Plug-in Electric Vehicle Infrastructure Deployment and Grid Integration Research

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Idaho National Laboratory

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Idaho National Laboratory

- Multi-program U.S. Department of Energy (DOE) federal laboratory
- 890 square mile site with 4,000 staff
- Support DOE’s strategic goal
  - Increase U.S. energy security and reduce the nation’s dependence on foreign oil
- Laboratory missions
  - Nuclear Energy
  - National Security
  - Clean Energy Integration
  - Advanced Transportation
  - Environmental Sustainability

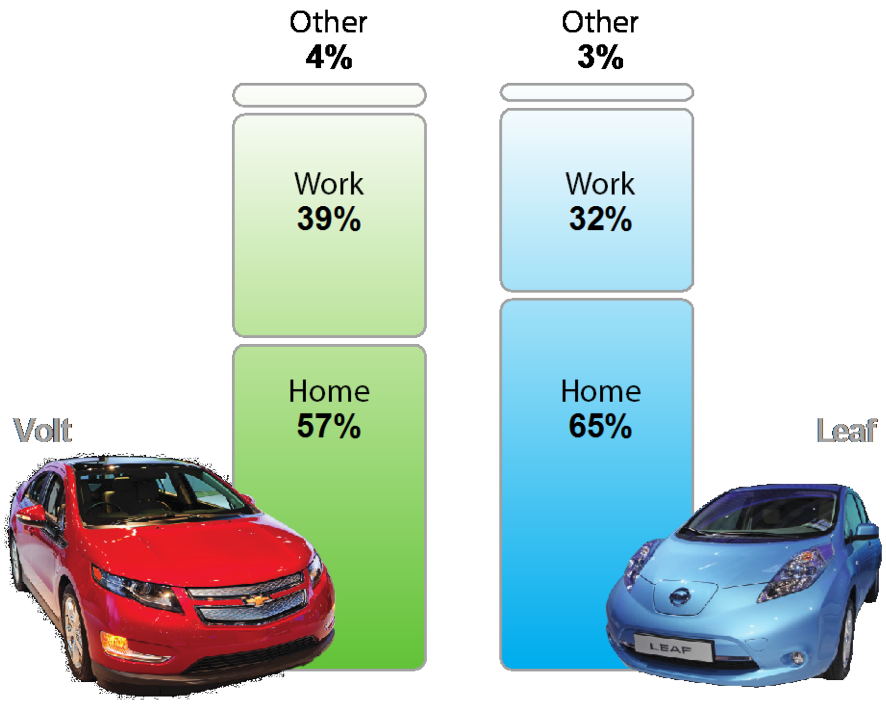
Outline

- Driver demand for charging infrastructure
- Corridor fast charging
- Installation costs
- New national laboratory research projects
  - Infrastructure network planning
  - Vehicle/grid integration

What Have We Learned about Demand for Charging Infrastructure?

In past studies when PEV drivers had access to charging at home and work…

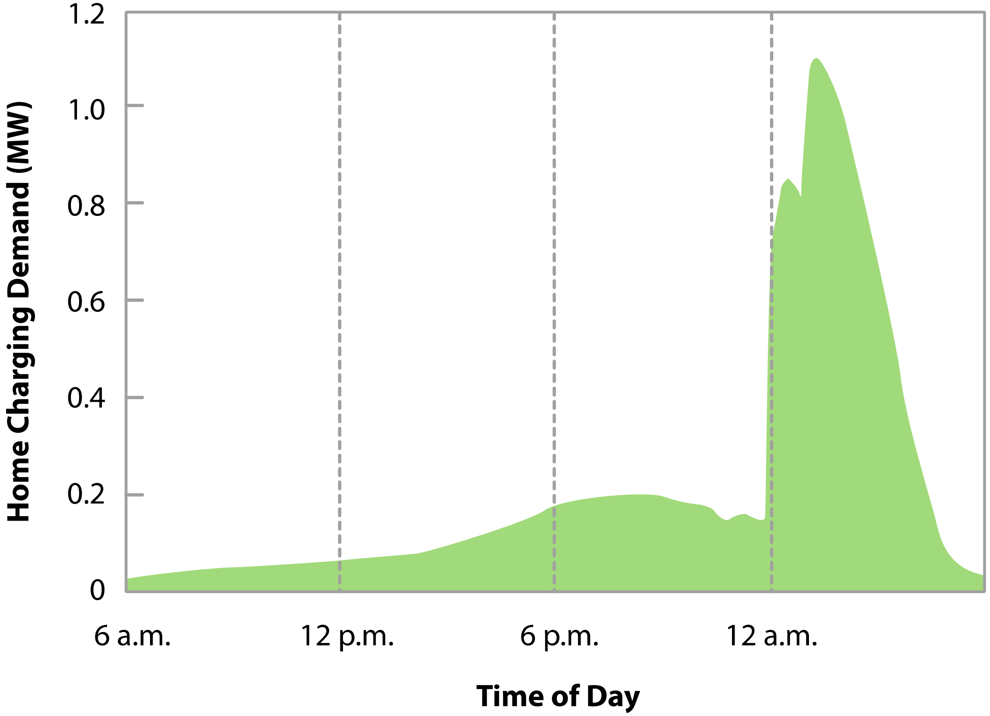
98% Of charging events were performed at home and work on work days



