Idaho National Laboratory Update on DE-FOA-000667 Wireless Charging for Electric Vehicles

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CERV 2013
Park City, Utah
February 2013

www.inl.gov

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Presentation Outline

- INL and Vehicle Technology Experience
- Conductive Charging Deployment Lessons-Learned That Transfer Directly to Wireless Deployment
- DOE-FOA-000667 Wireless Charging for Electric Vehicles
- Conductive Efficiency? – It depends on where you measure it: 23% to 99.7%
- INL Testing Equipment and Facilities

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INL and Vehicle Technology Experience

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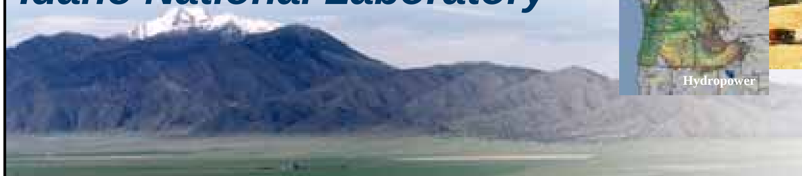

- U.S. Department of Energy (DOE) laboratory
- 890 square mile site with 4,000 staff
- Support DOE's strategic goal:
  – Increase U.S. energy security and reduce the nation's dependence on foreign oil
- Multi-program DOE laboratory
  – Nuclear Energy
  – Fossil, Biomass, Wind, Geothermal and Hydropower Energy
  – Advanced Vehicles and Battery Development
  – Homeland Security and Cyber Security

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Vehicle / Infrastructure Testing Experience

- DOE’s Advanced Vehicle Testing Activity
- 80 million test miles accumulated on 10,736 electric drive vehicles (115 models). Currently 1 million miles per week
- EV Project: 7,317 Leafs, Volts and Smart EVs, 9,493 EVSE and DC Fast Chargers (DCFC), 60 million test miles
- ChargePoint: 3,799 EVSE reporting 553,439 charge events
- PHEVs: 14 models, 430 PHEVs, 4 million test miles
- EREVs: 1 model, 150 EREVs, 900,000 test miles
- HEVs: 21 models, 52 HEVs, 6.2 million test miles
- Micro hybrid (stop/start) vehicles: 3 models, 7 MHVs, 509,000 test miles
- NEVs: 24 models, 372 NEVs, 200,000 test miles
- BEVs: 47 models, 2,000 BEVs, 5 million test miles
- UEVs: 3 models, 460 UEVs, 1 million test miles
- Other testing includes hydrogen ICE vehicle and infrastructure testing

Conductive Charging Lessons-Learned That Transfer Directly to Wireless Deployment

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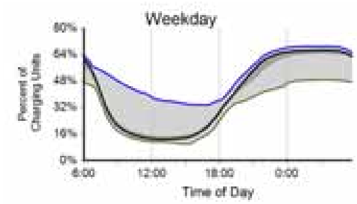
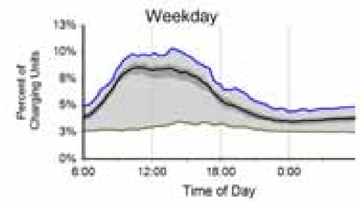
EV Project – EVSE Infra. Summary Report

- **Residential and Public L2 Weekday EVSE 4th Quarter 2012**
- **Residential and public connect time and energy use are fairly opposite profiles. Note different scales**

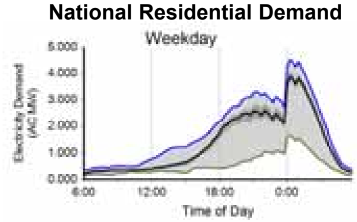
National Residential Connect Time



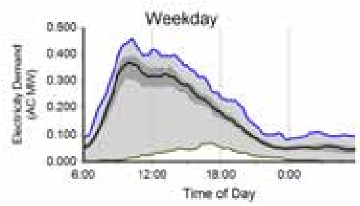
National Public Connect Time



National Residential Demand



National Public Demand



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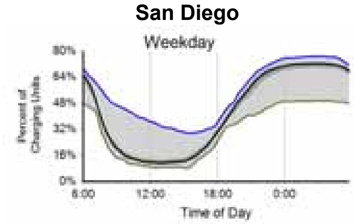
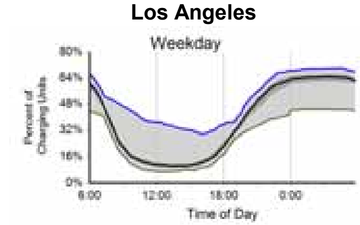
EV Project – EVSE Infra. Summary Report

