Preliminary Report on Vehicle Grid Integration Policy Recommendations

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Electric vehicles (EVs) are capable of being a grid asset, rather than a grid strain, if we treat them like distributed energy resources (DERs). Vehicle grid integration (VGI) does just that, through two “modes”: V1G and V2X.

V1G, commonly referred to as “managed charging”, is the unidirectional power flow from the charging source to the vehicle that is optimized to some degree to yield grid benefits.[1] Many viable V1G use cases are in existence today, and many more are feasible within the next decade. However, without managed charging, EVs will exacerbate California’s duck curve, as most drivers charge at home, and during the week they would likely return home from work and plug in their vehicles during peak demand. The ability to increase V1G granularity and thus advance EVs as DERs to realize more use cases can be achieved through several technology and policy factors, including load management capability, rate design, incentives, and building codes.

V2X is the bidirectional power flow, absorption and discharge, that is classified either as V2G (vehicle to grid), V2H (vehicle to home), or V2B (vehicle to building).[1] In contrast to V1G, V2X use cases are predominantly only feasible post 2030, although two use cases are now salient for consideration in California: V2H as a Public Safety Power Shutoff (PSPS) resiliency measure and V2BG/V2G using school buses.

This document provides policy recommendations that 1) create retail revenue for vehicle grid integration, 2) create wholesale revenue for vehicle grid integration, 3) create incentives for consumers and prosumers, and 4) create alignment among California agencies and industry players.

Creating retail revenue for vehicle grid integration

1. **Require managed charging capability in utility customer programs, incentives, and DER procurements.**
   Agencies: California Public Utilities Commission (CPUC), California Energy Commission (CEC)
   Timeframe: 2021
   Relevant use cases: All VGI use cases.

Recent research found that deploying 950,000 to 5 million smart charging EVs on California’s roads avoids $120 to $690 million in grid upgrade costs and reduces renewable energy curtailment by up to 40 percent compared to the same number of EVs with unmanaged charging.[2] This is equal to about 50 percent of the incremental cost of adding EV load, and about 2 to 10 percent of California’s total system costs. Managed charging requires “smarts” − electronic controls and communication, which can come from the charger, the car, or from other power electronics, such as smart panels and inverters as well as

[1] https://www.caiso.com/Documents/Vehicle-GridIntegrationRoadmap.pdf
[2] https://www.sciencedirect.com/science/article/pii/S030142151930638X

other ancillary hardware/software solutions. Smart controls and communication enable load management capability, which is the throttling of EV charging power (increased or decreased) to respond to price signals and local site requirements.[3] While many technologies can be used to achieve this, California should look for opportunities to require load management and other "smarts" in various utility programs, codes, and standards. California can draw inspiration from the United Kingdom's Automated and Electric Vehicles Act, which requires all government-funded chargers to have smart functionality.[4]

2. **Design and offer various rate and metering configurations to increase participation in EV rate programs intended to increase grid flexibility and reduce grid strain.**
   Agency: CPUC
   Timeframe: 2021
   Relevant use cases: All VGI use cases.

Managed charging also requires precise, validated metering. For residential buildings, this could be a whole house meter, second meter, submeter, electric vehicle supply equipment (EVSE) submeter, load disaggregation using advanced metering infrastructure (AMI), or even validated/audited application programming interfaces (APIs) from the loads themselves. While whole house meters are the most cost-effective upfront, without some sort of load disaggregation via submeter or AMI shaping and measuring the EV load specifically is difficult, which could lead to "customer concerns about bill increases or potential inconvenience related to charging behavior", according to the Smart Electric Power Association (SEPA).[5] But, as more home appliances become "smart", whole house tariffs might make sense as appliances can shift demand in concert to respond to price signals. Commercial buildings likely also have varying metering arrangements, except for charging depots, which likely already have a dedicated meter. To increase participation in EV rates, utilities should offer rates for as many metering configurations as possible. For example, PG&E currently has two residential EV time-of-use (TOU) rates, one for homes with submeters and one for whole house meters. Additionally, EV drivers can subscribe to a rate that is not specific to EVs if it aligns best with their electricity usage.

Additionally, a variety of rate structures should be available to EV customers. For example, many drivers work away from home, therefore a rate that focuses on shifting early evening charging to late evening or early morning charging is most effective. But many EV drivers work from home or generally have more flexibility and variability, so a rate that provides price signals for when it's most beneficial throughout the day would indicate to those customer when is best to charge. Drivers would be more likely to comply during a timeframe that aligns with their daily schedule, and this would ultimately minimize "timer peak", which occurs when there is no staggering of TOU rates. An alternative to a TOU rate is a bill credit for charging off-peak. SEPA found that Braintree Electric Light District (BELD) captured 80 percent of the known EVs in its service territory using AMI and used a bill credit incentive to achieve 95 percent off-peak charging.

