VSS104

Dynamic Feasibility Study

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Center for Transportation Analysis

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Oak Ridge National Laboratory
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Overview

Timeline

- Start – Nov FY13
- Finish – July FY14
- 95% complete

Barriers

Project Barriers:

- Cost, weight and range impacts of ESS
- Standards for Dynamic Wireless Power Transfer (WPT) are not well formulated
- Existing traffic data not sufficient

Budget

- Total project funding
  - DOE share – 100%
- Funding to ORNL for FY13: $225
- Funding for FY14: $0K

Partners

- Idaho National Laboratory
- Argonne National Laboratory
- National Renewable Energy Laboratory
- DOT
- SRA International

Project Objective

- **Overall Project Scope**
  - To highlight major opportunities, impacts and barriers to the adoption of wireless power transfer (WPT) for electric vehicle charging in-motion. Commonly referred to as dynamic wireless power transfer. (DWPT)
  - Identify critical characteristics required for DWPT & shape future research, also create necessary partnerships for this paradigm in transportation technology to occur outside of railed vehicles.
  - Define implementations/deployments of DWPT with a high probability of success and best return on investment which allow maturity of the technology.

Relevance *

- **Directly supports 2 VSST cross-cutting activities:**
  - Develop understanding of market readiness for grid-connected vehicles
  - Address codes & standards (requirements development)

- **Indirectly supports VSST laboratory and field vehicle evaluations.**
  - Utilization of data from these important resources

- **Addresses the following VSST Barriers:**
  - **Risk aversion**: Integrates technology assessment with market projections to inform key market participants
  - **Cost**: Utilizes data and models from other OVT projects
  - **Infrastructure**: Emphasizes overall system impact beyond vehicle improvements with both road construction information and power distribution impact

***Reference: Vehicle Technologies Multi-Year Program Plan 2011-2015:**
http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/vt_mypp_2011-2015.pdf

Relevance

Current Technology Assessment and Literature Review

- **Static WPT Commercial Products Limited Availability**
  - OEM system's nearing production 2016
  - Cost and deployment impacts still studied
  - Standards under development
  - Communications guidelines/topics

- **Dynamic WPT**
  - Transportation topic since 1970's
  - Mid 2000's short route fleet conversions to BEV
  - KAIST first demonstrated its On Line Electric Vehicle system OLEV in 2009

http://www.electricvehiclesresearch.com/

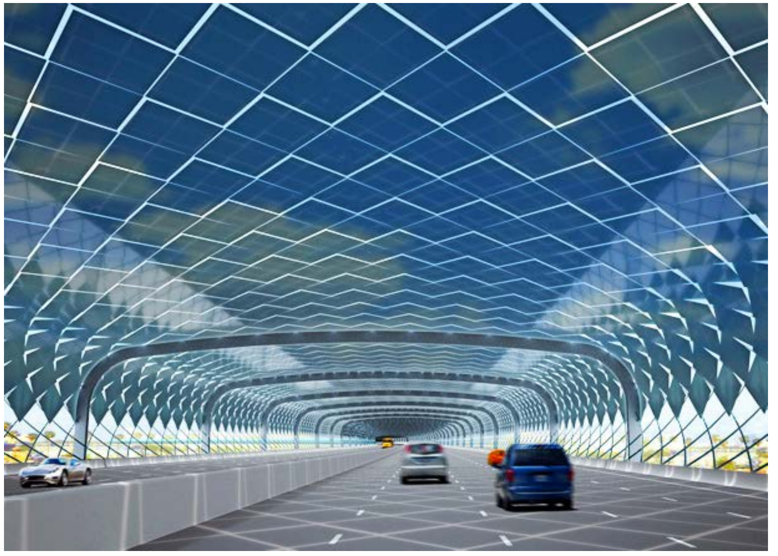
Milestones

Date	Milestones and Go/No-Go Decisions	Status
Nov-2012	Milestone: Kick-off meeting and individual lab focus areas defined	**Complete**
Dec 2013	Milestone: Project update to DOE	**Complete**
July-2014	Go/No-Go decision: Final report to DOE	**On Schedule**

Strategy

Lessons learned from previous grid connected and wireless activities drove the need for this type of study:

- Thorough understanding of current status of technologies and characteristics used for quantitative comparisons – (difficult to obtain)
- Develop scenario of interest (SOI) Atlanta area commuter traffic
- Determine technology 'system' impact