- **Residential Level 2 Weekday EVSE 4th Quarter 2012**
- **San Diego and San Francisco, with residential L2 TOU rates, are similar to other regional EVSE connect profiles**

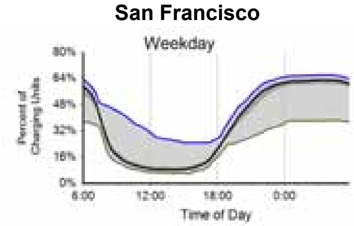
San Diego



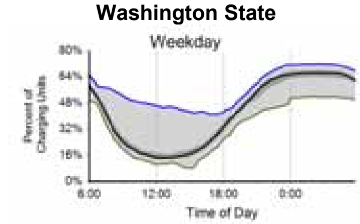
Los Angeles



San Francisco

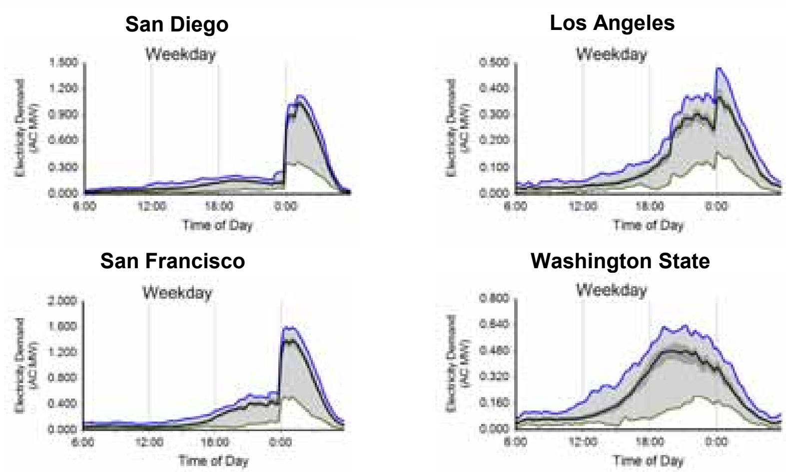


Washington State



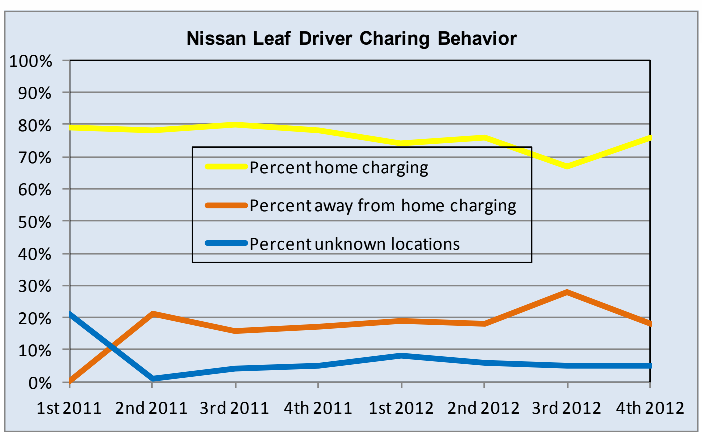
EV Project – EVSE Infra. Summary Report

- Residential Level 2 Weekday EVSE 3rd Quarter 2012
- TOU kWh rates in San Diego and San Francisco clearly impact when vehicle charging start times are set



EV Project – Leaf Charging Location Trends

- 9% increase in home charging and 10% decrease in non-home charging as a revenue model is introduced



Number of Leafs reporting each quarter							
35	956	2,394	2645	2987	2911	3200	3696

EV Project - Residential Lessons Learned

- Permit timeliness has not been a problem
- Majority are over-the-counter
- Permit fees vary significantly- $7.50 to $500.00

Region	Count of Permits	Average Permit Fee	Minimum Permit Fee	Maximum Permit Fee
Arizona	66	$96.11	$26.25	$280.80
Los Angeles	109	$83.99	$45.70	$218.76
San Diego	496	$213.30	$12.00	$409.23
San Francisco	401	$147.57	$29.00	$500.00
Tennessee	322	$47.15	$7.50	$108.00
Oregon	316	$40.98	$12.84	$355.04
Washington	497	$78.27	$27.70	$317.25

