC converter
 - 175Adc continuous (buck)
 - » 12.5 to 15.5Vdc controllable output
 - 2.35Adc continuous (boost)
- 300Vdc to 42Vdc DC/DC converter
 - 25Adc continuous
 - 50Adc 4 seconds
- Engine compartment mount
- -40 to 105° C ambient, 75° C 50/50 WEG cooled

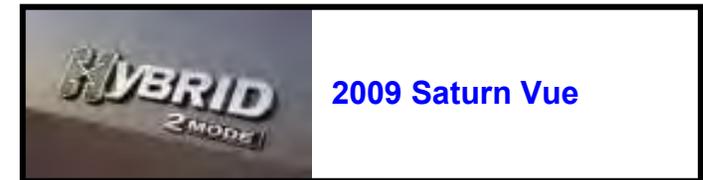


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In Production (since Summer 2008)

300V/14V DC/DC Converter

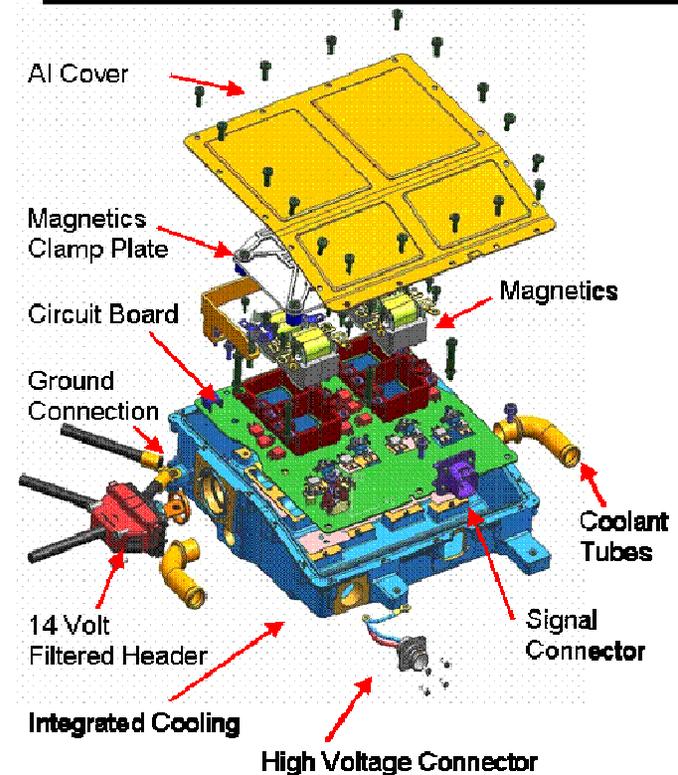
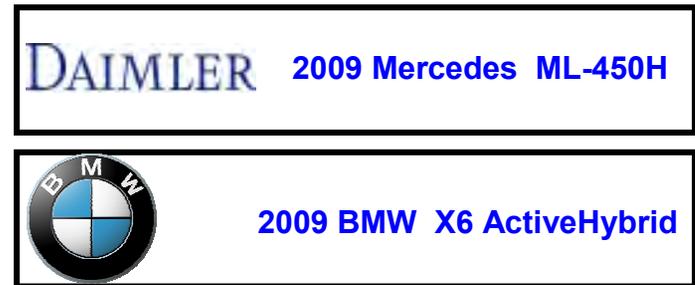
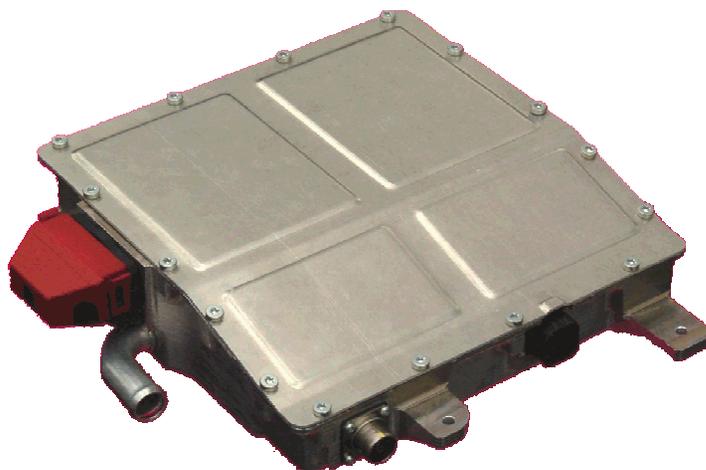
- Bi-directional 2.2kW DC/DC Converter
- Input voltage range
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- 300Vdc to 14Vdc, bi-directional DC/DC converter
 - 175Adc continuous (buck)
 - » 12.5 to 15.5Vdc controllable output
 - 2.35Adc continuous (boost)
- Engine compartment mount
- -40 to 105° C ambient, 75° C 50/50 WEG cooled



