Advanced Vehicle Electrification and Transportation Sector Electrification

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General Motors

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Overview

Timeline

- Work start: 11/09
- DOE signing & official start: 3/10
- End: 9/13

Barriers

- Cost of the advanced technology for electric vehicles
- Utility Infrastructure needs to be put in place to support electric vehicles

Budget

- $61 mil project
  - $30.5 mil DOE
  - $30.5 mil GM

Partners

- DOE
- EPRI
- Ten Utilities:
  - DTE Energy
  - Duke
  - PEPCO
  - Dominion
  - Con Edison
  - Pacific Gas and Electric
  - So Cal Edison
  - Progress
  - SMUD
  - Austin Energy

Objectives

- **Develop Electric Vehicle with Extended Range advanced propulsion technology and demonstrate a fleet of vehicles to:**
  - Gather data on vehicle performance and infrastructure
  - Understand impacts on commercialization
- **This will be done:**
  - In real world conditions
  - With customers in several diverse locations across the United States including installation, demonstration and testing of charging infrastructure

Relevance

- **The Chevrolet Volt introduces new vehicle technologies powered by domestically produced alternative fuels that will:**

Reduce our dependence on petroleum

- Up to 40 mile electric vehicle range
- Increases use of domestic resources

Decrease greenhouse gas emissions

- No tailpipe emissions for up to the first 40 miles
- Provides additional options, including renewables, for fueling vehicles

Maintain skilled jobs required to sustain U.S. technical leadership

- Vehicle and battery engineering

- **Vehicle usage and typical operation needs to be understood to**
  - accelerate the vehicle usage learning curve
  - achieve mass market penetration

Milestones for 2009 & 2010: Vehicle

- ✔ **Milestone 1**: Over one-quarter of a million miles driven in Volt fleet
- ✔ **Milestone 2**: Hot weather testing – Death Valley
- ✔ **Milestone 3**: Mountain testing – Pike's Peak and Baker's Grade
- ✔ **Milestone 4**: Achieved 65% calibration test drive
- ✔ **Milestone 5**: Full vehicle simulator test competed 700,000 miles

Milestones for 2009 & 2010: Battery

- ✔ **Milestone 1:** >67,000 cells on test – all without failure
- ✔ **Milestone 2:** >300 prototype battery packs built
- ✔ **Milestone 3:** >700,000 miles of customer use lab testing to date
- ✔ **Milestone 4:** >30 Battery Systems Laboratory test channels fully dedicated to Volt battery
- ✔ **Milestone 5:** Brownstown Battery Assembly Plant in process tests developed
- ✔ **Milestone 6:** Battery Lab achieves ISO certification March 2010

Project Schedule – Vehicles & Batteries

On time !

Engineering Development

On time !

Mule

On time !

Pre-Production

2007 2008 2009 2010

Vehicle Assembly

Start of Production

Late 2010

On time !

1st Supplier Built Pack

On time !

First 300 packs GM /Supplier Built

On time !

1st GM Built

Battery Plant Brownstown, MI

Approach – Deployment

- **Chevrolet Volt is an electric vehicle with extended range capability:**
  - Powered by electricity all the time
  - Battery provides up to 40 miles driving, using no gasoline and with no tail pipe emissions
  - Batteries can be charged from the grid, but engine generator means driver will not be stranded
  - Driver can take long trips
- **Volt will be developed and validated by General Motors with start of production in late 2010**
- **GM will launch Volts in key markets including: Washington D.C., Michigan and California**
- **Utilities will install charging stations in residential houses, workplaces, and in public areas**

Approach – Data Demonstration

- **Data will be collected on vehicles starting in Fall 2010**
- **Demonstration data will be used to:**
  - Better understand customer expectations
  - Evaluate how well the system addresses customer needs
  - Focus upon understanding operating costs and the customer value equation
  - Understand driver behavior effects on fuel economy
- **Charging and vehicle usage data will be critical for making informed decisions about infrastructure development and integration into smart grid networks**
  - Charging behavior (home verses public)
  - Level 1 (120 volt) verses Level 2 (240 volt) experience
  - Installation of charging infrastructure
- **Information gathered during this period will support the next generation battery designs and infrastructure and to expedite learning cycle progression**

