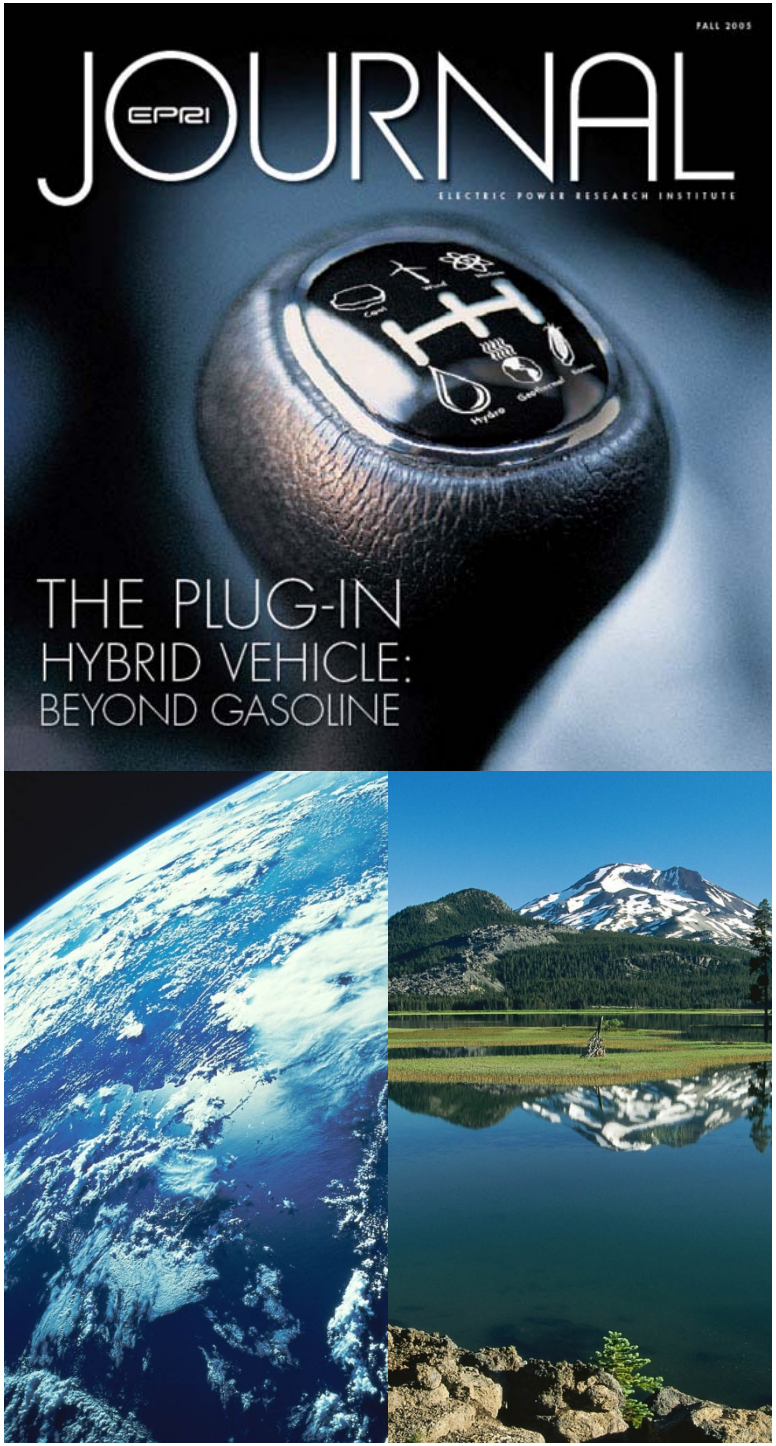

ELECTRIC POWER RESEARCH INSTITUTE

Plug-In Hybrid Electric Vehicles – Utility Perspective

Mark Duvall

Transportation Research Board Meeting

Washington, D.C.

January 22, 2007

Overview

- EPRI plug-in hybrid objectives
- PHEV research, development, and demonstration programs
- Energy storage for plug-in hybrids
- Environmental and electric sector analyses
  - Greenhouse gases
  - Air quality
  - Electric sector impact
- Intelligent charging infrastructure

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Tomorrow Has Arrived
(Now what do we do?)

GM Volt

Ford Airstream

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PHEV Status – Present

- GM and Ford showcase Plug-in Hybrid Technologies
- Initiation of DOE PHEV R&D Program
- Multiple, significant public announcements of interest by several other major OEMs
- Beginning of first public PHEV demonstration by a major OEM (DaimlerChrysler PHEV Sprinter Van)
- Strong bi-partisan political support for PHEV development
- Re-emerging utility interest in electric transportation

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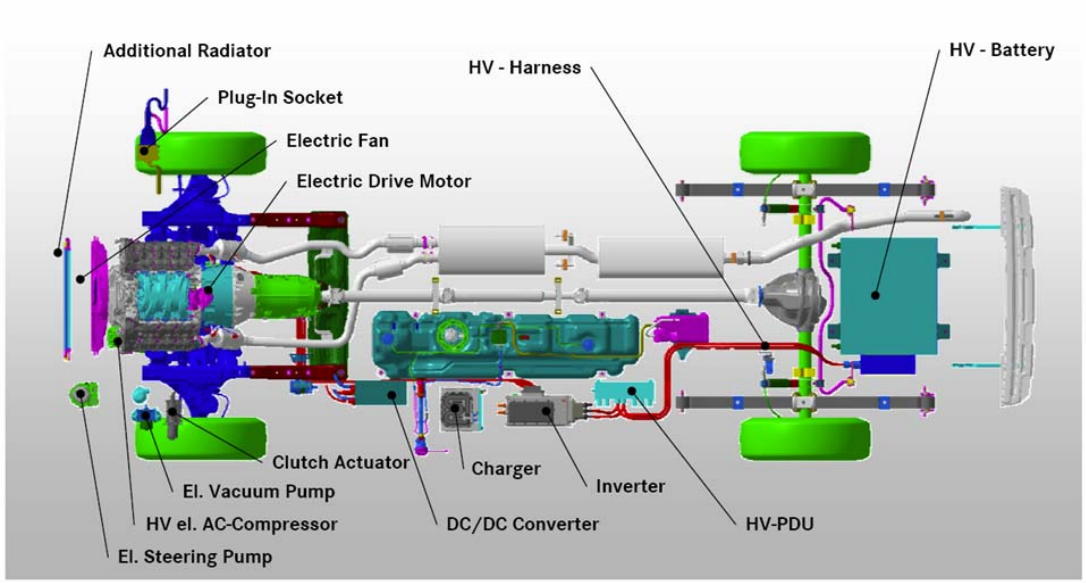
PHEV Dodge Sprinter Program

- Plug-in hybrid commercial van
- 20 miles all-electric range (urban)
- Li Ion battery
- EPRI/DCX collaboration (Utility & public support)



- Several locations (CA, NY, TX, NJ, AL, KC, etc)
- Extensive vehicle test, data collection and analysis program

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PHEV F-550 Trouble Truck

- Eaton, Ford, EPRI, Utilities, AQMD
- PHEV system for Class 3,4,5 commercial trucks and vans
- Phase 1 – 4 prototype vehicles demonstrated in utility fleets (2007)
- Phase 2 – 50 vehicles for utility, public fleets, F550 chassis + E450 van chassis

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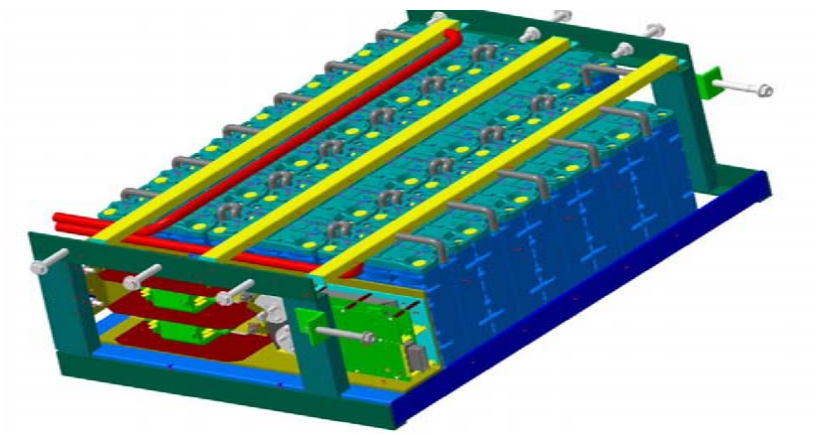
Advanced Battery Challenge

