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**EV Charging and Grid Capacity: A California and Texas Comparison**

**Background on Electric Vehicle Adoption**:

The U.S policy push towards clean energy on roadways has gained new momentum following the passage of Biden’s Bipartisan Infrastructure Deal. This recent legislation provides a multitude of tax credits for EV purchases as well as funding for EV charging infrastructure. Furthermore, the President has also signed an Executive Order that would establish a target to make 50% of all new vehicles sold in 2030 zero emissions[[1]](#footnote-0) . This drastic transformation of the transportation sector would have huge implications on mitigating climate change as transportation is one of the main contributors to anthropogenic climate change worldwide, accounting for 23% of energy-related emissions[[2]](#footnote-1). California is the leader in EV ownership across all states and has the most expansive set of financial incentives to support EV adoption. The state has many state funding programs ranging from CEC administered loans and rebates for EVSE (Electric Vehicle Supply Equipment), rebates for purchases of EV light-duty fleet vehicles by state and local public entities, funding for multifamily unit charging stations, tax exemptions for Zero-Emissions transit buses, and HOV lane access for EV owners[[3]](#footnote-2). Many states across the US have followed suit with similar incentive programs for the procurement of EV and EV charging infrastructure but California is unique in having a stringent Zero Emissions Vehicle Mandate Program, which requires all automakers to produce a minimum amount of vehicles as qualified plug-in hybrid or fully electric.

Texas, a state comparable to California in terms of population, energy consumption, and economic activity, is only third in EV adoption, registering a mere 52,190 electric vehicles in 2020 compared to California with 425,000. The 2020 EV ownership count in Texas is less than 1% of the 22 million total vehicles registered in the state according to Texas DMV data. In terms of charging infrastructure, Texas ranks number 5 in total EV charging points behind California, Florida, New York, and Washington[[4]](#footnote-3). The AFDC database counts an aggregate of 4,946 EV chargers state-wide (\* this includes Level 1 Ports, Level 2 Ports , and DCFC Ports) and the state has a mean ratio of 15.89 EVs to Charging Ports, close to the national average of 14.6 EVs per charging station but not nearly close to the US Department of Energy recommended ratio of 40 level 2 charging ports and 3.4 fast chargers (DCFC) per 1,000 EVs[[5]](#footnote-4) Texas mirrors California in being a large vehicle-centric economy and a large consumer of electricity yet its EV ownership rate and EV infrastructure lag far behind California. Since both states consume and provide more electricity than any other state in the US, they provide a glimpse into the future of EV. In both states, growing demand will ensure more electricity consumption, which in turn, puts more strain on the grid system. A report by GreenBiz estimates that if all passenger vehicles in Texas were electrified, the state would need about 110 terawatt-hours of electricity- the average consumption of 11 million homes.This increased load would require a 30% increase in grid capacity[[6]](#footnote-5). In comparison, California has a much temperate climate and demands less electricity especially on summer days compared to Texas. The larger seasonal variations in electricity demand in the Lone Star State means there are more power plants sitting idle during off-peak hours compared to California. The availability of spare capacity might make it easier for Texas to integrate EV but this would depend on whether or not EVs are charged during off-peak hours. As both states compete to expand a growing network of public charging stations, it is important for policy makers to make preparations for the surge of demand response on the Electric Grid through coordinating with private utilities, PUC regulators, ISO, and municipalities.