Objective: High Level Cost and Impact Study of Dynamic WPT

"WHY"

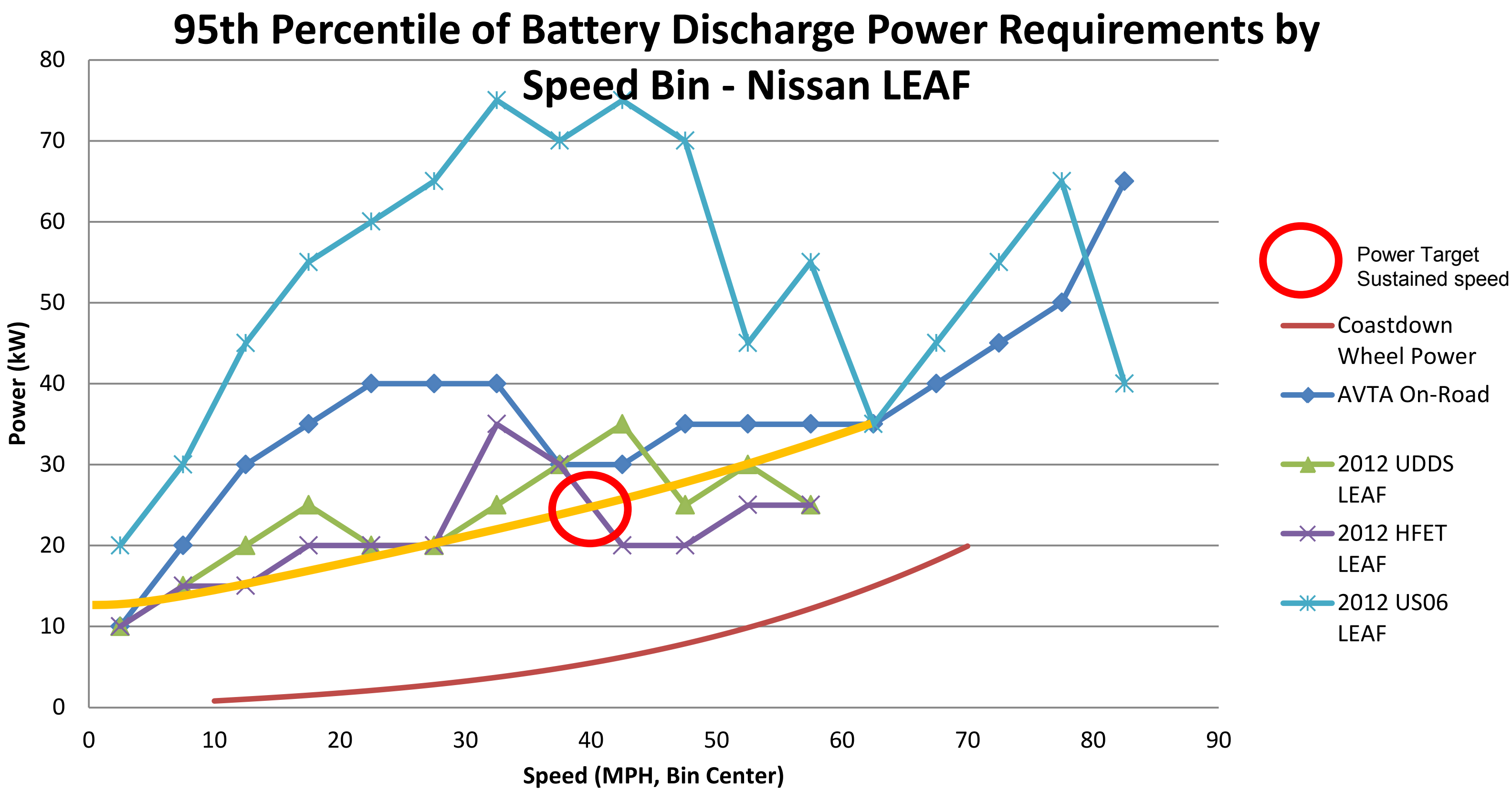
- WPT is seen as an EV enabler – DWPT should be viewed as a transportation 'Game Changer'
- DWPT requires a "Transportation System" perspective not seen by any current vehicle program
- The "Transportation Formula" in the U.S. is unique, how to determine what application might work

