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The Value of Vehicle-to-Grid Systems in the Clean Energy Transition: Policy and Regulatory Issues

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I. INTRODUCTION

The climate change problem is an energy problem. Energy production and use are responsible for approximately 75% of greenhouse gas emissions;[1] therefore, reducing emissions from the energy sector is the key to any solution. Due to a combination of policy and market drivers, the United States has been accelerating its transition to clean energy at the federal and state level.[2] Twenty-five states and the District of Columbia have committed to reductions in greenhouse gas emissions, with several aiming for net-zero greenhouse gas emissions within the next few decades.[3] Much of the effort at transitioning to clean energy has focused on solar and wind,[4] which, over the last few years, have become cost competitive with traditional fossil fuel generation sources.[5] The main problem with wind and solar is that they are intermittent resources:[6] the sun is not always shining, and the wind is not always blowing. This impacts the reliability of the electric grid, the operators of which must call upon energy from various generation sources and dispatch it to residential, commercial, and industrial customers in an intricate dance that requires forecasting and real-time monitoring to balance supply and demand.[7] The

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[1] *Greenhouse Gas Emissions from Energy Data Explorer*, INT'L ENERGY AGENCY, https://www.iea.org/data-and-statistics/data-tools/greenhouse-gas-emissions-from-energy-data-explorer [https://perma.cc/77JE-WR9Y] (last updated Sept. 27, 2022).

[2] *See U.S. Renewable Electricity Generation Has Doubled Since 2008*, U.S. ENERGY INFO. ADMIN. (Mar. 19, 2019), https://www.eia.gov/todayinenergy/detail.php?id=38752 [https://perma.cc/Q738-M99C](showing that renewable electricity generation has doubled since 2008 and that renewables accounted for 17.6% of electricity generation in the U.S. in 2018).

[3] *U.S. State Greenhouse Gas Emissions Targets*, CENTER FOR CLIMATE AND ENERGY SOLUTIONS, https://www.c2es.org/document/greenhouse-gas-emissions-targets/ [https://perma.cc/4DHM-TUNM].

[4] CHARLES F. KUTSCHER, JEFFREY S. LOGAN & TIMOTHY C. COBURN, UNIV. OF COLO. BOULDER, ACCELERATING THE US CLEAN ENERGY TRANSFORMATION: CHALLENGES AND SOLUTIONS BY SECTOR 11 (2020), https://www.colorado.edu/rasei/sites/default/files/attached-files/accelerating_the_us_clean_energy_transformation_final.2.pdf [https://perma.cc/J2BL-55N9].

[5] *See Levelized Cost of Energy and Levelized Cost of Storage 2020: Levelized Cost of Energy Comparison—Unsubsidized Analysis*, LAZARD (Oct. 19, 2020), https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2020/ [https://perma.cc/C73L-DSMM] (showing that utility-scale solar and wind are cheaper than coal and on par with combined-cycle natural gas).

[6] *See* KUTSCHER, *supra* note 4, at 11 (noting that the variable nature of wind and solar power will require additional measures to be taken to ensure a reliable supply of electricity to the grid).

[7] *Electricity Explained: How Electricity is Delivered to Consumers,* U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/electricity/delivery-to-consumers.php [https://perma.cc/LQD7-TBXS].

electric grid's reliability is also required by law, with reliability standards set at both the state and federal level.[8]

Along with increases in solar and wind generation, the number of electric vehicles (EVs) is also growing.[9] While EVs reduce greenhouse gas emissions, they also place additional demands on the electric grid.[10] Without policies and methods for addressing peak demand times, increased EV use will strain the grid and further exacerbate congestion and aging-infrastructure issues.[11] This is where the vehicle-to-grid (V2G) system comes in: V2G can help mitigate the grid reliability issues that accompany increased market penetration of solar and wind, provide ancillary services to the grid, and reduce grid strain caused by increased EV charging.[12]

V2G is "a system in which there is capability of controllable, bi-directional electrical energy flow between a vehicle and the electrical grid."[13] The vehicle battery is charged from the grid, but energy can also flow from the vehicle back to the grid when the grid operator calls upon it.[14] A subset of V2G is V1G, which is when grid managers turn up, turn down, turn on, or turn off the charging of EV batteries in response to grid needs, but the battery cannot send power back to the grid.[15] Since vehicles are not in use about 95% of the time, there is a substantial period of time during each day when the batteries' stored energy remains unused.[16] V2G would allow grid managers to manage the charging and discharging of the batteries and utilize that energy most efficiently for grid operation while also leaving enough power for customers to use their vehicles for transportation.[17]

V2G offers the prospect of both bolstering transportation electrification and providing benefits to the electric grid. This is a two-for-one proposition that is attractive in the urgent push to reduce greenhouse

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[8] ASHLEY J. LAWSON, CONG. RESEARCH SERV., R45764, MAINTAINING ELECTRIC RELIABILITY WITH WIND AND SOLAR SOURCES: BACKGROUND AND ISSUES FOR CONGRESS 1 (2019). The North American Electric Reliability Corporation (NERC) develops reliability standards for large-scale generators and electricity transmission systems, which are subject to Federal Energy Regulatory Commission (FERC) approval; state public utility commissions set standards for small-scale generators, publicly owned utilities, and local distribution systems. See *id*.

[9] *See infra* note 24.

[10] *See* ERIKA H. MYERS, TED DAVIDOVICH & HARRY CUTLER, SMART ELEC. POWER ALL., A REGULATORY ROADMAP FOR VEHICLE GRID INTEGRATION 4 (2020) https://theclimatecenter.org/wp-content/uploads/2020/12/A_Regulatory_Roadmap_for_Vehicle_Grid_Integration.pdf [https://perma.cc/9NPF-NRT7] (noting that EVs could increase peak load by 10–20 GW across the U.S.).

[11] NICHOLAS DEFOREST, JAMIE FUNK, ADAM LORIMER, BOAZ UR, IKHLAQ SIDHU, PHIL KAMINSKY & BURGHARDT TENDERICH, UNIV. OF CAL. BERKELEY, IMPACT OF WIDESPREAD ELECTRIC VEHICLE ADOPTION ON THE ELECTRICAL UTILITY BUSINESS—THREATS AND OPPORTUNITIES 6, 10 (2009), https://ikhlaqsidhu.files.wordpress.com/2010/03/nr_utilities_final_8-31-09.pdf [https://perma.cc/P226-JX4M].

[12] Jonathan Coignard, Samveg Saxena, Jeffery Greenblatt & Dai Wang, *Clean Vehicles as an Enabler for a Clean Electricity Grid*, 13 ENVT'L RES. LETTERS 054031, 1 (2018).

[13] ADRIENE BRIONES ET AL., IDAHO NAT'L LABORATORY, VEHICLE-TO-GRID (V2G) POWER FLOW 5 (2012), https://www.energy.gov/sites/prod/files/2014/02/f8/v2g_power_flow_rpt.pdf [https://perma.cc/KAV5-UVGM].

[14] BRIONES, *supra* note 13, at 5.

[15] MYERS, *supra* note 10, at 5.

[16] BRIONES, *supra* note 13, at 5.

[17] BRIONES, *supra* note 13, at 5 ("[T]he underlying premise for V2G is that during these times, the battery can be utilized to service electricity markets without compromising its primary transportation function.").

gas emissions and keep climate change at a manageable level. While V2G is not a panacea for all the issues society must address in making the transition to clean energy, the value it can provide makes it a good option for policymakers and utilities to adopt as part of their long-term strategies for clean energy. In Part I, this paper makes the case for V2G's value as a grid asset that can balance the grid by reducing the strain of increased EV charging and by smoothing the peaks and troughs of renewable generation. V2G's versatility means that it can easily integrate into distributed energy resource aggregations and act as an energy storage resource, a demand response resource, or an ancillary services provider. Part II explains how several technology and infrastructure barriers to V2G viability have been reduced or eliminated and discusses issues that still require resolution. Part III makes policy and regulatory recommendations for integrating V2G into grids operating in vertically integrated, monopoly markets or in restructured markets and for resolving two issues central to V2G grid integration: ownership and compensation.

II. THE V2G SYSTEM AS A VALUABLE ASSET FOR THE ELECTRIC GRID

V2G offers significant value to the grid for several reasons. The V2G system can maximize the benefits and minimize the drawbacks of increasing EV usage by managing EV battery charging. Through charge management and by acting as a storage resource, V2G can mitigate the grid effects caused by the variable nature of renewable generation sources. V2G-enabled batteries can also provide standard ancillary services to the grid. Several V2G projects have already been conducted or are underway and have demonstrated the usefulness and viability of using V2G as part of a grid management program. V2G will likely be more viable in some areas than in others due to various local factors, but V2G's value as a grid asset means that it will be a part of the clean energy transition.

A. How the Grid Works

The electric grid consists of three general systems: generation, transmission, and distribution.[18] The generation system is composed of the power plants that generate power via solar, wind, fossil fuel, nuclear, or hydro systems.[19] That power is then moved through the transmission system by high voltage transmission lines that take the electricity over long distances to where it is needed.[20] Before electricity is delivered to the end-use customer, it goes through the distribution system where transformers at substations "step down" the voltage and make the final delivery of the

[18] LAWSON, *supra* note 8, at 2.
[19] *Id.*
[20] *Id.*

electricity to homes and businesses.[21] Balancing authorities, which are either electric utilities or independent system operators (ISOs)/regional transmission organizations (RTOs), manage the regional operation of the grid and are responsible for balancing supply and demand.[22] The changes occurring in the electric grid, i.e., increases in renewable generation and concomitant decreases in fossil fuel generation, changing consumer patterns, and technological developments, require balancing authorities to adapt to new grid conditions.