- Key questions are cycle life, and cost/availability of energy batteries for PHEVs
- Current durability test data shows potential for current advanced batteries to meet cycle and calendar life requirements
- Need to understand recent innovations in Li Ion field on cycle life durability, wide-temperature range operation, low cost materials
- Ongoing sub-pack testing augmented by full pack tests of JCS (DOE-provided)



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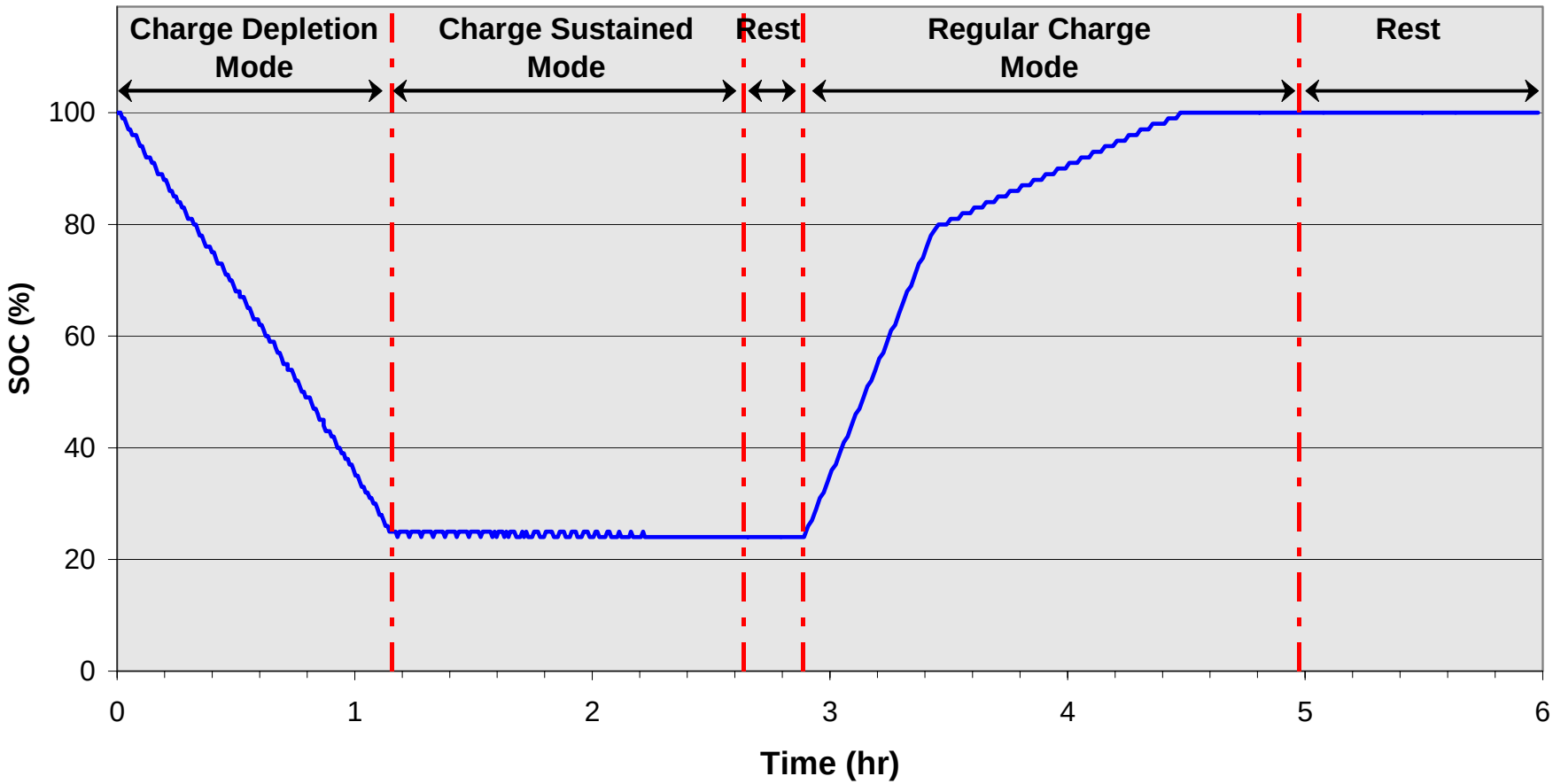
Actual Test Profile



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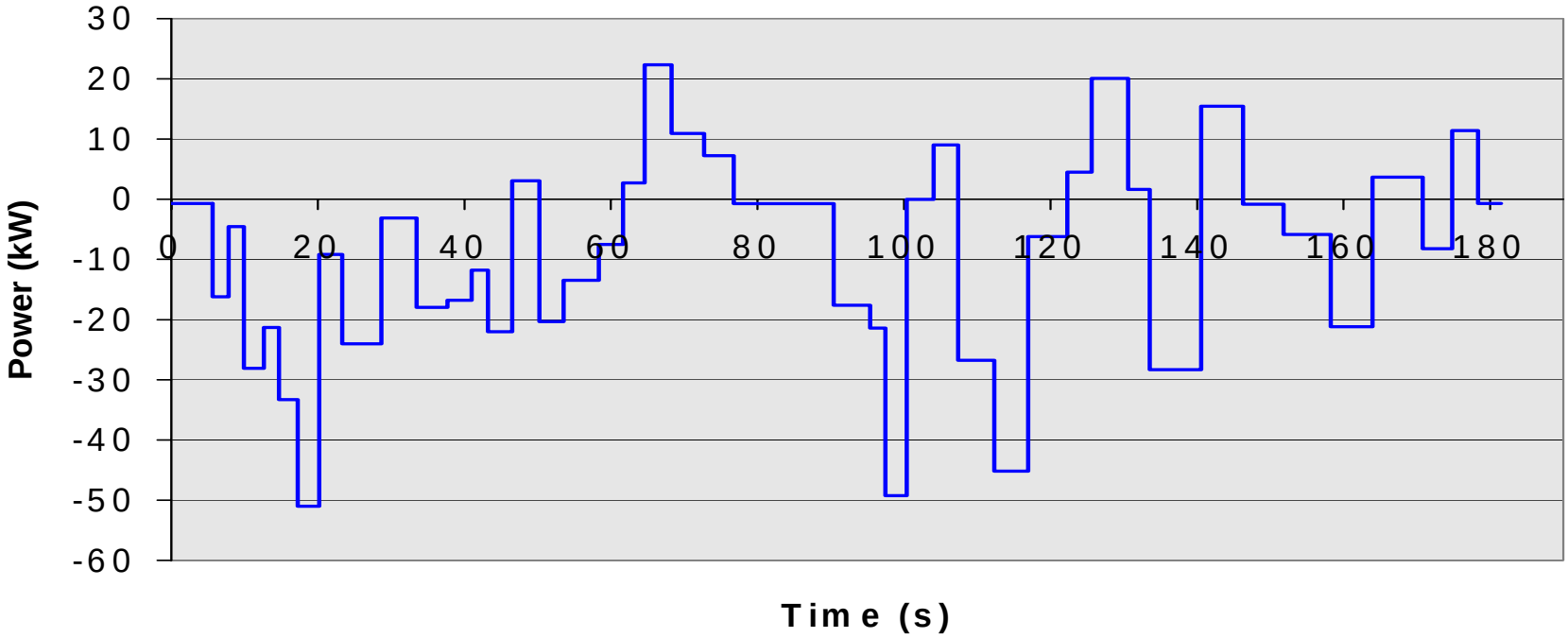
Charge Depletion Mode