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[3] https://www.caiso.com/Documents/Vehicle-GridIntegrationRoadmap.pdf
[4] http://www.legislation.gov.uk/ukpga/2018/18/contents/enacted
[5] https://sepapower.org/resource/residential-electric-vehicle-time-varying-rates-that-work-attributes-that-increase-enrollment/

3. **Reduce or eliminate demand charges for DC fast chargers (DCFC), but scale up with utilization to create more demand-responsive rate.**

   Agencies: CA utilities, CPUC
   Timeframe: 2020
   Relevant use cases: V1G use cases involving DCFC.

EVSE providers have historically been challenged by and therefore opposed to demand charges, especially for DCFC. These high-powered chargers currently have relatively low utilization and with demand charges as part of their tariffs, their monthly bill is dominated by the demand charge with little opportunity for the EVSE owner to offset those costs with more charging sessions during the billing period. Rocky Mountain Institute found that demand charges have been responsible for more than 90 percent of electricity costs at some locations during summer months.[6] In response to this challenge, Southern California Edison (SCE) removed demand charges for five years on commercial EV rates and PG&E proposed to remove demand charges from its commercial EV tariff to encourage more DCFC installs.[7, 8] Overall, demand charges should be scrutinized to eliminate cost-causation rationale bias. For now, it makes sense for the other California utilities to either follow suit (halting demand charges) or create a tariff that scales demand charges with utilization until more EVs are on the road and rates are more demand responsive, which will create more upside opportunities.[9] The cost of providing electricity can be recovered through time-varying volumetric rates. Alternate ways to recoup DCFC costs include bundling the full cost of installed EV infrastructure, offering a storage-as-a-service offering, or locating transformers with capacity for additional load.[10]

Tariff	*Host Type A*	*Host Type B*	*Host Type C*	*Host Type D*
SCE ToU EV 4 *(actual)*	70%	75%	77%	81%
SCE ToU EV 8 *(proposed)*	0	0	0	0
SDG&E AL-ToU Commercial *(actual)*	88%	91%	92%	94%
SDG&E Public Charging GIR *(proposed)*	0	0	0	0
PGE A-6 ToU with Option R *(actual)*	0	0	0	0
PG&E A-10 *(actual)*	67%	73%	76%	81%

Table 11: Demand charge bill fraction under various rates

Source: ROCKY MOUNTAIN INSTITUTE

[6] https://rmi.org/wp-content/uploads/2017/04/eLab_EVgo_Fleet_and_Tariff_Analysis_2017.pdf
[7] https://library.sce.com/content/dam/sce-doclib/public/regulatory/tariff/electric/schedules/general-service-&-industrial-rates/ELECTRIC_SCHEDULES_TOU-EV-7.pdf
[8] https://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20181105_pge_proposes_to_establish_new_commercial_electric_vehicle_rate_class
[9] https://rmi.org/insight/dcfc-rate-design-study/
[10] https://sepapower.org/knowledge/three-things-you-think-you-know-about-evs-are-wrong/

4. **Create tariffs specific to electric school buses that potentially account for V2G.**

   Agency: CPUC
   Timeframe: Two-five years
   Relevant use cases: V2G school bus use cases.

Electric school buses provide a great initial opportunity for V2B and eventual opportunity for V2G because they only operate during certain times of the day and otherwise are parked and ready for on-site use. Electric school buses represent a large and valuable source of flexibility as fleets scale up, and as California continues investing in school bus fleet electrification, the Commission will need to ensure that utilities are creating tariffs that make sense for this unique customer class.[11, 12] While regulators should prioritize creating a tariff specific to electric school buses, many other fleets with unique usage patterns will need tariffs as well, including medium- and heavy-duty vehicles, as well as ridesharing.

5. **Consider technologies beyond rooftop solar in NEM 3.0, such as vehicles and storage, to start building the policy framework for export DER technologies.**

   Agency: CPUC
   Timeframe: Two-five years
   Relevant use cases: All V2G use cases.