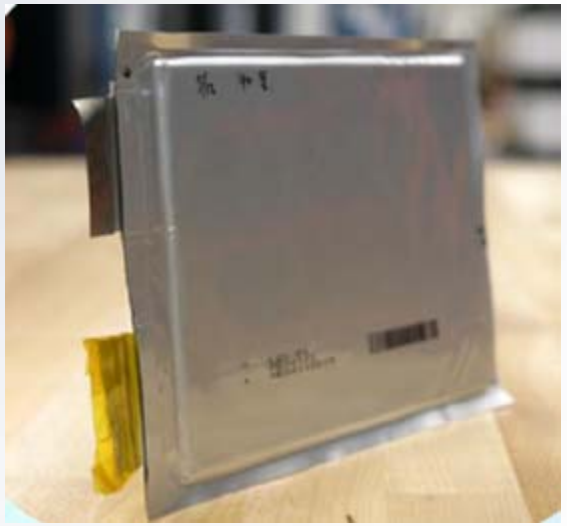
Technical Accomplishments

- ✔ Built 80 pre-production cars currently in use for engineering and crash testing
- ✔ 30 Crash tests performed
- ✔ 300 pre-production battery packs built with excellent test results
- ✔ Volt's smartphone application by OnStar developed to help drivers stay connected to their Volt 24/7
- ✔ Efficiency gauge and green leaf screens developed to guide the driver to drive more efficiently
- ✔ Program kickoff meeting with DOE in March 2010

Volt Battery is an Integral Part of Vehicle Structure

Cell Tests Ensure Superior Cell Performance

- **Over 150 Tests Conducted**
  - Cell penetration
  - Cell crush
  - Cell life cycling
  - Cell thermal testing stress
  - Cell overcharge
  - Cell performance characterization



Battery Pack Tests Evaluate Performance under Real Life Conditions

- **Over 20 Tests Conducted**
  - Crash
  - Mechanical vibration (shaker table)
  - Corrosion
  - Thermal cycling and shock
  - Customer use life cycle

Driving over Various Pavements Assess Effect on Vehicle Structure

- **Twisted ditch** – subjects vehicle and pack to torsional stress

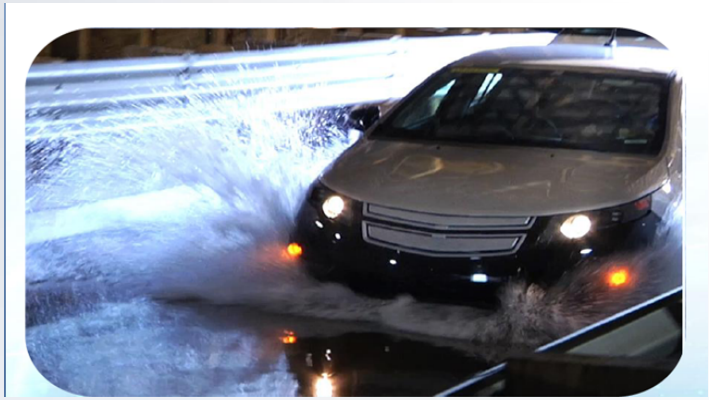
- **Belgian block test** – tests impact of very rough roads on electronics