- 180 sec test cycle
- Run from 100% SOC down to approximately 25% SOC
- Mode ends when the battery voltage stays below a pre-defined threshold for more than 10 sec

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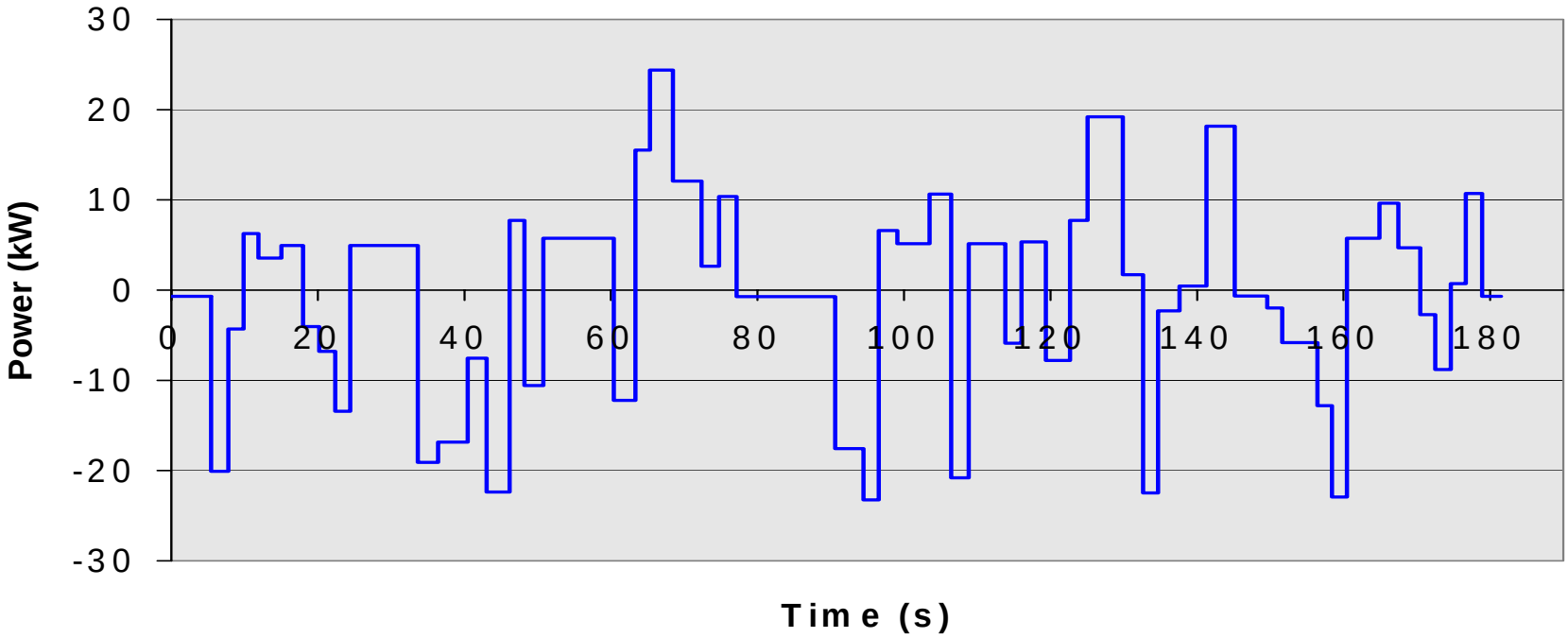
Charge Sustained Mode



- 180 sec test cycle
- Run at approximately 25% SOC
- Mode ends when the duration of the charge depletion mode plus the duration of the charge sustained mode reaches 2.6 hours

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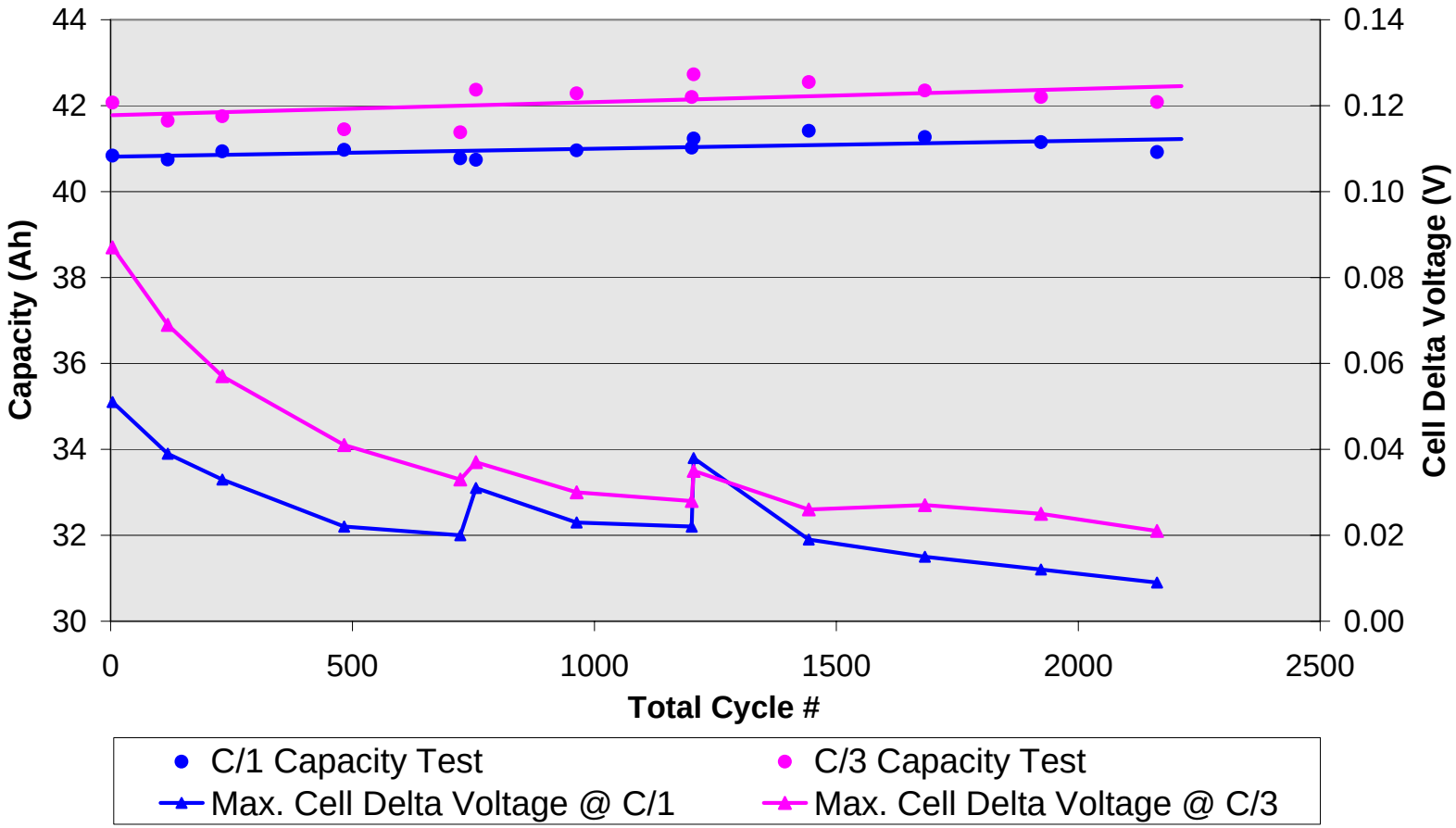
Project Status

- VARTA NiMH Battery (DNP2)
  - Battery went through **2280** cycles – 21.5 Months
  - No significant capacity degradation
  - ~ 10% of power degradation

- SAFT Li-Ion Battery
  - Battery went through **1790** cycles – 18.5 Months
  - ~ 6% of capacity degradation
  - ~ 5% of power degradation

