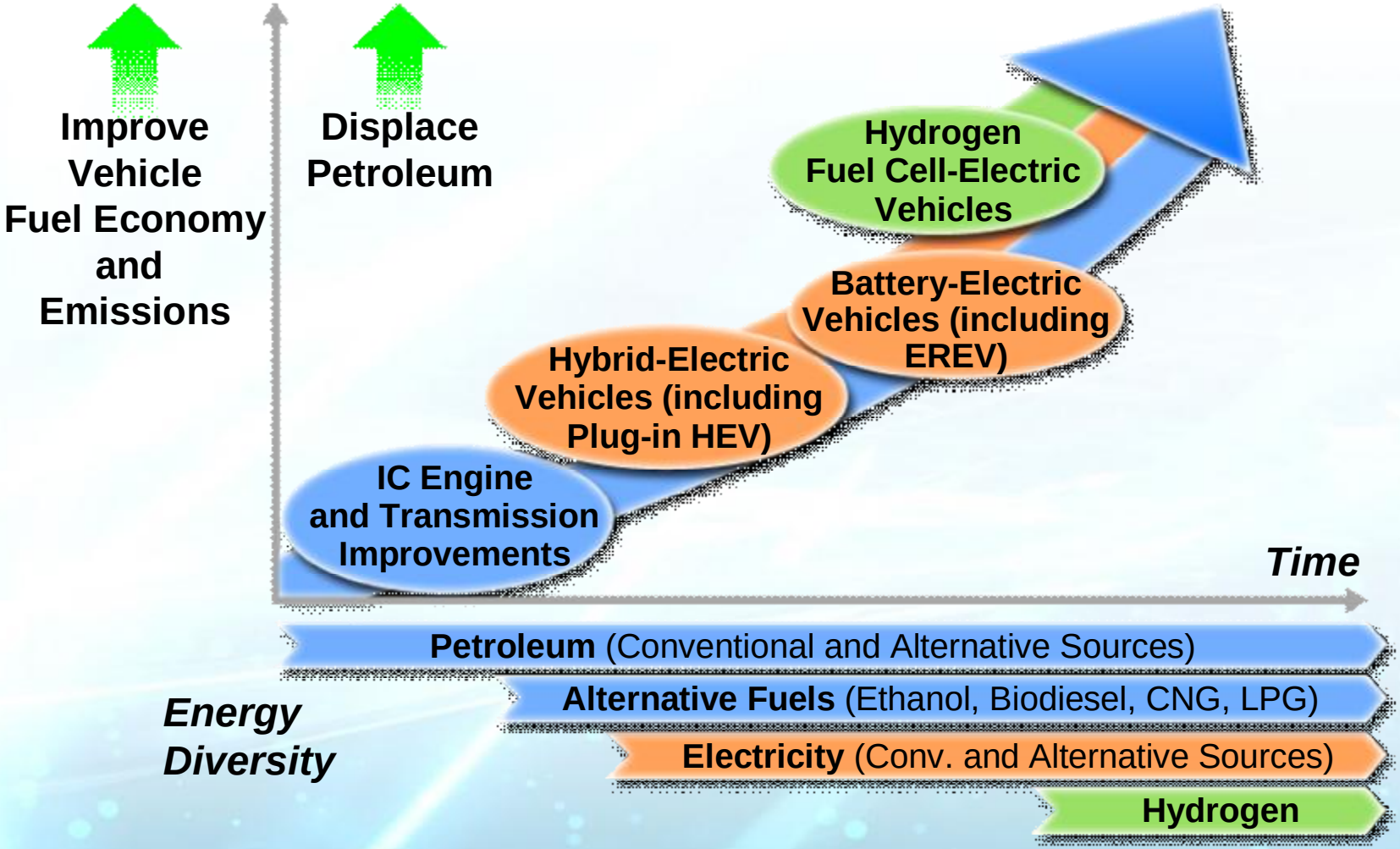
ELECTRIFYING THE AUTOMOTIVE INDUSTRY

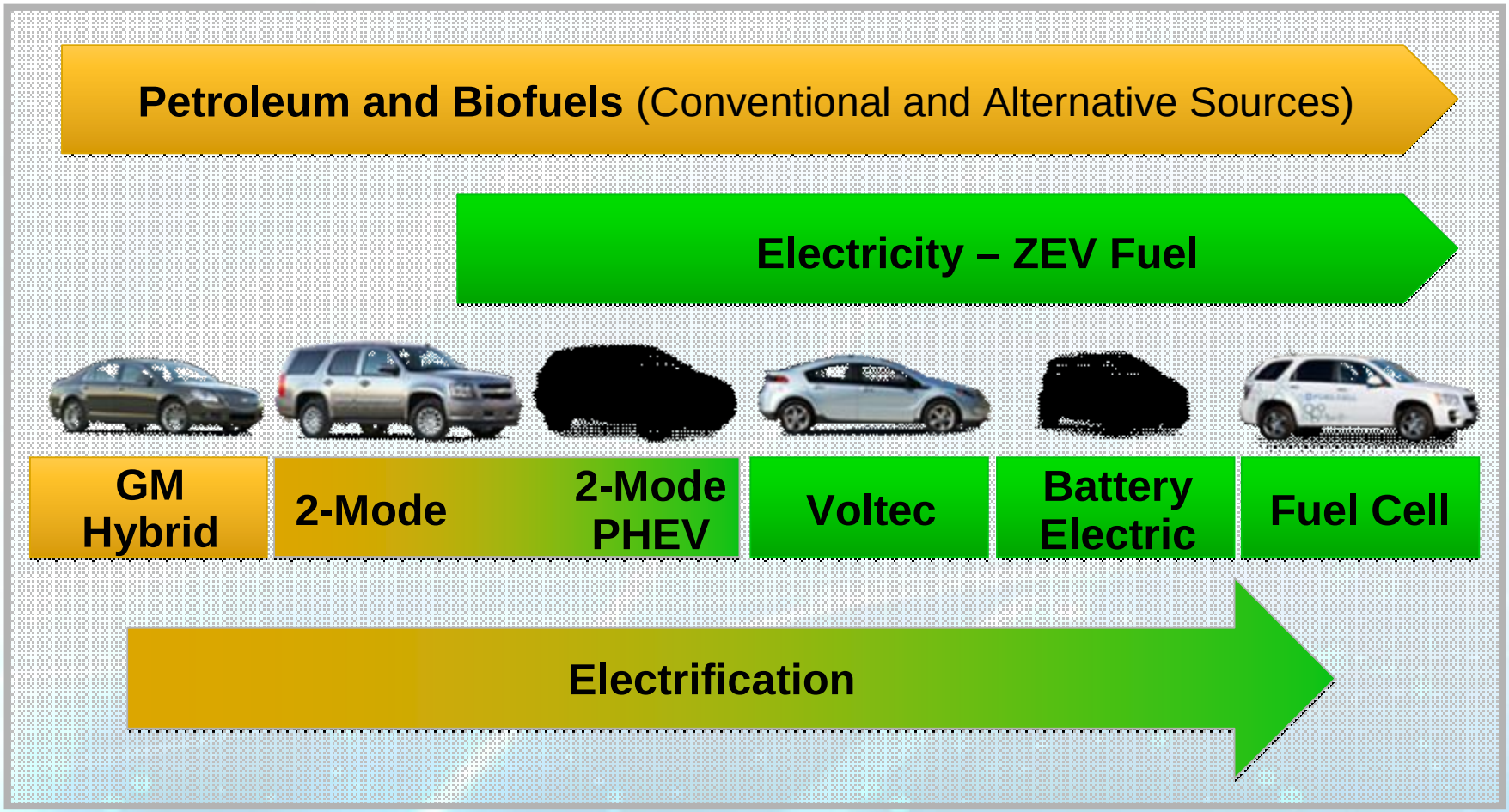
Gary Smyth
Executive Director, Global Research & Development
General Motors Company

