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Is there a near-term market for vehicle-to-grid electric vehicles?

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HIGHLIGHTS

- We used a CV design to estimate WTP for V2G enabled EVs.
- We compared WTP estimates with projected vehicle cost under different battery cost scenarios.
- In all scenarios, WTP estimates are smaller than projected costs.
- Range anxiety, stringent V2G contract, and battery cost explain the outcome.

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ABSTRACT

We assess the near-term market for vehicle-to-grid electric vehicles (V2G–EVs) using an internet-based contingent-valuation survey. V2G–EVs are a special breed of electric vehicles used to return power to the grid for ancillary service support or during periods of peak electricity demand. Whether or not these vehicles are economically viable is of interest to policy makers and utility companies. We estimate a demand function for V2G–EVs, consider the importance of different vehicle attributes on demand, and then assess their likelihood of near-term success on the market. To assess the potential market, we compared consumer's willingness to pay for V2G–EVs with the estimated cost of V2G–EVs under different scenarios of battery cost projection. We found, in all scenarios, WTP estimates are lower than projected costs. Range anxiety, stringent V2G contract, and high battery costs are the primary reasons for the outcome.

1. Introduction

Concerns about global warming and energy security have increased interest on electric vehicles (EVs). The United States, Japan, China, and many European countries are spending billions of dollars to develop EVs. The Obama Administration, for example, allocated $2.4 billion toward the development of EV batteries as part of the 2009 stimulus package (American Recovery and Reinvestment Act). Those efforts have encouraged research on EVs and several innovations of EV design are in the pipeline. One such innovation is the design of EVs with vehicle-to-grid (V2G) capability.

V2G refers to the flow of power from EVs or Plug-in hybrid electric vehicles (PHEVs) to a power grid. The basic idea behind the concept of V2G is to use vehicle batteries for grid-related storage services while a car is parked. The average US car is parked 95% of the time [1] and can represent a significant resource to the grid. The grid can use EVs' battery as a reserve for peak load demand, reserve to meet unforeseen equipment failures (spinning reserve), or as a reserve for frequency regulation (regulation up and regulation down). EVs that can provide these functions are called Vehicle-to-Grid Electric Vehicles (V2G–EVs).

Designing EVs and PHEVs with V2G capability has economic and environmental benefits. Economically, both consumers and power companies benefit. Consumers earn money by selling V2G services to the grid. Several studies have estimated the economics of providing V2G service to drivers and depending on the assumptions built into the estimation, consumers can earn as high as $4000 per year [2,3]. Sioshansi and Denholm [4] framed their analysis in terms of payback period and found providing V2G services reduces the payback period for PHEVs from over nine years to around seven years. Organizations that own fleets of vehicles and who have predictable driving patterns may also benefit from switching to V2G enabled vehicles. Noel and McCormack [5] found, compared to diesel fueled school buses, V2G enabled electric school buses can save school districts about $6000 per seat in net present value. Similarly, De Losi Rios et al. [6] found, compared to diesel–fueled trucks, V2G enabled trucks have 5–11% lower lifetime ownership cost. These estimates indicate the potential for

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V2G enabled vehicles. [2] indicate the reserve market that is economically feasible for V2G enabled vehicles has a twelve billion dollar annual market value. If EVs are designed with V2G capability, drivers can tap into this market.

Power companies may also benefit economically, since V2G reserve has faster response rate, better economy, and higher reliability than generated reserve [7,29]. For example, Sioshansi and Denholm [4] estimated a fleet of PHEVs providing V2G service could save the grid up to $200 annually per vehicle. These savings come mainly from reducing the need to reserve controlled generator capacity. Power companies will also see improved efficiency with large scale V2G–EV deployment, since V2G–EVs are more likely to charge during night when there is excess capacity. This may increase their profit significantly. For example, Weis et al. [8] found controlled charging – shifting charging of PHEVs to off peak hour - results in significant cost savings to the system and the benefits are larger with higher wind penetration.

The environmental benefits of V2G technology come in two ways. First, V2G–EVs will help to reduce emission by replacing generators currently providing reserve service. Second, V2G–EVs will support intermittent sources of energy such as wind and solar by providing storage for excess power during periods of high output and supply power during periods of low output. These environmental benefits may appeal to policy makers and there have been several initiatives to support the development of V2G technology. For example, in 2002, the California Air Resource Board and the California Environmental Protection Agency sponsored a study to evaluate the feasibility and practicality of V2G power for regulation service [9]. The Department of Energy (DOE), on its part, developed regulations and building code requirements for V2G vehicles [10] and the Federal Energy Regulation Commission issued an order revising existing regulation so that participants like V2G vehicles get fair payments [11].

