PECAN STREET

Vehicle to Grid Technology and Energy Storage

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Vehicle to Grid Technology and Energy Storage: Testing Texas' First V2G System as A Dispatchable Resource

Vehicle to Grid technology, or V2G, allows energy to flow from the grid to the vehicle when charging the vehicle, and vice-versa, from the vehicle to the grid to provide additional power to the grid. This allows V2G-equipped electric vehicles to act as Energy Storage Systems (ESS) when they are parked and connected, which can help improve the efficiency and value of intermittent renewable energy like solar and wind.

Project Snapshot

Pecan Street successfully implemented a V2G pilot project in our lab by creating custom code that linked the communication between the local utility and the vehicle's battery system.

Charging and discharging events were triggered based on grid signals through DERO – the centralized management and control software deployed for all assets used as part of Austin SHINES. When integrating the V2G system, Pecan Street kept the customer as the biggest priority and assured the vehicle's battery would never discharge below a specific driving range.

Pecan Street's V2G is the first project of its kind deployed in Texas. During the first year of the demonstration phase, Pecan Street was able to have the vehicle participate as a Behind the Meter (BTM) asset to aid Austin Energy in reducing its peak load during ERCOT's 4CP events. Additionally, during that first year, Pecan Street did not see major battery degradation from daily charge/discharge events requested by the utility.

About Pecan Street Inc.

Pecan Street's mission is to accelerate the transition to clean, low-carbon energy and integrated water management through innovative technology and policy. Our research, data, and technology expertise give researchers, entrepreneurs, policymakers, and impact investors the insight they need to change the world.

Pecan Street is the only organization or company that combines expertise in the "Internet of Things," high-velocity data acquisition, big data analytics, and lean product development to drive disruptive innovation for water and energy.

Our real-world testbed of volunteer research participants is the first of its kind on the planet and has become an international model for how to develop and conduct energy and resource research and product testing. Our commercialization lab is an affordable, world-class proving ground for major corporations and startups alike. And our database, the largest source of disaggregated customer energy data, is used by university researchers and industry-leading companies around the world. Learn more at pecanstreet.org.

Austin SHINES

In October 2018, Pecan Street started integrating the first V2G vehicle in Texas. A 2019 Nissan Leaf with a 40kWh battery was integrated as part of the residential aggregator under Austin Energy's Austin SHINES project. In addition to the Leaf, the residential aggregator included stationary batteries installed in the homes of seven Pecan Street research network participants in Austin's Mueller neighborhood. The stationary batteries added up to 35kW of capacity when aggregated. With the vehicle connected through a 10kW bi-directional charger, the capacity increased to 45kW.

The Austin SHINES project studied the best use cases for Energy Storage Systems (ESS) as assets to increase the value and penetration of solar PV generation. Under Austin SHINES, ESSs were deployed in three different scales: utility, commercial, and residential.

All assets under Austin SHINES were controlled through a centralized DER Management System (DERMS) called the DER Optimizer (DERO). DERO uses historical and current load, weather, and market data to make decisions about charging or discharging the assets. Figure 1 shows the concept diagram between DERO, Austin Energy and Pecan Street's residential assets.

