VEHICLE-GRID INTEGRATION

A Review of Available Approaches and Existing Programs

By Conner Smith and Nick Nigro

OCTOBER 2019

ATLAS PUBLIC POLICY
WASHINGTON, DC USA

ALLIANCE FOR TRANSPORTATION ELECTRIFICATION (ATE)
SEATTLE, WA

This brief lays out the challenges and opportunities of vehicle-grid integration (VGI). Electric vehicles (EVs) can help increase the utilization of existing electrical grid assets and put downward pressure on electricity rates by decreasing the average cost of delivering electricity. Many aspects of VGI, including time-of-use (TOU) rates and demand response programs have similar characteristics to other grid management programs. As mobile energy storage systems, EVs also present unique challenges to grid integration. When applied effectively, VGI programs can minimize the impact of EVs on the distribution grid and lead to a more resilient and reliable power grid.

DEFINING VEHICLE-GRID INTEGRATION

VGI is a promising way for electric utilities to maximize the benefits of the increasing number of EVs on the road. In SB-676, the California State Legislature defines VGI as "any method of altering the time, charging level, or location at which grid-connected electric vehicles charge or discharge, in a manner that optimizes plug-in electric vehicle interaction with the electrical grid and provides net benefits to ratepayers" [1]. The tools used in VGI strategies include:

1. **EV Rate Design**: TOU rates, dynamic/real time pricing, and other rate mechanisms designed to shift EV charging to off-peak times where the cost to generate electricity is lower. Rate mechanisms can also reduce the overall impact (kW demand) on the grid.
2. **Incentives**: monetary or other incentives for customers willing to take part in VGI programs.
3. **Managed/Smart Charging Technology (V1G)**: active control of unidirectional power flow from the grid to the vehicle, where vehicle charging is controlled by grid operators, aggregators, automakers, or other entities utilizing managed/smart charging technology depending on grid conditions. This functionality is similar to traditional demand response. However, charging can be both decreased or increased and shifted across broad time horizons or even charging ports or locations, providing for enhanced capabilities. Managed/smart charging technology is commercially available today, with these capabilities built into many of the networked smart chargers and network services offered on the market. Automakers are also actively engaged in developing this technology.
4. **Bi-directional Power Flow (V2G)**: programs where the grid operator can charge vehicles and pull power from their batteries based on the overall system needs. As is the case with V1G, the battery functions as a distributed energy resource (DER) to be flexibly managed on the grid. This can be done at all charging levels with compliant technology, although V2G technology is still operating at the pilot level and has not reached full commercialization.

While the opportunities for VGI are considerable, any solutions must consider the customer's primary use of the vehicle: transportation. Integrated VGI approaches such as the Honda SmartCharge program and the BMW ChargeForward program incorporated the customer's transportation needs, the vehicle state of charge, and the utility's charge management requests [2].

VGI programs of utilities utilize charging technology to beneficially shape charging patterns through both indirect tools such as TOU rates and direct, or active, EV load management such as managed/smart charging to improve the overall performance of the grid and reduce operating costs by balancing the electric load profile [3]. While indirect or passive tools have been in use for a while, active managed charging programs are newer in the marketplace, despite the technologically being commercially viable. V2G or bidirectional managed charging still must overcome significant operational and regulatory issues among the key industries, including utilities, automakers, and charging service and equipment providers.

When applied effectively, active V1G and V2G programs can control the power flow to charging stations to offer ancillary services to the grid including frequency regulation and spinning reserves. The value proposition of these services depends heavily on the market design (independent system operator, regional transmission operators, vertically integrated utilities, etc.), and how the Commissions regulate electricity rate tariffs and services. Both indirect and active VGI tools can be applied to achieve the following grid benefits [4]:

1. **Peak shaving:** setting the maximum charging rate on the charger and ensures that the grid can handle EV loads.
2. **Load balancing:** distributing a preset capacity proportionally over all active charging stations. This can also be analyzed and distributed dynamically in real-time. Managed charging can actively shape, utilize, and dispatch flexible EV charging loads and improve overall grid efficiency. Smart charging technology can enable a site host to provide multiple charging ports and optimize charge across them in cases when the location has access to limited power.
3. **Dynamic energy storage:** using grid-connected EVs as flexible energy storage resources for the grid to respond dynamically to demand fluctuations. EVs can offer this service either through one-way managed charging (V1G) where the vehicle provides energy or through bidirectional charging (V2G) where the vehicle can both provide and absorb energy.
4. **Onsite energy production:** sharing power between the grid and intermittent onsite generation like solar and wind. Smart charging technology can optimize charging to match this onsite generation which in turn can minimize impact on the distribution grid and lead to a more resilient and reliable power grid.
5. **Grid-scale renewables integration:** supporting their utilization by synchronizing charging with periods of overgeneration. Managed charging can absorb excess renewable energy generation during off-peak hours that would otherwise be curtailed for some electrical grids.