B. Increased Market Penetration of EVs

The growth rate of EVs in the U.S. has been "high and sustained and is likely to remain so."[23] The number of EVs in the U.S. is projected to be 10-30 million by 2030. California, the state with the most EVs, has approximately 580,000.[24] As of early 2021, twelve states have zero-emission vehicle mandates, covering 30% of the U.S. population, and other states have proposed adopting such programs.[25] California and Washington have set some of the most aggressive standards. The California Air Resources Board approved a rule in August 2022 requiring all new passenger vehicles sold in the state to be zero-emission by 2035,[26] and Washington State, which has tied its vehicle emission rules to California's, is beginning the rulemaking process to require all new light-duty cars and trucks sold in Washington to meet zero-emisson vehicle standards by 2035.[27] Some of the other seventeen states—New York, Massachusetts, Vermont, Maine, Pennsylvania, Connecticut, Rhode Island, Oregon, New Jersey, Maryland, Delaware, Colorado, Minnesota, Nevada, Virginia, and New Mexico[28]—that have tied their own vehicle emissions rules to California's may follow with similar mandates.[29] Over

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[21] U.S. ENERGY INFO. ADMIN., *supra* note 7.
[22] *Id.*
[23] GARRETT FITZGERALD, CHRIS NELDER & JAMES NEWCOMB, ROCKY MOUNTAIN INST., ELECTRIC VEHICLES AS DISTRIBUTED ENERGY RESOURCES 16 (2016), https://rmi.org/wp-content/uploads/2017/04/RMI_Electric_Vehicles_as_DERs_Final_V2.pdf [https://perma.cc/QPN7-32E2].
[24] THE BRATTLE GROUP, GETTING TO 20 MILLION EVS BY 2030: OPPORTUNITIES FOR THE ELECTRICITY INDUSTRY IN PREPARING FOR AN EV FUTURE 6–7 (2020), https://www.brattle.com/wp-content/uploads/2021/05/19421_brattle_-_opportunities_for_the_electricity_industry_in_ev_transition_-_final.pdf [https://perma.cc/WF3H-25HX].
[25] *Id.* at 9; Jennifer Hijazi, *States Adopt California Car Rules Amid National Standards Debate*, BLOOMBERG LAW (Mar. 26, 2021), https://news.bloomberglaw.com/environment-and-energy/states-adopt-california-car-rules-amid-national-standards-debate [https://perma.cc/2N38-SMJ4].
[26] Press Release, California Air Resources Board, California Moves to Accelerate to 100% New Zero-Emission Vehicle Sales by 2035 (Aug. 25, 2022), https://ww2.arb.ca.gov/news/california-moves-accelerate-100-new-zero-emission-vehicle-sales-2035 [https://perma.cc/5JAN-LC82].
[27] Press Release, Washington Dep't of Ecology, Washington Sets Path to Phase Out Gas Vehicles by 2035 (Sept. 7, 2022) https://ecology.wa.gov/About-us/Who-we-are/News/2022/Sept-7-Clean-Vehicles-Public-Comment [https://perma.cc/VF75-RDK8].
[28] California Air Resources Board, *States that have Adopted California's Vehicle Standards under Section 177 of the Federal Clean Air Act* (May 13, 2022), https://ww2.arb.ca.gov/resources/documents/states-have-adopted-californias-vehicle-standards-under-section-177-federal [https://perma.cc/BAT6-2KAG].
[29] Steve Karnowski, *17 States Weigh Adopting California's Electric Car Mandate*, AP (Sept. 3, 2022), https://apnews.com/article/technology-california-clean-air-act-vehicle-emissions-standards-eebb48c13e24835f2c5b9cb56796182a [https://perma.cc/N9VM-BRTQ].

90% of states offer incentives for EV charging infrastructure.[30] Under the Biden administration, the U.S. Department of Energy (DOE) will be investing billions of dollars over the next few years in EV technologies, which will further speed EV market penetration.[31] However, unmanaged EV charging could increase peak load by 10-20 GW across the U.S., requiring the construction of more natural gas plants and unplanned, expensive grid upgrades.[32] Although utilities can manage the effects of EV charging on the grid in other ways—such as through time-of-use rates or V1G smart charging—V2G offers utilities more options for grid balancing.[33] Since the number of EVs continues to grow, it is good policy for governments and utilities to facilitate the use of V2G to manage EV charging in a way that provides cost savings to the grid instead of unnecessary expenses and gives utilities more tools for balancing the grid.

Importantly, the usefulness of V2G does not require access to a substantial percentage of EVs. One large utility, Southern California Edison, states that having access to even 5-10% of the EV fleet for battery capacity could substantially benefit grid resource needs.[34] With at least one company already using EV batteries to bid demand response,[35] and the projected rapid penetration of EVs into the market,[36] EV capacity to support more widespread deployment of V2G will likely be available. Even if V2G-enabled batteries make up only a small percentage of total EV batteries, there may not be a threshold percentage necessary for V2G to provide grid benefits. Various behind-the-meter generation and storage devices are being aggregated into so-called distributed energy resource (DER) aggregations and constitute a growing part of the grid services sector. Since these aggregations can be composed of mixed resource types, any number of V2G batteries could be a part of the aggregation and contribute services to the grid.[37]

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[30] Jacqueline Holman, *US EV Market Sales to Rise to 6.9 Million Units by 2025: Frost & Sullivan*, S&P GLOBAL PLATT (Nov. 19, 2020, 5:16 PM), https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/111920-us-ev-market-sales-to-rise-to-69-million-units-by-2025-frost-amp-sullivan [https://perma.cc/Y2E4-CFN8].

[31] Robert Walton, *DOE Will Spend Billions on Electric Vehicle R&D in Jobs Fight with China, Granholm Says*, UTILITY DIVE (Mar. 10, 2021), https://www.utilitydive.com/news/doe-will-spend-billions-on-electric-vehicle-research-in-jobs-fight-with-china/596441/ [https://perma.cc/2DHR-E979].

[32] MYERS, *supra* note 10, at 4.

[33] *See* CHARLES HARPER, GREGORY MCANDREWS & DANIELLE SASS BYRNETT, NAT'L ASS'N OF REGULATORY UTILITY COMM'RS, ELECTRIC VEHICLES: KEY TRENDS, ISSUES, AND CONSIDERATIONS FOR STATE REGULATORS 25 (2019) (discussing rate design and smart charging as ways to manage increased EV charging and adding that V2G can provide even more grid services than the other two options).

[34] SOUTHERN CALIFORNIA EDISON, PATHWAY 2045: UPDATE TO THE CLEAN POWER AND ELECTRIFICATION PATHWAY 10 (2019).

[35] Shepard, *infra* note 96.

[36] THE BRATTLE GROUP*, supra* note 24, at 6–7.

[37] *See infra* Part I(D).

C. Renewable Generation Reliability Issues

The primary challenge faced by grids with increasing renewable energy generation profiles is reliability.[38] Reliability means ensuring that there is enough electricity supply to meet demand as well as ensuring that the grid is maintaining the right voltage and frequency necessary for its operation.[39] The variability of solar and wind power presents planning issues for grid operators who have historically been able to rely on a steady, readily dispatchable energy supply from fossil fuel and nuclear plants.[40] Increased amounts of wind and solar generation lead to midday overgeneration risks and the inability to meet steep evening electricity demands.[41] California is already grappling with this issue; electricity supply shortages during the early summer evenings when the state's solar power plants are no longer producing power—coupled with extreme temperature and fire events—have led to rolling blackouts in recent summers.[42] To address these renewable generation issues, the grid requires flexible resources with the ability to sustain upward or downward demand ramps, respond for a defined period of time, change ramp directions quickly, store energy, react quickly, and start and stop multiple times per day.[43] A battery storage resource such as V2G can assist in providing those capabilities.[44] The flexibility and multi-purpose nature of V2G make it an attractive solution to renewable reliability issues.

D. Distributed Energy Resource (DER) Aggregation

"There is no single definition for distributed energy resource[s],"[45] but one of the most comprehensive definitions is from the Smart Electric Power Alliance: "DERs are physical and virtual assets that are deployed across the distribution grid . . . usually behind the meter, which can be used individually or in aggregate to provide value to the grid, individual customers, or both."[46] Examples of DERs include energy storage devices, solar photovoltaic, EV batteries, demand response, and energy efficiency.[47] The basic characteristics of a DER are that it is connected to

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[38] *See, e.g.*, Coignard, *supra* note 12.
[39] Amy Stein, *Distributed Reliability*, 87 U. COLO. L. REV. 887, 892 (2016).
[40] *See* LAWSON, *supra* note 8, at 1 (contrasting weather-dependent and non-weather-dependent generation sources).
[41] CAL. INDEP. SYS. OPERATOR, WHAT THE DUCK CURVE TELLS US ABOUT MANAGING A GREEN GRID 3 (2016) https://www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf [https://perma.cc/G57F-PZRK].
[42] Anne C. Mulkern, *California Faces Summer Blackouts from Climate Extremes*, SCIENTIFIC AMERICAN (May 23, 2022), https://www.scientificamerican.com/article/california-faces-summer-blackouts-from-climate-extremes/ [https://perma.cc/9P94-UJC4].
[43] CAL. INDEP. SYS. OPERATOR, *supra* note 41, at 2.
[44] *See* Coignard, *supra* note 12, at 1 (discussing how California enacted a storage mandate to ensure reliability with increased renewable generation).
[45] NAT'L ASS'N OF REGULATORY UTILITY COMM'RS, DISTRIBUTED ENERGY RESOURCES RATE DESIGN AND COMPENSATION 41 (2016), https://pubs.naruc.org/pub/19FDF48B-AA57-5160-DBA1-BE2E9C2F7EA0 [https://perma.cc/PR9H-FR83].
[46] Jamie Mandel, Tanuj Deora & Lisa Frantzis, *Distributed Energy Resources 101: Required Reading for a Modern Grid*, SMART ELECTRIC POWER ALLIANCE (Feb. 13, 2017), https://sepapower.org/knowledge/distributed-energy-resources-101-required-reading-modern-grid/ [https://perma.cc/HB3H-23VB].
[47] NAT'L ASS'N OF REGULATORY UTILITY COMM'RS, *supra* note 45, at 45.

