NATIONAL RENEWABLE ENERGY LABORATORY

Analysis of Battery Wear and V2G Benefits Using Real-World Drive Cycles and Ambient Data

DOE VTP Annual Merit Review

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Organization: NREL

May 9, 2011

Project ID: VSS044

This presentation does not contain any proprietary, confidential or otherwise restricted information

Project Overview

Timeline

- Project start in March 2011 (anticipated receipt of funding)
- Project end in September 2011
- Project is 0% complete

Barriers Addressed

1. Risk Aversion
2. Cost
3. Computational models, design and simulation methods

Budget

- Total DOE project funding
  - FY11: $200k

Project Interactions

- NREL Energy Storage team
- NREL Electric Vehicle Grid Integration team

Project Relevance

Premise

- Battery life as a function of temperature and disparate usage patterns is complex and not well understood.
- Vehicle simulation scenarios that capture varying ambient temperature patterns, driving profiles, and vehicle-to-grid (V2G) utility would be of value to battery manufacturers, vehicle OEMs ,and utilities.
- Certain plug-in electric vehicle (PEV) platforms may lend themselves to V2G services.

Project Objectives

- Leverage NREL competencies in vehicle simulation and driving profiles, battery life modeling, and electric vehicle grid integration to simulate battery life and PEV value to the grid.
- Examine the value and utility of large energy capacity PEV school buses with usage profiles that may be conducive to V2G services.
- Help answer industry and end-user questions, accelerate deployment, magnify impact of PEVs, and reduce petroleum consumption.

Project Milestones

Month-Year	Milestone
September 2011	Draft technical report and/or conference paper summarizing analysis.

Project Approach

Drive Cycle Analysis

- Assess passenger car GPS daily travel profiles and school bus drive cycle database
- Identify sets representative of certain geographic regions

Ambient Temperature Profiles

- Assemble hourly temperature data for several cities
  - Phoenix; LA; Chicago; Washington, DC

Create Grid Service Demand Curve Scenarios

- Renewable variability
- Frequency regulation
- Price based
- Load following
- One- and two-way power flow