"HOW"

- Determine technology capability
- Gain understanding of deployment scenario impact
- Identify promising paths for implementation, cost impact and project benefits vs cost

Accomplishments: Identify Requirements

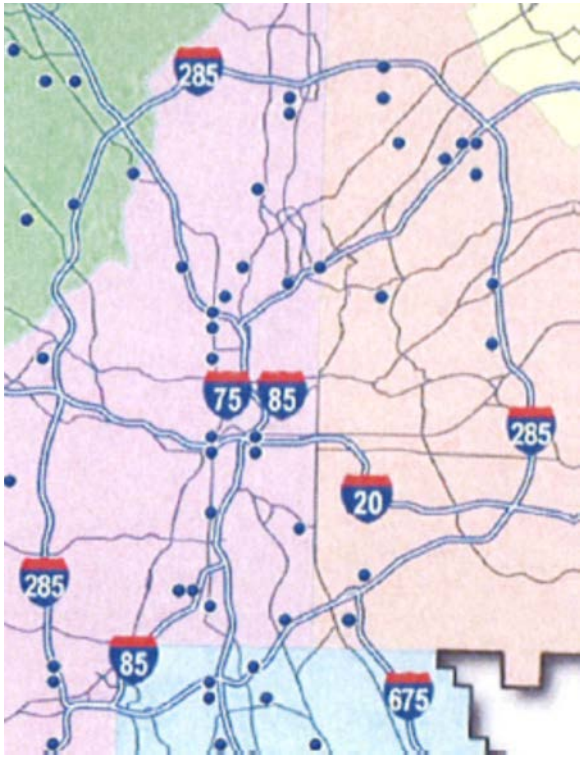
Argonne National Lab Test and Idaho National Lab Field Usage Data



Accomplishments: Developing Scenario of Interest

- **Considerations for DWPT deployment**
  - Environmental/Vehicle load impacts to roadway and WPT tech
  - Road modification traffic interruption, maintenance changes
  - Roadway usage, speeds, time of day

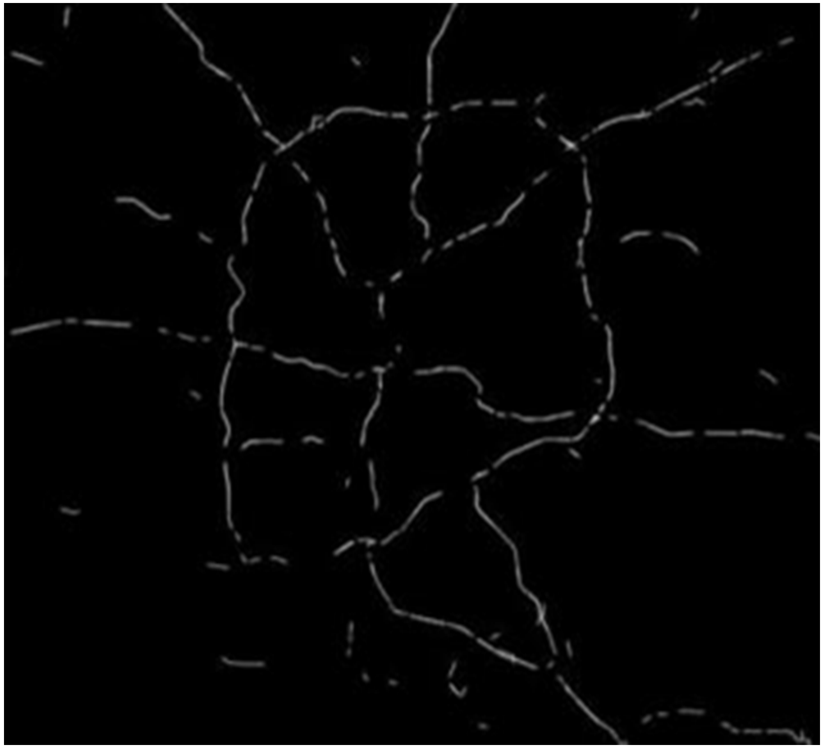
- **Example Scenario- LDV Commuter Routes**
  - HOV lane stem route metropolitan highway
  - Road usage high percentage VMT
  - Speeds varied ➡ higher speed/higher power
  - Replacing high power consumption portion of trip with charging opportunity, maximizes range and reduces ESS size and weight
  - System failure impact, traffic, range and routing

