Sustainable TRANSPORTATION

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

U.S. DOE Battery and Electric Drive Technology R&D Strategy to Achieve EV Everywhere Goals

3rd October 2013

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Presentation Outline

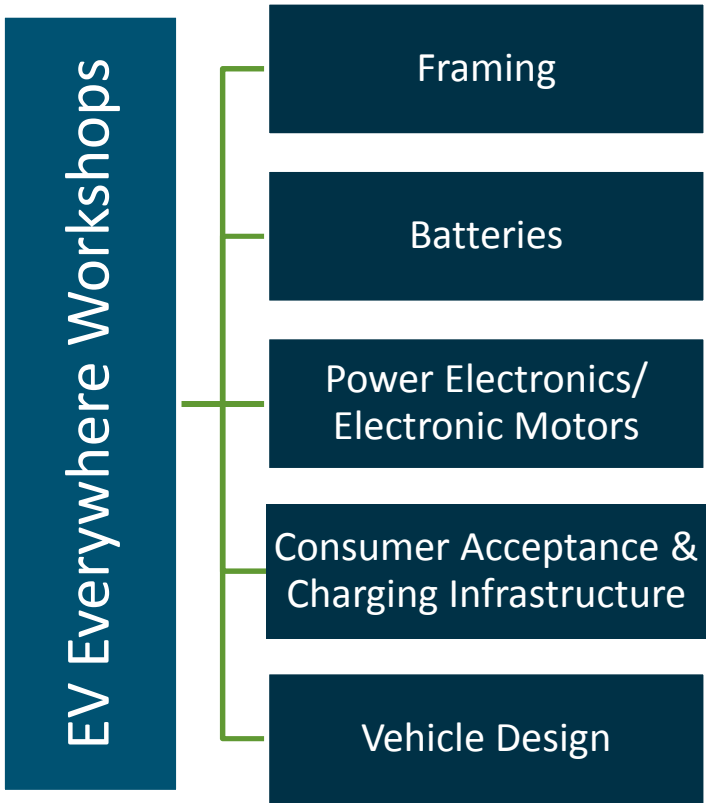
- EV Everywhere Grand Challenge Announcement
- Defining EV Everywhere Technical Targets
- Individual Technology Targets and R&D Pathways
- Infrastructure, Education, and Policy
- Current Projects and Initiatives

EV Everywhere Grand Challenge Announcement March 2012

President Obama, March 7, 2012,
Daimler Truck Manufacturing Plant
Mount Holly, North Carolina

- Grand Challenges – ambitious but achievable goals that capture our imagination and inspire breakthroughs in science and technology
- "The EV-Everywhere Challenge is focused on advancing electric vehicle technologies and continuing to reduce costs, so that a decade from now, electric vehicles will be more affordable and convenient to own than today's gasoline-powered vehicles."
- The aggressive goal of this initiative is, by the year 2022, to enable companies in the United States to be the first in the world to produce a 5-passenger affordable American electric vehicle with a payback time of less than 5 years

What is the EV Everywhere Grand Challenge?



- **March 2012**
  Challenge announced
- **June 2012**
  Initial Framing Document published
- **Summer/Fall 2012**
  Stakeholder input gathered
- **January 2013**
  EV Everywhere Blueprint published

See workshop presentations, notes, and output at www.electricvehicles.energy.gov

EV Everywhere Goal

Enable the U.S. to be the first in the world to produce plug-in electric vehicles that are as affordable and convenient as today's gasoline-powered vehicles within the next 10 years.

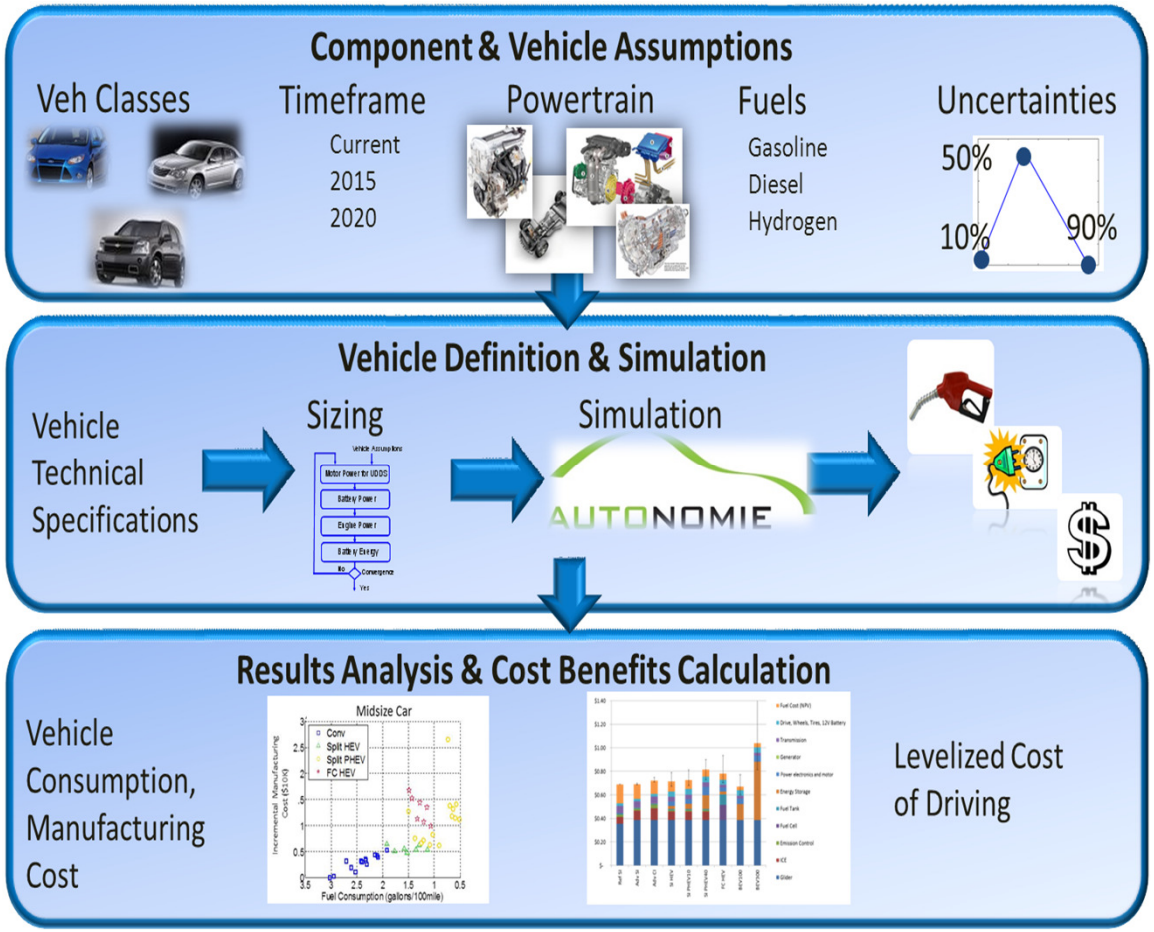
Defining Technical Targets for EV Everywhere