the local distribution grid and not the bulk transmission system, and it is a small resource, normally under 10 megawatts (MW).[48]

A DER aggregation is a "virtual" resource formed by aggregating multiple distributed energy resources from different points of interconnection on the distribution system.[49] A DER aggregation could be composed of a single resource, such as rooftop solar, or it could be composed of multiple types of resources.[50] The DER aggregation may be modeled as a single resource at its "virtual" point of interconnection at a particular transmission-distribution interface even though individual DERs comprising the aggregation may be located at multiple transmission-distribution interfaces.[51] DER aggregators are the entities that aggregate these behind-the-meter energy resources to provide services to the grid.[52]

V2G-enabled EVs offer the greatest benefit when part of a DER aggregation. Since a single EV battery can provide only negligible power to the grid, the most promising application of V2G is in aggregating many EV batteries together—either in a single-resource-type DER aggregation or in a multiple-resource-type DER aggregation.[53] DERs are becoming an increasingly significant part of the electricity sector due to favorable government policies, developments in technology, reduction in costs, and demonstrated benefits for both customers and the grid,[54] and they have been described as a "transformative force" in the power sector.[55] V2G batteries are a natural addition to DER aggregations and will only increase the benefits of such aggregations to the grid through provision of ancillary services and battery storage capacity.

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[48] *Id.* at 44. For reference, 1 MW is enough to power approximately 800 homes for a year, depending on the resource and local weather. *Megawatt*, NORTHWEST POWER AND CONSERVATION COUNCIL, https://www.nwcouncil.org/reports/columbia-river-history/megawatt/ [https://perma.cc/2VUT-2KSU].

[49] NORTH AM. ELEC. RELIABILITY CORP., DISTRIBUTED ENERGY RESOURCES: CONNECTION MODELING AND RELIABILITY CONSIDERATIONS 1 (2017), https://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/Distributed_Energy_Resources_Report.pdf [perma.cc/B29F-E85B].

[50] *See* Michael Lavillotti, *DER Market Design Update: Additional Overview for Aggregations*, N. Y. INDEP. SYS. OPERATOR 8–12 (Nov. 5, 2018), https://www.nyiso.com/documents/20142/3710819/DER%20Market%20Design%20Updates%20Nov%205th_Final.pdf/1fd5be1e-221f-2edc-7b93-f631da5ad2fc [https://perma.cc/7F9E-VZFY] (discussing rules for single-resource-type aggregations and mixed resource aggregations).

[51] NORTH AM. ELEC. RELIABILITY CORP., *supra* note 49, at 1.

[52] *See* Robert Walton, *DER Aggregation 101: For Utilities, Smaller Resources Can Go a Long Way*, UTILITY DIVE (Jul. 24, 2017), https://www.utilitydive.com/news/der-aggregation-101-for-utilities-smaller-resources-can-go-a-long-way/446617/ [https://perma.cc/2DYG-DEB7] (discussing how aggregators either can be third-party aggregators who sell DERs on the wholesale electricity markets or can be utilities directly providing aggregation services).

[53] Christophe Guille & George Gross, *A Conceptual Framework for the Vehicle-to-Grid (V2G) Implementation*, 37 ENERGY POL'Y 4379, 4380 (2009).

[54] NAT'L ASS'N OF REGULATORY UTILITY COMM'RS, *supra* note 45, at 41.

[55] STEVE CORNELI & STEVE KIHM, LAWRENCE BERKELEY NAT'L LABORATORY, ELECTRIC INDUSTRY STRUCTURE AND REGULATORY RESPONSES IN A HIGH DISTRIBUTED ENERGY RESOURCES FUTURE 1 (2015), https://eta-publications.lbl.gov/sites/default/files/lbnl-1003823.pdf [perma.cc/3E5W-TSME].

E. Ancillary Services

As part of a DER aggregation, V2G batteries can provide several ancillary services to the grid. Ancillary services are the services used in the bulk electric power system to ensure the reliability of the grid. DERs such as battery storage are more efficient than traditional, natural gas-fired generators at providing the necessary load balancing to ensure grid reliability.[56] As DERs have become more cost-competitive, they can replace natural gas peaker plants (power plants that generally run only during peak demand periods)[57] in providing supply-side flexibility for power systems.[58] Data from California's August 2020 blackouts showed that natural gas plant performance was no better than DERs.[59] If EV penetration reaches the median projected number of 20 million EVs,[60] that represents up to 1,600 GWh of energy storage capacity.[61]

The stabilizing effect of V2G on the grid can also allow for greater increases in the amount of renewable energy added to the grid. In one modeled scenario in which the PJM Interconnection had no electrochemical storage, it would be able to construct only 175 GW of renewable electricity generation compared to 226 GW of renewable generation with V2G.[62]

As both EVs and renewable energy sources increase their market shares, V2G can be one method of alleviating daytime overgeneration problems, reducing evening peaks, and mitigating down-ramping and up-ramping.[63] In a scenario modeling the effects of a mix of V1G and V2G (assuming 1,500,000 EVs) on California's daily net electricity load, researchers at Lawrence Berkeley National Laboratory found that ramping was mitigated by 7 GWh—the equivalent of thirty-five new, 600 MW natural gas plants.[64] However, the overall value of V2G for ramping mitigation is uncertain due to seasonal and geographic factors that would affect its usefulness.[65]

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[56] Grid-Scale Energy Storage: Hearing Before the S. Comm. on Energy & Natural Resources, 111th Cong. 15 (2009) (statement of Jon Wellinghoff, Chairman, Federal Energy Regulatory Commission).
[57] DEFOREST, *supra* note 11, at 18.
[58] Herman K. Trabish, *'A Total Mindshift': Utilities Replace Gas Peakers, 'Old School' Demand Response with Flexible DERs*, UTILITY DIVE (Mar. 8, 2021), https://www.utilitydive.com/news/a-total-mindshift-utilities-replace-gas-peakers-old-school-demand-res/595415/ [https://perma.cc/6RVM-E9QL]. If peaker plants—which are expensive and capital-intensive—can be replaced with DER, it could save utilities millions of dollars in deferred infrastructure spending. BRIONES, *supra* note 13.
[59] Trabish, *supra* note 58.
[60] THE BRATTLE GROUP, *supra* note 24.
[61] *Id.* at 12.
[62] Lance Noel, Joseph F. Brodie, Willett Kempton, Cristina L. Archer & Cory Budischak, *Cost Minimization of Generation, Storage, and New Loads, Comparing Costs With and Without Externalities*, 189 APPLIED ENERGY 116 (2017).
[63] Coignard, *supra* note 12, at 4.
[64] Coignard, *supra* note 12, at 3, 4.
[65] Evening ramps are caused by both reduction in renewable generation and increases in customer load. When and how sharply the reductions in renewable generation occur will depend on the geographic location and time of year (summer vs. winter daylight hours) and percentages of solar and wind that are serving the load, since increasing wind generation in the evening can mitigate

Alleviating daytime over-generation and evening peaks is a more certain application of V2G. To mitigate the effects of overgeneration and peak demand, the California Public Utilities Commission (CPUC) issued a storage mandate in 2013, targeting 1.3 GW of stationary storage.[66] Storage can absorb excess power generated by renewables during the day and then discharge during the evening peak to reduce generation requirements.[67] Researchers found that almost all of California's storage mandate could be fulfilled with V1G EVs only, while a mix of V1G and V2G vehicles would substantially exceed the necessary 1.3 GW of storage.[68] Researchers did not consider driving and charging behavior in deriving these numbers and acknowledged that ensuring EV owners participate in a controlled charging program like V2G could be challenging.[69] But policymakers and utilities can incentivize drivers to bring their driving and charging behavior more in line with desired grid service goals,[70] and EV-owner contractual arrangements with DER aggregators will bring additional EVs into a controlled charging program. So, while the true value may be lower than the numbers in the study, the value of V2G in providing these grid services remains promising.

A V2G system can also contribute to frequency regulation and spinning reserves.[71] The electrical grid system needs to operate at approximately 60 Hz frequency.[72] Frequency can go up or down when there is a disruption to the supply-demand balance, and automated equipment on generation sources adjusts electricity output to correct the imbalance.[73] Frequency regulation is an ancillary services product that provides compensation to resources that are able to adjust output or consumption in response to the automatic signal.[74] Batteries and other DERs already participate in ancillary services markets,[75] and V2G EV batteries are a natural addition to the frequency regulation market because they can quickly adjust output or consumption. Spinning reserves are power plants that are on standby to provide power to the grid within ten

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reduced solar. *See* BING HUANG, VENKAT KRISHNAN & BRI-MATHIAS HODGE, NAT'L RENEWABLE ENERGY LABORATORY, ANALYZING THE IMPACTS OF VARIABLE RENEWABLE RESOURCES ON CALIFORNIA NET-LOAD RAMP EVENTS 1 (2018) (discussing the effects of solar and wind on ramping). V2G ramping mitigation may be more feasible and useful on weekends, since driving behavior is different on weekends compared to weekdays.