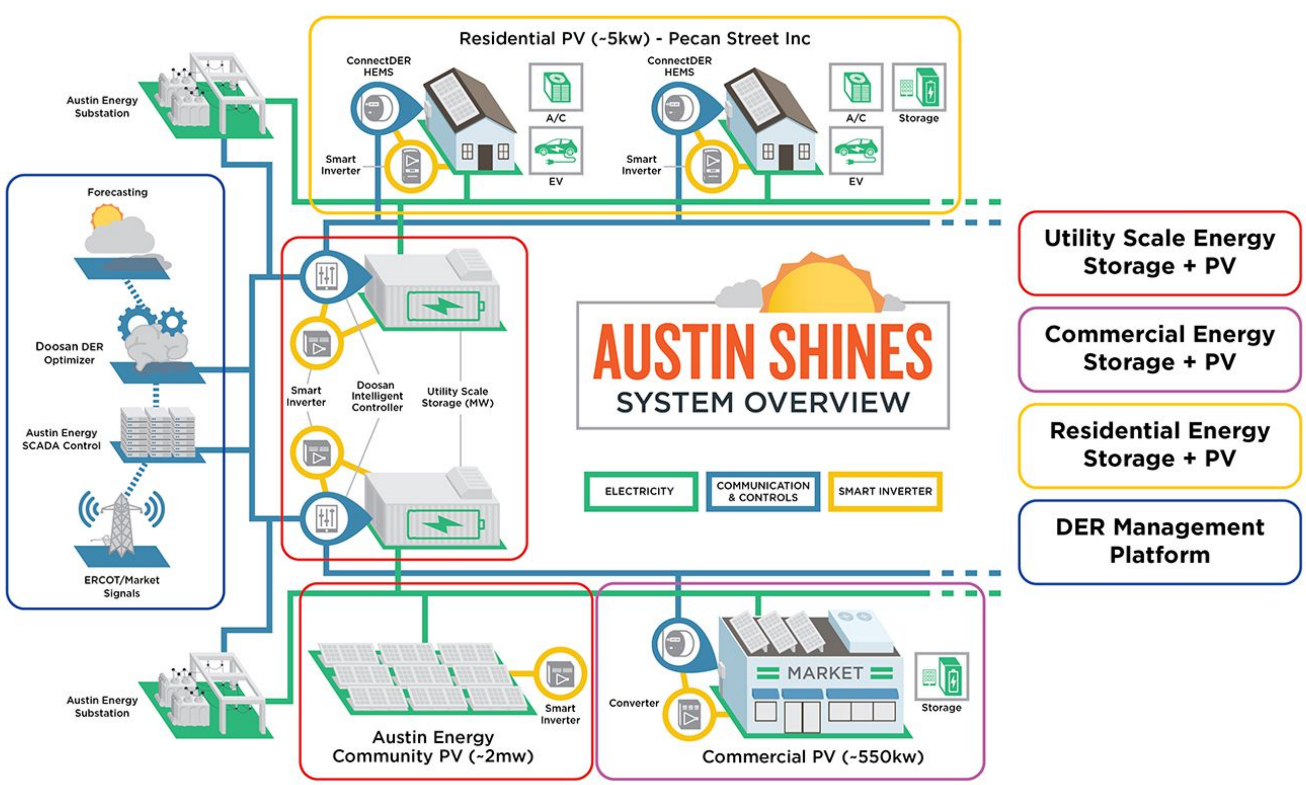


Figure 1. Concept Diagram for the Austin SHINES project. Source: Austin Energy.

Implementing a Dispatchable V2G System

Pecan Street built the code to communicate between a bi-directional EV charger (the Princeton Power CA-10) and the residential aggregator. The code needed to send the status availability to the aggregator and pass schedules from the aggregator to the charger. The communication between aggregator and vehicle was possible thanks to open standards such as MODBUS and TCP protocols. Additionally, Pecan Street included certain rules that prioritized the customer's needs for the vehicle. For example, Pecan Street included a maximum discharge level that reserved a portion of the battery capacity for driving.

The V2G system at Pecan Street's Austin lab consisted of a Nissan Leaf with a 40kWh battery and a 10kW bi-directional charger. Pecan Street created custom code that allowed communication between the charger and the residential aggregator.

Pecan Street implemented two rules in order to guarantee a hypothetical customer would always have the final decision whether the vehicle would be used as an ESS or as transportation. The first was to add a bypass switch that, when pressed, indicated to the aggregator that the vehicle was not available for discharge. When this bypass switch was enabled, the total capacity of the residential aggregator was 35kW. The second rule guaranteed the vehicle would always have 40 miles of range. That is, once the charger reported to the aggregator that the total State of Charge (SoC) of the vehicle was 20%, then the aggregator would not call upon the vehicle to discharge. In this instance, again, the total capacity of the residential aggregator would be reduced to 35kW.

The residential aggregator sent the charge and discharge commands to each asset after distributing the requested power (from DERO) evenly. For example, if DERO requested a discharge of 30kW, each battery would discharge 3.33kW while the vehicle discharged 6.66kW if all assets were equally charged and online. As discussed in the next section, this was not always the case.

