Overview

Timeline
Project Start Date: Sept 2012
Project End Date: Oct 2013
Percent Complete: 50%

Budget
Total Project Funding: $415k
Funding Received in FY12: $165k
Funding for FY13: $250k

Barriers Addressed
• Risk Aversion
• Cost of Vehicle Electrification
• Infrastructure

Partners (more on later slide)
• ORNL – Lead for dynamic WPT feasibility study; input on WPT device assumptions
• ANL & INL – Input on light-duty PEV lab and field test data
• Industry – Additional input on WPT device and vehicle/implementation assumptions

WPT = wireless power transfer; ORNL/ANL/INL = Oak Ridge/Argonne/Idaho National Laboratories
Relevance for DOE Fuel-Saving Mission

• Increased electric energy available to a vehicle
  → Increased fuel displacement

• Potential BEV enabler
  o In-motion recharging would mitigate range anxiety
  o Could improve market penetration and aggregate fuel savings

• Opportunity to improve electrification cost-effectiveness
  o For BEVs, PHEVs and HEVs
  o Smaller/more affordable energy storage configurations may realize fuel displacement similar to a large-battery plug-in vehicle
  o Improve sales and total fuel savings
Relevance for Addressing Barriers

• **Risk aversion**
  - Very much an emergent area with significant uncertainties and risks
  - Manufacturers therefore unlikely to pursue aggressively
  - DOE investment warranted, given potentially large national benefits if successful (this project will help better quantify benefits)

• **Cost**
  - Remains a barrier to widespread penetration of electrified vehicles
  - WPT may improve the cost vs. benefit and marketability of electrified vehicle technologies

• **Infrastructure**
  - Critical to coordinate R&D and analyze potential issues in parallel with vehicle and component investigations
Objectives

- Establish/apply a comprehensive analysis methodology
- Quantify petroleum consumption and GHG emission impacts
  o Capture interaction between input assumptions
  o Evaluate marketability and resulting aggregate impact potential
  o Consider multiple vehicle and implementation approaches
- Coordinate efforts with ORNL and other partners

GHG = greenhouse gas
# Milestones

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>Status (as of March 2013)</th>
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<tbody>
<tr>
<td>May 2013</td>
<td>Dynamic Wireless Power Transfer Technology Report</td>
<td>On track</td>
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<tr>
<td>Sept 2013</td>
<td>Report on Cost/Benefit Analysis of Interstate Electrification with Commercial Trucks</td>
<td>On track</td>
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Approach: Overview

• Analyze technology potential
  o In coordination/collaboration with partners
  o Baseline modeling supported by validation data
  o Informed by real-world vehicle usage and market drivers
  o Considering multiple road, vehicle, drive cycle scenarios
    – With and without roadway electrification
    – Including system integration analyses

• For passenger vehicles
  o Real-world driving data from travel surveys
  o Consumer choice model predicts market penetration, aggregate petroleum, and GHG impacts

• For commercial vehicles
  o Draw from fleet driving data
  o Net present value/payback analysis for economic viability
  o Particular focus on Class 8 trucks (large fuel user)
Approach: Technology Analysis

• **Coordinate with partners (ORNL & others)**
  - Device power, efficiency, and costs
  - Impact of separation gap and misalignment
  - Commercial system comparisons

• **Consider fuel savings and cost sensitivities**
  - Infrastructure type and penetration
  - Device power, spacing, efficiency, and alignment
  - Different vehicle classes and powertrain types

• **System integration analysis**
  - Construction and maintenance implications
    - Leverage DOT interactions
  - Magnitude and timing of additional grid load
  - Rough assessment of V2I communications
    - Correlation with DSRC attributes

V2I = vehicle to infrastructure; DSRC = dedicated short-range communication
Approach: LD Vehicle Evaluation Tools and Techniques

• Real-world GPS data
  o Multiple cities in NREL’s TSDC
  o Driving type and location/road overlap

• Powertrain model for costs vs. fuel use
  o Rapidly evaluate many scenarios
  o Range of inputs and considerations
    – Driving distribution, battery life, component costs, and efficiency characteristics
    – Vehicle performance and fuel economy
    – Conventional, HEV, PHEV, BEV powertrains

• Consumer choice model for market prediction
  o Consider vehicle characteristics, fuel prices, income distribution, infrastructure availability
  o Additional details in back-up slide section

LD = light-duty; GPS = global positioning system; HEV = hybrid electric vehicle; PHEV = plug-in hybrid electric vehicle; BEV = battery electric vehicle
Approach: Link for Aggregate Impact Estimation

- **WPT and Other Component Specifications**
- **Powertrain Models**
- **Infrastructure Coverage and Driving Profiles**
- **Costs for Batteries and Other Components**
- **Optimize for market share**