GM Advanced Propulsion Technology Strategy



GM Vehicle Electrification Strategy

Portfolio of solutions for full range of vehicles that provide customer choice




KILOWATTHOURS


BlackBerry
Mobile
Updated 11/5/2010 4:27 PM from Sparky
Battery
55 %
EV Range
22 Miles
Total Range
282 Miles
Charge Mode - Grid Friendly
PLUG IN TO CHARGE

VOLT

Variations on Electric Vehicles

Chevrolet Volt: The Electric Vehicle with Extended Range

PHEV	EV with Extended Range	Pure EV
Plug-in Hybrid Electric Vehicle	Electric Vehicle with "Extended-Range"	Pure Electric Vehicle
• All-electric at low speed/power • Blended electric/gas at higher speed/power • Primary fuel is gasoline supplemented with electricity (typical)	• All-electric for up to 40 miles • Gas generator for +300 miles extended driving range • Primary fuel is electricity supplemented with gasoline (Volt)	• All-electric for ~100 miles • Fuel is electricity (typical)

Lithium-Ion Battery

- 16 kWh (8kWh usable)
- High energy, high power in minimized package
- 8-year / 100,000-mile warranty

Charging Power Levels

- 120V (1.2 kW) charging
  - Plugs into standard household outlet
  - Full charge in about 10 hours (temperature dependent)
  - No additional equipment or installation typically required
  - Charge cord standard with the vehicle in NA
- 240V (3.3 kW) charging
  - Full charge in about four hours
  - Efficient and enables more opportunity to drive electrically
  - Will usually require a one-time investment to upgrade garage with dedicated 240V circuit
- Charger and control logic onboard the vehicle

120V Cordset

240V Charge Station

Electricity as Low-Cost Fuel

7-13¢ per mile

1-2¢ per mile

Progress on Chevrolet Volt

On time! On time! On time! On time!

Cell
2007
CPI/LG Chem/ GM Cell

1st Pack
10/31/07
1st CPI Built Pack Delivered

Packs 50-300
2008-Present
GM Designed, CPI Built

Battery Validation Completed
7/10

On time! On time! On time! On time!

