Vehicle Electrification and Dynamic Pricing

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Topics

- Background on electric vehicles
- Electric capacity and energy impacts of electric vehicles
- Implications for dynamic pricing by electric utilities

Background on Electric Vehicles

Compact Car with Internal-Combustion Engine

- Fuel use: 25 miles per gallon in ‘typical’ local driving
- Gasoline cost: $3.00 per gallon
- Total fuel cost: 12.0 cents per mile
  (includes taxes of 2.24 cents per mile)
- Fuel use: 5,865 Btu’s per mile, ‘well to wheel’

Compact Car with Electric Motor and Battery

- Car type
  - Five passenger compact
  - ~3,500 lbs vehicle weight (including ~600 lb battery pack)
- Electric motor
  - 80 kilowatt sustained output (1 kilowatt = 1.34 horsepower) → 107 horsepower
  - 200 foot-lbs of torque
- Battery system
  - 24 kWh lithium ion (20 kWh per typical charge cycle)
  - 3.3 kW onboard charger
- Performance
  - 90 MPH top speed
  - 60 to 100 mile range, depending on type of driving, weather

Compact Car with Electric Motor and Battery

- Electricity use: 0.410 kWh per mile in ’typical’ local driving
- Electricity cost: 2.46 cents per mile (assumes 6 cents per kWh)
- Battery cost: 18.6 cents per mile
- Tax: 2.24 cents per mile
- Total ‘fuel’ cost: 23.3 cents per mile
- ‘Fuel’ use:
  - 1,400 Btu per mile (busbar to wheel)
  - 3,040 Btu per mile (well to wheel, if electricity generated by combined-cycle gas turbine)

Electric Capacity and Energy Impacts of Electric Vehicles

Residential Recharging

- Class 2 in-home recharging unit
  - 240 volts, 3.3 kW, 6 hours recharge time (per car)
- Peak load
  - 3.3 kW recharging load is comparable to daily peak use in a typical Washington home
- Energy load
  - 12,000 miles per year requires 4,560 kWh of electricity
  - 4,560 kWh is roughly 38% of existing annual energy use in a typical Washington home
  - Time recharging: 1,380 hours/year

Impact on Local Distribution Systems

- Typical residential distribution transformer
  - Size: 25 kVa
  - Serves: 4 to 7 homes

→ Existing neighborhood distribution facilities are not designed to support uncontrolled recharging of multiple electric vehicles during peak load hours

Impact on Bulk Power System

If 10% of the existing car fleet in Washington State converts to plug-in electric (80 kW motor, 20 kWh battery, 3.3 kWh charger)

- 420,000 cars
- ~ 5 billion miles per year
- Energy: ~ 2.05 billion kWh per year
  - ~ 234 average megawatts
  - ~ 5.7% increase in annual residential load
- Non-Coincident Demand: ~ 1,386 megawatts

Impact on Bulk Power System

If 10% of the existing car fleet in Washington State converts to plug-in electric (80 kW motor, 20 kWh battery, 3.3 kWh charger)

- Motors with aggregate capacity of 33,600 megawatts connected to the power system (!)
- Although only a small fraction of this capacity would actually be usable, the potential is still significant

Impact on Bulk Power System

Potential for integrated use of car vehicle batteries

- System regulation, e.g., to accommodate intermittent sources of generation
- Reserve capacity
- Integrated use requires Smart Grid capabilities

Implications for Dynamic Pricing by Electric Utilities

Pricing Depends on State of the Grid

- Existing Grid
- Smart Grid

Existing Grid

- Recharging during on-peak hours is problematic
  - Secondary distribution facilities not built to handle recharging of multiple vehicles on-peak
  - On-peak recharging would also have large negative impacts on overall load-resource balances
- But, the existing grid could more easily support recharging during off-peak hours
  - Secondary distribution capacity available off-peak
  - Bulk power system (may affect use of hydro as a ‘battery’)

Existing Grid

Implementation

- Separate meter for vehicle recharger
- Time-of-use rates for battery recharging
- Under cost-based ratemaking, off-peak rate can likely be much lower than on-peak rate
- Limited ability to integrate battery use for grid support

Smart Grid

- Recharging during on-peak hours still problematic
  - Not cost-effective to build secondary distribution facilities to handle recharging of multiple vehicles on-peak
  - On-peak recharging would still have negative impacts on overall load-resource balances
- But, the Smart Grid could more fully integrate vehicle batteries
  - Secondary distribution capacity available off-peak
  - Use car batteries as a sink and a source to support the grid

Smart Grid

Implementation

- Optional real-time pricing, including time-varying prices for recharging and time-varying credits for grid support
- Could still offer time-of-use rates for customers who just want battery recharging
- Separate meter for vehicle recharger (may be less important under real-time pricing?)
- Real-time pricing integrates batteries use for grid support