**The Challenges to Tackling Grid Capacity in the Two States**:

The surge in electricity demand as a result of EV ownership in both states is likely to accelerate generation capacity with priority investments in wind, solar, and other renewable energy sources. Increasing generation capacity solely to meet EV demand is costly and in most cases, there is sufficient generation capacity if vehicles are charged during off-peak hours. Policies focusing on changing EV charging behavior shifts the question from electricity demand and capacity to when EV should be consumed. Incentives that induce charging during off-peak hours such as TOU rates could nudge EV drivers to charge during times when electricity is cheaper to supply. Another significant strategy to tackle grid capacity is to directly use the Electric Vehicle Battery as an energy storage asset. For this strategy to be effective, vehicles must be charged during off-peak hours or during times when intermittent renewable energy sources are being used. The owner can then use the excess battery storage from the vehicle to supply the grid during on-peak hours. This is one key aspect of Vehicle Grid Integration, a type of strategy in which energy demand from EV’s is turned into flexible load, and the energy storage from the battery can be used as back-up storage during on-peak hours[[7]](#footnote-6). The costs of increasing grid upgrades per electric vehicle ranges from $1700-$5800 according to a Boston Consulting Group Study. Although Utilities will recover some of these costs with higher rate increases and additional revenue from charging, optimizing charging patterns through VGI would have the greatest impact on keeping infrastructure and energy costs low. [[8]](#footnote-7) Given all of these policy considerations to managing grid capacity, the central technical focus of this paper is on comparing how Texas and California approach this policy issue. Are the states converging towards similar policies in regards to grid capacity or do differences in policies across both states reflect the inherent differences in EV market penetration, regulatory structure, grid systems or seasonal conditions among other considerations?

**A Tale of Two Grids, Two Market Systems**

California and Texas are often juxtaposed to emphasize the political and ideological differences between the two states. This could never be as clear as in the grid systems of the two states. Most notably, California’s grid is integrated into the Western Interconnection and often outsources energy from other western states whereas Texas grid lies primarily within state boundaries. This allows Texas to circumvent FERC since there is no exchange of electricity across state lines. California’ s grid is also partially deregulated, allowing wholesale competition among energy generators with retail competition dominated by private utilities. Texas on the other hand, has a slightly different market design, with a deregulated wholesale but a more competitive retail market where consumers can more freely choose between energy providers and energy plans. Most regions within Texas has competitive retail markets that cover 85% of the state and includes most major metropolitan areas such as Dallas, Houston and Fort Worth, however there are a handful of private electric cooperatives and local utility cooperatives that don’t offer retail electric choice[[9]](#footnote-8). In California, the retail market is not as competitive. Private utility companies such as PG&E and local municipalities serve as retail providers. In both states, PUCs regulate the rates and services provided by private utilities. They also play a key role in consumer protection against unfair rates and they oversee investments in energy infrastructure- including EV charging stations. This paper focuses on how the different market structure, grid systems, and regulatory structure impacts EV charging infrastructure development and policy across both states.

**Thesis**: It is important for policymakers to recognize how different energy market structures, grid systems, EV markets, and regulatory structures across both states impact the development of EV charging policy. Furthermore these factors shape the priorities of EV charging policies in state jurisdictions. The central question that this paper addresses is to what extent do differences between the states cause policy divergence or policy convergence in regards to EV charging and related concerns over grid capacity.

This analysis begins by describing and comparing three different programs, two from Texas and one from California. These three policies target concerns about EV charging demand and grid capacity through pilot programs, TOU rate plans, and smart charging. The comparison is further put in context of the Public Utilities Commissions (PUCs) , grid systems, and EV markets.

**FlexEV Smart Rewards Program & FlexEV Off-Peak Rewards Program**

**Overview:**

San Antonio’s Municipal Electric Utility, CPS Energy pilots 2 rewards programs: FlexEV Smart Rewards and FlexEV Off-Peak Rewards. The FlexEV Smart Rewards provides financial incentives to EV owners for charging at times when demand on the electric grid is lower, outside of peak hours.[[10]](#footnote-9) EV owners can sign up for the FlexEV Smart Rewards and receive a $250 credit on their utility bill if they allow CPS to make remote adjustments to the owners level 2 Wifi Chargers. These types of charging stations, typically found in single-family homes, are wifi-integrated ‘smart’ devices that can survey grid capacity in a given area , keep track of billing, and remotely monitor energy consumption. One of the key features of smart chargers is the ability for energy use to be controlled remotely through a centralized cloud-based management platform that can be managed by a charging operator such as CPS. In light of the FlexEV Smart Rewards program, the CPS operators of an EV owner's smart charger would allow for adjustments to occur between the hours of 2:00 PM and 9:00 PM, Monday through Friday, when demand for energy is high. The program also gives participants an extra $5 on your utility bill for each month enrolled in the program[[11]](#footnote-10). The other incentive program, FlexEV Off-Peak rewards, gives participants a rebate of $125 for choosing to charge outside of peak hours. This information is verified by sharing charger usage data with CPS Energy but unlike the FlexEV Smart reward, the EV owner doesn’t need to allow CPS to make adjustments to their charging. For both programs, the rewards are paid in the form of bill credits on CPS Energy utility bills and cover only eligible charging equipment. Furthermore, eligible chargers must be installed and activated with internet WIFI connectivity.[[12]](#footnote-11)

