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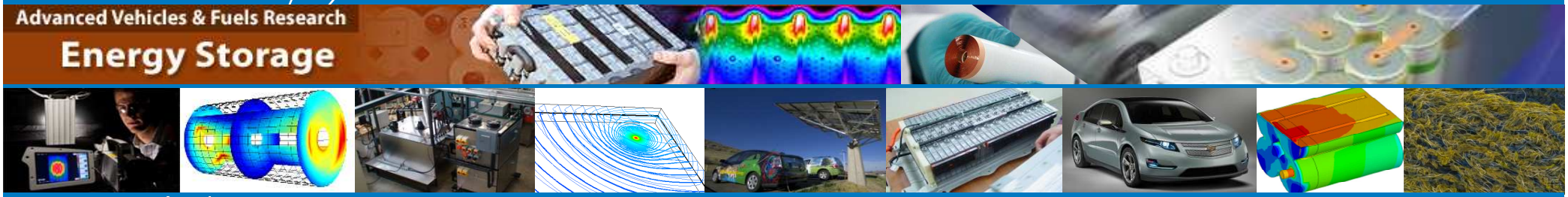
NATIONAL RENEWABLE ENERGY LABORATORY

A Techno-Economic Analysis of BEVs with Fast Charging Infrastructure



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evs 27

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Brian Cunningham
David Howell

Motivation

- Battery electric vehicles (BEVs) could significantly reduce the nation's gasoline consumption and greenhouse gas emissions rates.
- However, both the upfront cost and the limited range of the vehicle are perceived to be deterrents to the widespread adoption of BEVs.
- A service provider approach to marketing BEVs, coupled with a fast charging infrastructure deployment could address both issues and accelerate BEV adoption,
  but does it make financial sense to the consumer?

Outline

- Customer Selection
- Service Usage Statistics
- Service Plan Fees
- Driver Economics

A household with a single EV

Or

A household with 2 or more cars, one is EV

Customer Selection: Unachievable Travel

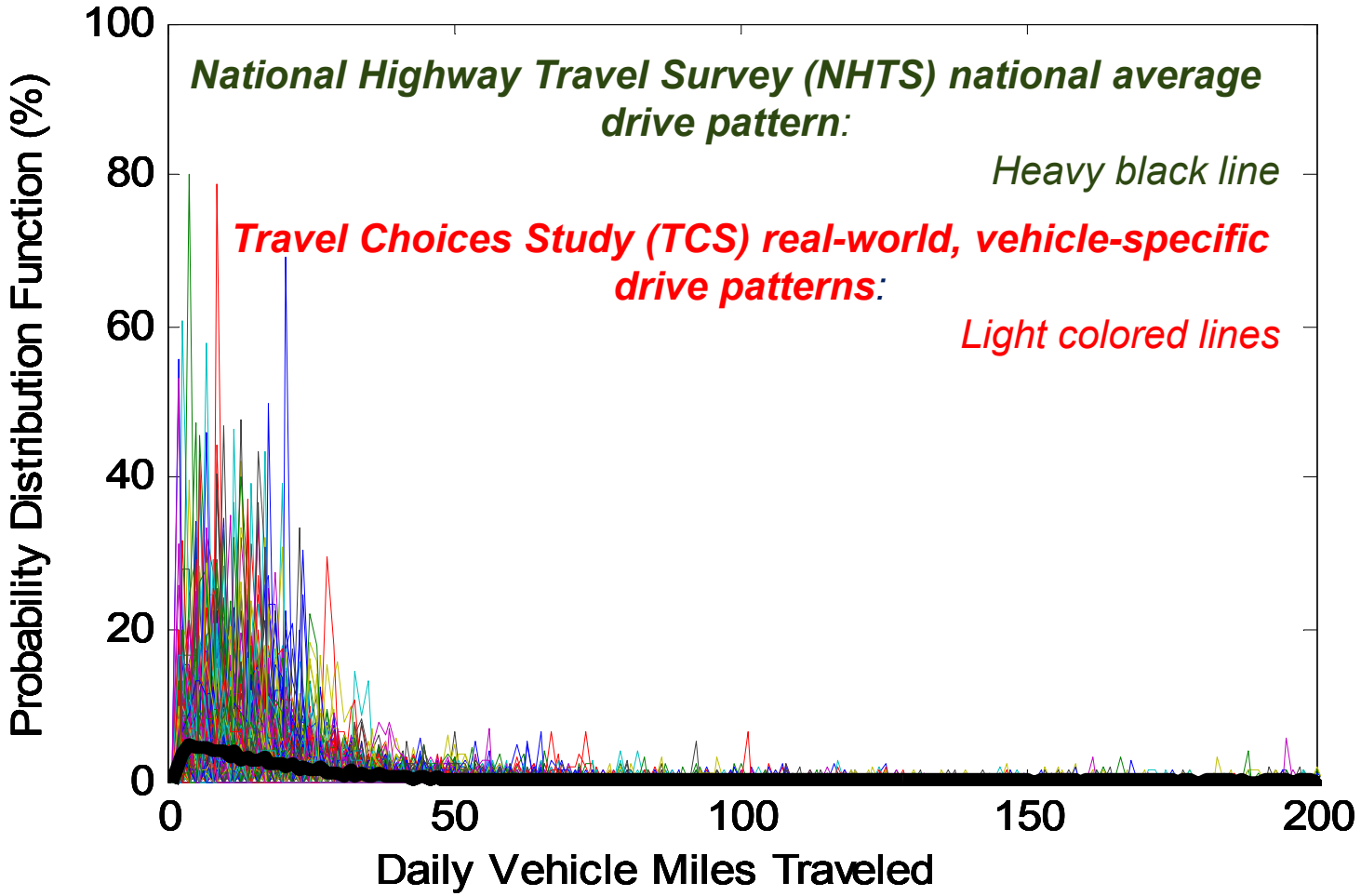
- Our studies have shown that how a driver completes travel not achievable with a BEV (e.g., day trips longer than the range of the vehicle) strongly impacts economics.