Concept
9/07–8/08

Early Design
8/08–6/09

Pre-Production Operation (PPO)
6/09–3/10

Plant PPO
3/10-6/10

Next Steps

Q4 2010

Basic Concept Development

Powertrain and Chassis Development

Charging & Car/Customer Interaction

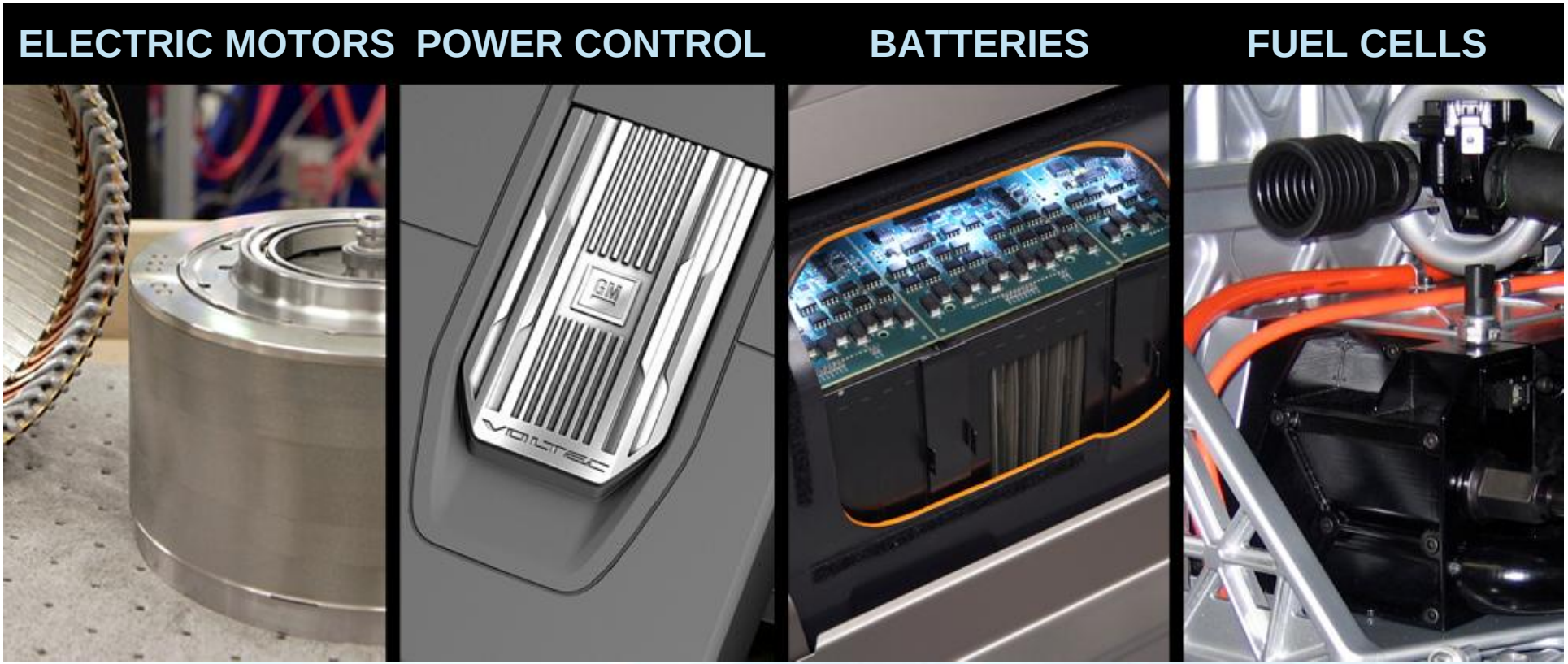
Calibration, Testing, & Fit and Finish

GM

Pre-production Chevrolet Volt Drives Through Water Trough to Test Reliability and Durability

First Pre-production Chevrolet Volt Moves Along the Assembly Line at Detroit-Hamtramck Assembly Center – March 29, 2010

Vehicle Electrification



Global Battery Systems Lab

New – Global Battery Systems Lab Expansion

- GM doubling size of lab to 63,000 square feet
- $8 million investment
- Improve on-site testing capabilities for battery cells, modules, and packs

GM/U-M Advanced Battery Coalition for Drivetrains (ABCD)