Active VGI tools can be paired with indirect load management approaches, such as TOU rates, or operate separately and independently of rates and rate design. The combination of both direct and indirect VGI can help balance electricity supply and demand, maximizing the reduced operating costs for electric utilities and downward pressure on rates. If the customer's use case allows it, VGI programs can also defer or delay significant investment in the upgrade of the electric distribution systems and also reduce customer investment in the required electrical upgrades when installing a charger.

INCREASED UTILITY ENGAGEMENT REVEALS IMPORTANCE OF VGI

Commission Proceedings

- 42 investor-owned electric utility in 24 states have approved EV programs
- 26 investor-owned utilities in 22 states have pending programs

Utility Investments

- More than $1.3 billion in investments by investor-owned utilities has been approved
- More than $1.5 billion in investments is pending at public utility commissions

VGI Program Elements

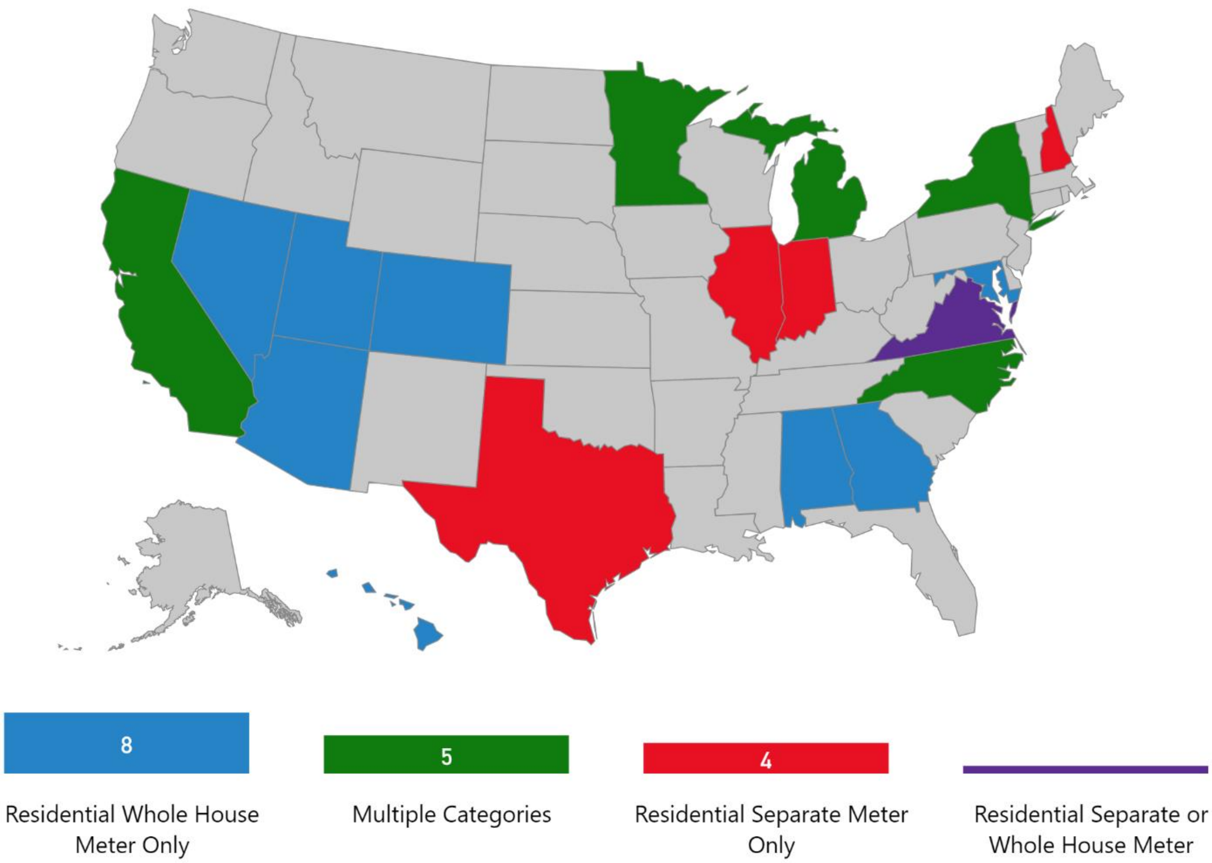
- Nearly 50 EV charging programs for all vehicle types have been approved
- More than 30 EV rates have been approved
- 15 education and outreach programs have been approved