- If one can complete unachievable travel at low marginal cost (e.g. use another CV owned by the household), fast charging is unlikely to be cost-effective.

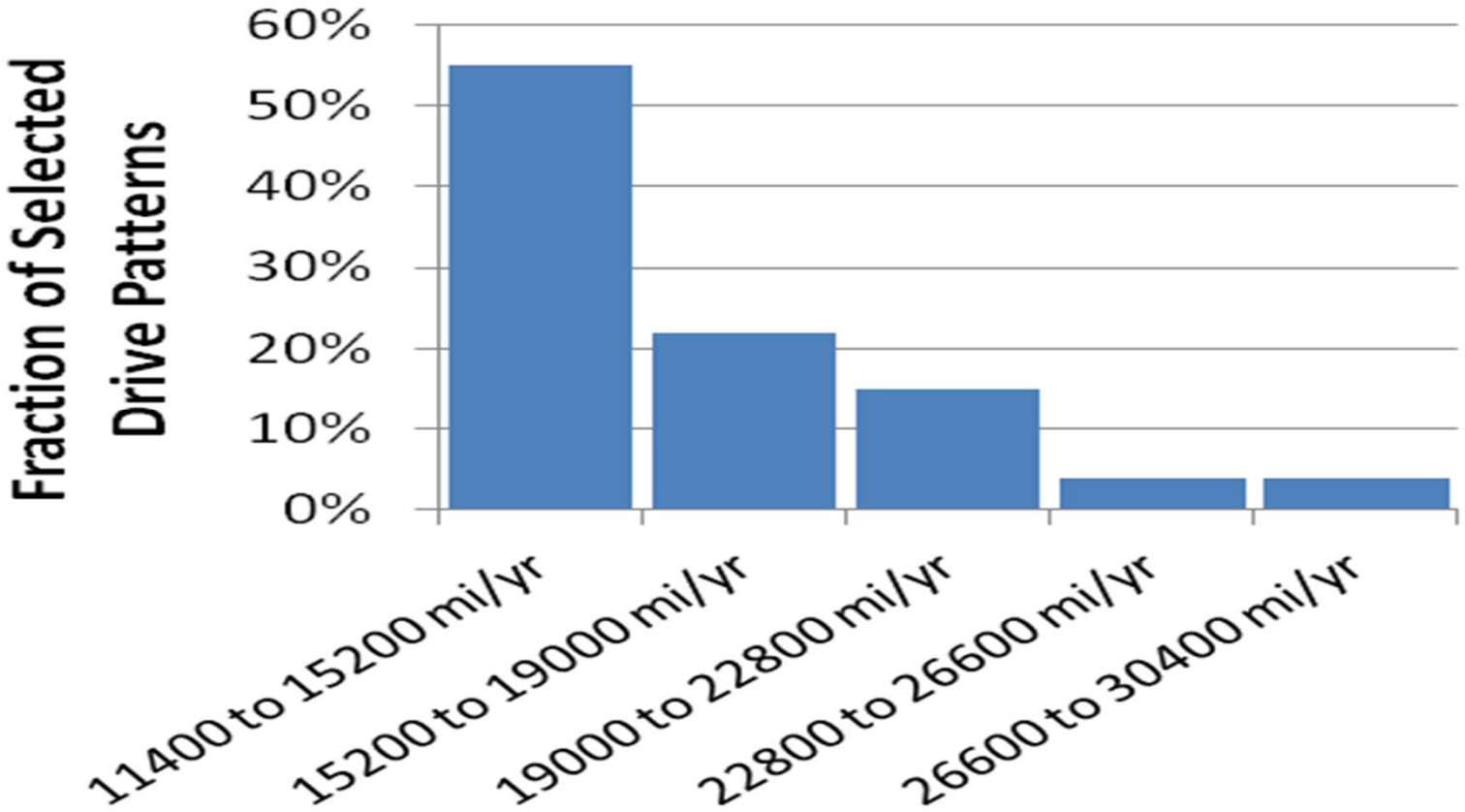
- However if unachievable travel is expensive (e.g. a rental car is required), then fast charging may be an attractive option. Thus we restrict our study to this scenario.

