Advanced Technology Vehicle Lab Benchmarking – Level 1

2012 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review

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Argonne National Laboratory

Project ID # VSS030

Overview

- **Timeline**
  - Benchmarking at ANL started in 1998
  - FY12 Completed Testing
    - Sonata HEV
    - Volt PHEV
    - Leaf BEV
    - Civic Prototype (Pb-Acid Battery)
  - FY12 and FY13 Test Vehicles
    - Conv: Civic CNG, Jetta TDI
    - HEV: Infiniti M35h, Regal e-assist
    - PHEV: Cmax Energi, Prius PHEV
    - BEVs: Focus, Mitsubishi i
- **Budget**
  - 2012FY $600 k
  - Other Leveraged DOE Projects (separate funding)
    - Codes and Standards test support
    - TADA (OEM PHEV)
    - Mass Impact Study
    - Thermal Evaluations
- **DOE strategic goals/barriers addressed:**
  - Cost
    - New, lower-cost Sonata HEV design
  - Lack of Standardized Testing Protocols
    - Validating BEV test procedures
    - Validated PHEV test procedures
  - Constant advanced in technology
    - Data generation and benchmarking recent mass-produced BEV and PHEV.
    - New HEVs compared to previous models
- **Partners:**
  - AVTA (Advanced Vehicle Technology Activity): DOE, INL, ANL, ECOtality
  - DOE, National Laboratories, USCAR, OEMs, Suppliers, Vehicle Competitions

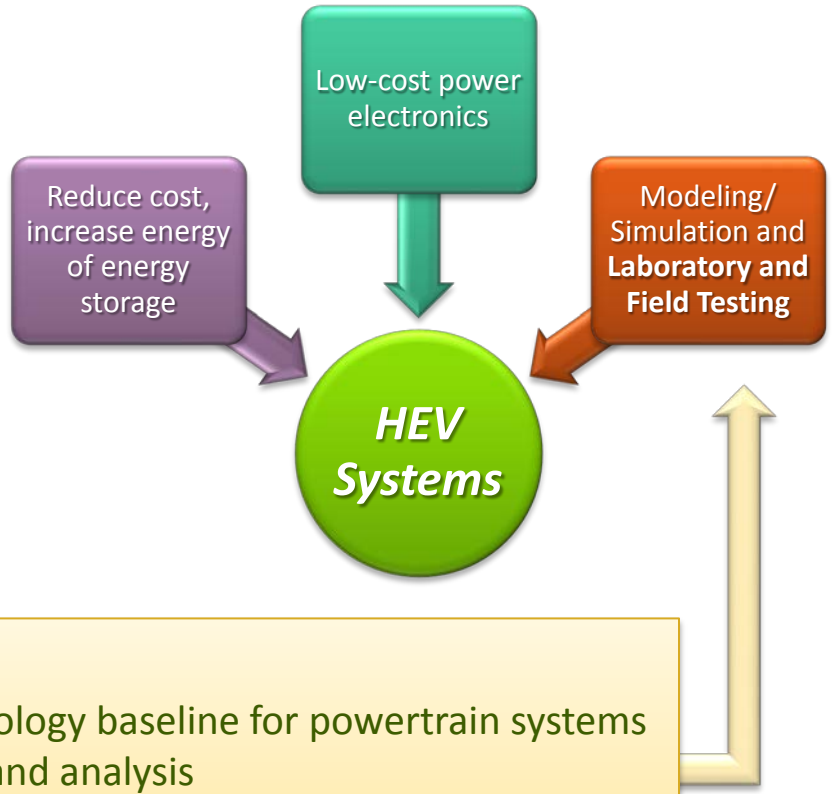
Relevance

Three Components of DOE's HEV Systems Program

"VTP is advancing the large-scale, cost-competitive production of the next generation of electric-drive vehicles through **three complementary component-and system-level technology pathways**:"[1]

Level 1 benchmark vehicles decided at DOE/INL/ANL/ECOtality summit meeting

- **Hyundai Sonata HEV**
- **Chevy Volt PHEV**
- **Nissan Leaf BEV**
- **Infiniti M35h HEV**
- **Buick Regal e-assist HEV**
- **Ford Focus BEV**
- **Toyota Prius Plus PHEV**
- **Ford C-Max Energi HEV**
- **VW Jetta Hybrid**
- **Honda Civic GX CNG**

