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%.

2011 Findings (cont.)

- 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 that gasoline fueled vehicles , but the differential is even larger -- an NPV $5,789 less that 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

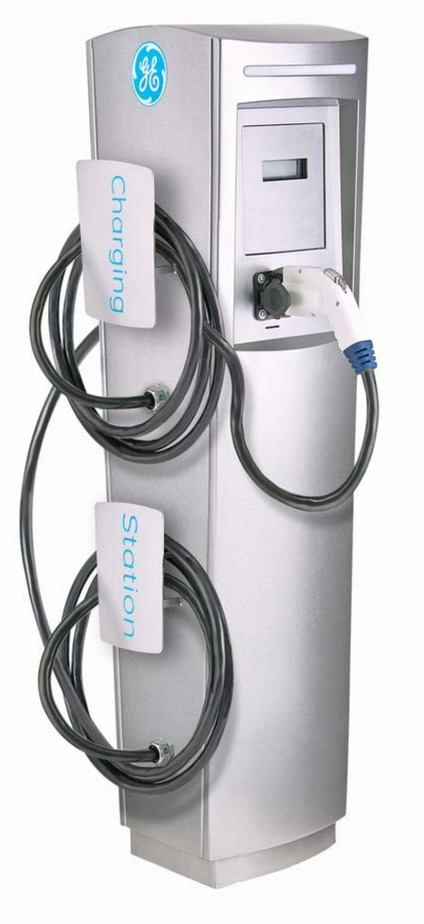
Charging Equipment: 6 options

Charger Type	Current Type	Average Power Delivered (kW)	Time taken to replenish daily usage (13.6 KWh or 37 miles/day)	Time taken to charge 100 miles	Range added per minute (miles)
Level 1	AC	1.4	9h 45m	26h 26m	0.06
Level 2 [standard]	AC	6.6	2h 4m	5h 36m	0.30
Level 2 [maximum]	AC	19.2	43m	1h 55m	0.86
Level 3	DC	50	16m	44m	2.25
Level 4	DC	150	5m	15m	6.76
Level 5	DC	350	2m	6m	15.77

Charging Equipment: 6 options

Level 1 charger
Residential

Level 2 charger
Residential



Level 2 charger
Public

Level 3/4/5 charger
Public

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

	L1 Res.*	L2 Res.*	L2 Public	L3 Public	L4 Public	L5 Public
Equipment (per charger)	0	1,000	3,842	35,000	50,000	100,000
Installation (per charger)	0	1,354	3,108	22,626	22,626	22,626
Site preparation (per charger)	0	0	3,000	12,500	12,500	12,500
Utility service	0	0	4,000	17,500	17,500	17,500
Transformer	0	0	5,698	32,500	40,000	40,000

* 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:
    - 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.