An analysis process using three steps was developed to define specific technology-level development targets:

1. DOE experts **define the bounds of technical possibility** for technology key metrics
   - 90% "low progress" scenario
   - 50% "mid case" scenario
   - 10% "high progress" scenario

2. **Define virtual vehicles** in Argonne National Lab's *Autonomie* modeling and simulation software

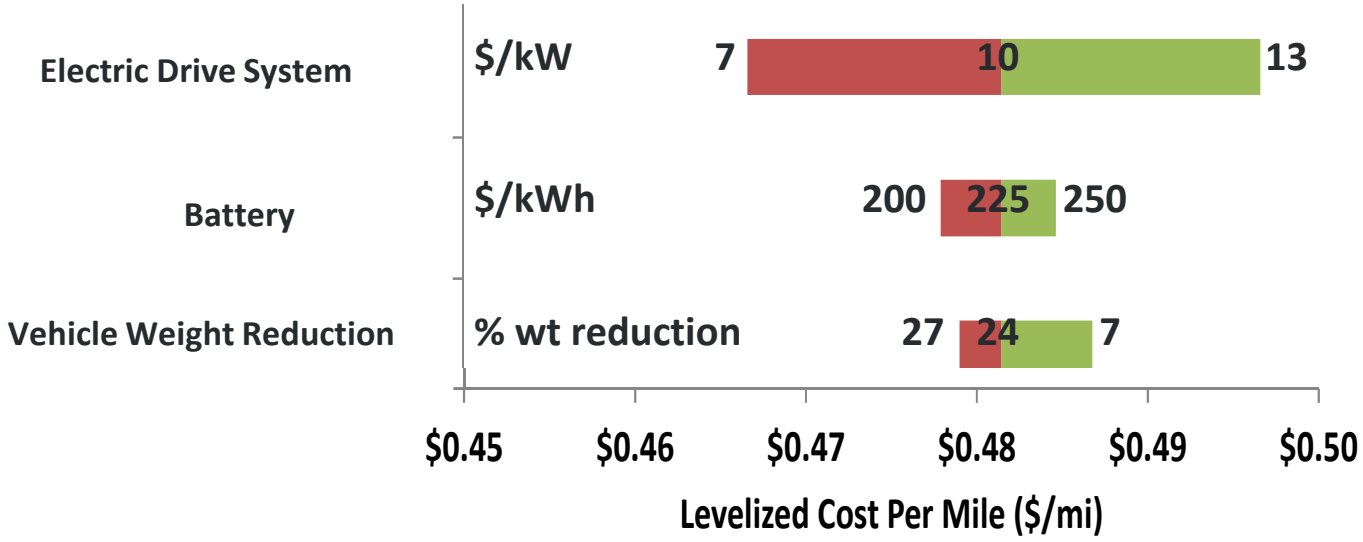
3. **Compare vehicles in a 5-year simple payback framework** within bounds defined by experts



EV Everywhere uses levelized costs to determine the true cost to consumers of vehicles in 2022. The goal is to have the same 5-year levelized cost for an electric drive vehicle and conventional vehicle.

