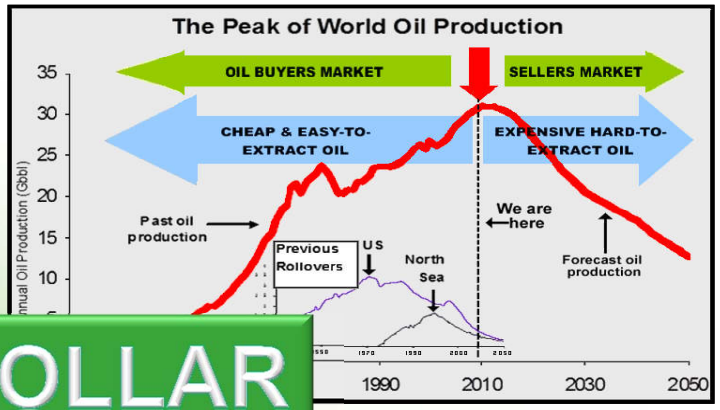
Kev Adjemian, PhD
Department Manager, Energy Storage
and Transportation Systems • at.inl.gov

Why we do what we do….

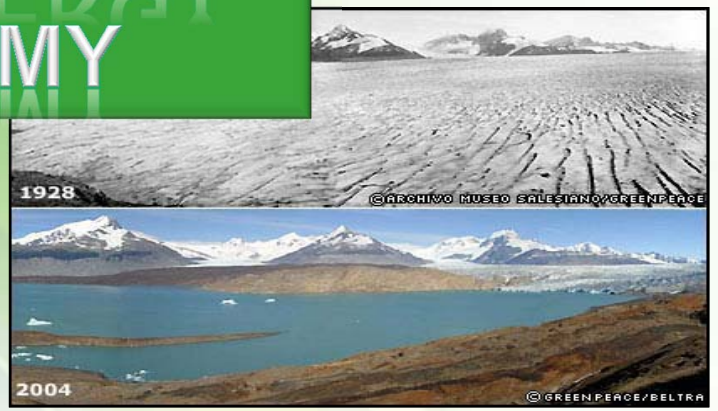
Energy



Resource

TRILLION DOLLAR CLEAN ENERGY ECONOMY

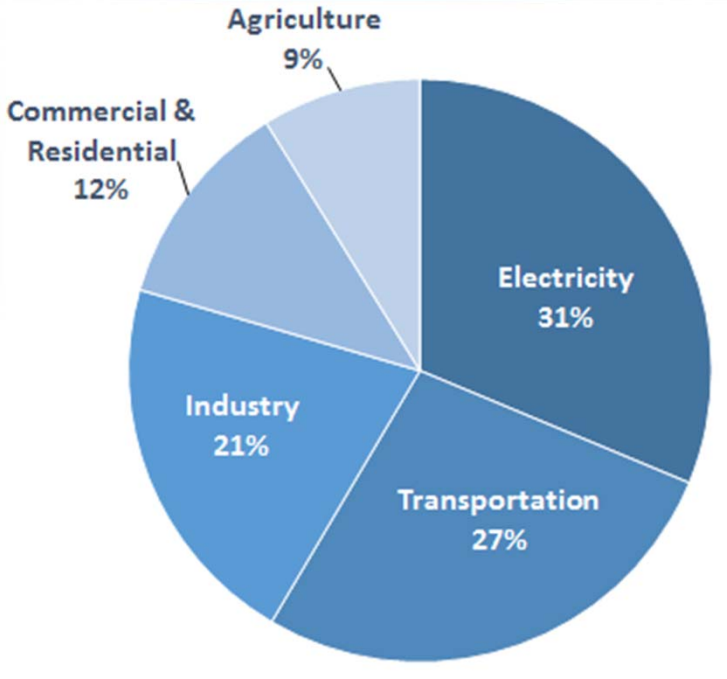
Air Quality



Climate Change

Impact of Transportation

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2013 (EPA)



