NREL
NATIONAL RENEWABLE ENERGY LABORATORY

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Battery Ownership Model: A Tool for Evaluating the Economics of Electrified Vehicles and Related Infrastructure

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Many New Vehicle Technologies, Power Sources, Infrastructure Technologies, and Business Models Are Being Proposed for Transportation

How Do We Make Sense of These Options as They Relate to Component Development, Economics, Energy Use, Greenhouse Gases, and the Role of Government?

Solar Power
Wind Power
Swap Stations
City Charge Points
Aggregators
Charge Service Provider
PHEVs
Traditional EVs
Smart Grid
Location
Drive Profile
Battery Life
V2G
Vehicle Characteristics
Cost of Money
Charging Algorithms
Subsidies
Battery Specific Power & Specific Energy
Job Creation
Consumer Behavior
Battery Secondary Use
Future Cost of Gasoline

→ Model →

Battery Ownership Model Multi-Disciplinary Team

Jeremy
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battery secondary use, project subtask lead

Michael
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economics & financing

John
Rugh
vehicle ancillary loads reduction & driving statistics

Terry
Penney
advisor on project direction

Aaron
Brooker
vehicle systems analysis, optimization & programming

Caley
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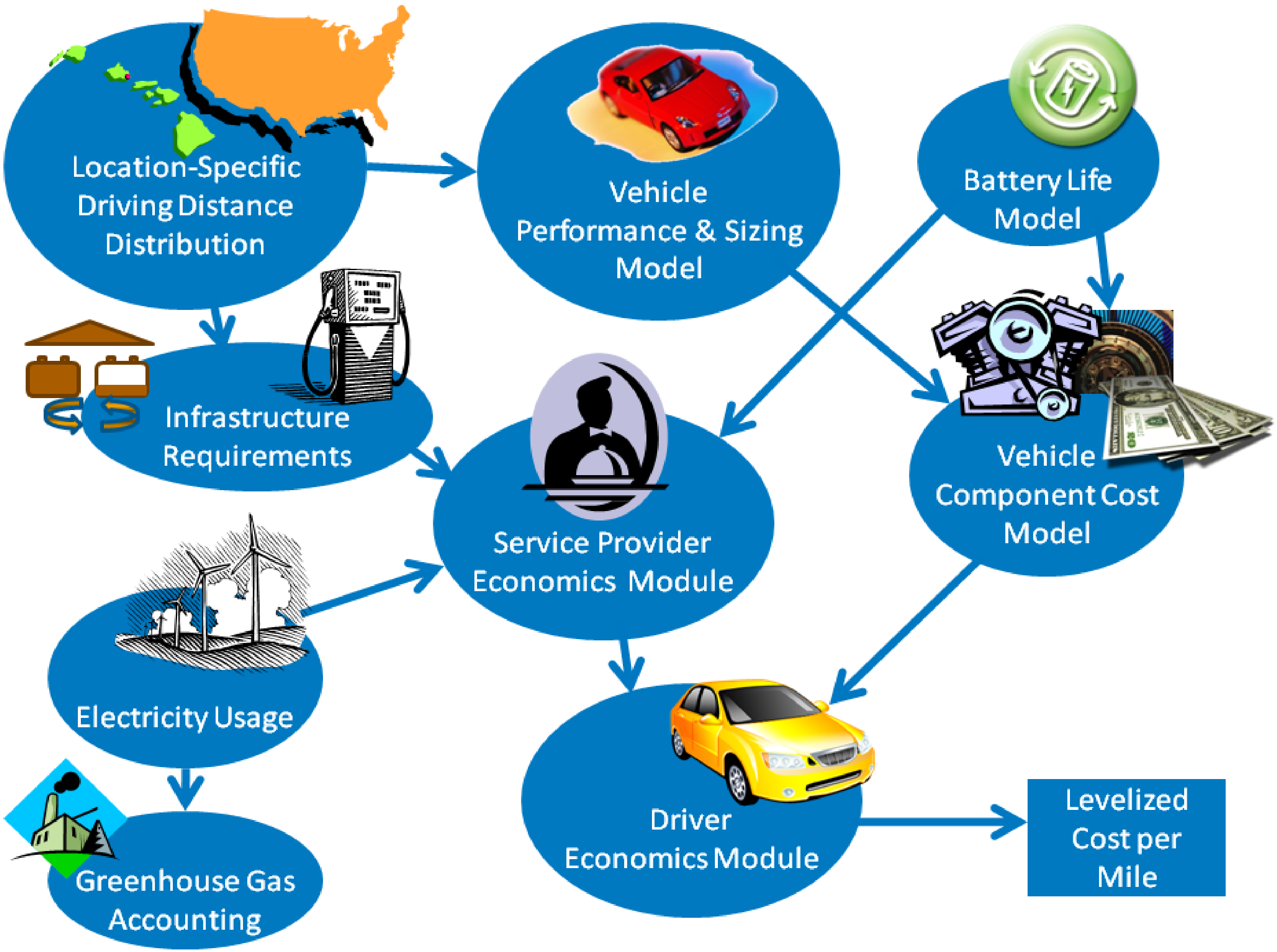
carbon markets, policy analysis & fueling stations

Michael
O'Keefe
power electronics, EV grid integration & programming

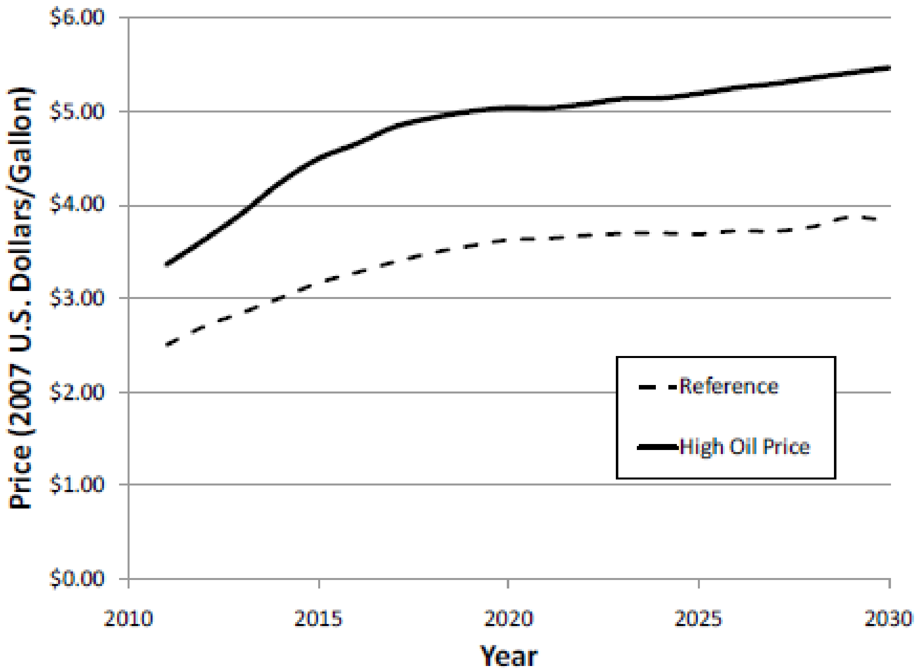
Ahmad
Pesaran
energy storage system task lead