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300V/14V DC/DC Converter

- Bi-directional, 2.2kW DC /DC Converter
- Input Voltage Range
 - 216 to 422Vdc operation
- 300Vdc to 14Vdc, bi-directional DC /DC converter
 - 175Adc continuous (buck)
 - » 11.0 to 15.5Vdc controllable output
 - 2.5Adc continuous (boost)
- Engine compartment mount
- -40C to 110° C ambient, 75° C 50/50 WEG cooled
- Integral cooling jacket



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DC/DC Converter Production Line Kokomo, Indiana

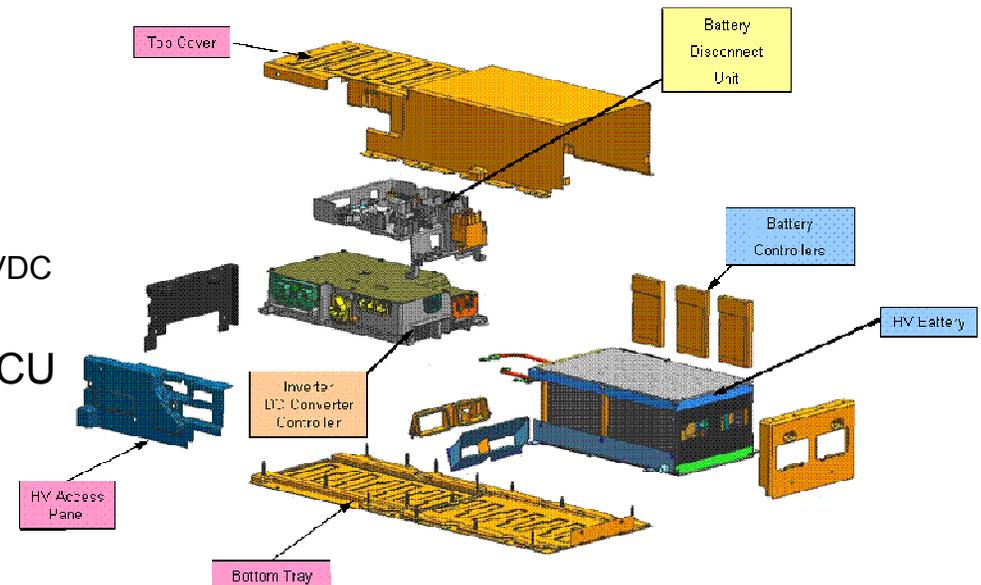


Final Assembly & Test Cell

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Power Box Mild Hybrid System

- Integrated Inverter, DC/DC Converter, Hybrid Controller, BDU and Battery Pack
- Input Voltage Range
 - 80 to 134Vdc normal operation
- 3-phase DC/AC Traction Inverter
 - 35kW Peak Motoring Power (Battery Limit is Less)
 - >10kW Continuous Motoring Power
 - 32-bit, 128Mhz Processor, Vector-controlled
- 1.6kW, Isolated, 120V to 14V DC /DC Converter
 - Uni-directional
 - Adjustable Output Voltage Range: 12.5 to 15.5 VDC
 - Output Current 5 to 120 Adc
- 32-bit, 128Mhz, 3M Flash, 128k SRAM HCU
- Air-cooled design
 - 10 to 65 cfm air at up to 55° C
- -30° to +70° C Ambient Operation



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14-Volt Belt Alternator Starter System

An electric machine that acts as the vehicle starter/generator plus an electronic regulator-inverter-controller that work together to help increase fuel economy