Data Analysis

Storage Capacity

Although Pecan Street used the vehicle mainly as stationary storage, it was also driven. During the last year of demonstration, when the vehicle had been parked and mainly used as a stationary battery, Pecan Street has not seen a significant battery degradation.

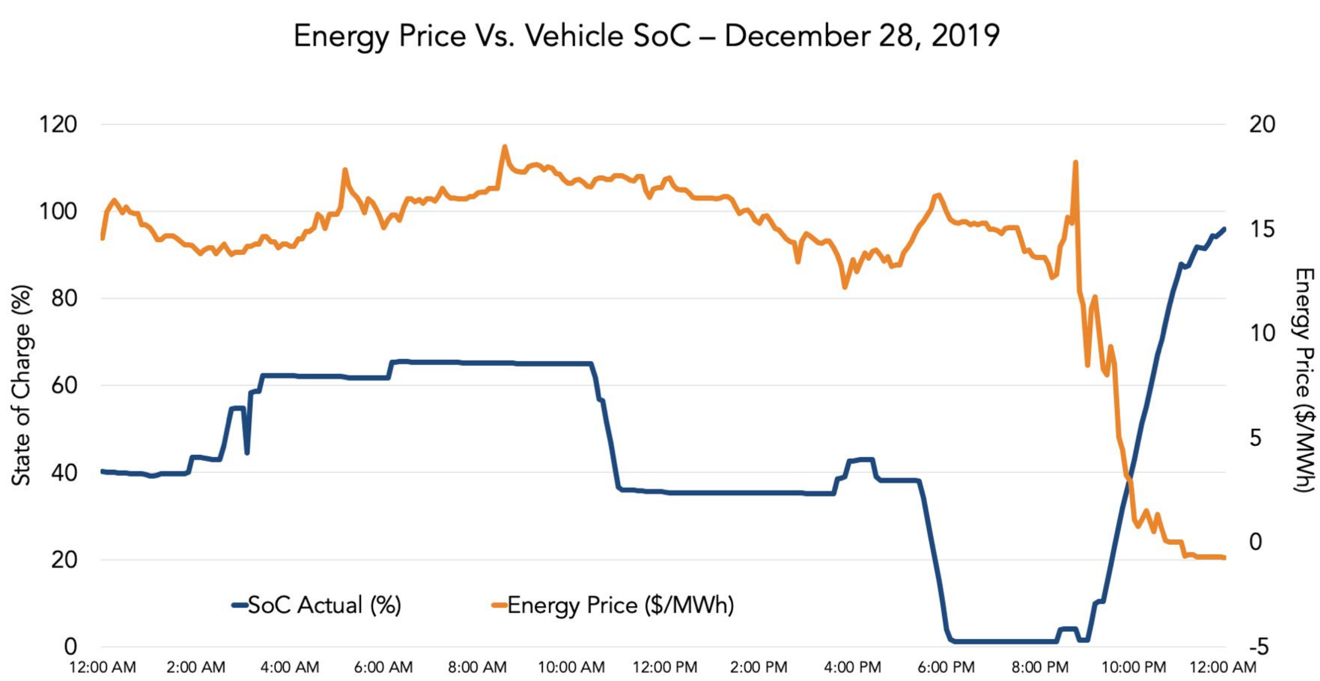
The average range available when the battery is fully charged has stayed around 160 miles since the beginning of the program. The car was used as part of the aggregator mainly during the months of December (2019) through February (2020), when it was going through two cycles almost every day (Figure 4). Regardless, this did not seem to degrade the battery during those months.

Summer Months and 4CP Events

ERCOT determines a utility's (and subsequently, a customer's) transmission cost via its 4 Coincident Peak (4CP) program. If utilities are able to conserve during these periods, their transmission costs for the following year can be reduced. The 4CP months are June, July, August, and September. Pecan Street was able to add the vehicle to the September 4CP event. The seven stationary residential batteries were too hot to provide load reduction, but the vehicle was stored in a climate controlled garage. As a result, the vehicle was able discharge 10kW during the 4CP event in September, resulting in an approximate savings to Austin Energy of $600.