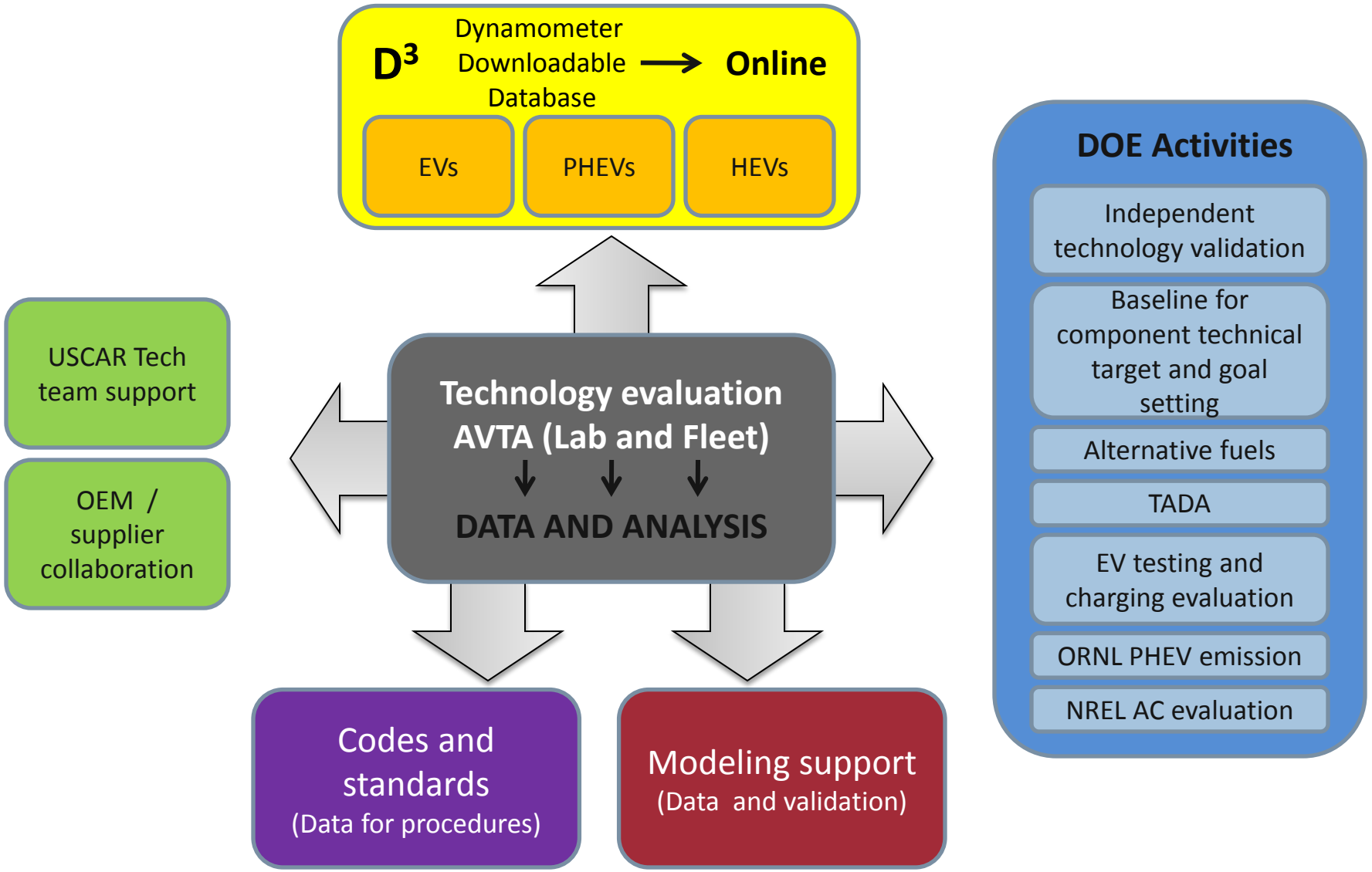


Laboratory Testing Objectives

- Establish the state-of-the-art automotive technology baseline for powertrain systems and components through test data generation and analysis
- Provide independent evaluation of technology
- Generate data to support target creation and hardware/model validation

[1] "Vehicle Technologies Program: Goals, Strategies, and Top Accomplishments," DOE/GO-102010-3164, December 2010