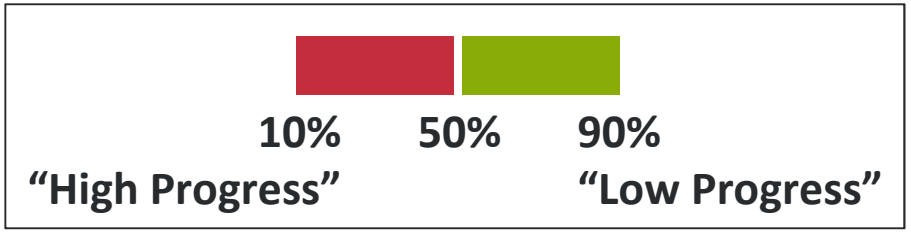
Determining Levelized Cost Per Mile: 2022 Midsize PHEV40

A PHEV40 (40 mile Plug-In Hybrid Electric Vehicle) was chosen for analysis because this type of vehicle allows a majority of typical trips to be driven using electricity instead of gasoline.



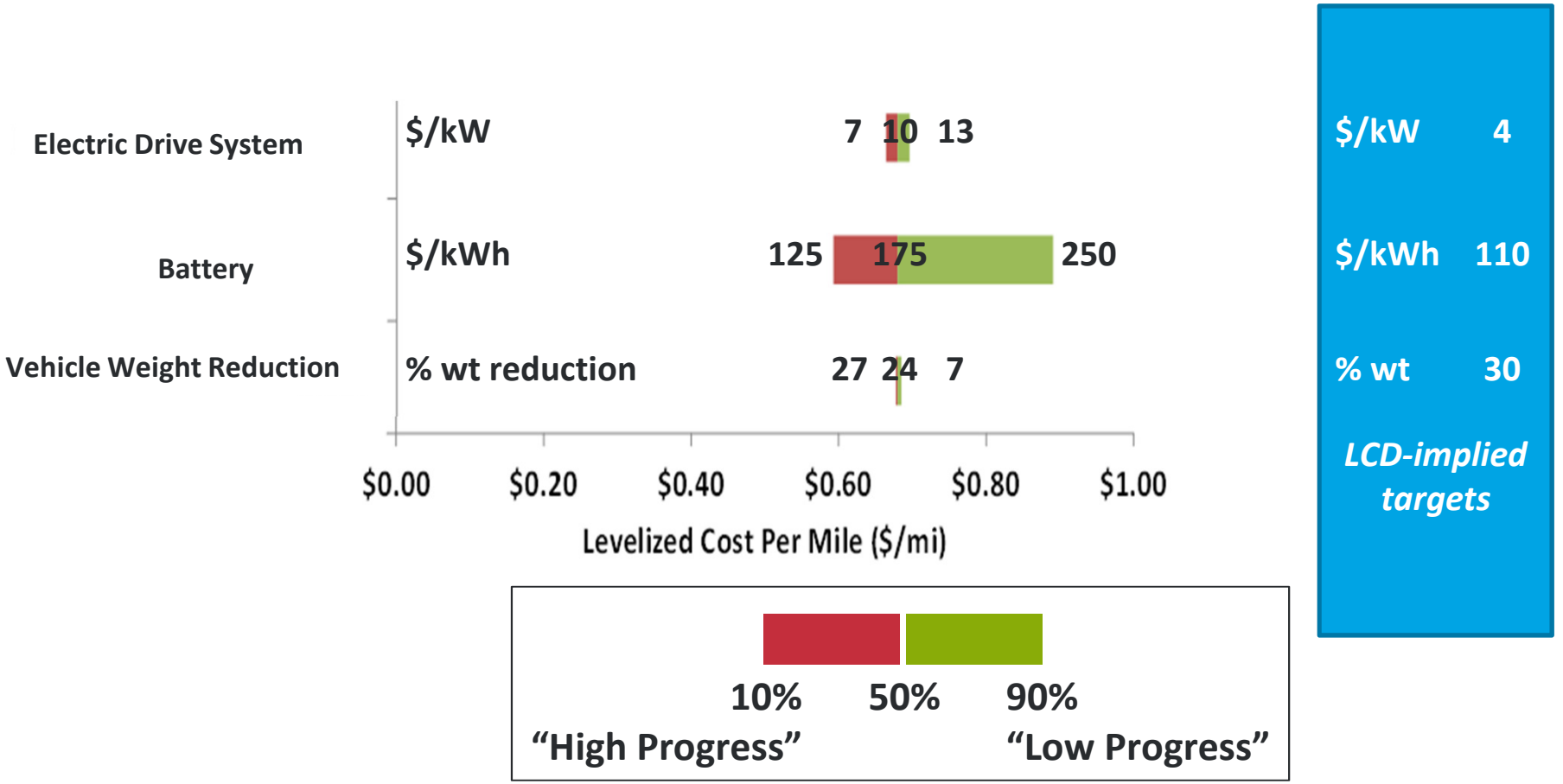