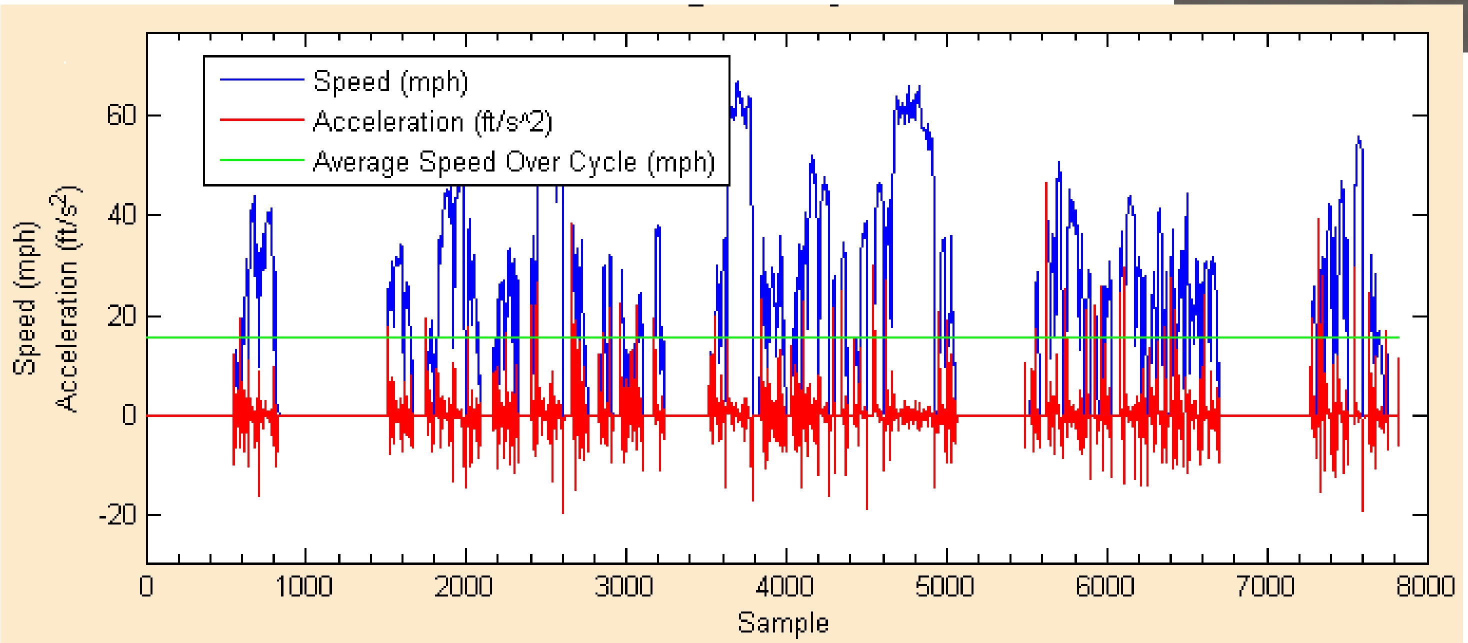
Analysis

- Vehicles: PEV10, PEV20, PEV40, PEV40s EV100, EV school bus
- Charging: End of day, opportunity, just in time, grid services
- Simulate each day of the year
- Extrapolate battery life 5-15 years

Project Approach

Leverage extensive growing dataset of school bus drive cycles:

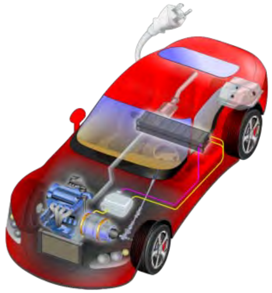
- Diverse geography (TX, CO, NY)
- 109 individual vehicles
- 861 unique trips

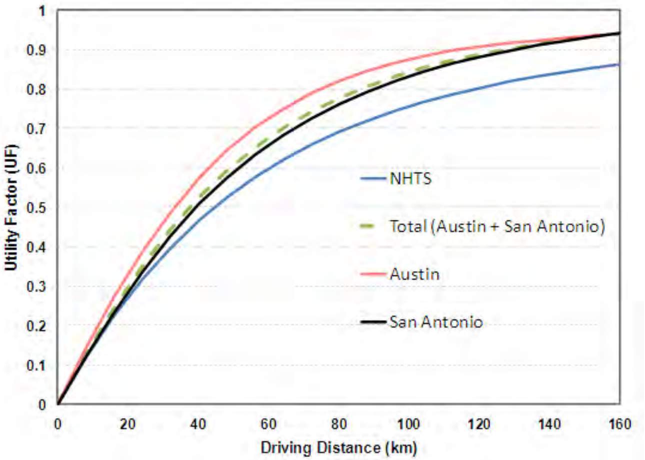


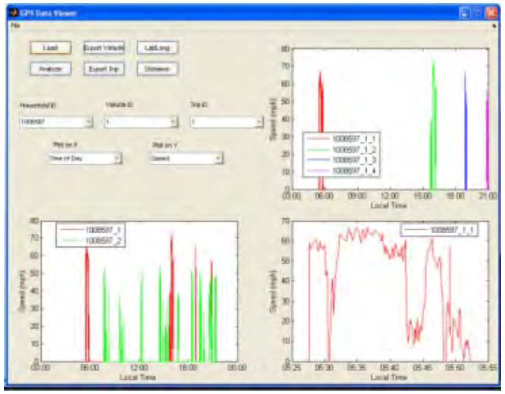
Project Approach

Utilize GPS passenger car driving profile data from several sources:

1. Texas DOT (San Antonio and Austin)
2. Puget Sound Regional Council (Seattle, WA area)
3. National Household Travel Study
4. Commute Atlanta study