Customer Selection: Drive Pattern Data

- Not all drivers are well suited to a fast charging service plan, and no fast charging service provider would target the entirety of the vehicle market.



Customer Selection: Drive Patterns



- We down-select 100 drive patterns (~25% of the complete TCS set) that show the best potential cost effectiveness relative to directly-owned conventional vehicle (CV) and BEV alternatives using a simplified TCO analysis.

- We find that annual VMT is the single most important factor driving our down-selection

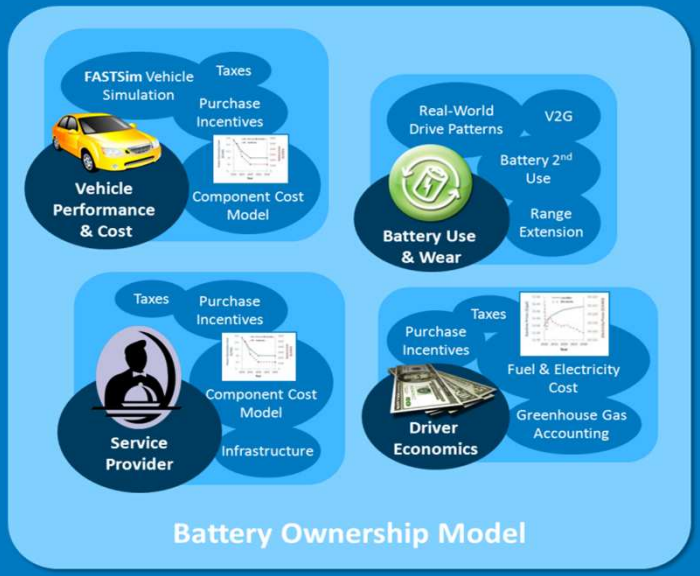
Service Usage Statistics: Approach

- To calculate service plan fees, we need to know infrastructure requirements and operating expenses.

- Approach: Apply techno-economic analysis.
- We use our **Battery Ownership Model (BOM)** to calculate electricity usage, fast charging frequency, battery life, and vehicle utility factor for each combination of 100 drive patterns, three vehicle ranges, three maximum battery SOCs, and two fast charge wear factors.

  – Note we apply a limit of two fast charges per day (max) to account for temporal and spatial restriction on swapping availability, as well as a driver's willingness to change behavior.