<Vehicle Usage is Global>

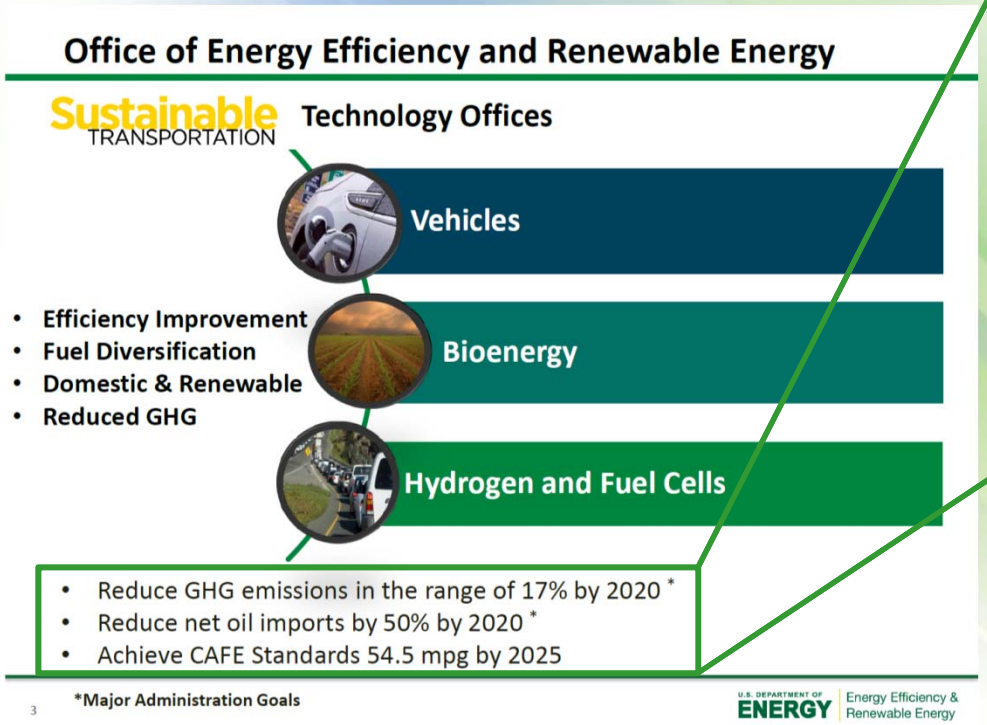
Sales:

16.5 M Sales US (2014)
5.5 M Sales Japan (2014)
11.8 M Sales EU (2014)
19.7 M Sales China (2014)

Total: 88.5 M globally

Federal Government's Response
Office of Energy Efficiency & Renewable Energy (EERE)

- **EERE is split into three areas:**
  - **I. Renewable Energy: $370M**
  - **II. Energy Efficiency: $664M**
  - **III. Sustainable Transportation: $558M**



Drivers of Technology:

- **Reduce GHG emissions by 17% by 2020**
- **Reduce net oil imports by 50% by 2020**
- **Achieve CAFE Standards 54.5 mpg by 2025**

Japan, China, EU
50+ mpg by 2020

California's Response for Advanced Transportation

State Level:

California Air Resource Board (CARB) introduced the Zero Emission Vehicle (ZEV) mandate starting in 1990 in order to:

1. **Reduce smog**
2. **Reduce greenhouse gas**
3. **Promote cleanest cars**
4. **Provide fuels for cleanest cars (electricity & hydrogen)**

California Environmental Protection Agency
Air Resources Board

- **Zero Emission Vehicle (ZEV) mandate drives sales in California**
  - **7,500 ZEVs 2012-2014; 25,000 ZEVs 2015-2017**
- **10 other states will mandate the same:**
  - **Connecticut, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Rhode Island, and Vermont**
- **ZEV credits have their own market…**

Advanced Transportation: Drivers & Gaps

<Drivers>:

- **High Level Goals at the Federal Level - DOE-EERE:**
  - **Reduce GHG emissions by 15% by 2020**
  - **Reduce net oil imports by 50% by 2020**
  - **Achieve CAFE Standards 54.5 mpg by 2025 (Others: 50+ mpg by 2020)**

- **State Level Mandates Driving Sales - CARB:**
  - **Reduce smog / reduce greenhouse gas**
  - **Promote cleanest cars / provide fuels for cleanest cars (e^- & H_2)**
  - **7,500 ZEVs between 2012 - 2014; 25,000 ZEVs between 2015 - 2017**