A third program, the FlexEV Flat Rate Pilot Program, is available to EV owners who charge at one of the 57 CPS owned charging ports around San Antonio. Participants can enroll in the Flat Rate Pilot Program and are given access to unlimited charging at any of the CPS owned charging stations for an annual fee of $96. For EV owners not subscribed to the program, they can pay as they charge, with off-peak rates of $1.5 per hour applied between 9:01 PM-3:59PM, On-Peak rates of $2.00 per hour applied between 4:00 PM and 9:00 PM, and a minimum charge per charging session of $3.00. [[13]](#footnote-12) CPS recommends drivers who embrace the Always Charging Approach (ABC) and plug in whenever a charger is available as the best fit for the Rate Pilot Program. All three pilot programs encourage good charging habits that help to manage grid capacity.

Key Findings: Still in Progress

**Main Takeaways**:

* The program supports the city of San Antonio’s initiatives for reducing air pollution, particularly Ozone formation. The vehicle sector in San Antonio is a main contributor to NOx emissions, which forms Ozone pollution through the interaction of volatile organic compounds (VOCs) and sunlight. As a non-attainment city, there are much stricter regulations in place to meet Ozone pollution standards. Since EV has zero tailpipe emissions, it serves a key driver of reducing ozone formation but stricter regulations compared to the rest of the state could affect the industry as it grows.[[14]](#footnote-13)
* The main objective of the three programs is to shift EV charging to off-peak periods such as during the night time when demand on the grid is much lower. The combination of smart charging, rebates on energy bills, and TOU rates not only encourages strategic charging at certain times but it potentially cuts down on costs of upgrading grid infrastructure and it also supports utilization of renewable wind energy during night hours.[[15]](#footnote-14)
* With 80% of personal EV charging taking place at home, this program directly targets grid capacity in relation to most owners' primary charging needs. Through the FlexEV Smart Charging Pilot, participants in the program receive rebates on their monthly utility bill by allowing CPS remote access to their smart charging devices and carefully managing the participants' charging device. This program design incorporates VGI by allowing a public utility company to manage the flow of energy to the charger to take pressure off the grid in response to peak load times, extreme weather conditions, and price fluctuations.

**San Diego Gas and Electric (SDG&E) Power Your Drive Program**

**Overview**:

As part of this pilot program, the San Diego Gas and Electric company owns and operates charging stations at multi-family housing and commercial sites to meet VGI-related goals such as reducing grid operation costs, increasing energy efficiency, and reducing load at peak-hours. The program focuses on Vehicle-Grid-Integration as a demand response mechanism - SDG&E operates the charging stations at sites while owners charge their vehicles. Using smart technology and the high capacity storage of the EVs, EV charging can be strategically managed in response to price fluctuations, high net load on the grid, and other grid needs. Unique to this VGI program is the utility offering of a 6 tier EV charging period. Sites hosting a charging station through this program can choose one or more of the charging time tiers for billing purposes or choose a tier for shutting down their power due to price hikes during peak hours . The Time-Of-Use tiers include: “Super Off-Peak”, from 12:00 AM - 5:00 AM, “Off-Peak Morning” 5:00 AM - 12:00 PM, “On-Peak” 12:00 PM - 6:00 PM, “Off-Peak Evening”, 6:00 PM - 12 AM, as well as single event prices or double event prices - targeted price signals that are determined by a case by case basis[[16]](#footnote-15). The TOU billing structure is intended to maximize driver response to price signals to discourage charging during peak hours when price per KWH is highest. Some sites can opt-out of this billing structure but are required to develop a load management plan that limits charging during peak hours[[17]](#footnote-16). As of 2019, the SDG&E has installed a total of 3040 charging ports at 254 locations, surpassing their target of installing 10% of their charging sites in Disadvantaged Communities (“DAC”)[[18]](#footnote-17). According to the 2021 report, approximately 4500 drivers are currently enrolled in the pilot program and the charging stations collectively have avoided the emittance of more than 3.4 million kilograms of carbon dioxide (C02) compared to gasoline powered vehicles. To date, the PYD pilot has one of the most successful deployments of a dynamic electric rate tariff for EV charging throughout the state.

