EXCITING TIMES FOR EVs

Dr. Kara Kockelman, UT Austin’s Transport Engineering
Should we be anxious about EV Range?

- GPS units provided **360 days (!)** of daily VKT data on **445 household vehicles** across Seattle between 2004 & 2006.

- **Average vehicle-distance per day** is **41 km**, with **standard deviation** of **20 km** (across all vehicles & days).

- Multi-day data reflect Americans’ **great variability in day-to-day personal-vehicle use**.

- **Household weights** used to reflect entire Seattle population.
Analysis Framework

Household

Single-vehicle household
- Switch to a BEV (Case 1)
- Switch to a PHEV (Case 2)

Multi-vehicle household
- Switch a vehicle to a BEV
- Switch a vehicle to a PHEV

What % Days can VKT be served if just charging at night?

Switch to a PHEV (Case 2)

What % Miles are electrified?

Switch a vehicle to a BEV

Which Vehicle to switch?

Swap w/vehicle that travels less on average (Case 3)

Swap w/vehicle that travels less on any given day (Case 4)

What % Days can VKT be served if charge only at night?

Switch a vehicle to a PHEV

Which Vehicle to switch?

Swap w/vehicle that travels more on average (Case 5)

Swap w/vehicle that travels more on any given day (Case 6)

What % HH Miles are electrified?
%Days BEV Range Not Exceeded: 2+ veh HHs

90% of days
95% of days
99% of days

All Electric Range (AER), in miles

% of Households

Nissan LEAF (95 miles AER)

BEV Replacing the Lower Overall-VMT Vehicle (Case 3)
**% VMT Electrified:** Multi-vehicle HHs

Average Shares of Household Miles Electrified *(with Std. Deviations shown)* using PHEVs in Multiple-vehicle Seattle Households
Key Findings

- Typical PEV designs show great potential for adoption & use, with minimal household adjustment.

- If owners are willing to charge >2 times/day on heavy-use days, or use another form of transport a few days a year, even limited-range BEVs appear feasible for significant shares of households.

- When assigned thoughtfully to household drivers (based on planned travel distances each day), even limited-AERange PHEVs offer significant distance electrification – even for multi-vehicle households!
But will a PEV be **Pricey**?

\[
NPV = \sum_{t=0}^{15 \text{ yr}} \frac{Cost_{EV} - Cost_{ICE}}{(1 + i)^t}
\]

- **Fuel Prices**: Varied here, providing insight into NPV for regions with different energy prices.
- **Battery Replacement**: $0 cost under 8-year, 160,000-km warranty, else replace at various $/kWh values in Year 8.
- **Electric-power cost** of US average $0.12/kWh.
- **241,000-km vehicle lifetime** (U.S. average) over 15 years.
## Volt vs. Cruze over 15 yr/150k miles

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<th>Gasoline Price ($/Gallon)</th>
<th>$0 No Battery Replacement</th>
<th>$150</th>
<th>$250</th>
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</table>

**Assumptions:** 5-% (real) discount rate; 150,000 miles over 15 years; Cruze: 28 miles/gallon; Volt: 40 miles AER, 2.78 miles/kWh (electric); cost of electricity: $0.1175/kWh; Battery replacement in ninth year (after eight-year warranty’s expiration); 2011 Volt price of $33,500 (after $7,500 Federal Tax Credit) vs. 2011 Cruze at $25,100 (comparably equipped to Volt); Terminal values of both vehicles assumed equal.
How “Clean” are EVs?

- EV emissions costs 45-80% lower (per VKT) around TX.
- DFW offers lowest-cost EV emissions (gen + exposure).
- Vehicle emissions regs. had lowered ICE emissions faster than those for electric power generation, but fracking for natural gas, plus solar advances, will take over.
- In an interconnected grid, costs & benefits are shared across the region (state or province, for example), but are not necessarily equally distributed.
- Reliance on coal, especially eastern (high-sulfur) coal does not deliver EV emissions-cost benefits.
Where is Best for Charging Stations?