[66] Coignard, *supra* note 12, at 4.

[67] CAL. INDEP. SYS. OPERATOR, *supra* note 41, at 3–4.

[68] Coignard, *supra* note 12, at 6.

[69] *Id.*

[70] *See id.* (discussing ways in which EV owners could be incentivized to participate in controlled charging).

[71] BRIONES, *supra* note 13 at 6.

[72] CAL. INDEP. SYS. OPERATOR, *supra* note 41, at 4.

[73] *Id.*

[74] *Regulation Market*, PJM LEARNING CENTER, https://learn.pjm.com/three-priorities/buying-and-selling-energy/ancillary-services-market/regulation-market.aspx [https://perma.cc/B8ZP-2EED].

[75] ELEC. POWER RES. INST., ANCILLARY SERVICES IN THE UNITED STATES: TECHNICAL REQUIREMENTS, MARKET DESIGNS AND PRICE TRENDS, at 1-8 (2019).

minutes of being called upon and are used infrequently.[76] V2G batteries and other DERs can provide the same service and replace some of the conventional power plants currently used for spinning reserves. Spinning reserves and frequency regulation are well-suited for V2G battery systems because "they require quick response times yet low total energy demand."[77]

Some experts predict that the ancillary services market will quickly saturate with the proliferation of new battery energy storage systems, thereby reducing the per-vehicle value of participation; however, there may be opportunities at the distribution grid level to provide local ancillary services.[78] Additionally, in states with vertically integrated utilities and no ancillary services market,[79] oversaturation will be less of an issue. These utilities have always provided ancillary services as a normal part of conducting business and incur significant costs to supply those services.[80] The ability of V2G to supply ancillary services from customer EV batteries may be very attractive to those utilities as a way of lowering their costs, especially in an era when vertically integrated utilities will need to look at ways to shrink costs in order to keep pace with shrinking revenues.[81]

The military has demonstrated the feasibility of V2G by providing frequency regulation services in the Los Angeles Air Force Base Electric Vehicle Demonstration project.[82] LA Air Force Base outfitted twenty-nine EVs with bidirectional capability and Lawrence Berkeley National Laboratory provided the necessary software to allow the EVs to participate in the California Independent System Operator (CAISO)'s ancillary services market.[83] The project also explored using V2G for demand response and load shifting.[84] Over a twenty-month period, the EVs provided a total of 373 MWh of frequency regulation to CAISO.[85]

Provision of ancillary services in the market through V2G also offers one way of defraying the cost of an EV. One of the reasons the Department of Defense participated in the LA Air Force Base V2G demonstration was

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[76] BRIONES, *supra* note 13 at 7.

[77] WILLETT KEMPTON ET AL., A TEST OF VEHICLE-TO-GRID (V2G) FOR ENERGY STORAGE AND FREQUENCY REGULATION IN THE PJM SYSTEM 3 (2008), https://www1.udel.edu/V2G/resources/test-v2g-in-pjm-jan09.pdf [perma.cc/NFK2-QDAH].

[78] *E.g.*, Coignard, *supra* note 12, at 6; Derek Sackler, *New Battery Storage on Shaky Ground in Ancillary Service Markets*, UTILITY DIVE (Nov. 14, 2019), https://www.utilitydive.com/news/new-battery-storage-on-shaky-ground-in-ancillary-service-markets/567303/ [perma.cc/SB6T-QZQ2].

[79] BRENDAN J. KIRBY, OAK RIDGE NAT'L LABORATORY, FREQUENCY REGULATION BASICS AND TRENDS 1 (2004), https://info.ornl.gov/sites/publications/Files/Pub57475.pdf [perma.cc/J4NT-68GC].

[80] *Id.*

[81] *See* CORNELI, *supra* note 55, at 17–18 (discussing how utilities will need to control costs because they can no longer simply recover costs from customers due to increasing customer options in the electricity market and arguing that customer-owned DER assets can reduce the amount of capital that utilities must invest).

[82] DOUGLAS BLACK ET AL., CAL. ENERGY COMM'N, FINAL PROJECT REPORT: LOS ANGELES AIR FORCE BASE VEHICLE-TO-GRID DEMONSTRATION 1 (Oct. 2018), https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2018-025.pdf [https://perma.cc/Z82A-GTU4].

[83] *Id.* at 1. CAISO is one of the seven ISOs/RTOs that are responsible for overseeing the wholesale energy markets as well as coordinating, controlling, and monitoring the electric grid for their respective areas.

[84] *Id.* at 2.

[85] *Id.* at 3.

to see if the use of V2G to provide ancillary services would decrease the overall cost of operating an EV fleet and bring it into parity with the cost of a traditional internal combustion engine fleet.[86] While the project found that frequency regulation revenue by itself would not be enough to defray the cost of converting traditional fleets to EV,[87] the provision of ancillary services as a cost reduction mechanism for EV ownership is one of the benefits of V2G. Additionally, as the cost of batteries continues to fall, EVs will only become cheaper; Bloomberg predicts that as early as 2023, batteries will have fallen to a price point that will allow certain EVs to sell at the same price as comparable internal combustion vehicles.[88] At that point, any revenue that customers could earn from their V2G-enabled EVs would simply be a bonus rather than a necessary component of financing.

For V2G to provide ancillary services, the DER aggregator or utility will need to have greater control over the battery, and that may provoke some customer resistance. Concern about insufficient battery charge when the car is needed for transportation and a wariness of relinquishing control over one's property are both natural customer concerns with using a V2G-enabled EV.[89] However, there are options for balancing customer and DER aggregator needs. For example, the V2G program could allow the user to choose among different modes, with each mode providing V2G services to a greater or lesser extent depending on user preference.[90] The user will still maintain overall control, since the primary function of the EV remains transportation, and a V2G contractual arrangement with a DER aggregator could include provisions such as an allowance for a certain number of times per month or per year where a user can override an established V2G schedule without incurring a penalty. This would allow for flexible use of the car and allow aggregators to incorporate expected variations into their planning. Demonstrated DER aggregator success in using EV batteries[91] shows that concerns with battery charge and relinquishment of control can likely be addressed through the right policies.

F. V2G as a Storage Resource

V2G is also a cost-effective way to increase storage resources for the grid. Most of the utilities surveyed for the 2021 State of the Electric

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[86] *Id.* at 1.
[87] *Id.* at 4.
[88] *Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh*, BLOOMBERG NEF (Dec. 16, 2020), https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/ [perma.cc/2RL4-AA3K].
[89] Coignard, *supra* note 12, at 6.
[90] *See* Hannes Krueger & Andrew Cruden, *Integration of Electric Vehicle User Charging Preferences into Vehicle-to-Grid Aggregator Controls*, 6 ENERGY REP. 86, 89 (2020) (suggesting V2G modes for user participating in a DER aggregation, such as a mode where a user could specify a state of charge for the battery below which the aggregator may not discharge).
[91] *See* Shepard, *infra* note 96.

Utility Survey Report named high costs as the biggest challenge facing their organizations in adding more storage to their systems. [92] Energy storage is a necessary component of a grid with increasing percentages of renewables because it helps to address reliability issues.[93] When solar or wind are not able to provide power at the necessary times, utilities can draw on storage resources. Storage also "adds significantly" to a utility's ability to integrate DERs effectively and economically into the system.[94] EV batteries participating in a V2G system could fulfill a considerable proportion of storage needs without utilities having to invest in standalone battery storage.[95]

V2G can be used to create virtual storage batteries as part of a DER. For instance, in 2018, DER aggregator eMotorWerks, a subsidiary of Enel X, successfully deployed a 30 MW virtual energy storage battery comprised of 6,000 EV chargers across California.[96] eMotorWerks controls the charging through the company's software and aggregates and bids EV loads in the CAISO wholesale day-ahead and real-time markets.[97] Since storage is a necessary component of a grid with increasing percentages of renewable generation, V2G offers a cost-effective solution for utilities and regulators searching for ways to incorporate more storage into the grid.

G. Current V2G Projects

Several V2G projects underway in various states have demonstrated proof of concept for V2G systems. One of the most promising applications of V2G in the near-term is for school bus fleets. Since school buses have large battery packs, operate during set times of each day, and park for known durations, there is substantial potential to leverage school buses as part of a V2G system.[98] Dominion Energy in Virginia has already started incorporating V2G electric school buses as a grid flexibility asset.[99] Since school districts will not have the funds to convert their fleets to electric on their own, companies like Highland Electric Transportation are working to make EV transition attractive and affordable for school districts.[100] Highland takes on the upfront and