Unlike a typical EV related time-of-use tariff, the pilot program incorporates a much more dynamic and responsive structure. Participants in the pilot program can access day-ahead pricing information at each of the charging sites via online map and data portal. This enables participants to be more responsive to price hikes, which often correspond with peak load times. Not only does the portal allow participants to search up maximum hourly prices, but they can also review the duration of VGI charging and total energy their vehicle requires to manage their vehicle’s energy use. The rates for the program are billed directly to the user's account or to the organization that owns the charging station as part of their total energy bill. [[19]](#footnote-18)

**Main Takeaways:**

* The primary purpose of the pilot program is to help reduce GHG and criteria pollution emissions by encouraging EV adoption and increasing the number of EV miles traveled. Specifically, the program is designed to support California’s goal of reducing greenhouse gas emissions by creating access to EV charging infrastructure at workplaces and multi-unit dwellings and by creating a dynamic electric rate that encourages charging when there is ample capacity on the grid. SDG&E believes that the dynamic VGI charging rates would increase the use of renewable sources of energy by shifting charging time to hours when renewable energy is most available.
* Participants who charge at the EV site installations are offered a day-ahead time-variant hourly VGI rate. This VGI rate “provides a price signal that is intended to minimize EV charging impacts to SDG&E system and local distribution capacity”[[20]](#footnote-19). The VGI rate incentivizes charging during off-peak periods or when there is a surplus of electricity generation such as in the afternoon. Like the CPS SmartFlex program, the VGI program is designed to alleviate the impact of increased load from EV charging by shifting charging behavior. SDG&E contends that this TOU rate structure would reduce costly installations such as transformers, distribution, and transmission lines to meet the anticipated growth from EV charging.[[21]](#footnote-20)
* Key to the program is studying the way customers EV charging behaviors change when exposed to hourly price fluctuations. The primary research question of this pilot program is in exploring whether “lower hourly prices encourage EV charging when available energy and capacity resources are more abundant and whether “higher hourly prices discourage EV charging when these resources are more scarce.”[[22]](#footnote-21)
* SDG&E goal is to deploy a total of 5,500 charging stations at a mix of Multi-Unit Dwellings (MUDs) and workplaces. The CPUC capped the costs of the pilot program at $103 million and allows the SDG&E to recover $59 million in costs through the rate-base, which would represent an increase in monthly rates for SDG&E customers of less than 0.5% .This approach to VGI represents a case in which a regulatory body such as the CPUC allows a public utility company to include the cost of installation of electric vehicle charging stations in its ratemaking.[[23]](#footnote-22)

