A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy

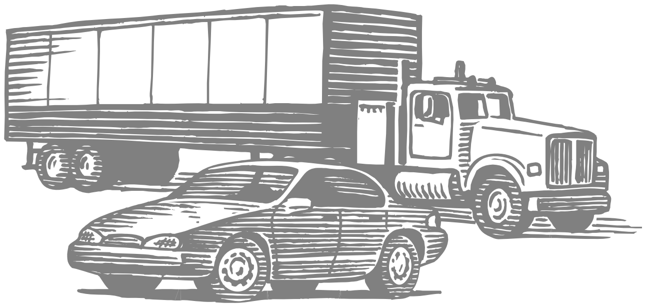
NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

Cost-Benefit Analysis of Plug-In Hybrid-Electric Vehicle Technology

22nd International Electric Vehicle Symposium
Yokohama, Japan
October 25-28, 2006

Ahmad Pesaran for
Andrew Simpson and Tony Markel
Tony_Markel@nrel.gov
National Renewable Energy Laboratory



With support from the
Lee Slezak
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
FreedomCAR and Vehicle Technologies Program

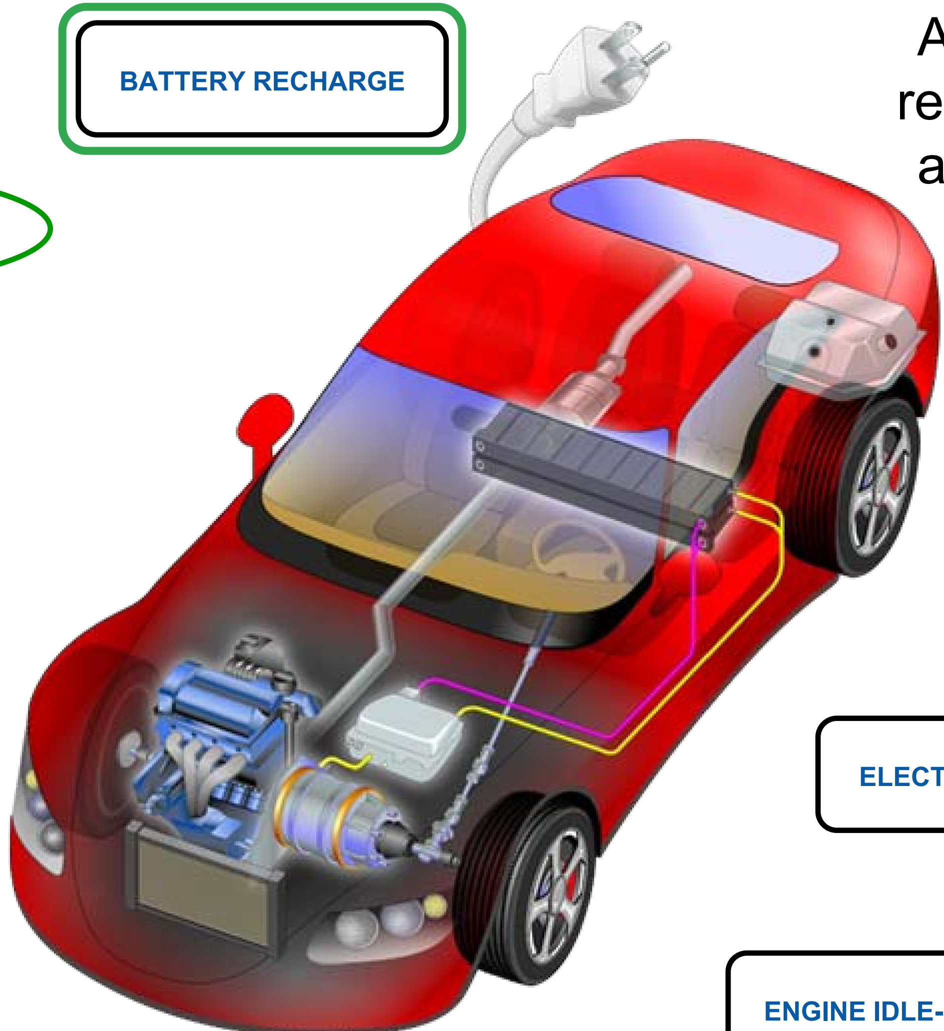
NREL/PR-540-40847

Presentation Outline

- Plug-in hybrid-electric vehicle (PHEV) as a solution
- Potential petroleum reduction from PHEVs
- Simulation of PHEV efficiency and cost
  - Baseline vehicle assumptions
  - Powertrain technology scenarios
  - Components models (cost, mass, efficiency)
- Results
  - Component sizing
  - Fuel Economy
  - Incremental cost
  - Payback scenarios
- Conclusions & Next Steps

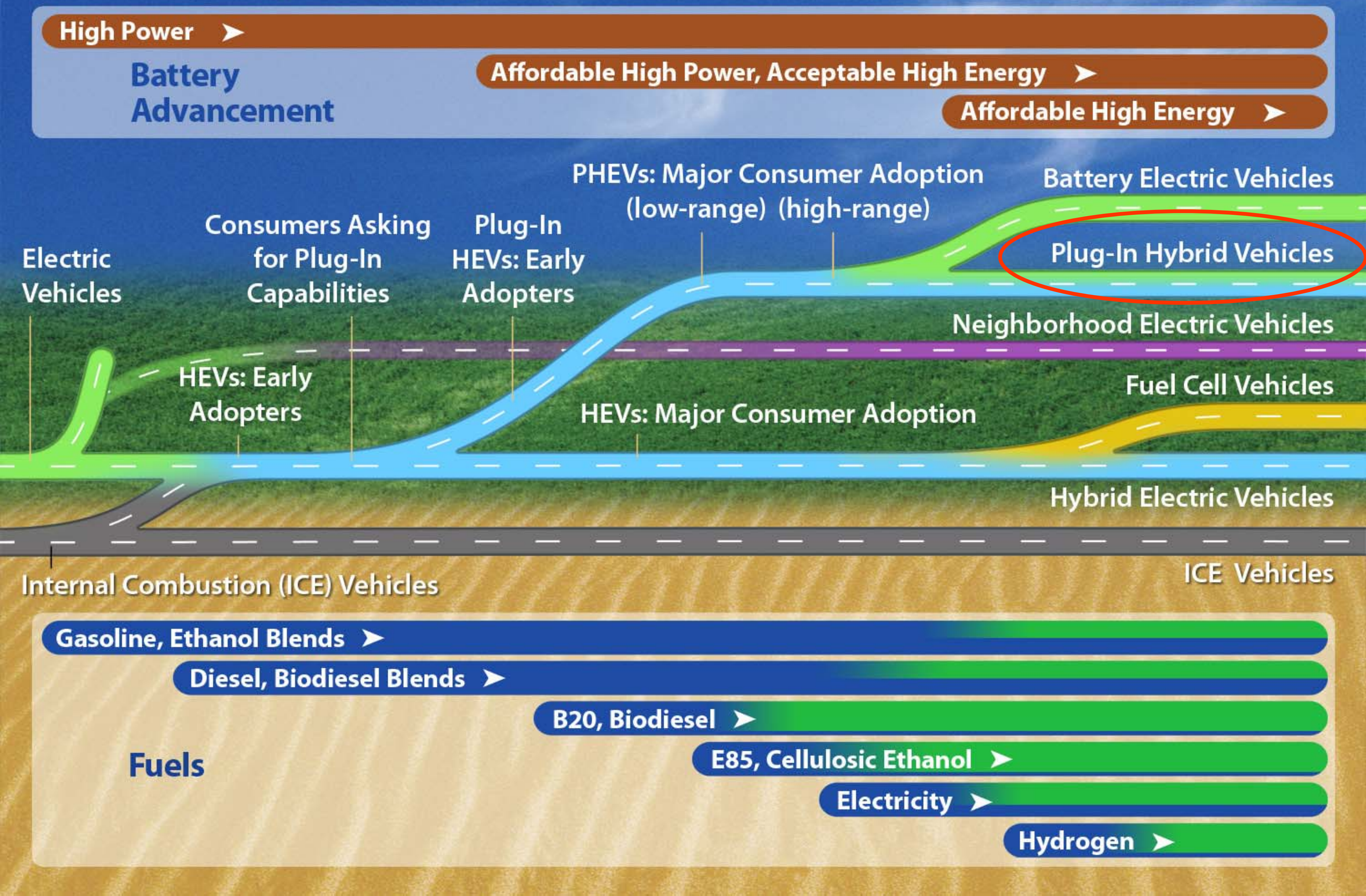
A Plug-In Hybrid-Electric Vehicle (PHEV)