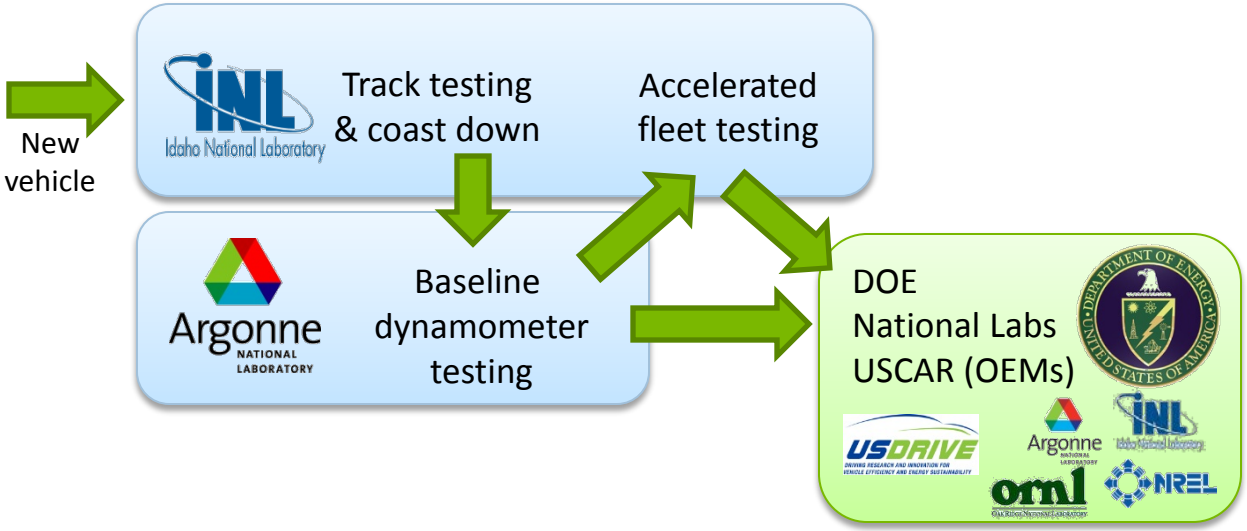
Data Dissemination and Technology Assessment



"Knowing how good you are requires an accurate picture of how good everybody else is"

Well-Established and Proficient Testing Approach Adjusted to Individual Vehicles

Advanced Vehicle Testing Activity (AVTA) Process:



The vehicle benchmark activity has been refined during the past decade. This results in:

- Continuous improvement of testing procedures
- Standard test plan including instrumentation and drive cycles (adjusted for individual vehicles)
- Advanced and unique facility and instrumentation
- Significant knowledge of testing and advanced vehicles

Wide range of vehicle technologies tested

Powertrains

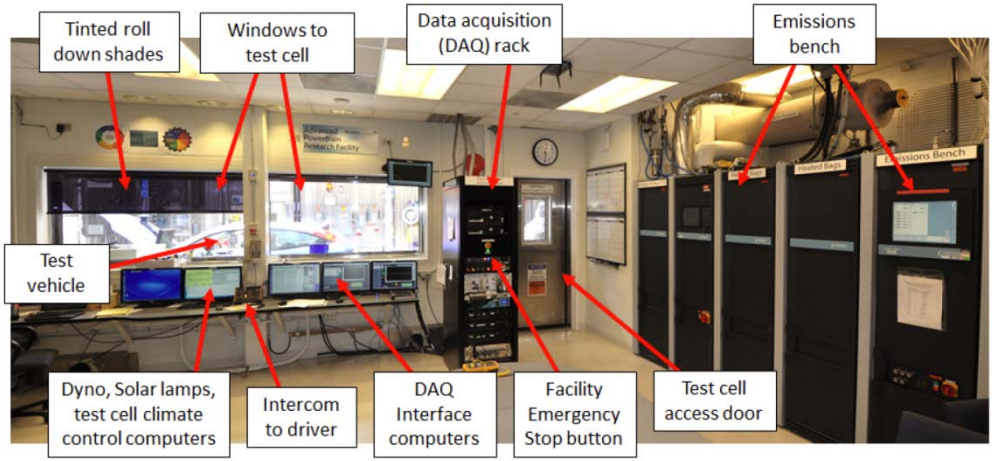
- Conventional
- Hybrid Electric (HEV)
- Plug-in HEV (PHEV)
- Battery Electric (BEV or EV)
- Fuel Cell Vehicle

Alternative fuels

- Hydrogen
- Ethanol, Butanol
- Diesel (Bio, Fisher-Tropsch)

Dynamometer Benchmarking Testing Tools and Approach

- Vehicle-level testing
  - Energy consumption (fuel + electricity)
  - Emissions
  - Performance
  - Vehicle operation and strategy
- Drive cycles and test conditions
  - "5-Cycle" tests
  - Research testing at other conditions
- Powertrain systems data collection
  - Level 1 = non-intrusive, vehicle-level
  - CAN-decoded data, speeds, thermocouples



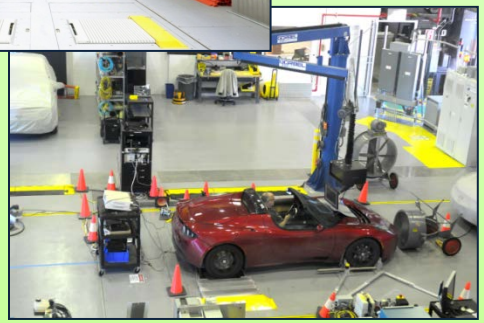
APRF

Advanced Powertrain Research Facility

Objective: The right tools for the task

- **Two dynamometer cells**
- **Custom DAQ, flexible, module-driven, used in both cells**
- **5-Cycle compliant (+)**

