Smart Electric Power Alliance

The State of Bidirectional Charging in 2023

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The State of Bidirectional Charging in 2023

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Authors

Brittany Blair, Senior Analyst—Research & Industry Strategy, Smart Electric Power Alliance

Drake Moran, Analyst—Research & Industry Strategy, Smart Electric Power Alliance

Garrett Fitzgerald, Senior Director—Electrification, Smart Electric Power Alliance

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The Smart Electric Power Alliance (SEPA) is dedicated to helping electric power stakeholders address the most pressing issues they encounter as they pursue the transition to a clean and modern electric future and a carbon-free energy system by 2050. We are a trusted partner providing education, research, standards, and collaboration to help utilities, electric customers, and other industry players across three pathways: Electrification, Grid Integration, Regulatory and Business Innovation. Through educational activities, working groups, peer-to-peer engagements and advisory services, SEPA convenes interested parties to facilitate information exchange and knowledge transfer to offer the highest value for our members and partner organizations. For more information, visit www.sepapower.org.

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About This Report

This report is a continuation of SEPA's State of Managed Charging Series and provides an overview of major developments in North America's bidirectional charging landscape. SEPA's "A Comprehensive Guide to Electric Vehicle Managed Charging" and "State of Managed Charging in 2021" provide context on the managed charging space.

SEPA has published complementary reports on these subjects including: "Managed Charging Programs: Maximizing Customer Satisfaction and Grid Benefits" and "Managed Charging Incentive Design: Guide to Utility Program Development." These reports provide detailed reviews of managed charging incentives, program design best practices, key insights and lessons learned from existing programs, and recommendations for incentive structures and program recruitment.

Table 1. Report Overview

Section	What Is in This Section
Chapter 1: Introduction	Provides an overview of the market opportunity of bidirectional charging and an introduction to different bidirectional charging use cases. Highlights the relationship between managed and bidirectional charging.
Chapter 2: Utility Perspectives on Bidirectional Charging	Provides an overview of SEPA's utility interview series and highlights utility perspectives on bidirectional charging.
Chapter 3: Manufacturer and Non-Utility Perspectives on Technology and Interconnection Considerations	Highlights insights from manufacturers, software service providers, nonprofits, and project implementation companies. This chapter focuses on technology and interconnection considerations associated with bidirectional charging.
Chapter 4: Opportunities for Wide-scale Adoption	Highlights major opportunities for industry stakeholders to expand their relationships with customers, to establish the value of bidirectional charging, and to support policy and regulatory changes.
Conclusion: Bidirectional Charging—A Valuable Resource for Grids and Customers	Summarizes the report's major findings and provides a future outlook for bidirectional charging.
Appendix: Bidirectional Charging Technology and Vendors	Provides a landscape review of vehicle OEMs, EVSE manufacturers, software service providers, and project implementation companies.

Source: SEPA. (2023).

Table 2. Bidirectional Charging Projects and Programs	
Customer Projects	
Customer & Location	**Type of Bidirectional Charging Project & Incentive Type**
North Boulder Recreation Center (Colorado)	Commercial V2B with Peak Demand Savings
Plymouth State University (New Hampshire)	Commercial V2B with a Transactive Energy Rate
Revel Rideshare (New York)	Commercial Fleet V2G with Demand Response Rate
Utility Programs	
Utility & Location	**Type of Bidirectional Charging Program**
Dominion Energy (Virginia)	Electric School Bus Fleet V2G
National Grid (Massachusetts)	V1G/V2G Demand Response
Pacific Gas & Electric (California)	V2X Pilots

Source: SEPA. (2023).

Chapter 1: Introduction

The Opportunity for Bidirectional Charging

Bidirectional charging has significant potential in transforming how consumers view and use their electric vehicles (EVs). Bidirectional charging allows EVs to become a flexible resource for power systems. At high rates of adoption, EVs can have significant impacts on coincident-system and feeder-level peaks. To mitigate these load impacts, utilities and EV charging site hosts often utilize a variety of managed charging solutions to optimize EV charging. As part of the continuum of managed charging solutions, bidirectional charging creates an opportunity for EVs to be used as an energy resource and to discharge back to the grid. Bidirectional charging's ability to act as both a flexible load and an energy resource creates new revenue and grid services value streams for customers and utilities alike.