VARTA – Capacity Test Results



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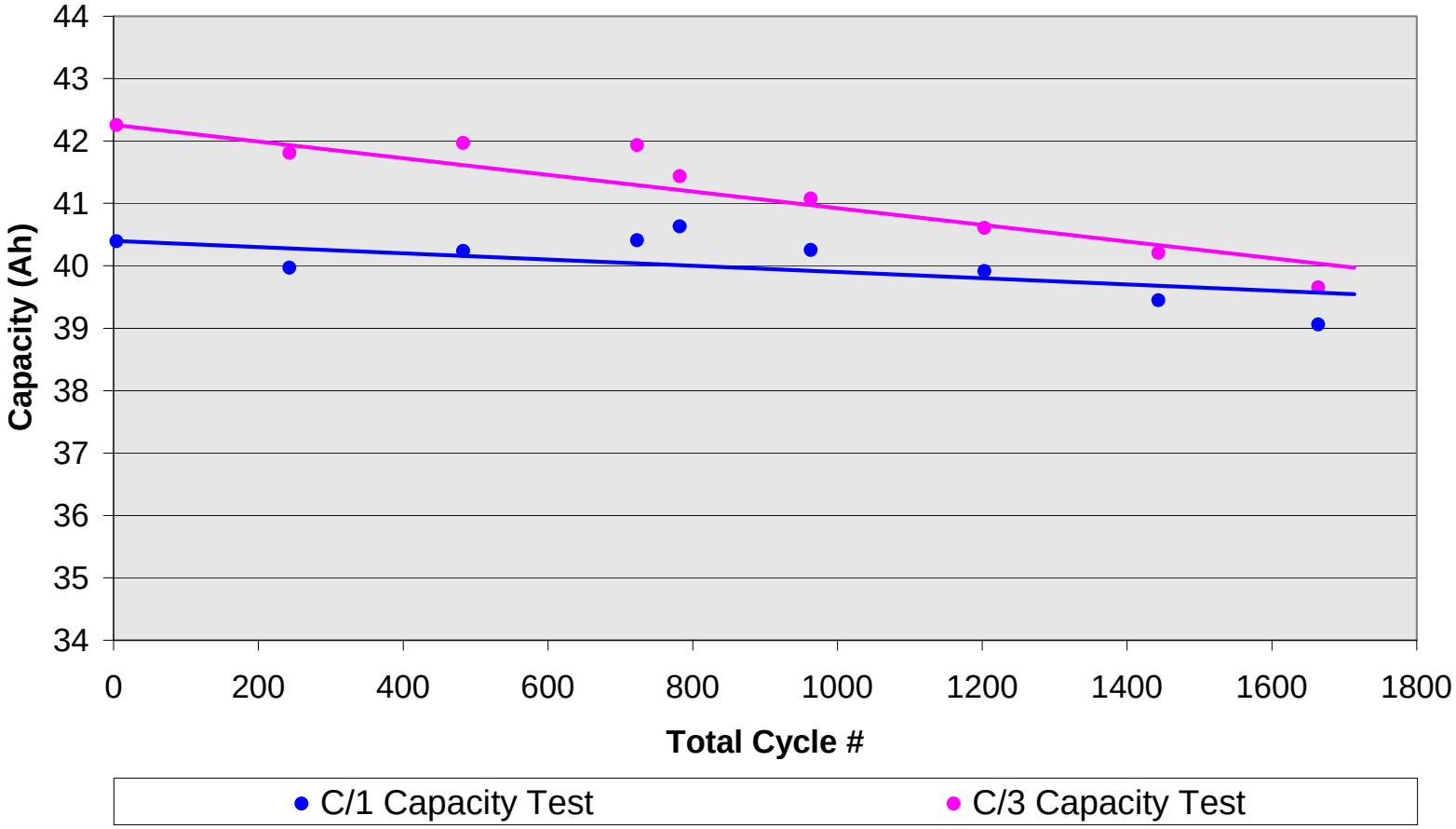
SAFT – Capacity Test Results



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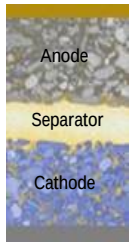
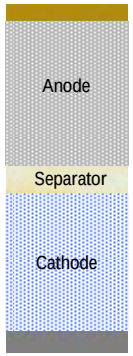
Seven Potential Areas for Nanotechnology Impact

1. Battery life—deep cycle durability
2. Specific energy
3. Specific power—dramatically reduce cell impedance
4. Environmental performance
   - Greater temperature range
   - Lower cooling requirements
5. Safety
6. Facilitate adoption of new materials/chemistries
7. Lower cell cost

Electrode Thickness	
Standard Li Ion	A123 Doped Nanophosphate Li Ion
Thin (20 micron particles) 	Thick (100nm particles) 

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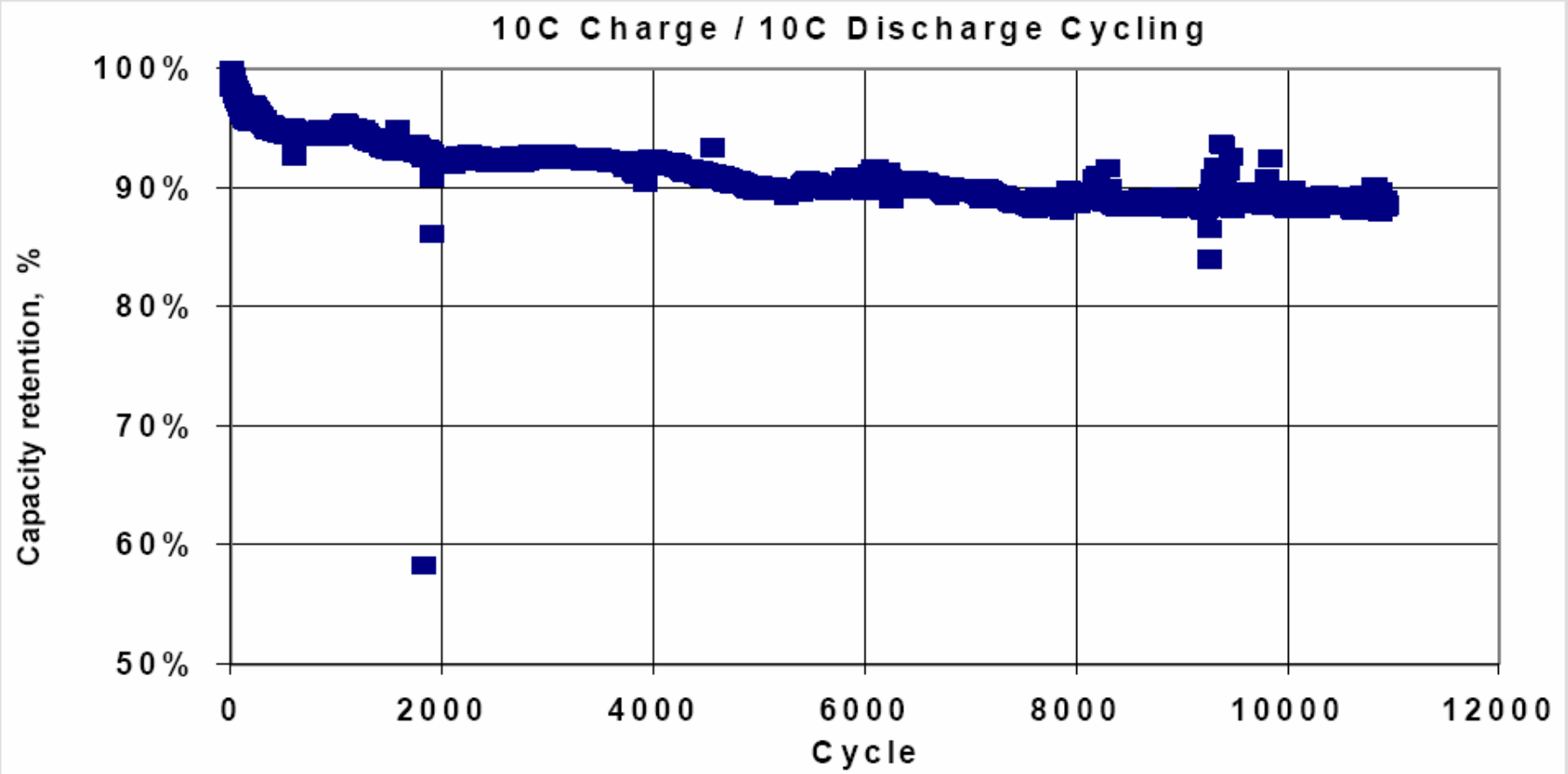
NanoSafe Cycle Life

