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—

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Payback (?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI HEV</td>
<td>Yes, at mid technology case</td>
</tr>
<tr>
<td>SI PHEV10</td>
<td>Yes, between mid and high technology case</td>
</tr>
<tr>
<td>SI PHEV40</td>
<td>No, requires push just beyond high technology case</td>
</tr>
<tr>
<td>AEV100</td>
<td>Yes, even at “low” technology case</td>
</tr>
<tr>
<td>AEV300</td>
<td>No, requires aggressive push beyond high technology case</td>
</tr>
</tbody>
</table>

(Off chart: AEV300 costs range from 57-67 ¢/mi.)
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 less aggressive push to the target:

- 90% “Low” Target
- 50% “Middle” Target
- 10% “Stretch” Target

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

- AEV100
- HEV
- PHEV10
- PHEV40 AEV300

Vehicle architectures that are not LCD-competitive even at the stretch target level (red dots) require an even more aggressive push beyond stretch targets:
Target Implications–

### Analysis Subcomponent Inputs

<table>
<thead>
<tr>
<th>Subcomponent</th>
<th>Current Status</th>
<th>PHEV40</th>
<th>AEV100</th>
<th>AEV300</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Battery</strong></td>
<td>$/kWh</td>
<td>~650</td>
<td>190</td>
<td>300</td>
</tr>
<tr>
<td><strong>Power electronics and motor</strong></td>
<td>$/kW</td>
<td>~20</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td><strong>% Weight Removed</strong></td>
<td>%</td>
<td>n/a</td>
<td>29</td>
<td>3</td>
</tr>
<tr>
<td><strong>On-board charger</strong></td>
<td>$/kW</td>
<td>~150</td>
<td>35</td>
<td>140</td>
</tr>
<tr>
<td><strong>Lightweighting</strong></td>
<td>% wt</td>
<td>5-29</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Electric Traction Drive</strong></td>
<td>$/kW</td>
<td>7-13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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AEV100* ~“Low” Target

PHEV40 AEV300 ~“Stretch” Target

90% ~“Low” Target

50% ~“Middle” Target

10% ~“Stretch” Target

Current Status
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

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
\[ = \$1,309/\text{year} \]

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.*

*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

Cumulative Sales Since Market Introduction

- Prius HEV
- Volt
- Leaf

New Vehicle Cumulative Sales

Months Since Market Introduction

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

12,000
14,000
16,000
18,000

- Cumulative Sales Since Market Introduction

- Prius HEV
- Volt
- Leaf

- New Vehicle Cumulative Sales

- Months Since Market Introduction
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

![Graph showing market share vs payback period with data points for different years (2002, 2004) and two gamma distributions.](image)
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

<table>
<thead>
<tr>
<th>2012</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>650 $/kWh</td>
<td>110 $/kWh</td>
</tr>
<tr>
<td>20 $/kW</td>
<td>4 $/kW</td>
</tr>
<tr>
<td>--</td>
<td>20%</td>
</tr>
<tr>
<td>~known.</td>
<td>How do we get to 2022?</td>
</tr>
<tr>
<td>~known.</td>
<td>How do we (who?) rollout through 2022?</td>
</tr>
<tr>
<td>?</td>
<td>What do we (who?) study through 2022?</td>
</tr>
<tr>
<td>???</td>
<td>How do consumers learn (and who teaches?) through 2022?</td>
</tr>
</tbody>
</table>

### Advanced Batteries
- Cost reduction from 650 $/kWh to 110 $/kWh?

### Advanced Electric Traction Drives
- Cost reduction from 20 $/kW to 4 $/kW?

### Advanced Lightweighting
- Lightweight at reduced cost, 20%?

### Advanced Charging Technologies
- How do we get to 2022?
- What’s needed by 2022?

### Advanced Infrastructure Rollout
- 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?