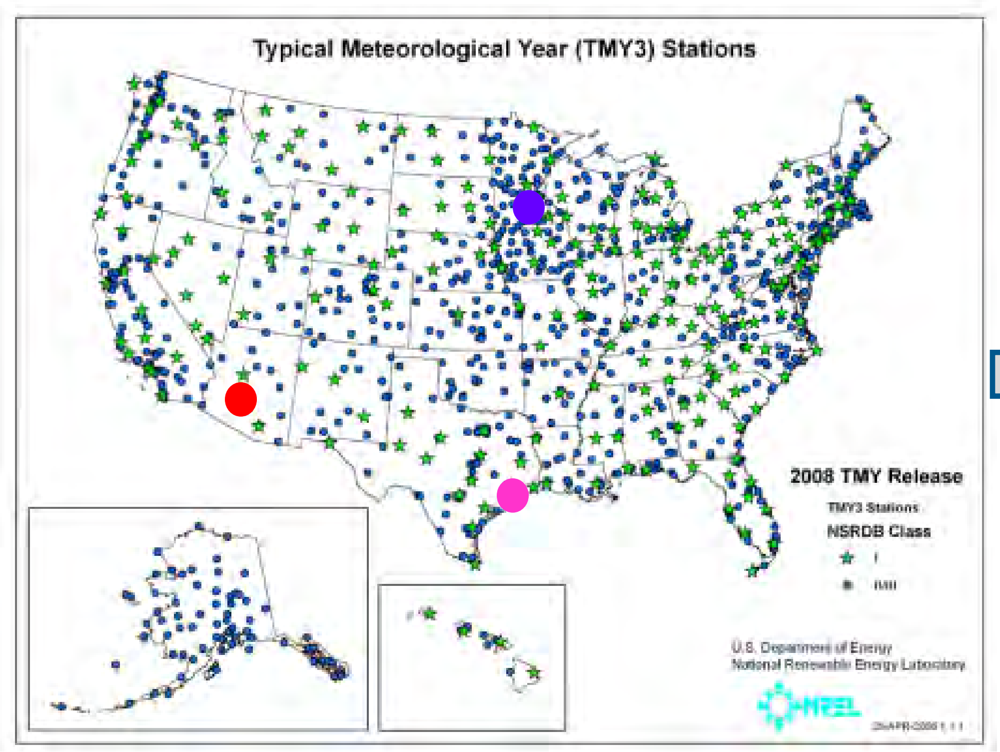


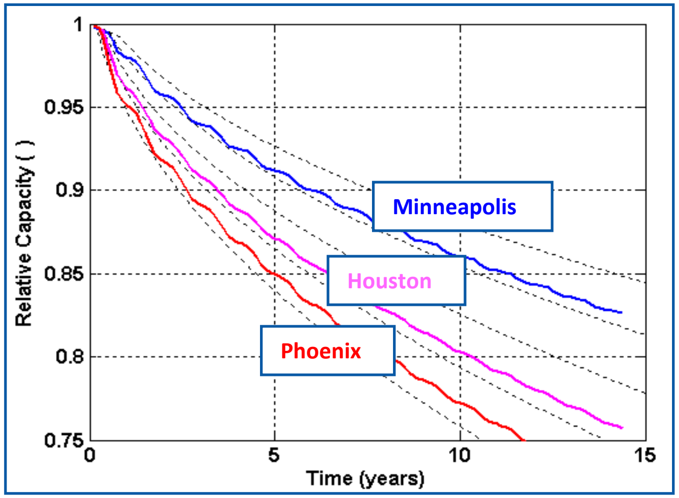




Project Approach

Assemble geographically diverse ambient temperature profiles due to variable impact on battery life.