Altairnano
innovation at work

Common Li-Ion Capable of ~750 Cycles at C/2 Rate



Altair = Over 15 Times the Cycle Life at 20 Times the Rate

Initial Findings

- Existing Li Ion batteries showing exceptional performance against PHEV requirements—outlook is positive
- Industry innovation—rapid development of new chemistries or incorporation of new materials
- Innovation is accelerating—battery companies are developing nano-structured materials for production batteries (A123)
- Altair has developed a nano lithium titanate chemistry with high power and inherent safety (no carbon anode, no metallic lithium)
  - Show test data of > 10,000 100% cycles (5,000 current industry stretch goal).
  - Useful operating range of -30C to 65C
  - Specific energy is lower than typical Li-Ion, but usable lifetime energy far greater.
- Outlook promising—however more data needed to quantify performance against full range of PHEV requirements

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Impacts of Electricity as an Alternative Transportation Fuel

- Many drivers in the utility industry
  - Regulation
  - Fuel cost
  - Infrastructure
  - Capital costs
- Generating portfolio varies widely by region
- There is no simple answer
- Must examine the details very closely

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Environmental and Electric Sector Study

- Complex problem
- Must consider simultaneous evolution/progression of both transportation and electric sectors
  - E.g., track PHEV market share with expected electric sector evolution to 2030 (or beyond)
- Marginal analysis via production simulations
  - Scenarios to track different electric sector constraints
    - GHG costs/constraints, fuel prices, generating technologies
- Air quality modeling
  - Temporal and geographic distribution of emissions different from base case to PHEV case

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Scope and Methodology Air Quality Task

- **National and California/Ohio Analysis**
- **Two Scenarios in 2030:**
  - 0% and ~50 % PHEV market (new) penetration
  - Includes all current EPA regulations:
    - Clean Air Interstate Rule, Clean Air Mercury Rule, Clean Air Non-Road Diesel Rule, Clean Highway (Heavy Duty) Diesel Rule, etc.
  - Model power-plant emissions using North American Electricity and Environment Model (NEEM)
  - Full-year air quality analysis using EPA CMAQ model
    - Outputs:
      - O_3, $PM_{2.5}$, $PM_{10\text{-}2.5}$, Hg, VOC, NOx, SO_2
      - Deposition: Hg, NH_4^+, NO_3^-, SO_4^{2-}
      - Visibility in Class I Areas (e.g. National Parks)

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Scope and Methodology Air Quality Task

- **National and Focused California/Ohio Analysis**
  - **Phase I:**
    - Consistent with U.S. Department of Energy's 2006 Annual Energy Outlook (AEO) and California Electricity Commission's 2005 Integrated Energy Policy Report (IEPR)
    - Reflects a generation mix in the absence of any national or state greenhouse gas policies
  - **Phase II**:
    - Second phase will look at a scenario that is consistent with a generation portfolio that includes greenhouse gas abatement policies.
    - Expand focused air quality analysis to other regions

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Scope and Methodology Air Quality Task (Phase I)

- **Principal Assumptions Beyond AEO 2006 and 2005 IEPR**
  - Project Clean Air Visibility Rule emissions developed by Regional Planning Organizations for 2018 to 2030
    - Develop mobile source emissions for Base Case (no-PHEV) Scenario and PHEV Scenario
      - Includes all EPA and CARB regulations
    - Develop EGU emissions from NEEM modeling
      - Includes all EPA regulations
    - Assume that for all other emissions technology improvements offset emissions growth, i.e. emissions remain at 2018 levels
    - Special consideration for non-EGU point sources in Southern California

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Scope and Methodology Air Quality Task (Phase I)

Additional Consideration in NEEM Modeling

- New Source Review
- Regional Clean Air Incentives Market (RECLAIM)
- New Transmission Intertie Capacity
- Renewable Portfolio Standards (RPS)
- California Million Solar Roofs Initiative

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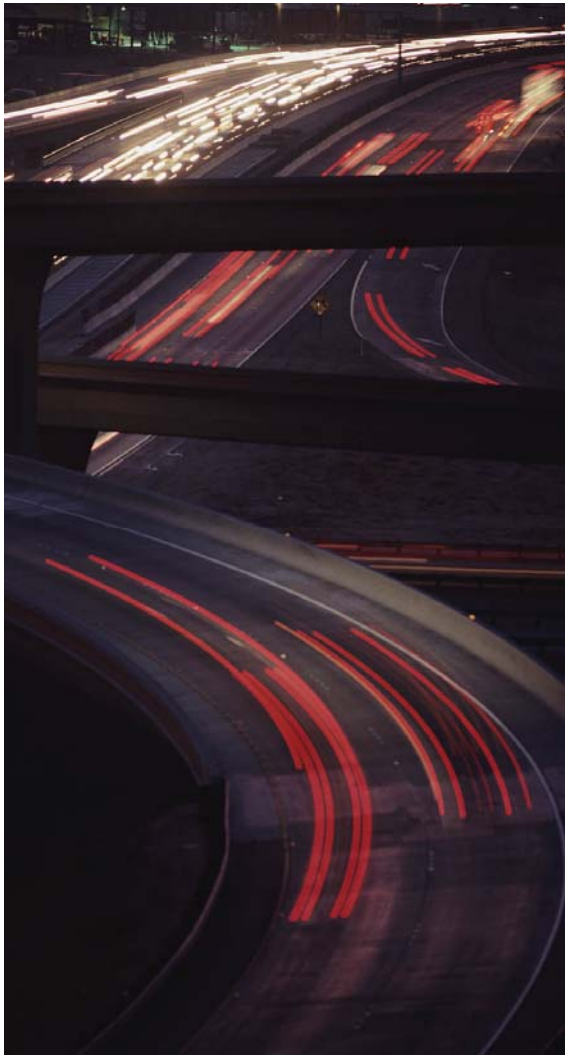
Scope and Methodology Air Quality Task (Phase I)



- **Key Transportation Assumptions**

- 2030 Base Case (no-PHEV) scenario
  - EIA-consistent assumptions
  - Vehicle growth in vehicles miles traveled (VMT)
  - Fleet turnover

- 2030 PHEV scenario
  - ~30% Vehicle Penetration by 2030
    - ~14% of VMT provided in all-electric mode
    - Additional benefits from lower upstream (refinery, transport, storage, refueling evaporative, spillage) emissions per VMT

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Scope and Methodology Climate Task

- Nationwide CO_2 analysis
  - Based on EPRI electric system model (NESSIE)
  - Expanded scenario matrix
    - High, medium and low carbon intensity electric generation portfolios
      - Additional scenario consistent with air quality task
    - Different transportation sector & PHEV technology/adoption scenarios
    - 2010 to 2050 timeframe
  - Primary outputs:
    - CO_2 emissions
    - Generation mix
    - Fuel usage

