ELECTRIC VEHICLE-GRID INTEGRATION

CASE STUDY FOR THE STATE ROUNDTABLE ON ELECTRIC VEHICLE INFRASTRUCTURE

THE PERSPECTIVE

You work at an automaker as the Product Manager for a forthcoming electric vehicle (EV) offering and are making a decision on what level of vehicle-grid integration (VGI) you plan to support in a new mid-market EV. Your CEO has asked for a briefing on the features you intend to integrate.

EV CHARGING MODES AND GRID SERVICES

EVs have the potential to become one of the largest flexible loads on the grid in the near future, creating new strategic challenges and opportunities for the automakers that design and market them. You are considering supporting one, two, or all three of the following VGI modes, including:

- **Grid-to-Vehicle (G2V)**: Allows the grid to remotely control EV charging by turning power flow up, down, or off to correspond with the needs of the grid. Because G2V only requires a one-way flow of power, G2V is low cost to incorporate from an automaker perspective. G2V is also known as managed charging, smart charging, or V1G.
- **Vehicle-to-Building (V2B)**: Allows a building (including homes and business) to draw electricity from an EV to provide back-up power, demand charge management, or emergency services. V2B requires bi-directional flows of power and is high cost to incorporate from an automaker perspective.
- **Vehicle-to-Grid (V2G)**: Allows the sending of power back to the grid from an EV using available battery capacity. V2G requires bi-directional flows of power and is high cost to incorporate from an automaker perspective.

Each of these three modes supports different types of grid services, as identified by an expert panel recently convened by the U.S. Department of Energy and summarized in Table 1 of Appendix A.

POTENTIAL VALUE PROPOSITION TO THE CUSTOMER

EV buyers have the potential to reap benefits from their vehicle's batteries by allowing the device to serve as an energy storage appliance for the electrical grid and/or their home. To date, the most common VGI programs feature utilities offering special electricity rates for residential EV owners and charging providers in exchange for basic G2V functionality. These rates can lower the cost of charging at home by 50 to 90 percent in exchange for charging at preferred times (see Figure 1 and Figure 2, Appendix A) for examples of these rate structures). Automakers can use this benefit as a marketing tool to potential EV owners.

Given the small size of each individual EV storage resource, multiple EVs will need to be aggregated and managed centrally as a single grid resource to realize the full value of VGI. Car owners, automakers, charging providers, third-party providers, and electric utilities could each serve as an aggregator as they attempt to capture the value associated with EV-linked grid services (i.e., compensation for bidding into power markets). EV owners would receive cash or other incentives (like free public charging) for participating in an aggregator's program. Once these benefits are more clear, automakers could market them to potential EV owners as part of a package of lower total lifecycle costs, especially in comparison to vehicles that still use internal combustion engines.

CHALLENGES WITH VGI

Challenges exist which are unique to automakers considering supporting VGI. They include:

- Unclear Value Proposition: Given the immature market for EV-enabled grid services, automakers are just beginning to invest in the software needed for consumers to participate in VGI. While most EV software supports Time-of-Use rates, more dynamic forms of pricing (e.g., real-time pricing) and ancillary services (e.g., frequency regulation) are not yet supported because there are few mechanisms to compensate car owners for these services. More work is needed to determine which rate structures and payments support EV adoption.
- Battery Degradation: Because bi-directional charging (required for V2B and V2G) may degrade vehicle battery life, no automaker currently extends vehicle warranties to batteries where bi-directional charging is enabled. While deep discharge of batteries in repeated V2B and V2G cycling will harm battery life, some experts believe that proper battery management in these applications can reduce wear to an acceptable level. More technical and economic work is necessary to validate this view.
- Range Anxiety: Because EVs are primarily used for transportation, some customers may be concerned about VGI reducing their ability to make it to their final destination with adequate charge. Opt-out / VGI override are important features that automakers must consider. See Figure 3, Appendix A for a current example of how EV owners can program their vehicle to charge during off peak rates and, if desired, override this feature.
- Communications/Interoperability: While most EVs are equipped with on-board telematics, no single industry standard for VGI messaging protocols and network communications protocols has been agreed upon, which will be critical if vehicles and utility grids are to interact.
- Cyber Security: Communications links between connected EVs or chargers and battery control software and hardware are expected to be an attractive point of entry for cyber-attacks.
- Cost: Developing the hardware and software necessary to support VGI is time consuming (because industry has yet to agree on a standard) and costly (involving new devices and millions of lines of code).

LESSONS FROM PILOTS AND SIMULATIONS

- In 2015 and 2016, BMW's iChargeForward pilot utilized about 100 EVs and a stationary battery bank made of recycled EV batteries to provide demand response services to Pacific Gas & Electric. Combined, the batteries responded to over 200 demand response events, totaling 19.5 MWh.

