U.S. DEPARTMENT OF ENERGY

EV Everywhere Consumer/Charging Workshop:

Target-Setting Framework and Consumer Behavior

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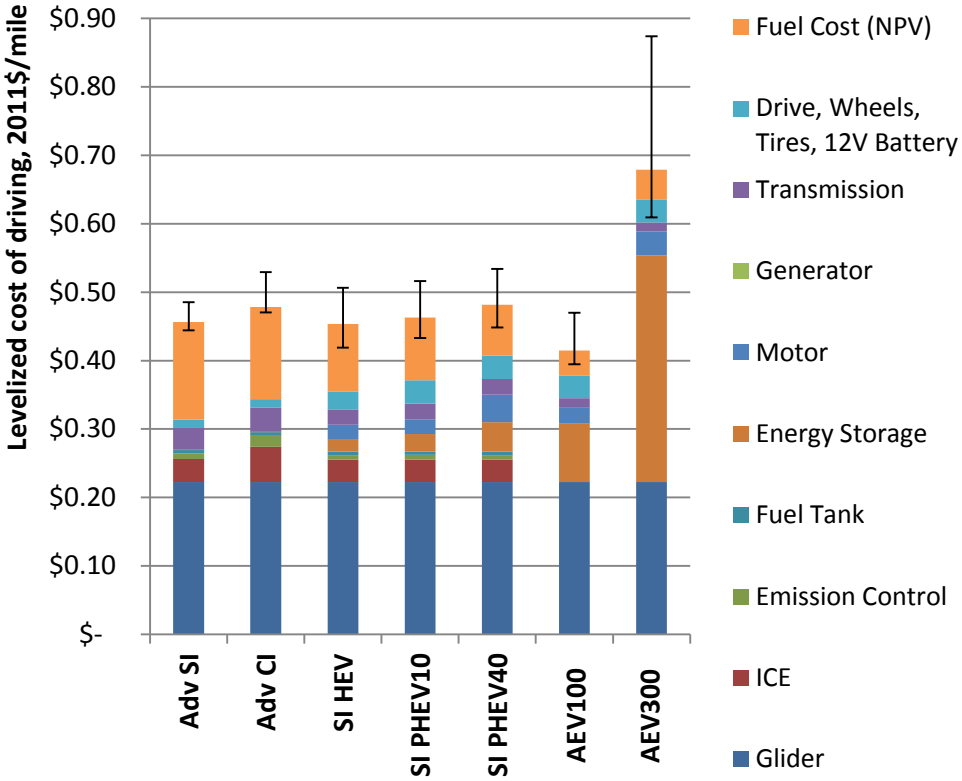
For "EV Everywhere" Analysis, Three Scenarios

1. **PHEV40** – reduces battery size while removing range issues, but involves the higher cost of two powertrains
2. **AEV100** – minimizes vehicle purchase cost, but introduces range/vehicle use/infrastructure tradeoffs
3. **AEV300** – helps to address range issues, but large battery leads to high vehicle cost

Vehicle-level analysis provides a starting point for setting EV Everywhere technical targets for these vehicles.

Levelized Cost of Driving (LCD)

vehicle purchase price + fuel expenditure over 5 years, expressed per mile traveled



Analysis Assumptions: *2022 midsize vehicle, mid-case technology projection (with high and low technology sensitivities), EIA's AEO11 "High Oil" fuel prices projections for 2022 = {Gasoline $5.12/gal, diesel $4.76/gal, Electricity $4.12/gge), 14.5k miles/year, 5-year analysis period, no discounting, retail markup over manufactured cost = +50%*