**Key Findings** **From the 2021 Research Report**

* The 2021 research report issued a survey to EV participants and found that 60% of respondents who adopted an EV after the charging stations were installed influenced their position to purchase or lease an EV. 43% of respondents also report that they use the PYD stations to meet 80-100% of their charging needs. [[24]](#footnote-23)
* SDG&E installed a total of 3040 charging ports at 254 locations, exceeding its target of 10% installment in Disadvantaged Communities (DACs) and 40% target for multi-family dwellings. Furthermore, the program enrolled about 4500 drivers and the PYD stations have dispensed over 4 million kWH of electricity, avoiding an estimated 3.4 million kilograms of carbon dioxide emissions compared to gasoline powered vehicles. (6)
* In the revised version of the Pilot Program, participants chose between two billing programs: the Rate-to-Drivers (RTD) program in which participants were directly exposed to dynamic price rates and billed individually, or Rate-to-Host (RTH) in which site hosts rather than individual drivers were exposed to the rates. As part of the Rate-to-Drivers (RTD) program, participants could set a maximum price threshold via their smart-devices and their vehicle would automatically stop charging when the price exceeded the threshold, providing a response mechanism to mediate grid capacity. Given a price threshold of $0.4 per Kwh, about 5% of total energy over a given period was consumed by RTD customers at that price whereas 35% of total energy was consumed by RTH customers at that price and over the same time period.[[25]](#footnote-24) This evidence suggests that drivers billed under the RTD program shifted their charging behaviors significantly more than drivers under the RTH program in response to high price periods. Participants who were given direct exposure to the VGI rates were more responsive to price signals and thus more incentivized to charge during off-peak periods. The study concludes that the RTD billing mechanism was much more effective at connecting charging behavior with grid conditions.[[26]](#footnote-25)

**El Paso Electric Company Vehicle Electrification Plan**

**Overview**:

The primary goals of El Paso Electric’s Vehicle Electrification Plan is to increase the use of electric vehicles by providing incentives for the installation of EV charging stations and by promoting the usage of smart charging. Specifically, the Transportation Electrification Plan (TEP) includes: A Customer Outreach Program to promote widespread awareness of EV and the benefits of vehicle electrification, Customer rebate pilot programs for smart charging infrastructure for residential and commercial customers, Pilot rate options to incentivize charging during off-peak hours, and an electrification grid impact study to assess the impact of increased EV adoption and electricity consumption on the grid system.[[27]](#footnote-26) As part of EPE’s efforts towards customer education and outreach, the Transportation Electrification Plan includes the creation of an EV Community website registration page. The purpose of this page is to provide EV owners with information about the availability of charging stations, news on the industry, and a forum to share testimonials. Another key purpose of the website is to keep track of registration of EV owners to assess charging demand. This information allows the EPE to plan future capacity needs such as upgrades in EV transformers or electrical upgrades to meet the charging needs of new EV owners.

Another way the EPE plans to tackle future capacity needs is by offering a special EV Charging Rate (Rate No. 42), and a whole-house Time-of-Use (TOU) rate as part of the Transportation Electric Vehicle Plan. The EV specific rates and TOU incentivize off-peak charging, saving customers money and reducing load on the grid. Furthermore, the special EV charging rates are available for residential and commercial EV owners who charge their vehicle at qualifying chargers. In order to receive the Electric Vehicle Charging Rate, participants must install a separate meter that records energy usage of an electric vehicle. The Monthly Time-of-Use rates are divided into Summer On-Peak and Off-Peak rates which include the months June through September and only winter Off-Peak rates which include the months October through May. The rates are as follows: Summer On-Peak Period rate of $0.26366 per Kwh, Summer Off-Peak Period rate of $0.00502 per Kwh, and Winter Off-Peak period rate of $0.00502 per Kwh. Although there is no On-peak rate for Winter months, there is a customer charge of $9.75 per meter per month. During the summer season, the on-peak period is from 12pm through 6pm, Mountain Daylight Time, for the months of June through September. Off-peak periods shall be all other hours not covered in the on-peak period.[[28]](#footnote-27) In terms of the TOU rate option, it is available to residential customers and also provides incentives to charge EVs during off-peak hours when rates are lower. Unlike the EV rate, this option doesn’t require the installation of a separate meter but it may require a meter change. Most importantly, the TOU rates are not specific to EV charging but instead apply to total household consumption of energy[[29]](#footnote-28).