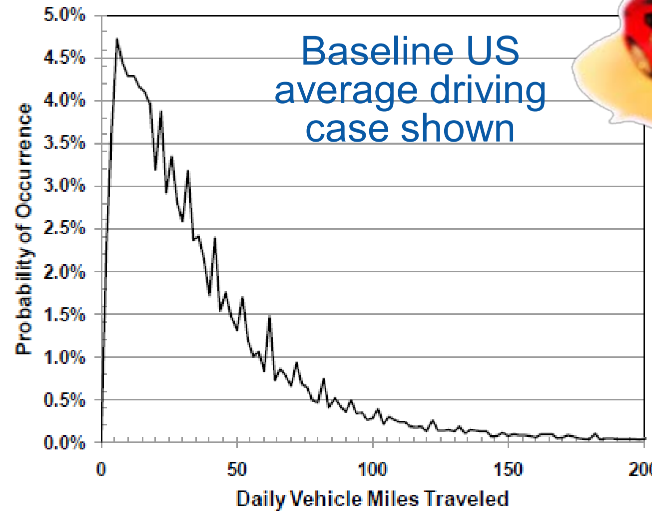
NREL developed the **Battery Ownership Model** to answer this question

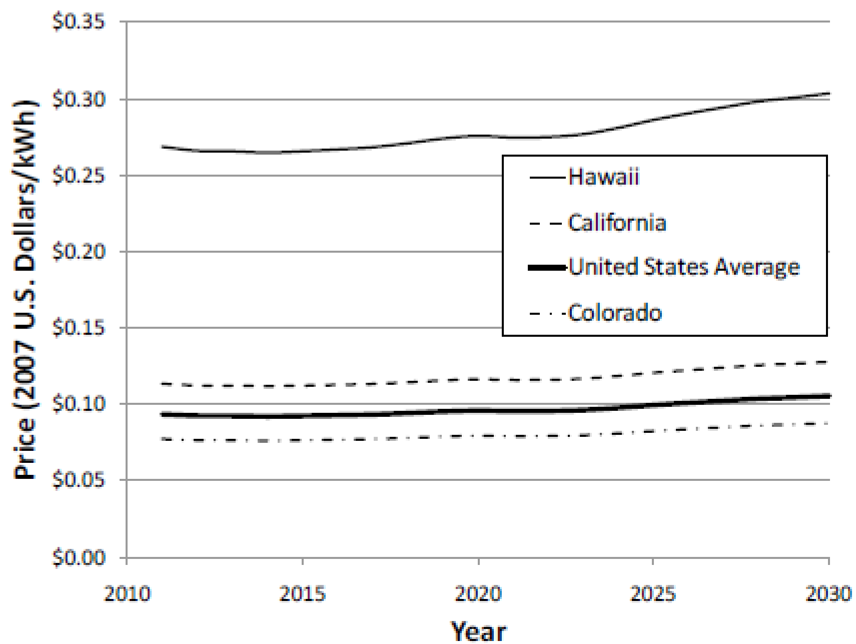


Location-Specific Driving Distance Distribution

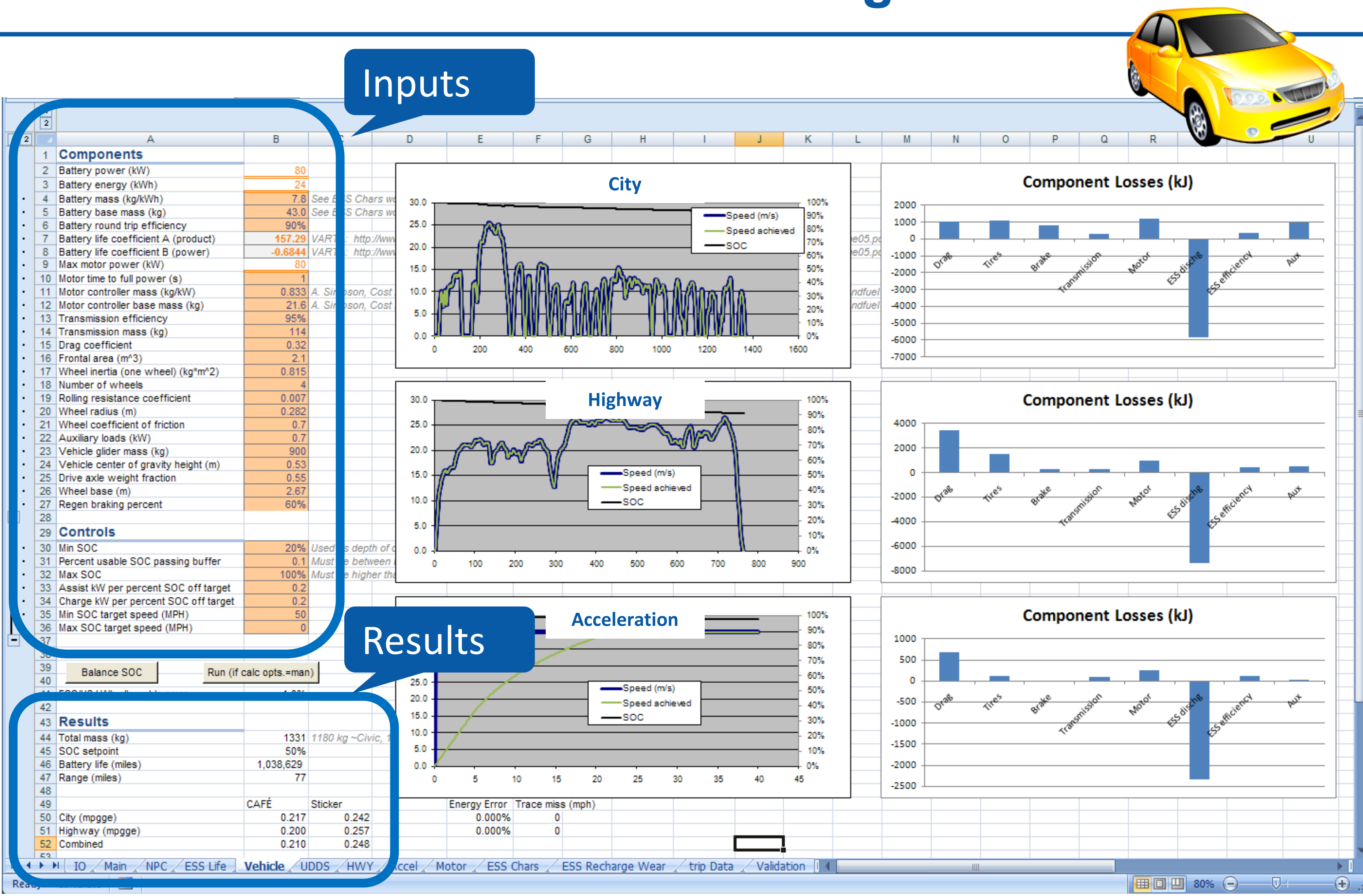
Price of Gasoline







Vehicle Performance and Sizing Model



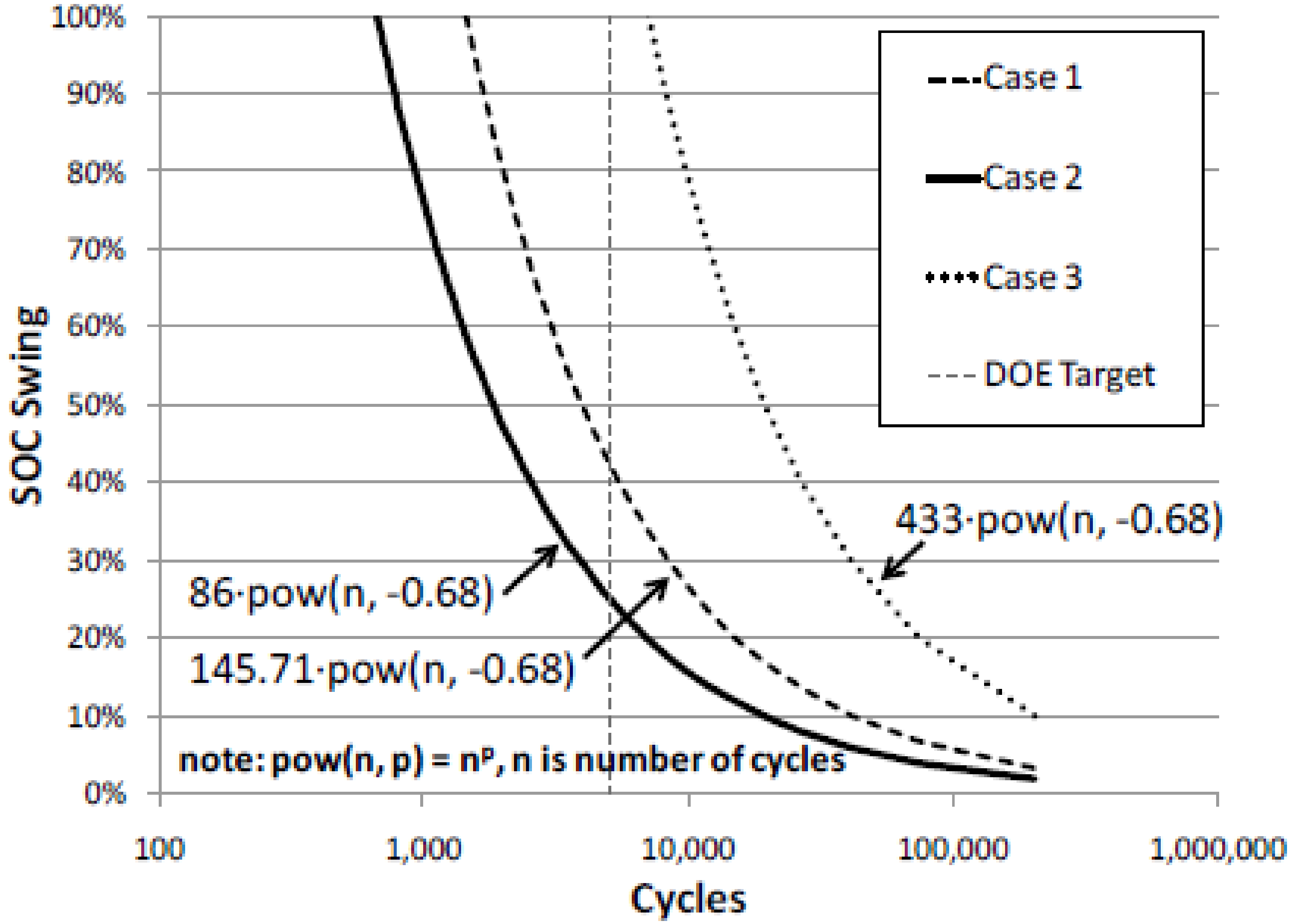
Vehicle Component Cost Model

Baseline technology costs have been calibrated against currently available vehicles

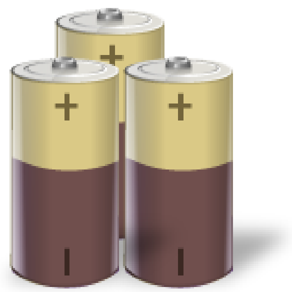
Equation coefficients can be varied to explore sensitivities and future scenarios

Battery	$\frac{\$22.00}{kW} \cdot P_b + \frac{\$700.00}{kWh} \cdot E_b + \$680.00$
Motor & Power Electronics	$\frac{\$21.70}{kW} \cdot P_m + \$425.00$
Engine	$\frac{\$14.50}{kW} \cdot P_e + \$531.00$