Global Lithium Battery Technology

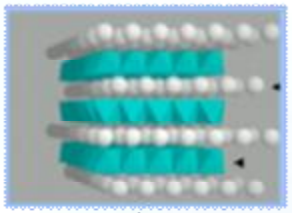
Frontier Cathode (Positive) Materials

Layered Oxides

$LiCoO_2$ $LiNiO_2$

Expensive

Safety



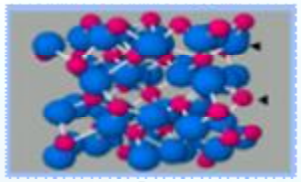
$LiMO_2$

Spinel Oxides

$LiMn_2O_4$

Dissolution &

Structure Stability

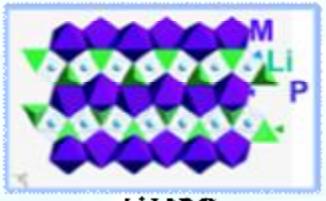


LiM_2O_4

Polyanions, Olivines

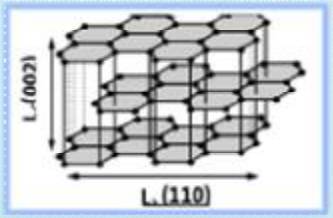
$LiFePO_4$

Insulator



$LiMPO_4$

Current Anode (Negative) LiC_6



Battery Companies

Sony, Mitsubishi
Saft, Hitachi,
China, Korea

NEC, Hitachi
China, Korea, Sanyo

A123, Canada
China, Japan

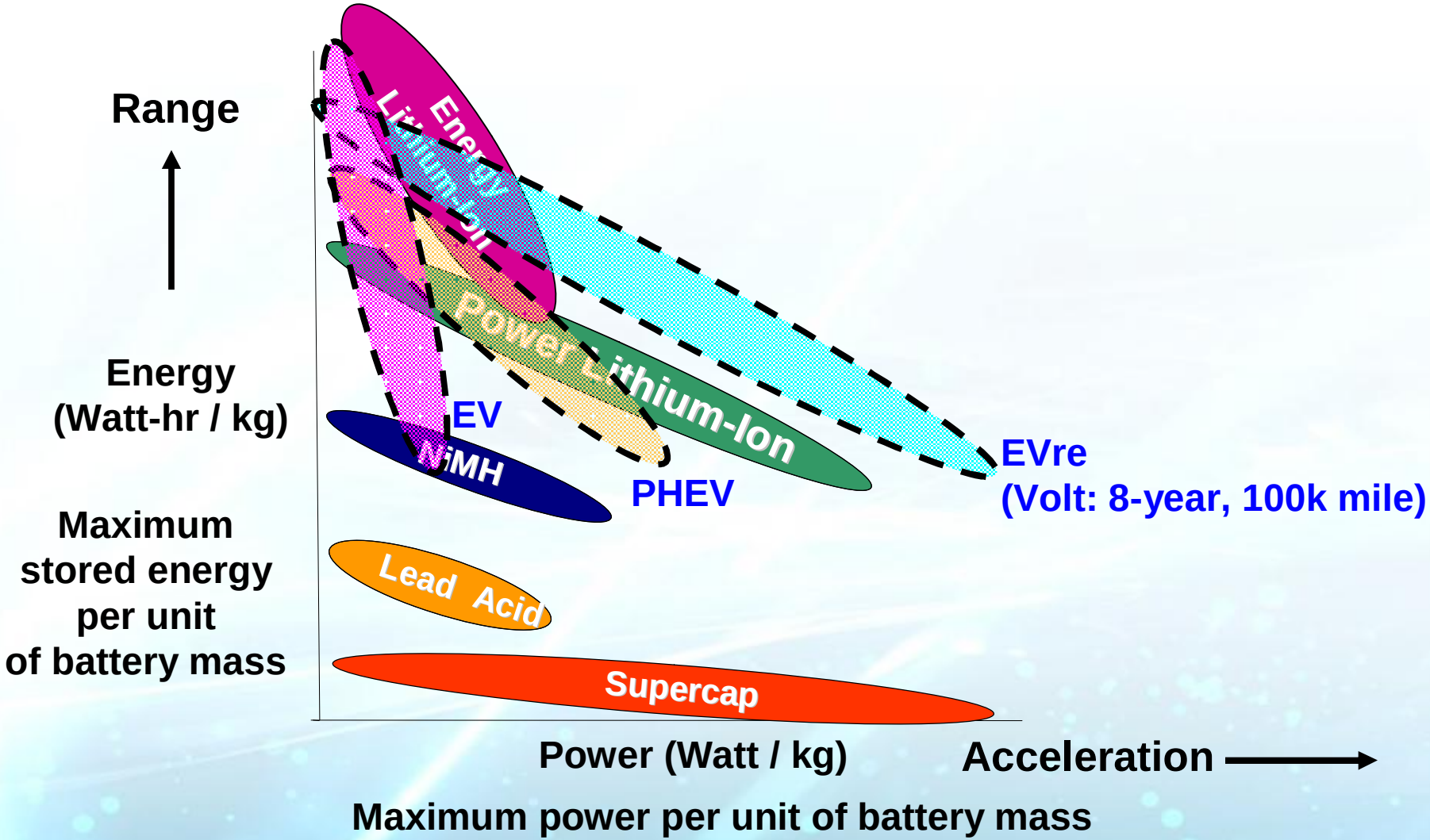
All Common

Brownstown Township
Battery Manufacturing Plant

Electric Motor Development and Manufacture

- GM is the first U.S. based automaker to design, develop, process, and manufacture its own electric motors
- Facilities
  - Wixom, Pontiac, Indianapolis, Torrance – R&D and validation
  - White Marsh, Maryland – high-volume manufacturing
- GM investment will be more than **$246M** in electric motors and electric drive facilities
- Design and manufacture electric motors in-house, and work with our best suppliers to provide the very best electrified vehicle solutions to our customers

Battery Technology Improvements and the EVre Challenge



Comparison of GM's Requirements to USABC Specs

(See www.uscar.org)

Requirements of End of Life Energy Storage Systems for PHEVs					