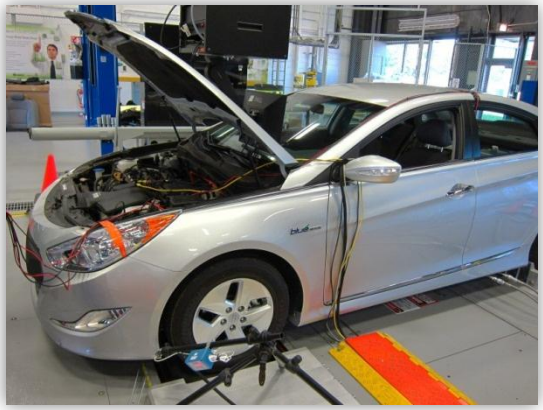
4WD chassis dyno



2WD chassis dyno

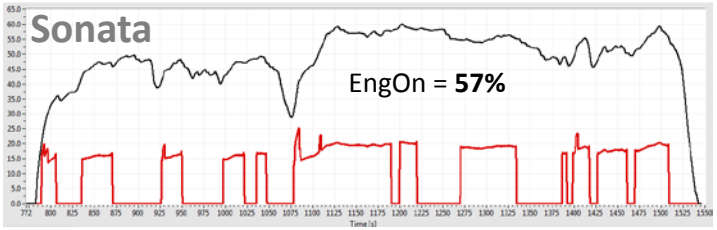
Sonata HEV Benchmark Testing

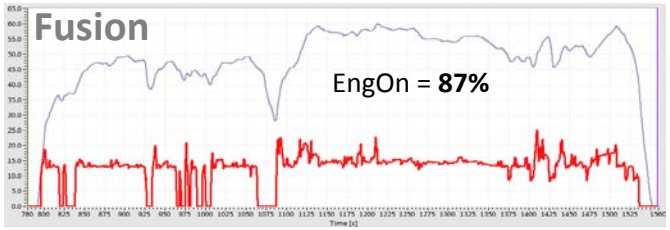
- First generation of recent “P2” hybrids
- Sonata Motors: 8 kW + 30 kW = 38 kW
- Fusion Motors: 58 kW[1] + 78 kW[2] = 136 kW



Advantages

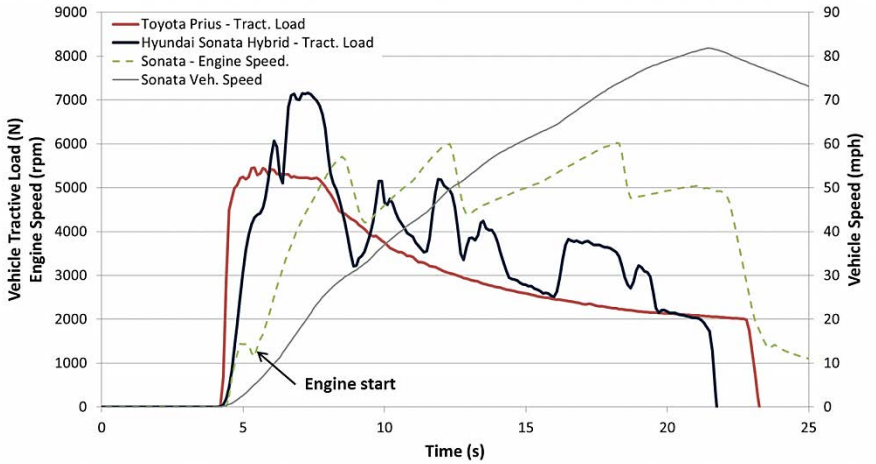
- Less losses with fixed gear
- Below 81 MPH, engine can shut down, less engine-on time,





Disadvantages

- Motor torque lacking during initial launch (affects driveability)
- Fixed gears not as smooth as e-CVT