All days

Residential Charging Demand on the Grid

PEV owners in areas where time-of-use rates were offered have shown a willingness to delay charging at home until off-peak periods

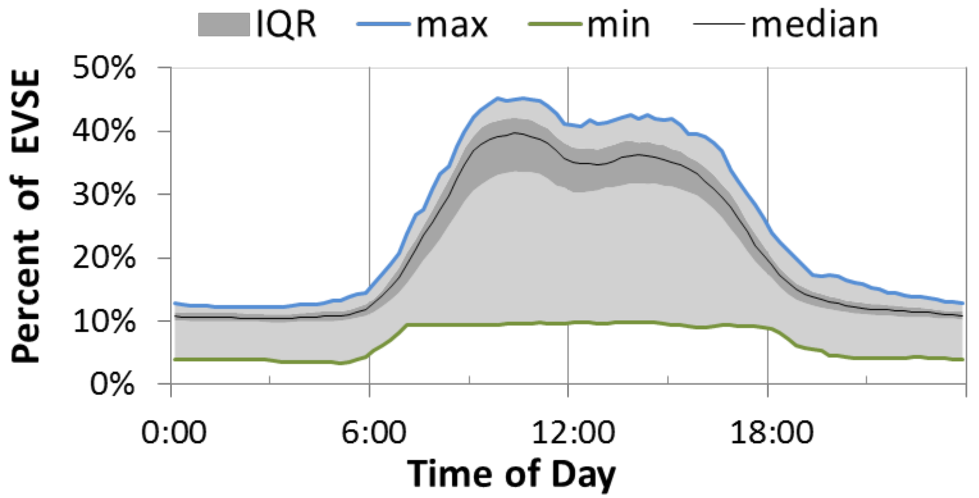


In San Diego, where the cheapest time to charge was midnight to 5 a.m., most PEV owners in The EV Project programmed their charging to start at midnight or 1 a.m.