- A National Renewable Energy Laboratory analysis looked at different levels of managed EV loads in a 2030 scenario with 3 million EVs in California. It found savings between $210-$660 million annually in generation system costs.
- A 2015 SAE Technical Paper found that EVs could provide between $623 and $1,014 per vehicle in annual revenue when connected in V2G mode.
- UPS is partnering with the Department of Energy to develop bi-directional wireless charging for its electric delivery trucks so that trucks can operate in V2B or V2G mode in the event of a power outage.
- In August 2018, Honda announced a partnership with eMotorwerks (a DR provider) to offer California EV drivers $350 in annual benefits for participating in a program that uses pricing signals from the grid to determine optimal charging periods within customer preferences.

THE CHALLENGE

As the Product Manager, you must decide which features you will support in your forthcoming vehicle. You are attempting to minimize costs and difficulty associated with incorporating VGI features, while maximizing customer benefits. First, as individuals, on a scale of 1-5 (5 being highest) rate each grid service in terms of the potential value to EV owners and the potential to improve grid resilience services on Worksheet 1. Second, as small groups, choose which VGI mode(s) you would recommend to your CEO for your new EV, and identify three reasons why for each mode. Discuss the following questions to help you make your decision.

DISCUSSION QUESTIONS

- As an automaker, would you rather incorporate VGI directly into the vehicle or depend on charging infrastructure for VGI features?
- Are electric utilities prepared to support VGI (including one-way – G2V? bi-directional flows - V2B and V2G)? What barriers remain?
- How do you evaluate the tradeoffs between consumer benefits and battery degradation for bi-directional flows? Under what conditions would you recommend changing OEM warranty policies to allow this?
- What cyber security issues does VGI raise? What responsibilities exist among different actors (federal government, utilities, car companies, etc.)?
- As an automaker, how would you market the various VGI modes to potential EV owners?
- What are the competing motivations between players in the VGI space (utilities, regulators, automakers, charging providers, vehicle owners, etc.)? How would you attempt to bridge these gaps in order to speed VGI deployment?

APPENDIX A

TABLE 1: DEFINITIONS OF POTENTIAL EV PROVIDED GRID SERVICES (AND MODES SUPPORTED)

Grid Service	Definition	Mode
Demand Response	Reducing EV charging use at times of high system prices or unstable conditions	G2V
Valley Filling	Encouraging EV charging when system demand is low (off-peak) to reduce peak demand	G2V
Negative Demand Response	Encouraging EV charging (and other non-essential loads) during negative pricing periods to avoid curtailment	G2V
Coordinated Charging	Synchronizing EV charging to avoid timer peaks (i.e., TOU rate load spikes)	G2V
Demand Charge Reduction	Using EV batteries to reduce building demand charges	V2B
Emergency Back-up	Using EV batteries to power a building during outages	V2B
Capacity Firming	Using EV batteries to smooth the output associated with variable power generation	V2G
Voltage Control	Using EV batteries to help maintain voltage at a building on the grid	V2G
Frequency Regulation	Ramping EV batteries up or down over milliseconds to maintain grid frequency	G2V, V2G
Reserves	Using EV batteries to supplement reserve capacity requirements	G2V