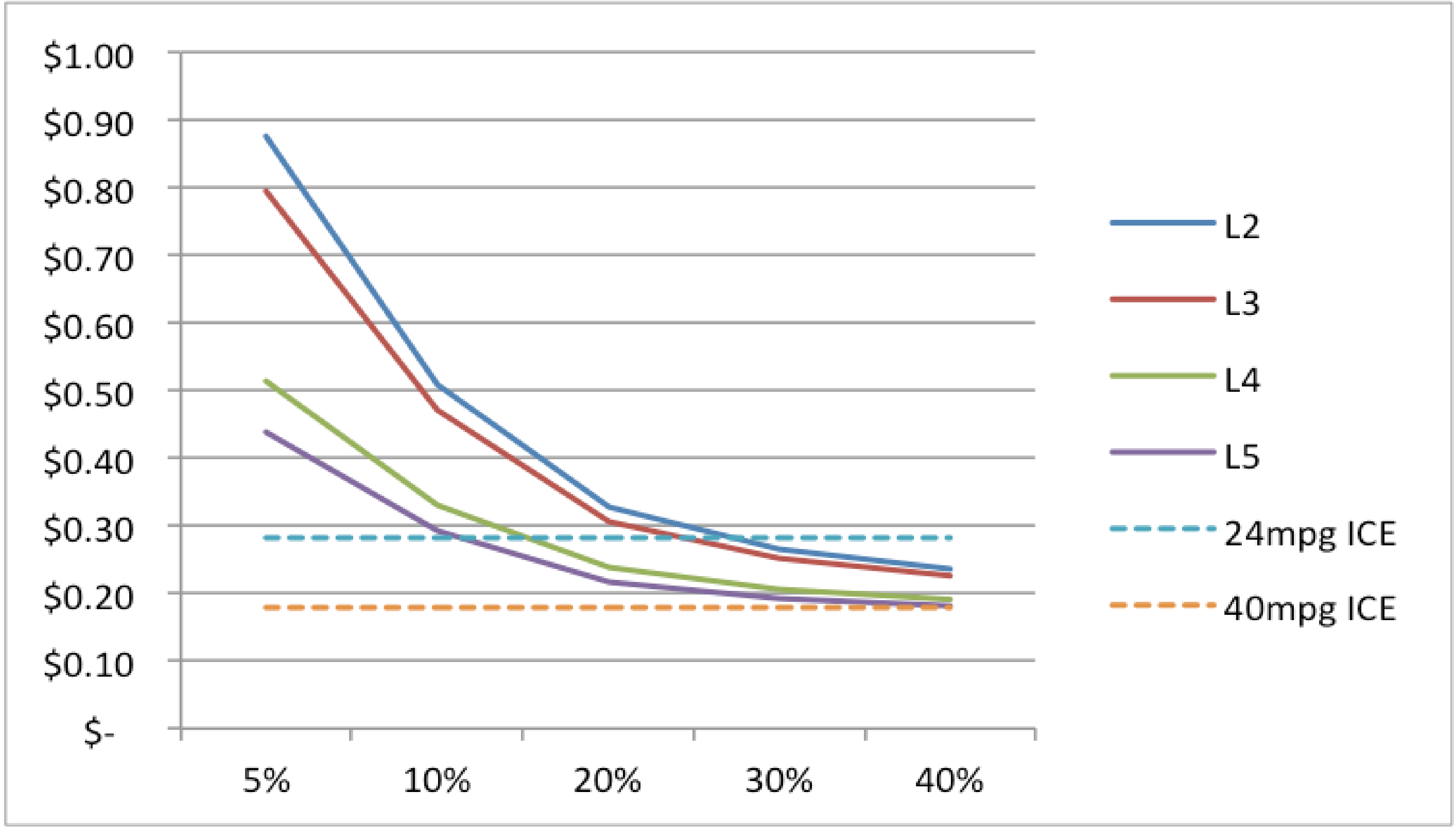
Demand Charges

- 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.
    - 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.