An HEV with wall recharge capability and fuel flexibility



Vision of Future Transportation

National Renewable Energy Laboratory • Concept - Ahmad Pesaran • Illustration - Dean Armstrong • NREL/GR-540-40698

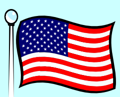


PHEV Key Benefits and Challenges

KEY BENEFITS

Consumer:

- Lower "fuel" costs
- Fewer fill-ups
- Home recharging convenience
- Fuel flexibility



Nation:

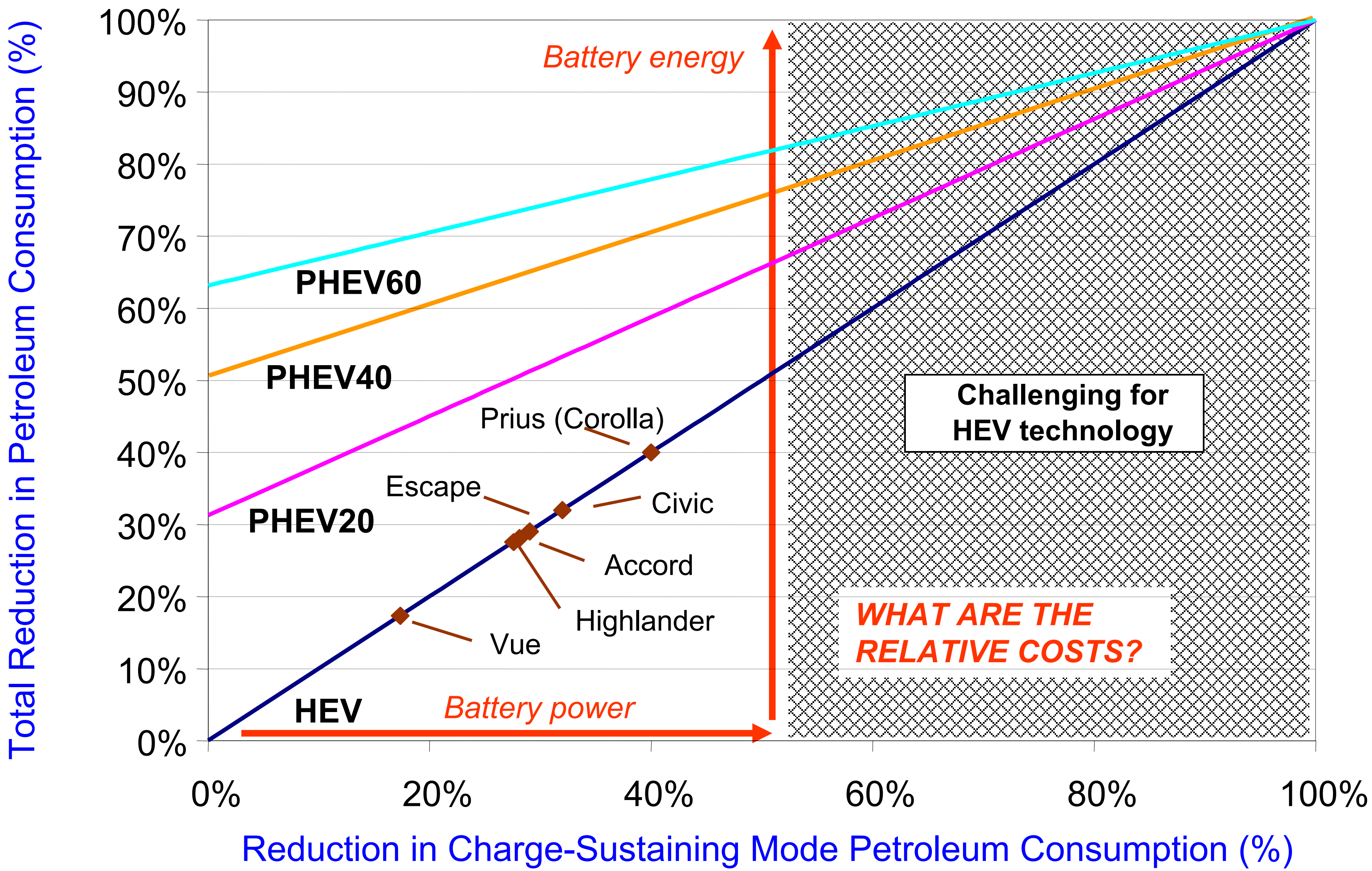
- Less petroleum use
- Less greenhouse and regulated emissions
- Energy diversity/security