Electric utilities are in a unique position to facilitate the expansion of transportation electrification through a variety of measures. For example, utilities can take a direct role by investing in and owning charging infrastructure or offering vehicle and charger rebates to customers. They can also pursue charging infrastructure make-ready investments for site hosts including workplaces, multifamily dwellings, public transit agencies and other fleets. Make-ready investments cover the cost to provide electric service from the grid up the meter, or up to the charging station, but not including the charging station itself.

Since October 2012, regulators have approved 42 electric utilities across 24 states and Washington D.C. to invest more than $1.3 billion in transportation electrification, according to the Atlas EV Hub. More than 80 percent of approved investment includes some focus on VGI programs or smart charging technology deployment. Pending investment for programs including smart charging technology or other VGI elements could bring in an additional $500 million to the transportation electrification sector and could support more than 50,000 Level 2 charging stations [5].

Electric utilities can also encourage EV adoption by highlighting the cost savings and other benefits associated with switching to electric. Education and outreach programs can also help ensure that consumers are aware of VGI programs and shift their charging to off-peak hours to improve overall grid performance. Although outreach programs managed by utilities cover many areas to accelerate EV adoption and charging infrastructure deployment, these programs are especially important for VGI generally, and for more advanced programs like V2G. Research has shown that investments in these programs now is likely required to accelerate the pace of EV adoption and participation in VGI programs and reduce challenges in the long term. [6]. Accordingly, there is a significant gap today between electric utility investment in charging infrastructure and customer education efforts, in part due to the occasional reluctance of regulatory commissions to approve such education and outreach investments. Of the $1.3 billion approved for investment by electric utilities in transportation electrification, less than five percent has been allocated for outreach efforts [5]. Figure 1 shows states where utilities have been approved to offer residential EV rates through September 2019, many of which have not invested in educational programs to support these programs.

FIGURE 1: RESIDENTIAL EV RATES AS OF SEPTEMBER 2019



This chart from the EV Hub shows the residential EV rates in place throughout the country.

Source: [5]

VGI Offers Significant Savings Potential

Independent reports estimate hundreds of millions of dollars in savings potentials for utilities that actively pursue VGI:

- EV drivers served by the two largest California utilities generated up to $584 million in revenue above costs between 2012 and 2018. Under a high participation scenario with 75 percent of EV drivers served by TOU rates, revenue still exceeded costs by $450 million. Only about 25 percent of drivers have adopted TOU rates [7].

- In Illinois, reports estimate an $856 million price tag on EV-related stress to the grid by 2030 if vehicles are charged during peak demand times. If regulations encouraging off-peak charging are implemented, stress is minimized and shared savings for both utilities and customers could reach upwards of $2.6 billion across the state by 2030 [8].

A REVIEW OF EXISTING PROGRAMS

Many VGI programs are still in the early stages and recent EV market growth has created urgency for electric utilities and regulators to ensure that more EVs benefit rather than strain the grid. It is also important that VGI programs are designed in a way that delivers benefits to consumers and aligns with the needs and expectations of individual drivers and fleet operators. In addition to proposing new programs and investment, electric utilities can leverage existing rate structures that promote off-peak demand to integrate a growing fleet of EVs. For example, Baltimore Gas and Electric (BGE) in Maryland developed new educational campaigns to highlight the fuel cost savings potential associated with off-peak charging to encourage more EV drivers to take advantage of existing TOU rates. BGE also harnesses their awareness campaigns to promote other offerings including rebates for residential smart charging technology [9].

Similar to the EV market overall, California is leading the way in VGI. A study from Synapse Energy Economics found that Pacific Gas and Electric (PG&E) and Southern California Edison (SCE) have already seen more than $580 million in EV-related revenue above costs between 2012 and 2018 [7]. Regulators have approved PG&E, SCE, and San Diego Gas & Electric to invest in V2G pilot programs exploring the potential uses of electric school buses as flexible energy storage and demand response resources. On August 15, 2019, SDG&E was approved to invest more than $109 million in electric buses and trucks. This approval includes a $1.7 million electric school bus V2G pilot. All of these utilities have also implemented EV TOU rates and other indirect methods to improve integration [5].