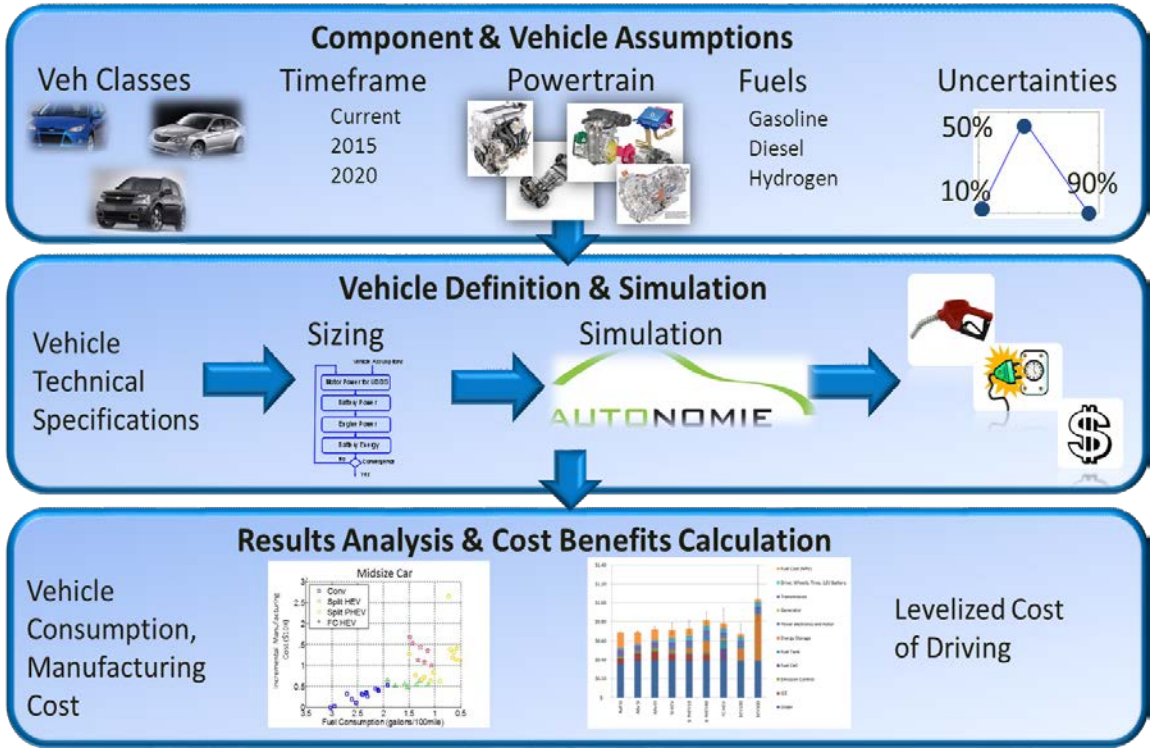
EV Everywhere Analysis Process Flow

in three steps…

1. DOE experts **define the bounds of technical possibility** for technology key metrics
   - 90% “low progress” scenario
   - 50% “mid case” scenario
   - 10% “high progress” scenario

2. **Define virtual vehicles** in Argonne National Lab’s *Autonomie* modeling and simulation software

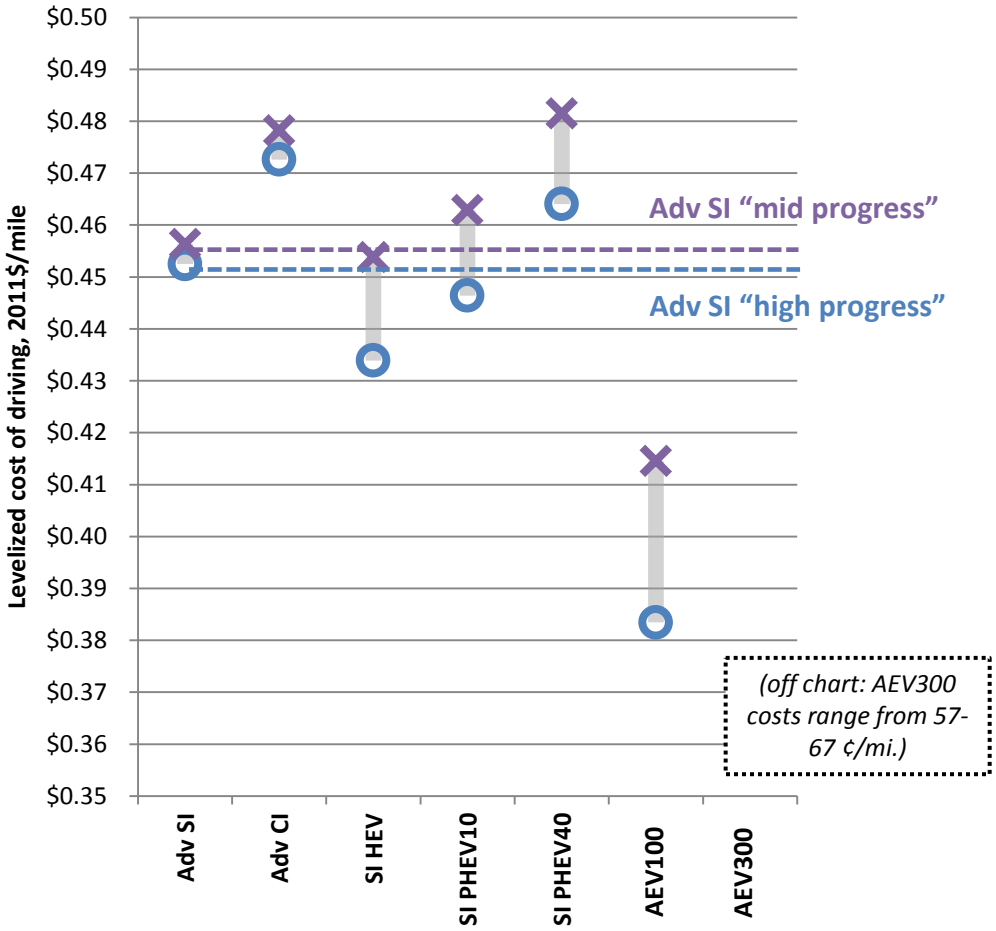
3. **Compare vehicles in a 5-year simple payback framework** within bounds defined by experts