KEY CHALLENGES

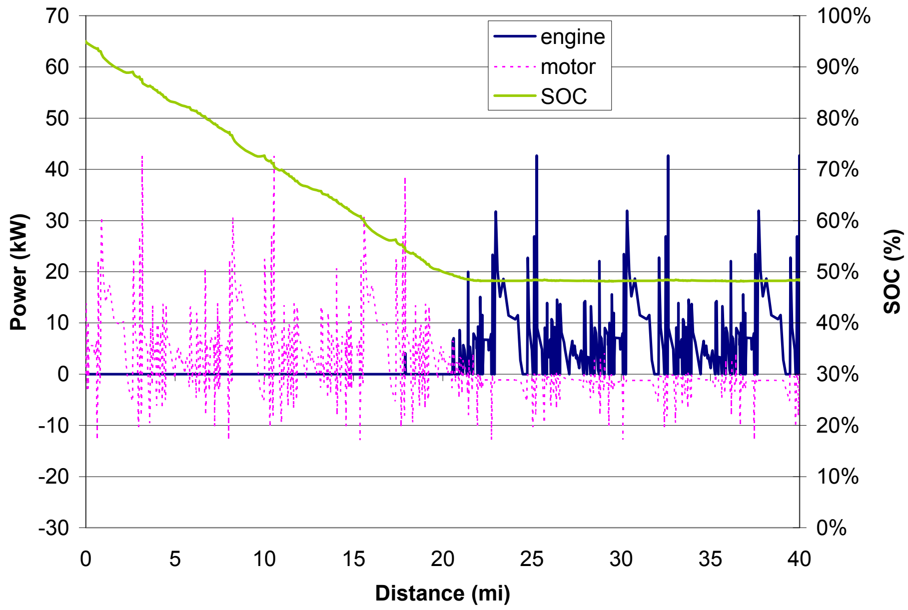
- Recharging locations
- Battery life **?**
- Component packaging
- Vehicle cost

Cost-Benefit Analysis

Potential Petroleum Reduction from PHEVs



PHEV Study Scope and Approach



Vehicle Configurations

- conventional automatic
- pre-transmission parallel hybrid: HEV or PHEV
- 2 technology scenarios
  – near term and long term

Approach

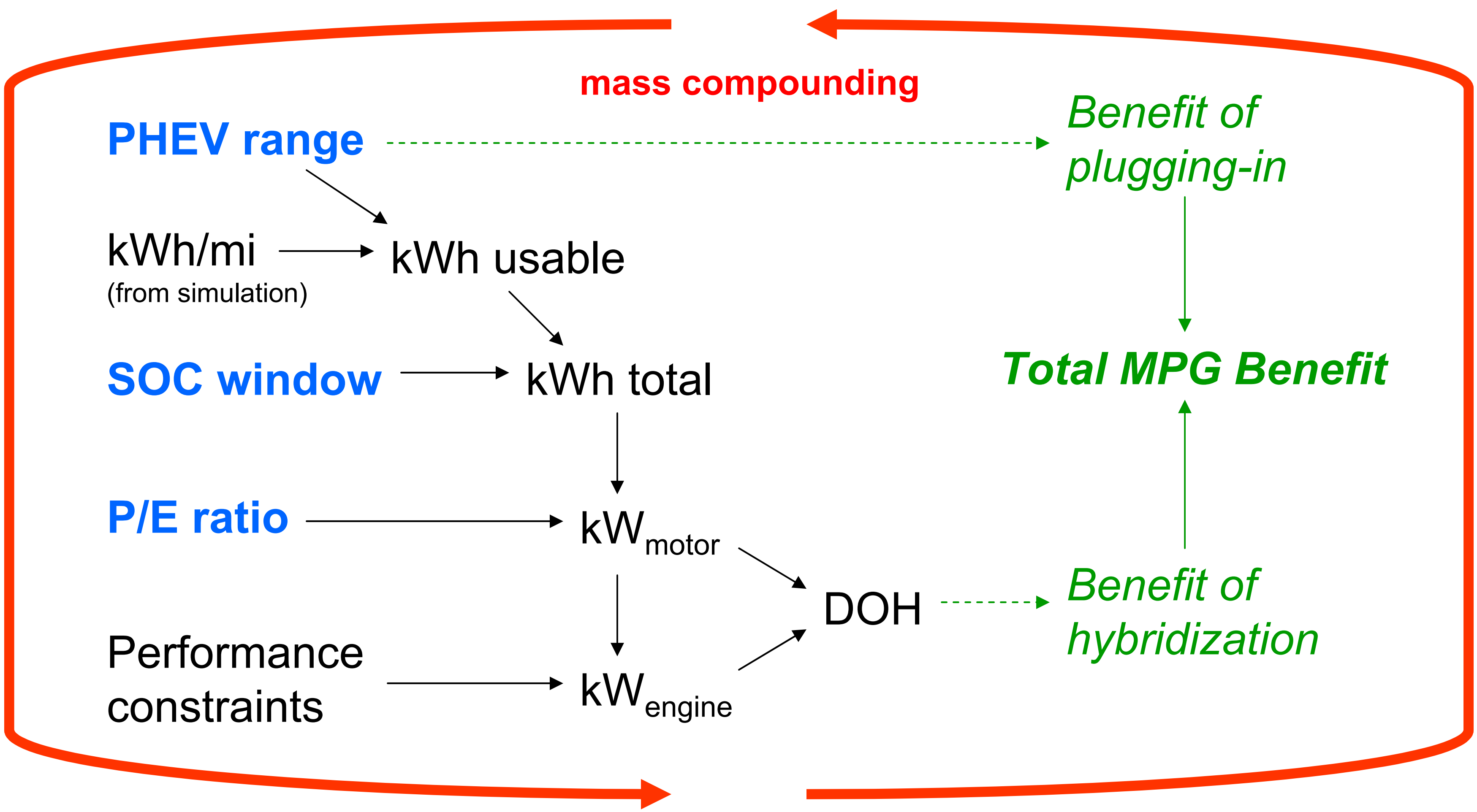
- Dynamic, power-flow simulation
- Calculates component sizes and costs
- Iterative mass-compounding
- Measures fuel/electricity consumption using NREL-proposed revisions to SAE J1711
- *Battery definition is key input to the simulation*

Key Study Assumptions

- Usable State of Charge window varies from 40% for HEV0 to 70% for PHEV60
  - Based on battery life of 15 years and daily travel distance probability
- Mid-size car platform (Malibu/Camry)
  - High volume vehicle
  - Performance equivalent to existing vehicles
  - No platform engineering and no engine technology improvements
    - Isolate the PHEV technology impacts
- Battery attributes scale with Power/Energy ratio