- **Pothole test** – effect on suspensions and shock absorbers

See battery and vehicle testing videos at www.chevroletvoltage.com

Vehicle Tests Simulate Aggressive Environments

- **Volt water trough tests**
  - Measures how well the battery is sealed



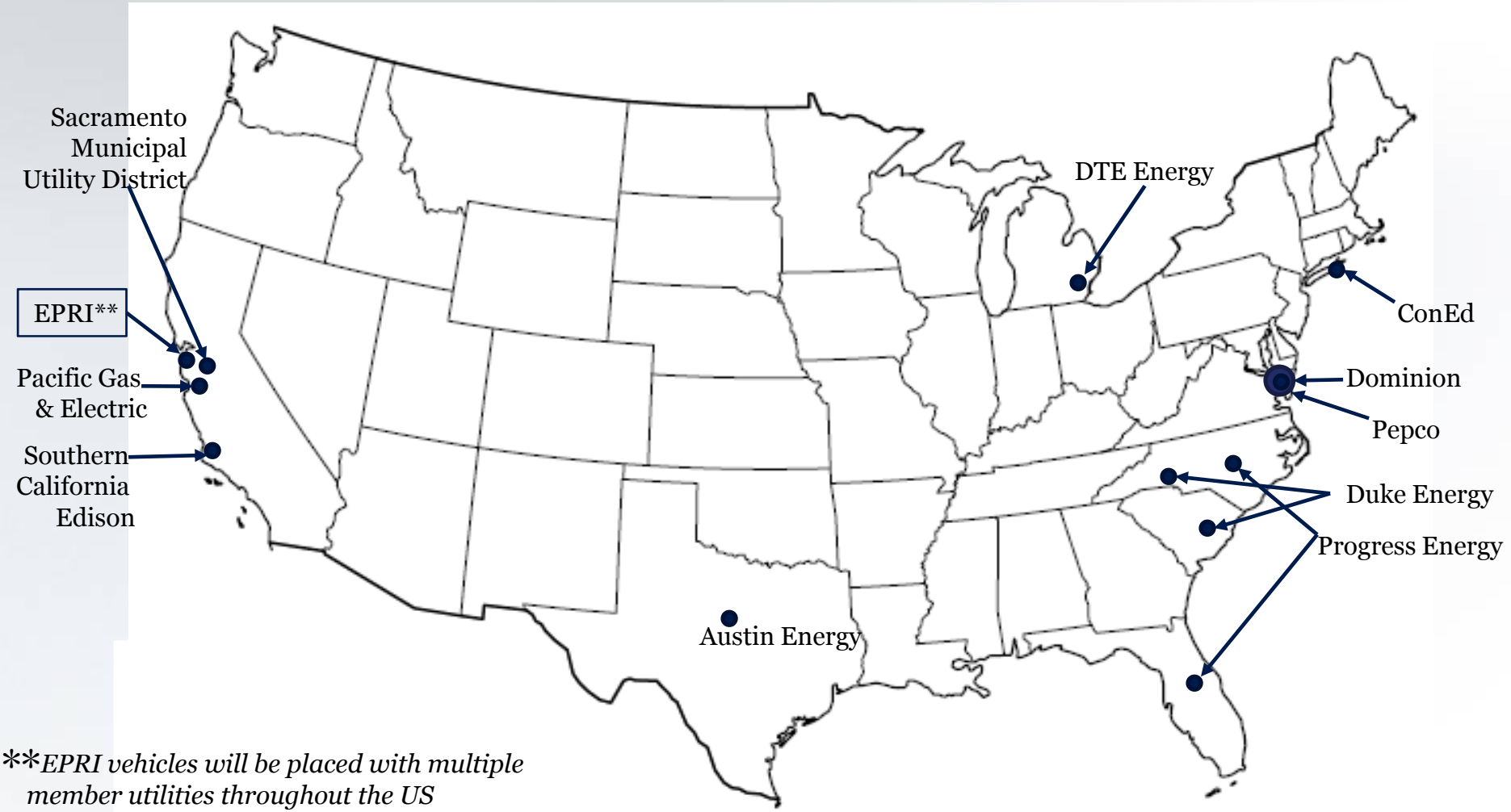
- **Full vehicle vibration test**
  - Analyze effect of vibration on vehicle components