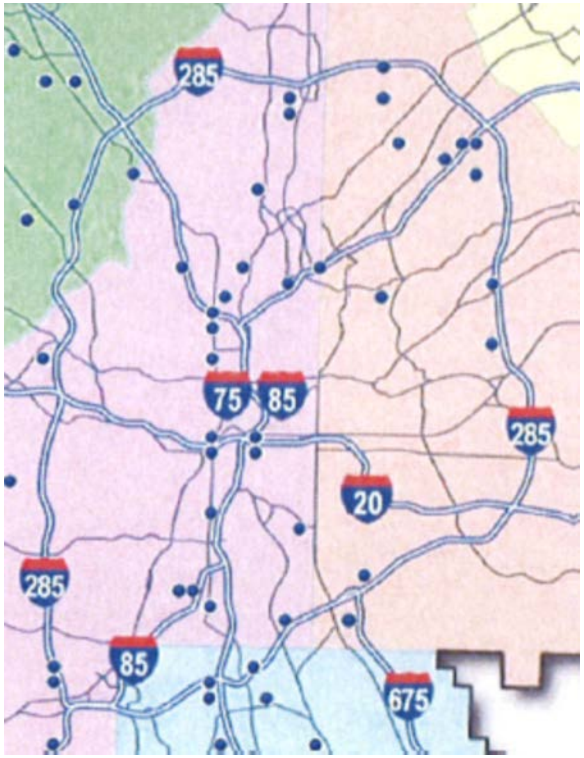


Accomplishments: Developing Scenario of Interest (cont'd)

1% of the Roads

- 17% of vehicle miles traveled (VMT)
- Road classifications
- Reducing points of connection to grid



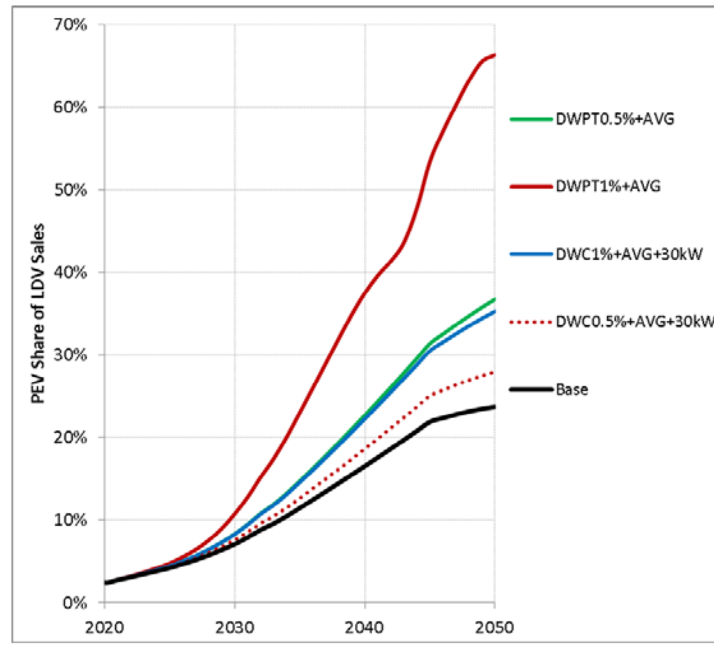


Accomplishments: Determining Technology Deployment

- **Cost for DWPT deployment vary greatly on technology selected**
  - Environmental/Vehicle load impacts to roadway and WPT tech
  - Road modification traffic interruption, maintenance changes
  - Roadway usage, speeds, time of day