<Gaps>:

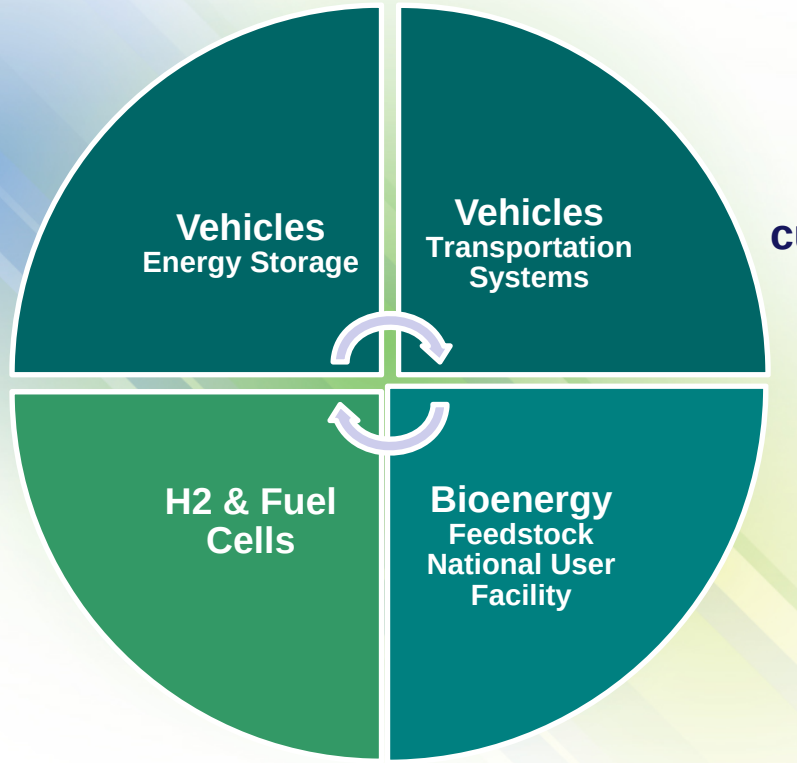
1. **Cost of vehicle is prohibitive to consumer**
2. **Vehicle does not meet the perceived needs of the consumer (range, fill-time, infrastructure accessibility, cost, convenience)**
3. **Infrastructure / fuel is cost prohibitive or does not exist**

INL's Advanced Transportation Activities

- **Attacking the key challenges of cost, consumer acceptance & infrastructure for alt-fuel vehicle mass-adoption at INL with:**
  - **Talent**
  - **Facilities**
  - **Partnerships**

Investigating next generation low cost batteries

Enabling low cost hydrogen production & grid services



Educating the customer, policy-maker, and industry

Developing next gen low-carbon / low cost fuels

INL's Advanced Transportation Activities

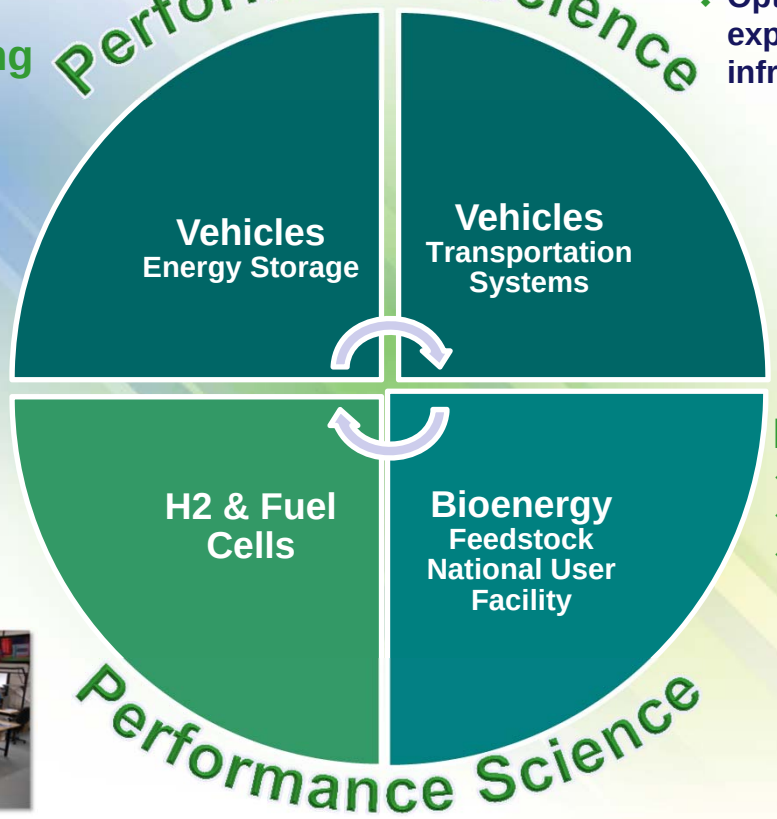
- Attacking the key challenges of cost, consumer acceptance & infrastructure for alt-fuel vehicle mass-adoption at INL with:
  - Talent
  - Facilities
  - Partnerships