- **Demographics/Income Distribution**
- **Fuel Prices**
- **Consumer Choice Model**
Approach: Coordinate with Industry, Lab and Field Testing for Commercial Vehicle Modeling → Cost vs. Benefit Analysis

NREL Activities

Vehicle Testing

Test Data

Stakeholders

Vehicle and Component Modeling

Drive Cycle Analysis

Market Penetration Prediction

Optimization and Distributed Computing

Simulated Data

In Use Evaluation

In-use Data

GPS Data Loggers

On-Road Testing

• Additional ORNL collaboration (Class 8 truck data)
Accomplishment:
Explored Travel Distribution Across the Road Infrastructure

- Evaluated GPS data

Atlanta Dataset

• Found that a significant amount of travel occurs on a small fraction of roads
  - If 1% of roadways electrified, 17% of travel would be covered
  - At 5%, \( \approx 40\% \) of travel would be covered
  - At 25%, \( \approx 80\% \) of travel would be covered

Significance

- Shows that relatively little infrastructure can cover a significant amount of travel (minimizes costs and maximizes benefits)
Accomplishment:
Examined Infrastructure Placement

• Evaluated spatial coverage of most heavily-traveled roads
  o Match between heavy travel and high-utility roads, e.g., Interstate highway
  o Interstate electrification would enable BEVs to travel beyond a roughly 50-mile radius to anywhere across the country

Significance
• Identifies opportunity to improve consumer preference for BEVs
  o Mitigates low range and slow recharge drawbacks that otherwise prevent long-distance trips
Accomplishment: Incorporated Model Enhancement for Infrastructure Rollout

- **Added infrastructure rollout impact on consumer preferences**
  - Based on research from PA Consulting
  - Survey refined three times to ensure best possible results
  - Preference based on three parameters:
    - Metro area coverage
    - Medium distance coverage (within 150 miles of metro area)
    - Long distance coverage

**Significance**

- **Key to estimating a city-by-city approach to rolling out electric roadway infrastructure**

- **Enables electric roadway rollout impact analysis to help determine**
  - The best approach
  - The corresponding impact on market adoption

Draft results from integrated passenger vehicle modeling and market approach

Assumptions: No electric roadway, gasoline price based on trend from last 10 years, no battery cost reductions

Assumptions: Same except electric roadway installed on 5% of roads (≈40% of travel, 7 year rollout starting in 2015)

Significance

- Evaluates the potential impact of electric roadway infrastructure on vehicle electrification and DOE’s end goals

Draft results from integrated passenger vehicle modeling and market approach

Assumptions: No electric roadway, gasoline price based on trend from last 10 years, no battery cost reductions

Assumptions: Same except electric roadway installed on 25% of roads (~80% of travel, 7 year rollout starting in 2015)

Significance
- Evaluates the potential impact of electric roadway infrastructure on vehicle electrification and DOE’s end goals
Accomplishment: Initial Estimates of Roadway Electrification Contribution to Existing Grid Loads

Draft results using GPS driving profiles

• Starts with typical grid load for a metropolitan area
• Overlays added load if given percentage of vehicles pull from the grid in real time for all power requirements (worst case assumption)

Significance
• Illustrates that incremental load may be significant relative to the base load, and that alignment with midday peak will likely need to be addressed
  o Could require infrastructure to vehicle communication to manage (e.g., draw from vehicle battery instead of electrified roadway when grid at peak load)
Accomplishment (Class 8 Analysis): Conventional and HEV Truck Model Development & Validation

Significance
- Confidence in modeling baseline for electrification evaluation

WVU City/HHDDT/CILCC = West Virginia University City/ Heavy Heavy-Duty Diesel Truck /Combined International Local and Commuter Cycle
Accomplishment (Class 8 Analysis): Influence of Cycle Characteristics on Hybridization Fuel Savings

Significance

• Improved understanding of hybridization-only Class 8 benefit potential
• Identified important cycle considerations for HD vehicle WPT analysis

HD = heavy-duty
Collaboration and Coordination

- **Oak Ridge National Laboratory**
  - WPT project coordination, assumptions
  - Class 8 line-haul truck duty cycles
- **Argonne and Idaho national labs**
  - LD dyno and field data
- **ReFUEL Laboratory**
  - HD dyno test data
- **Transportation Secure Data Center**
  - Passenger vehicle GPS profiles
- **DOE Vehicle Technologies Analysis**
  - Consumer preference modeling
- **Utah St. University and KAIST**
  - Additional WPT device assumptions
- **GM, Ford, Chrysler**
  - Input on LD/consumer preference modeling
- **Navistar, Volvo**
  - Past/planned input on HD modeling and analysis
Proposed Future Work

• Refine and add sensitivity analysis to LD modeling and aggregate market predictions

• Assess road construction and maintenance implications
  o Leverage DOT interactions