Value

- Stop/start feature increases fuel economy by 4 - 6%
- Offers the potential for up-integration of energy management
 - Discrete or software I/O communication to vehicle
- Provides consumer and environmental benefits
 - Cleaner air
 - Reduced fuel consumption
 - Quieter starts than conventional starter
 - Opportunity to remove 14V starter on small engines

Functionality

- Turns the engine off at idle and promptly restarts the engine via the accessory belt when the driver is ready to proceed
 - Executive coding in RIC or Vehicle.
- Remote regulator-inverter-controller (RIC) transforms 12Vdc battery power into 3-phase alternating current for use by the electric motor to start the engine.
 - 50Nm machine cranking torque
 - Air cooled FET power electronics
- Converts 3-phase current back to 12 Vdc for conventional AGM battery charging
 - 1.5 to 2.0 Kw
 - Over 70% motor efficiency due to FET power electronics

Availability

- Demonstration parts currently available
- Start of Production - Q4 2009

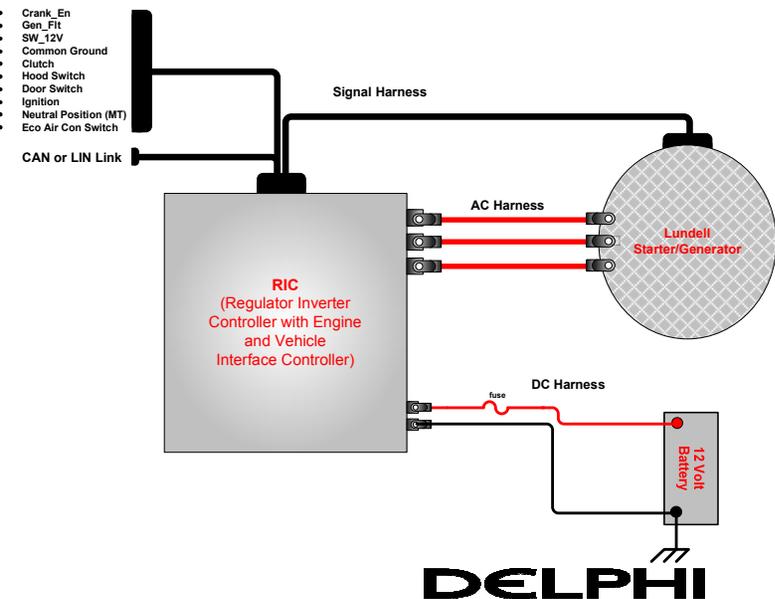


Power Electronics RIC

Electric Motor

Vehicle Connections

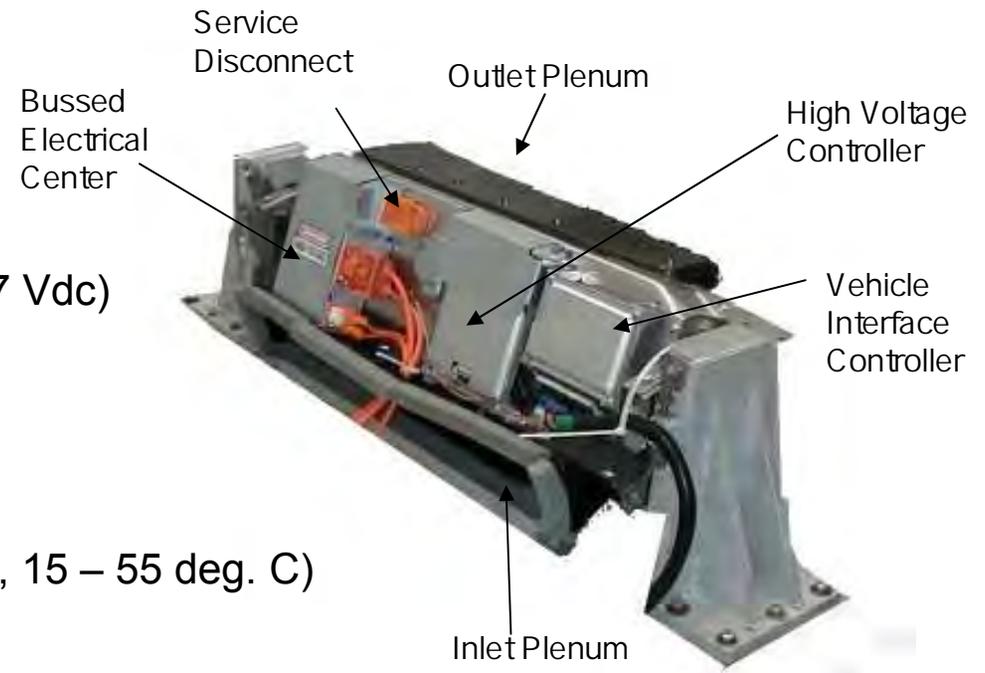
- Crank_En
- Gen_Fit
- SW_12V
- Common Ground
- Clutch
- Hood Switch
- Door Switch
- Ignition
- Neutral Position (MT)
- Eco Air Con Switch