As V2X use cases become more prevalent over the next decade or so, they will require new accounting measures for V2G. Demand response value will be determined by markets, but the Commission will need to determine value-based compensation policies for a varied group of technologies that export electricity. And, not only will the DERs become more heterogeneous, they will likely be increasingly co-located with each other (solar-plus-EV, for example), which should also be a consideration for establishing policies. The metering arrangement at a certain location will also determine, and potentially simplify, compensation for a set of DERs (for example if the solar-plus-EV is separately metered). Determining specific V2G compensation schemes right now does not make sense as the use cases are mostly far out into the future, but the Commission should consider technologies beyond rooftop solar in NEM 3.0, such as vehicles and storage, to start building the broad policy framework for export DER technologies. One key idea reported by IRENA that the CPUC should take into consideration is a lesson learned in Europe with V2X demonstrations, which is that as DER business models evolve towards value stacking, doubling up on taxes and grid charges should be avoided; fees should only apply to the net energy transmitted.[13]

6. **Create a strategic demand reduction performance incentive mechanism, include EVs as technology that can reduce and shift peak demand.**

   Agency: CPUC
   Timeframe: 2021

[11] https://www.energy.ca.gov/solicitations/2020-06/distributed-energy-resource-solutions-medium-and-heavy-duty-electric-vehicle
[12] https://www.greencarreports.com/news/1126753_volkswagen-diesel-settlement-funding-electric-school-buses
[13] https://www.irena.org/publications/2019/May/Innovation-Outlook-Smart-Charging

Relevant use cases: All VGI use cases.

An improvement on TOU rates comes from incorporating more "active" demand response elements – the frontier we're at right now – and California has several opportunities to prompt more active demand management from growing EV load. One recommendation is incorporating EVs into a strategic demand reduction (SDR) performance incentive mechanism (PIM). There are several approaches to this type of PIM, but typically these PIMs reward utilities for reducing peak demand. Recent research conducted by ACEEE and Energy Innovation found that between .82 percent and 4.4 percent of summer peak demand was reduced among the mechanisms studied.[14] The report also concluded that EVs were not utilized in existing cases of SDR PIMs, but are a great technology to include given they are a single, large load with sophisticated electronics to increase load flexibility and decrease peak demand.

Creating wholesale revenue for vehicle grid integration

7. **Enable aggregations of EVs on managed charging to participate as resources in real-time energy markets and ancillary services market.**

   Agency: California Independent System Operator (CAISO)
   Timeframe: Two-five years
   Relevant use cases: All V1G use cases.

V1G could also enable EV aggregations on managed charging to participate as resources in real-time energy and ancillary services markets – either on the supply side using a demand response paradigm with baselines, or by making granular price data and settlement available to the aggregator for dynamic price response. The EU Electricity Market Design Directive found that EVs can be aggregated with a diverse set of DERs to create a "mixed pool of energy resources" to augment system reliability.[15] IRENA found that for EV services to be useful at the wholesale market level, aggregated capacities of at least 1 to 2 megawatts must be transacted, which is roughly 500 EVs.

8. **Create market opportunities in CAISO Energy Storage and Distributed Energy Resources (ESDER) Initiative Phase 4 that allow utilities to pay V1G aggregators to use managed charging to reduce the local distribution grid impacts of EV charging.[16]**

   Agency: CAISO, CPUC
   Timeframe: 2021
   Relevant use cases: All V1G use cases.

Aggregators effectively deliver price signals to behind-the-meter DER technologies to achieve the load shape that benefits wholesale markets and utilities. CAISO should create opportunities for aggregators to bid directly into the market as well as also market opportunities for utilities since they are best positioned to determine how aggregators should participate based on local grid conditions. This arrangement will require a clear framework for fairly compensating the utility acting as a conduit.

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[14] https://energyinnovation.org/publication/performance-incentive-mechanisms-for-strategic-demand-reduction/
[15] https://www.smarten.eu/e-mobility-as-an-energy-resource/
[16] http://www.caiso.com/StakeholderProcesses/Energy-storage-and-distributed-energy-resources

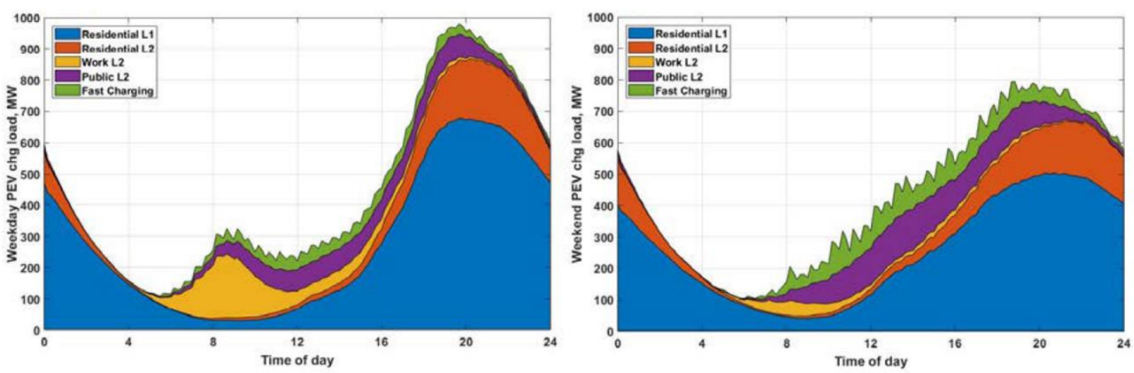
Creating incentives for consumers and prosumers