[92] Kavya Balaraman, *State of the Electric Utility 2021: Despite Sharp Drop, Cost Remains Key Obstacle to More Storage Some Say* (April 1, 2021), https://www.utilitydive.com/news/state-of-the-electric-utility-2021-despite-sharp-drop-cost-remains-key-ob/596581/ [perma.cc/QW8J-EK2F].
[93] SOUTHERN CALIFORNIA EDISON, *supra* note 34, at 1.
[94] JIM LAZAR, THE REGULATORY ASSISTANCE PROJECT, ELECTRICITY REGULATION IN THE U.S.: A GUIDE 116 (2nd ed. 2016).
[95] *See* Coignard, *supra* note 12, at 6 (stating that V2G could fulfill CPUC's entire storage mandate).
[96] Paul Shepard, *eMotorWerks Deploys a 30MW Virtual Energy Storage Battery in California*, EE POWER (Sept. 12, 2018), https://eepower.com/news/emotorwerks-deploys-a-30mw-virtual-energy-storage-battery-in-california/# [perma.cc/J73T-QKAM].
[97] *Id.*
[98] BRIONES, *supra* note 13, at 22.
[99] Neil Wright, *Is Vehicle-to-Grid Technology the Key to Accelerating the Clean Energy Revolution?*, POWER (Nov. 9, 2020), https://www.powermag.com/is-vehicle-to-grid-technology-the-key-to-accelerating-the-clean-energy-revolution/ [perma.cc/VMD7-PA3M].
[100] Jeff St. John, *Highland Electric Raises $235M, Lands Biggest Electric School Bus Contract in the US*, GREENTECH MEDIA (Feb. 25, 2021), https://www.greentechmedia.com/articles/read/on-heels-of-253m-raise-highland-electric-lands-biggest-electric-school-bus-contract-in-the-u.s [perma.cc/2BU9-Z4TM].

ongoing costs of EV school bus fleets in exchange for a fixed leasing fee that is equal to or less than a school district's current budget for its fleet.[101] Highland will recoup its investment utilizing V2G to earn money from the battery capacity of the bus fleets.[102] In 2021, Montgomery County Public Schools in Maryland awarded Highland a contract to supply 326 buses and charging systems to be delivered over the next four years.[103] Highland is betting that the alignment of school bus schedules and grid needs will make them "the killer V2G app."[104] In Indiana, three companies are collaborating on the first large-scale V2G system pilot project in the Midwest to support the school bus fleet and other customer applications.[105] The project data will guide Midwest utilities in developing policies for V2G programs as part of the DER mix.[106]

DER aggregation projects, in which EV batteries participate, are also progressing. OhmConnect, a residential demand response and energy services company, and Sidewalk Infrastructure Partners have started a project for a 550 MW virtual power plant, which will be the largest distributed clean power plant in North America.[107] The plant will be comprised of a network of hundreds of thousands of California homes and the millions of smart devices therein, including EV batteries.[108] OhmConnect previewed the significant impact that the virtual power plant will have when it was able to reduce energy usage by nearly one GWh during the 2020 August blackouts in California and paid customers $1 million to do so.[109] OhmConnect reports that, at scale, the virtual power plant could provide 5 GWh of energy conservation, equal to the full amount of the energy shortfall in the August blackouts.[110]

In a survey of utility concerns about vehicle-grid integration, utilities noted that they would like to have more large-scale pilot programs to capture the data needed to conduct cost-benefit analyses of vehicle-grid

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[101] Jeff St. John, *Electric School Bus Fleets Test the US Vehicle-to-Grid Proposition*, GREENTECH MEDIA (Nov. 16, 2020), https://www.greentechmedia.com/articles/read/electric-school-bus-fleets-test-the-u.s-vehicle-to-grid-proposition [perma.cc/UUP6-X5DR].

[102] *Id.*

[103] St. John, *supra* note 100.

[104] St. John, *supra* note 101.

[105] Press Release, EV Connect Pilots First Vehicle-to-Grid Charging Project in the Midwest, POWER (Mar. 16, 2021), https://www.powermag.com/press-releases/ev-connect-pilots-first-vehicle-to-grid-charging-project-in-the-midwest/ [perma.cc/Q7QY-RRFR].

[106] *Id.*

[107] Kavya Balaraman, *Thousands of California Homes to be Linked for 550 MW Virtual Power Plant, North America's Largest*, UTILITY DIVE (Dec. 8, 2020), https://www.utilitydive.com/news/sce-590-mw-storage-550-mw-virtual-power-plant/591786/ [perma.cc/6Z3A-4826].

[108] *Id.*

[109] *Id.*

[110] Press Release, Sidewalk Infrastructure Partners & OhmConnect, Sidewalk Infrastructure Partners (SIP) and OhmConnect to Create North America's Largest Distributed Clean Power Plant, (Dec. 7, 2020), https://assets.website-files.com/53cda9eccbc8e0894bcf7766/5fce6f871f4224502c080707_news-sip-ohmconnect-press-release-12.07.2020.pdf [perma.cc/RRC9-ABJ8].

integration programs for their service areas.[111] As the survey shows, utilities are unlikely to commit to V2G projects without the necessary data. Additional, large scale V2G pilot programs will be crucial to demonstrating the viability of the technology as a part of the larger transition to renewables and the smart grid and to encouraging utilities to invest in V2G.

III. TECHNOLOGY AND INFRASTRUCTURE REQUIREMENTS FOR V2G: BARRIERS REMOVED AND CHALLENGES THAT PERSIST

While the V2G concept has existed for over a decade, the necessary technology and infrastructure have only recently developed to the extent needed to make V2G practicable. Battery technology, charging infrastructure, advanced metering infrastructure (AMI), and DER management systems have sufficiently developed to make V2G a viable option in certain areas. While not a barrier to V2G's use, cybersecurity gaps and the environmental costs of batteries pose long-term problems that need to be addressed.

A. Battery Longevity

Since the battery is the most valuable part of the V2G system, one threshold issue to consider is whether EV batteries that are part of a V2G system suffer greater battery degradation than EV batteries that are not part of a V2G system. V2G systems can put more stress on batteries through increased cycling, i.e., more frequent charge/discharge cycles, thereby reducing their capacity more quickly.[112] One study found that using V2G for frequency regulation and peak load shaving would not significantly accelerate battery degradation compared to non-V2G EV battery use.[113] However, if V2G batteries are used for net load shaping, i.e., charging or discharging to better balance grid supply and demand, then battery degradation will be higher because, for that usage, the batteries are charging and discharging more often.[114] But a more recent study distinguished between V2G use in current, "unintelligent" grids and V2G use in smart grids and found that in a smart grid system, the adverse effects of V2G on the battery could be avoided. There is even potential for the life of the EV battery to be extended by using V2G to optimize the battery's resting condition.[115] Additionally, battery technology continues to advance, with companies such as Tesla making improvements in charge and discharge rates as well as battery life.[116] With smart grid upgrades and

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[111] MYERS, *supra* note 10, at 13.
[112] Dai Wang et al., *Quantifying Electric Vehicle Battery Degradation from Driving vs. Vehicle-to-Grid Services*, 332 J. POWER SOURCES 193, 194 (2016).
[113] *Id.* at 202.
[114] *Id.*
[115] Kotub Uddin, Matthieu Dubarry & Mark B. Glick, *The Viability of Vehicle-to-Grid Operations from a Battery Technology and Policy Perspective*, 113 ENERGY POL'Y 344–45 (2018).
[116] Mark Anderson, *Companies Report a Rush of Electric Vehicle Battery Advances*, IEEE SPECTRUM (Mar. 19, 2020), https://spectrum.ieee.org/transportation/efficiency/companies-report-rush-electric-vehicle-battery-advances [https://perma.cc/U7VJ-AQK7].

battery technology advances, battery degradation will be a resolvable issue.

B. Charging Infrastructure

Adequate charging infrastructure will be important for successfully using all the potential value paths of V2G. One of the most commonly cited barriers to greater EV adoption generally is adequate charging infrastructure.[117] The question of whether public charging infrastructure will need to be as ubiquitous as gas stations has been clearly answered in the negative by Idaho National Laboratory's three-year EV charging study that looked at EV charging behavior in cities across the United States.[118] The study found that the majority of charging was done at home and work, with certain public charging locations such as shopping malls, airports, and parking lots also seeing consistently high use.[119] This means that ensuring sufficient charging infrastructure in multi-unit dwellings—especially as the number of people living in apartments continues to increase[120]—will be important. Moreover, if people drive their EVs to work and there is no charging infrastructure at the workplace, then the EVs will be disconnected from the grid for a significant portion of the day, and some of their functionality as a grid asset will be lost.[121] Therefore, ensuring sufficient charging infrastructure at workplaces will also be important to V2G success.

Another important aspect of charging infrastructure that could affect V2G is interoperability. There is a danger that absent regulation, a mix of utility-owned and privately owned infrastructure and resulting incompatibilities could make it too difficult for a comprehensive V2G grid program.[122] Even within privately owned infrastructure, interoperability issues have cropped up. For example, the Chevrolet, Nissan, Mitsubishi, and Toyota EVs use a 120V charger, whereas Tesla uses its proprietary connector.[123] The issue has already spurred the creation of adapters,[124] but absent regulatory standards, there is no guarantee that complete interoperability will be achieved.

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[117] IDAHO NAT'L LABORATORY, PLUGGED IN: HOW AMERICANS CHARGE THEIR ELECTRIC VEHICLES 1 (2015), https://avt.inl.gov/sites/default/files/pdf/arra/PluggedInSummaryReport.pdf [perma.cc/CK8S-BELN].
[118] *Id.* at 3.
[119] *Id.*
[120] Robert Pinnegar, *The Top Five Reasons More People Are Choosing to Rent Rather Than Buy a Home*, WASH. POST (Jan. 27, 2020), https://www.washingtonpost.com/business/2020/01/27/top-five-reasons-more-people-are-choosing-rent-rather-than-buy-home/ [https://perma.cc/6ERY-YFW2].
[121] *See infra* Part I(E) (discussing various ancillary services that V2G can provide).
[122] *See* Uddin, *supra* note 115, at 346 (stating that resolution of interoperability issues is key to V2G success).
[123] *Id.*
[124] *Id.* (Tesla offers adapters to ensure that Tesla owners can use other networks; the JDapter Stub allows owners of non-Tesla EVs to charge at Tesla's Destination Chargers or using the Tesla Wall Connector).