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250V NiMH HEV Battery System

- **Nominal Voltage**
 - 250 Vdc (scalable design to 307 Vdc)
- **1.25 kW-H Capacity**
- **Peak Discharge Power**
 - 27 kW (BOL, 10 secs., 50 % SOC, 15 – 55 deg. C)
- **Peak Charge Power**
 - 25 kW (BOL, 10 secs., 50 % SOC, 25 – 55 deg. C)
- **Cold Discharge Power**
 - 3 kW minimum (BOL, 1 sec., -40 deg. C)
- **Continuous Current @ 25 deg. C**
 - 50 A



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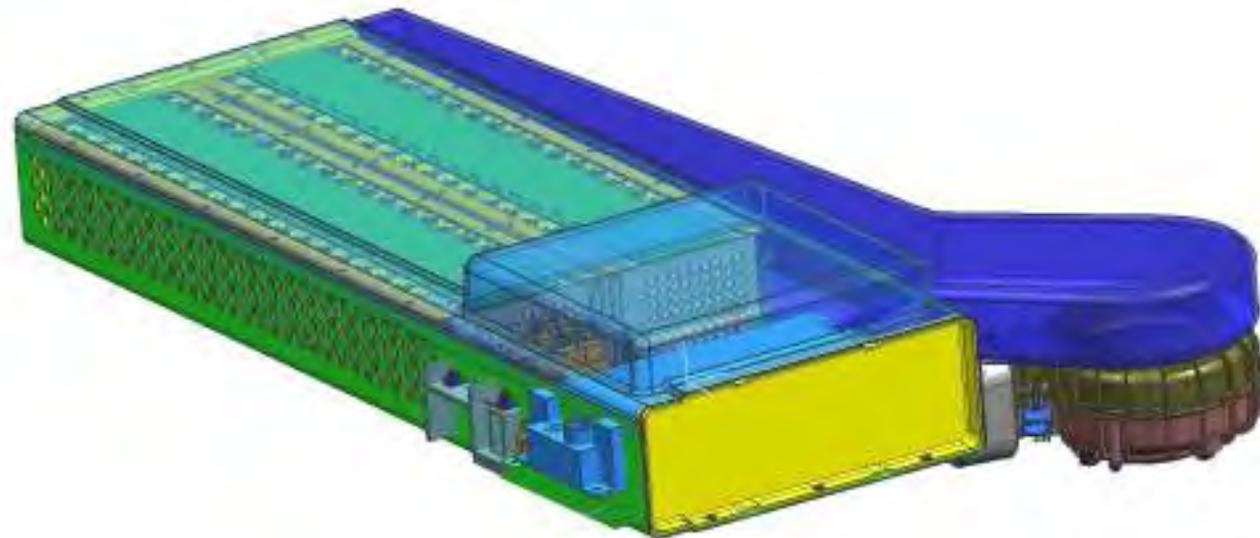
Battery Pack Production Line Reynosa Mexico



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300V Lithium HEV Battery System

- Nominal Voltage
 - 300 Vdc (scalable design)
- 1.7 kW-H Capacity



Lithium Cell Chemistry Experience

- Delphi/EnerDel LiNiMxCo, LiMn_2O_4 +LTO
- Saft LiNiMxCo
- Sanyo LiMxCo
- Gaia UHP LiNiMxCo
- Eone/Molicel LiMn_2O_4
- Toshiba – LiMnO + LTO
- Hitachi LiMnO
- Samsung - LiNiMxCo
- Kokam Lithium Polymer
- A123 Nanophosphate™

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