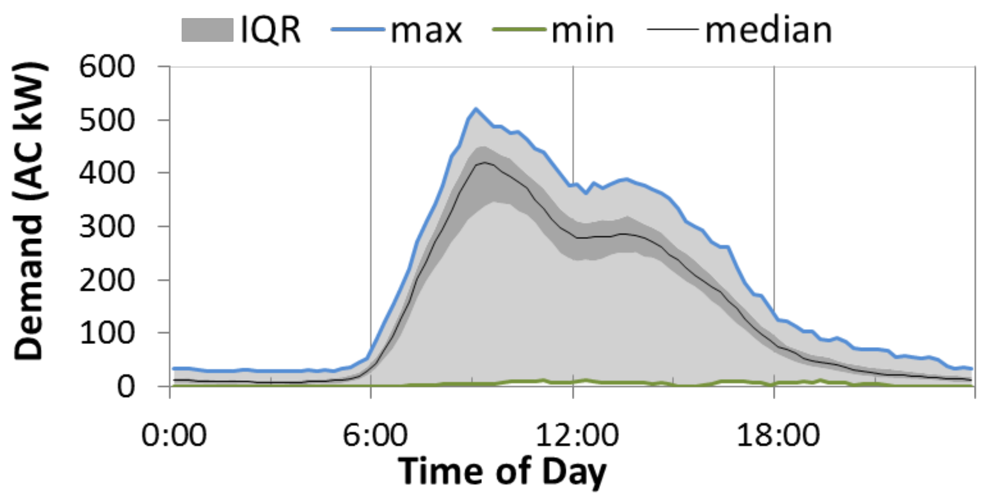
Workplace Charging Demand on the Grid

441 AC Level 2 Workplace EVSE, 6/2013 – 1/2014
Weekdays

Percent of EVSE connected to a vehicle



Aggregate charging demand



Demand for Public Charging

Public charging stations are still needed…. What if you can't charge at home or work?

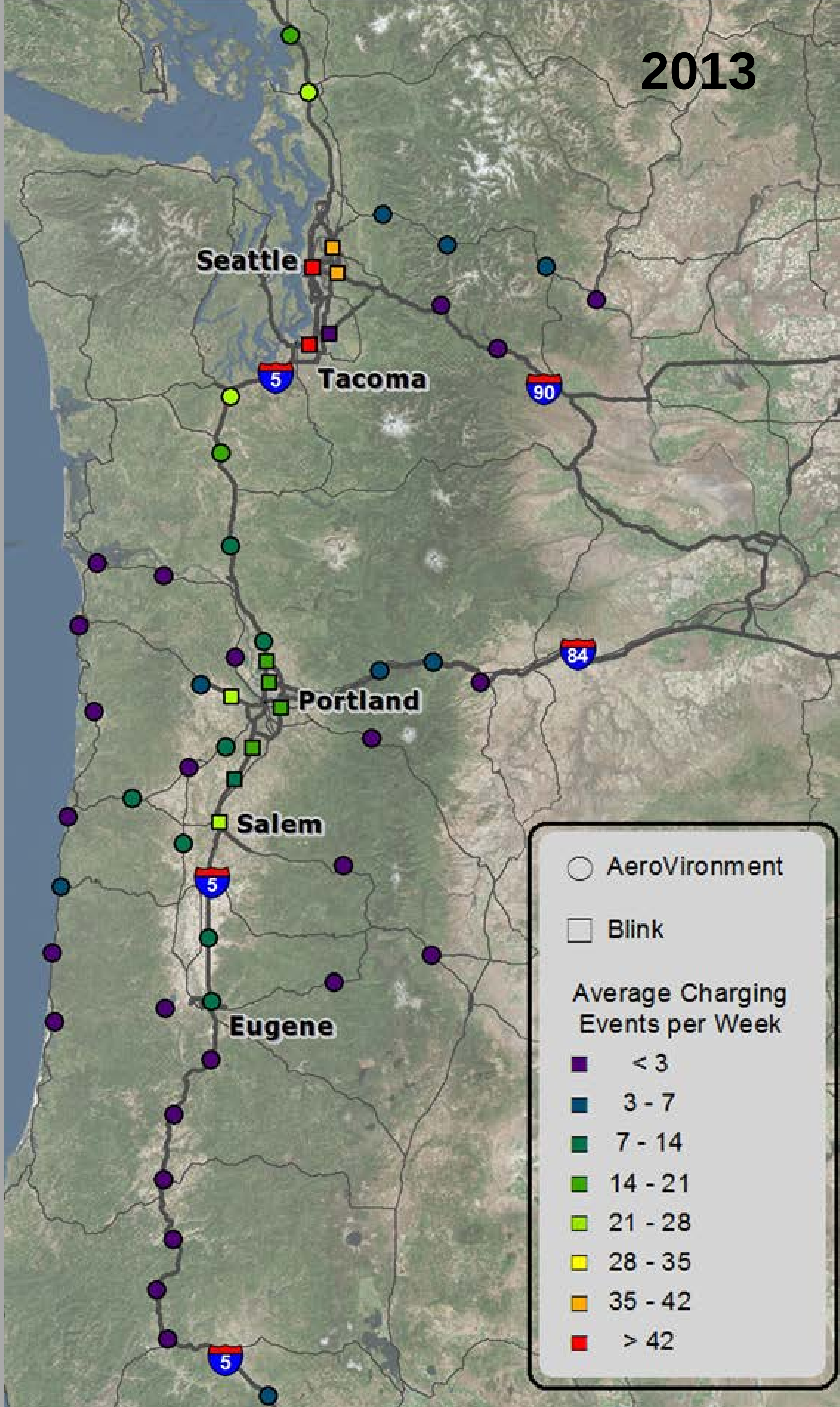
AC Level 2 stations at shopping malls, airports and commuter parking lots, and downtown parking lots and garages with easy access to multiple venues are the most popular