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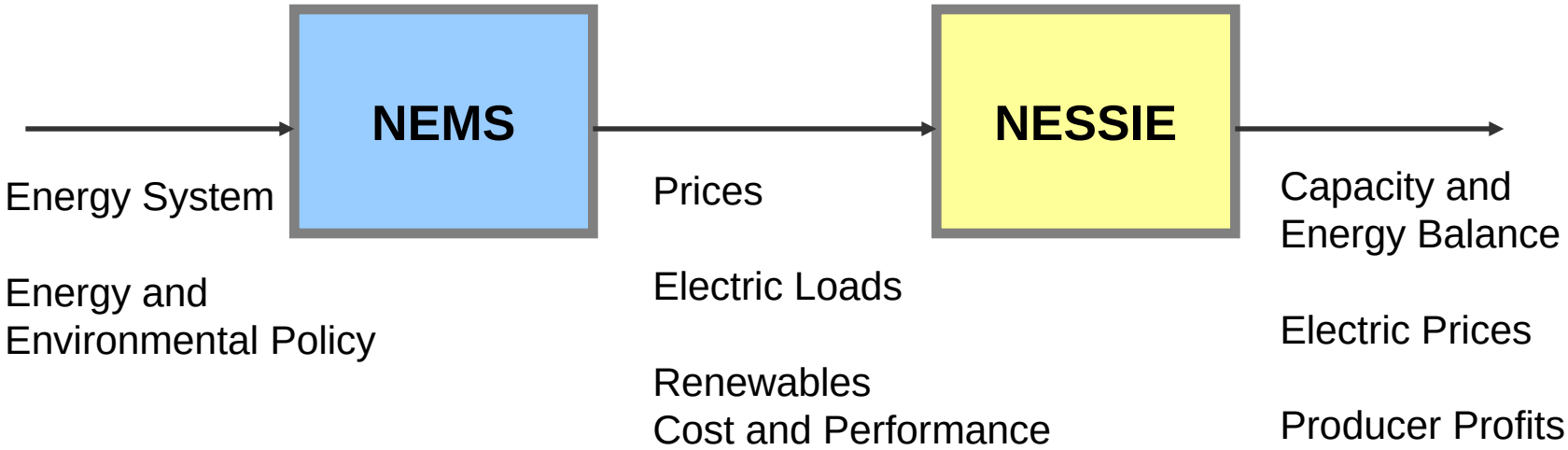
CO_2 Analysis Background & Objectives

- Understand the value of the PHEV technology
  - CO_2 emissions
  - Gasoline consumption

- Understand the impact of the PHEV on the electric system



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Methodology – Evolution of the Electric System Over Time

- Capacity is added to serve new load plus retirements
- Technology economics reflect all costs, **including the monetized value of the right to emit CO2**
- California tracked carefully
  - 20% renewable energy by 2010
  - No coal except IGCC with CO2 capture and sequestration
  - No nuclear until 2020

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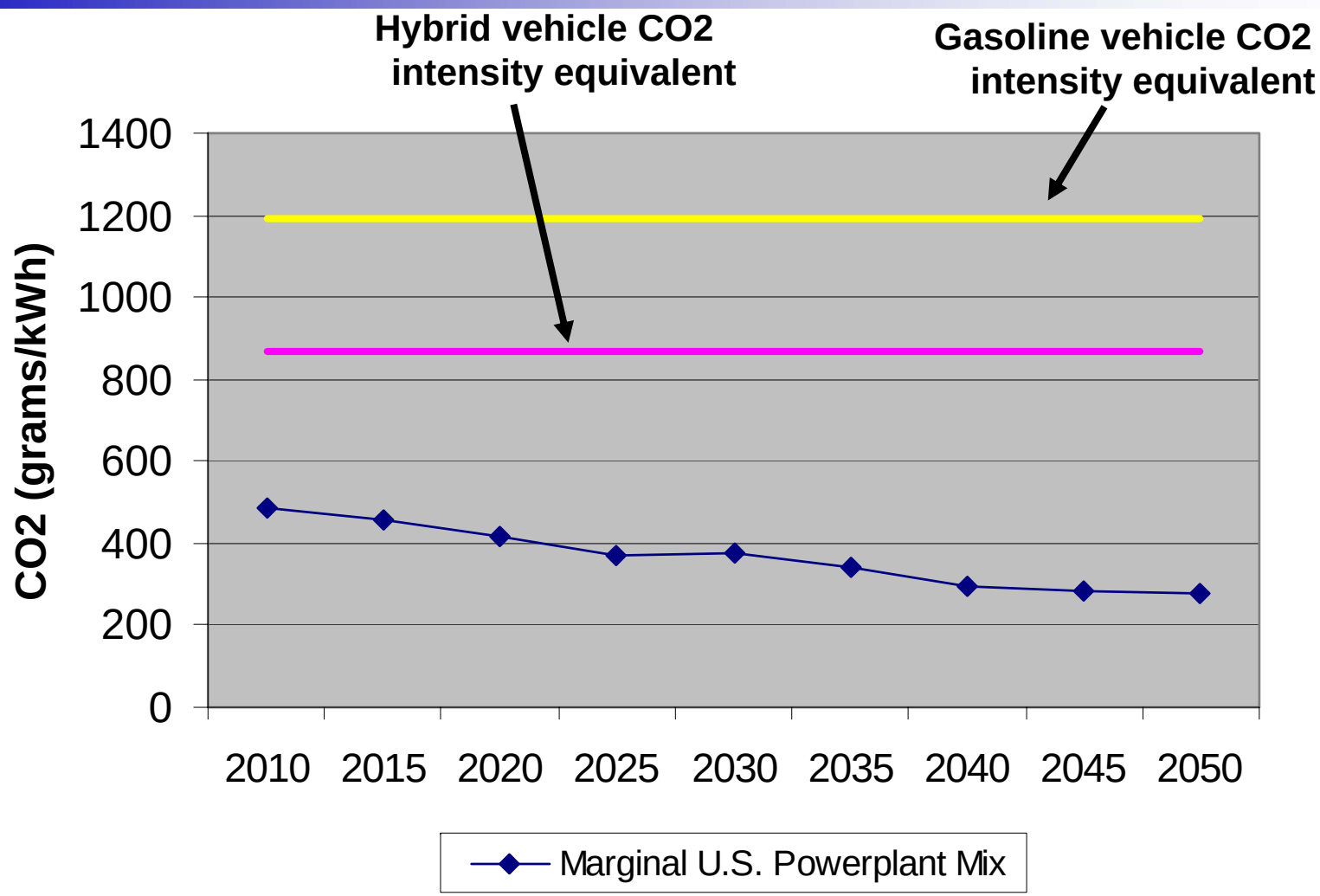
Preliminary National CO2 Results Versus HEV and ICE Breakeven