See battery and vehicle testing videos at www.chevroletvoltage.com

Technology Transfers / Collaborations

- **Idaho National Labs (INL)**
  - Has received data on multiple DOE hybrid and electric vehicle projects
  - Will receive Volt raw data (fuel used, miles driven, etc.) and amalgamate
  - Will facilitate common presentation of data to DOE
- **Electric Power Research Institute (EPRI)**
  - Will facilitate involvement of additional utilities in data demonstration
  - Will provide information and facilitate demonstrations of smart charging, fast charging and battery to grid
- **10 Utility Partners**
  - DTE, Duke, PEPCO, Dominion, Con Edison, Pacific Gas and Electric, Southern California Edison, Progress, SMUD, Austin Energy
  - Will install charging stations and participate in vehicle demonstrations
- **North Carolina State University**
  - Will study charging infrastructure in a parking structure

Utility Demonstration Locations
(115 Vehicles)



***EPRI vehicles will be placed with multiple member utilities throughout the US at locations to be determined*

Proposed Future Work

- Chevrolet Volt electric vehicle launch and transition to utilities will continue the vehicle data demonstration and the infrastructure demonstration for an additional two years
- 600+ charging stations will be installed by GM and the utilities
- Data will be gathered to document installation, charging and driving events
- Data will be aggregated and sent to the Department of Energy for their review
- Special projects will be performed to support fast charging, smart charging and battery secondary use

Data Collected and Reported

All trips combined

- Overall fuel economy
- Total number of trips
- Total distance traveled
- Average ambient temperature
- Vehicle maintenance records

Trips in charge depletion mode

- Fuel economy
- Number of trips
- Percent of trips city / highway
- Distance traveled
- Average trip aggressiveness (on scale of 0-10)
- Percent of total distance traveled

Trips in both charge depletion and charge sustaining mode

- Fuel economy
- Number of trips
- Percent of trips city / highway
- Distance traveled
- Average trip aggressiveness (on scale of 0-10)
- Percent of total distance traveled

Trips in charge sustaining mode

- Fuel economy
- Number of trips
- Percent of trips city / highway
- Distance traveled
- Average trip aggressiveness (on scale of 0-10)
- Percent of total distance traveled

Charging

- Number of charging events
- Average number of charging events per day when vehicle is driven
- Average number of trips between charging events
- Average duration of charging event
- Average energy per charging event
- Total charging energy

Infrastructure

- Installation process, steps and number of contacts
- Time for permit , inspection and installation
- Installation cost, reliability and customer satisfaction
- Grid impact analysis

Electric Vehicle Charging Infrastructure supported by Project including future Fast Charging

Current: Hardwired
240 Volt, 3.3 kW
4 hour charging time

Current: Portable
120 Volt
1.2 kW
9 hour charging time

Future: Fast
480 Volt 3 phase AC
30 – 80 kW
<1/2 hour charging time

Fast Charging Development

Goals

- Support development of industry standard electrical and communication interfaces
  - Increase understanding of vehicle and grid impacts of fast charging

Tasks

- Support development of standard connection interface and communication standard
- Design and integrate into vehicle
- Install fast charging systems
- Modify demonstration vehicles
- Collect data and analyze:
  - Grid impacts
  - Vehicle impact
  - User ergonomics and efficiency