DC fast chargers are used to support both local and long-distance driving


Photo courtesy of nrgevgo.com

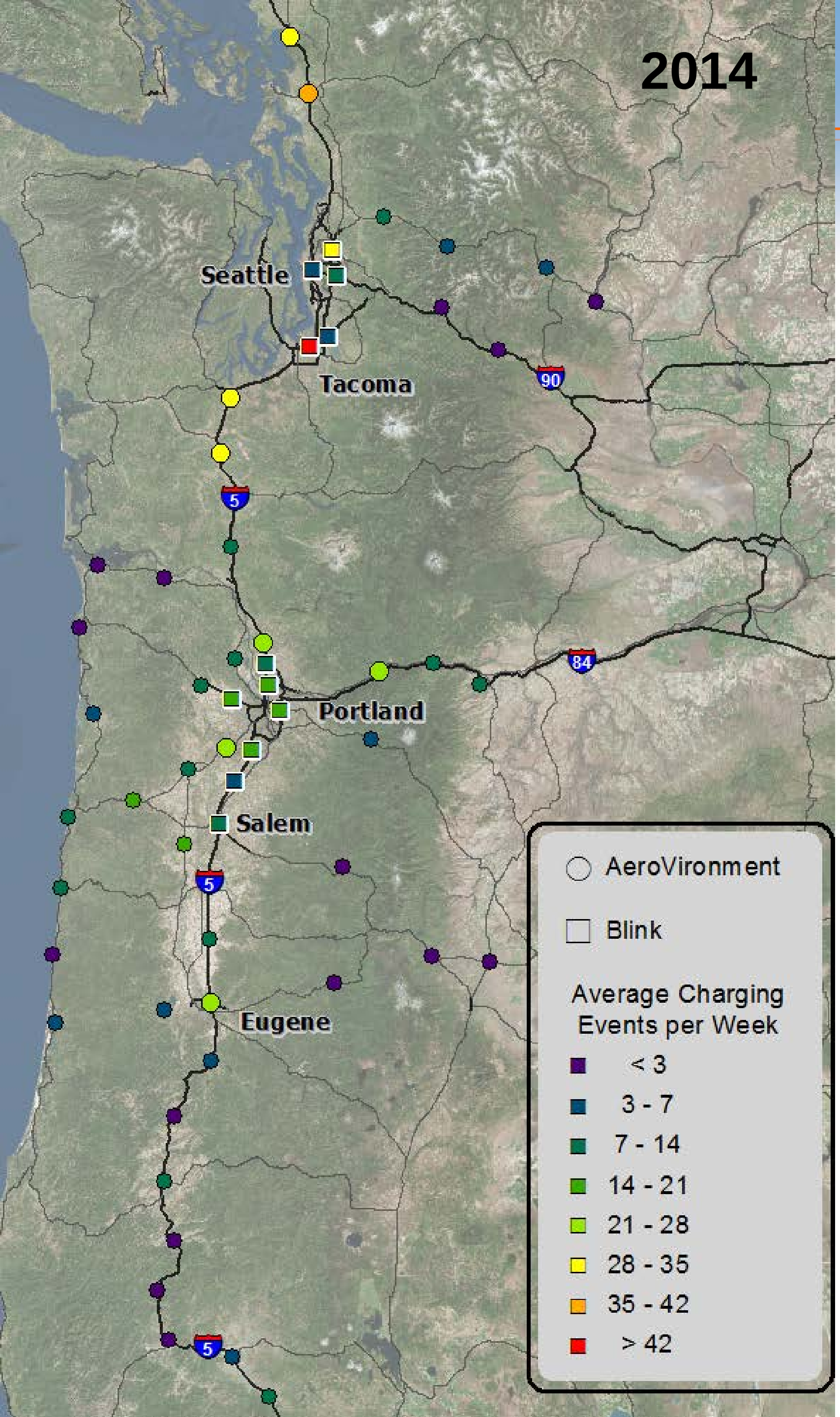
Fast Charging in the Pacific Northwest

12 Blink DCFCs and 45 AeroVironment DCFCs in Washington and Oregon