$/kW	5
$/kWh	190
% wt	29

LCD-implied targets

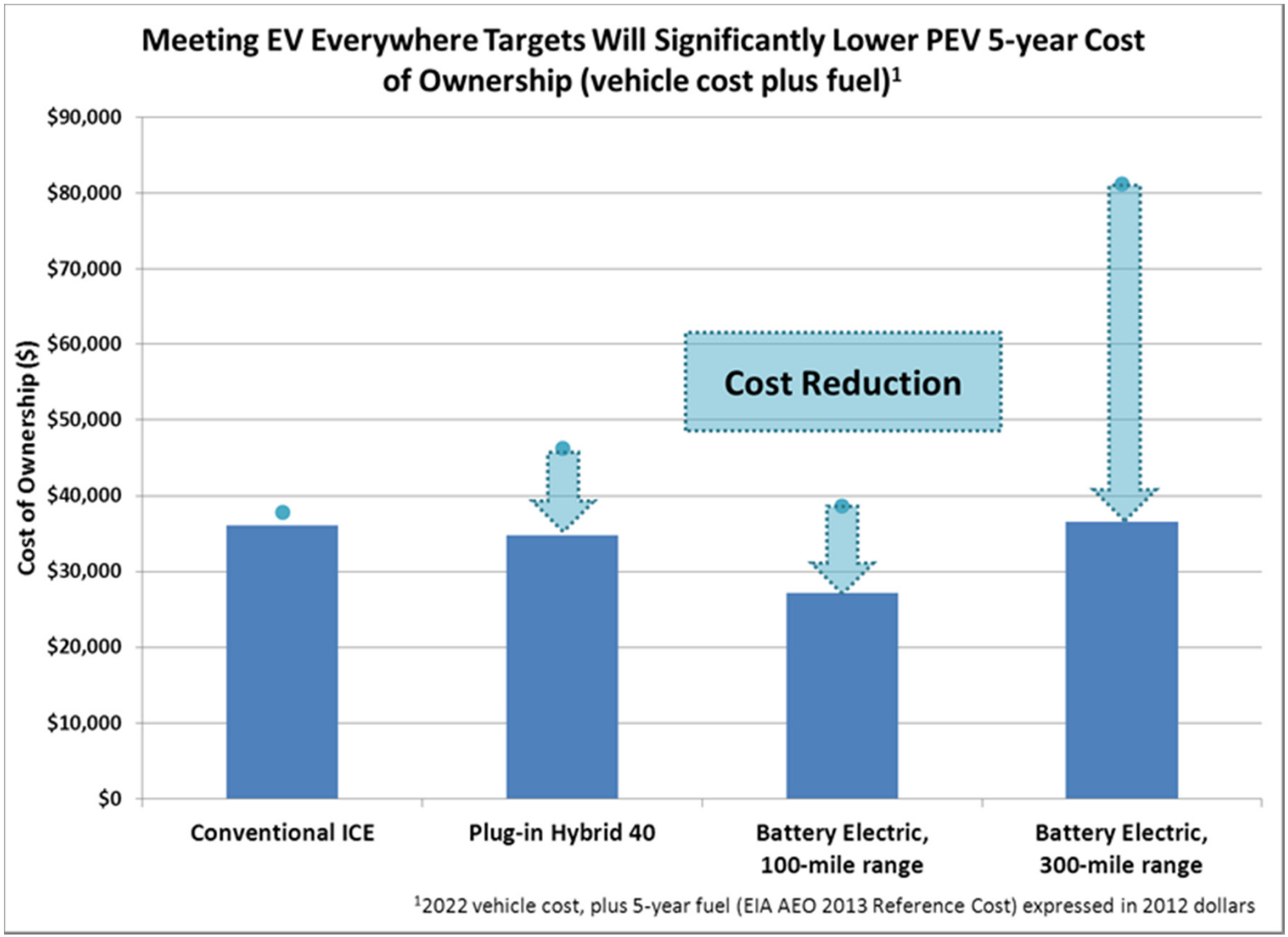


Determining Levelized Cost Per Mile: 2022 AEV300

An AEV300 (300 mile All-Electric Vehicle) was chosen for analysis because this type of vehicle gives a substantial amount of electric range that is comparable to conventional vehicles