**Key Takeaways**:

* Although El Paso is in Texas, the city’s Public Utilities Company lies outside the jurisdiction of ERCOT and services more than just El Paso. In New Mexico, the El Paso Electric Company (EPE) provides power for Sunland Park, Santa Teresa, Chaparral, and some local military bases. Because of this large service area encompassing parts of Southern New Mexico and Western Texas, El Paso Electric is governed by the rules and regulations of the two states PUC’s. Although both PUCs would be responsible for the approval of the EPE Electrification Plan, EPE recently filed the Transportation Electrification Plan (TEP) with the New Mexico Public Regulation Commission (NMPRC). Similar to the SDG&E pilot program, the TEP represents a PUC allowing a Regulated Public Utility to include the cost of the program in the rate case. Specifically, the EPE seeks approval to recover the costs of the EPE commercial and residential programs which would offer a series of rebates to cover some of the installation costs of DC Fast Charging and Level 2 charging stations.[[30]](#footnote-29) The EPE is proposing a rate increase of $0.00176 per kWh to recover the $605,420 total budget for the TEP rebate programs. (citation above) . In addition to the TEP rebate program, the EPE also seeks approval of its Experimental Electric Vehicle Charging Rate, Rate No.42. The proposed changes would include a customer charge that varies by rate class, three kWh energy charges which differ by rate class and period, and a per kWH super off-peak demand charge that varies by rate class. [[31]](#footnote-30)
* With the approval of the EPE Vehicle Electrification plan, residents serviced by EPE would have access to EV rate plans with cheaper off-peak hours. This incentivizes EV owners to charge during night time hours when rates are lowest and when the utility has amble generating capacity. By shifting charging times to night-time hours, the utility would have enough grid capacity to handle the growth in EV demand. Environmentally, off-peak charging might not decrease C02 emissions since at night, almost all of the EV charging would come from natural gas and nuclear power.[[32]](#footnote-31)

Key Findings: Still in Progress

Table summarizes the different programs and how they tackle the issue of grid capacity in the context of EV

| Program or Policy | Key Actors | Program Summary | How does this Program Tackle Grid Capacity ? | Potential Challenges |
| --- | --- | --- | --- | --- |
| FlexEV Smart Rewards Program & FlexEV Off-Peak Rewards Program | CPS (San Antonio’s Municipal Utility) ,  EV Owners in San Antonio, | -> FlexEV Smart Charging program provides rebates on electricity bill for participants who allow CPS to remotely control their smart charging stations    -> FlexEV Off-Peak Rewards provides participants with reduced rates if an EV is charged during off-peak hours. | ->The FlexEV Smart Rewards Program allows CPS to remotely control charging by adjusting charging during peak and off-peak hours  -> With the FlexEv Off-Peak customers provide charger usage data from their smart chargers and are rewarded a $125 rebate on their utility bills from charging during off-peak hours | -> With more EVs connected to the grid, this puts more pressure on CPS to handle maintenance issues with power plants, prepare for extreme weather events, and incorporate more intermittent renewable power during off-peak charging.  -> Without a firm consensus about EV demand forecasts, CPS cannot accurately forecast increased load on the grid  -> Off-peak charging is vital to moderating grid load since San Antonio has significant peak loads during summer and winter seasons |
| SDG&E Power Your Drive Pilot | SDG&E ( San Diego regulated public utility) | -> VGI pilot program deployed by SDG&E. | -> PYD sites can choose to charge during the designated charging blocks and reduce charging during peak hours  -> Site Hosts and participants can use online platform to monitor hourly changes in electricity rates and take advantage of off-peak hours when prices are low  -> Under the RTD (Rate-to-Driver) billing program, charging can be stopped when rates are over a certain price threshold, this mechanism adjusts load during peak-hours | -> the scale of the program means that it is costly and the PUC filing reveals contention over how much of the costs would be recovered in the rate base  -> The success of the SDG&E program is driven in part by the state's strong zero emissions vehicle adoption goals, already large EV market, larger budget, and stakeholder base. This makes the program less comparable to other regions interested in scaling a similar program. |
| Rate No. 42 - Experimental Electric Vehicle Charging Rate  (El Paso Electric (EPE) Transportation Electrification Plan (TEP) | El Paso Electric (EPE) Regulated Public Utility  New Mexico Public Regulation Commission | -> The TEP provides a  Customer Outreach Program, EV registration website, customer rebate pilot programs for smart charging infrastructure, Special EV rate options to incentivize charging during off-peak hours, and an electrification grid impact study | -> The EPE offers residential and commercial EV owners special Time-of-Use Rate schedule that offer cheaper charging when there is lots of extra generation capacity  -> incentivizes EV owners to reduce charging during peak periods ( 12 p.m - 6 p.m Mon-Fri), and during summer season  -> EV Charging Incentive Credit, Rate No. 45 would apply on a kWH basis during off-peak hours | -> Very low EV market penetration in El Paso and few DCFC chargers in the EPE service area  -> Off-peak charging will come mostly from natural gas and nuclear power not necessarily from renewable energy |