PG&E has taken an active approach to exploring the benefits of the utility's growing number of EVs in its territory. PG&E partnered with BMW in 2015 to implement the ChargeForward pilot program. Set to conclude in 2019, the pilot included both demand response and incentive elements by offering BMW drivers up to $900 to participate in the program in exchange for data sharing and flexible charging managed by the grid operators including the California Independent System Operator [10]. While limited in its scope, early success with this pilot and high participation has informed PG&E's wider VGI strategy and the accelerated deployment of smart charging technology to enable managed charging and provide direct benefits to consumers and fleet operators for participating in these programs. The program also includes second life use of EV batteries to provide stationary energy storage for the grid [11].

Ride-hail vehicles have also played a constructive role in California's VGI efforts. EVgo, which offers bundled charging for drivers who rent EVs from Maven Gig, General Motors' carshare service provider, has rapidly increased their fast charging services throughout the state. This partnership has generated more than 21 million electric miles driven since the beginning of 2017 [12]. Of the 75 million electric miles in total that EVgo reports for 2018, more than one third were accounted for by fleets covering rideshare, carshare, and delivery vehicles [13]. Reports from EVgo show that ride-hail drivers' use of charging stations in California is well-aligned to avoid curtailing solar energy generation [13].

Utilities and agencies outside California are also leading on VGI. In North Carolina, VGI is a core component of Duke Energy's $76 million plan to invest in a suite of transportation electrification pilot programs. One of the largest elements of this proposal is an $18.5 million pilot of school bus electrification that includes grants for both vehicles and utility-owned charging stations. A core focus of this pilot is to study the impacts of these buses on the grid and explore the possibilities of using the bus batteries as distributed energy resources through V2G technology. The utility will collect data on charging behavior from the bus owners and use this information to manage the bi-directional power flow between the grid and the bus. This allows the buses to operate as flexible resources for the grid, generating additional value to cover higher costs associated with the technology. Duke plans to recycle the batteries for second-life energy storage after they can no longer sufficiently power the vehicles [14].

In New York, Consolidated Edison manages the SmartCharge program for both residential and public fleet operators. At the residential level, Con Edison has partnered with companies like FleetCarma to provide rebates for customers charging during off-peak times as well as to collect data on the integration with the grid [15]. The New York Department of Citywide Administrative Services estimates that their participation in the program will generate $150,000 per year in reward revenue for the department [16].

Hawaii is seeking to enhance smart charging efforts to encourage electric transit bus adoption. The Hawaii Public Utilities Commission approved Hawaiian Electric's TOU charging rates for electric buses in March. The company hopes these incentives will help facilitate commitments from each of Hawaii's four counties to achieve 100 percent renewable public and private transportation by 2045. The utility is also exploring some demand response programs that will inform upcoming electric school bus pilots [17].

A BRIGHT FUTURE FOR VGI

As more VGI programs are deployed, more data will become available on how these efforts are influencing charging behavior and leading to utility and driver operational cost savings and lower electricity rates for all ratepayers [5]. Despite significant expansion in VGI programs, a robust market for grid integration where EV owners and fleet operators can generate revenue from services provided is unlikely to materialize in the near term [18]. Instead, VGI efforts will likely focus on improving the value proposition of switching to an EV through charging rebates or other incentives, or increased fuel cost savings through reduced rates like those offered by Con Edison in New York. Programs positioned to deliver benefits such as rebates or cost savings directly to consumers are likely to achieve higher participation and succeed in shifting EV loads to off-peak times.

Integrating indirect tools such as TOU rate design with direct VGI strategies such as V1G and V2G pilot programs will allow utilities to maximize customer benefits and can help better ensure that the expectations of drivers and fleet operators are met and that their transportation needs are not interrupted. Putting the vehicle user in control of charging is central to adoption of any VGI solution, such as the Honda SmartCharge program and the BMW ChargeForward program previously mentioned.

There may be opportunities to use savings from VGI rates to recover costs from public investments in DC fast charging infrastructure and the associated distribution infrastructure. New efforts like the VGI Working Group in California led by Gridworks are exploring the value potential of different strategies and actively engaging an array of public agencies and stakeholders in the space to determine the next steps for the extension of existing programs beyond the pilot phase [19].