How ownership of charging infrastructure is managed will also impact V2G success. While many regulators and EV proponents advocate for third-party companies to own the charging systems, the cost of chargers is very high. It can require the companies to charge fees equal to or greater than the per-mile cost of gasoline, which eliminates the economic advantage of EVs over combustion engine vehicles.[125] Regulators in some states, such as California, are considering the advantages of utility-owned charging infrastructure, with the California Public Utilities Commission (CPUC) reversing an initial prohibition on utility ownership of charging infrastructure.[126] As there will likely be a mix of third-party-owned and utility-owned charging infrastructure, state utility commissions will need to pass regulations to ensure some level of interoperability among systems and manage interactions among third parties, utilities, and EV users.

A corollary issue is that a DER aggregator will likely want access to the EV battery for as much of the day as possible,[127] and that means that the workplace charging infrastructure would need to be configured to allow different aggregators access. If the DER aggregator is using proprietary charging software to manage the battery when the EV is parked at home,[128] the aggregator may not be able to access the car when it is at work unless the workplace is using the same charging software. The interactions among EV users, DER aggregators, charging infrastructure companies, and utilities will require some combination of technological, contractual, and regulatory solutions to manage those interactions in a way that will not be detrimental to expanded EV usage. However, with other states adopting zero-emission vehicle policies like those in California,[129] state policies will drive solutions to charging infrastructure issues.

C. Smart Meters and DER Management Software

Another infrastructure requirement for V2G is advanced metering infrastructure (AMI). AMI meters allow two-way communication between utilities and customers so that utilities can measure and analyze energy use and power demand levels.[130] AMI can include home components that may be controlled remotely.[131] When an EV is connected and communicating with the utility through an AMI meter, the utility can curtail charging or draw on the battery power as needed.[132] AMI meters provide utilities with near real-time energy use data which can allow utilities to track energy use patterns, manage demand response programs, and implement rate designs,

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[125] FITZGERALD, *supra* note 23, at 22 (2016).
[126] *Id.* at 48.
[127] If a DER aggregator is providing daytime frequency regulation or demand response, it will need access to the battery during the workday. *See infra* Part I(E).
[128] *See, e.g.*, *Juicebox*, ENEL X, https://evcharging.enelx.com/products/juicebox [https://perma.cc/M9W2-5TLC].
[129] THE BRATTLE GROUP, *supra* note 24.
[130] BRIONES, *supra* note 13, at 20.
[131] *Id.*
[132] *Id.*

such as time-of-use rates.[133] The more granular data provided by AMI is beneficial not only for utilities, but also for customers.[134] Customers can see hourly usage and price information, which can help them understand the potential costs and benefits of installing devices that can provide services to the grid.[135] By 2020, U.S. electric utilities had installed about 102.9 million AMI systems[136] and one estimate puts smart meter penetration in the U.S. and Canada combined at 81% by 2024.[137] Due to the widespread adoption of AMI, the smart meter requirements for V2G are already present in many areas and provide a gateway to V2G utilization.

If V2G will be used to make EVs part of a DER aggregation, a corollary to AMI is that DER management software will also be necessary.[138] One software option is Advanced Distribution Management Systems (ADMS), which integrates several different utility systems into one, enterprise-wide network management system.[139] ADMS can be used to monitor and control utility-owned assets and DERs but does not reach customer-owned DERs.[140] A second type of software known as Distributed Energy Resource Management Systems (DERMS) has been introduced by various companies to manage behind-the-meter, customer-owned DERs.[141] DERMS allows utilities to forecast supply and demand conditions up to two days in advance, integrate AMI data with other utility systems, communicate with third-party systems, and dispatch resources.[142] Several utilities are already working on integrating DERMS with ADMS to provide real-time situational awareness and forecasting analysis for their DER operations.[143] The necessary management software is on its way to being able to support more widespread V2G integration.

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[133] Jeff St. John, *Why Most US Utilities Are Failing to Make the Most of Their Smart Meters*, GREENTECH MEDIA (Jan. 10, 2020), https://www.greentechmedia.com/articles/read/why-most-u-s-utilities-arent-making-the-most-of-their-smart-meters [https://perma.cc/7E7V-KPT9].
[134] NAT'L ASS'N OF REGULATORY UTILITY COMM'RS, *supra* note 45, at 51–52.
[135] *Id.*
[136] *Frequently Asked Questions*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/tools/faqs/faq.php?id=108&t=1 [https://perma.cc/F678-FNS4](last updated Nov. 2, 2021).
[137] Nicholas Nhede, *Smart Meter Penetration in North America Will Reach 81% by 2024*, SMART ENERGY INT'L (Jul. 5, 2019), https://www.smart-energy.com/industry-sectors/smart-meters/smart-meter-penetration-in-north-america-will-reach-81-by-2024/ [https://perma.cc/U7VJ-AQK7].
[138] NAT'L ASS'N OF REGULATORY UTILITY COMM'RS, *supra* note 45, at 52.
[139] *Id.* at 53.
[140] Aakriti Gupta & Varun Mehra, *ADMS Versus DERMS: Who Unlocks Value at the Grid-Edge?*, ENERGYHUB (Sept. 23, 2019), https://info.energyhub.com/blog/adms-versus-derms-value-at-the-grid-edge [https://perma.cc/2NNH-A96G].
[141] *Id.*
[142] NAT'L ASS'N OF REGULATORY UTILITY COMM'RS, *supra* note 45, at 53.
[143] Trabish, *supra* note 58.

D. Cybersecurity Gaps

Cybersecurity is a critical component of the smart grid and lags behind the current state of technology. As more and more devices in people's homes become a part of the Internet of Things, cybersecurity becomes even more important. In the 2021 State of the Electric Utility Survey Report, utilities ranked "strengthening cybersecurity requirements for utilities" as one of their highest priorities for the Federal Energy Regulatory Commision (FERC) to address,[144] and cybersecurity incidents involving utilities have highlighted the need to address risks to the power system.[145] In 2021, a U.S. Government Accountability Office (GAO) report stated that U.S. grid distribution systems are growing more vulnerable due to control systems that allow remote access and connection to business networks as well as increasing numbers of networked consumer devices and DERs, which provide threat actors with additional attack vectors.[146] Utilities currently have limited influence on the cybersecurity of networked consumer devices, such as EVs and charging stations, because consumers typically retain control.[147] However, some companies that offer DER services have retained the capability to monitor and manage their devices.[148] The GAO report points out that an attacker could infiltrate a company's systems, access the devices, and instruct them to perform unwanted actions, such as injecting power into the grid to cause a power outage.[149]

The use of V2G systems could mitigate the vulnerability of EV charging points in certain scenarios. In a V2G system where the DER aggregator or the utility has visibility and control over EV charging, the aggregator or utility could implement cybersecurity measures for the charging device rather than relying on customers to manage their own device security. For V2G to be an effective vulnerability mitigator, however, state public utility commissions will need to promulgate rules ensuring utilities are implementing cybersecurity measures for all smart devices within their control. Ideally, comprehensive federal and state laws will be enacted to mandate specific cybersecurity measures for all grid activities. Regardless of the method used, though, the expansion of the smart grid requires governments and utilities to implement enhanced cybersecurity procedures.

E. Environmental Costs of Batteries

Battery technology is the core of V2G, and although battery technology continues to evolve, there are environmental costs to the

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144 KAVYA BALARAMAN ET AL., UTILITY DIVE, STATE OF THE ELECTRIC UTILITY: 2021 SURVEY REPORT 38 (2021).
145 *Id.* at 27.
146 U.S. GOV'T ACCOUNTABILITY OFF., ELECTRICITY GRID CYBERSECURITY: DOE NEEDS TO ENSURE ITS PLANS FULLY ADDRESS RISKS TO DISTRIBUTION SYSTEMS 11 (2021), https://www.gao.gov/assets/gao-21-81.pdf [https://perma.cc/X3F8-TVAM].
147 *Id.* at 18.
148 *Id.* at 20.
149 *Id.*

increasing number of batteries. Critical minerals that are required for conventional lithium-ion batteries, such as lithium and cobalt, are often mined using unethical practices.[150] Mining activities create hazards for human health, bioaccumulation in aquatic species, and toxicity effects from the disposal of mine tailings.[151] Disposal of end-of-life batteries also poses hazardous waste concerns.[152] Some components of the battery can be recycled, but more research and development is needed to enlarge recycling efforts in the U.S.[153] Additionally, battery manufacturers are working to develop batteries that do not require cobalt[154] and are seeking alternatives to lithium, such as zinc, which is non-toxic and recyclable.[155] The environmental issues with increased battery use do not have a simple solution, and the best hope lies in advances in technology and better recycling processes that can substantially lessen the negative environmental effects. Policymakers promoting increased battery usage should also concurrently promote investment in materials engineering and recycling to find solutions to the accompanying environmental issues.

As technology and infrastructure develop to support V2G systems, regulators must also consider how V2G will integrate into current regulatory frameworks and what additional regulations may be needed.

IV. HOW TO REGULATE V2G

The number of EVs in the United States will increase significantly over the next several years whether or not systems are in place to manage vehicle-to-grid integration. To capture the full benefits of EVs, regulators must map out a framework for integrating V2G into the existing grid system. Different market structures and regulations mean that the integration of V2G will vary from state to state. Regulatory design parameters will be different in both states with vertically integrated markets and states with partially or fully restructured markets. The scope of this issue is too broad to be fully discussed here, so this paper recommends two broad regulatory changes that will facilitate V2G and suggests different compensation, ownership, and management frameworks for integrating V2G in vertically integrated versus restructured markets.