The table is helpful in demonstrating the variety of ways in which the different EV pilot programs approach the issue of grid capacity. Common across all three programs is the utilization of a TOU tariff designed specifically for EV charging. Although the timing of these TOU rates vary across the three programs, the use of a pricing signal to indicate peak and off-peak periods appears to be the most effective method to manage charging load. Only the SDG&E pilot program provides concrete evidence to support this claim. The 2021 pilot program report finds that EV participants are responsive to changes in the hour-by-hour EV charging rates, choosing to charge their EV vehicles during off-peak hours when prices are lower and when renewable energy is readily available on the grid. The hour-by-hour rate structure is unique to the SDG&E program whereas the other two Texas programs implement TOU tariffs that have fixed prices for off-peak and on peak periods. Although there is still a price mechanism in place to encourage off-peak charging, giving individual participants exposure to price changes in wholesale electricity markets for instance might be more effective at encouraging electricity when electricity is more abundant. In the case of the two Texas programs, there are additional roadblocks that make it difficult for EV participants to take advantage of the time-of-use pricing. For instance, the Experimental EV Charging rate is only available to participants who have a separate meter installed to separately record EV charging usage but the costs of installation of separate meters might disincentivize participants from utilizing the special EV charging rates. The CPS SmartFlex EV requires participants to have very specific home-chargers installed. The qualifying chargers must be installed and activated with internet WiFi prior to enrollment in the SmartFlex program. The prices of these chargers average $1000-$2500 and this doesn’t include the costs of installation which vary by location, which station purchase, and whether the charger is hardwired to the home or portable. [[33]](#footnote-32) Although 80% of EV charging happens at home, the costs of installations on top of the purchase price of an EV excludes lower-income people from participating in the FlexEV program.

The TOU rate structure in all three pilot programs is just one aspect in the application of VGI. VGI more broadly involves the varying of time or rate at which an electric vehicle is charged in order to manage load on the grid. This is a broad definition that also encompasses the use of smart technology for timing vehicle charging and the use of existing software or hardware to control grid load via bi-directional power flows, in which the EV vehicle acts as a battery storage device. None of the three programs incorporate VGI approaches that use the EV vehicle as a battery storage device but in all three cases the VGI approach is tailored to unique grid conditions that are suitable for integrating renewable energy. For example, the Pilot-Your-Drive program in San Diego takes full advantage of renewable energy generated during the day since the location of charging stations at work-places and MUDs induces charging during times when solar and wind energy are most abundant. In contrast, the special EV charging rates offered to residents through El Paso’s Electrification Plan incentivizes off-peak charging during night-time hours. The off-peak charging would come primarily from natural gas and nuclear plants, not renewable energy sources like solar. More investment in battery storage could help solve the problem of intermittency of renewable energy sources and better integrate clean energy to manage load from EV charging. The San Antonio EV pilot programs are much better at managing load at times that match renewable energy generation. The CPS Off-Peak Rewards program provides a $125 credit on their utility bill for participants who choose to charge during off-peak hours, typically during the night when grid use is lowest. The strategic replacement of load during night-time supports the use of wind power, which makes 63% of CPS renewable energy generation[[34]](#footnote-33). However, even with CPS contracts that allow supply to be labeled as renewable, there is no guarantee that the energy supply during off-peak hours is renewable.[[35]](#footnote-34)