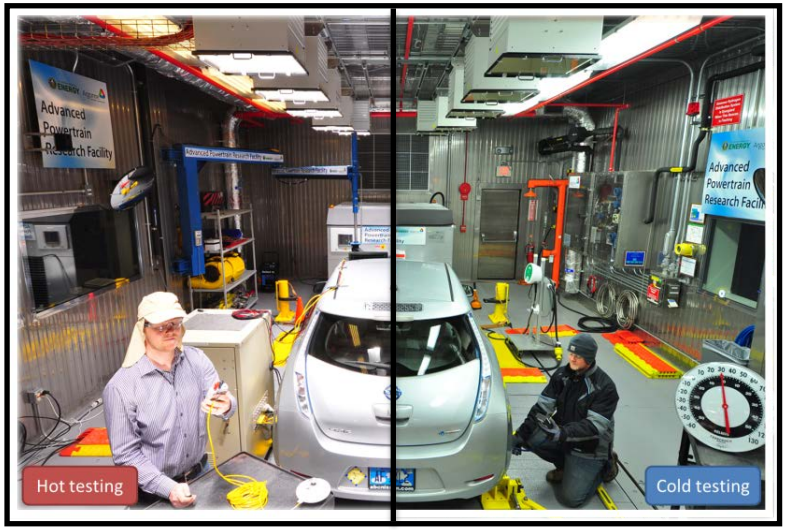


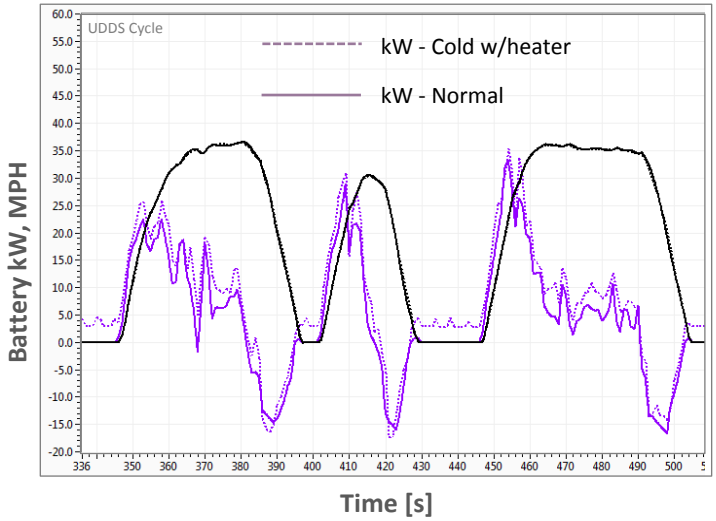
[1] Based upon CAN data during ANL testing
[2] Based upon manufacturer’s rating

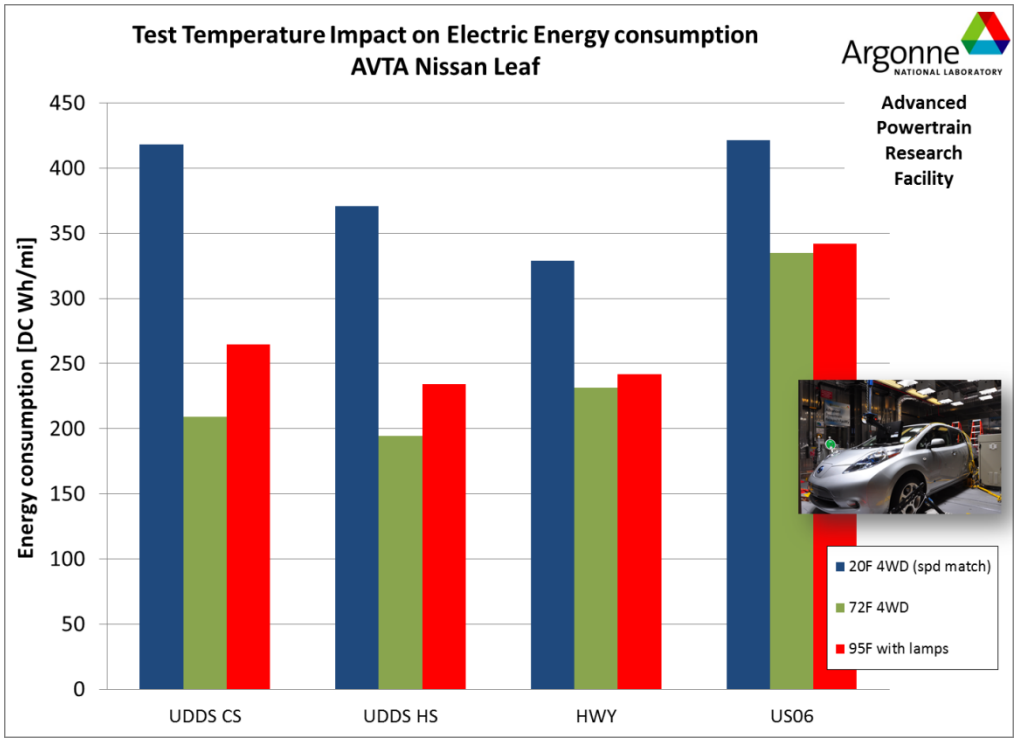
Leaf Efficiency/Range Testing at Hot/Cold