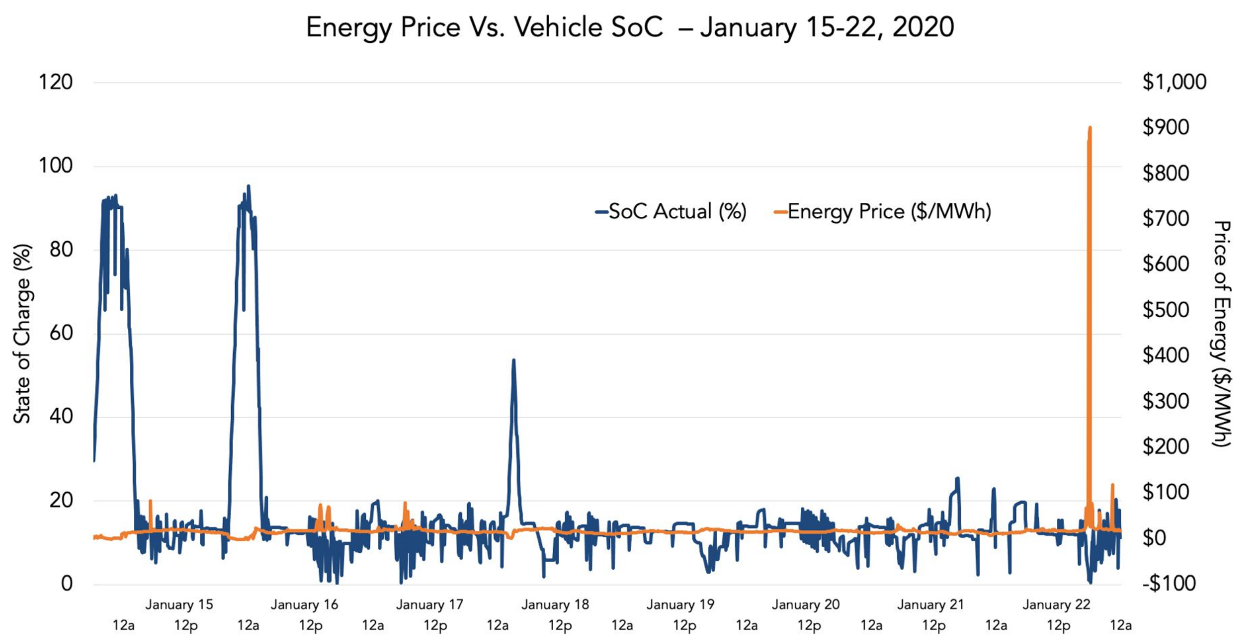
Winter Months

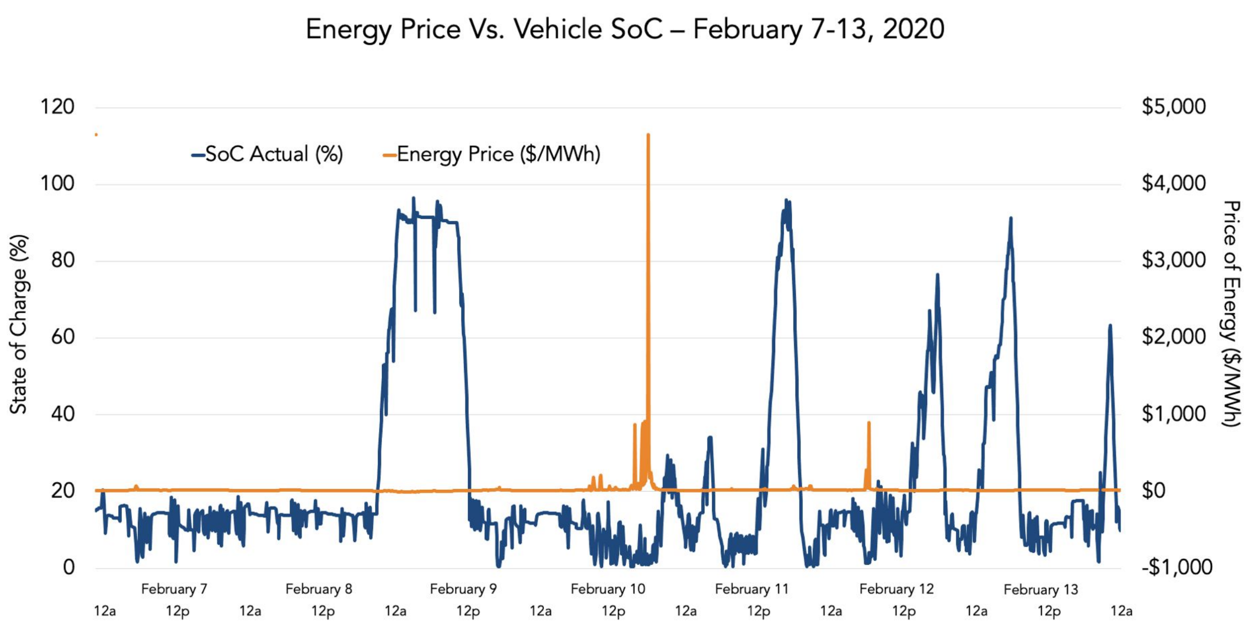
Between December and February, the main charge/discharge driver was ERCOT's price signals. The chart below shows an average day in late December 2019.