Public investment in states like California is seeking to bring down the upfront cost of EVs and expand the pool of vehicles participating in VGI programs. Announcements in July 2019 from the California Energy Commission to invest $90 million in at least 200 electric school buses represent the largest public award to date for this technology and will be used to support existing V2G programs throughout the state [20]. The Commission also administers $130 million annually through the Electric Program Investment Charge (EPIC) Program which is generated from the rate base of the major California utilities and allocated to fill policy and funding gaps related to the development of new energy technologies [21].

Outside of California, utilities are also teaming up with public agencies to increase investment in VGI programs. In late August, Dominion Energy announced a new program to invest in more than 1,000 electric school buses through the eight states in their service territory over the next five years [22]. Shortly afterwards, Virginia's governor announced a complementary award of $20 million for electric school buses that will deploy buses outside of Dominion's territory and further V2G development in the state [23].

Utilities and public agencies in Michigan and New York are also working together on school bus electrification with a VGI focus. The Michigan Department of Environment, Great Lakes, and Energy recently announced $4.2 million for an electric school bus program, accelerating investments already made by DTE Energy to implement V2G pilots in the state [24]. In New York, the Con Edison and the New York State Energy Research and Development Authority are sharing the costs associated with a school bus V2G program that evaluate the benefits of this technology [25]. Overall, public funding for school buses has increased from less than $30 million to more than $150 million following announcements made since July 2019 [26].

Increased public and utility investment in these technologies is positioned to rapidly increase fleet size and could help to develop markets for bundled energy storage services. Over time, V2G pilot programs that harness vehicles to provide flexible demand response could be extended to include other types of EVs. Meanwhile, already commercialized V1G technology can deliver much of the same value, albeit to a somewhat lesser degree. Coordination of public and utility investment can maximize savings and ensure that the benefits of VGI serve both drivers and fleet operators as well as the general population through lower electricity rates.

REFERENCES

[1] State of California , "SB-676 Transportation electrification: electric vehicles: grid integration," February 2019. [Online]. Available: http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB676. [Accessed September 2019].

[2] American Honda Motor Co., Inc, "Honda SmartCharge™ Beta Program Helps Electric Vehicle Drivers Save Money and Reduce Environmental Footprint," Honda, 31 July 2018. [Online]. Available: https://hondanews.com/en-US/honda-automobiles/releases/release-6f25579543b44faa86f2530d9d8c003b-honda-smartcharge-beta-program-helps-electric-vehicle-drivers-save-money-and-reduce-environmental-footprint. [Accessed 01 October 2019].

[3] California Independent System Operator, "California Vehicle-Grid Integration (VGI) Roadmap," CAISO, Sacramento, 2014.

[4] P. MacDougall, "Smart EV Charging: What's in It for You?," September 2018. [Online]. Available: https://www.nrdc.org/experts/pamela-macdougall/smart-ev-charging-whats-it-you. [Accessed June 2019].

[5] Atlas EV Hub, "Utility Filings Dashboard," 2019. [Online]. Available: https://www.atlasevhub.com/materials/electric-utility-filings/. [Accessed June 2019].

[6] Rocky Mountain Institute, "Electric Vehicles as Distributed Energy Resources," 2017. [Online]. Available: https://rmi.org/insight/electric-vehicles-distributed-energy-resources. [Accessed 3 October 2019].

[7] Synapse Energy Economics , "Electric Vehicles Are Driving Electric Rates Down," June 2019. [Online]. Available: https://www.synapse-energy.com/sites/default/files/EV-Impacts-June-2019-18-122.pdf. [Accessed June 2019].

[8] Illinois Citizens Utility Board , "Charging Ahead," March 2019. [Online]. Available: https://www.citizensutilityboard.org/wp-content/uploads/2019/03/Charging-Ahead-Deriving-Value-from-Electric-Vehicles-for-All-Electricity-Customers-v6-031419.pdf. [Accessed June 2019].

[9] Baltimore Gas and Electric Company , "EV Savings & Benefits," Exelon , July 2019 . [Online]. Available: https://www.bge.com/SmartEnergy/InnovationTechnology/Pages/EV-Savings-Benefits.aspx. [Accessed July 2019].

[10] BMW, "BMW CHARGEFORWARD," 2019. [Online]. Available: https://www.bmwchargeforward.com/#/home. [Accessed June 2019].