(Newest J1634 Procedures Employed)

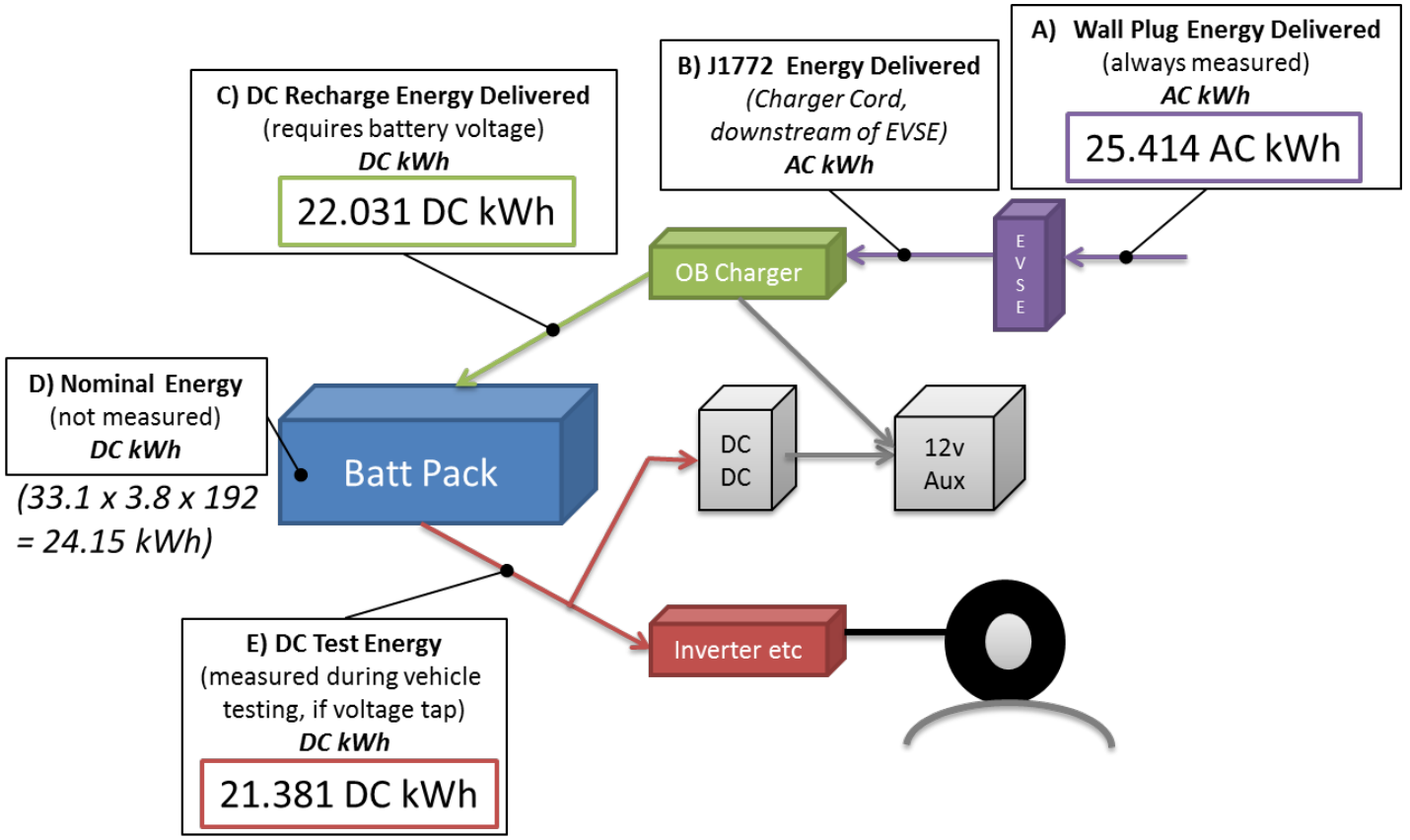
- Heater and A/C cause dramatic differences in consumption
- With heater and A/C consumption per minute is as important as per mile
  - Heater: 2.5 to 5.2 kW
  - A/C: 1 to 1.5 kW







Leaf Recharge System Efficiencies Defined



Draft Terms:

Charger Efficiency = C / B = *unknown, modifications to EVSE required*
Charger & EVSE Efficiency = C / A = 86.69%
Overall Trip Efficiency = E / A = 84.13%
Battery Efficiency = E / C = 97.05%
Pack Utilization = E / D = 88.5%
Energy counted in J1711 and J1634 → A