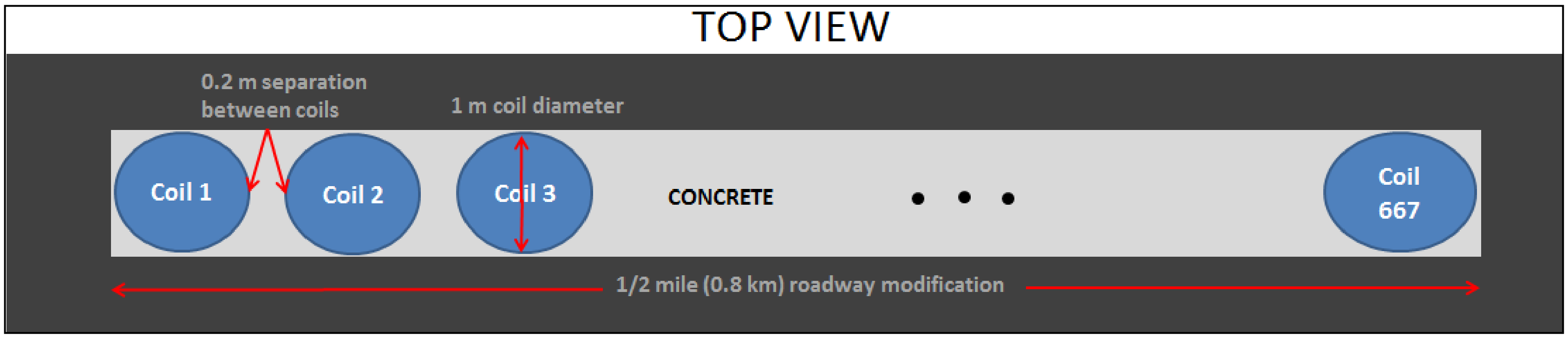
- **E-Roadway impact on EV adoption**
  - ORNL's Zenhong Lin effort with MA3T
    - PHEV 10-40 purchase impact
    - Four US city average
      - Los Angeles, Long Beach, Anaheim, CA (LA), San Francisco--Oakland, CA (SF), San Diego, CA (SD) and Atlanta, GA (AT).
    - 0% Electrified roadways in 2020
    - Base case, 100 kW & 30 kW WPT

Building the Business Case



Accomplishments: Cost Projections

- Coupling coil technology deployment @ 25kW with Power Electronics

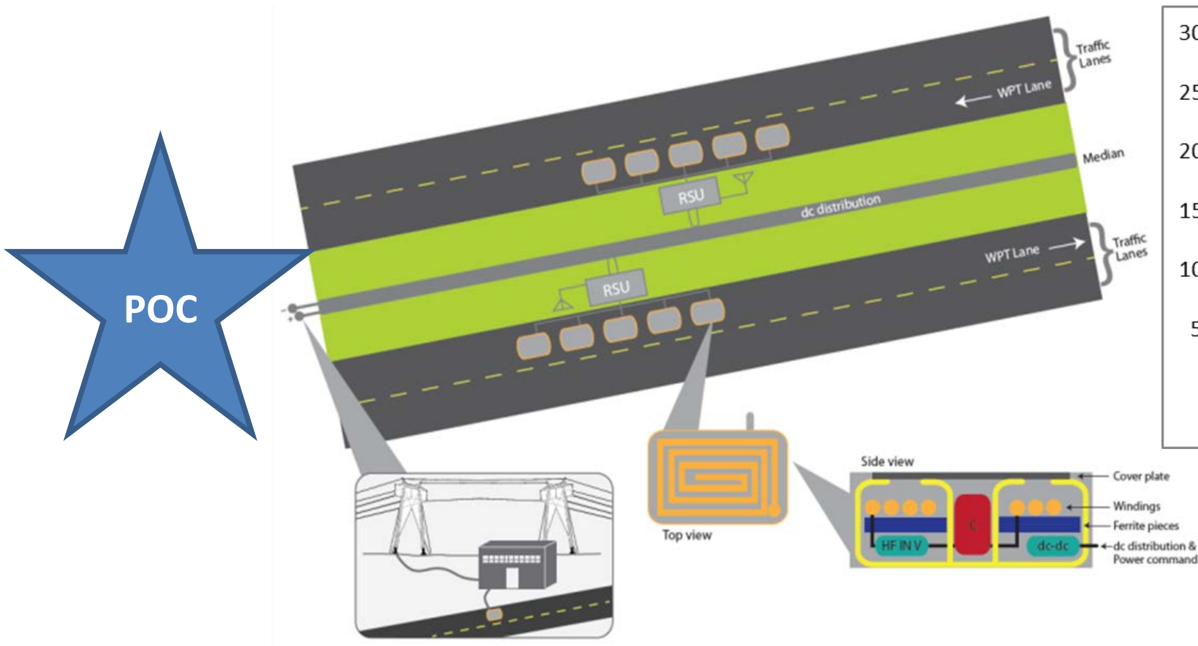


Assuming power electronics with approximate current mass production cost targets, A 25 kW dynamic roadway would cost around **$2.8M/mi of electrified roadway, per lane – this would not include required power distribution improvements.**