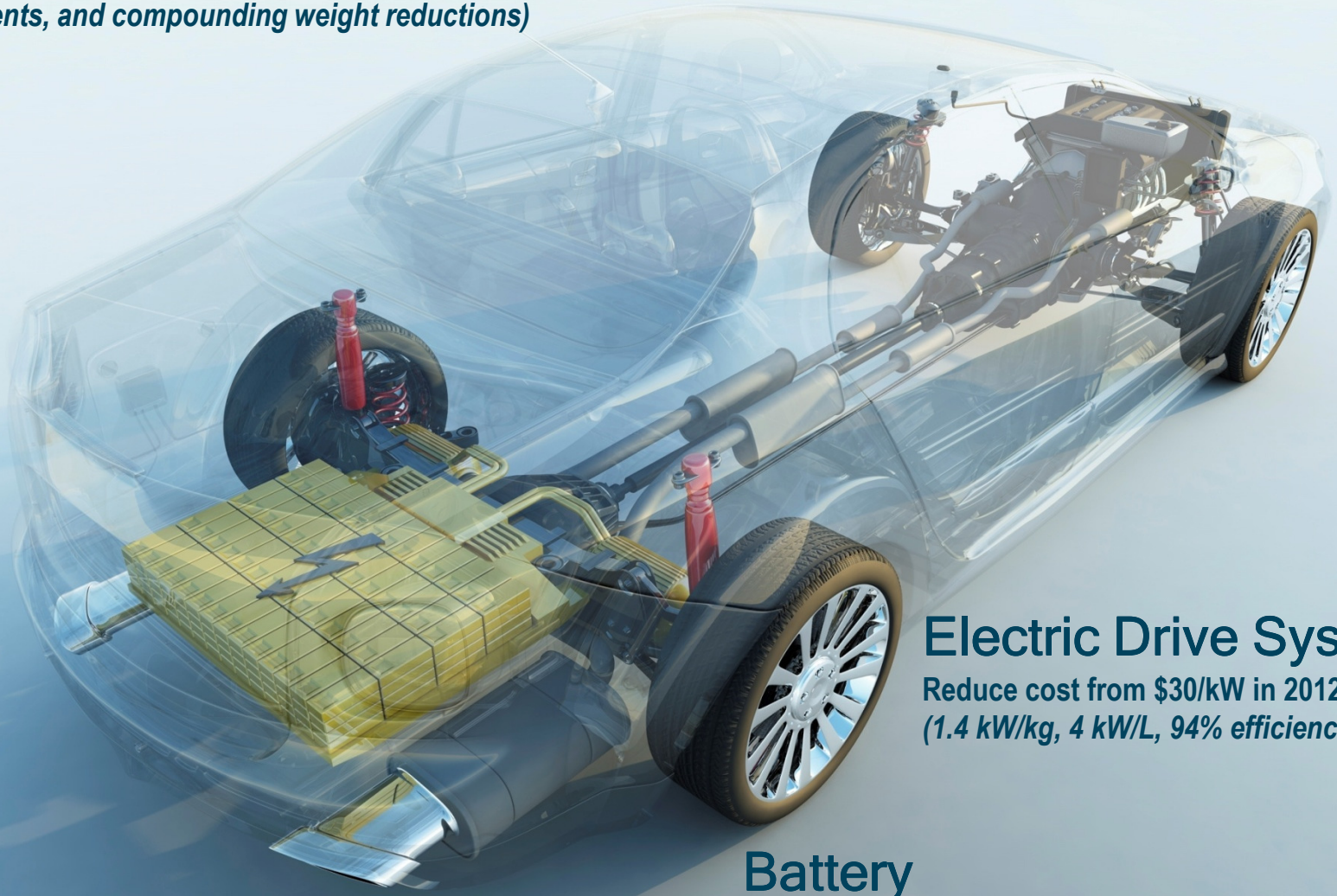


Reductions in cost and improvements in performance of key technologies will meet the President's EV Everywhere goal by 2022



Vehicle Weight Reduction

Reduce vehicle weight by nearly 30%
(Includes body, chassis, interior, electric drive components, and compounding weight reductions)



Electric Drive System

Reduce cost from $30/kW in 2012 to $8/kW
(1.4 kW/kg, 4 kW/L, 94% efficiency)

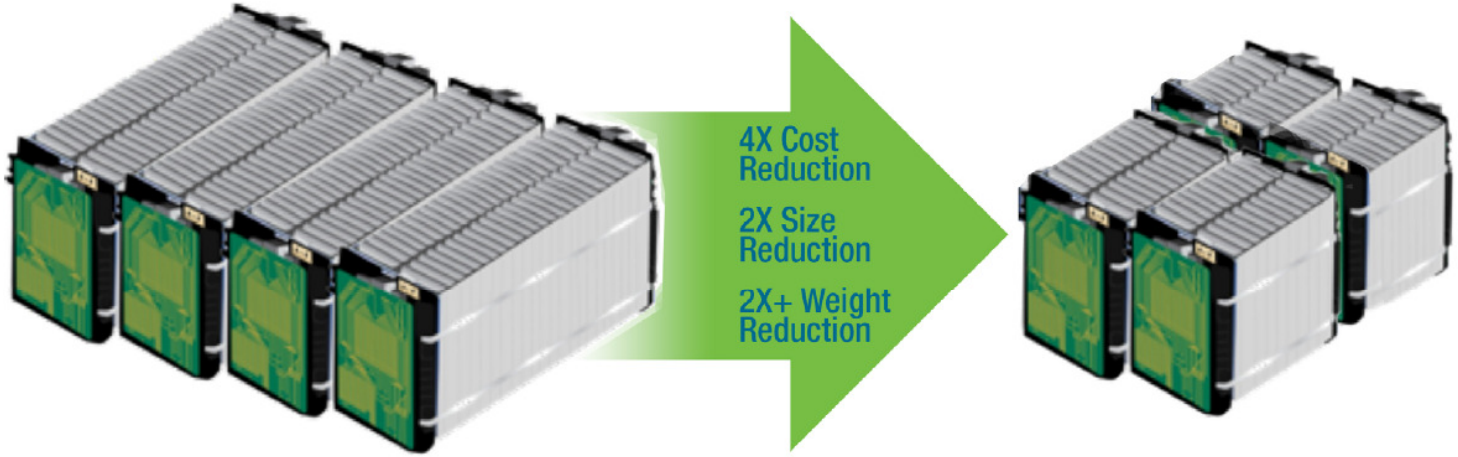
Battery

Reduce cost from $500/kWh in 2012 to $125/kWh
(250 Wh/kg, 400 Wh/L, 2 KW/kg)

Need to develop more cost-effective, long lasting, and abuse-tolerant PEV batteries

Battery Challenge

Battery advancements needed to enable a large market penetration of PEVs



2012 Battery Technology

$500/kWh, 100 Wh/kg, 200 Wh/l, 400W/kg

Lithium-ion batteries in today's electric drive vehicles use a combination of positive active materials based on nickel, manganese, or iron; matched with a carbon or graphite negative electrode.