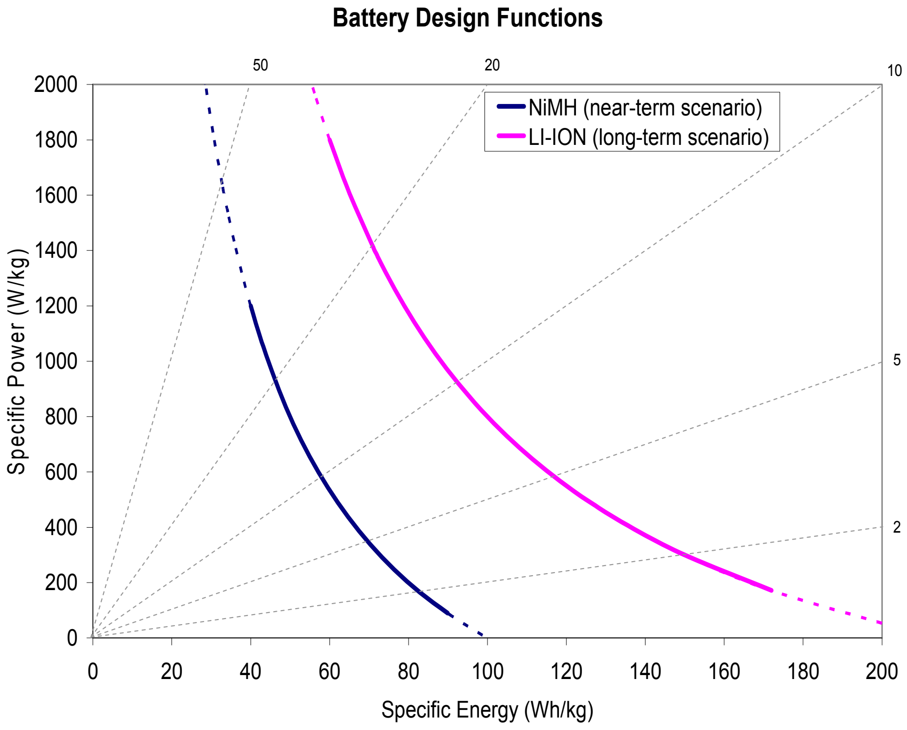
Battery Definition as Key Input to Simulation

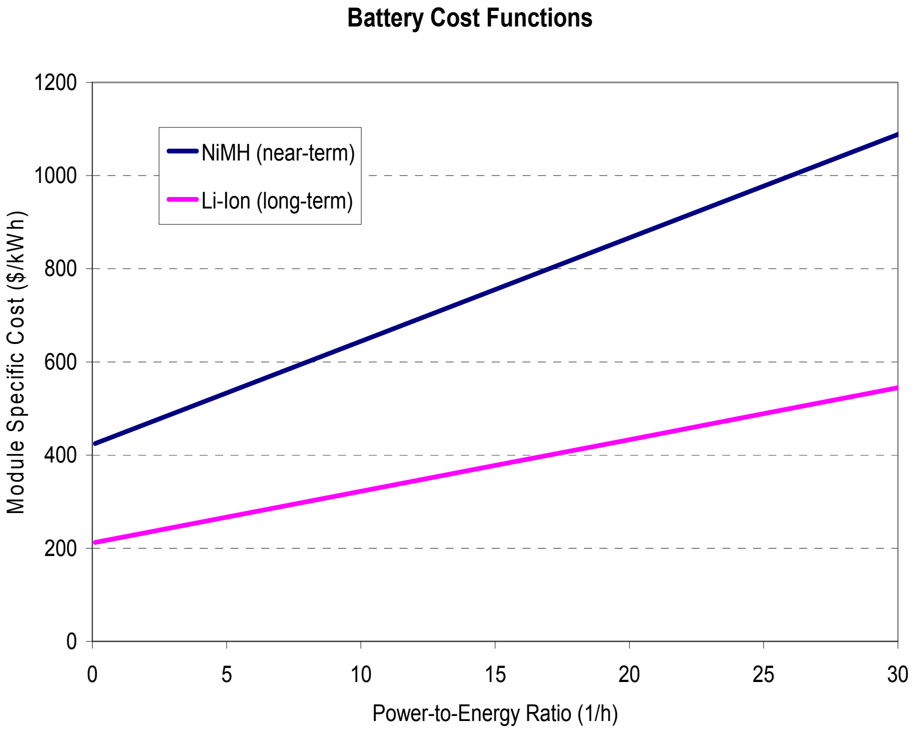
Input parameters that define the battery in BLUE



DOH = degree of hybridization

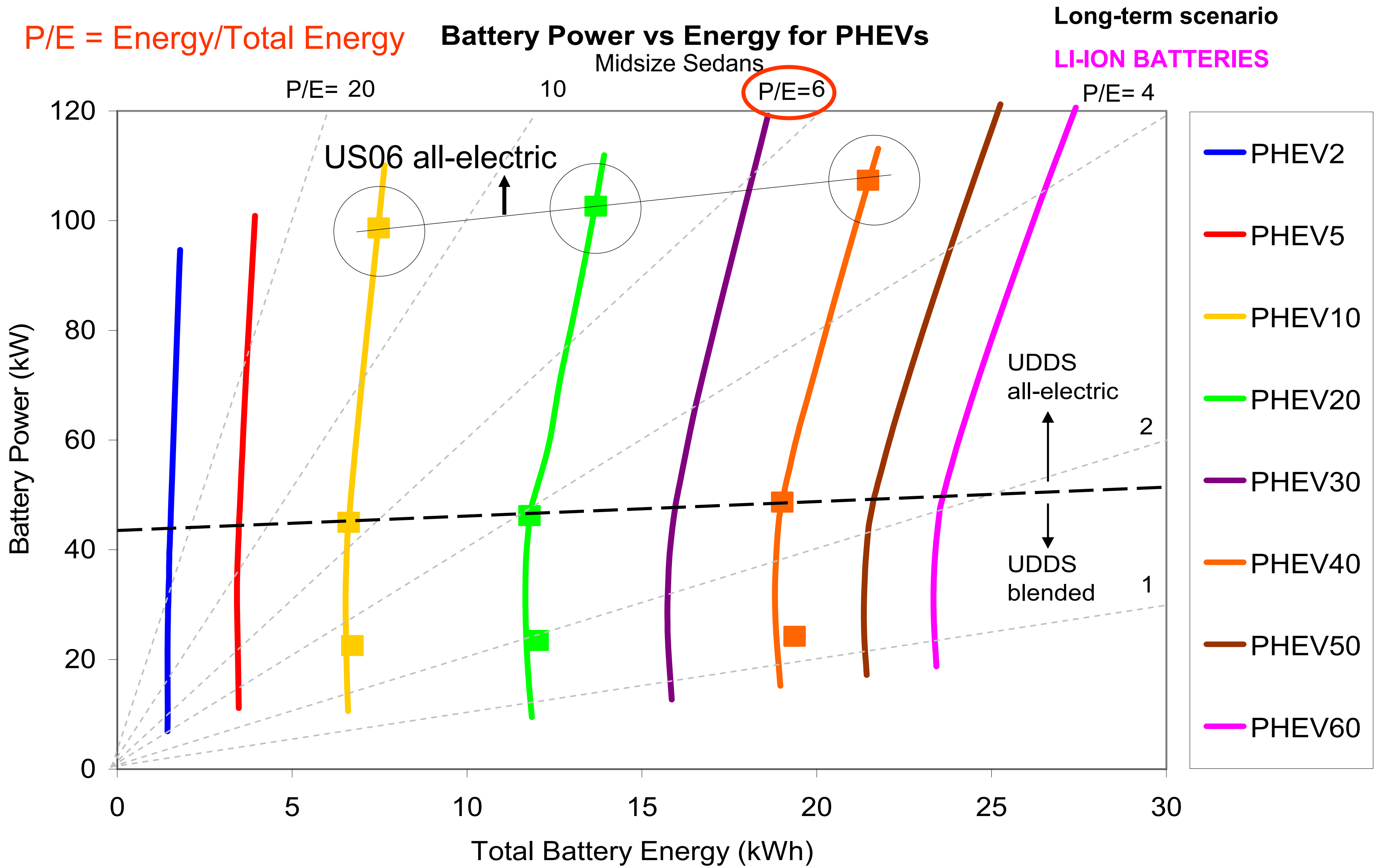
Battery Models (Scaleable)