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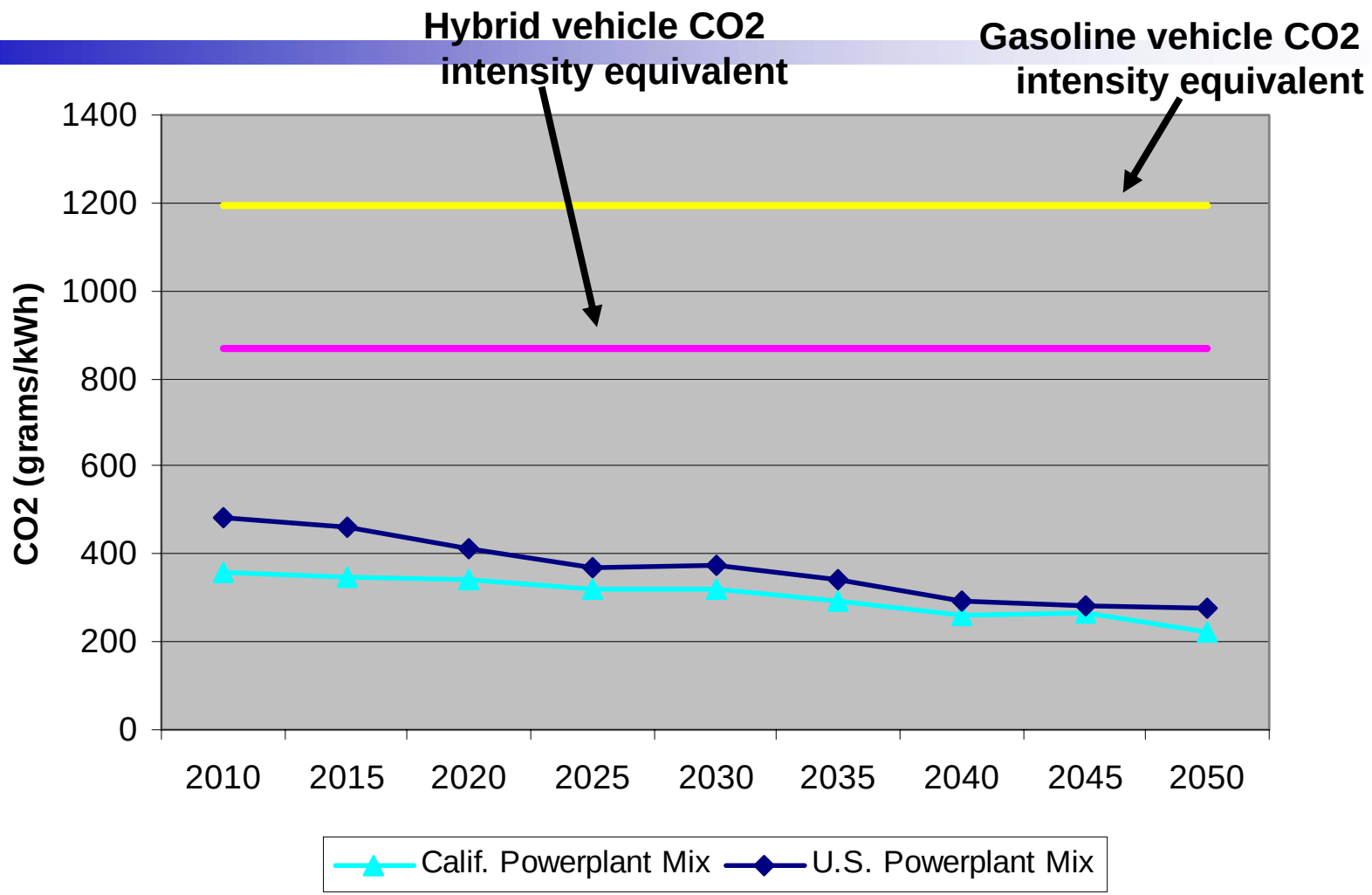
Adding California to the National Results



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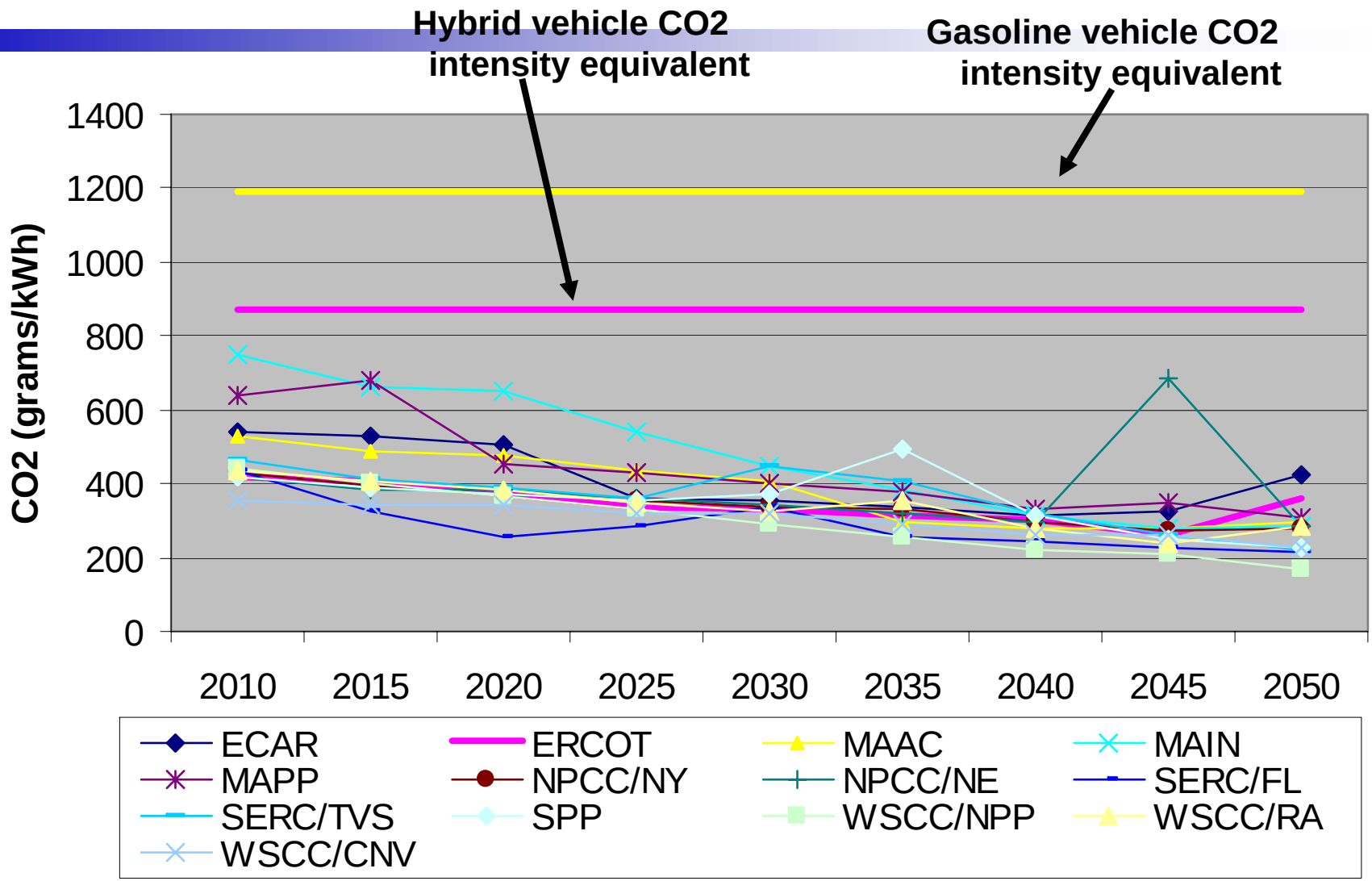
Results for a Number of Regions



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Summary – CO2

- Detailed modeling of the electric system shows a true picture of the CO2 impacts of PHEVs.
- The electric system is getting less CO2 intensive over time.
- On a national basis PHEVs can save a large fraction of the CO2 emissions on the all electric range of the vehicle.
- The California grid is marginally cleaner that the national average, and also offers the potential for saving CO2.
- The impacts on the grid are not significant.