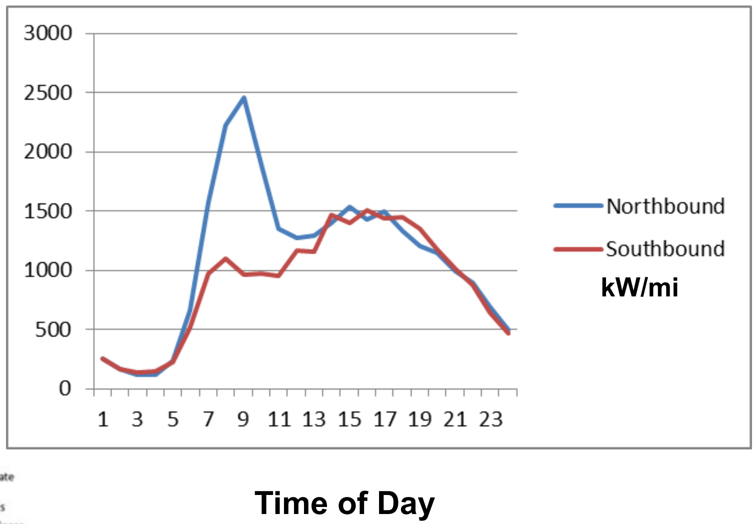
At operating speeds around 40-45 mph, this deployment scenario would transfer enough power to sustain travel for the assumed LD vehicles.

Accomplishments: Cost Projections (cont'd)

- **Infrastructure Improvement Costs**
  - Power demand variations impact cost
  - $350K/mi per side interstate traffic to bring power to Point of Connection (POC)



I-75 south of Atlanta



Responses to Previous Year Reviewer Comments

- **Comments concerning the project approach:**
  - The reviewer commented that the approach assumes existing DWPT technology is adequate, which is 'unclear'.
  - ***ORNL response: It would be appropriate to state that the technology will be at an acceptable level of readiness in the same time frame as the expected deployment timing of 2020 given the current state of laboratory demonstrations. The lack of certain standards in this field may delay technology readiness.***
- **Comment on the technical accomplishments and progress:**
  - This reviewer observed that there was good progress towards goal of assessment of DWPT from the performance side (vehicle power requirements, proposed routes, etc.) and that there was less clarity around cost/benefits.
  - ***ORNL response: The cost and benefits portions of the study had not yet been preformed as of last years AMR, this was noted in the presentation. The final report to DOE in FY14 will include cost – discussed briefly this year, and high level petroleum displacement benefits.***
- **Comments on level of collaboration and coordination with other institutions:**
  - The reviewer indicated that this project requires use of many resources from other labs and the DOT. The reviewer added that the results have been obtained by working closely with these groups.
  - ***ORNL response: The collaboration with other partners was an imperative due to the low budget amounts, but has had some impact on the ability to meet expected timelines for the project.***

Collaboration and Coordination

- **NREL**
  - Drive cycle energy balance and infrastructure impact
  - Market EV adoption scenarios
  - Traffic Volume and End-User DATA
- **Argonne National Laboratory**
  - PHEV (Nissan Leaf and Chevy Volt) operational energy data
    - Advanced Powertrain Research Facility test data
- **Idaho National Laboratory**
  - Advanced Vehicle Testing Activity Data (Leaf and Volt)
    - In-use field data filling in use-gaps from standardized testing
- **Other**
  - ORNL applications of DOE's MA3T market adoption model and various deployment cost projections
  - DOT input for construction methodology and cost
  - SRA – Power distribution cost projections

Proposed Future Work

- **FY2014**
  - Support investigation of infrastructure impacts due to power required at various traffic volumes.
  - Evaluate impact of fuel displacement based on available traffic data.
  - Complete final report to DOE
- **FY2015**
  - Utilize summary information to assist with infrastructure development of dense urban areas that are projecting large traffic volumes of electric vehicles

Summary:

The projected investment required for dynamic wireless power transfer technology deployment is substantial – More information is required to fully determine all of the benefits.