Comparing LCDs

Implications for 5-year payback—

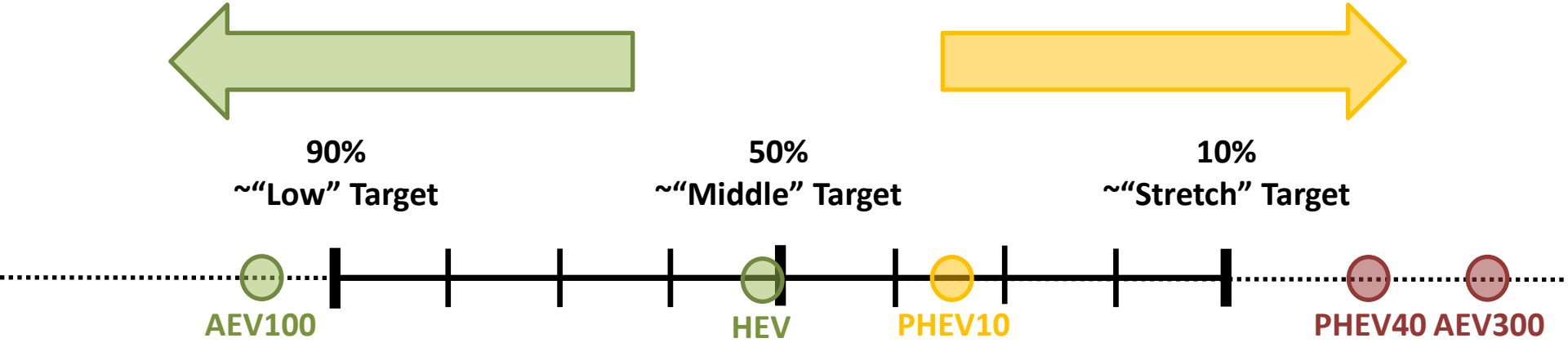
Vehicle	Payback (?)
SI HEV	Yes, at mid technology case
SI PHEV10	Yes, between mid and high technology case
SI PHEV40	No, requires push just beyond high technology case
AEV100	Yes, even at "low" technology case
AEV300	No, requires aggressive push beyond high technology case



Setting Targets – how aggressive?

*Vehicle architectures that are already LCD-competitive in the analysis framework at current targets **(green dots)** can still be cost competitive with a <u>less aggressive</u> push to the target:*

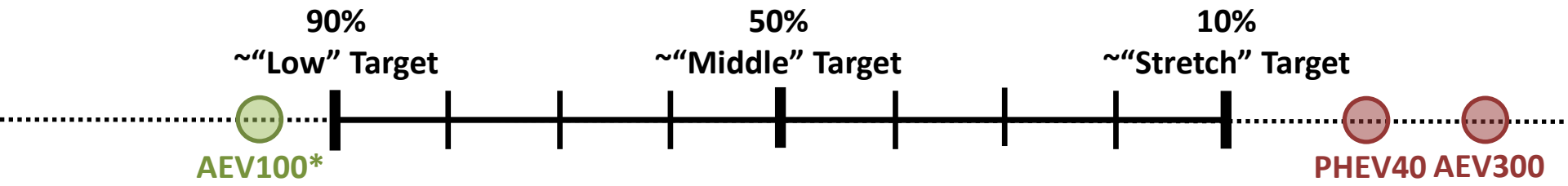
*Vehicle architectures that are not LCD-competitive in the analysis framework at current targets **(yellow dots)** can still be cost competitive with <u>more aggressive</u> push to the target:*



Vehicle architectures that are not LCD-competitive even at the stretch target level (red dots) require an <u>even more aggressive push beyond stretch targets</u>:

Target Implications–

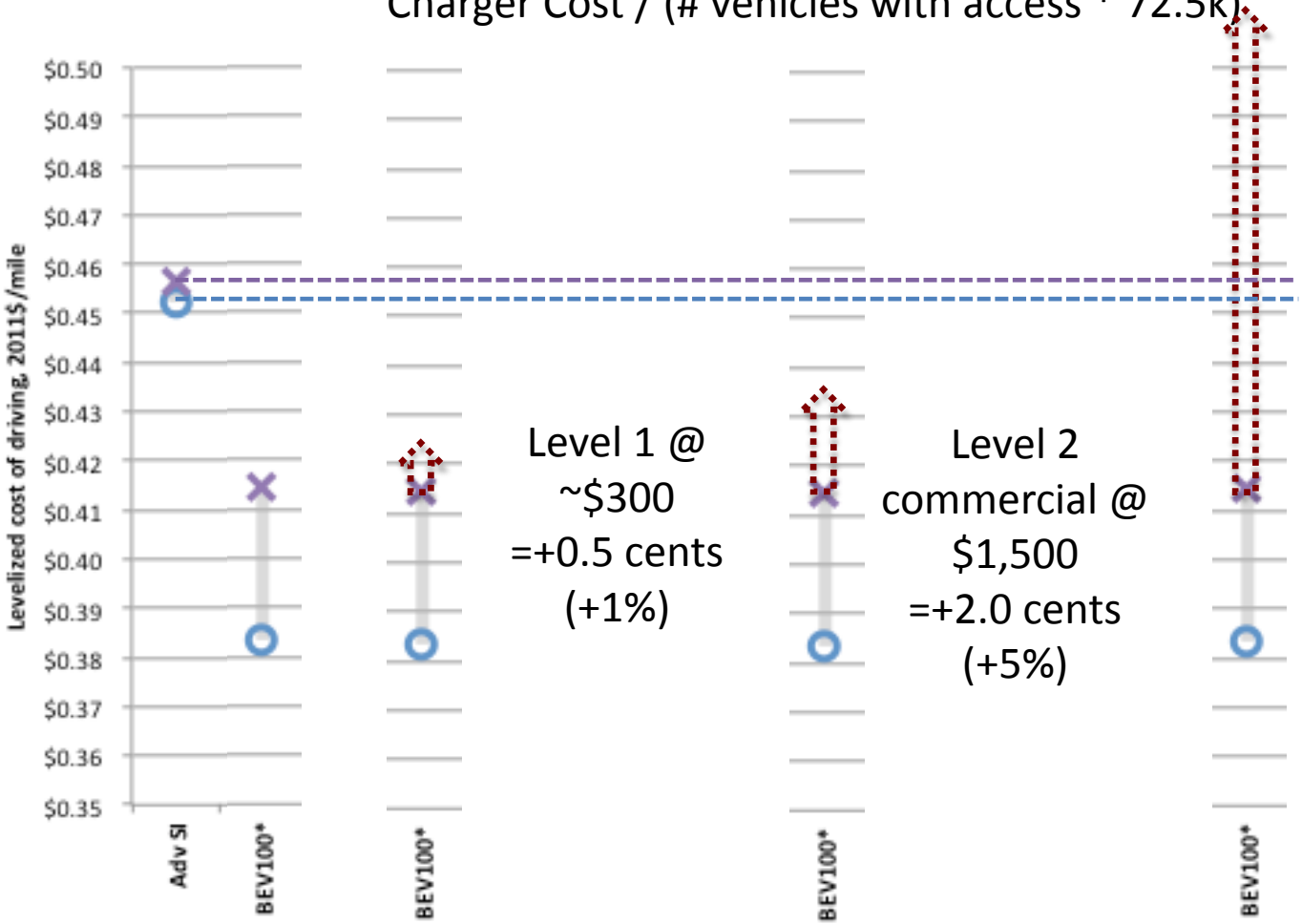
Analysis Subcomponent Inputs		
Battery	$/kWh	125-250
Electric Traction Drive	$/kW	7-13
Lightweighting	% wt	5-29
On-board Charger	$/kW	40-120



		Current Status	PHEV40	AEV100	AEV300
Battery	$/kWh	~650	190	300	110
Power electronics and motor	$/kW	~20	5	14	4
% Weight Removed	%	n/a	29	3	30
On-board charger	$/kW	~150	35	140	25

Adding Charging Infrastructure to the LCD Equation?