• Refine and expand analysis of load alignment with existing grid demands

• Complete assessment of V2I communication requirements and correlation with DSRC attributes

• Evaluate cost vs. benefit of various Class 8 truck roadway electrification scenarios against conventional/HEV baselines
  o Consider payment structures to recover infrastructure cost
  o Assess other commercial vocations (e.g., bus charging at stops)
  o Evaluate shared roadway use by multiple vehicle types
Summary

• Identified potential for roadway electrification to increase viability and aggregate fuel savings of electric drive vehicles

• Integrated multiple techniques to conduct thorough analysis
  o Partner inputs
  o Powertrain modeling
  o Market forecasting
  o Real-world LD travel profiles
  o Commercial fleet in-use data
  o Chassis dynamometer testing

• Formulated initial results
  o Much VMT is supported by a small number of roads (e.g., Interstate)
    – Improved mobility can increase consumer interest in BEVs
    – Electrifying just 5% of roads could double electric drive penetration vs. business as usual case

• Continued analysis will further explore impacts of
  o Road coverage
  o Device efficiency
  o Vehicle types
  o Fuel price
  o Construction and maintenance
  o Existing grid loads

VMT = vehicle miles travelled
Technical Back-Up Slides
NREL Captures Important Consumer Preference Aspects and Validates Model Predictions

- Consumer preferences change based on income
  Relative importance by income bin

- Income levels change over time, and number of sales vary by income

- Competes advanced vehicles with entire existing fleet
- Successful models are duplicated (more options for the consumer)
- Extensive validation
  - Multiple years
  - 10 different regions
  - 10 dimensions

Significance
- Increased accuracy and confidence in market penetration modeling predictions
NREL’s Transportation Data Centers

**Alternative Fuels & Advanced Vehicles Data Center (AFDC)**
- Clearinghouse of information on advanced vehicles and fuels

**Hydrogen Secure Data Center (HSDC)**
- Tech validation of hydrogen-powered applications and their infrastructure

**Transportation Secure Data Center (TSDC)**
- Secure archival of and access to detailed transportation data (e.g., GPS travel profiles)

**Commercial Fleet Data Center (CFDC)**
- Detailed MD/HD drive cycle and powertrain data from advanced fleets

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<th>Functions</th>
<th>AFDC</th>
<th>HSDC</th>
<th>TSDC</th>
<th>CFDC</th>
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<tbody>
<tr>
<td>Securely archive sensitive data</td>
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<td>Application process for controlled access</td>
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<td>Detailed GPS drive cycle analysis (including the interactive DRIVE tool and Fleet DNA portion of the CFDC)</td>
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GPS = global positioning system; MD/HD = medium-/heavy-duty vehicles; GIS = geographic information system
Transportation Secure Data Center (TSDC)

www.nrel.gov/tsdc

- Secure archival of, and access to, detailed transportation data
  - Travel studies increasingly use GPS → valuable data
  - TSDC safeguards anonymity while increasing research returns

- Various TSDC functions
  - Advisory group supports procedure development and oversight
  - Original data securely stored and backed up
  - Processing to assure quality and create downloadable data
  - Cleansed data freely available for download
  - Controlled access to detailed spatial data
    - User application process
    - Software tools available through secure Web portal
    - Aggregated results audited before release

Sponsored by the U.S. Department of Transportation (DOT)
Operated by the NREL Center for Transportation Technologies and Systems (CTTS); Contact: Jeff.Gonder@nrel.gov

GPS = global positioning system
* See recommendations from this 2007 National Research Council report: books.nap.edu/openbook.php?record_id=11865
Commercial Fleet Data Center (CFDC): Supporting Transportation Energy Data Collection for the Fleet DNA Project

- A medium & heavy duty, vocationally-focused, Web-based, drive cycle database of core vehicle usage metrics

- Value:
  - Helps quantify drive cycle impacts on MD/HD Technology: many, many more vocations than LD
  - Provides reference data for drive cycle development (could support EPA / NHTSA rule making)
  - OEMs: better understanding of customer use profiles.
  - Fleets: information on how to achieve the maximum return from new vehicle technology investments
  - Funding Agencies: optimize impact of financial incentive offers.
  - R&D Activities: data source for modeling and simulation

- DOE, AQMD, CARB, Calstart, and others participating
  - NREL partnering with ORNL to acquire data

- Ongoing field evaluation projects will help to supply data

- 10-12 vocations targeted initially – highest fuel usage and/or VMT
NREL’s Renewable Fuels and Lubricants Laboratory

- Dynamometer test cells
  - Chassis dynamometer
  - HD engine dynamometer
  - Single cylinder engine dynamometer
- Emissions measurement
- Portable emissions measurement system
- Fuel storage and handling

ReFUEL Lab Located at RTD Facility in Denver

The ReFUEL Team