2022 Battery Technology

$125/kWh, 250 Wh/kg, 400 Wh/l, 2000 W/kg

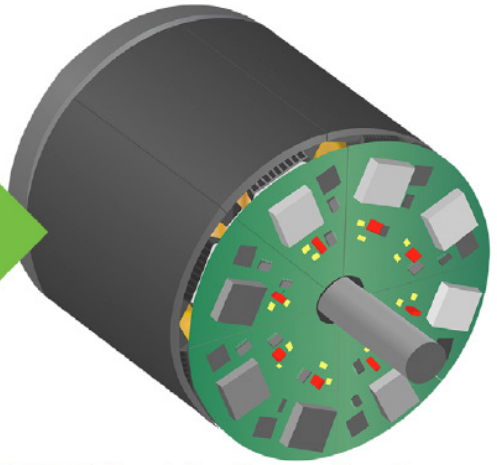
New battery technologies may meet the challenges of *EV Everywhere*. New concepts in lithium-ion technologies have the potential to double the performance and significantly reduce the cost. "Beyond lithium-ion" technologies (lithium metal, lithium-sulfur, and lithium-air) may also meet the challenge.

Electric Drive System R&D strategy areas include: Electric Motors, Power Electronics, and On-Board Chargers

Electric Drive System Challenge

Advancements needed for an electric drive system to support meeting *EV Everywhere* targets

4X Cost Reduction
35% Size Reduction
40% Weight Reduction
40% Loss Reduction



2012 Electric Drive System
$30/kW, 1.1 kW/kg, 2.6 kW/L
90% system efficiency

55kW SYSTEM COST OF $1650
Today's electric drive systems use discrete components, silicon semiconductors, and rare earth motor magnets.

2022 Electric Drive System
$8/kW, 1.4 kW/kg, 4.0 kW/L
94% system efficiency

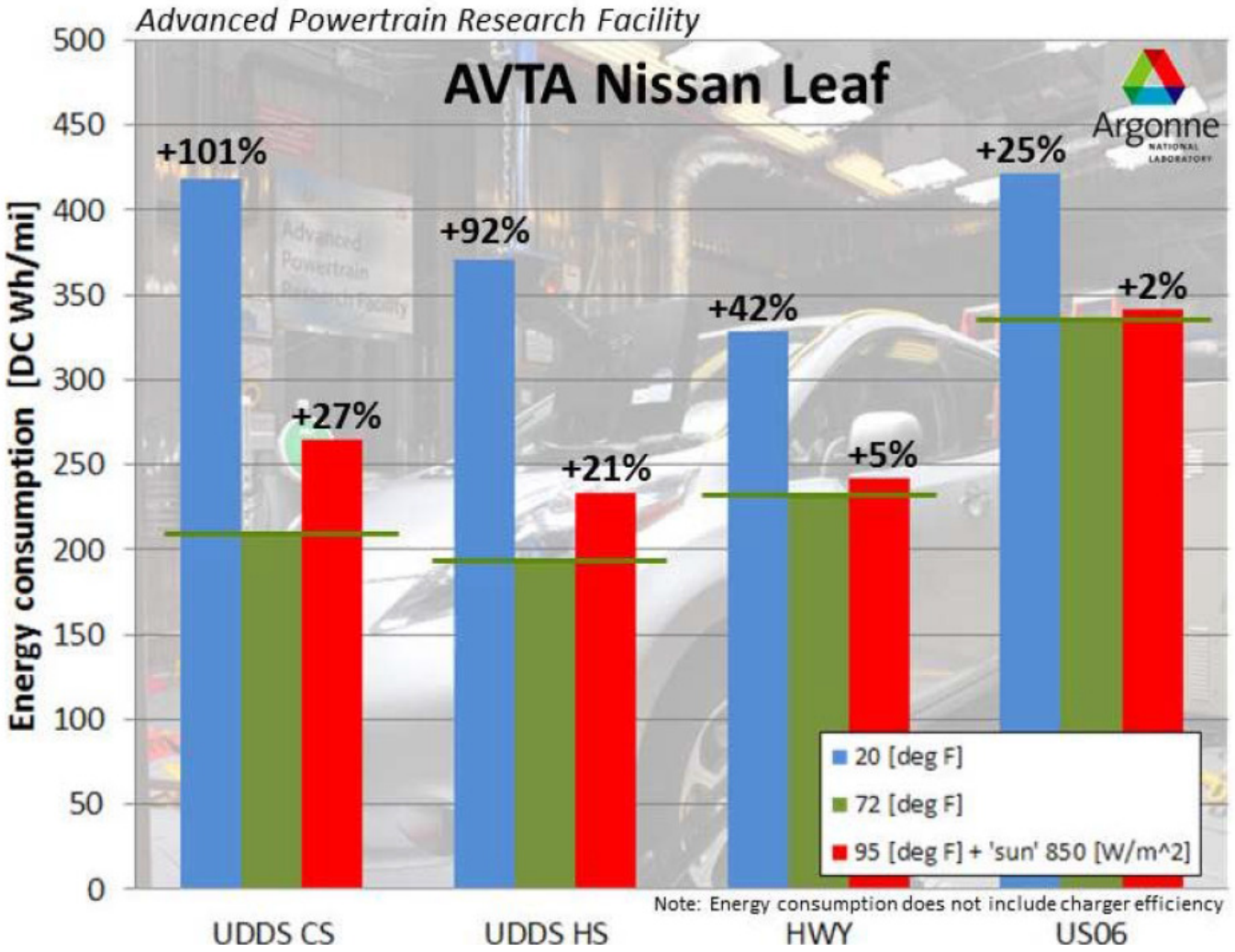
55kW SYSTEM COST OF $440
Future systems may meet these performance targets through advancements such as fully integrating motors and electronics, wide bandgap semiconductors, and non-rare earth motors.