What is the Battery Ownership Model?



An advanced techno-economic simulator for EVs intended to analyze complex use-scenarios like battery swapping, fast charging, car sharing, etc.

Service Usage Statistics: Results

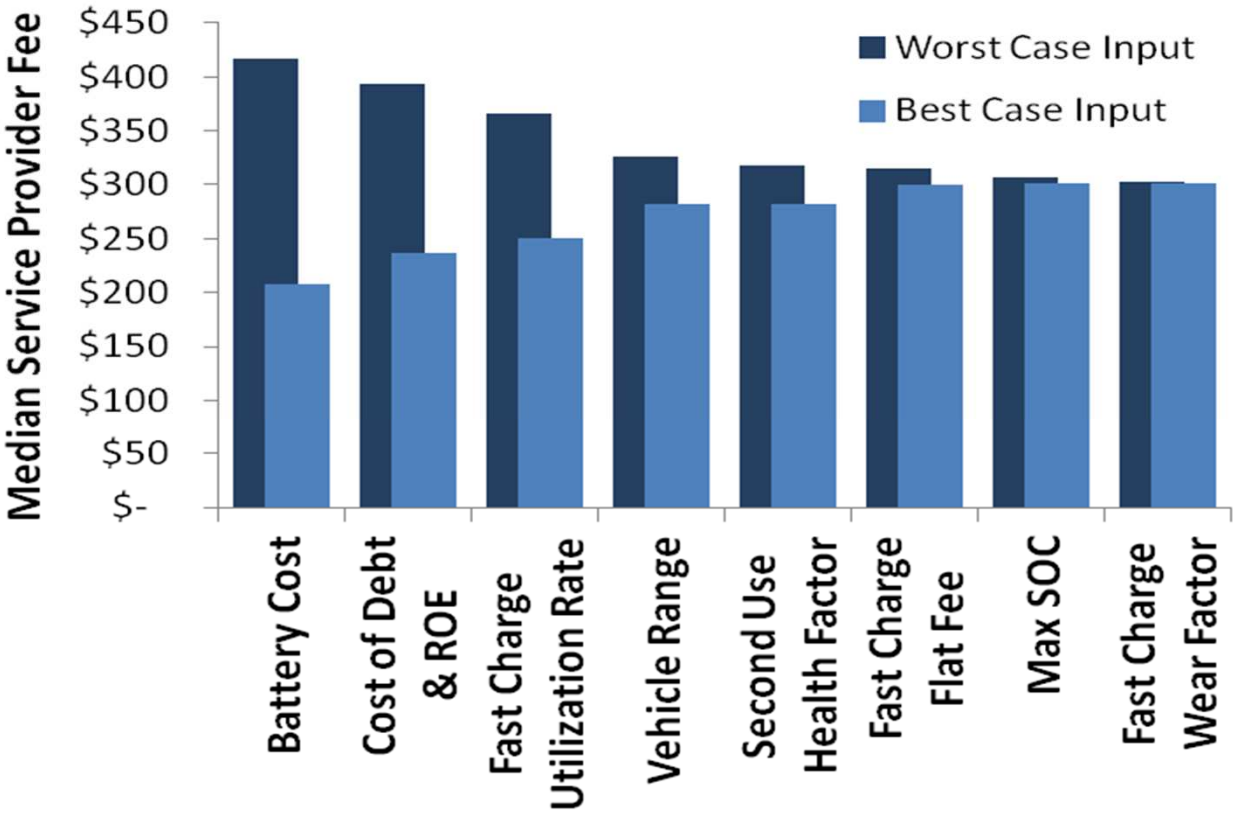
Range	Max SOC	Battery Wear Sensitivity to Fast Charging	Battery Life (yrs)	Fast Charge Events per Year (No.)	Utility Factor
50 mi	100%	Low	9.0	135.1	76%
		High	7.9	135.1	76%
100 mi	100%	Low	9.0	29.4	86%
		High	9.0	29.4	86%

- All data **averaged** across 100 customers
- BEV50: high fast charging frequency, battery life sensitive to fast charge effects, good utility factor
- BEV100: low fast charging frequency, negligible sensitivity to fast charge effects, better utility factor