Big Data

- Optimizing consumer experience w/alt-vehicles & infrastructure

Performance & Life Testing

- Cost reduction
- Performance improvements



Infrastructure

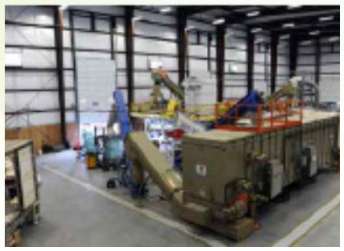
- Development of global standards

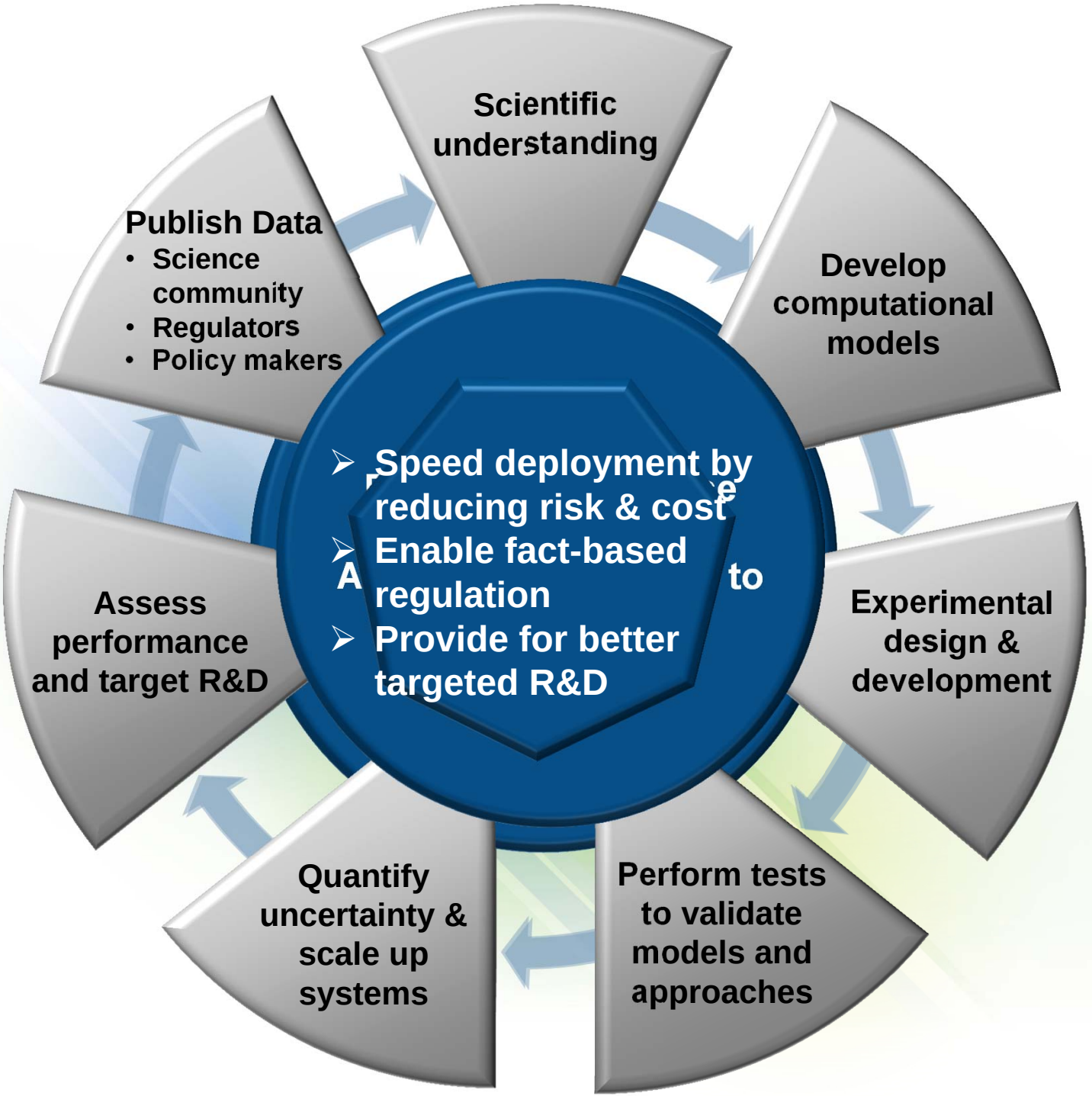
Emulation & Simulation

- Added value hydrogen production

Feedstocks

- Cost reduction
- Quality improvement
- Scale-up and integration

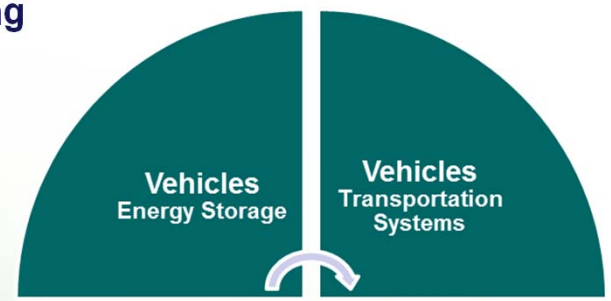


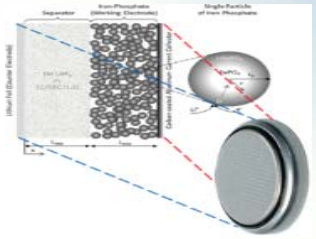

Scientific understanding
Develop computational models
Experimental design & development
Perform tests to validate models and approaches
Quantify uncertainty & scale up systems
Assess performance and target R&D
Publish Data
• Science community
• Regulators
• Policy makers