Reducing the weight of a PEV can extend its electric range, reduce the size and cost of the battery, or achieve some of both

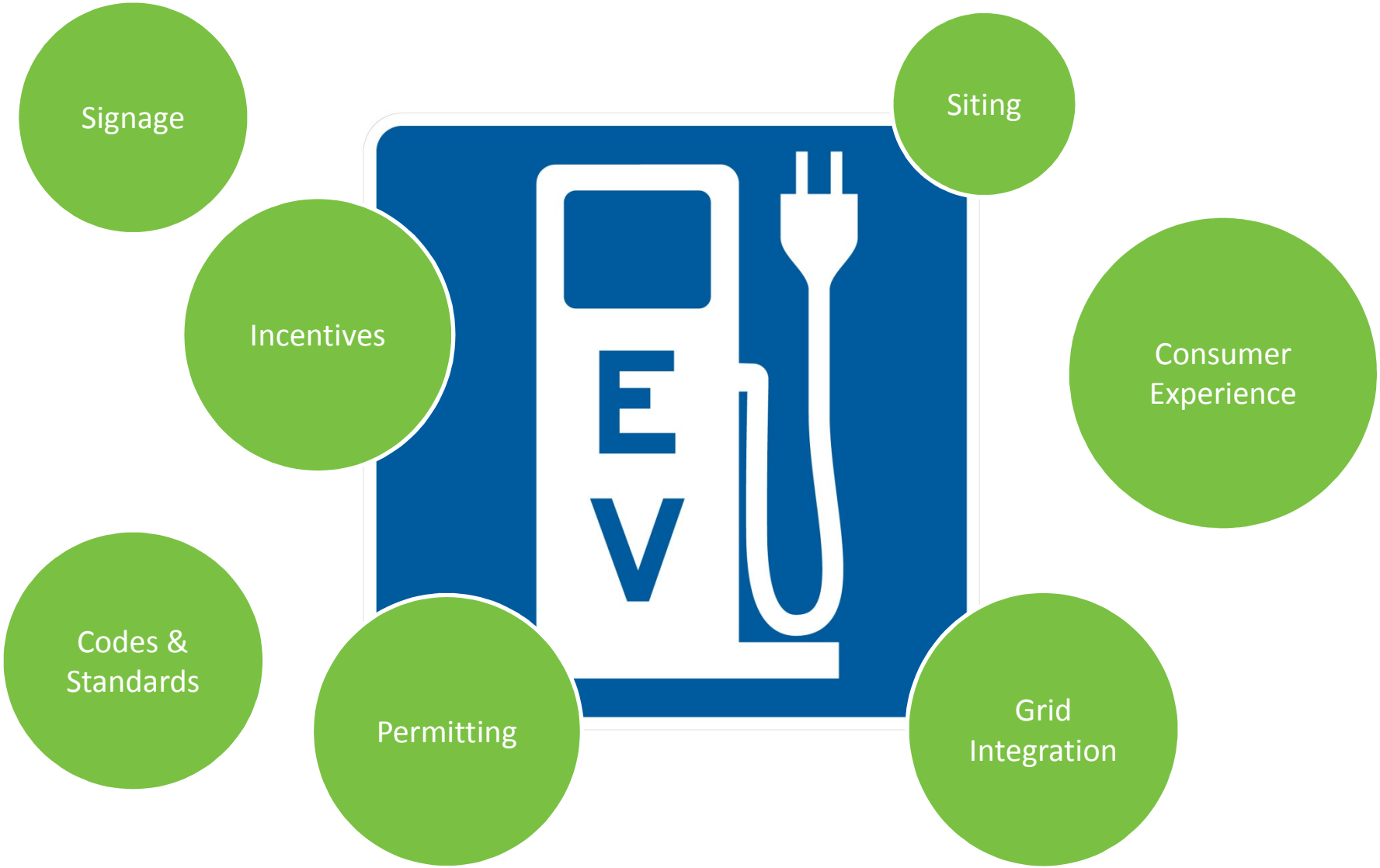
2022 targets for weight reduction for materials lightweighting

Using less energy in PEVs to achieve comfortable climate control will allow for a smaller, less expensive battery and lower cost PEV