On this day, the vehicle stayed at 40-60% State of Charge (SoC). During peak hours (5:00-7:00pm) the vehicle was discharged fully. It wasn't until there was a significant drop in price that DERO started recharging the battery. After 8:00pm, the vehicle went from zero availability to 100% SoC.

The charts below show representative data for one week in January and one in February. Although there were price spikes for both weeks, they were not long enough for DERO to respond with a discharge command to maximize profit. For the majority of both weeks, the vehicle stayed at approximately 20% of the allowed vehicle battery capacity.





Data Conclusions

The V2G pilot demonstrated the successful use of a vehicle as both energy storage and transportation.

This project found some challenges that suggest the market is not fully prepared to exploit this technology. That is, due to the limited amount of demand for this technology, manufacturers of bi-directional charging infrastructure have not taken on the challenge of producing bi-directional chargers that could provide ancillary services to the grid. As a result, an aggregator (such as Pecan Street) is required to aggregate assets and build the software to connect the assets.

Additionally, the cost of the limited bi-directional chargers is prohibitive, even for middle- or high-income electric vehicle owners.

Vehicle battery degradation was not as steep as expected. This is promising, considering that a battery is perhaps the most valuable single component of an electric vehicle. Additionally, the response of the vehicle to commands from the aggregator was equally as fast as those from smart inverters used for residential batteries.

Highlights, Challenges and Lessons Learned

Pecan Street learned valuable lessons that should spur additional research on V2G as an ESS.

Price and Limited Product Supply

Limited product availability and high prices for a residential bi-directional charger (to allow for V2G) presents a significant roadblock to market expansion of this technology. The economies of scale are currently not present for V2G.

The Austin SHINES project required that all products used or purchased be commercially available. Pecan Street identified that a residential, bi-directional charger for an electric vehicle needed to be able of charging and discharging power within an 8-15kW range and compatible with a single phase 240V system to ensure that the main service panel in the residential sector would not need to be significantly upgraded. Additionally, the charger needed to be able to communicate through open standards such as MODBUS or TCP protocols.

Pecan Street was able to identify only two vendors that met these requirements. Furthermore, the charger was priced $2,000 higher than the vehicle itself.

Power Factor Not Available

Despite assurances from the technology vendor that its V2G system would allow for Power Factor (PF) correction, Pecan Street was unable to configure the system to allow for the PF to be anything other than "unity."

One use case for the DER assets under the residential portion of Austin SHINES was to provide voltage support. To do so, DERO sent charge commands with a PF associated with it. For the seven stationary batteries, the smart inverters were able to change the PF to provide voltage support to the utility. For the vehicle, however, the Princeton CA-10 charger did not allow for the PF to be anything other than unity. When the charger was purchased, Princeton claimed they would allow for PF correction. Unfortunately, months after installation of the V2G at Pecan Street's lab, this was still not the case.

No Communication Between In-Car Batteries

There is a lack of communication between the two batteries in the vehicle – the large 40kWh battery and the standard 12V battery. The aggregator queued each asset every ten seconds to see its availability. For this communication to happen, the assets use a small amount of self-derived power. For the vehicle, this power is supplied by the 12V battery. After a weekend, the Pecan Street team realized the 12V battery was completely drained even though the 40kWh battery was fully charged. Every time the aggregator requested an availability status from the vehicle, the 12V battery would slowly drain.