LCD additional cost =
Charger Cost / (# vehicles with access * 72.5k)



Level 1 @ ~$300 =+0.5 cents (+1%)

Level 2 commercial @ $1,500 =+2.0 cents (+5%)

DC Fast Charge @ $20,000 =+27.5 cents (+50%)

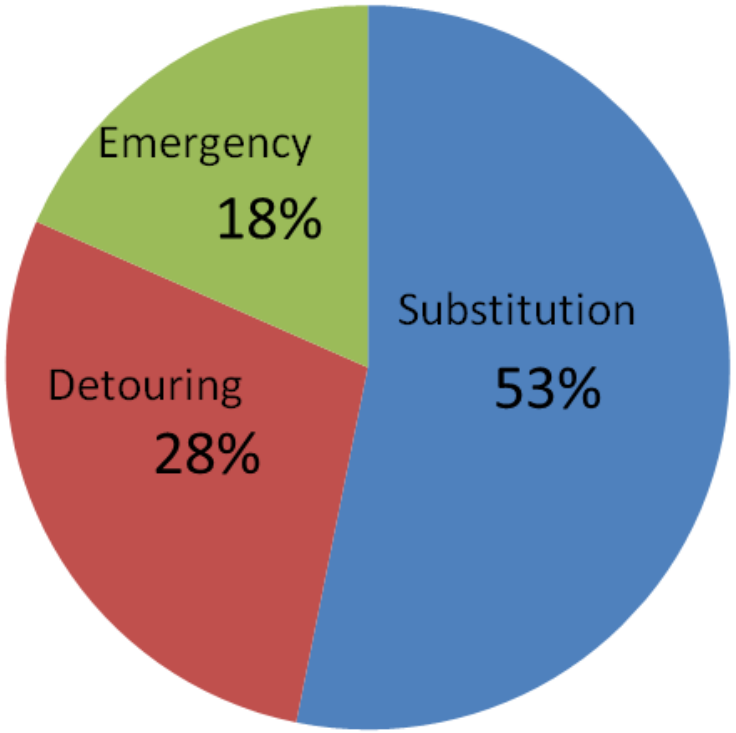
…OR divide by 5 vehicles and look cost-competitive against the Adv SI

[Starting to…] Make Sense of Range Anxiety

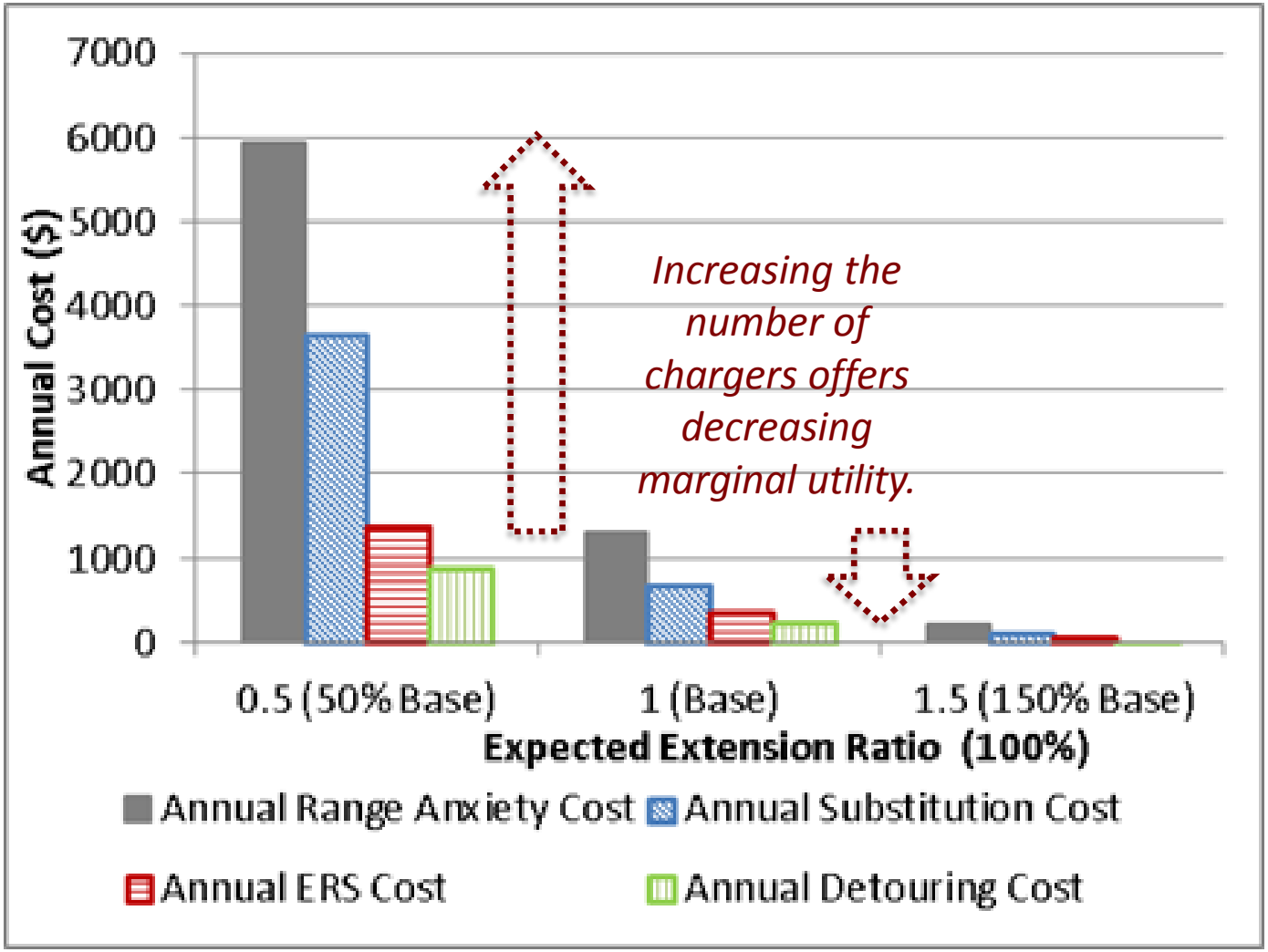
$$\text{Range Anxiety Cost} = \sum \text{Costs of} \left(\begin{array}{c} \text{Vehicle Substitution} \\ \text{Emergency Roadside Service} \\ \text{Detouring for Public Charging} \end{array} \right)$$