EV Project - Residential Lessons Learned

- Average residential installation cost ≈$1,375
- Individual installations vary widely
- Some user bias to lower costs

Marlets In Ascending Order Of Residential Installation Cost	Number of Installations	Average Installation Cost	Variation From Project Average
Tennessee (entire State)	542	$ 1,113.07	-19.0%
Arizona (Phoenix & Tucson)	357	$ 1,148.88	-16.4%
Washington DC	3	$ 1,197.44	-12.9%
Oregon (Portland, Eugene, Coralvis & Salem)	465	$ 1,229.06	-10.6%
Washington (Seattle & Olympia)	730	$ 1,289.56	-6.2%
Maryland	39	$ 1,311.75	-4.5%
Washington	80	$ 1,321.36	-3.8%
Virginia	38	$ 1,341.01	-2.4%
San Fransisco	1254	$ 1,386.13	0.9%
Texas (metro Houston & Dallas)	128	$ 1,422.77	3.5%
San Diego	726	$ 1,593.91	16.0%
Los Angeles	415	$ 1,794.64	30.6%

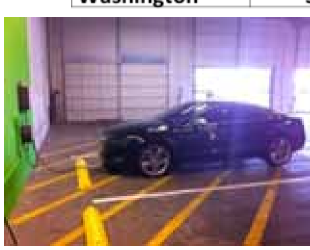
EV Project - Commercial Lessons Learned

- ADA significantly drives cost
  - Accessible charger
  - Van accessible parking
  - Accessible electric and passage routes to facility
- Permit fees and delays can are significant
  - Load studies
  - Zoning reviews

EV Project - Commercial Lessons Learned

- Commercial permits range $14 to $821

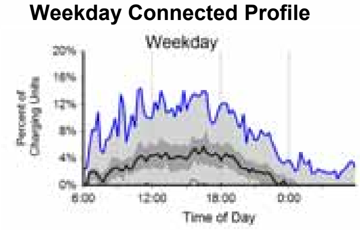
Region	Count of Permits	Average Permit Fee	Minimum Permit Fee	Maximum Permit Fee
Arizona	72	$228	$35	$542
Los Angeles	17	$195	$67	$650
San Diego	17	$361	$44	$821
Texas	47	$150	$37	$775
Tennessee	159	$71	$19	$216
Oregon	102	$112	$14	$291
Washington	33	$189	$57	$590



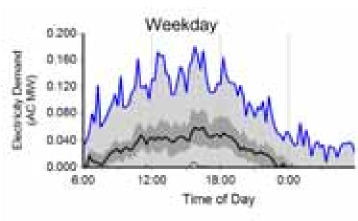
EV Project – EVSE Infra. Summary Report

- **DC Fast Chargers Weekday 4th Quarter 2012**
- **54 DCFCs connected and demand profiles**

Weekday Connected Profile



Weekday Demand Profile



- **1.9 average charge events per day per DCFC**
- **Leafs 39% charge events and 41% energy**
- **Unknowns other charge events and energy**
- **18.8 minutes average time connected**
- **18.8 minutes average time drawing energy**
- **7.0 kWh average energy consumed per charge**

Commercial Lessons Learned

- **Recurring Nissan Leaf DC fast charge demand charges are significant in many utility service territories**

Utility Demand Charges - Nissan Leaf		Cost/mo.	
CA	Glendale Water and Power	$	16.00
	Hercules Municipal Utility:	$	377.00
	Los Angeles Department of Water and Power	$	700.00
	Burbank Water and Power	$	1,052.00
	San Diego Gas and Electric	$	1,061.00
	Southern California Edison	$	1,460.00
AZ	TRICO Electric Cooperative	$	180.00
	The Salt River Project	$	210.50
	Arizona Public Service	$	483.75
OR	Pacificorp	$	213.00
WA	Seattle City Light	$	61.00

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DOE-FOA-000667 Wireless Charging for Electric Vehicles

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DE-FOA-000667 Wireless Charging for Electric Vehicles - Objective

- "……**research and develop a production-feasible wireless charging system, integrate the system into a production-intent vehicle, and to demonstrate the technology's readiness to deliver the benefits of static (and possibly quasi-dynamic) wireless charging to drivers of light-duty…..Grid-Connected Electric Drive Vehicles (GCEDV)"**

FOA 667 Awardees

- Oak Ridge National Laboratory
  - Evatran
  - Clemson University ICAR
  - General Motors
  - Toyota
- Hyundai America Technical Center Inc.
  - Mojo Mobility

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FOA 667 Phase I

- Awardees develop production-feasible wireless charging system
- INL Tests Performed at End of Phase (1 year)
  - Efficiency Test > 85% ?
  - Power Test > 3.3 kW ?
  - Gap Spacing and Alignment Flexibility ?
  - Electric Field Emissions
  - Magnetic Field Emissions
  - Object Detection
  - Power Factor
- GO / NO-GO to Phase II?