AeroVironment DCFCs part of

WEST COAST ELECTRIC HIGHWAY



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Fast Charging in the Pacific Northwest

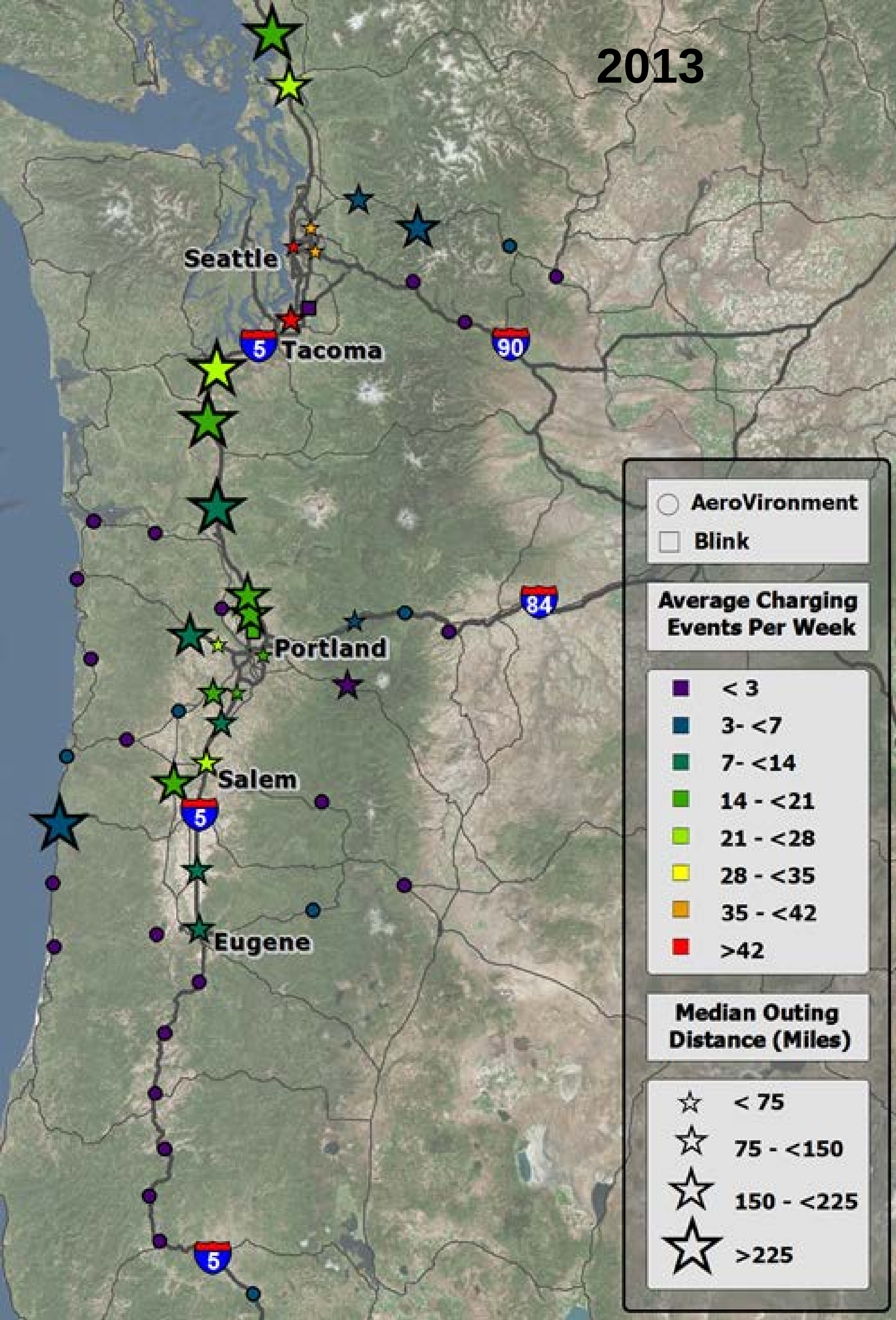
12 Blink DCFCs and 45 AeroVironment DCFCs in Washington and Oregon