Service Plan Fee: Approach

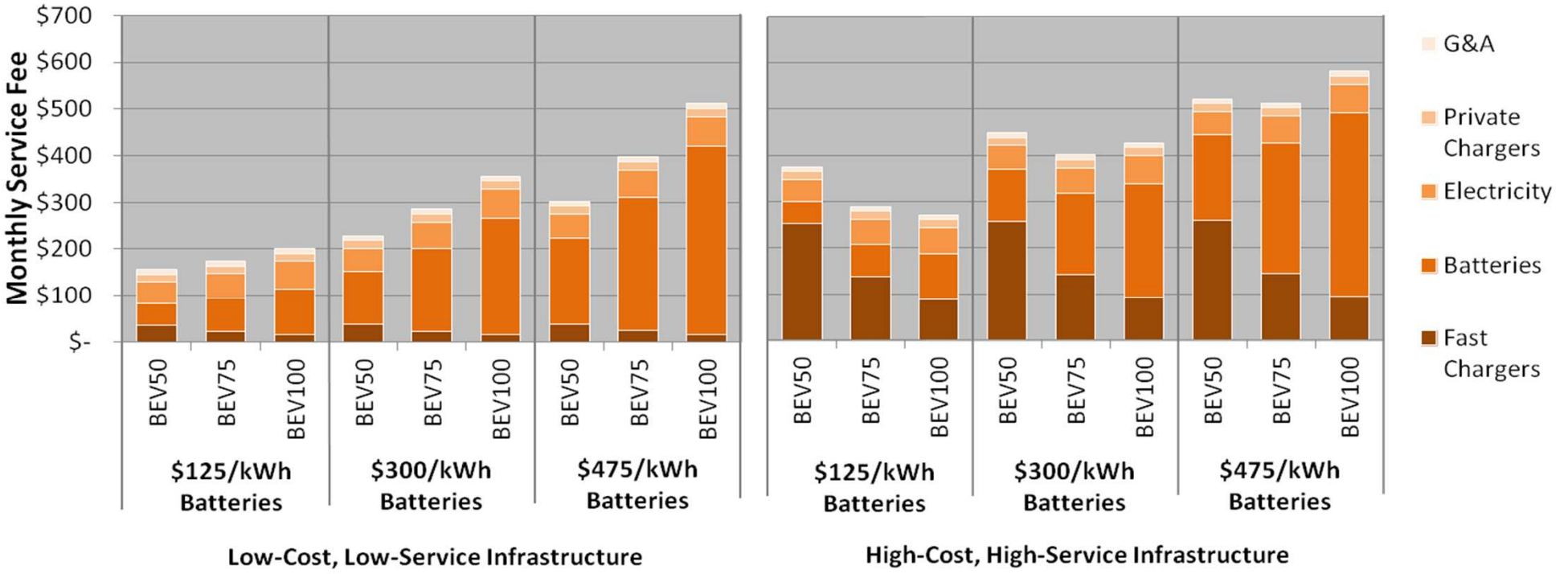
- Input service usage statistics.
- Calculate fast charge infrastructure requirements.
  - Utilization rate (hrs/day) drives number of customers per fast charger (1.2 hrs/day for typical U.S. gas pump).
- Account for all fast charge infrastructure, battery, home charger, electricity costs, and operating expenses.
- Calculate service plan fee using a detailed business model to meet return-on-equity (ROE) requirement.
  - Build infrastructure in year zero for 10,000 subscribers using 50/50 equity/debt financing.
  - Remaining working capital following all expenses, taxes, and debt payments is applied to build new infrastructure each year, thereby determining increase in subscribers.
  - Service plan fee is calculated such that the value of the company at year 15 is equal to the initial equity investment had it grown at the prescribed ROE.

Service Plan Fee: Input Sensitivity



- Battery cost, cost of financing, and fast charge utilization rate are the highest impact factors.
- Fast charge wear factor has a negligible impact.