➢ Speed deployment by reducing risk & cost
➢ Enable fact-based regulation
➢ Provide for better targeted R&D

Vehicles – Energy Storage & Transportation Systems

Development of Next-Generation Low Cost / Reliable Batteries:

- **Leverage unique INL capabilities to lead Performance Science**
- **Foundation: Battery Testing Center & Advanced Vehicle Testing**
- **Growth via strong partnerships with:**
  1. **DOE-EERE (USABC)**
  2. **Automotive OEMs**
  3. **Battery Developers**
- **Impact: Enabling / accelerating next gen low cost batteries**





Half-Cell / Coin

Pouch / Cell

Pack

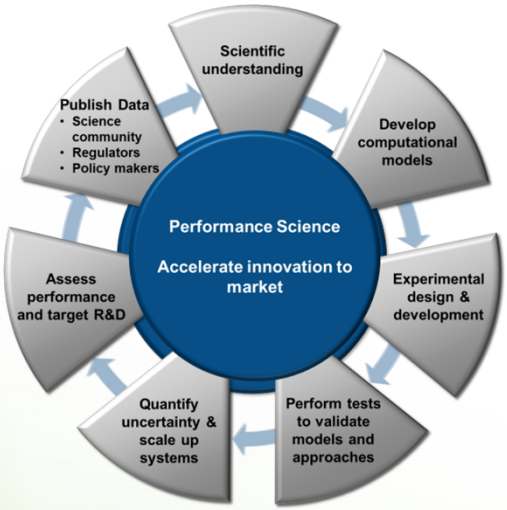
Vehicle

Performance Science: Half-Cell to Vehicle & Back

Vehicles – Energy Storage & Transportation Systems

Example of Performance Science:

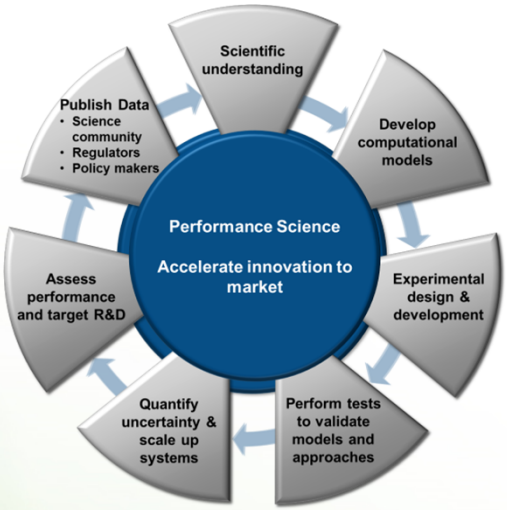
- **Battery Degradation of Level II (240V) vs. DCFC (480V)**
  - **Pre-conceived notions that DCFC would be extremely detrimental for battery durability**
- **Performance Science Based testing of vehicles on the road and in the lab**

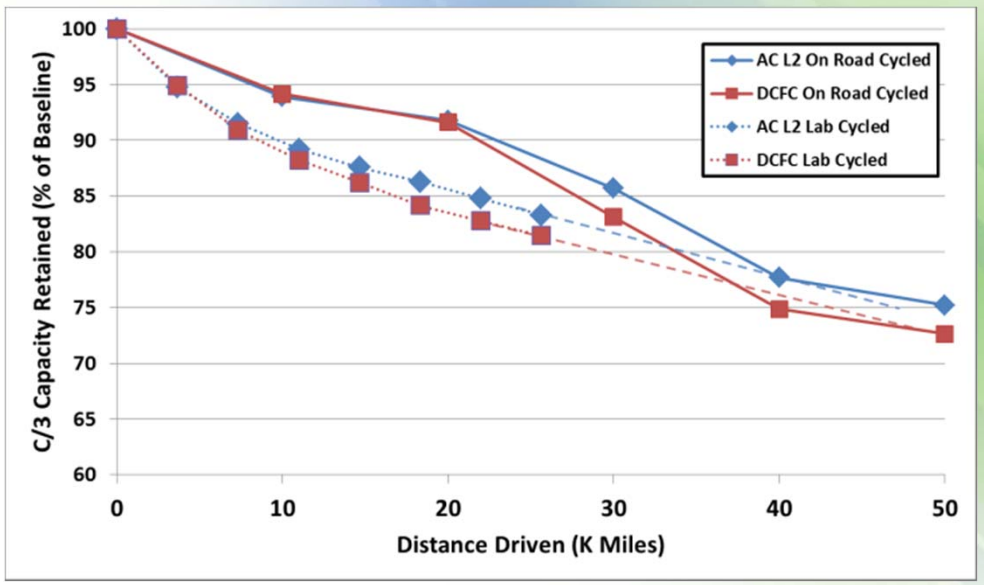


Vehicles – Energy Storage & Transportation Systems

Example of Performance Science:

- Battery Degradation of Level II (240V) vs. DCFC (480V)
- On-road and pack testing indicates otherwise…
  - High-temperatures is by far more detrimental than DCFC
- Higher return on investment on future infrastructure; new understanding, new experiments





After 50,000 miles (80,000 km):

- No appreciable difference in capacity loss (~2%) between Level II and DC Fast Charging
- On-Road cycled packs subjected to varying temperatures each period
- In-lab cycled packs cycled in constant ambient temp (30°C)
- Capacity loss rate approaches steady state in constant temperature testing

Vehicles – Transportation Systems

Enhance Consumer Experience with Alt-Fuel Vehicles:

- Leverage unique INL capabilities to lead big data analysis
- Foundation: Advanced Vehicle Testing & EV Infrastructure Laboratory
- Growth: Steward to DOE-EERE, auto OEMs, SAE & CARB
- Impact: Increasing return on investment on alt-fuel infrastructure development / deployment