Characteristics at EOL (End of Life)		**High Power/Energy Ratio Battery**		**High Energy/Power Ratio Battery**	**EV with Range-Extender**
Reference Equivalent Electric Range	miles	**10**		**40**	**40**
Peak Pulse Discharge Power - 2 Sec / 10 Sec	kW	**50 / 45**		**46 / 38**	**115/110**
Peak Regen Pulse Power (10 sec)	kW	**30**		**25**	**60**
Available Energy for CD (Charge Depleting) Mode, 10 kW Rate	kWh	**3.4**		**11.6**	**8**
Available Energy for CS (Charge Sustaining) Mode	kWh	**0.5**		**0.3**	**0.35**
Minimum Round-trip Energy Efficiency (USABC HEV Cycle)	%	**90**		**90**	**90**
Cold cranking power at -30°C, 2 sec - 3 Pulses	kW	**7**		**7**	**8**
CD Life / Discharge Throughput	Cycles/MWh	**5,000 / 17**		**5,000 / 58**	**4700 / 54**
CS HEV Cycle Life, 50 Wh Profile	Cycles	**300,000**		**300,000**	
Calendar Life, 35°C	year	**15**		**15**	**10**
Maximum System Weight	kg	**60**		**120**	**160**
Maximum System Volume	Liter	**40**		**80**	**100**
Maximum Operating Voltage	Vdc	**400**		**400**	**410**
Minimum Operating Voltage	Vdc	**>0.55 x Vmax**		**>0.55 x Vmax**	**232**
Maximum Self-discharge	Wh/day	**50**		**50**	**5% in 60 Days**
System Recharge Rate at 30°C	kW	**1.4 (120V/15A)**		**1.4 (120V/15A)**	**3.6 (230V/16 A)**
Unassisted Operating & Charging Temperature Range	°C	**-30 to +52**		**-30 to +52**	**-30 to +52**
Survival Temperature Range	°C	**-46 to +66**		**-46 to +66**	**-46 to +66**
Maximum System Production Price @ 100k units/yr	$	**$1,700**		**$3,400**	