Battery Life Model



A simple model for battery degradation has been tied to the driving profile



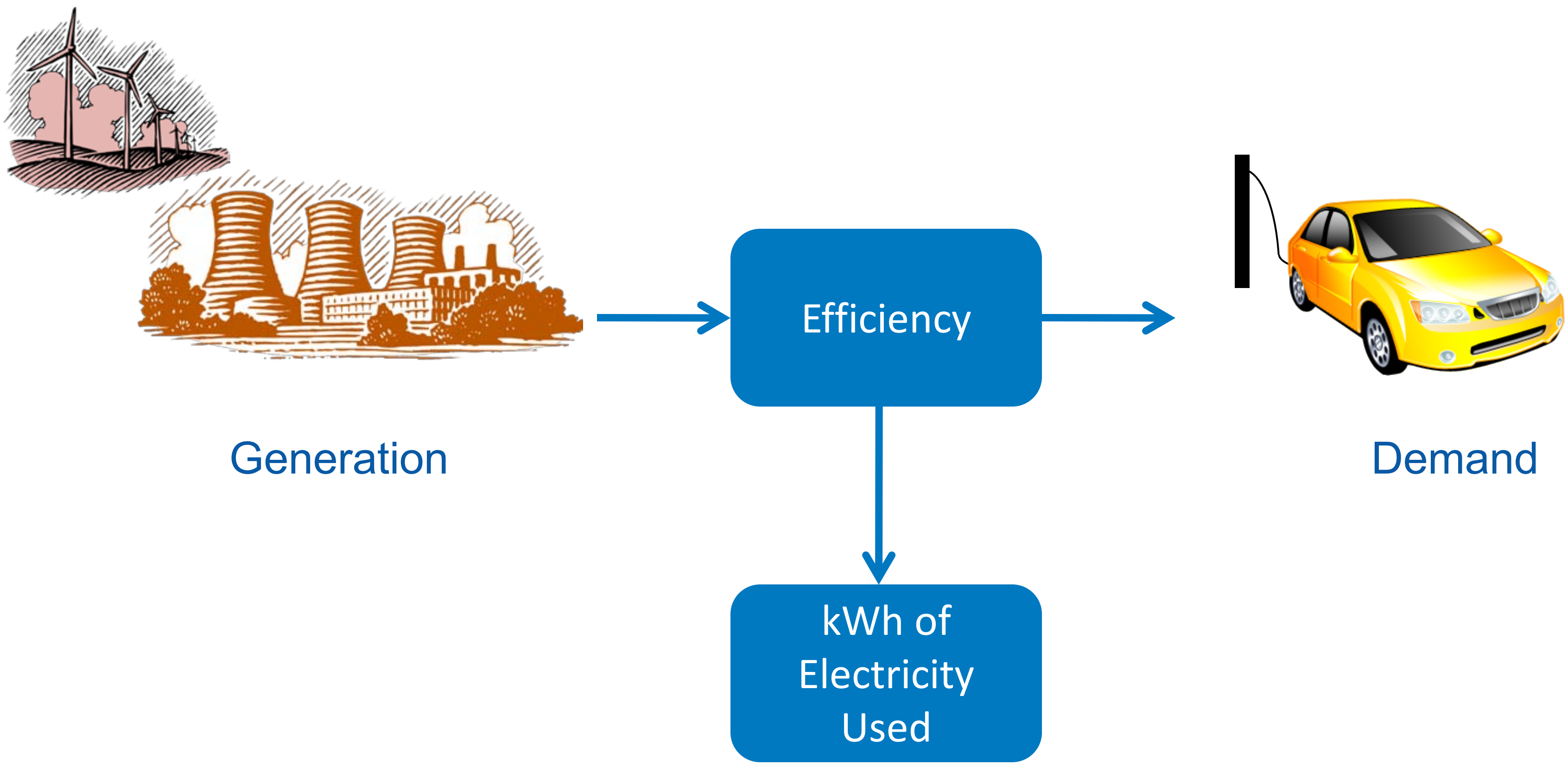
Infrastructure Requirements

Swap Fraction	Swap Stations per 10,000 Cars
11%	11
09%	9
01%	1

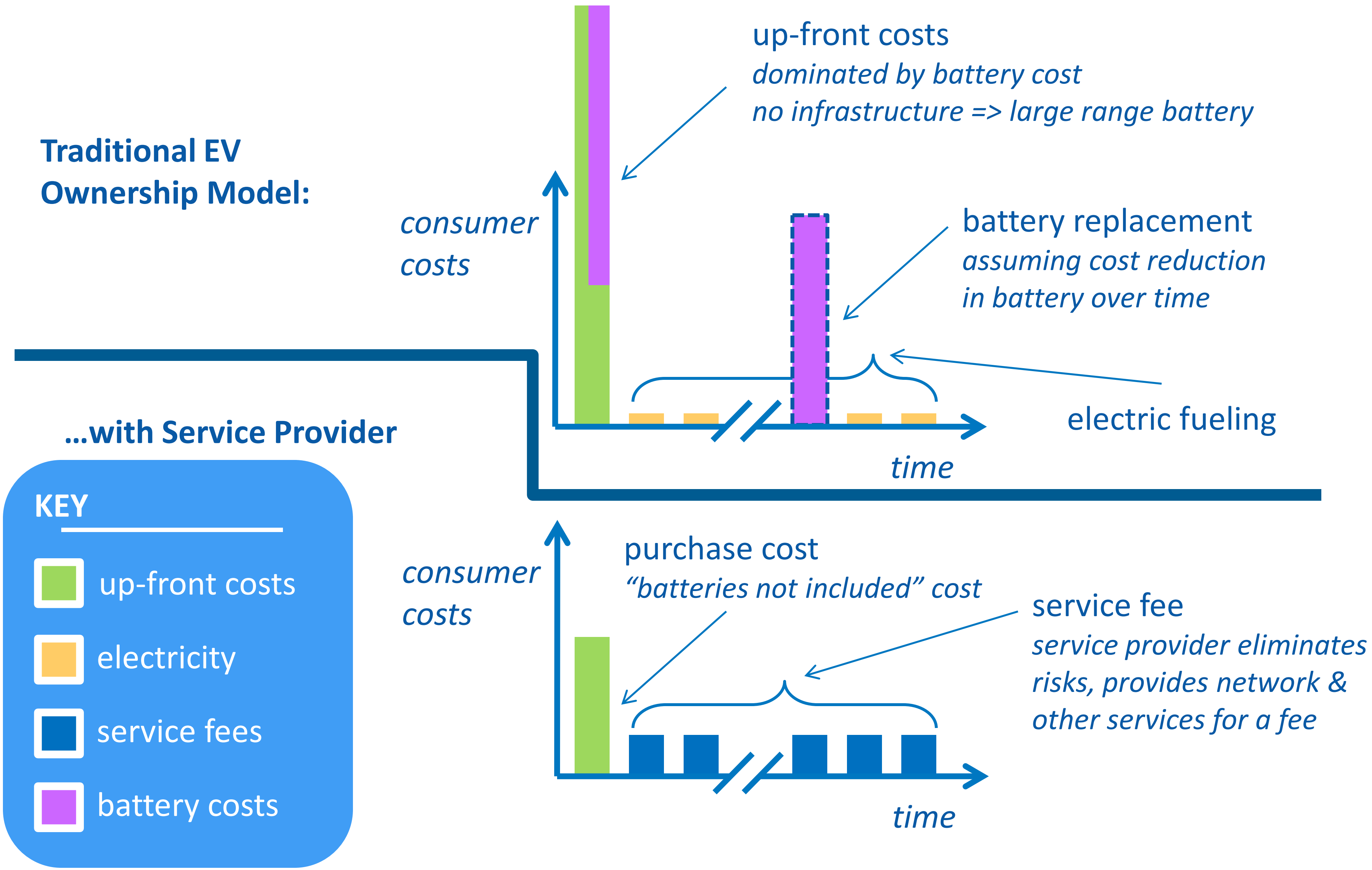
For reference: ~6.4 gasoline stations (~54.7 pumps) per 10,000 cars

Assuming: same “level of convenience” for swap station as gasoline station in terms of cars per “pump” & time per fueling