Smart Charging Development

Goals

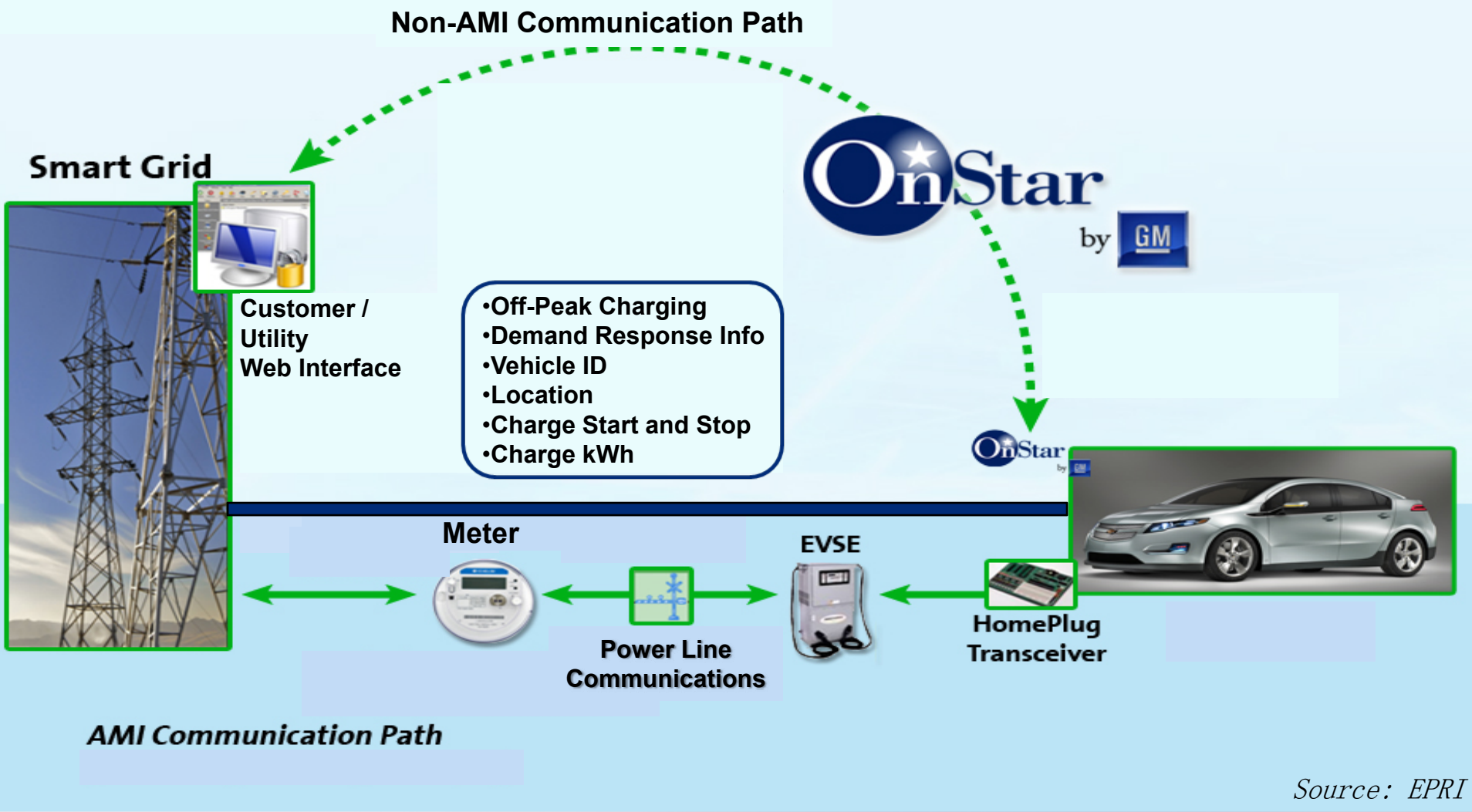
- Electrical usage varies throughout the day with
  - Peak usage during the day
  - Non-peak usage at night
- Charging during non-peak times can save energy, reduce costs, increase grid reliability and address energy independence and global warming issues

Tasks

- Method 1: Basic: Demonstrate OnStar, a non-AMI (non-automated meter infrastructure) solution, to have customers and utilities control when vehicles are being charged
- Method 2: Advanced: Develop and demonstrate a home area network solution using AMI (automated meter infrastructure), power line communications and OnStar. Communicate pricing information from the utility to the vehicle to further align charging to non-peak time of use rates