EVre requires 2.5 times the power of USABC requirements

Charging and Infrastructure

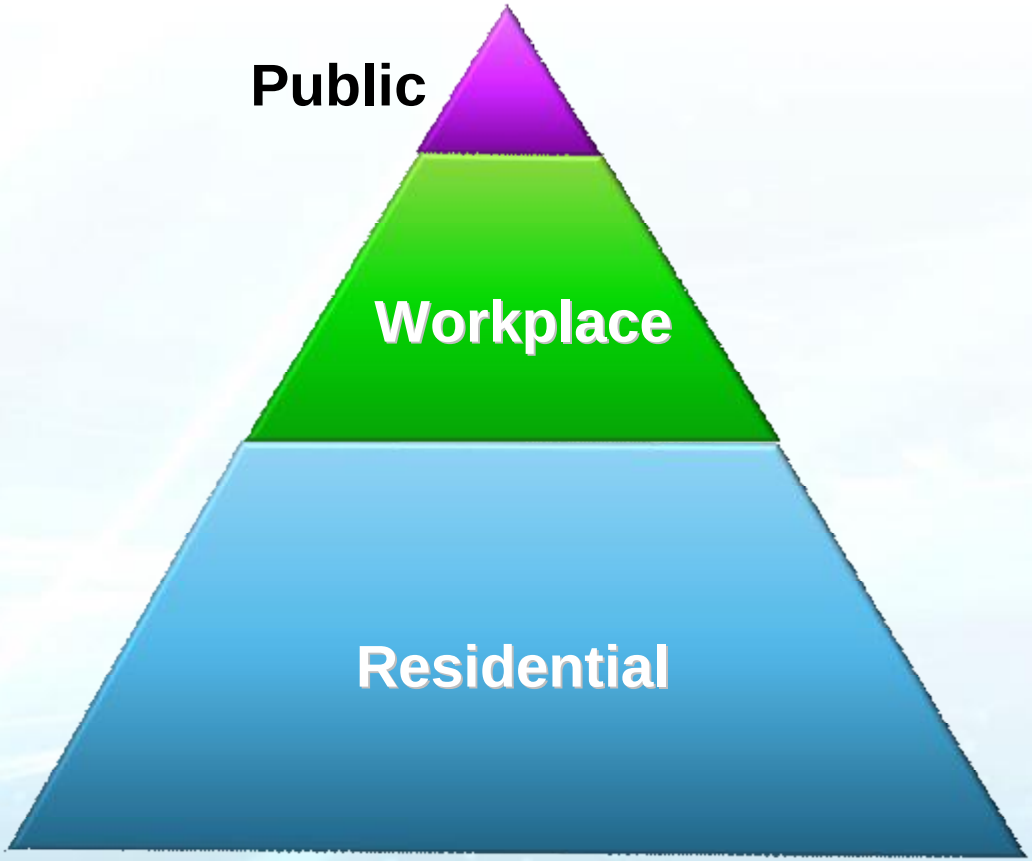
Automakers and Utilities Need to Collaborate to:

- Accelerate use of electricity to replace gasoline
- Create affordable, desirable vehicles that take advantage of the grid
- Provide accessible, reliable, convenient, low-cost electricity (assure that homes are ready and charging is easy – standards in place)
- Educate the public about electric vehicles
- Realize environmental benefits of the plug-in revolution

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Charging Infrastructure

- Public charging
  - High visibility
  - Commercial/Retail
  - Public education and outreach
- Workplace
  - Corporate, municipal parking lots
- **Residential (majority)**
  - **Satisfying consumer-driven home installation process**
  - **Permits, electricians, inspections, meters, rates**

