Simulating the Value of Vehicle-Grid Integration Using a Behaviorally-Realistic Model

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Background
Vehicle grid integration (VGI) is a broad concept that describes linking the electric power and transportation systems in ways that may provide benefits to both. Previous modeling studies of VGI have generally ignored how consumer behavior and policy affect the impact of UCC. To improve understanding of VGI’s impact, we develop a behaviorally-realistic model of VGI, specifically analyzing the unidirectional flow of electricity from the grid to plug-in electric vehicles (PEVs) manipulated by a central entity (i.e., utility-controlled charging, or UCC). The model simulates:

- How consumer behavior and policy affect the impact of UCC
- The potential value of UCC, in terms of reducing 2050 electricity prices (in a low-carbon world with significant penetration intermittent renewables)

Data and Case Study Regions
Consumer behavior for vehicle purchase choices and charging choices (i.e. to participate in UCC or not) is parameterized with data from a representative survey (the 2013 Canadian Plug-in Electric Vehicle Survey). Survey respondents are from two interconnected grids, one that is dominated by hydroelectricity (British Columbia, or BC, n=496), and one that is dominated by coal and gas-fired generation (Alberta, or AB, n=289).

The survey included:
- A discrete choice experiment on vehicle preferences;
- A discrete choice experiment on PEV charging preferences; and
- A questionnaire about PEV familiarity, home recharging access and driving patterns.

Vehicle attributes (e.g. fuel prices, range, market supply parameters (e.g. number of models available, number of certified dealerships), and electricity generation parameters (e.g. capacity cost, renewable energy hourly availability) were derived from the literature and industry reporting.

Scenario Dimensions:
- With UCC vs. without UCC
- Policy simulation scenario vs. “forced” scenario (i.e. without consumer choice behavior and assuming carbon capture and storage (CCS) not possible)

Policy implications:
- UCC is unlikely to incentivize more PEV adoption, and unlikely to significantly change the market share of renewable generation. Strong policy is still needed.
- UCC can reduce the cost of achieving a given GHG reduction target, reducing electricity prices by 0.6% to 4%.
- When estimating the value of UCC, it is important to account for human behavior and climate policy.

UCC Value Per Vehicle
Value of UCC per participating PEV is ~$500-$100 per year. If we assume only intermittent renewable electricity generation, this amount is over $200/yr (i.e. Alberta forced scenario).

The net present value (NPV) of UCC per participating vehicle is ~$500, with values accruing to electricity rate payers rather than PEV owners. Results show that because some PEV owners participate in UCC with no incentive, an incentive for further participation does not reduce electricity system costs (i.e. the cost optimal incentive for UCC participation is $0).