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150 RICHARD K. LATTANZIO & CORRIE E. CLARK, CONG. RESEARCH SERV., R46420, ENVIRONMENTAL EFFECTS OF BATTERY ELECTRIC AND INTERNAL COMBUSTION ENGINE VEHICLES 7–10 (2020), https://fas.org/sgp/crs/misc/R46420.pdf [https://perma.cc/KP62-R3C4].
151 *Id.* at 7–8.
152 *Id.* at 21.
153 *Id.*
154 Anderson, *supra* note 116.
155 Umar Ali, *Beyond Lithium: Alternative Materials for the Battery Boom*, POWER TECH. (Feb. 6, 2020), https://www.power-technology.com/features/lithium-battery-alternatives/ [https://perma.cc/SA8A-WWF8].

A. Vertically Integrated Monopoly Markets vs. Restructured Markets

For most of the twentieth century, electric utilities were considered natural monopolies, and each utility owned and controlled generation, transmission, and distribution of electricity for its service area.[156] Today, some utilities still maintain this structure, known as vertical integration. In a vertically integrated market, the utilities are allowed to recover their costs and receive a reasonable rate of return in exchange for regulation by the state.[157] After the energy market restructuring of the 1990s, electricity generation was opened to competition, and most utilities in the restructured markets divested themselves of their generation and transmission assets and retained only their distribution functions.[158] As part of the restructuring, ISOs/RTOs were formed to manage grid balancing and wholesale auctions for selling power to distribution utilities.[159] Some jurisdictions decided not to participate in the competitive restructuring, so certain areas of the country retain a vertically integrated model where the utility is responsible for most aspects of grid operations.[160]

B. Rate Design and Energy Storage Mandates

One thing that will be necessary for V2G, whether it is in a vertically integrated market or restructured market, is the modification of rate designs. Some utilities are using time-of-use (TOU) rates, real-time pricing, and demand charges to manage EV charging;[161] however, these designs do not involve the more direct control exercised over the customer's battery in a V2G situation. In a scenario where V2G batteries are being utilized for frequency regulation or other ancillary services, customers will need to be compensated for the services provided by their batteries. This raises several questions that regulators need to answer in their rate designs. Will TOU rates still be applied to customer charging when their V2G-enabled batteries are also participating in a DER aggregation? Will there be one rate for the V2G battery and other DER-participating devices and a separate rate for the rest of the household electricity consumption? These are just a few examples of the issues that utilities and regulators must address when determining rate designs for V2G and how those rates will interact with and affect other grid services.

Additionally, for those areas that participate in a competitive wholesale market, the ISOs/RTOs must revise their tariffs to accommodate DERs if they have not done so already. This will include specific maximum size limits, what resources may participate, how single-resource-type versus multiple-resource-type DERs will be treated, and what services the DER is allowed to provide, i.e., demand response,

[156] W.M. WARWICK, U.S. DEP'T OF ENERGY, A PRIMER ON ELECTRIC UTILITIES, DEREGULATION, AND RESTRUCTURING OF U.S. ELECTRICITY MARKETS, at 6.6 (2002); LAZAR, *supra* note 94, at 13.
[157] Stein, *supra* note 39, at 893–94.
[158] *Id.* at 894; LAZAR, *supra* note 94, at 13.
[159] LAWSON, *supra* note 8, at 3.
[160] *Id.*
[161] HARPER, *supra* note 33, at 26.

frequency regulation, etc.[162] ISOs/RTOs will also have to ensure that their parameters for DER market participation do not unnecessarily stymie that participation. For example, participants have noted that CAISO's DER structure precludes participants from pursuing advantages outside the wholesale markets and charges energy storage systems twice for the energy they use to charge their systems—once at the retail rate and again at the wholesale rate.[163] If the DER tariff structure disincentivizes DER energy storage resources, then it will also disincentivize V2G since one of V2G's primary value propositions is as an energy storage resource in a DER aggregation.

Another regulatory addition that will support V2G is the implementation of state energy storage mandates. Mandates that require utilities to include energy storage in their integrated resource plans will drive the adoption of different storage strategies,[164] and V2G could be one prong of an innovative storage strategy. Particularly if a storage mandate specifies that behind-the-meter storage is a necessary component, then V2G could fulfill that part of the mandate.

C. Compensation Framework for V2G

One long-standing method for compensating and managing the distributed generation subset of DERs is net metering.[165] As defined in the Energy Policy Act of 2005, net metering (also known as NEM) is "service to an electric consumer under which electric energy generated by that electric consumer from an eligible on-site generating facility and delivered to the local distribution facilities may be used to offset electric energy provided by the electric utility to the electric consumer during the applicable billing period."[166] Previous articles on V2G have suggested that state net metering laws should be modified to include V2G.[167] However, net metering may not be the best compensation framework for V2G.

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[162] *See* LAVILLOTTI, *supra* note 50 (discussing rules for single-resource-type aggregations and mixed resource aggregations).
[163] ADVANCED ENERGY ECONOMY, PUTTING DISTRIBUTED ENERGY RESOURCES TO WORK IN WHOLESALE ELECTRICITY MARKETS 9 (2019), https://info.aee.net/hubfs/Putting%20Distributed%20Energy%20Resources%20to%20Work%20in%20Wholesale%20Electricity%20Markets.pdf [https://perma.cc/EWX3-4S2Q].
[164] Andy Colthorpe, *Nevada Becomes Sixth US State to Adopt Energy Storage Target*, ENERGY STORAGE NEWS (Mar. 18, 2020, 12:07 PM), https://www.energy-storage.news/news/nevada-becomes-us-sixth-state-to-adopt-energy-storage-target [https://perma.cc/W5MK-L65G].
[165] ASHLEY J. LAWSON, CONG. RESEARCH SERV., R46010, NET METERING: IN BRIEF 1 (2019).
[166] 16 U.S.C. § 2621(d)(11) (2021).
[167] *See* Matthew Hutton & Thomas Hutton, *Legal and Regulatory Impediments to Vehicle-to-Grid Aggregation*, 36 WM. & MARY ENVTL. L. & POL'Y REV. 337, 355–56 (2012) ("[A] prerequisite to V2G is for state legislature to adopt statutory patches expressly providing for net metering of energy supplied by EVs. . ."); *see* Bryan Lamble, *Of Nesting Dolls and Trojan Horses: A Survey of Legal and Policy Issues Attendant to Vehicle-to-Grid Battery Electric Vehicles*, 86 CHI.-KENT L. REV. 193, 212–13 (2011) (stating that net metering legislation is a precursor for EVs to provide ancillary services and implying that it is a necessary foundation).

Although states are not required to adopt the standards established in the Energy Policy Act,[168] Congress's use of the term "generating facility" shows that net metering was intended to compensate customer generation of electricity, not customer storage of electricity. In a V2G battery scenario, the customer is storing electricity that has already been generated and is not generating any additional electricity. CAISO's definition of net metering mirrors the federal definition in defining retail net metering as a program that allows participating resources to net excess generation against future electricity bills.[169] Storage is a different service than generation, so it would be more appropriate for V2G to be regulated under laws and regulations for storage rather than for generation.

Additionally, including V2G batteries in a DER aggregation will be more beneficial for the grid and for customers. The V2G battery will be able to earn more from participating in a DER aggregation because the value of the grid services rendered as part of an aggregation would be more than the value of sending small amounts of electricity back to the grid on an individual basis.[170] Also, a V2G battery participating in a NEM program would not be able to participate in a DER aggregation because that would result in double counting the energy.[171] For that reason, CAISO specifically excludes any resource that participates in an NEM retail program from participating in a DER aggregation.[172]

Due to the various grid services a V2G battery can provide, the total value of a V2G battery is greater in a DER aggregation than in a NEM program. Paying NEM retail rates to customers for their V2G grid services can create added costs for utilities because utilities may be overcompensating customers for the energy they provide. Customers may also be undercompensating the utilities for generation, transmission, and distribution investments.[173] Therefore, V2G participation in DER aggregations instead of NEM programs makes more sense from an overall cost and value perspective, and DER and energy storage laws and regulations, rather than net metering laws and regulations, are the better vehicle for managing and compensating V2G services.

D. Who Owns and Manages the Resource

DER-related regulatory changes will also be necessary to facilitate V2G. There are a few questions that must be answered when making these

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[168] LAWSON, *supra* note 165, at 1 n.3.
[169] Justin Gundlach & Romany Webb, *Distributed Energy Resource Participation in Wholesale Markets: Lessons from the California ISO*, 39 ENERGY L.J. 64 n.103 (2018).
[170] *See* Guille, *supra* note 53, at 4380 (noting that a single vehicle battery has a negligible impact on the grid).
[171] *See* 155 F.E.R.C. ¶ 61,229 at P 6 (2016) ("[U]nder California's current net energy metering program, a participating resource already receives benefits from netting its excess energy against subsequent electricity bills; therefore, there is no energy available to offer into the CAISO markets [as part of a DER aggregation] because excess energy is banked for later withdrawal.").
[172] *Id.*
[173] NAT'L ASS'N OF REGULATORY UTILITY COMM'RS, *supra* note 45, at 89; *see* CAL. PUBLIC UTILITIES COMM'N, UTILITY COSTS AND AFFORDABILITY OF THE GRID OF THE FUTURE: AN EVALUATION OF ELECTRIC COSTS, RATES, AND EQUITY ISSUES PURSUANT TO P.U. CODE SECTION 913.1, 29 (2021) ("[T]he utility pays more to NEM customers than it would pay elsewhere for the same amount of energy and other electric grid benefits.").

regulations. Can utilities be DER aggregators, or can only third parties act as aggregators? Should V2G-participating batteries be bundled with other DERs, or should they be a separate category? Public utility commissions and RTO/ISOs must decide what entities are allowed to be DER aggregators and what resources will be allowed to participate in a DER aggregation.