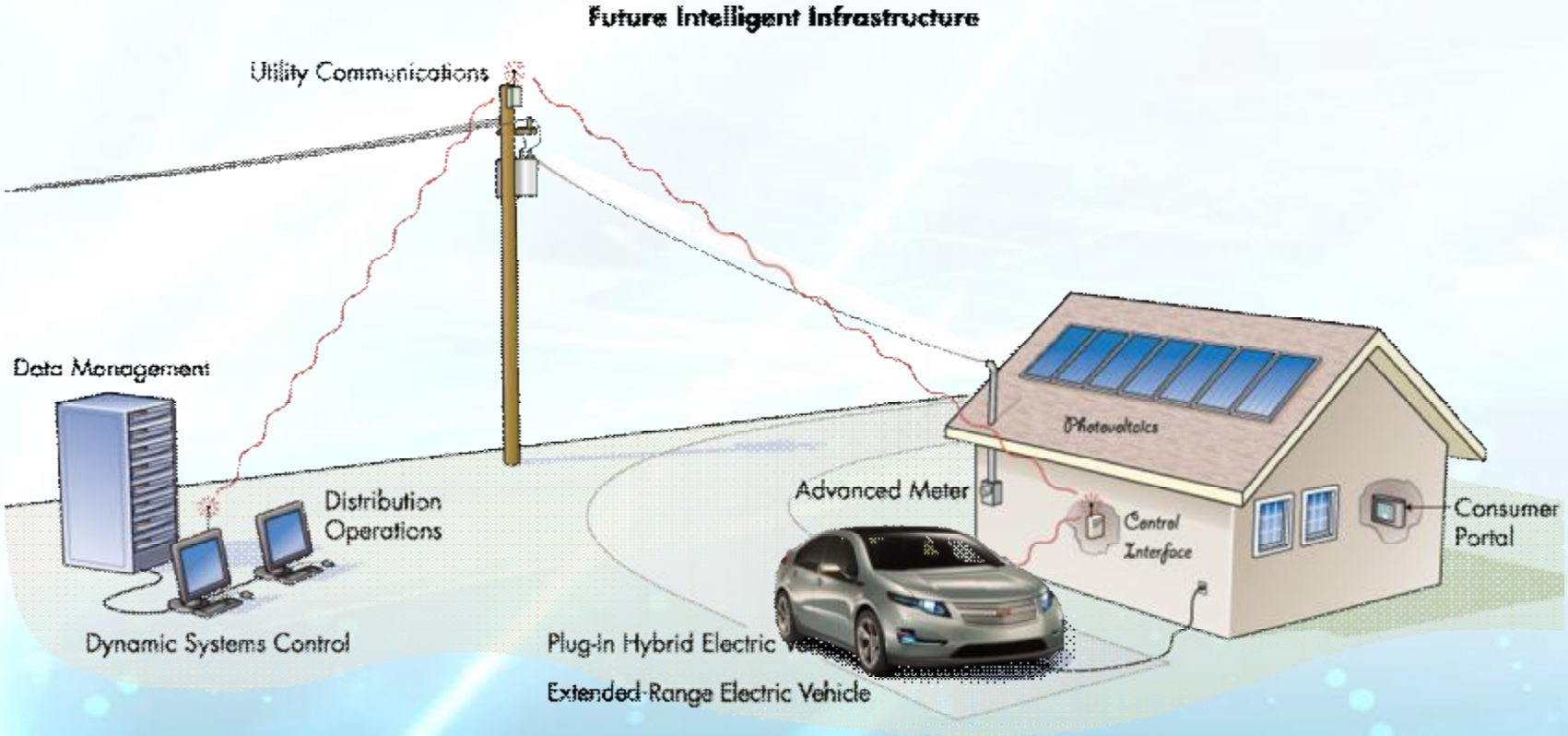


GM/Utility Partners and Volt Retail Market Rollout

Creating Connections – Grid-enabled Smart Cars Connect to the Smart Grid

Extended-Range Electric Vehicles (EREVs) and Plug-in Hybrid Electric Vehicles (PHEVs)

Components of Increasingly Sophisticated Local Energy Networks



Courtesy: EPRI Journal


Robust Supply Base
Partnership Between Automakers & Electric Utilities
Collaboration Between Automakers & Academia
Engaging the Customer

- Critical need for electrically driven vehicle components and system
- Suppliers can help find solutions

- Seamless integration into electric grid will require close collaboration between automotive and electric sectors

- Great demand for technical work force with expertise in new regimes
- GM has initiated research and education programs at universities around world

- Ensure customers of plug-in cars can fully enjoy their ownership experience
- Requires customer-pleasing vehicles, mature supply base, capable grid, plug-in-ready communities, and plug-in-ready car buyers


Robust Supply Base
Partnership Between Automakers & Electric Utilities
Collaboration Between Automakers & Academia
Engaging the Customer

Transformational Partnerships Required

U.S. Government Agencies & National Labs

U.S. Auto Industry

Public/Private Partnership
Promising Transformational Technology

Suppliers & Other Key Stakeholders

Energy and Infrastructure Industries


GM