Wide variation in usage

- DCFCs in/near cities and along I-5 were used significantly more frequently than outerlying DCFCs
- Overall average events per week was 11.3
- Max average events per week was 53.6

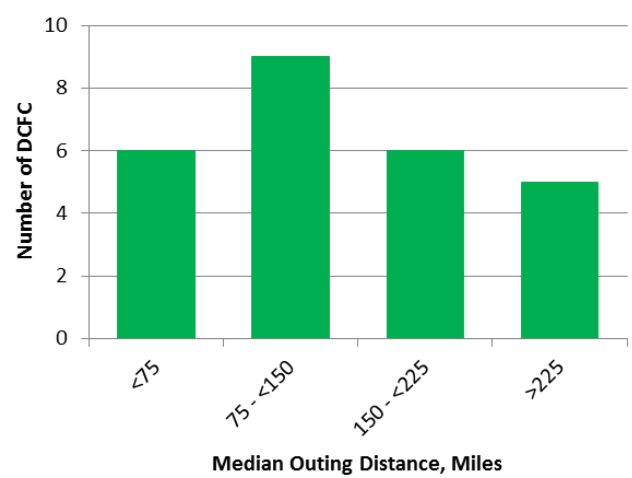
AeroVironment DCFCs part of

WEST COAST ELECTRIC HIGHWAY



Corridor Range Extension

- Of the 1,063 Nissan Leafs whose data were analyzed, 319 were charged at least once
- Provided significant range extension, esp. between Portland and Seattle



What have we learned about charging station installation costs?

$150 —  — >$8000

$600 —  — $12,660

$8,500 —  — >$50,000

NEW NATIONAL LABORATORY RESEARCH PROJECTS

DOE SMART Mobility

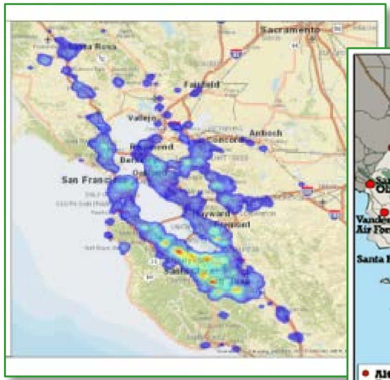
SMART Mobility identifies and explores untapped transportation system level energy efficiencies to complement DOE's traditional vehicle-level focus in a way that will accelerate sustainable transportation

Focus Area	Future New Technologies/Models/Knowledge	Performance Metrics
Decision Science	• New knowledge and applications of socio-behavioral science to collect and analyze real-world data on transportation decision making, EV and AFV market drivers and barriers, as well as new mobility options.	For all new transportation as a system studies and models: • Survey existing resources • Complete gap analysis • Propose synthesis and expansion of state-of-the-art analysis • Sub-topical deep dives that can inform future technology deployments • Deliver new cutting-edge transportation system models • Apply priority scenario illustrative examples to inform discrete conclusions
Connected and Automated Vehicles	• An increased understanding of the impact of connected and automated vehicles and their implications on transportation and vehicle technologies, such as electrification and overall mobility.	
Multi-Modal	• Dynamic passenger/freight modal and energy-intensity modeling with explicit consideration of consumer/market preferences and energy implications.	
Urban Science	• Integrated city-scale models that explicitly consider energy impacts of urbanization by collecting real-world data and collaborating with local governments	
Vehicles and Infrastructure	• Integrated vehicle-fuel models to explore consumer and provider business models and opportunities for increased sustainable transportation deployment.	