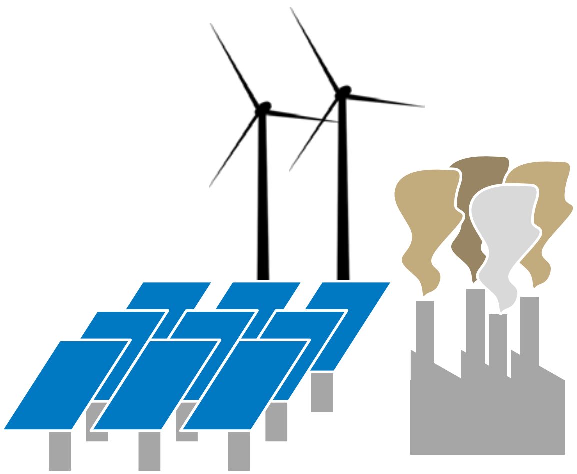


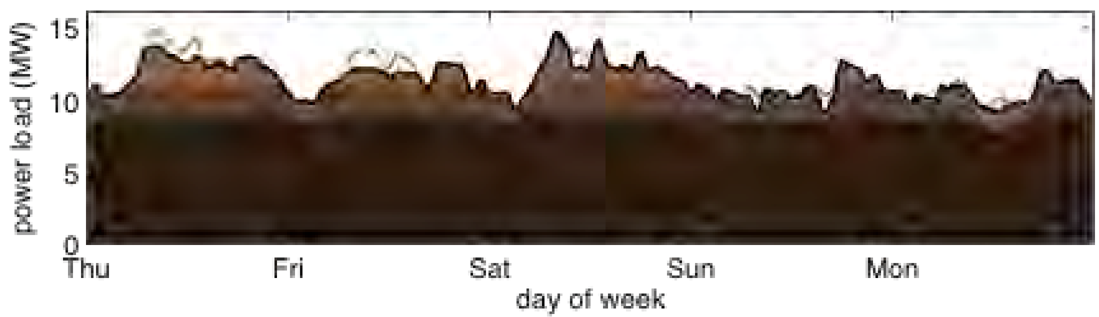


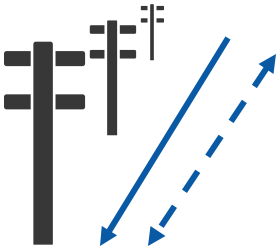
Project Approach

Create Grid Service Demand Curve Scenarios:

- •Renewable variability
- •Frequency regulation
- •Price based
- •Load following
- •One- and two-way power flow







Battery Life Modeling Approach

Calendar fade

- SEI growth (partially suppressed by cycling)
- Loss of cyclable lithium
- a_1, d_1 = f(ΔDOD,T,V)

Cycling fade

- Active material structure degradation and mechanical fracture
- a_2, e_1 = f(ΔDOD,T,V)

Resistance Growth

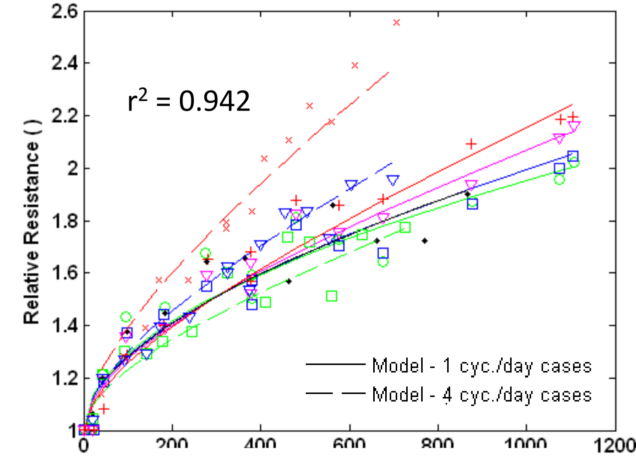
$$R = a_1 t^{1/2} + a_2 N$$

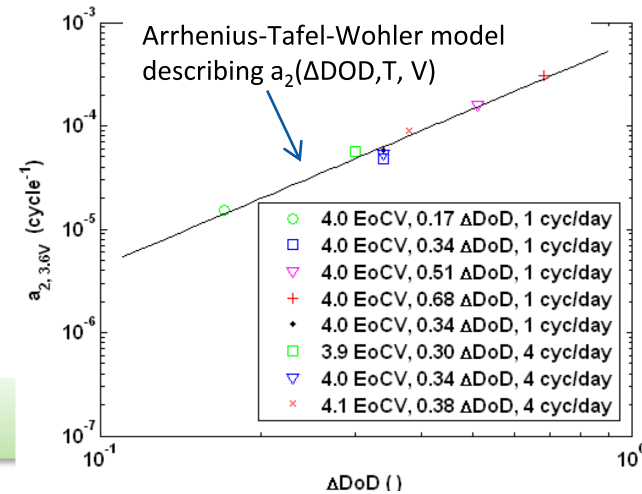
Relative Capacity

$$Q = \min(Q_{Li}, Q_{active})$$

$$Q_{Li} = d_0 + d_1 t^{1/2}$$

$$Q_{active} = e_0 + e_1 N$$





•Data shown above: J.C. Hall, IECEC, 2006.

- *Multiple cycling & storage conditions efficiently captured by single model*
- *Model extends to arbitrary real-world scenarios*

Project Approach

Matrix of analytic scenarios

Vehicles

- PEV10
- PEV20
- PEV40
- PEV40s
- EV100
- EV School Bus

Daily Driving Profiles

- Mixed light-duty vehicle driving profiles
- Mixed school bus drive cycles

Ambient Temperatures

- Los Angeles, CA
- Chicago, IL
- Phoenix, AZ

V2G Usage Profiles

- End of day
- Opportunity
- Just in time
- Grid services

Technical Accomplishments

As of date of poster submission, no FY11 funds had been received. Thus, no technical accomplishments can be reported.

Acknowledgments

Special thanks to:

Lee Slezak and David Anderson – DOE Vehicle Technologies Program