Big-Data Analysis

Heat maps of EV chargers

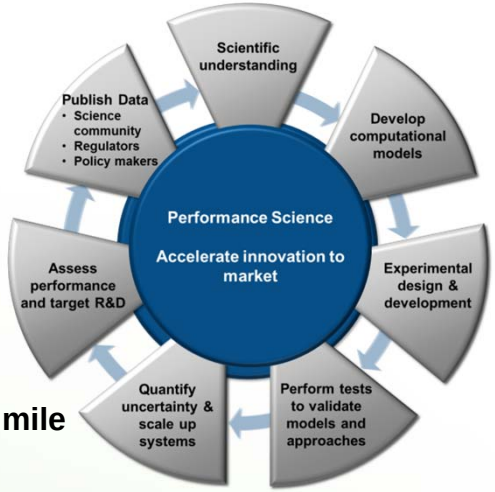
Global standardization of wireless charging with SAE & OEMs

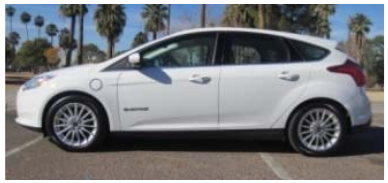
Alt-fuel corridor analysis

Vehicles – Transportation Systems

Example of Performance Science:

- **CARB ZEV credit ratios for EVs, HEVs, PHEVs, EREVs etc.**
  - **Preconceived notion that EVs should have the highest ZEV credit as it truly is zero emission (no onboard ICE)**





EV (Electric Vehicle):
Pure electric - Charged by Plugging In (no engine) – 100 mile electric range Fully ZEV

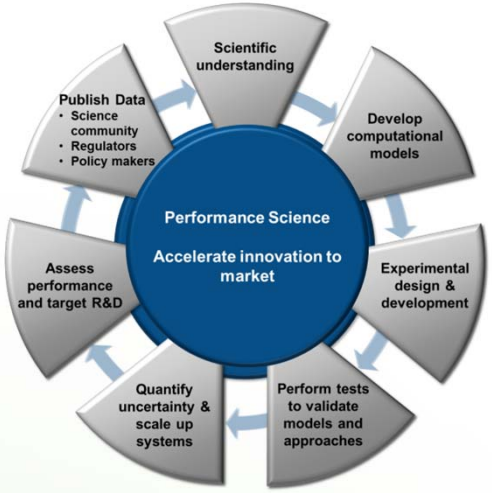
EREV (Extend Range Electric Vehicle):
Pure electric for 40 miles, then engine kicks on for extended range (series)
Partial ZEV but is it….

PHEV (Plug-in Hybrid Electric Vehicle): **Similar architecture as HEV (parallel) but battery can also be charge by plugging in (series); minimal ZEV range (10 miles) Both Partial ZEV**

Vehicles – Transportation Systems

Example of Performance Science:

- **CARB ZEV credit ratios for EVs, HEVs, PHEVs, EREVs etc.**
- **INL's data collection and analysis from EV Everywhere actually indicates EREVs eVMT (electric vehicle miles traveled) is comparable to pure EVs (PHEVs are about half)**
- **CARB may equalize ZEV credit ratios between EVs and EREVS which could potentially shift billions of auto OEM R&D dollars**



	BEV			EREV	PHEV				
	Nissan LEAF	Ford Focus Electric	Honda Fit EV	Chevrolet Volt	Ford Fusion Energi	Ford C-Max Energi	Honda Accord PHEV	Toyota Prius PHEV	Total
Number of Vehicles	4,039	2,193	645	1,867	5,803	5,368	189	1,523	21,627
Total Vehicle Miles Traveled *VMT* (miles)	28,520,792	10,043,000	4,912,920	20,950,967	33,098,000	39,376,000	1,794,494	19,772,530	158,468,703
Total Calculated Electric Vehicle Miles Traveled *eVMT* (miles)	28,520,792	10,043,000	4,912,920	15,599,508	11,572,000	12,918,000	399,412	3,224,981	87,190,613
Percent of EV-equivalent miles	100%	100%	100%	74%	35%	33%	22%	16%	
estimated Annual VMT	9,697	9,548	9,680	12,238	12,403	12,403	14,986	15,136	
estimated Annual eVMT	9,697	9,548	9,680	9,112	4,337	4,069	3,336	2,484	

Hydrogen and Fuel Cells

Providing Added Value to Hydrogen:

- Leverage unique INL capabilities and real-time data connection with NREL to provide higher value grid services – H_2 or e^- for grid / vehicle
- Foundation: Fuel Cell Technology Office
- Growth: EERE Advanced Transportation & Nuclear Energy (leverage Hybrid ES)

H2 & Fuel Cells

SOFC

e- heat

Thermal

Real-time Hardware-in-the-loop (HIL) Emulation & Simulation between INL and NREL

Renewable

e-

PEMFC

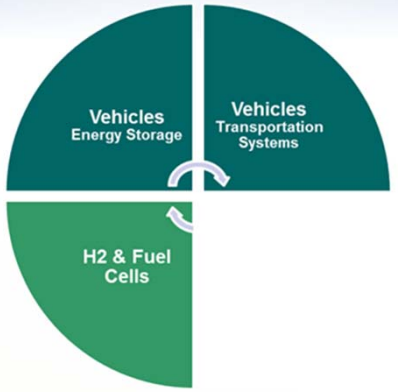
e- H_2

Fuel Cell Electric Vehicles

Electric Vehicles

e- H_2

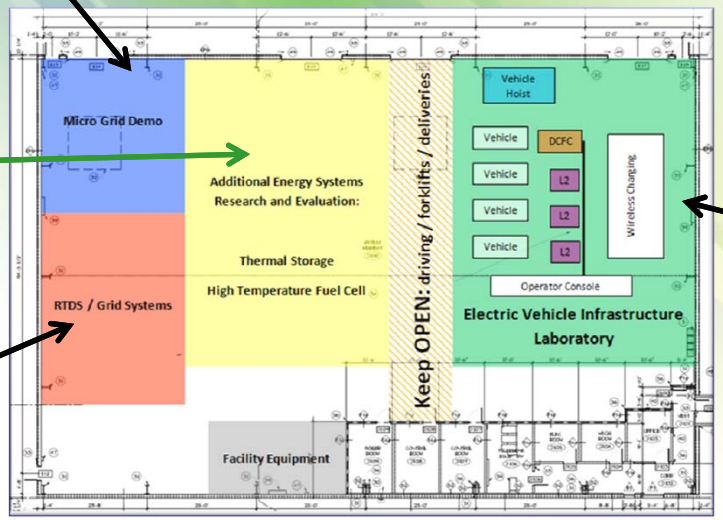
Cross-cut EERE & Nuclear Energy



Leveraging Existing Data Connection:

- **Fully Integrated ESL Facility with hydrogen production, storage, distribution, and bus fleet to "the site"**
- **Energy systems performance science evaluation of the following technologies:**
  - **Energy storage (Li-ion, flow-cell, super-caps, flywheels, FCs), vehicles (EV, FCEV) and grid (solar, wind & nuclear)**
- **Impact: Clean Grid, Clean Vehicles / Clean Federal Fleet**

RTDS



Bioenergy – Biofuels

Feedstock Performance Science

- Leverage unique INL capabilities to lead feedstock Performance Science
- Foundation: Lead feedstock RD&D for EERE Bioenergy office
- Growth: Expanding industry impact through National User Facility
- Impact: Risk reduction to pioneer refineries, advanced technologies for expanding the market

Bioenergy – Feedstock National User Facility

Supply & Logistics

Preprocessing (EERE Bioenergy Core Competency)

Process Demonstration Unit (PDU)

Performance Characterization

- Biomass Characterization Lab
- Biomass Library

Cost, Quality & Sustainability Analysis

Advance Sustainable Transportation

- **With stretch targets to reduce greenhouse gas emission, improve CAFE mileages, and decrease dependency on foreign oil; alt-fuel vehicles (electric, biofuel, hydrogen) will continue to be developed regardless of the commodity price of oil**

- **Gaps towards achieving these targets are primarily around the cost of the alt-fuel vehicle, its corresponding infrastructure / fuel and customer education**

- **INL is attacking these gaps across our Advanced Transportation Activities**

- **Performance Science approach to:**
  - **Reducing battery costs / electrified power-trains**
  - **Educating consumers with alt-fuel vehicles and their respective infrastructure**
  - **Adding grid services via hydrogen production**
  - **Analyzing and modeling of alt-fuel infrastructure**


INL
Idaho National Laboratory