To rectify this, Pecan Street modified the existing code. Instead of directly queuing the car every ten seconds, Pecan Street created a text file that would show the latest state of the vehicle. This allowed the aggregator to gauge the car status every ten seconds without actually queueing the car.

Figure 2 shows the flow chart diagram for the updated code used to communicate between the aggregator and the charger.

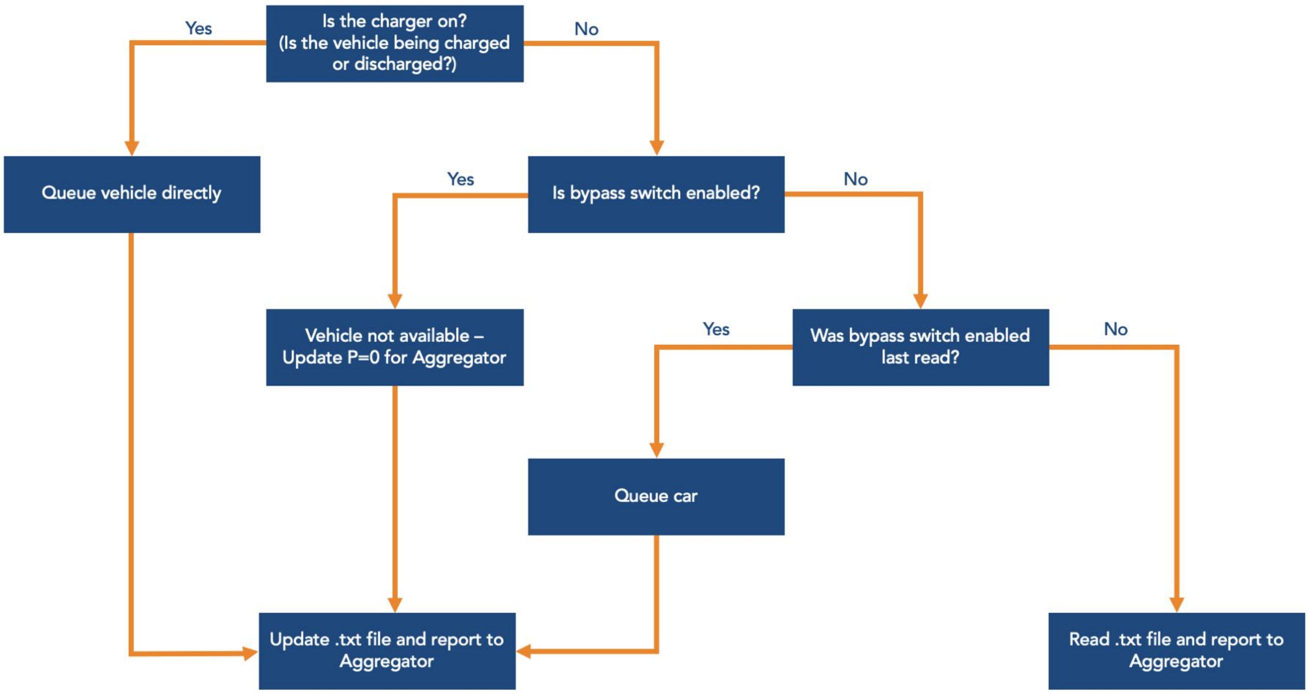


Figure 2. Flow chart for aggregator-charger communication.

By writing the code in the manner shown above, Pecan Street obtained the latest state of the vehicle without disturbing the 12V battery every ten seconds.

- If the car was charging or discharging, the aggregator could directly obtain the state of the vehicle by reading the registers directly.
- If the bypass switch was enabled (the customer did not want the vehicle to be part of the aggregator at that moment), the aggregator knew the power available from the car was zero.
- If the bypass switch was not enabled but it was enabled during the last time the aggregator queued the car, the registers needed to be updated. In order to do so, the car must be queued. This is the only instance the 12V battery powered the communication bus. This instance happened a few times during the week – not enough to drain the battery.
- If the bypass switch was not enabled during the current and last read, the status of the car had not changed. As a result, the status of the vehicle was obtained from the text file without disturbing the 12V battery.