Electric Vehicles: Opportunities and Challenges

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Introduction

• In 2011, Grant Lovellette and I wrote a report on the state of the electric car (BEV) comparing it to plug-in hybrids (PHEV) and gasoline powered cars.

• The study had a U.S. focus.

• Subsequently there has been showing enthusiasm for electric vehicles as the ultimate answer to those seeking a low carbon energy future in the transportation sector.

• Although in the short term, carbon emissions may actually increase, if the vehicle fleet is electrified.
Enthusiasm

• Volkswagen Group will offer 30 BEV models by 2025, Ford 13 and General Motors 20.
• Volkswagen is predicting that BEVs will be 25% of new car sales by 2025.
• Daimler is investing close to $12 billion in BEVs over the next nine years.
• The UK announced that it would ban the sale of gasoline powered cars by 2040.
• China has made a similar announcement, but without a date and has a BEV sales target of 8% by 2018.
• Bloomberg New Energy Finance projects EVs will be cheaper to buy and operate than a conventional car in most countries by 2025-2029 and will make up 54% of new car sales by 2040.
Findings in 2011 Study

• Over their useful life, BEVs were on average $4, 819 more expensive than conventional gasoline fueled vehicles.

• But if the industry could reduce the cost of batteries from $600 per KWh to $300, and gasoline prices rose to $4.50 -- the net present value of buying and operating a BEV would be $3,478 cheaper than if you purchased and drove a gasoline powered car of similar size and power.

• We assumed no government subsidies and used a discount factor of 15%.
Costs were not the only factor that consumers weighed in selecting a new car:
  - Safety
  - Range anxiety
  - Availability of charging infrastructure
  - Adequacy of the power grid to meet the incremental demand

We concluded that of these the absence of the charging infrastructure was the most challenging and difficult.
Findings from today’s Reassessment

- Continued to assume no government subsidies.
- Gasoline prices are now lower--$2.50 range.
- Average electricity rates are higher -- $0.17 per KWh.
- Installed battery costs have decreased –we assumed $400 per KWh, which may be conservative.
- BEVs average energy consumption is 0.37 KWh per mile—which may be conservative as well.
- Discount factor remained at 15%.
Results

• BEVs remain more expensive than gasoline fueled vehicles, but the differential is even larger -- an NPV $5,789 less than a comparable ICE.
• However, if battery manufacturers can reduce the price to $300 per KWh, BEVS will be competitive; if they can decrease the costs below $200, BEVs will have a significant price advantage over ICEs.
• The automobile industry is placing emphasis on reducing range anxiety by increasing battery capacity from around 30 KWh (Nissan Leaf) to 60-75KWh (Tesla, Chevy Bolt) – though this depends on the target market.
• Charging Infrastructure remains the biggest uncertainty, as charging transitions from a marketing tool to attract buyers to a commercial enterprise.
BEV cost comparison

• The definition of battery costs is not consistent and may or may not include installation, the capital cost of building the manufacturing plant and a return on investment.

• Using secondary sources, we calculate a battery cost of between $318 and $400 per installed KWh.

• At costs below $300, BEVs will be cost competitive with gasoline powered cars, but PHEV will not be – because of higher fuel and maintenance costs.
Charging Infrastructure
## Charging Equipment: 6 options

<table>
<thead>
<tr>
<th>Charger Type</th>
<th>Current Type</th>
<th>Average Power Delivered (kW)</th>
<th>Time taken to replenish daily usage (13.6 KWh or 37 miles/day)</th>
<th>Time taken to charge 100 miles</th>
<th>Range added per minute (miles)</th>
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</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>AC</td>
<td>1.4</td>
<td>9h 45m</td>
<td>26h 26m</td>
<td>0.06</td>
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<tr>
<td>Level 2 [standard]</td>
<td>AC</td>
<td>6.6</td>
<td>2h 4m</td>
<td>5h 36m</td>
<td>0.30</td>
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<tr>
<td>Level 2 [maximum]</td>
<td>AC</td>
<td>19.2</td>
<td>43m</td>
<td>1h 55m</td>
<td>0.86</td>
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<td>Level 3</td>
<td>DC</td>
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<td>44m</td>
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<tr>
<td>Level 4</td>
<td>DC</td>
<td>150</td>
<td>5m</td>
<td>15m</td>
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<tr>
<td>Level 5</td>
<td>DC</td>
<td>350</td>
<td>2m</td>
<td>6m</td>
<td>15.77</td>
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</tbody>
</table>
Charging Equipment: 6 options

- Level 1 charger
  - Residential

- Level 2 charger
  - Residential
  - Public

- Level 3/4/5 charger
  - Public

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Modeling: Base Case Assumptions

- 10 year usable lifetime
- 13,476 miles travelled per year / 36.9 miles per day (USDOT)
- 8% cost of capital
- 3% annual increase in electricity and gasoline prices
- Utilization
  - Residential: 41% (Level 1), 30% (Level 2) – based on recharging average daily usage
  - Public: 10% utilization, 10% increase per year
- Electricity prices (EIA):
  - Residential: $0.1759 per KWh
  - Commercial: $0.1447 per KWh
  - Demand charge: $13 per KW
- Residential time-of-use:
  - Off-peak: $0.08 per KWh
  - Summer peak: $0.35 per KWh
  - Winter peak: $0.27 per KWh
Modeling: Base Case Assumptions (cont.)