However, these benefits of V2G technology also come with some costs. In particular, there are three costs associated with providing V2G service. First, configuring EVs and PHEVs to provide V2G service involves additional electronic, communication, and connection costs. These costs are relatively small and are often incorporated into the calculation of net revenue from V2G service. Second, providing V2G service reduces battery life. Battery depreciation due to V2G service is also often incorporated in the calculation of net revenue from V2G service, but there is no consensus in the extent of the damage to battery life. Peterson et al. [12] found mild effect of V2G service on battery wear. Bishop et al. [13], on the other hand, found providing V2G service results in multiple battery replacement over the vehicle lifetime. The third cost is inconvenience cost associated with providing V2G service. Providing V2G service limits the freedom and mobility of the driver to some degree. The vehicle is not available for driving for the hours contracted to provide V2G service and it may have only limited power for immediate driving after those hours. Drivers may perceive this as inconvenience cost. Unlike the other two costs, inconvenience cost is largely ignored in the calculation of revenue from V2G service or implicitly assumed to be less than the revenue from V2G services. Sovacool and Hirsh [14] challenge this assumption. Inferring from the experience of other nontraditional energy technologies, they point out consumers generally fail to properly evaluate future savings from new energy technologies, apply very high discount rates when assessing such benefits, and require large compensation for perceived loss of freedom and mobility when considering to switch to EVs. If these consumer behaviors apply in the decision to switch to V2G enabled vehicles, the estimated revenues from providing V2G service may not be large enough to persuade consumers. To the best of our knowledge, there is no study that empirically compared the inconvenience cost and net revenue of providing V2G service to consumers. In this study, we try to fill this gap in the literature by designing a stated preference survey of potential car buyers.

We used a contingent valuation (CV) design to estimate consumer willingness to pay (WTP) for a V2G–EV that provides grid service in return for annual revenue payment. To capture the inconvenience cost of providing V2G service, we proposed a V2G contract that requires the car to be available for certain number of hours per day to provide grid service and a minimum driving range the vehicle will have after each episode of providing service for immediate driving needs of the driver. The value for these attributes is set similar to those assumed in the literature for calculating net revenue from V2G service. The revenue payment is also set in the neighborhoods of the revenues estimated in the literature.

The balance of the paper is organized as follows. The next section presents the design of the survey, the characteristics of the data collected, and the econometric model used to analyze the data. Section three presents estimation results and section four assesses the market for EVs in the near-term. Section five presents conclusion and policy implications of our findings.

2. Materials and methods

2.1. Study design

As noted above we designed a stated preference survey of car buyers in the US. The objective of the study was to assess consumer preference for EVs and V2G–EVs. For EVs to provide reliable grid service, there must be a certain number of V2G-ready vehicles plugged to the grid, at any point in time. That number must be large enough to generate the minimum capacity required for participating in a particular power market. Moreover, since the primary purpose of the vehicles is transportation and grid service is secondary, one needs more vehicles than the number required to generate the minimum capacity. This implies, for V2G–EVs to provide grid service, there must be significant adoption of EVs in the market and considerable number of EV owners must be persuaded to participate in the market for V2G service. To assess this dynamics, we designed three choice experiments.

The first experiment sought to assess the potential market for EVs and identify the factors that mater to consumer choice of EVs as a first step toward assessing the potential for V2G–EVs. The second experiment was designed to assess consumer preference for V2G contract terms. Even with a widespread adoption of EVs, participation of EV owners in V2G service will depend on how they perceive the terms of participation (V2G contract terms). This part of the study used choice experiment design to assess the tradeoffs consumers will make in V2G service market. The third experiment used a CV design to assess the potential market for V2G–EVs in the near future. The design of the first two experiments and analysis of the data can be found in Hidrue et al. [15] and Parsons et al. [16], respectively. Here, we will focus on the CV question.

The CV questions were designed to assess potential market for V2G–EVs in the near future. The proposed V2G–EV has two sets of attributes: attributes related to the design of the vehicle and attributes related to the design of V2G contract. Table 1 presents the attributes used, their definition, and the levels used in the design. To make the choice exercise as realistic as possible, we set the value of the vehicle attributes similar to the specification of a prototype V2G–EV (eBox). The vehicle can drive 140 miles on full charge, charge 50 miles of driving range in one hour, cost the equivalent of $1.00/gallon of gas to charge, perform better than a comparable gas vehicle (5% faster), and generate less pollution (75% lower) than a comparable gas vehicle.