From a grid point-of-view, EV batteries are mobile storage assets that can be used in a similar manner to stationary batteries. Grid-tied, bidirectional-capable EVs can support peak shaving, store renewable generation, provide ancillary services (such as voltage support, ramping support, and distribution congestion), and act as resilience assets.[1] In particular, vehicle original equipment manufacturers (OEMs) have marketed the resilience benefits of using EVs as backup generation, increasing customer awareness of bidirectional charging.

The scale at which bidirectional-capable EVs can participate in grid services is a significant benefit for grid operators. With a sales-weighted average battery size of 60 kilowatt-hours (kWh) for light-duty EVs,[2] the United States' (U.S.) 2.1 million battery electric vehicles (BEVs) represent approximately 126 Gigawatt-hours (GWh) in storage capacity.[3] This amount of battery storage represents five times the amount of stationary battery storage currently on the grid (25 GWh in 2023).[4] While few of these vehicles have bidirectional charging capabilities today, this amount of storage provides a largely untapped resource for power systems.

The bidirectional charging industry is in the early stages of transitioning to a commercial product ready for mass-market adoption. At this time, challenges and barriers to implementing bidirectional charging at scale remain.

This report:

- Provides an overview of the current state of the bidirectional charging industry in the U.S.
- Highlights perspectives from electric utilities, vehicle OEMs, charger manufacturers, software providers, and project implementation providers
- Explores existing bidirectional charging deployments
- Explains the opportunities and barriers that exist to wide-scale adoption of bidirectional charging

Bidirectional Charging Context within Managed Charging

Managed charging is an umbrella term for the implementation of any passive or active strategy that optimizes EV charging. Managed charging can include:

- Charging a vehicle outside of a utility's peak times
- Dynamically charging the vehicle in response to market signals
- Scheduling EV charging to coincide with periods of high renewable energy supply
- Reducing EV charging rates to limit load congestion at site and feeder levels
- Pausing and/or reducing EV charging to reduce a site's or feeder's peak demand
- Creating efficient charging schedules for fleets
- Using bidirectional charging to support customer and grid needs

Bidirectional charging is a sub application of managed charging and has greatly benefited from the adoption of

1 Fitzgerald, Garrett, James Mandel, Jesse Morris, and Hervé Touati. (2015). The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid.

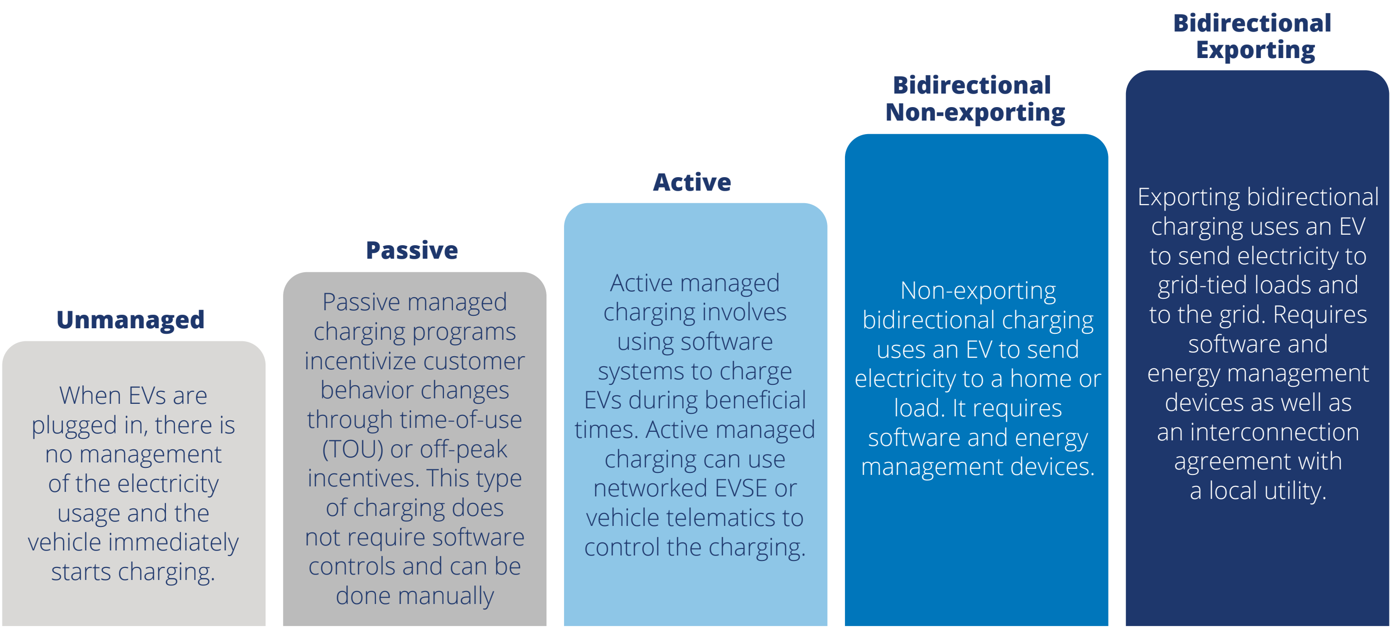
2 IEA. (2023). Global EV Outlook 2023: Catching up with Climate Ambitions.