Vehicles & Fueling Infrastructure Pillar

New Tools, Technologies, and Trends: Designing Next-Generation Alternative-Fuel Vehicle Fueling Infrastructure

- Modeling and analysis leading to informed infrastructure investments that overcome barriers to sustainable transportation today and in the future



S. White, J. Smart, *Public Charging Infrastructure Use in California*, 2014

M. Melaina, J. Bremson, K. Solo, *Consumer Convenience and the Availability of Retail Stations as a Market Barrier for Alternative Fuel Vehicles*, 2012

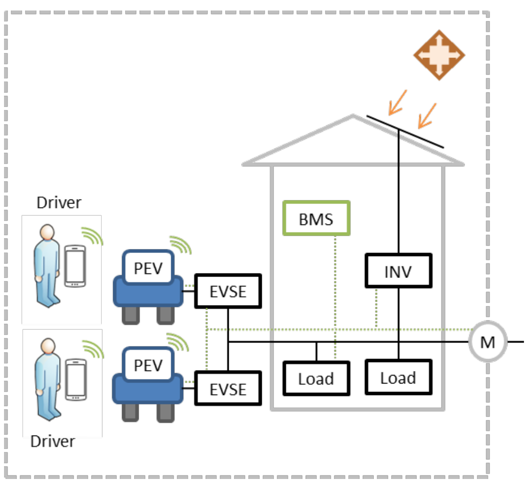
Vehicles & Fueling Infrastructure

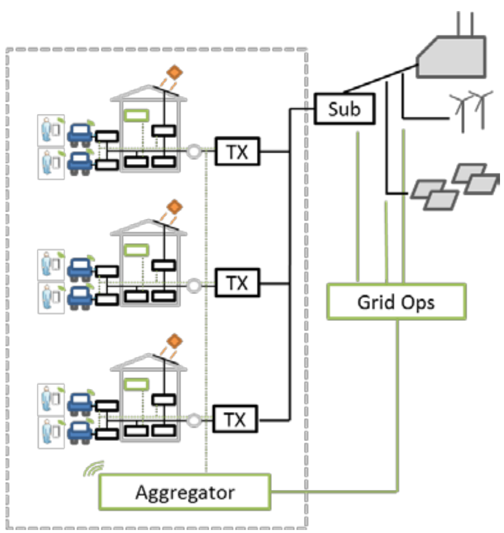
- Emphasis on cost modeling of future infrastructure
  - High-power DC fast charging
  - Local hydrogen production, storage, and dispensing
  - Dynamic wireless charging (i.e. roadway electrification)
- In the context of future transportation technology and trends
  - Connected and automated vehicles
  - Smart cities
  - Mobility as a service driving change in ownership models
  - New public transit transportation modes

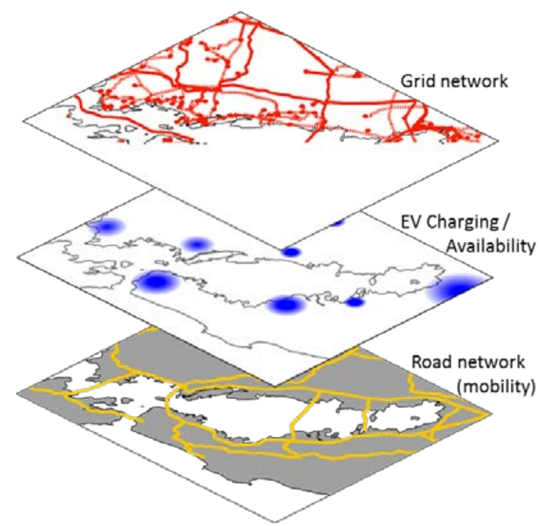
Vehicle/Grid Integration

INL is part of the Multi-lab Smart Grid Working Group, which is carrying out four projects funded by DOE’s Grid Modernization Laboratory Consortium

- Vehicle to Building Integration Pathway
- Systems Research Supporting Standards and Interoperability
- Modeling and Control Software to Support V2G Integration
- Diagnostic Security Modules for Electric Vehicles to Building Integration