FIGURE 1: POTENTIAL UTILITY RATE STRUCTURES

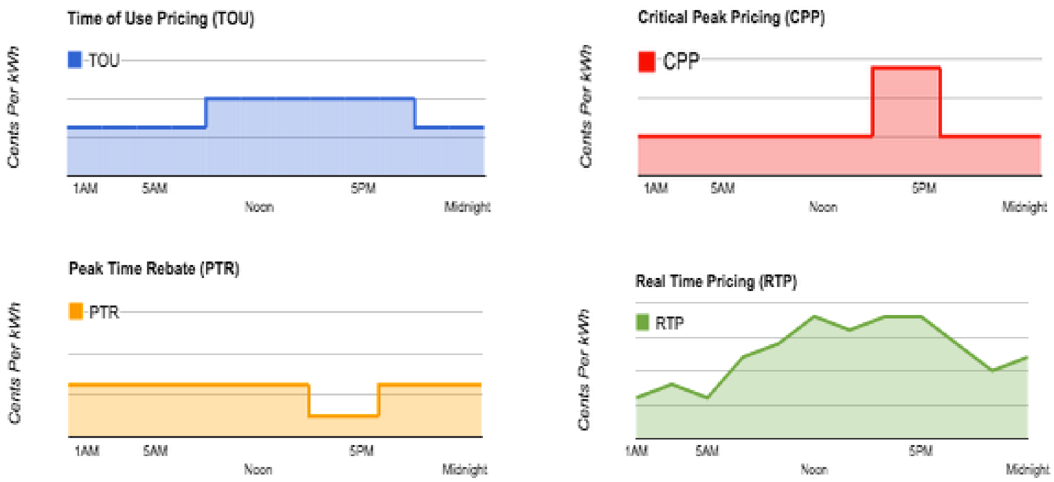
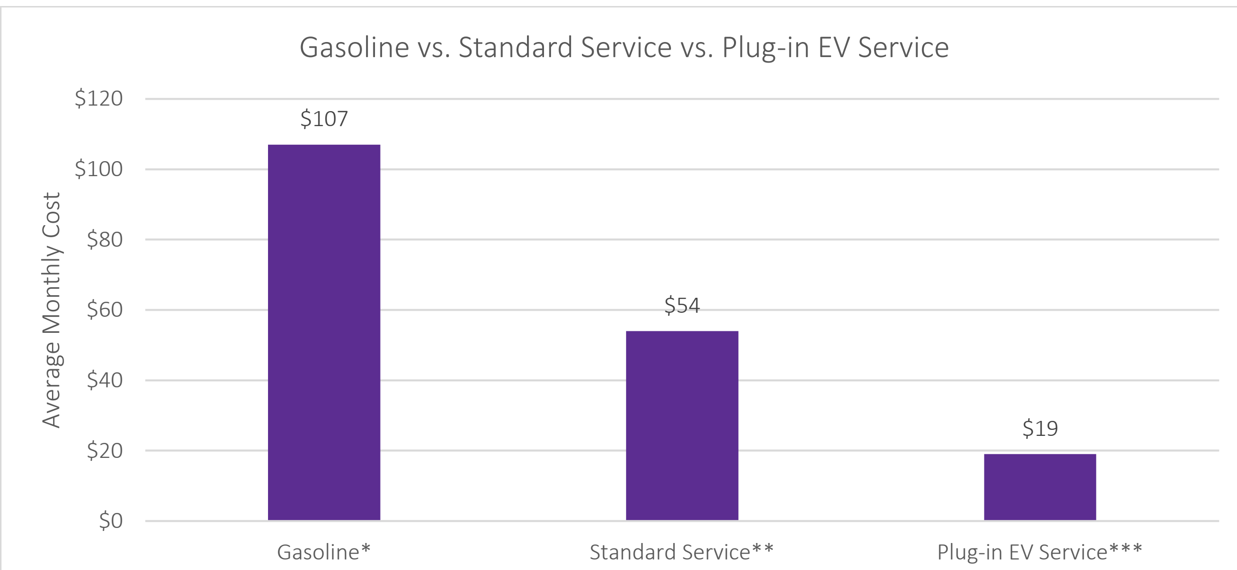


FIGURE 2: GEORGIA POWER EV CHARGING



*Notes: *Gasoline estimate based on a ratio of 1 kWh = 3.4 miles, 24.7 MPG, and a cost of $2.50 per gallon.*
***Georgia Power's Residential Standard Service features progressively increasing rates in three tiers of monthly electricity use (between 0-650 kWh, 650-1000 kWh, and above 1000 kWh). EIA form 861 data indicates that average monthly residential consumption in Georgia is 1138 kWh in 2016. For the purposes of this calculation, it is assumed that marginal electricity use to power an EV will be at Georgia Power's 1000 kWh and above electricity rate.*
****All charging under the Plug-in EV service is assumed to occur at the Super Off Peak Rate, which occurs between 11p and 7a each day of the year in Georgia Power's service territory.*
***, *** Non-energy charges occur at the same percentages and rates for both Residential Standard Service and Plug-in EV Service and are based on Georgia Public Service Commission approved rates as of September 2018*

FIGURE 3: FORD SYNC 3.0 SCHEDULED CHARGING INTERFACE – USER MANUAL (AVAILABLE ON FORD FUSION ENERGI)

"In the Charge Settings menu, you can monitor your vehicle's current battery charge status and schedule times to charge your vehicle, which allows you to take advantage of times when utility rates are lower (Value Charge). To access the Charge Settings menu, press the Settings icon in the feature bar at the bottom of the touchscreen. Then press the Charge Settings icon.

You can also set up My Go Times for cabin conditioning temperatures and charging times—so your vehicle is ready to drive when you are ready to go. The Cabin Conditioning feature lets you set the cabin temperature when you set your GO Time—in order to use energy from your home or charging station instead of your vehicle battery."

WORKSHEET 1: POTENTIAL VALUES FOR EV-LINKED GRID SERVICES

Rank each grid service on a scale of 1 to 5. (1 is lowest value and 5 is highest value)

Grid Service	Potential Value to EV Owners	Potential to Improve Grid Resilience
Demand Response		
Valley Filling		
Negative Demand Response		
Coordinated Charging		
Demand Charge Reduction		
Emergency Back-up		
Capacity Firming		
Voltage Control		
Frequency Regulation		
Reserves		

ATLAS PUBLIC POLICY

This case study was created by Atlas Public Policy. Atlas is a Washington, DC-based policy tech firm that works with federal and state agencies, private companies, and the advocacy community to develop strategies to advance clean energy technologies. Atlas has extensive experience in research and analysis on plug-in electric vehicles and related charging infrastructure. Atlas is a nationally-known resource on good practices on the role of government and the private sector in advancing the electric vehicle market. More information is available at www.atlaspolicy.com.