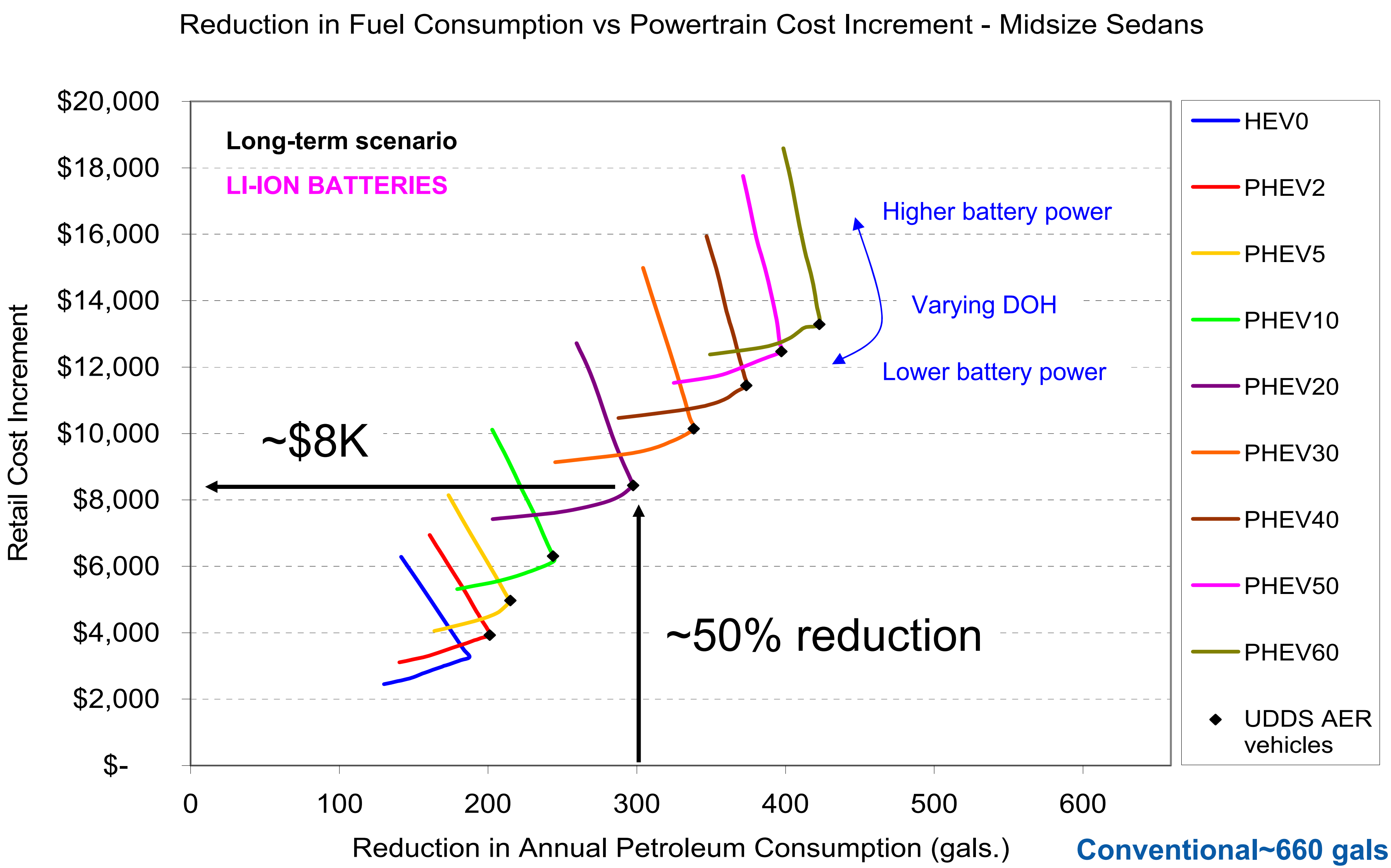


Results: Battery Specifications

P/E = Energy/Total Energy

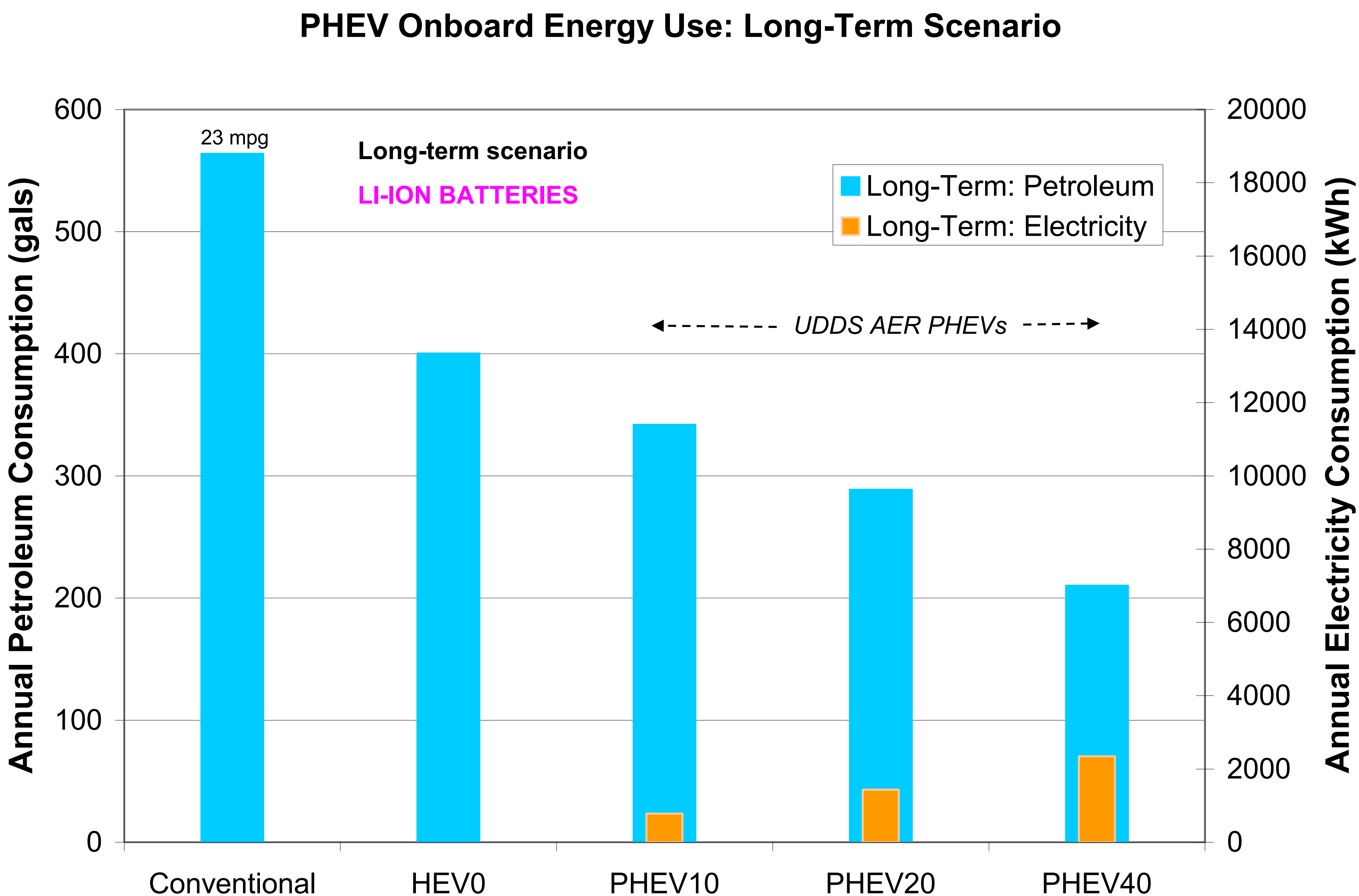


Results: Incremental Cost of Reduced Consumption

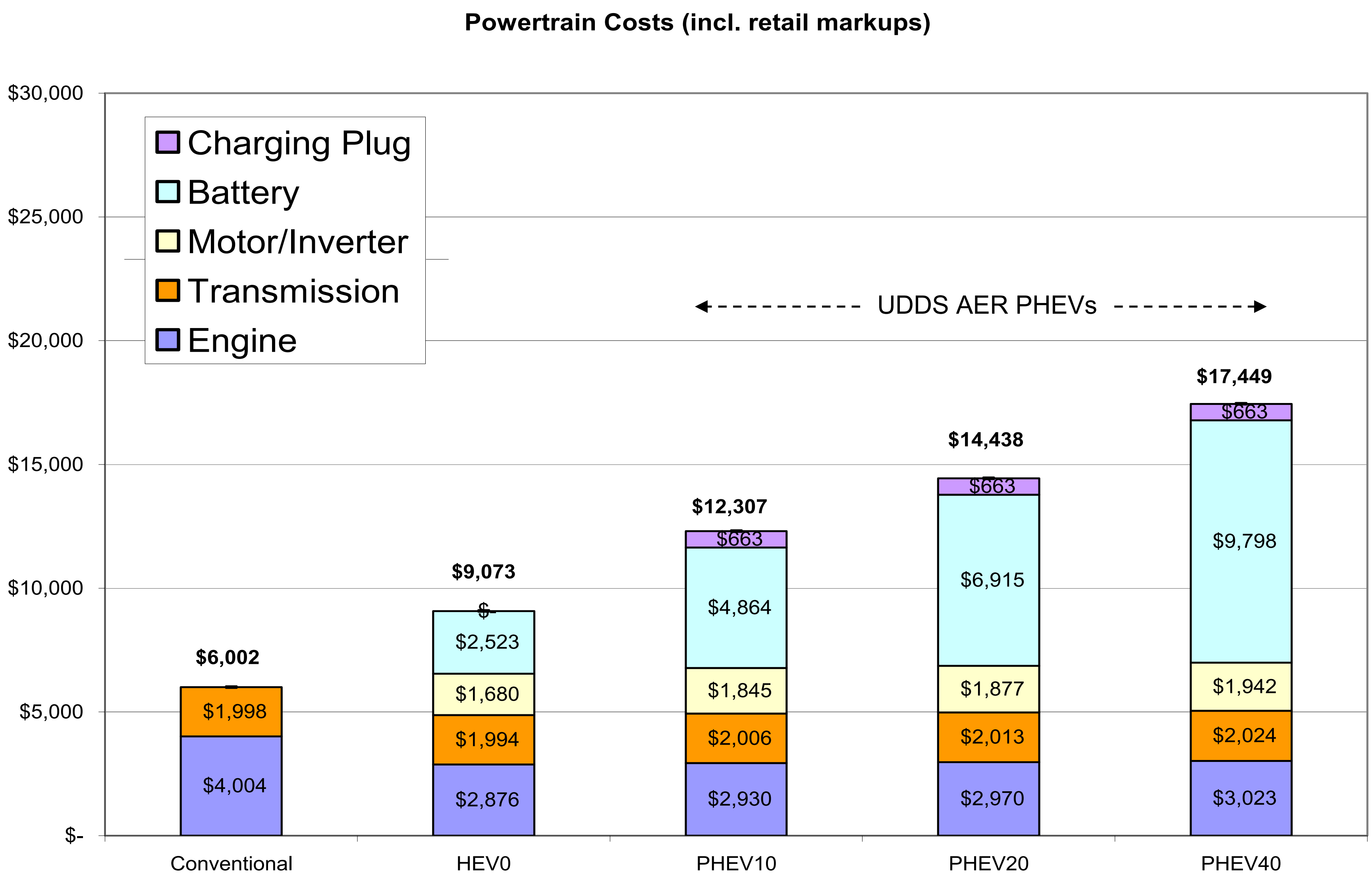


Conventional~660 gals

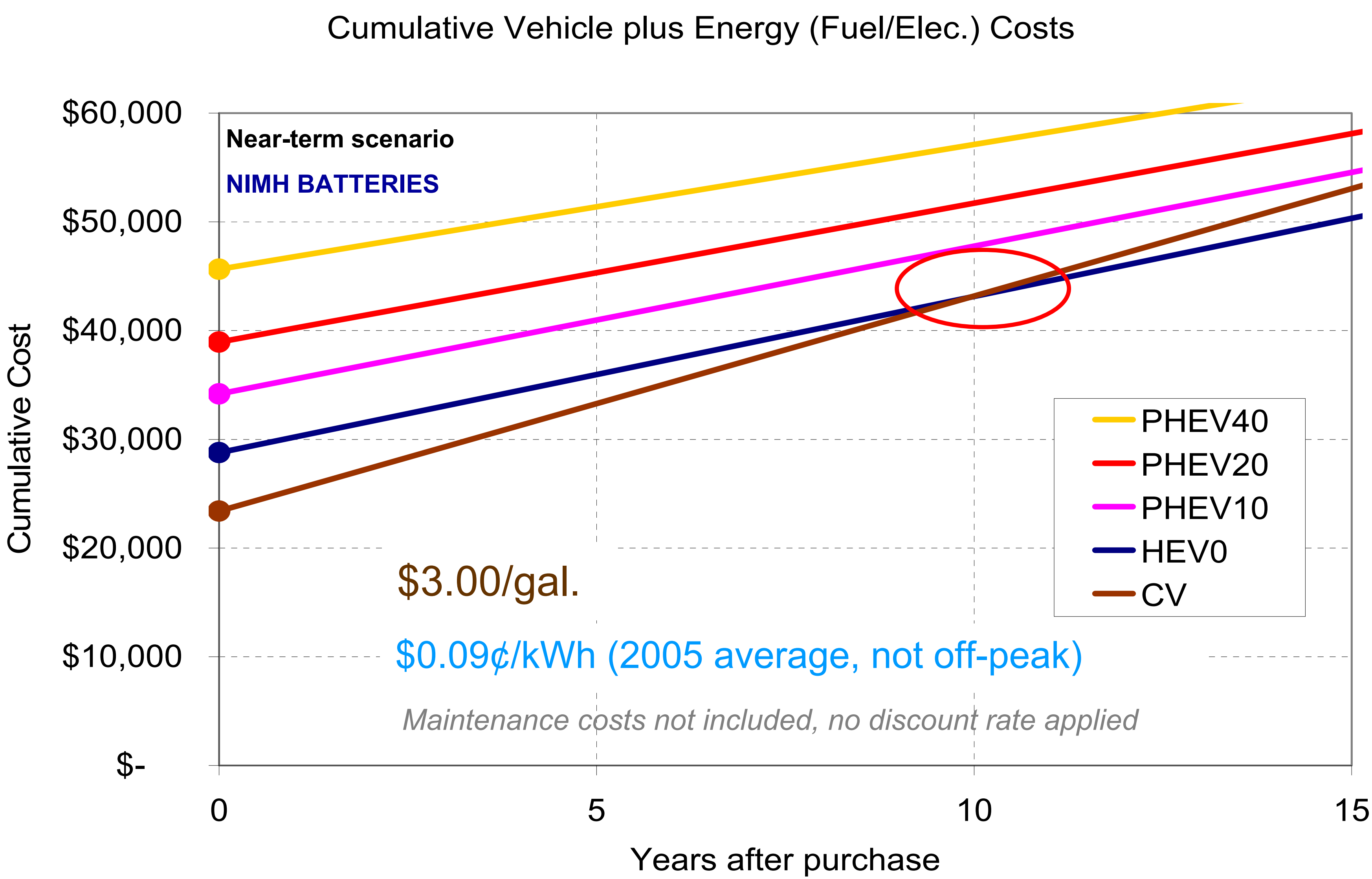
PHEV Energy Use



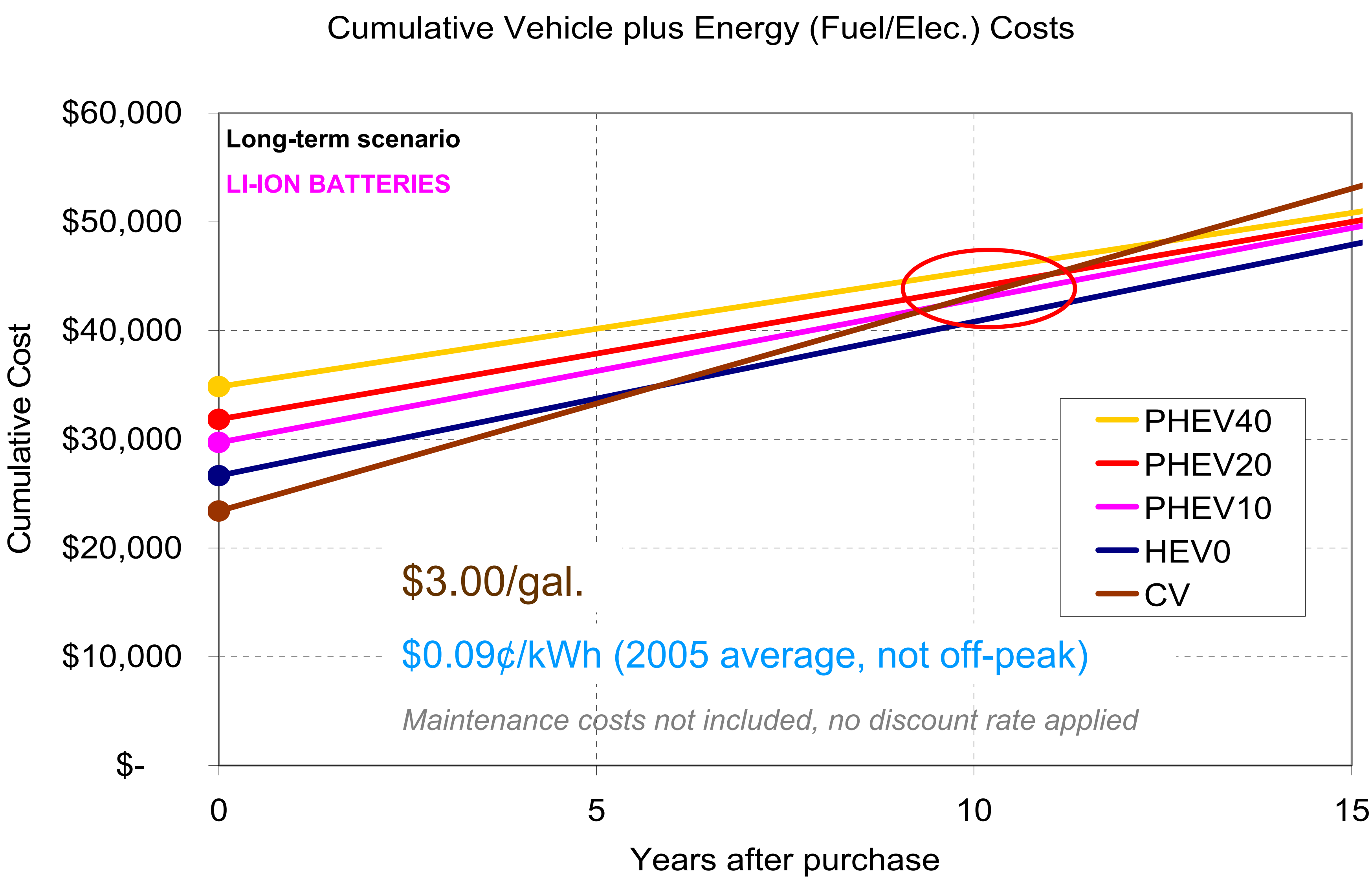
Powertrain Costs Comparison – Long Term



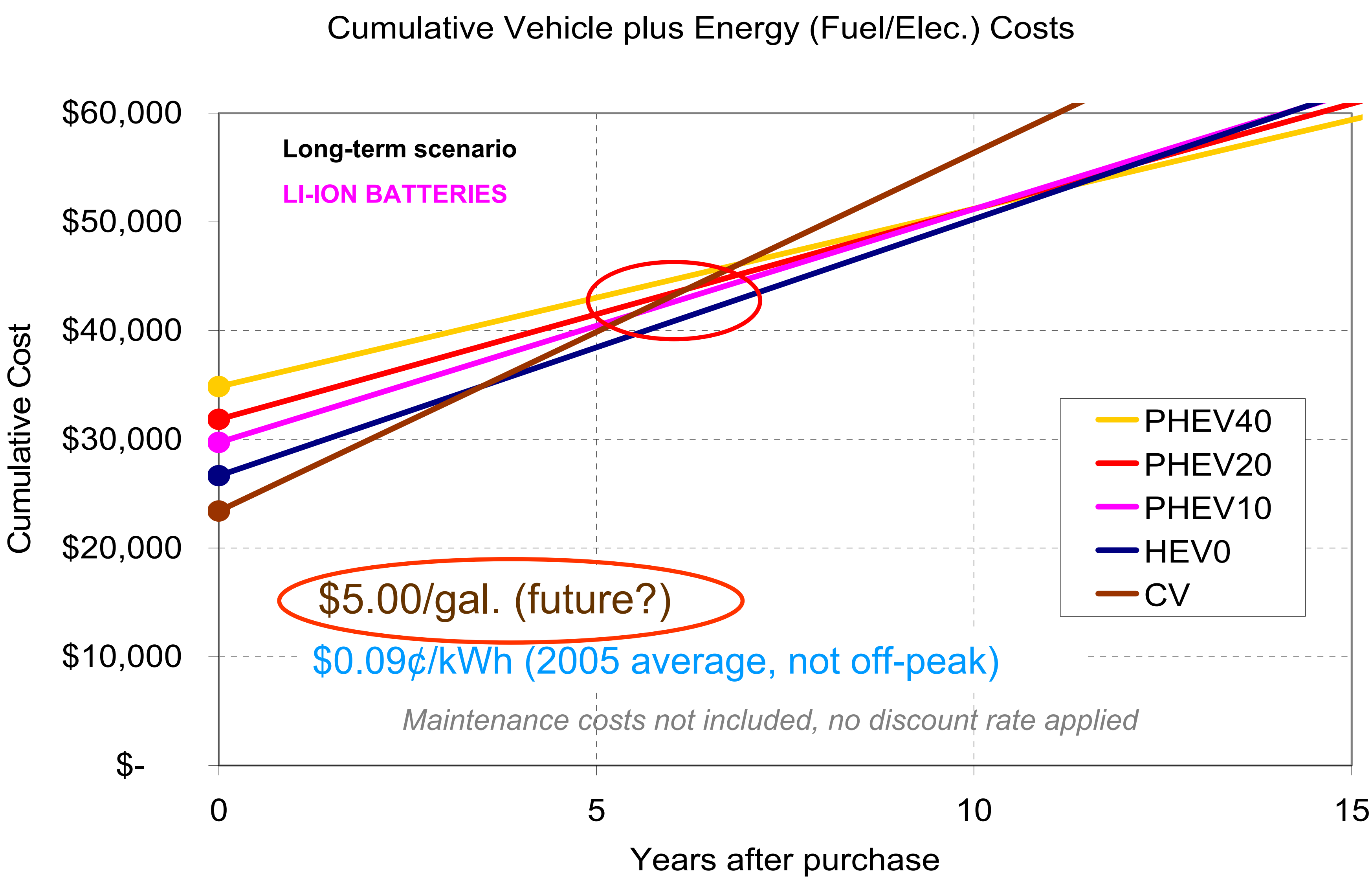
Near-term HEV Fuel Savings Offset Incremental Cost