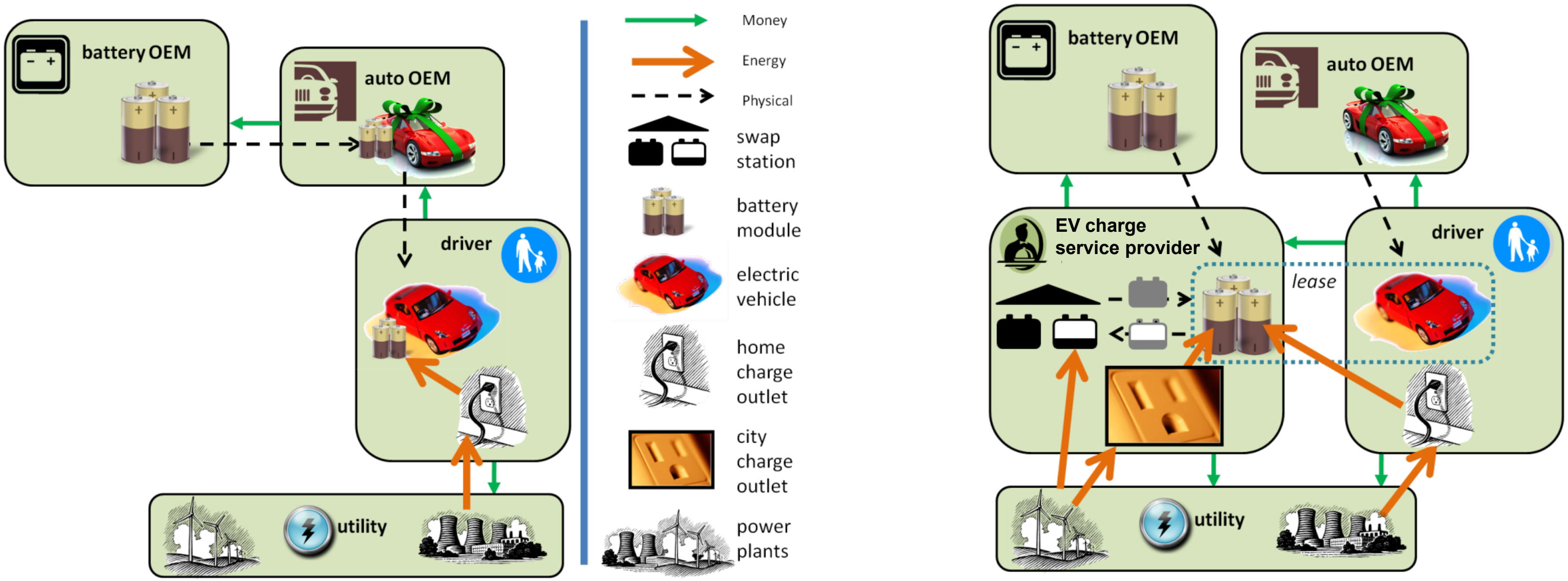
Electricity Usage

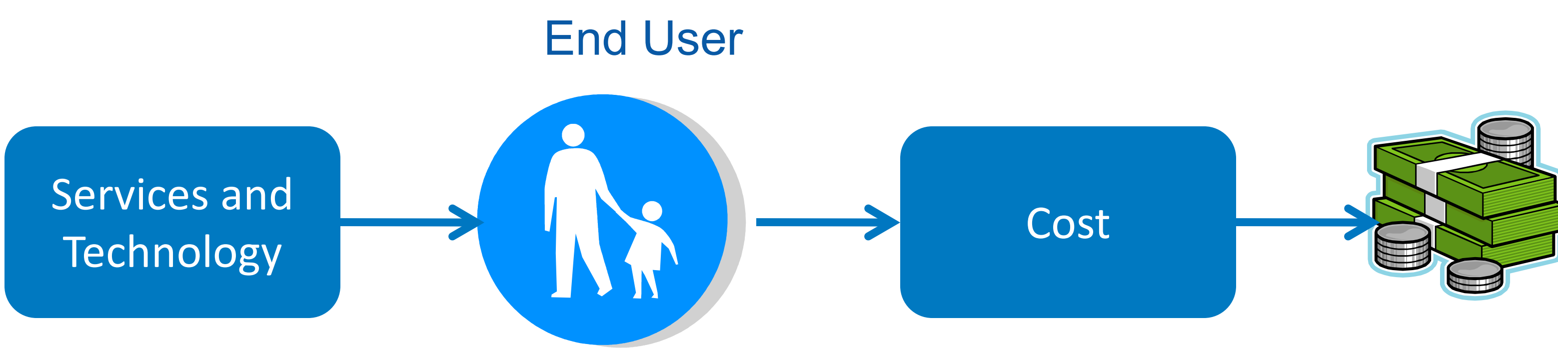


Service Provider Economics Module

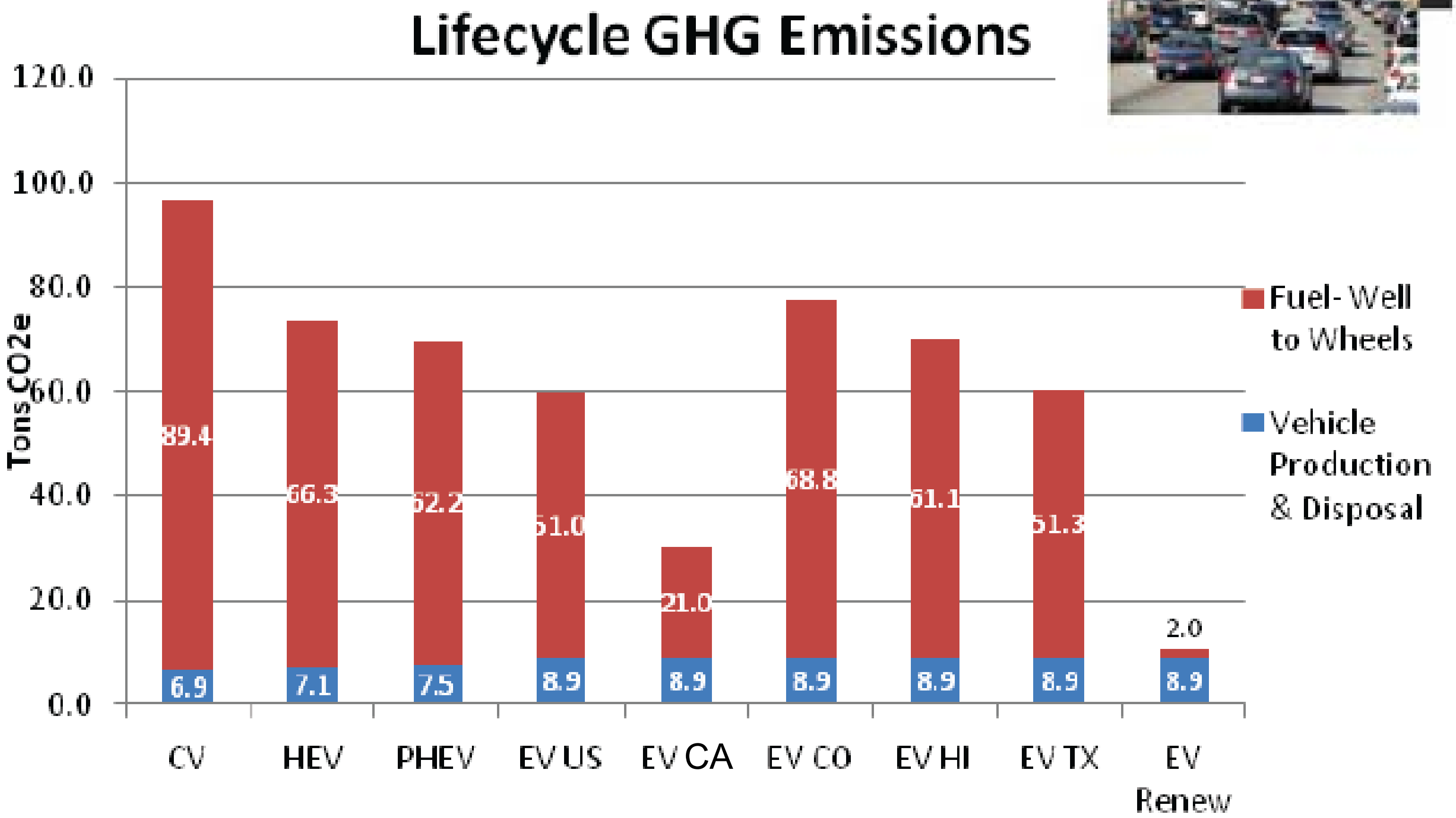


Driver Economics Module

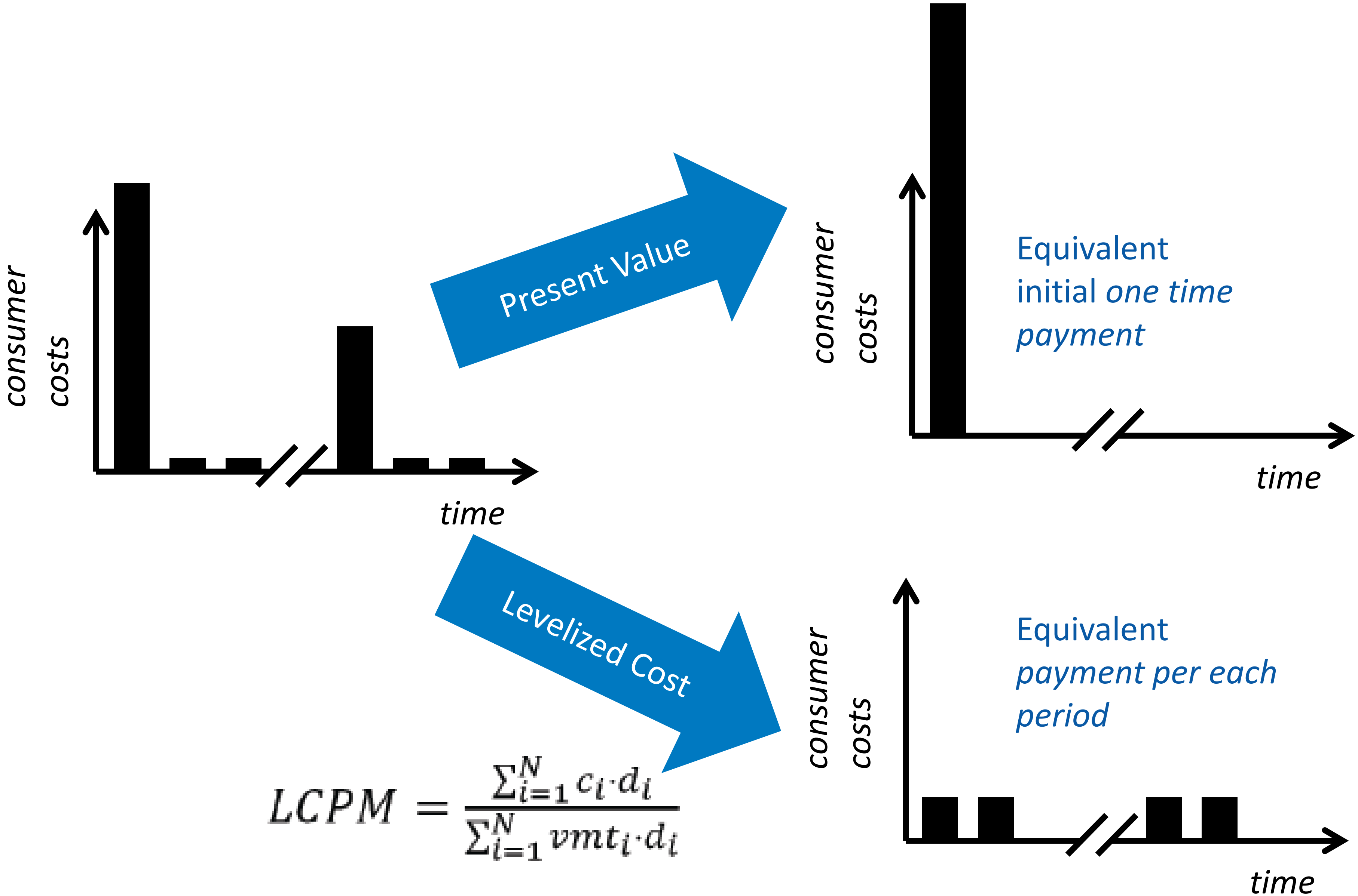




Greenhouse Gas Accounting

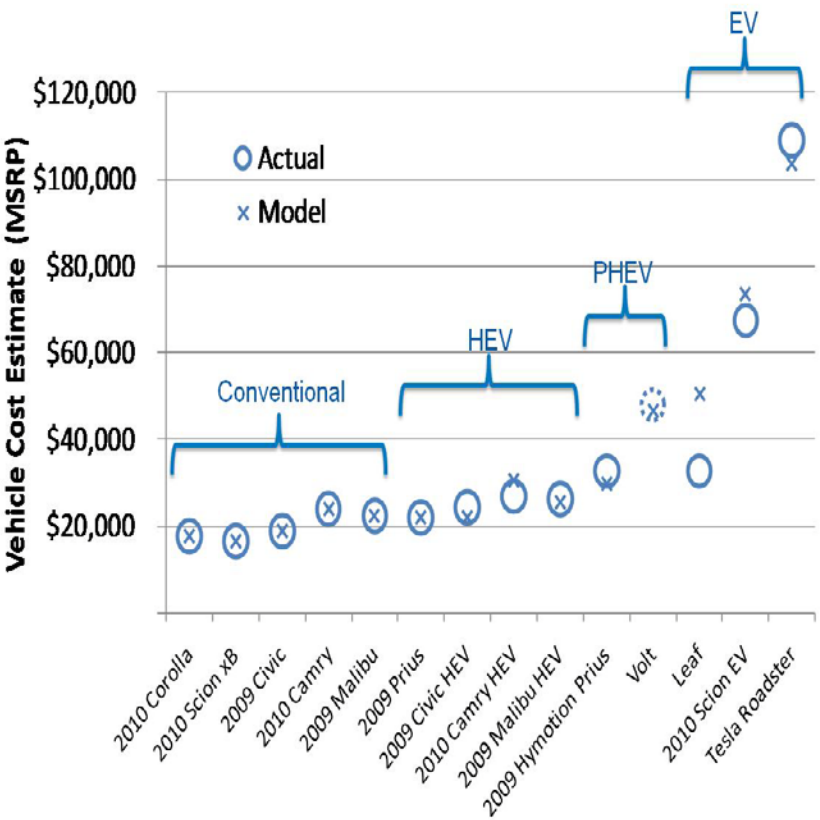


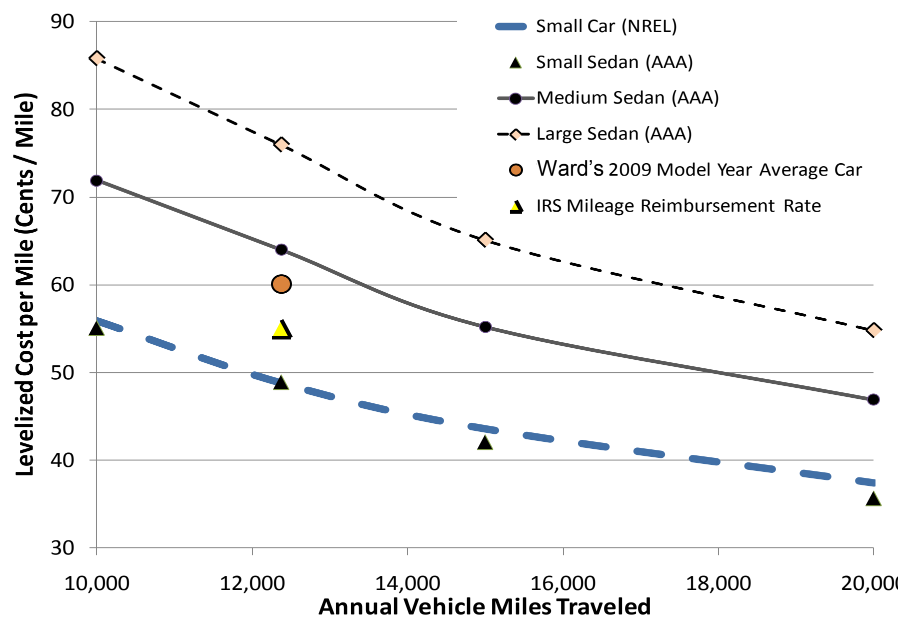
Levelized Cost per Mile (LCPM)



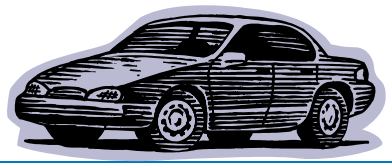
$$LCPM = \frac{\sum_{i=1}^{N} c_i \cdot d_i}{\sum_{i=1}^{N} vmt_i \cdot d_i}$$

Validation: The model does well at estimating the cost of vehicle technologies





We compared the LCPM of the following vehicles:



CV

Conventional Vehicle
(gasoline)

Hybrid Electric Vehicle
(gasoline)

HEV

Plug-in Hybrid Electric Vehicle [40 mile]
(electricity / gasoline)