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FOA 667 Phase II

- Awardees Integrate system into production-intent vehicle
- INL Tests Performed at End of Phase (another 1 year)
  - Same tests as Phase I
  - And, Vehicle Range (UDDS)
    - PHEV & EREV: > 10 miles
    - EV: > 80 miles
- Compare performance with J1772 Conductive Charge System
- GO/ NO-GO to Phase III?

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FOA 667 Phase III

- Awardees demonstrate 5 vehicles with 5 charging stations
- Awardees provide one vehicle and charging station to DOE within 3 months
- INL performs evaluations for 3 months
- Same as Phase II, plus fleet operations:
  - Operational Safety
  - Convenience
  - Reliability
  - Flexibility
  - Efficiency
  - Use Pattern
  - Range Capability
  - Interoperability
- Awardees provide a regular transfer of raw data to INL from the other four vehicles

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Conductive Efficiency? – It depends on where you measure it: 23% to 99.7%

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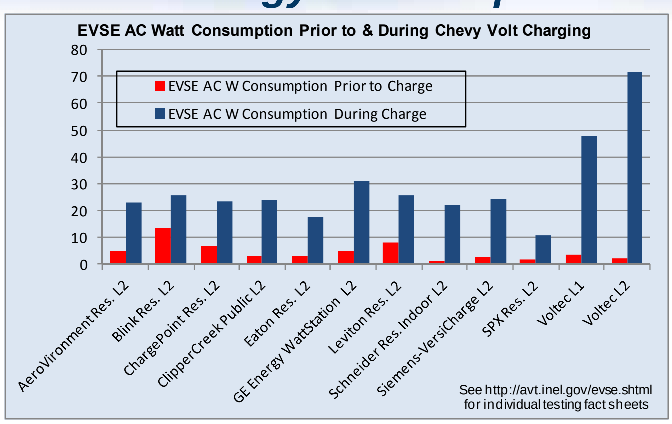
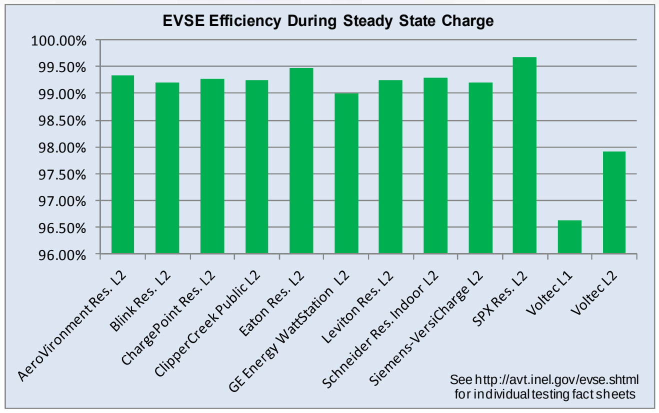
Conductive EVSE Energy Consumption



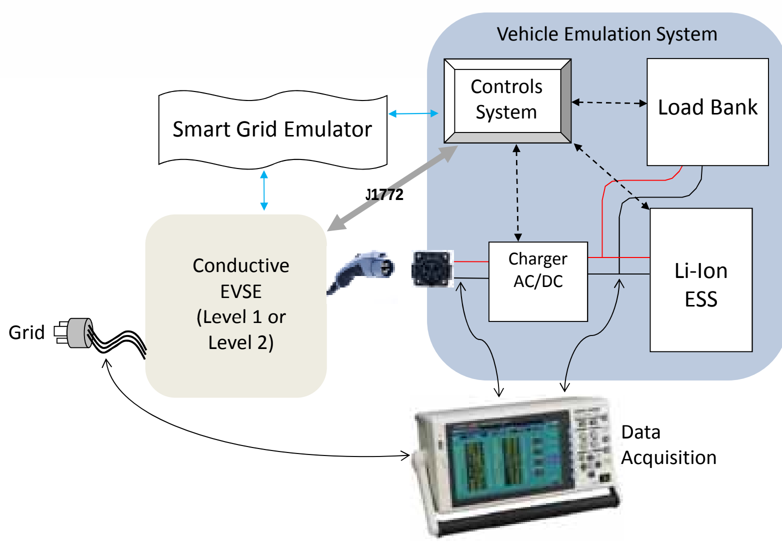
- AC energy consumption at rest and during Volt charging benchmarked
- Most EVSE consume 13 W or less at rest. Higher watt use at rest tied to more EVSE features
- Most EVSE watt use under 30 W during charge