[11] Pacific Gas and Electric Company , "BMW i ChargeForward: PG&E’s Electric Vehicle Smart Charging Pilot," PG&E, San Francisco , 2017.

[12] Atlas Public Policy, "Electrifying Ride-Hail Services," September 2018. [Online]. Available: http://evsharedmobility.org/wp-content/uploads/2018/09/Electrifying_Ride-Hail_Services.pdf. [Accessed June 2019].

[13] J. Pyper, "Electric Ridesharing Benefits the Grid, and EVgo Has the Data to Prove It," May 2019. [Online]. Available: https://www.greentechmedia.com/articles/read/electric-ridesharing-benefit-the-grid-evgo#gs.h1btlq. [Accessed June 2019].

[14] Duke Energy , "Duke Energy proposes $76M electric transportation program in North Carolina; Southeast’s largest utility EV initiative yet," April 2019. [Online]. Available: https://news.duke-energy.com/releases/duke-energy-proposes-76m-electric-transportation-program-in-north-carolina-southeasts-largest-utility-ev-initiative-yet. [Accessed June 2019].

[15] New York Public Service Commission, "Con Edison SmartCharge Program Expanded to Encourage Use of Electric Cars," September 2018. [Online]. Available: http://www3.dps.ny.gov/pscweb/WebFileRoom.nsf/ArticlesByCategory/EE441432E57A31D78525830600558404/$File/pr18076.pdf?OpenElement. [Accessed June 2019].

[16] New York Department of Citywide Administrative Services , "Overnight NYC Vehicle Charging Saves Taxpayer Money and Reduces Stress on the Electrical Grid," 2018. [Online]. Available: http://www.nyc.gov/html/dcas/downloads/pdf/misc/smartcharge.pdf. [Accessed June 2019].

[17] Hawaiian Electric , "PUC approves special rates for electric buses," March 2019. [Online]. Available: https://www.hawaiianelectric.com/documents/about_us/news/2019/20190321_puc_approves_hawaiian_electric_companies_special_rates_for_electric_buses.pdf. [Accessed June 2019].

[18] P. MacDougall, "EVs Can Do More Than Just Drive, They Can Help the Grid Too," June 2018. [Online]. Available: https://www.nrdc.org/experts/pamela-macdougall/evs-can-do-more-just-drive-they-can-help-grid-too. [Accessed June 2019].

[19] California Public Utilities Commission, "DRIVE OIR Vehicle-Grid Integration Working Group," September 2019. [Online]. Available: https://www.cpuc.ca.gov/vgi/. [Accessed September 2019].

[20] P. Dzikiy, "California replacing 200 polluting diesel school buses with all-electric buses," July 2019. [Online]. Available: https://electrek.co/2019/07/17/california-electric-school-buses/. [Accessed July 2019].

[21] California Energy Commission, "Electric Program Investment Charge Program," October 2019. [Online]. Available: https://ww2.energy.ca.gov/research/epic/faq.html.

[22] Dominion Energy, "Electric School Buses," Dominion Energy , August 2019. [Online]. Available: https://www.dominionenergy.com/ourpromise/innovation/electric-school-buses. [Accessed August 2019].

[23] Office of Governor Ralph Northam, "Governor Northam Announces $20 Million Electric School Bus Initiative," 24 Septemeber 2019. [Online]. Available: https://www.governor.virginia.gov/newsroom/all-releases/2019/september/headline-847559-en.html. [Accessed October 2019].

[24] Lion Electric, "The Lion Electric Co. to Deliver Michigan's First 11 Electric School Buses as Part of the Volkswagen Mitigation Settlement," 12 September 2019. [Online]. Available: https://www.prnewswire.com/news-releases/the-lion-electric-co-to-deliver-michigans-first-11-electric-school-buses-as-part-of-the-volkswagen-mitigation-settlement-300917333.html. [Accessed October 2019].

[25] K. Cluckey, "New York Electric School Buses to Feed Power Grid," 25 September 2019. [Online]. Available: https://news.bloombergenvironment.com/environment-and-energy/new-york-electric-school-buses-to-feed-power-grid. [Accessed October 2019].

[26] Atlas Public Policy, "Public Funding Awards Dashboard," October 2019. [Online]. Available: https://www.atlasevhub.com/materials/public-agency-requests-funding-awards/. [Accessed October 2019].

ATLAS
PUBLIC POLICY

WWW.ATLASPOLICY.COM