9. **Grant funding opportunities can be amended to provide "plus-up" funding for DER arrangements that optimize grid conditions.**

   Agencies: CEC, CPUC
   Timeframe: 2021
   Relevant use cases: All V1G use cases, especially ones that include DCFC.

Complementary DER arrangements supplementing EVs or EVSE that provide grid services should be evaluated by the CPUC and CEC. The CEC reported in its Staff Report on California Plug-In Electric Vehicle Infrastructure Projections that "appropriate electrical service and distributed generation and storage resources to effectively prevent system overloading and to avoid utility peak demand charges."[17] An example of this could be stationary "buffer batteries" that are co-located with DCFC stations can help smooth out the "spikiness" of DC fast chargers by drawing low voltage power consistently over long periods of time and then releasing power directly to the EVSE, reducing the burden on the grid. Some businesses and policymakers have envisioned using second life EV batteries as the buffer batteries to increase sustainability and bring down costs. Another example is solar canopies, which can be co-located with DCFC to increase flexibility of the station. Existing EVSE grant funding opportunities from CEC and other incentives from the CPUC can be amended to provide "plus-up" funding for EVSE plus DER arrangements that optimize grid conditions.

Figure ES.2: PEV Charging Load Profiles in 2025



Source: CALIFORNIA ENERGY COMMISSION
https://efiling.energy.ca.gov/URLRedirectPage.aspx?TN=TN222986_20180316T143039_Staff_Report__California_PlugIn_Electric_Vehicle_Infrastructure.pdf

10. **The Commission should consider bundled utility and community choice aggregation (CCA) program incentives for EVs, PV solar, inverters, and EV chargers to support resiliency efforts in wildfire prone, and therefore PSPS prone, areas.**

    Agency: CPUC

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17 https://efiling.energy.ca.gov/URLRedirectPage.aspx?TN=TN222986_20180316T143039_Staff_Report__California_PlugIn_Electric_Vehicle_Infrastructure.pdf

Timeframe: 2021
Relevant use cases? All single-family home back-up/resiliency use cases. Commercial customers that opt-in to CCA tariff.

PSPS and general resiliency issues can deter Californians from EV adoption. But as California continues to develop a stronger DER ecosystem, PSPS and wildfires will create less vulnerability and allow residents and businesses to feel more comfortable shifting off of fossil fuels even with the strong possibility of losing grid power.[18] EVs can play a supporting role in an off-grid microgrid, i.e., EVs with PV systems, that can supply power to single-family homes for up to 19-600 hours, depending on the time of year and vehicle configuration, during a PSPS event.[19] Most residences would need an inverter to do this,[20] but some automakers are planning to build inverters into the vehicles themselves.

11. **Require that electric buses funded under the School Bus Replacement Program have managed charging and V2G functionality.**

    Agency: CEC
    Timeframe: 2021
    Relevant use cases: 826.1, 826.2, 850.1, 850.2

California has already conducted pilots for V2G with school buses,[21] and the CEC has opened up funding to hasten the capital stock turnover of buses from predominantly diesel to electric.[22] The CEC can further support the V2X capability by requiring that buses funded under this program have V2X functionality.

Creating alignment among California agencies and industry players

12. **Update CalGreen to require installed charging infrastructure (not just EV-capability).[23] Ensure that Title 24-Part 6 and Title 20 sufficiently requires demand response-ready buildings. Eventually these measures ought to go beyond new buildings to existing buildings.**[24]

    Agencies: Building Standards Commission (BSC), Division of State Architects (DSA), California Air Resources Board (CARB), CEC
    Timeframe: Two-five years
    Relevant use cases: All VGI use cases.