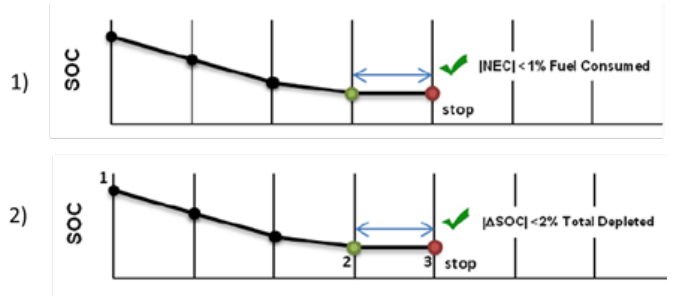
Accomplishments

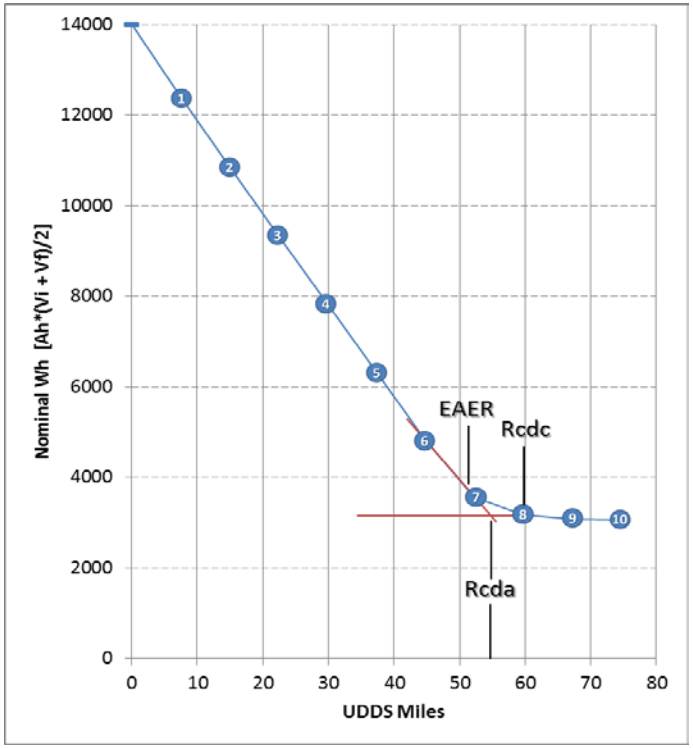
J1711 Concepts Validated on Volt

Volt UDDS Full Charge Test Data

				EOT Criteria		AC Wh Calcs	
Cycle	Miles	MPG actual	Ah x (Vi+Vf) /2	(1) Δ% of Fuel	(2) Δ% of Disch	Total % of Disch	AC Wh/mi[1]
1	7.43	inf	1582.9	25.72%	--	14.47%	255.3
2	14.86	inf	1535.7	25.22%	49.24%	14.04%	247.4
3	22.29	inf	1521.0	25.33%	32.78%	13.91%	245.1
4	29.73	inf	1515.2	25.61%	24.62%	13.85%	244.2
5	37.16	inf	1505.6	25.75%	19.65%	13.76%	242.7
6	44.59	inf	1506.1	26.12%	16.43%	13.77%	242.6
7	52.03	232.4	1267.6	22.44%	12.15%	11.59%	204.2
8	59.47	60.6	386.5	6.95%	3.57%	3.53%	62.2
9	66.90	51.0	86.2	1.56%	**0.79%**	0.79%	13.9
10	74.33	49.0	31.3	**0.57%**	**0.29%**	0.29%	5.0

[1] Based upon 13.102 AC kWh recharge to full





- End of Test Criteria checked for robustness. Argonne-prescribed option works best.
- Numerous SAE J1711 range definitions important for calculations of results.
- Same calculations for all PHEVs. PHEV type drives decision of which results are presented.

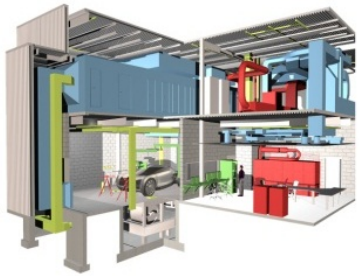
Existing Coordination with Other Institutions

J1711 HEV & PHEV test procedures
J1634 EV test procedures
SAE International®

International
- **KATECH (Korea)**
- **ISO**
- **JARI (Japan)**
- **IEA**
- **EC-Joint Research Centre**

AVTA (Advanced Vehicle Testing activities)
Baseline dynamometer testing of vehicles
INL Idaho National Laboratory, Argonne National Laboratory

APRF



DOE technology evaluation
- DOE requests
- National Lab requests

NREL, ornl Oak Ridge National Laboratory, INL Idaho National Laboratory, Argonne National Laboratory

USCAR, tech teams and OEMs
Shared test plans, data and analysis
USDRIVE Driving Research and Innovation for Vehicle Efficiency and Energy Sustainability