Total RAC
=$1,309/year

Assumptions:
$62 per emergency roadside service call, 0.5% charging accessibility, 100-mile BEV range, public charger power 60kW, 16000 miles driven per year typically at 20 miles per day, 2.5% standard deviation for daily travel distance, 20-mile standard deviation for BEV range, $30 per needed vehicle substitution



Charging infrastructure's value is relative



More work/public chargers and user-friendlier chargers allow/motivate multiple daily charges, extend ranges and reduce RAC.

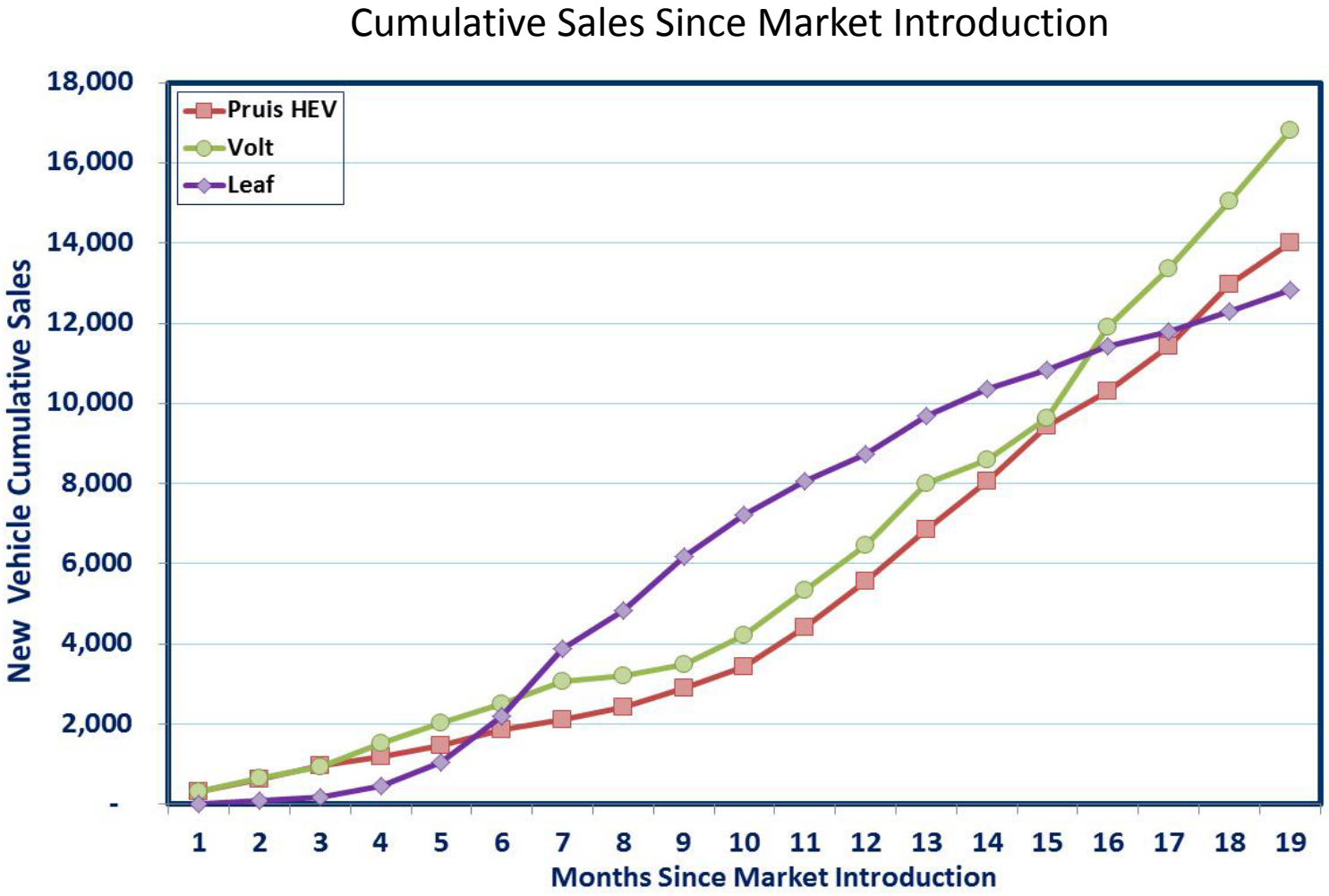
Increasing the number of chargers offers decreasing marginal utility.