In a state that participates in a competitive wholesale market managed by an RTO/ISO, third parties, rather than utilities, should act as DER aggregators. The primary value of a DER aggregation in a competitive market is its ability to sell services on the wholesale market, which is not a function of a distribution utility.[174] In September 2020, FERC's Order 2222 removed one large regulatory hurdle for DERs by allowing DER aggregations to compete in organized, wholesale electricity markets alongside traditional resources.[175] Importantly, FERC included EVs and their charging equipment in the definition of DER.[176] The Order requires RTO/ISOs to revise their tariffs to specifically allow DER aggregator participation and, with certain exceptions, bars state retail regulators from prohibiting DER participation.[177] FERC's order will spur the growth of competitive DER aggregation businesses, and in such a market scenario, third parties should be the DER aggregators.

In a state that participates in a competitive wholesale market managed by an RTO/ISO, V2G batteries can be bundled with other DERs. Even before Order 2222, DER aggregators were bidding EV batteries as demand response into the CAISO market.[178] With DER aggregations being a growing piece of the smart grid transition, EV batteries should be bundled into an aggregation along with other distributed resources. A mix of resources with different size and operational characteristics in a heterogeneous DER aggregation can likely offer more power stability because if one type of resource has low power availability due to conditions common to that resource type, other resource types can fill in.

In a state with vertically integrated utilities, utilities could function as the DER aggregator. The utility would not be acting in the same way as a DER aggregator would in a competitive market because it would not be selling aggregated resources on the wholesale market. Rather, it would be aggregating resources for its grid operations. While the utility does not need to own the DER resources, some utilities may choose to do so. When DER resources are located behind the customer meter and owned by the customer, the integration of DERs into a vertically integrated utility

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[174] *See* LAWSON, *supra* note 8, at 3 (stating that in restructured markets, generators compete to sell power to distribution utilities in contrast to vertically integrated markets where utilities provide power generation).
[175] *FERC Order No. 2222: Fact Sheet*, FED. ENERGY REGULATORY COMM'N (2020), https://www.ferc.gov/media/ferc-order-no-2222-fact-sheet [https://perma.cc/RE49-D6NT].
[176] *Id.*
[177] *Id.*
[178] Shepard, *supra* note 96.

business would be a virtual integration rather than a vertical integration, since the utility would not own the asset.[179] The utility could harvest many of the benefits of DERs without having to take on the risk and associated cost of direct ownership of DER assets.[180] Utilities will need to carefully accommodate DERs in their planning and decide which option is better in the long term: owning the assets and adding them to a utility's rate base, i.e., following the traditional model of a vertically integrated utility, or exploring a new model and utilizing DERs through a virtual integration and potentially eliminating some necessary utility investments while keeping rates down. The latter option is likely the best strategic choice in the long term,[181] as it gives utilities more flexibility and less exposure to risk from a new and evolving asset type. However, local conditions may make the former option the best choice in some areas.

For utilities that decide to own the DERs and put DERs in their rate base,[182] it may be a better policy to keep V2G separate from other distributed resources such as solar. Some experts have raised regulatory concerns about utilities aggregating solar DER, but if V2G batteries were kept separate as a distinct aggregation, the same concerns would not be present for V2G aggregation. Former FERC chairman Jon Wellinghoff has argued that a utility owning behind-the-meter DERs would violate the requirement that monopoly utility investments must be used and useful to current ratepayers.[183] Behind-the-meter investment in DER would benefit the customer who hosts the DER but not the rest of the ratepaying customer base.[184]

However, this argument is focused on solar as the source of the DER aggregation, and these arguments are not as applicable to DER aggregation of battery storage. Behind-the-meter battery storage is an investment that would be used and useful to ratepayers because of the demand response and ancillary services that batteries can provide to the grid.[185] DER-aggregated EV batteries even have the potential to reduce customer rates.[186] If enough behind-the-meter batteries are participating, utilities could satisfy their energy storage needs through customer-owned batteries and would not need to build standalone storage or additional gas peaker plants to address peak load events, and those savings can be passed along to the ratepayers.[187] A vertically integrated monopoly utility could

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[179] *See* CORNELI, *supra* note 55, at 12–13 (assuming that customer-owned DER will predominate in the market and discussing how virtual integration allows competitive firms to coordinate with a regulated network, such as a utility, to provide a product that creates economic value for all parties).
[180] *Id.* at 18 n.29.
[181] *See id.* at 18 n.28 (giving an example of how the utility ConEd substantially cut the cost of a new substation by using customer-owned DERs, thereby keeping rates lower for all customers).
[182] *Id.* at 18 n.29.
[183] James Tong & Jon Wellinghoff, *Should Utilities Be Allowed to Rate Base Solar?*, UTILITY DIVE (May 11, 2015), https://www.utilitydive.com/news/tong-wellinghoff-should-utilities-be-allowed-to-rate-base-solar/396283/ [https://perma.cc/43PG-HG2T].
[184] *Id.*
[185] *See supra* Part I(E)–(F).
[186] *See* CORNELI, *supra* note 55, at 18 n.28 (arguing that all customer-owned DERs can "reduce costs (and rates) for all customers, not just the DER hosts").
[187] *See, e.g.,* Wash. Rev. Code § 19.280.100 (2019) (stating that planning for DERs could allow utilities to reduce, defer, or eliminate unnecessary capital expenditures).

own and aggregate behind-the-meter batteries without the same concerns involved in solar DER aggregation.

A corollary to the concern that DER benefits the customer who hosts the DER but not the rest of the ratepaying customer base is that, as with net metering of rooftop solar, low-income ratepayers would bear additional costs caused by DER customers not paying enough to cover their share of grid costs.[188] However, if DER benefits the grid by deferring or eliminating costly infrastructure projects, then the reduction in rates would benefit all ratepayers. Additionally, some utilities already include fixed fees for grid maintenance costs for all customers as well as some type of low-income program fee on utility bills to defray electricity expenses for low-income ratepayers. DER-induced reduction in rates, low-income programs, and fixed maintenance fees will ensure that DER does not benefit DER hosts at the expense of low-income ratepayers.

Washington State, which is a vertically integrated utility jurisdiction, has already passed a law that specifically addresses utility DER planning. The law states that any utility DER planning process must identify the advanced metering and grid monitoring equipment needed to provide the utility data for assessing the value of DERs and show how metering and monitoring equipment upgrades will be leveraged to provide net benefits for customers.[189] The law also specifically directs utilities to identify opportunities for improving access to “transformative technologies” such as DER for low-income populations.[190] Washington’s law demonstrates that one advantage of vertically integrated utilities is that legislators and regulators can direct the utilities to address the inequities of the energy transition and ensure that clean energy benefits all ratepayers. It is a more complicated task for a state with a restructured market to address energy inequities because the wholesale markets are designed to manage costs and grid reliability, not address the unequal effects of technology transitions on low-income populations.[191]

Although there are different considerations when implementing V2G in vertically integrated markets versus restructured markets, V2G will likely have the most success in a vertically integrated utility state with strong clean energy mandates and programs directed at building battery storage capacity. In states with vertically integrated utilities, the state legislatures and utility commissions can enact laws and regulations that direct a greater range of utility behavior compared to a restructured market

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[188] *See* LAWSON, *supra* note 165, at 7 (discussing the extent to which non-NEM customers end up subsidizing NEM customers).

[189] Wash. Rev. Code § 19.280.100 (2019).

[190] *Id.*

[191] *See* JAQUELIN COCHRAN ET AL., MARKET EVOLUTION: WHOLESALE ELECTRICITY MARKET DESIGN FOR 21ST CENTURY POWER SYSTEMS v (2013), https://www.nrel.gov/docs/fy14osti/57477.pdf (“Wholesale electricity markets in restructured, competitive markets serve two roles: they define the security-constrained, merit-order dispatch that ensures short-term reliability, and they define the financial incentives and rules of eligibility for investment in resources that ensure long-term reliability.”).

and can incentivize third party investment in V2G by offering regulatory certainty and specified benefits. Unlike in a restructured market, there is no need to coordinate among the RTO/ISO, DER aggregator, distribution utility, and electric retail regulatory authorities. In a vertically integrated utility state with strong clean energy mandates, the government can quickly and directly make changes in utility practices that achieve clean energy goals. The state utility commission, as directed by the state government, can implement regulations to ensure that the necessary infrastructure, rate design, and utility management systems are in place to facilitate the use of V2G.

V. CONCLUSION

With increasing renewable electricity generation and increasing EV usage, grid managers will need to plan for ways to manage new load profiles and ensure grid reliability. V2G offers many benefits, including its ability to absorb daytime overgeneration of solar, shave peak demand, provide ramping mitigation, and provide frequency regulation and other ancillary services. The necessary technology and infrastructure already exist to begin implementing V2G programs in certain areas. However, expanded charging infrastructure, better battery manufacturing and recycling, enhanced cybersecurity, and appropriate regulatory changes require more work to enable V2G to reach its full potential. The transition to clean energy will not be without its setbacks and unintended consequences, but that is unavoidable when changing established practices, especially since energy production and usage touch on almost every aspect of modern life. Policymakers must weigh the pros and cons of different tools and approaches, and a variety of methods and solutions will be necessary to effectively facilitate the clean energy transition. With the right management, V2G can be one of the solutions to mitigating and managing the effects of transitioning to clean energy.