Service Plan Fee: Cost Breakdown

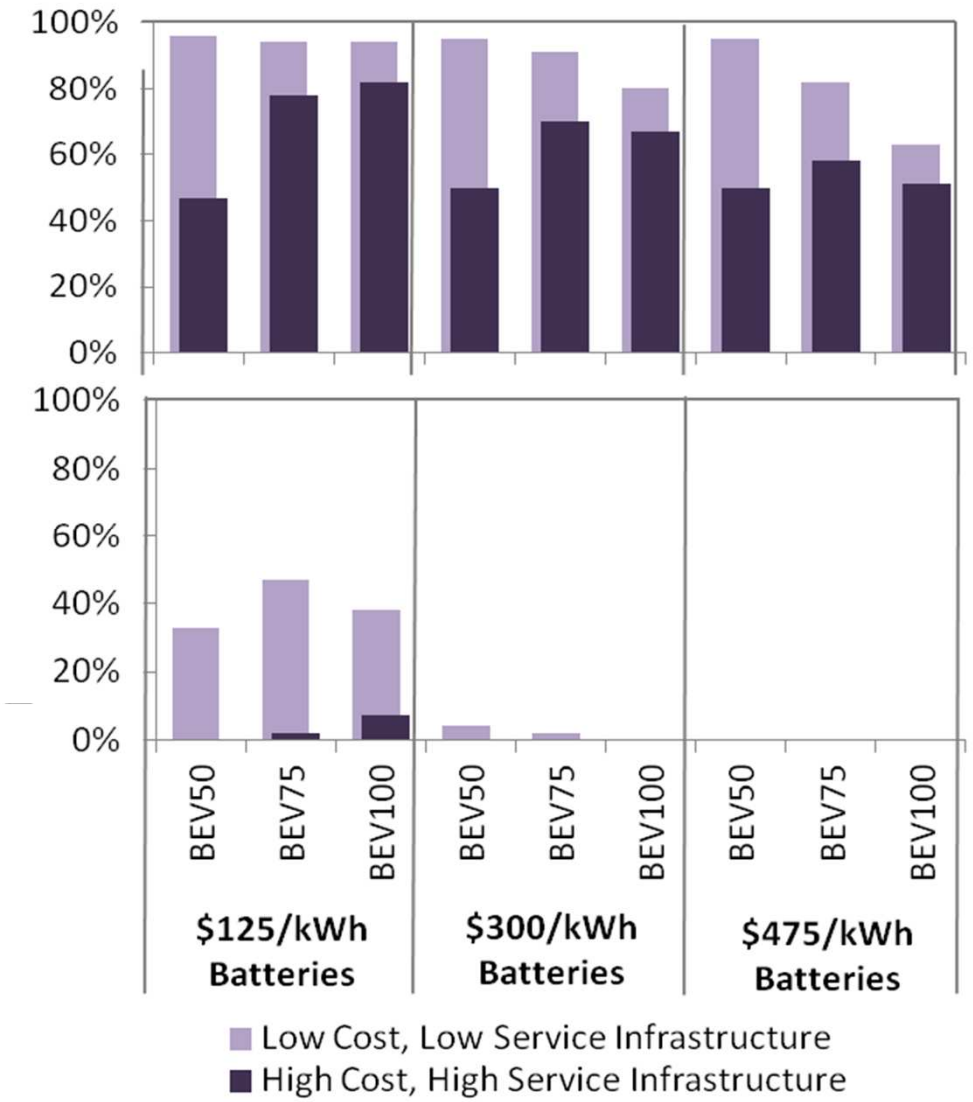


- Batteries are a major cost component in nearly every scenario.
- Fast charge infrastructure costs can vary from insignificant to the largest single cost element.