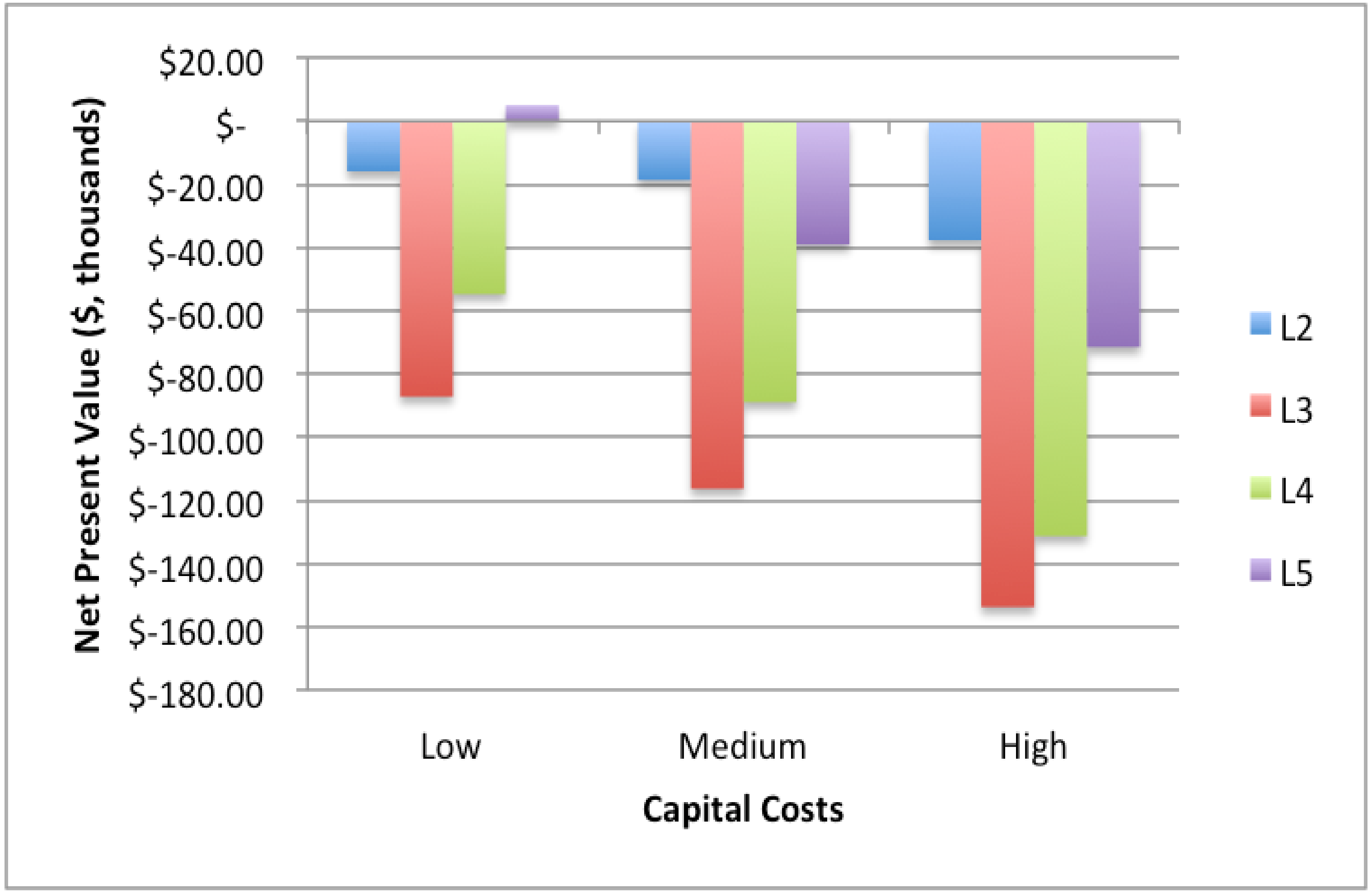
Public Level 2-5 charging

- More complex to model – must account for fixed & variable costs
  - Capital costs: equipment, installation, wiring and service extension, transformer
  - Variable costs: energy charges (per-KWh, commercial rates), demand charges (per kW), maintenance, insurance
  - Cost of capital = 8%, electricity price inflation = 3%
  - Utilization rate growth = 10%
- Model output is the cost of charging ($ per KWh) for the consumer.
- Gasoline equivalents:
  - 24mpg ICE = $0.282 per KWh
  - 40mpg ICE = $0.169 per KWh