Framing workshop relevant outcomes: digging to the next level

- Do “optimum” consumer-charging combinations exist?
- Which topics do we prioritize in researching EV consumer behavior?
  - How do EVs and the potential need for behavior change affect which payback times are acceptable?
  - Which technology amenities best improve EV-specific driver comfort, i.e. driver awareness of state of charge?
  - Which EV-specific value added components will/do consumers value most?
- To whom and through what media are public misconceptions of EVs combatted?
- Who and how are charging stations, signage, and payment “standardized”?

- **And, for all of the above: What is the Federal government’s role?**

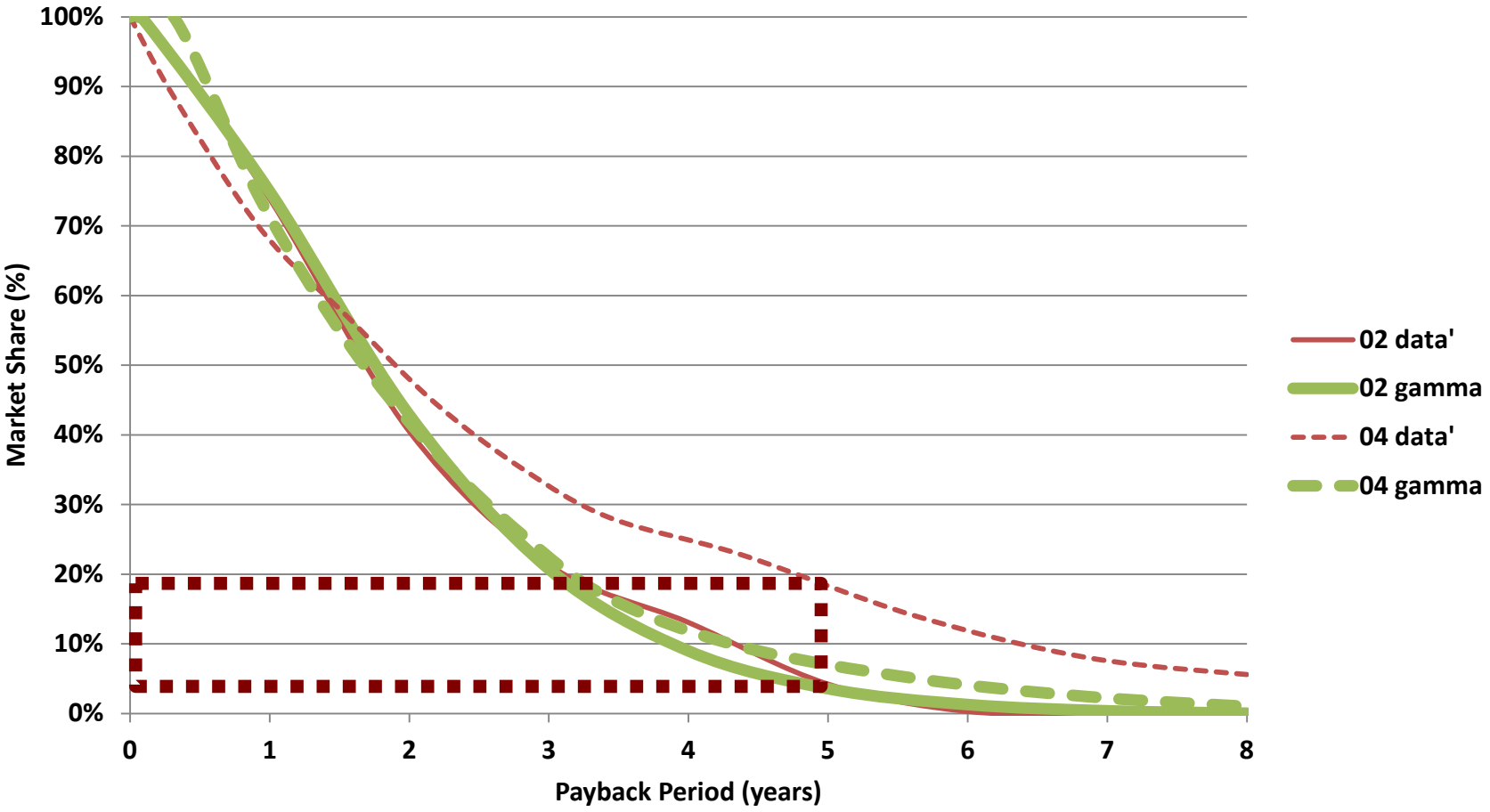
Early Sales of Prius HEV, Volt and Leaf



Critical Topic: Who will purchase PHEVS, AEVs?

- **Early Adopters**
  - Plug-in enthusiasts, those who prefer alternative to petroleum
  - Strong preferences, not very sensitive to prices
  - Heterogeneous, actually several different segments
- **Majority consumers**
  - If price is “right” (depends on fuel price)
  - If other features are attractive
  - Very heterogeneous, with wide range of preferences
- **Fleet managers**
  - Sensitive to vehicle and fuel prices, but also resale value, and operational issues
  - Different fleets have different needs and purchasing practices
- **For each segment, how will vehicle purchase and use behavior change in the next decade?**
  - Driving distance distribution, frequency of charging
  - More leasing, car sharing, etc.?

Payback Periods: Survey Data and Acceptability



Critical Topic: What is the market potential?

(and how can DOE set appropriate technology targets for these markets?)