3 IEA. (2023). Global EV Data Explorer.

4 American Clean Power. (Q4 2022). Clean Power Quarterly Market Report: Q4 2022.

managed charging by utilities, fleet operators, residential customers, and others. Advanced managed charging capabilities often require communication among multiple parties (including utilities, vendors, aggregators, and customers) and may require advanced software systems and smart devices. As utilities and customers have become more familiar with implementing managed charging solutions, it has become easier for them to see bidirectional charging as the next iteration of their managed charging solutions (Figure 1). SEPA's State of Managed Charging in 2021 report provides more detail on managed charging.

Figure 1. The Stages of Managed Charging

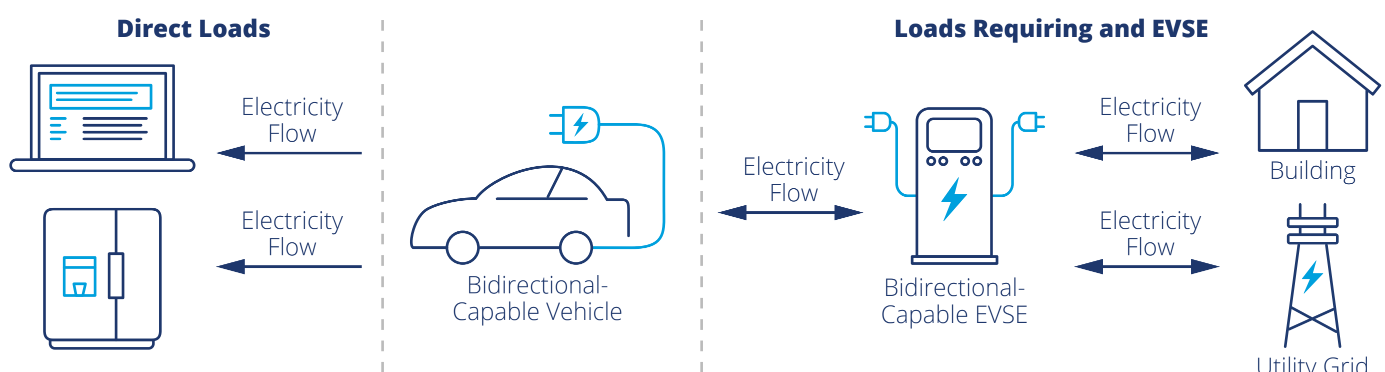


Source: ev.energy. (2023). The 5 Stages of Managed Charging. Adapted by SEPA.

Types of Bidirectional Charging

Bidirectional charging at a minimum requires a bidirectional vehicle and a bidirectional EVSE to discharge (Figure 2). Bidirectional charging systems also require software to communicate among these devices and to interact with utilities and aggregator providers. The bidirectional charging configuration is an important aspect to the types of use cases the system can support.

Figure 2. Illustration of a Bidirectional Charging System



Source: SEPA. (2023).