Smart Charging Technology Vision

Develop Automated Meter Infrastructure (AMI) and Non-AMI Methods



Source: EPRI

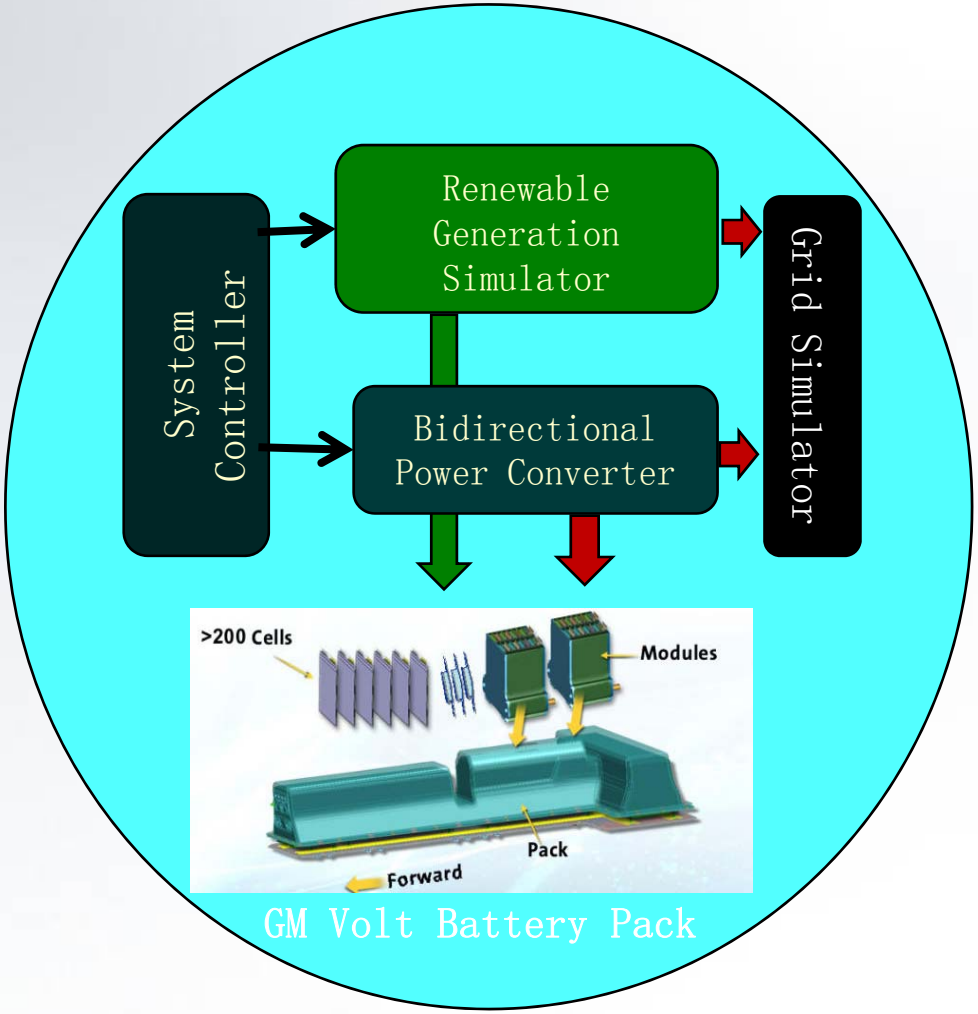
Secondary Use of Batteries as Grid Storage

Goals

- Create post vehicle residual value by extending the use of automotive batteries to satisfy stationary use requirements
- Enable renewable energy sources
- Reduce infrastructure stress through load management

Tasks

- Study the technical challenges and stationary energy storage requirements
- Integrate a grid-tied bidirectional power converter with a battery pack to demonstrate battery to grid functionality
- Collect and analyze data to study the grid and battery impacts of bidirectional power flow



Summary

- **Status:** First Annual Merit Review for this project
- **Relevance:** Consistent with DOE goals to reduce petroleum consumption, reduce greenhouse gases and maintain skilled jobs
- **Approach:** Develop electric vehicle with extended range
- **Technical Accomplishments and Progress:** Extensive validation work and new technologies
- **Collaborations:** Idaho National Labs, EPRI, ten utilities and North Carolina State University
- **Proposed Future Work:** Data will be collected on driving and charging events from Fall 2010 to December 2012. Information will be used to support next generation vehicle and infrastructure