• Maintenance and insurance
  • Zero for residential Level 1 and 2
  • $400/yr each for public/commercial Level 2
  • $2,500/yr each for commercial Level 3-5

• Subsidies
  • Zero for residential Level 1 and 2
  • $1,000 equipment subsidy / $1,390 tax credit for public Level 2
  • $15,000 equipment subsidy / $2,500 tax credit for public Level 3-5
## Base Case Assumptions: Capital Costs

<table>
<thead>
<tr>
<th></th>
<th>L1 Res.*</th>
<th>L2 Res.*</th>
<th>L2 Public</th>
<th>L3 Public</th>
<th>L4 Public</th>
<th>L5 Public</th>
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</thead>
<tbody>
<tr>
<td>Equipment (per charger)</td>
<td>0</td>
<td>1,000</td>
<td>3,842</td>
<td>35,000</td>
<td>50,000</td>
<td>100,000</td>
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<td>Installation (per charger)</td>
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<td>3,108</td>
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<td>Site preparation (per charger)</td>
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<td>12,500</td>
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<td>Utility service</td>
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<td>0</td>
<td>4,000</td>
<td>17,500</td>
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<td>Transformer</td>
<td>0</td>
<td>0</td>
<td>5,698</td>
<td>32,500</td>
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<td>40,000</td>
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* Res = Residential
Residential Level 1-2 charging

• We compared charging a BEV against the cost of fueling an efficient 40 mpg gasoline-powered car and a 24 mpg car (U.S. average) over the vehicles’ lifetimes.

• **Level 1:** a BEV would be $305 more costly as compared with a 40 mpg vehicle, but if time-of-use rates introduced, BEVs would require $1,945 less to operate.

• **Level 2:** because of the greater capital costs, BEVs would cost considerably more to fuel than a 40 mpg gasoline powered car, but $3,652 less than a 24 mpg car.
Residential Level 1-2 charging (cont.)

• If the average BEV owner only charged his vehicle with a Level 2 charger at home for the miles driven during an average day – 36.9 miles per day, she would pay $72.04 per month or $0.065 per mile traveled in fuel costs. This compares with $0.104 per mile for a 24 mpg gasoline powered car and $0.063 for a 40 mpg car.

• If the utility charged time of use rates and the owner possessed a smart meter to take advantage of them, the cost of power would drop from $0.179 per KWh to $0.1245, which would significantly improve the comparative economics.
Level 2: Residential vs Public

• Public Level 2 charging (on commercial tariffs) is more expensive than residential charging due to higher equipment, wiring, permitting and trenching costs. Such costs are very location-dependent.

• Push Government investment in Level 2 chargers is unlikely to pay for itself and may become stranded as car batteries grow in size. It takes ~11 hours for a Level 2 charger to charge a 75 KWh battery.
  - Public Level 2 charging competes with fast charging and residential charging

• If BEV deployment in a neighborhood is rapid, the grid managers and electric utilities will have an incentive to synchronize the charging over a 10-12 hour period and avoid additional investment in the local distribution grid (esp. transformer capacity).
Level 3-5: Fast Charging

• In most jurisdictions, fast charging stations would be considered a commercial or industrial site and would be subject to tariffs that include both a demand charge and a variable or energy charge.

• Level 3-5 stations’ demand will be quite volatile but they still incur demand charges on top of the cost of electricity:
  o Assume charging poles of 50 kW per pole and 10 poles per station, peak demand could equal 500 kW at some times and appreciatively lower (even zero) at others.

• **Utilization rates** are a major determinant of the profitability of the station. Hard to predict/estimate for potential investors.
Demand Charges

• A demand charge is calculated based on the highest demand of the customer over the course of one month times a preset per-kW rate. These charges are suppose to cover the infrastructure costs needed to meet the highest demand.

• For a BEV charging station, these costs can be very high and put tremendous pressure on the station to seek revenues to meet this charge.
  o For example, the summer rate in PG&E’s system (California) is close to $18 per kW. If you assume that our hypothetical station has a monthly peak of 500 kW, the station in PG&E’s territory would have to pay $9,000 per month or $108,000 per year. This would be for the fixed charge only. The variable charge would be additional.
Public Level 2-5 charging

• More complex to model – must account for fixed & variable costs
  o Capital costs: equipment, installation, wiring and service extension, transformer
  o Variable costs: energy charges (per-KWh, commercial rates), demand charges (per kW), maintenance, insurance
  o Cost of capital = 8%, electricity price inflation = 3%
  o Utilization rate growth = 10%

• Model output is the cost of charging ($ per KWh) for the consumer.

• Gasoline equivalents:
  o 24mpg ICE = $0.282 per KWh
  o 40mpg ICE = $0.169 per KWh
Breakeven price (zero NPV) vs utilization rate
Losses can be very large if utilization stays low

Assumptions:

- Initial utilization rate of 10%
- Electricity priced at $0.282 per KWh (competitive with 24mpg)
Even larger if priced to match an efficient ICE

Assumptions:

Initial utilization rate of 10%

Electricity priced at $0.169 per KWh (competitive with 40mpg)
Three other questions

• Who should own and operate Level 3-5 commercial charging stations?
  o Electric utilities
  o OEMs
  o Third party

• What is a reasonable business plan for a commercial charging station?
  o Monthly payments
  o Time-based payments
  o Energy-based payments, per KWh
  o All of the above?

• Can electric vehicles serve as a source of storage for the grid (V2G)?