Conductive EVSE Charging Efficiency



- Steady state charging efficiency benchmarked for EVSE only (from meter to vehicle. No onboard components included
- Most conductive EVSE 99+% efficient during steady state charge of a Volt

Laboratory EVSE Testing - Conductive



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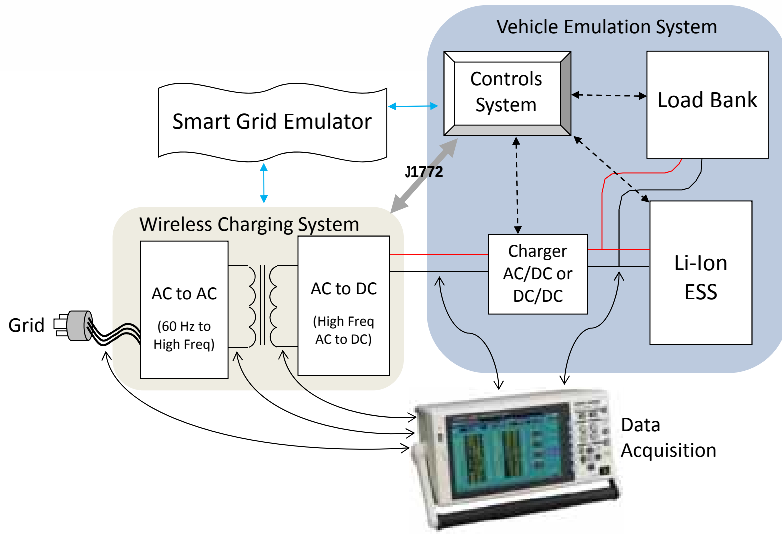
Laboratory EVSE Testing - Wireless



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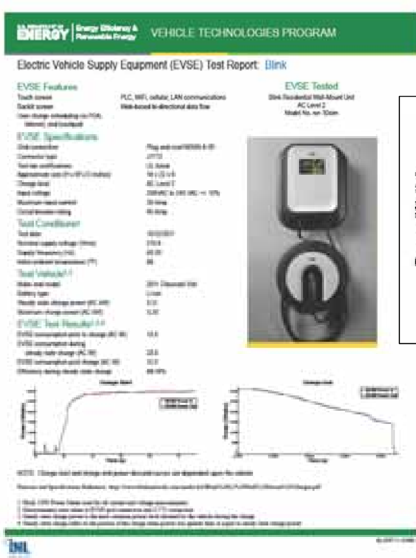
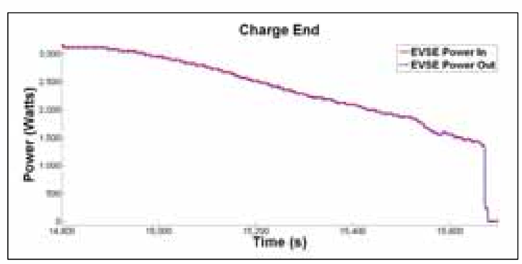
EVSE Conductive Benchmarking