Long-term Battery Cost Reductions Alone Insufficient For PHEV to Payback Relative to HEV



Both Higher Gas Prices and Lower Battery Costs Required for PHEV to Payback Relative to HEV



Why Consumers Might Pay More for PHEVs?

1. Green image, “feel-good factor”
2. Of-peak charging
3. Tax incentives
4. Reduced petroleum use, air pollution and CO_2
5. National energy security
6. Less maintenance
7. Reduced fill-ups
8. Convenience of home recharging (off-peak)
9. Improved acceleration (high torque of electric motors)
10. Alternative business models

Conclusions

1. Systems simulation extremely important and valuable for quickly exploring the broad HEV/PHEV design spectrum.
2. Key factors in the HEV/PHEV cost-benefit equation include:
   - Battery costs
   - Fuel costs
   - Control strategy (particularly battery SOC window)
   - Driving habits (annual VMT and trip-length distribution)
3. Based on the assumptions of this study:
   - HEVs can reduce per-vehicle petroleum use by approximately 30%.
   - Per-vehicle petroleum use reduced by up to 50% for PHEV20s and 65% for PHEV40s.
   - Long-term powertrain cost increments are predicted to be $2k-$6k for HEVs, $7K-$11k for PHEV20s and $11K-$15k for PHEV40s
4. Based on overall costs (powertrain plus energy):
   - HEVs become the most cost-competitive EITHER if gasoline prices increase OR projected battery costs are achieved.
   - PHEVs become cost-competitive ONLY if projected battery costs are achieved AND fuel prices increase.
   - Tax incentives and/or alternative business models (e.g. battery lease) may be required for successful marketing of PHEVs