- We started with Seattle application.
- Mixed integer program to locate 20 stations across 218 zones, objective = minimize average walk distance of those parking cars.
- 95% able to access within 1 mi, with 1.5 mi max walk distance (reducing range anxiety).
US Application for Long-distance Trips

- Constrained maximization of #LD trips completed by car across US (196 zones).
- Just **100 stations** + **200 mi range** serve 93% (!) of US inter-city car trips.
- **Adding range more beneficial** than adding stations.

![Graph showing the relationship between number of charging stations and percentage of long-distance trips served.](image-url)

**Optimal CS Locations**
for 150 mi range + 100-station solution
Energy + Travel Survey Findings

- **Policy of adaptation** (to climate change) more often preferred by workers & households owning many vehicles.
- **Caps on household energy use** preferred to **taxes**.
- **Long-term behavioral changes** are **difficult** to implement.
- Most agree that climate change is a concern, but are unwilling to change their own behaviors.
- Higher **income** & **education** levels associated with greater (stated) **concern** about one’s environmental impacts.
- **Information on gas costs & environmental costs** is very **powerful** in motivating vehicle (stated) choices.
US Fleet Evolution: Survey Results

- 42% Americans may pay $3,000 more to buy HEV version of a conventional vehicle.
- 36% express interest in buying a PHEV at $6,000 more than comparable ICE.
- 56% have power access when parked at home.
- Just 29% support a feebate policy, vs. 63% of Austinites.
HH Ownership & Use Microsimulation

The process is performed for each household, for each time period. The model calculates the number of households with specific vehicle technologies every period and updates the inputs.
Simulation predicts future U.S. fleet mix, overall usage, & associated emissions from 2010 through 2035.

Scenarios

- **TREND**: Status quo/business-as-usual.
- **GASPRICE$7**: Gasoline at $7 per gallon.
- **LOWPRICE**: Price of PHEV lowered by $4,100.
- **FEEBATE**: Rebates/fees to vehicles over/under 30 mpg at an average rate of $200 per mpg.
- **FEEBATE2**: Rebates/fees to vehicles over/under 30 mpg at an average rate of $400 per mpg.
- **HI-DENSITY**: Quadrupled job & household densities.
- **LAYERING** of LOWPRICE, FEEBATE, & FEEBATE2 scenarios with GASPRICE at $5 per gallon.
Results: US Fleet Simulation

- $7/gallon gas prices had greater impact on vehicle ownership & VKT than any other policy examined (including feebates).

- Changes in fleet mix, VKT, & emissions across scenarios are far less than needed to address environmental issues.

- Widespread use EVs may emerge with strategic & pronounced marketing, technological advances (lower prices + automated vehicles), as well as other incentives (e.g., HOV lane & fast-charge access) & greater awareness of energy & climate issues.
2017 Survey on EVs & AVs

• *n = 1,426* US adults (screened to remove insincere responses & *weighted* to match *U.S. population*).

• Anticipate future-year *vehicle & travel choices*

• Focus on *electric, autonomous, & shared* vehicles
  — CAVs, SAVs, SAEVs, + DRS
  *(dynamic ride-sharing)*

• *Questions* tailored for *regression model* variables for *fleet evolution simulation.*
AV Ownership Shares by US Households Over Time, across 7 Scenarios
Will AVs Make “Driving” too Easy?

- We expect +30% MORE VKT in US due to AVs (!)
- AV sensors & computers require power, prompting electrification of the drivetrain (so AVs are likely to be at least Hybrid EVs … phew!).
- Shared Autonomous Electric Vehicles (SAEVs) can eliminate range anxiety & charging delays for travelers…
  ... but shared HEVs are easier & less expensive to implement (45 ct/mi vs. 60 ct/mi).
- BEV technology will be KEY to offsetting AVs’ added energy use & emissions. Only BEV adoption (or strong road tolls?) can offset (or moderate) rising VKT, enabling 15% to 65% overall energy savings.
- Cleaner feedstocks (to power plants) also key to reducing transport’s emissions & GHGs (even beyond the 15 to 65% energy savings shared, battery-only AVs can provide).
Thank you for your kind attention!

Questions & Suggestions?

Papers available at www.caee.utexas.edu/prof/kockelman