http://avt.inel.gov/pdf/evse/EVSEECOtalityBlink.pdf

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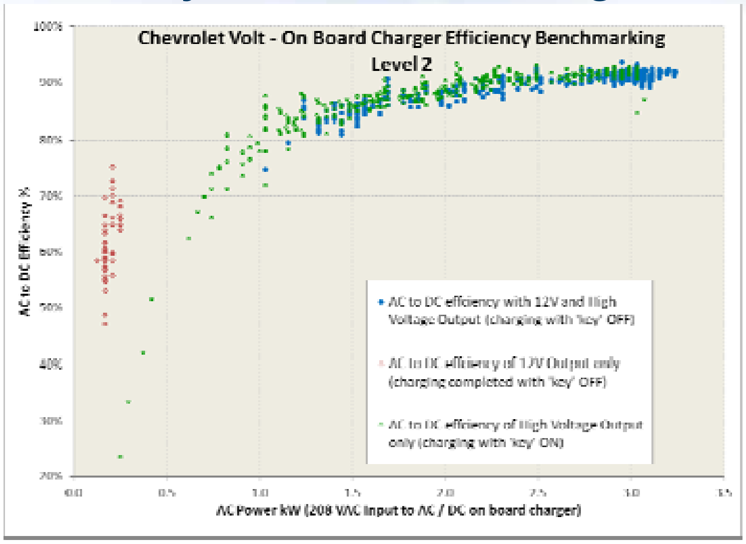
Conductive System Benchmarking



Entire report can be found at:
http://avt.inel.gov/pdf/phev/EfficiencyResultsChevroletVoltOnBoardCharger.pdf

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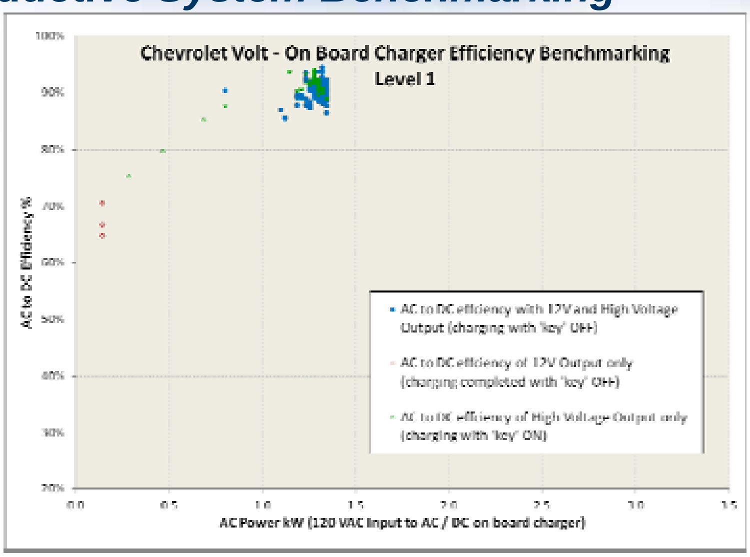
Conductive System Benchmarking



Entire report can be found at:
http://avt.inel.gov/pdf/phev/EfficiencyResultsChevroletVoltOnBoardCharger.pdf

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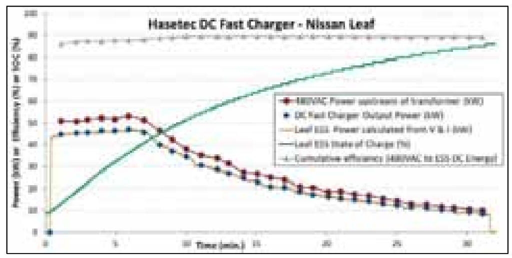
DCFC Benchmarking – Leaf Charging

- 88.7% Overall charge efficiency (480VAC to ESS DC)
- 53.1 AC kW peak grid power
- 47.1 DC kW peak power to Leaf energy storage system (ESS)
- 15.0 Grid AC kWh and 13.3 DC kWh delivered to Leaf ESS



http://avt.inel.gov/pdf/evse/DCFCHasetec.pdf

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INL Testing Equipment and Facilities

INL Wireless Charging Benchmarking

Custom Fiberglass Unistrut Secondary Coil Support

Custom Poly-Carbonate Primary Coil Support

Chroma AC/DC Loads

Hioki Power, Energy, Efficiency Meter

Narda EM Field Strength Meter

Custom Positioning System

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INL's Interoperability Test Bed

- 890 square mile remote site
  - 100 miles of high speed primary and secondary roads for on-road testing
  - No measureable background noise makes for a pretty convenient 890 square mile test chamber
  - 80,000 square foot vehicle support facility
- Ongoing use of year-round access to several Arizona vehicle testing complexes
- Multiple anechoic test chambers
- 625 battery test channels
- Data loggers on 21,000 vehicles, EVSE and DCFC
- Existing SAE testing partnership

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Acknowledgement

This work is supported by the U.S. Department of Energy's EERE Vehicle Technologies Program

More Information

http://avt.inl.gov

This presentation will be posted in the publications section of the above website

INL/CON-12-27034