- Scenario of interest definition relating to Atlanta area commuter traffic yielding a cost estimation and power requirements also identified new data requirements
- The current projection for system cost at 25 kW transferred power with construction cost and infrastructure improvements for power distribution runs approximately $3.1M per lane/mile.
- This high level study has identified the need for intrinsic data relating to the use patterns for a larger group of users in a few specific driver categories.

Acknowledgements

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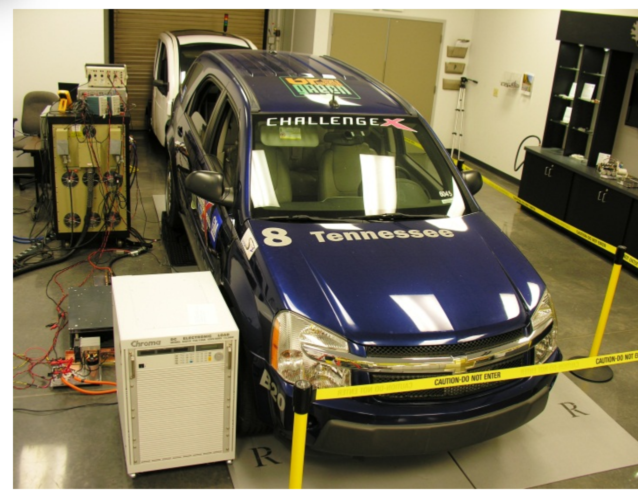
Technical Back-Up Slides

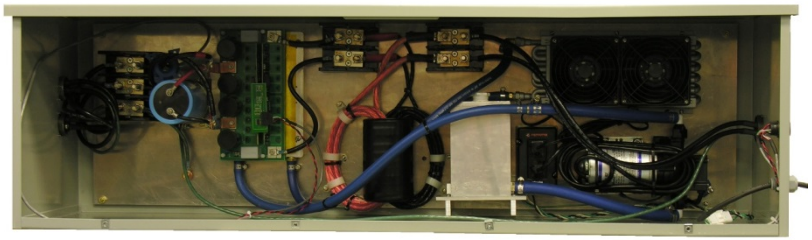
(Note: please include this "separator" slide if you are including back-up technical slides (maximum of five technical back-up slides). These back-up technical slides will be available for your presentation and will be included in the DVD and Web PDF files released to the public.)

Data Gathered from ORNL Vehicle Deployments

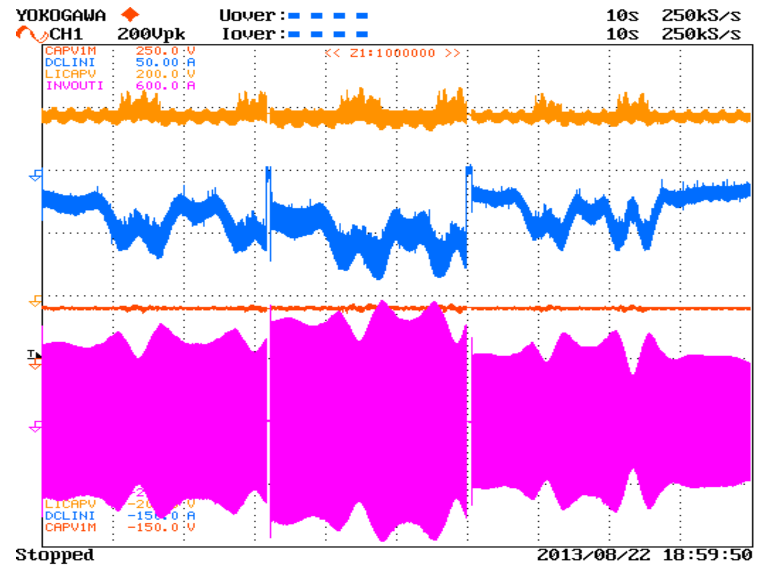


ORNL Dynamic WPT Demonstrator

- **Dynamic Wireless Power Transfer (WPT) Experimental Results**
  - Illustration of system hardware
  - Power flow as function of vehicle position



HF inverter system with HF transformer and self contained thermal management system



  - Future directions in dynamic WPT
    - Infrastructure issues (roadway integrity)
    - Communications requirements (latency)
    - Grid power distribution (intermittency)
    - Coil sequencing and power modulation & alignment
    - Local energy storage (smoothening)
  - Promote dc distribution along highway
  - Highly distributed vs. centralized HF stage