Transportation Fundamentals: Electric Vehicles

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Who We Are:

Graduate Degree Programs
- Transportation Technology & Policy
- Energy Systems

Research Centers
- Sustainable Transportation Energy Pathways
- Plug-in Hybrid & Electric Vehicle Research Center
- Energy Futures Program
- China Center for Energy and Transportation
- Sustainable Freight Center

Partner Programs
- National Center for Sustainable Transportation (NCST)
- UC Institute of Transportation Studies
- UC Pavement Research Center
- Policy Institute for Energy, Environment and the Economy
- Program on International Energy Technologies

Energy and Efficiency Institute
- California Lighting Technology Center
- Western Cooling Efficiency Center
- Center on Water-Energy Efficiency
PH&EV Center

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5 Research Staff, programmers, visiting scholars

10 Graduate Students

12 Undergraduate Students
280+ publications, 42 papers in 2017, 17+ under review
Introduction

• Electric Vehicles & Batteries
• Current EV Market
• EV Incentives
• ZEV Regulation
• Environmental Impacts of EVs
• Costs of EVs
• Consumer Experience

Key Terms:

**EV – Electric Vehicle** – A vehicle which uses electricity from an external source for motive power.

**Hybrid** – A vehicle which uses electricity generated on-board the vehicle to supply some motive power.

**ZEV – Zero-Emission Vehicle** – Regulatory term meaning a vehicle which can drive at least part of the time with no air pollutant emissions. Includes electric vehicles, fuel cell vehicles and plug-in hybrids.
Many Kinds of EV’s, Including Battery Electric and Plug-in Hybrid

Battery Electric Vehicles (BEVs)
• Powered only by a battery
• Electric range 100-300 miles
• Price $30,000-100,000

Examples: Tesla’s, Chevy Bolt, Nissan Leaf, Hyndai Ioniq (Electric Version)

Plug-in Hybrid Electric Vehicles (PHEVs)
• Combination of gasoline and battery
• Electric Range 12-50 miles, gas range 300 miles
• Price $25,000-100,000

Examples: Toyota Prius Prime, Chevy Volt, Ford C-Max Energi, Hyndai Ioniq (Plug-in Hybrid Version), Chrysler Pacifica Hybrid
Fuel Cell Electric Vehicles

Fuel Cell Vehicles (FCVs)

• Driving range 300 miles
• Refueled by hydrogen at one of 39 stations in California (Approx. 20 more in development)
• Can only be leased, for around $500 per month including fuel

Examples: Toyota Mirai, Honda Clarity FCV
EV Model Availability

- 47 Models currently available:
  - 15 BEV models
  - 29 PHEV models
  - 3 FCEVs
Batteries

• Key considerations: Energy and power.
  • Energy is how far you can go, power is how fast you can accelerate

• Power measured in kilowatts (kW)
  • A normal household microwave is rated at about 1 kW

• Capacity typically measured in kilowatt-hours (kWh)
  • Your electrical bill is measured in kWh.
Charging

Charging Levels

• Level 1 (120 volt)
  • Power level of standard plugs
  • 4 miles of range per hour (1 kW)
  • Cost: $0-$1500

• Level 2 (240 volt)
  • Power level of dryer plugs
  • 12-32 miles of range per hour (3-8 kW)
  • Cost: $1,200-$3,000

• DC Fast
  • 60-200 miles per hour (50+ kW)
  • Cost: $50,000+

Charging locations

• Home (level 1 or 2)
  • 75-85% of charging events

• Work (Level 1 or 2)
  • 15%-25% of charging events

• Public (Level 1, 2, or DC fast)
  • <10% of charging events
Market by vehicle type

US Annual Sales

- Total BEV
- Total PHEV
- Total FCEV


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2018 market by automaker
Vehicle Incentives

Purchase Incentives

1. Federal Tax Credit, up to $7,500 per vehicle. Phases out once a manufacturer sells 200,000 vehicles (GM & Tesla have hit cap, Nissan will soon)
2. CA Clean Vehicle Rebate Program (CVRP) funded by cap-and-trade revenue. $2500 for BEV, $5000 for FCEV, $1500 for PHEV.
3. Low Carbon Fuel Standard (LCFS) purchase incentive under development.
4. Several smaller programs offered by CARB, local utilities, air districts; mostly funded by cap-and-trade.

Other Incentives

1. Most ZEVs are allowed to use carpool lanes for up to 3 years.
2. Low Carbon Fuel Standard gives significant incentive for EV charging.
3. Some free/discounted parking incentives.
Importance of Incentives

• CVRP and federal tax credit is the most important incentive.
• HOV lane access is the second most important incentives.
• Incentives are getting more important over time.
  • As EVs get cheaper, more people are potentially in the market and 1000’s of dollars are a larger fraction of the purchaser’s budget.
Incentives should not be removed early

**Netherlands PHEV Sales**

**Denmark BEV Sales**

**Georgia BEV Sales**

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Infrastructure and Charging Incentives

- CPUC authorized over $700 million in charger installation in PG&E, SCE, SDG&E territory, mostly aimed at commercial vehicles, but several residential pilot projects.
- VW settlement funds used, in part, to support charger deployment
- Utilities have deployed local programs for charger installation, funded by rate-base, LCFS credit revenue or state incentives.
- LCFS adopted new provision to support deployment of DC FAST chargers, will likely result in several thousand installations.
ZEV Program

• Introduced in 1990, now in 10 states, soon 11 (Colorado).
• Goal is technology development and commercialisation
• Credit requirement is a percentage of total vehicle sales
  • 7% in 2019
  • 9.5% in 2020
  • 7-12% by 2025

For example if the mandate is 5%

Automaker continues to sell conventional vehicles
Automaker: sells 100,000 cars
Automaker must also sell X EVs totaling 5,000 credits
Why Are EV’s More Efficient Than Internal Combustion?

Typically, about 20-25% of fuel energy becomes motion.
Less Heat, Less Wasted Energy

60-70% of fuel energy becomes motion.
EV Emissions Are Affected by the Grid

- Cleaner grid = lower net emissions.
- Even on fairly dirty (coal-dominated) grid, EVs are usually no worse than a comparable car.
- As the grid gets cleaner, the emissions from EVs will decrease.
- Total EV load is likely to be relatively small. A 100% EV fleet would likely increase electricity demand by 20-30%
EVs purchase price is not changing yet....
...but EV technology and range is improving
Battery Prices Keep Falling

Pack Price $/kWh

- Whole Industry (Lowest Pack Price)
- Performance EVs (Market Leaders)

2011, 2018, 2025, 2032, 2039, 2046

2018, $231
2018, $93

Pack Price $/kWh:
- Whole Industry (Lowest Pack Price)
- Performance EVs (Market Leaders)

Ambrose 2019
Consumer Experience

Consumer engagement/knowledge/awareness of PEVs had not changed since 2014
Summary

• EVs are an ever-growing role in transportation
• There range of models is increasing rapidly
• Battery costs are falling rapidly
• While many models are still aimed at the higher end of the market, more affordable options are deploying rapidly
• EVs have strongly penetrated among some demographics, but most people still can’t correctly name one model
• EVs offer significant emissions benefits compared to conventional vehicles, under almost every circumstance
We Are Happy to Answer Questions!

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