Individual Driver Economics

Fraction choosing SP-BEV over DO-BEV75

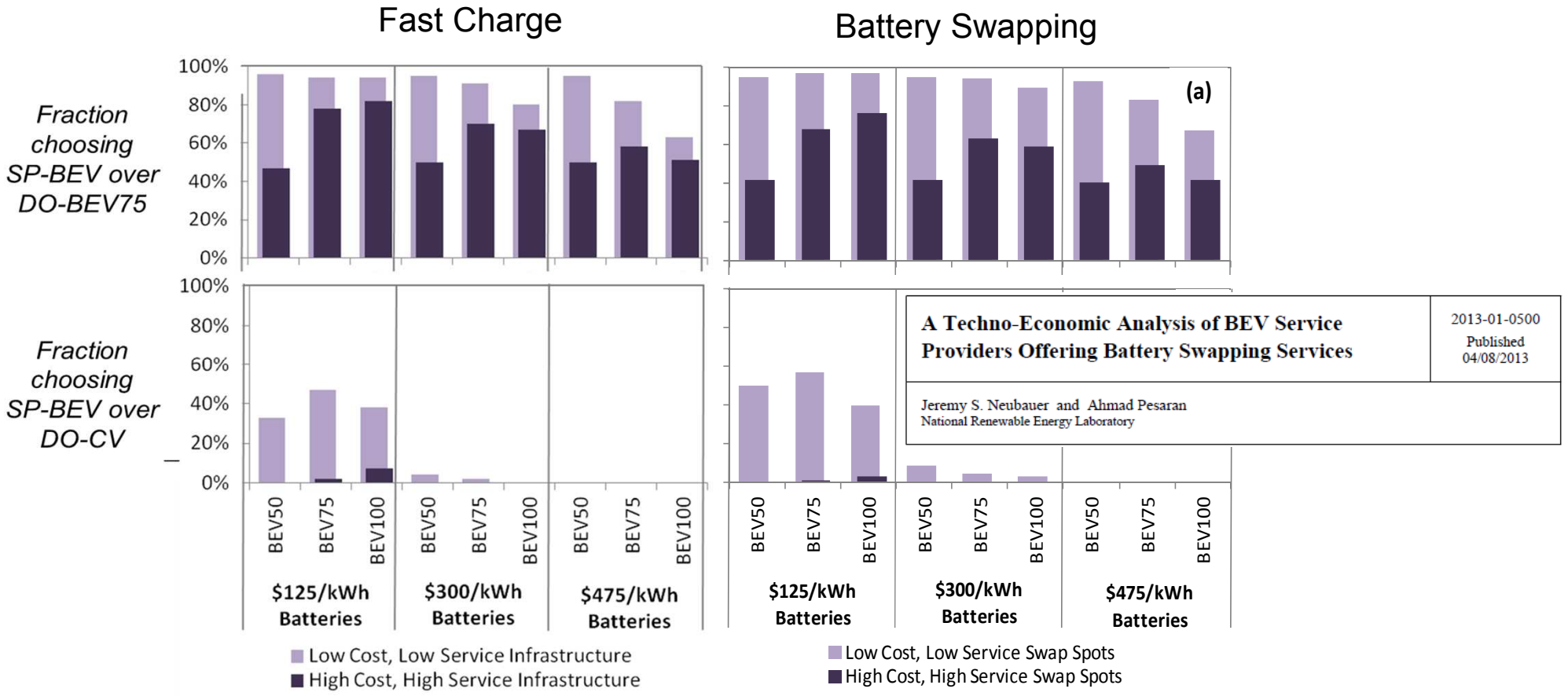
Fraction choosing SP-BEV over DO-CV



Note: We assume no federal, state, or local tax incentives for either scenario

What about Battery Swapping?

- A battery swapping service plan may be priced similarly, but offers faster service to the driver
- But battery swapping is challenged by the need to standardize pack design and swap strategy.



Conclusion & Future Work

- **A fast charge service plan BEV can be more cost-effective than a directly owned BEV for some single-vehicle, high-mileage consumers**
- **Battery swapping would be more convenient at a similar price point, but is challenged by battery standardization issues**
- **Owning a conventional vehicle is less costly under present expectations for battery and US fuel prices when BEVs are unsubsidized**
- **The case is not yet closed on fast charge, though**
  - How do incentives affect the economic equation?
  - What happens to economics when you remove the service provider?
  - How do spatial and temporal availability of fast chargers affect utility and economics?

Future Work

- **The case is not yet closed on fast charge, though**
  - How do incentives affect the economic equation?
  - What happens to economics when you remove the service provider?
  - How do spatial and temporal availability of fast chargers affect utility and economics?
  - **How do economic and behavioral assumptions from other parts of the world affect the outcome of this model?**

NREL can readily evaluate fast charging and battery swapping in other countries with willing partners!


Thanks!
Questions?