PHEV40

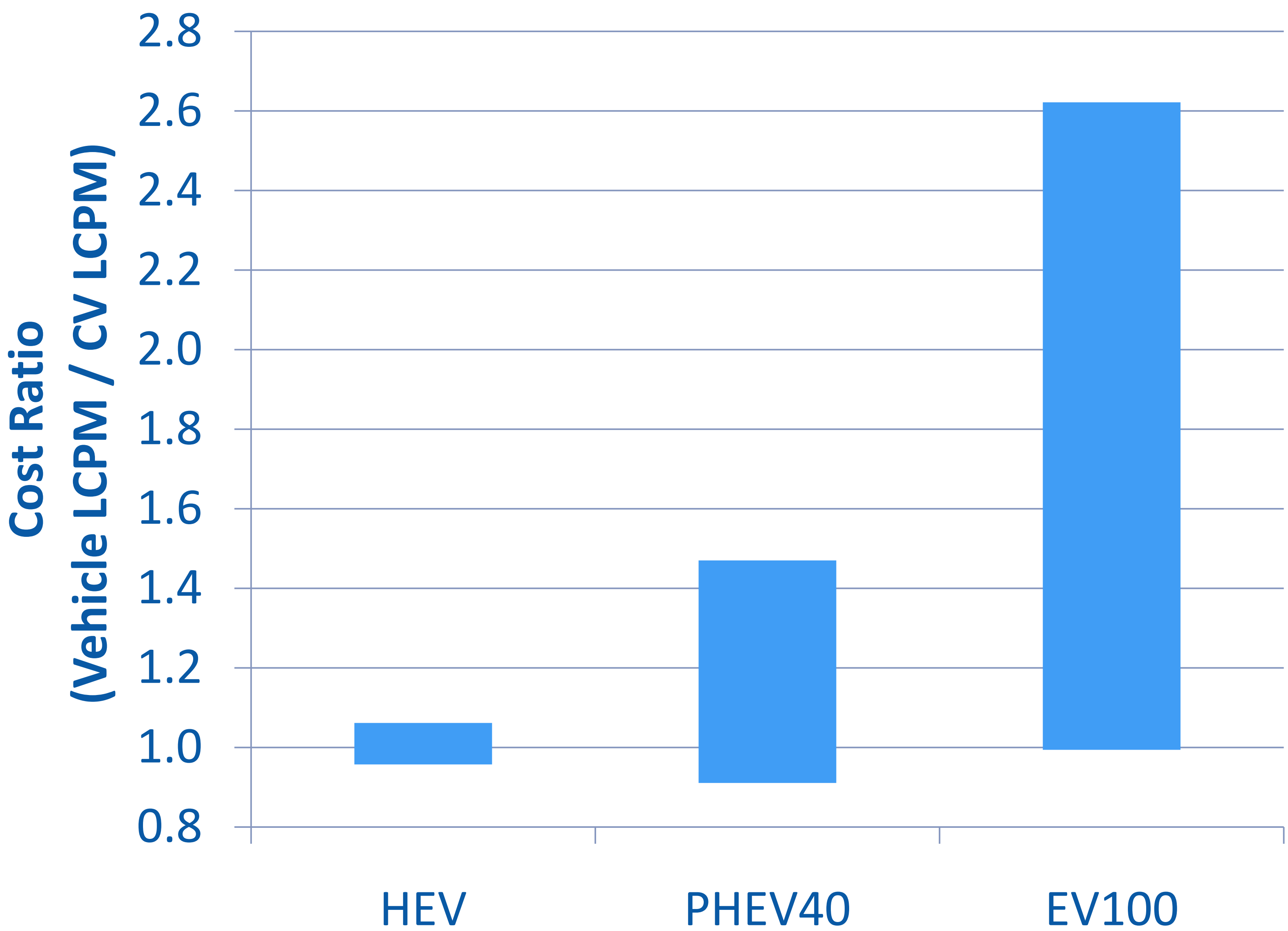
Electric Vehicle [100 mile]
(electricity)

EV100

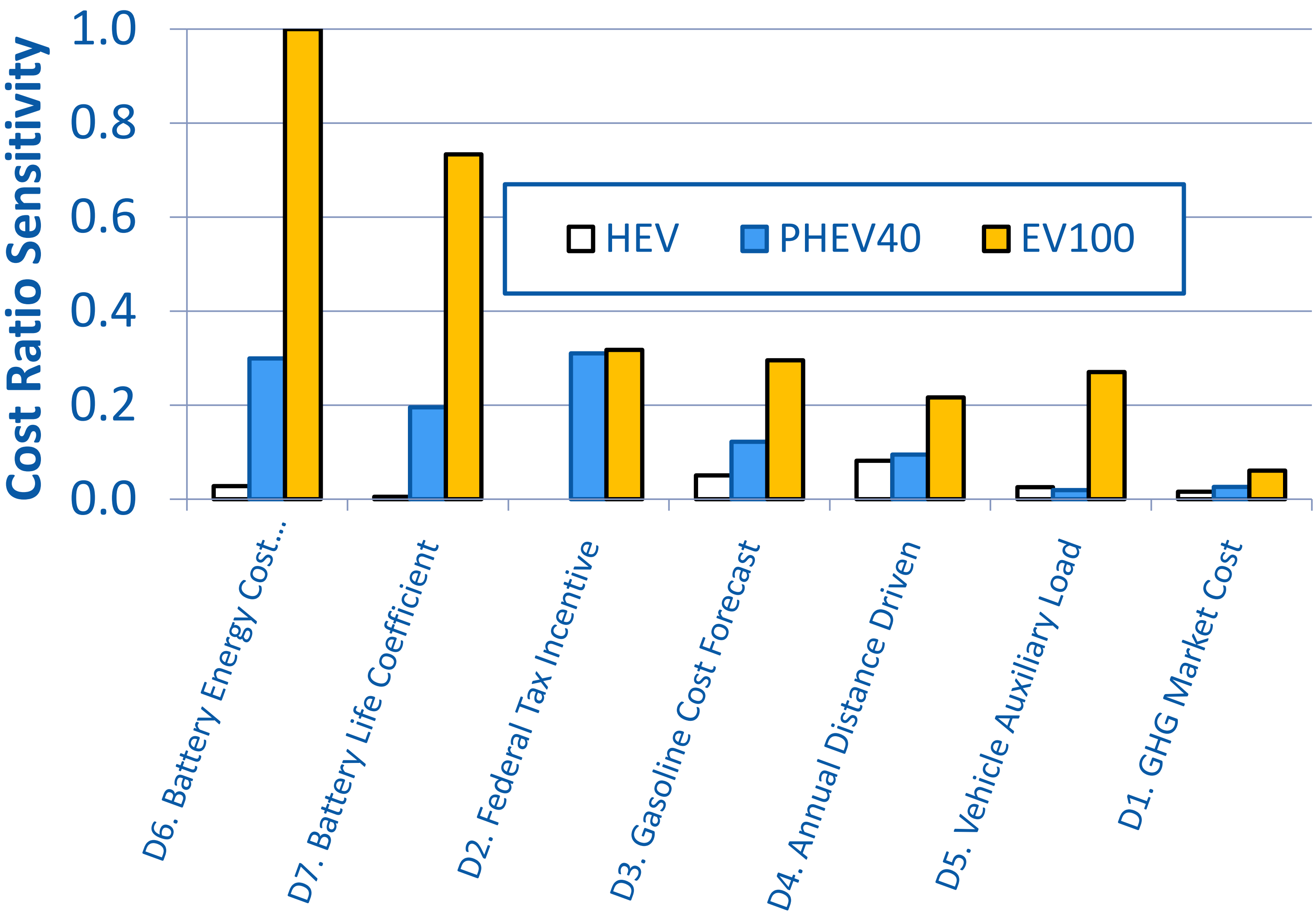
…considering the following variable inputs…

Variable	Min	Max
D1: GHG Market Cost (2007 U.S. Dollars/Ton CO2e-Year)	0.00	28.53
D2: Federal Tax Incentive (2007 U.S. Dollars)	0	7,500
D3: Gasoline Cost Forecast	EIA Reference	EIA High Oil Price
D4: Annual Distance Driven (Miles/Year)	9,059	15,691
D5: Vehicle Auxiliary Load (W)	700	2,200
D6: Battery Energy Cost Coefficient (2007 U.S. Dollars / kWh)	350	700
D7: Battery Life Coefficient	86 (low cycle life)	433 (high cycle life)

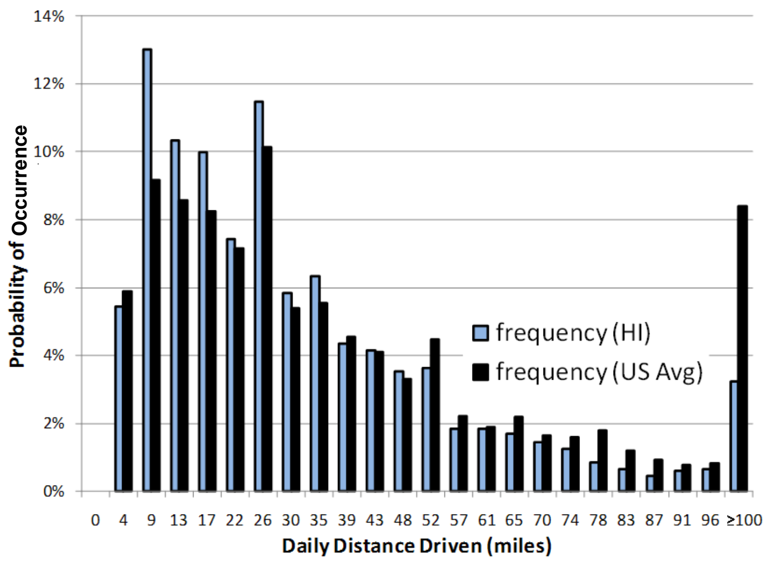
…and found the EV can be cost competitive, but is quite sensitive to changes in assumptions