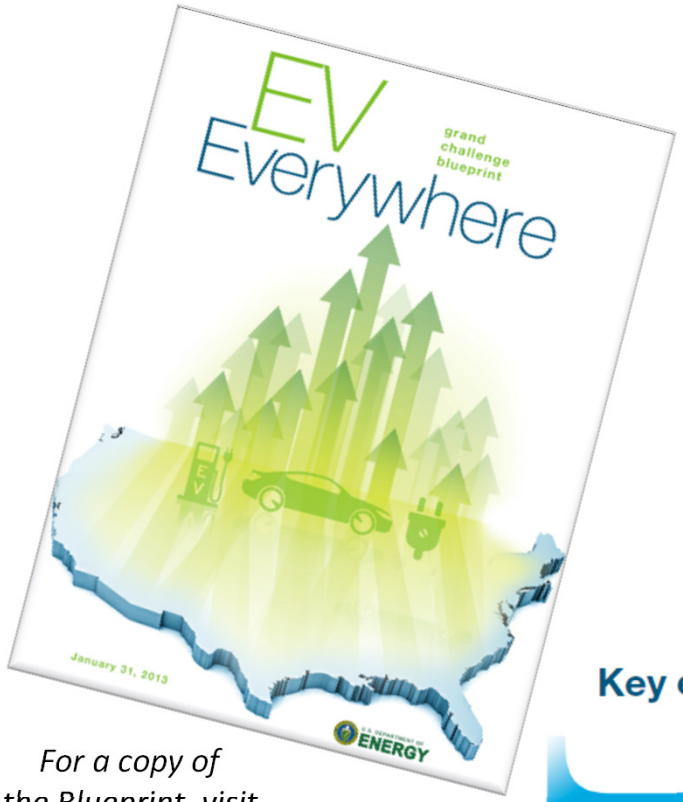
Impact of Temperature on Energy Consumption



Charging Infrastructure and Education & Policy



EV Everywhere Blueprint: a “living strategic framework”



For a copy of the Blueprint, visit electricvehicles.energy.gov

Key elements needed to meet the *EV Everywhere* Challenge

Workplace Charging Challenge

Workplace Charging Challenge Goal

Increase number of U.S. employers offering workplace charging by tenfold in five years.

Workplace charging availability is a critical part of the deployment strategy for EVs.

Benefits for the big picture

+ Fill infrastructure gap
+ Grow the PEV market
+ Increase visibility of PEVs
+ Add electric VMT

Benefits for the employer

+ Employee benefit
+ Corporate sustainability
+ Contribute to LEED certification
+ Keeping up with the Googles

48 Partners (as of 3rd September 2013), such as:

Raytheon, Duke Energy, Dell, nrg, Hertz, City of Sacramento, Ford, 3M, Nissan, Google, Lilly, SDGE, Verizon, Siemens, GE, Tesla, GM, biogen idec, nationalgrid, Coca-Cola, Bentley, OSRAM SYLVANIA, facebook, Bloomberg, Southern California Edison, The Hartford, Chrysler, New York Power Authority, AVL

10 Ambassadors

Center for Sustainable Energy California, California Plug-in Electric Vehicle Collaborative, NEXTENERGY, IPI International Parking Institute, Green Parking Council, Electrification Coalition, Rocky Mountain Institute, Plug In America, EDTA Electric Drive Transportation Association, CALSTART

Recent DOE Projects and Initiatives Supporting EV Everywhere

Vehicle Technologies Program – Recent FOA announcements

- Advanced batteries: *Improvements in cell chemistry, composition, and processing; computer aided engineering for batteries; advanced electrolytes for lithium ion chemistries (13 projects; $22.5 million)*
- Power electronics: *DC bus capacitor improvements and wide bandgap inverter R&D (Four projects; $8 million)*
- Advanced lightweighting and propulsion materials: *Magnesium alloy kinetics and corrosion, joining of aluminum and high strength steel, dissimilar material joining, and engine rotating components (15 projects; $10.2 million)*
- Vehicle systems: *Advanced climate control auxiliary load reduction (Two projects; $4 million)*

Complete list of projects and applicants at:
http://www.eere.energy.gov/pdfs/funding_selections_9-4-13.pdf

Recent DOE Projects and Initiatives Supporting EV Everywhere

ARPA-E (Advanced Research Projects Agency – Energy):

- REACT Program: developing cost-effective alternatives to rare earths, the naturally occurring minerals with unique magnetic properties that are used in electric vehicle (EV) motors and wind generators (14 projects, $42 million)
- RANGE Program: Seeks to improve EV driving range and reduce vehicle costs by re-envisioning the total EV battery system, rather than working to increase the energy density of individual battery cells (22 projects, $36 million)
- AMPED Program: Seeks to develop advanced sensing, control, and power management technologies that redefine the way we think about battery management (19 projects, $43 million)

Office of Science:

- EFRC (Energy Frontier Research Center) Center for Electrical Energy Storage Tailored Interfaces: Understand complex phenomena in electrochemical reactions critical to advanced electrical energy storage (Argonne National Laboratory, $19 million)
- Energy Storage Hub - Team led by Argonne National Laboratory will advance the next generation battery and energy storage technologies for electric and hybrid cars and the electricity grid ($25M/year for 5 years starting in FY2013)
- CMI (Critical Materials Institute) – Team of research partners led by Ames National Laboratory will address challenges in critical materials, including mineral processing, manufacture, substitution, efficient use, and end-of-life recycling ($120 M for 5 years)

Conclusions

- "EV Everywhere" is a challenge to produce plug-in electric vehicles (PEVs) as affordable and convenient as gasoline-powered vehicles by 2022
- EV Everywhere Technical Targets were defined based on a 5-year payback scenario
- Individual Technology Targets and R&D Pathways are set to meet vehicle cost and performance objectives, and guide research direction
- Current Projects and Initiatives are wide-ranging, including an emphasis on batteries, electric drive systems, and workplace charging

Thank You! For more information, please contact me

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www.electricvehicles.energy.gov