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[18] https://www.vox.com/energy-and-environment/2019/10/28/20926446/california-grid-distributed-energy
[19] https://www.researchgate.net/publication/261164996_Plug-In_Vehicle_to_Home_V2H_duration_and_power_output_capability
[20] https://dcbel.ossiaco.com/
[21] https://www.utilitydive.com/news/california-oks-100m-sdge-commercial-ev-charging-plan-testing-electric-bu/561071/#:~:text=SDG%26E's%20school%20bus%20pilot%20program,)%20V2G%20bi%2Ddirectional%20chargers.
[22] https://www.energy.ca.gov/programs-and-topics/programs/school-bus-replacement-program
[23] https://codes.iccsafe.org/content/CAGBSC2019
[24] https://pge-adr.com/title-24/

The state's green building code contains another opportunity to encourage more managed charging infrastructure installation through two elements: EV-ready and demand response-ready codes. EV-ready mandates live in Part 11 of Title 24, also known as CalGreen, which currently requires EV-capability in new buildings (i.e. panel capacity and conduit). The code should be updated to prescribe not just elements of make-ready, but installed charging infrastructure.[25] Demand response-ready code lives in Part 6 of Title 24 and Title 20, which focuses on Appliance Efficiency Regulations. Demand response-ready requirements for EVSE should be codified in Title 20 and implemented in the state's building code. Currently the EV-capable code section only applies to new construction but to bring cost-effective infrastructure to more California residents and businesses, the code will need to be applied to existing buildings. This requirement should apply to commercial and residential buildings, schools, and other building categories. California can look to the EU's Energy Performance of Buildings Directive (EPBD) to understand overcoming barriers to applying the policy to existing buildings as well as incorporating "smart" charging elements directly into the code.[26]

13. **Align LCFS smart charging framework with utility TOU rates.**

    Agency: CARB, CPUC
    Timeframe: Two-five years
    Relevant use cases: All V1G use cases (single family homes, multi-unit dwellings, commercial, DCFC)

The CPUC could create additional upside opportunity for EV drivers and EVSE owners by working with CARB to align the Low Carbon Fuel Standard (LCFS) smart charging framework with utility TOU rates to lower the marginal carbon intensity of electric fuel.[27, 28] LCFS is a fast-growing fund for supporting electric mobility in California, and as the electric portion of the program gets more sophisticated, it continues to help shape EV load across the state. Coordination between the two agencies can help realize more LCFS credit opportunities for electric mobility, creating greater driver incentive for beneficial charging behavior, and potentially greater coordination on using the funding as efficiently as possible.[29]

14. **Bring automakers to the table to agree to allow limited discharge activity for resilience purposes to be kept under warranty if customers are willing to pay for upgraded bi-directional charging hardware.**

    Agencies: CPUC, CARB
    Timeframe: 2020
    Relevant use cases: All single-family home back-up/resiliency use cases.

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[25] https://codes.iccsafe.org/content/CAGBSC2019
[26] https://bellona.org/news/transport/electric-vehicles/2018-01-newly-agreed-eu-buildings-law-to-require-buildings-readiness-for-electric-vehicles
[27] https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/comments/tier2/elec_update.pdf
[28] https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDS_EV%20(Sch).pdf
[29] https://www.ucsusa.org/sites/default/files/attach/2018/01/cv-fact-sheet-lcfs.pdf

Many automakers are yet not on board with V2X because frequently discharging batteries can lead to relatively rapid battery degradation. The primary exception is automakers that produce EVs with a CHAdeMO connector.[30] Automakers limit V2X activity by voiding battery warranties for bidirectional power flow. Ideally, automakers can be brought to the table to agree to allow limited discharge activity to be kept under warranty for resilience purposes if customers are willing to pay for upgraded bi-directional charging hardware. Given the advanced software in most EVs, a resiliency mode or setting would allow battery discharge in emergency situations. One key consideration for this mode is making sure that the car is still available for evacuation mobility purposes, and therefore keeping a certain number of electric miles available for that purpose, essentially limiting the “depth of discharge”.

15. Update Innovative Clean Transit Rule to include school buses.

Agency: CARB
Timeframe: 2021
Relevant use cases: 826.1, 826.2, 850.1, 850.2 initially for V2B, then V2G school bus use cases

The CARB should amend the Innovative Clean Transit rule to include school buses to ensure that school districts continue fleet conversion within a timeframe that meets state’s climate goals.[31, 32]

[30] https://www.chademo.com/technology/v2x/
[31] https://ww2.arb.ca.gov/sites/default/files/2019-10/ictfro-Clean-Final_0.pdf
[32] https://www.greentechmedia.com/articles/read/the-capital-stock-turnover-problem-for-100-clean-energy-targets