Across the three programs, there is also a lack of uniformity in the technological approaches to VGI. The different approaches highlight unique strategies for managing EV load in response to grid conditions. The FlexEV Smart Charging program for instance is unique in that it involves coordination between charging devices, EVs, and grid operators via cloud technology, rather than by interfacing with participants directly. Adjustments to charging load are made simultaneously in response to demand on the grid during the peak period of 2-9 PM and the changes are monitored by CPS. This approach to VGI through “Smart Charging” takes away the need to use a price signal or rebate incentive to encourage off-peak charging. With this type of charging strategy, curtailing load from EV charging is much easier to achieve since this approach takes away the inconvenience of individual choice to optimize charging time. However, participants are notified via a mobile app about the adjustments to charging and can opt out of the adjustments at a moment's notice.[[36]](#footnote-35) The SDG&E Pilot program involves coordination with customers directly via direct exposure to hour-by-hour charging rates that fluctuate in response to grid demand. If the goal of the utility is to optimize off-peak charging , this would be much easier to achieve with smart charging infrastructure since the process of load curtailment is largely automated and simultaneous. However, participants might still prefer to have more active choice in managing their EV charging. Additionally, some of the main roadblocks to implementing Smart Charging Technology are the costs of installation of qualified chargers, incompatibility of software, hardware, and other regulatory considerations. In many jurisdictions such as in El Paso, a Smart Charging approach to VGI is not feasible since at present, the El Paso Electric doesn’t have the budget to build-out smart-charging infrastructure nor the level of EV demand as San Diego. With a simple TOU or dynamic pricing structure to encourage off-peak charging, jurisdictions can avoid costly installations, logistical challenges, and regulatory hurdles withVGI smart charging policies.

**Regulatory Comparison**

Both Texas and California Public Utilities Commissions have similar regulatory approaches to EV charging. For one, both PUC's define EV Charging Stations as retail or end-use customers. This means that the Charging Stations are not just an extension of a public utility but are the entities purchasing electricity from the transmission lines owned by the utility. [[37]](#footnote-36)In sum, the EV charging stations are not facilities to provide retail electric service but instead are treated as a fueling station.[[38]](#footnote-37) Given this interpretation, both Texas and California PUC's generally support policies that allow third party vendors to own and operate EV charging stations. This regulatory principle did clash with SDG&E pilot program which under the original plan, would have allowed SDG&E to own and operate the EV charging stations installed as part of the pilot program. Under the revised settlement agreement, SDG&E modified the ownership structure of the charging stations, allowing site hosts to choose between different vendors providing electric vehicle charging equipment (EVSE). The modified settlement also allowed site hosts to take services under either the Rate-to-Host or Rate-to-Driver billing structure. The primary reason for this change was CPUC concerns over competition with vertically-integrated EV stations. By giving the site hosts free choice, the program would maintain competition among third-party vendors. At present, the two Texas pilot programs don't directly address any potential problems with vertically integrated charging station networks but given the competitive nature of the retail and wholesale energy market in some areas, this might become an important concern as the EV market grows.

**Conclusion**

This analysis shows how different policies across California and Texas tackle grid capacity in the context of EV. As the nation's vehicle economy transitions to fully-electric, evaluating pilot programs are key in determining what policies are most effective at managing the increased load from EV charging. The three pilot programs demonstrate how different Vehicle-Grid-Integration policies manage EV load from simple TOU rates to dynamic hour-by-hour rates and Smart Charging. Like all pilot programs, policy makers should exercise caution when deciding to scale similar programs without taking into account all of the differences that might dampen the success of a scaled program. States with larger EV markets, budgets, and stakeholder bases will have the resources to better prepare the grid to meet the demands of a rapidly growing EV economy and can better integrate renewable energy into the grid. Whether or not these states converge towards similar EV Charging policies, it is clear that they both share the singular vision of a cleaner,and smarter grid.

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