- **Early Adopters**
  - How many? 5 to 15%?
- **Majority consumers**
  - If price is "right"
  - If other features are attractive
- **Fleet managers**
  - In 2009 and 2010, 18 – 23% of new light-duty vehicle sales were to fleets

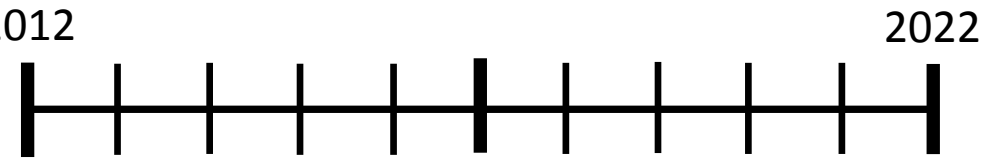
    (11 – 15% to rental, 5% to commercial, and 2% to government)
- **What technology targets will result in vehicles attractive to various markets?**

Some Factors Other Than Purchase Price or Operating Costs Can Influence Adoption

- Unfamiliarity, uncertainty of benefits/utility
- Availability in different makes/models and with other desired features
- Vehicle driving range, availability of charging stations, charging time
- Technology standardization (safety, ease of use, compatibility)
- Regulations and permitting of installation of charging equipment (esp. in multi-family dwellings)
- Consumer attitudes or disposition
- Consumer learning by driving

Some factors can be more important than price.
Most factors will depend on electric-drive technology performance and cost.

EV Everywhere consumer/charging through 2022



Advanced Batteries	650 $/kWh	→ cost reduction →	110 $/kWh ?
Advanced Electric Traction Drives	20 $/kW	→ cost reduction →	4 $/kW ?
Advanced Lightweighting	--	→ lightweight at reduced cost →	20% ?
Advanced Charging Technologies	~known.	How do we get to 2022?	What's needed by 2022?
Advanced Infrastructure Rollout	~known.	How do we (who?) rollout through 2022?	What does 2022 look like?
Advanced Understanding of Consumer Behavior	?	What do we (who?) study through 2022?	What do we know by 2022?
Advanced Consumer Understanding of EVs	???	How do consumers learn (and who teaches?) through 2022?	What do consumers know by 2022?