Breakeven price (zero NPV) vs utilization rate



Losses can be very large if utilization stays low

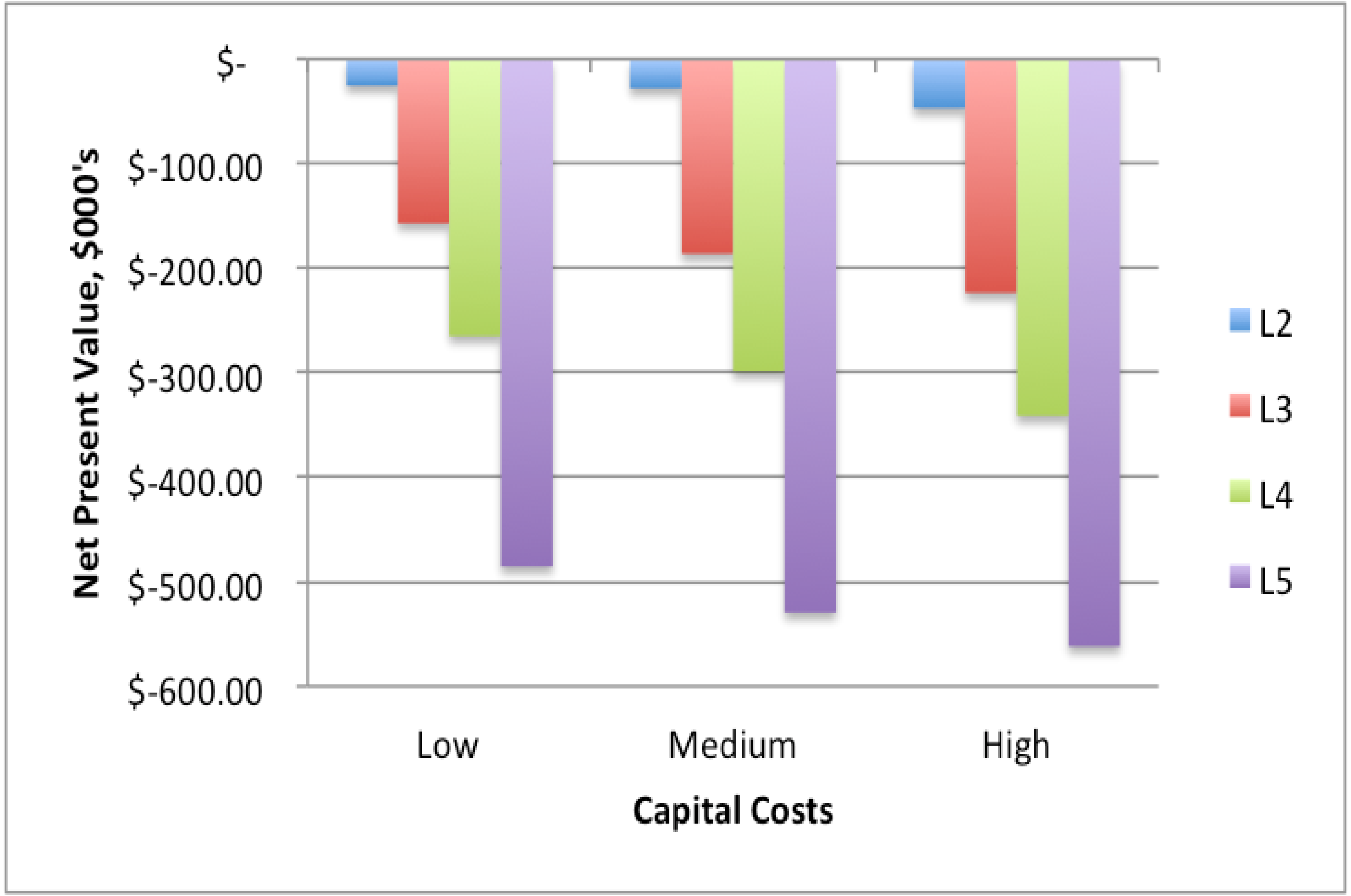


Assumptions:

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?
  - Electric utilities
  - OEMs
  - Third party
- What is a reasonable business plan for a commercial charging station?
  - Monthly payments
  - Time-based payments
  - Energy-based payments, per KWh
  - All of the above?
- Can electric vehicles serve as a source of storage for the grid (V2G)?