Autonomie®
Support of modeling and simulation with data
AUTONOMIE

Chrysler – CTC

GM – Powertrain, Milford

Ford – Powertrain, APTL

Future Work

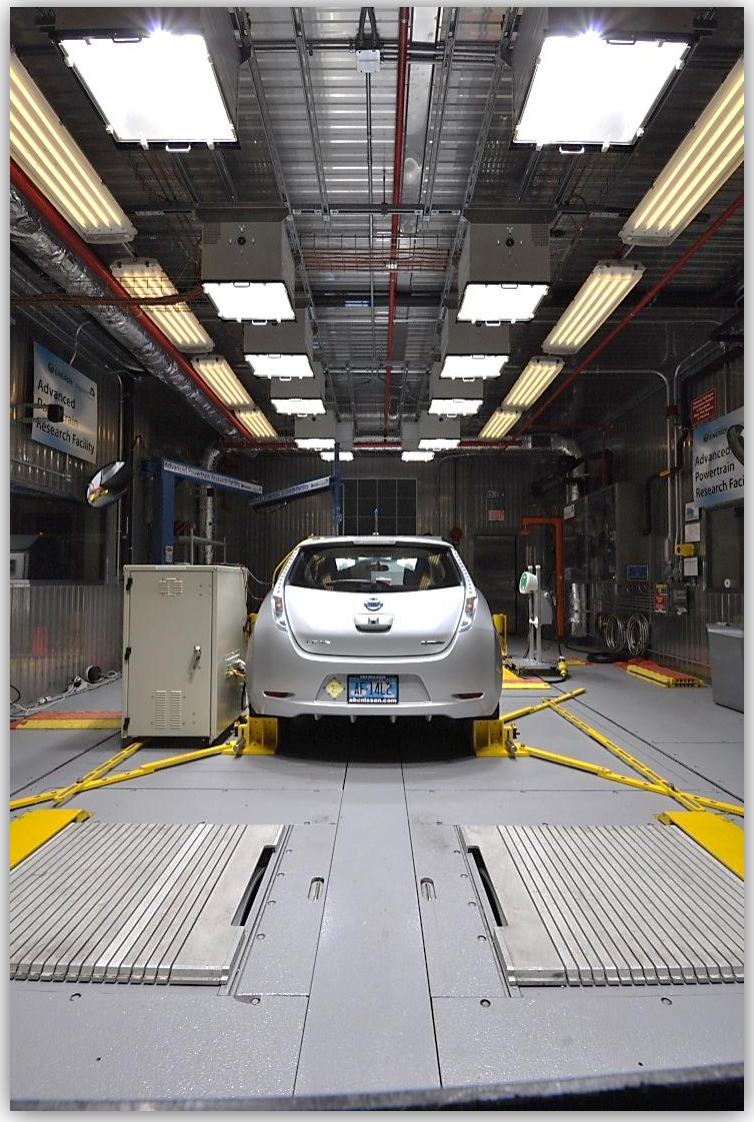
Future Level 1 Testing to Continue, Now With Hot/Cold Capability

Future AVTA Level 1 Vehicle Testing Plans (FY12 and FY13)

- Conv: Civic CNG, Jetta TDI
- HEV: Infiniti M35h hybrid, Regal e-assist
- PHEV: Cmax Energi, Prius PHEV
- BEVs: Focus, Mitsubishi I

New Vehicle Technology Evaluations

- Many OEMs adding novel warm-up hardware and controls
- Lab can achieve 0° F for investigations in very cold operation
- Prius PHEV using blended operation: how will it perform?
- New PHEVs/BEVs from other OEMs
- Lab continues to be Fuel Cell Vehicle capable
- Benchmark new Natural Gas Vehicles (NGV)



Summary

- The **Level 1 Benchmark Activity** provides precise laboratory test data for a wide range of vehicle technologies that address DOE goals
  - Establish state-of-the-art automotive technology baseline for powertrain systems and components through data collection and analysis
  - Providing independent evaluation of technology and support for DOE target setting
  - Generating test data for model development and validation to encourage speed-to-market of advanced technology
  - Supporting codes and standards development for unbiased technology weighting
- Link to industry an important component of vehicle testing
  - Best test practices, facility hardware recommendations, data analysis methods
  - Industry technology developers provide insight into what data is of interest
- Upgrade for hot/cold testing addressed important real-world operation
- ANL Level 1 testing addressed new technologies
  - The Sonata HEV data shows promise for “P2” hybrids. Controls and sizing issues likely to be addressed in future generations
  - Leaf BEV data will be an important benchmark to compare all future BEV advances
  - Volt PHEV data also important benchmark, also important for standards work