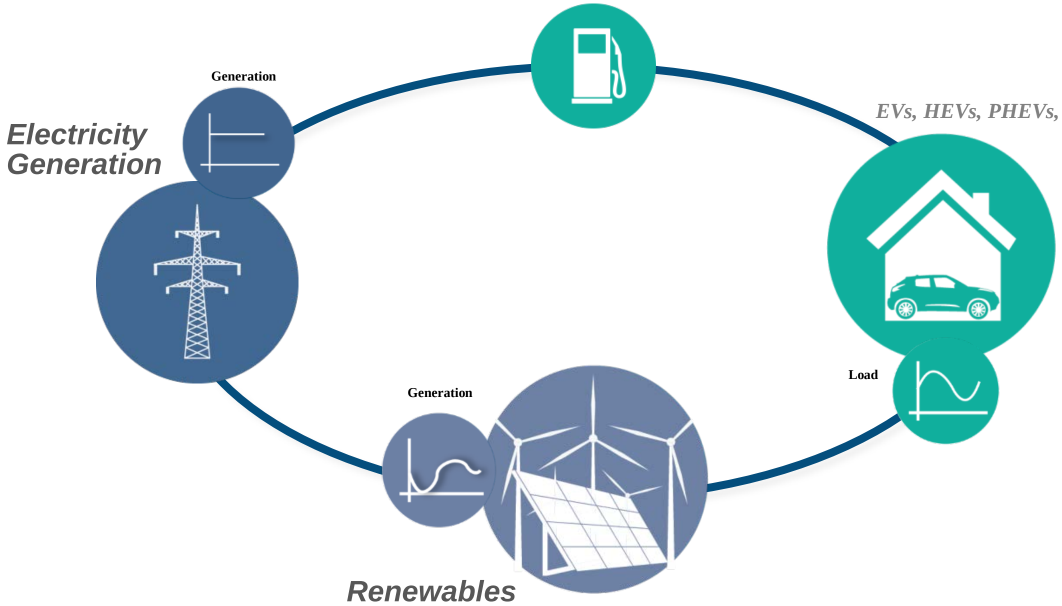






Systems Research Project Objectives

- Determine the feasibility of PEVs providing grid services and renewable energy integration at the electric utility distribution level without negatively impacting grid stability or the PEV customer experience
- Develop a hardware-in-the-loop (HIL) platform to demonstrate integration of numerous vehicles with distributed energy resources at numerous facilities
- Trial multiple communications pathways to accelerate standards development and understand how to prioritize the needs of the PEV customer, facility, third-party aggregator, and grid operator in multiple use cases



Approach

Develop a HIL platform that emulates an electric utility's distribution network, including a large number of PEVs and other distributed energy resources at numerous facilities

- Use power-HIL to characterize vehicle charging profiles under a wide variety of grid conditions and develop high fidelity models for vehicle emulation
- Emulate communications hardware with realistic latencies and protocols representative of standards under development
- Integrate actual control system hardware (controller-HIL)
- The platform will be based on dynamic real-time simulation (DRTS), which performs low-level physics modeling of the electrical system (micro-second resolution)
- This approach is the most accurate way to study electrical system dynamics, short of a real-world distribution network demonstration (cost prohibitive)

Use Cases

Distribution Load Management

- Distribution System Capacity Deferral (substation transformers)
- Distribution Voltage Support

Integrating Distributed Solar Generation

- Short Term Variability
- Daily Variability

Demand Response

Expected Outcome and Benefits

- Provide open communication and control architecture developed by this project as a benchmark for industry
- Share findings directly with standards development committees
- Enable quicker, cost-effective prototyping, as well as mitigation of potential risks associated with PEVs being interconnected to the grid
- Help business planners and policy makers make informed decisions about the effort required and potential benefits of building the infrastructure necessary to enable PEVs to provide grid services
- Enable VGI to help the electric utility industry manage increasing electricity demand, optimize utilization of existing generation, and integrate renewable.
- Possibly provide a new value stream to PEV owners, thus benefitting PEV customers, auto makers, and the large number of stakeholders who are promoting PEV adoption

Conclusion

- We have learned a lot about PEV charging infrastructure use and demand, but many questions remain
- DOE SMART Mobility will focus national laboratories expertise on big challenges, such as network optimization of corridor and urban charging infrastructure for private and commercial PEVs
- DOE Grid Modernization projects will model and demonstrate vehicle/grid integration, including
  - Distribution network impacts of PEV charging through HIL simulation
  - Technical requirements for controlled PEV charging to provide grid services