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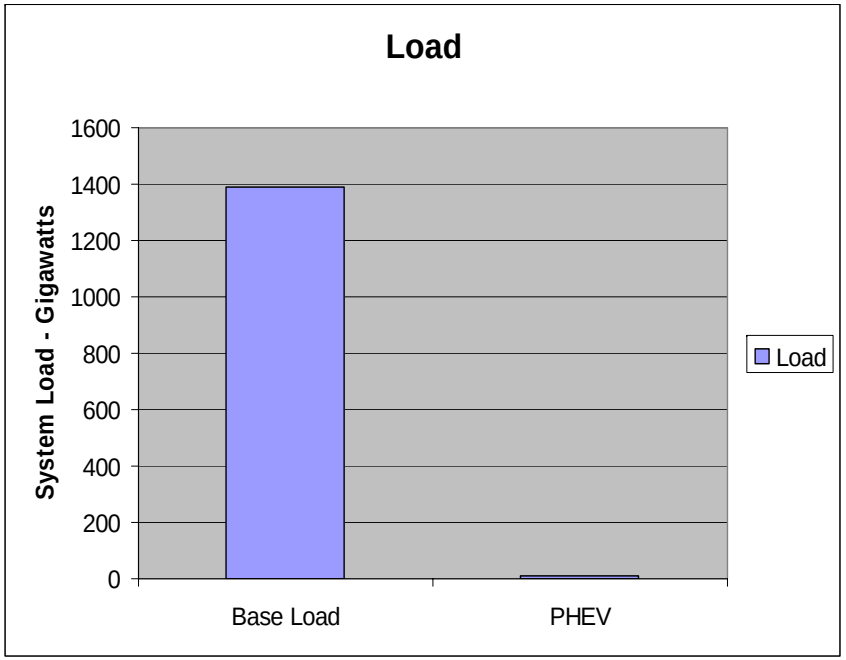
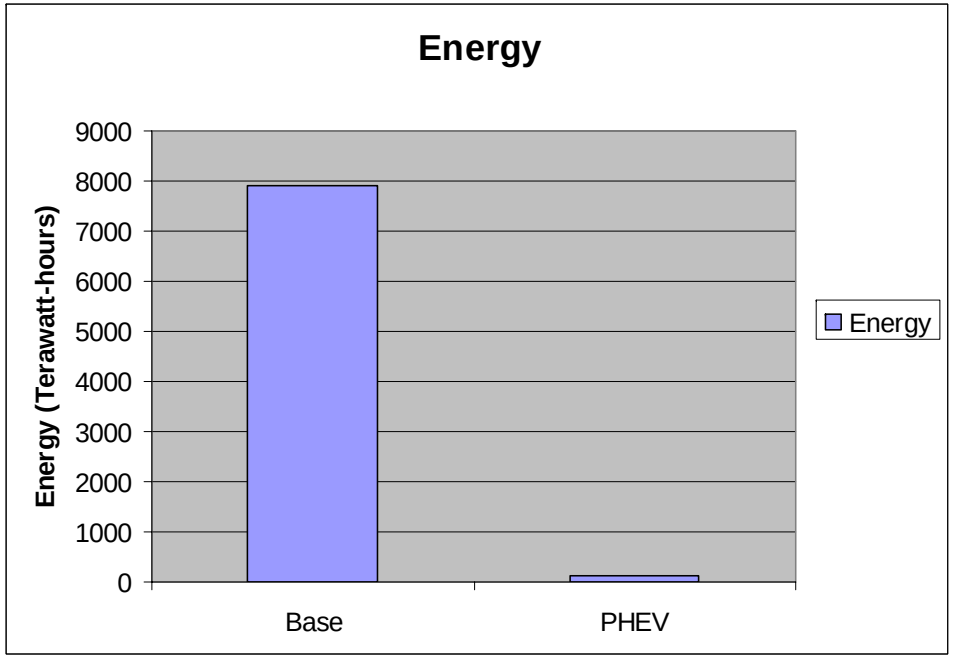
Impact of PHEVs on the Electric System





Peak demand increases 0.75% in 2050.

Energy increases 1.7% in 2050.

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Charging Infrastructure

- Plug-in hybrids require relatively low power charging
- Wide availability of infrastructure
  - Initial focus on private chargers
- Array of options
  - 120 VAC, 15 amp (~1.4 kW)
  - 120 VAC, 20 amp (~2.0 kW)
  - 208/240 VAC, 30 amp (~6 kW)
- 120 VAC strongly preferred due to cost, availability

PHEV 20 Vehicle	Pack Size	Charger Circuit	Charging Time 20% SOC
Compact Sedan	5.1 kWh	120 VAC / 15 A	3.9 – 5.4 hrs
Mid-size Sedan	5.9 kWh	120 VAC / 15 A	4.4 – 5.9 hrs
Mid-size SUV	7.7 kWh	120 VAC / 15 A	5.4 – 7.1 hrs
Full-size SUV	9.3 kWh	120 VAC / 15 A	6.3 – 8.2 hrs

1.2 – 1.4 kW power, 1 or 2 hours conditioning

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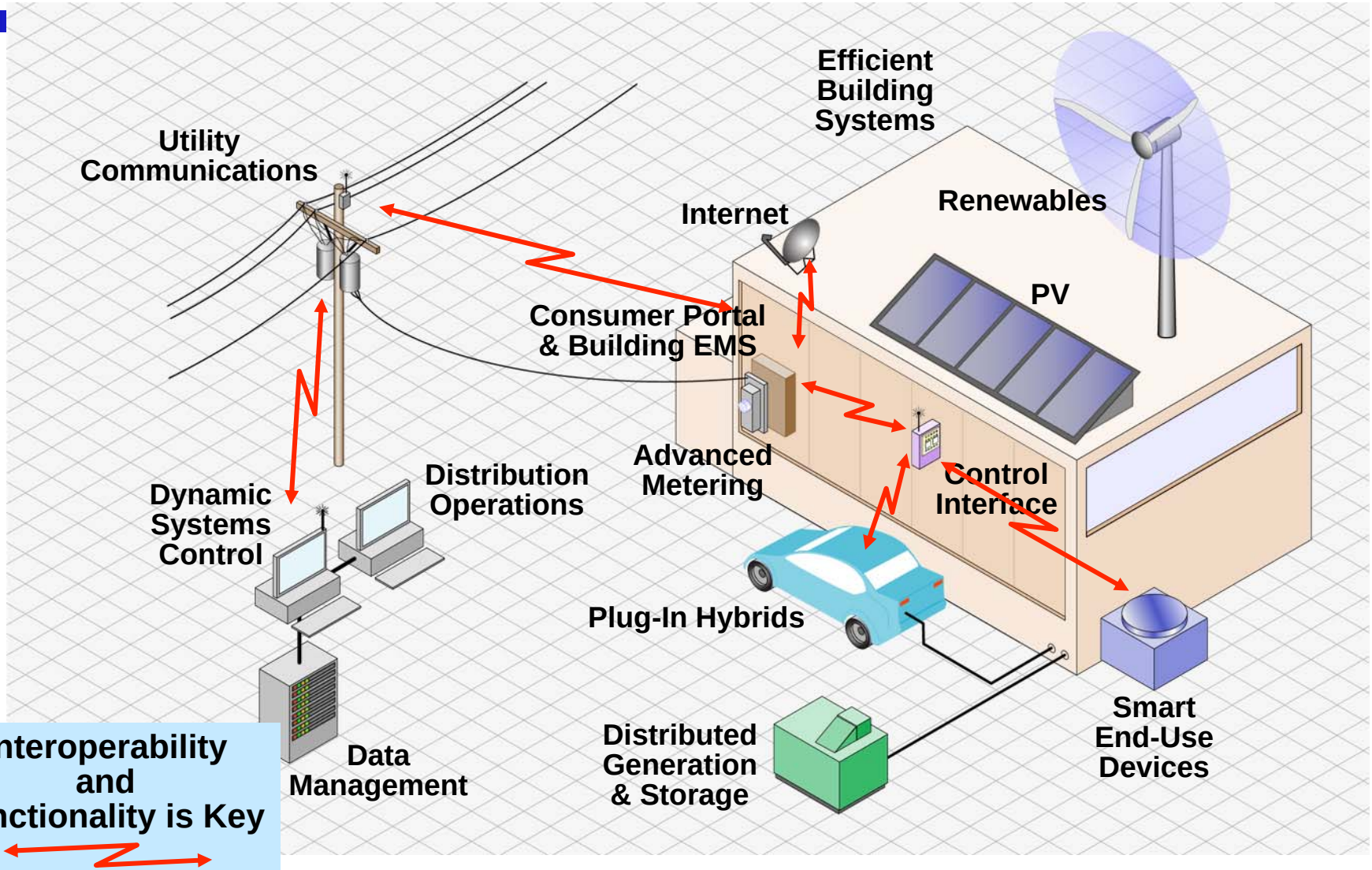
Future Intelligent Infrastructure Enabling PHEV and Consumer Choice



Interoperability and Functionality is Key

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Summary Thoughts

- Plug-in hybrids – now at the same stage as other historical technologies that “almost made it”.
- Public & political support is strong
- Industry and utility support growing
- Some needs:
  - Vehicles on the road – OEM/utility/public RD&D programs
  - Continue battery and powertrain system advances
  - Stakeholder collaboration on certification
  - Consensus on PHEV environmental characteristics

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