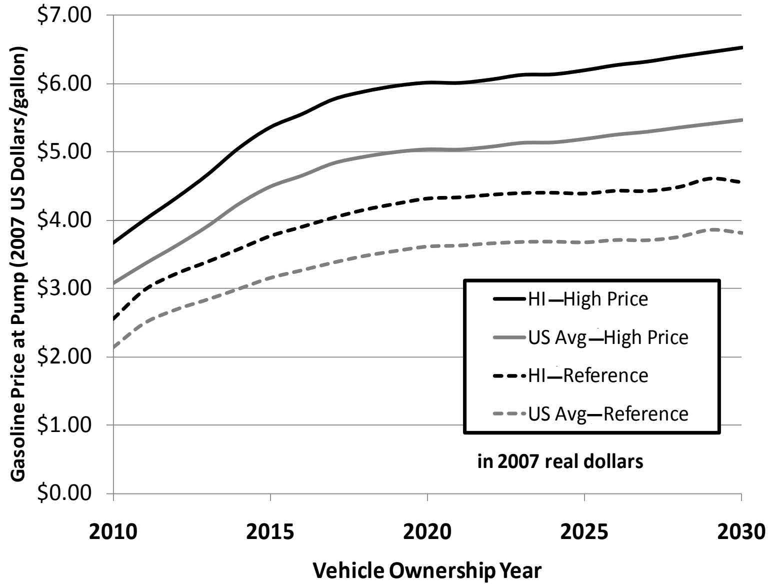


Battery Cost And Life Are The Strongest Factors



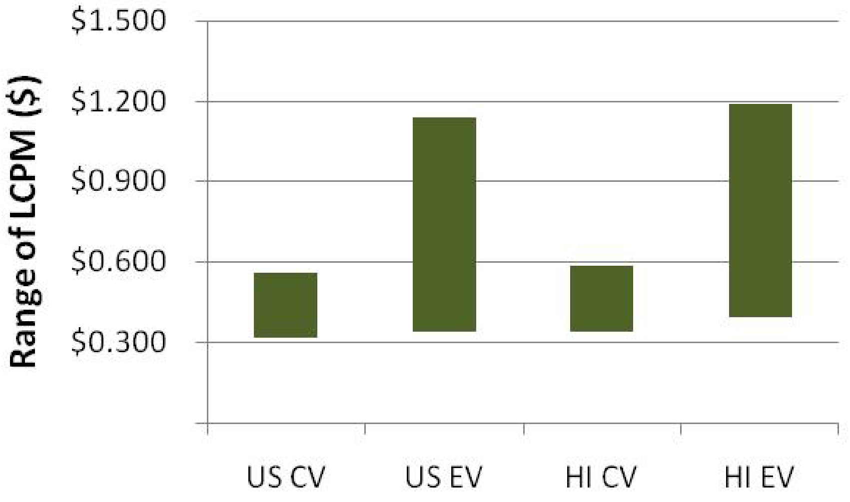
Niche Markets



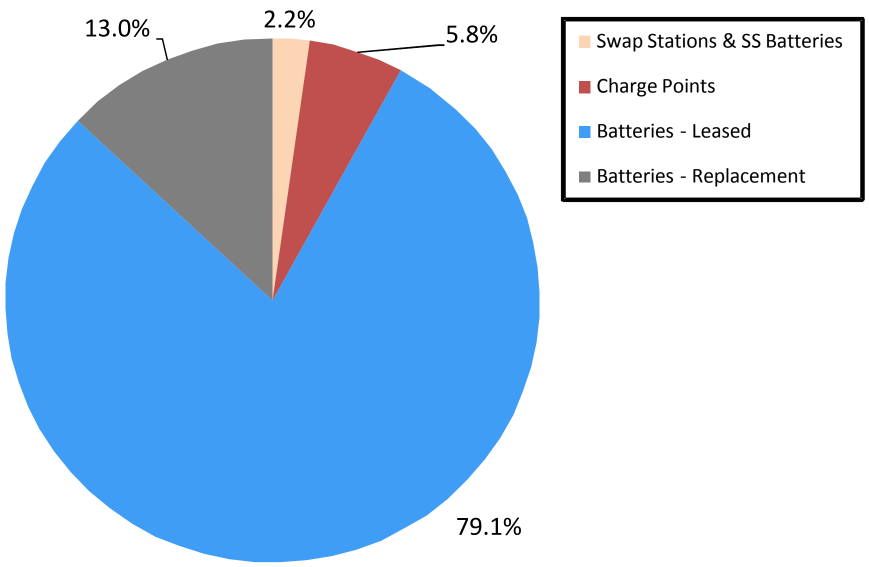


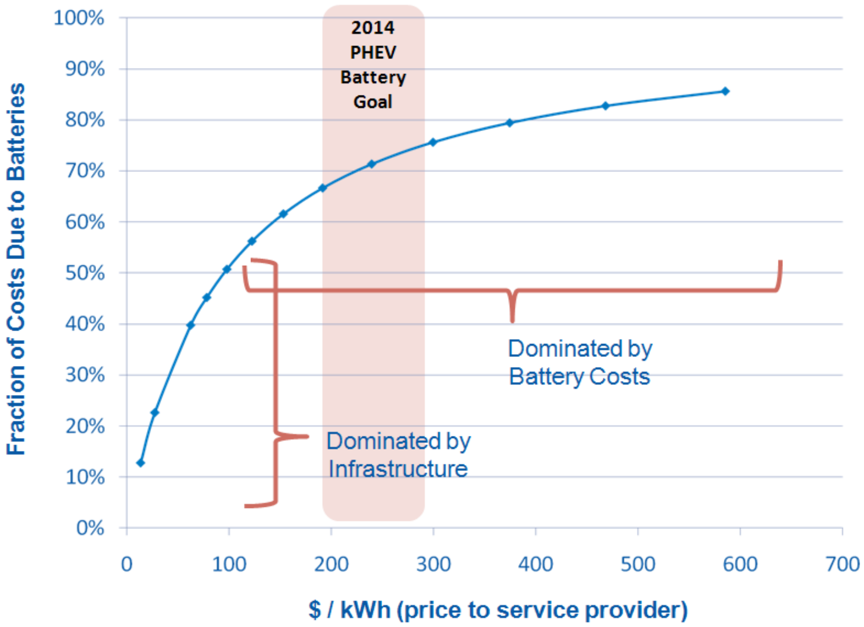
Hawaii: more battery-friendly driving distribution & higher gas prices…

…but higher electricity prices and no effect on dominant battery prices



Service Providers





Service provider costs are dominated by batteries (up to ~92%), allowing charge points and swap stations to be provided at minimal marginal cost

Summary

- This presentation is meant to give you a quick preview of the "Battery Ownership Model" and its capabilities

- The purpose of the model is to assist the U.S. Department of Energy in understanding how various business plans for EVs compare to other technologies

- The preliminary results presented herein show:
    - EV costs are most sensitive to battery cost and life assumptions within the scope of other parameters considered herein
    - Service provider costs are dominated by battery rather than infrastructure cost; thus one may be able to provide significant added value at minimal additional cost

- Additional application and development of the tool will continue in FY11

Acknowledgements

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