Bidirectional charging encompasses different types of use cases, usually under the term vehicle-to-everything (V2X). Depending on the stakeholder group, bidirectional charging can be synonymous with V2X. This report will use bidirectional charging as the main term for the technology and use V2X in reference to specific programs and use cases. V2X includes subcategories of unique use cases:

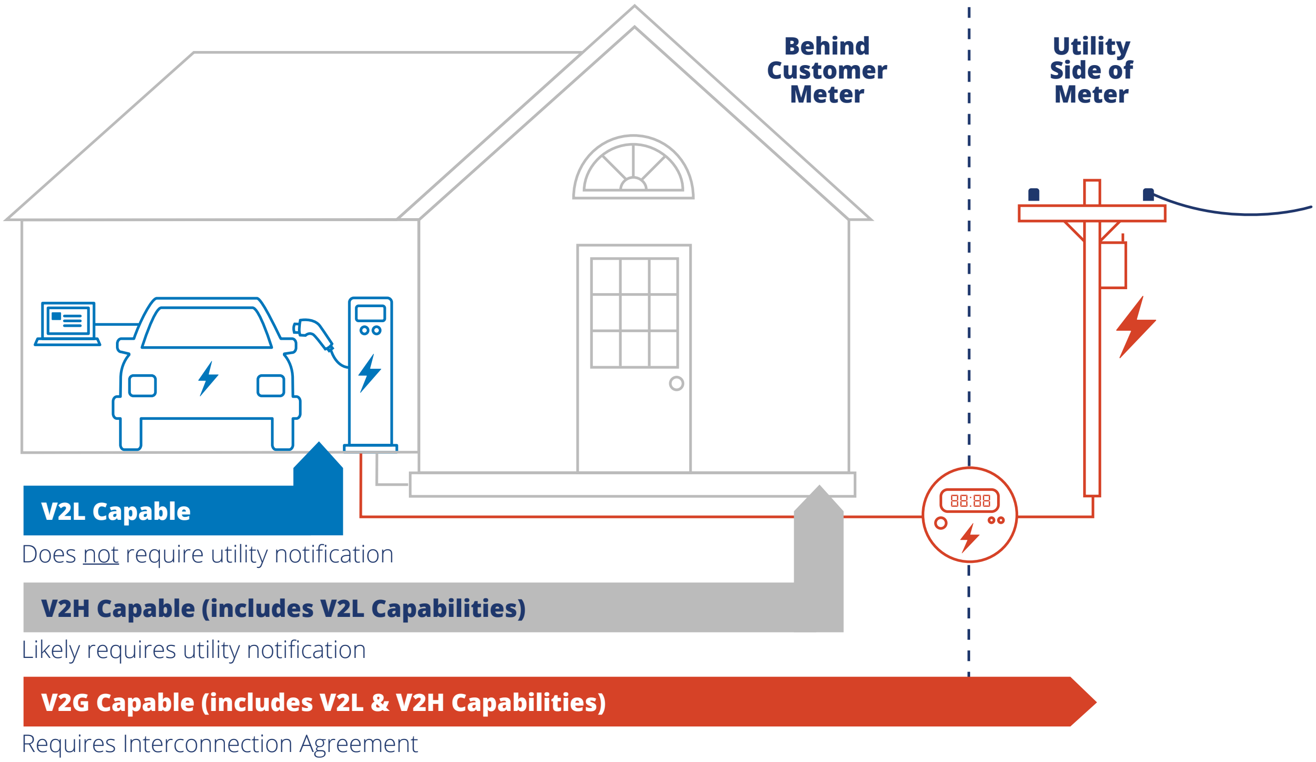
1. **Vehicle-to-Grid (V2G):** V2G is different from other V2X functionalities because it involves any grid-tied discharge from an EV battery in parallel to grid operations, whether to a building, home, or microgrid. Grid-tied discharge requires utility approval and interconnection studies and agreements. V2G supports grid services, including providing grid capacity, energy arbitrage, localized voltage support, frequency regulation, and other ancillary services. Individual vehicles can be aggregated and used in virtual power plants (VPPs) to provide these grid services.
2. **Vehicle-to-Microgrid (V2M):** V2M is a resilience application of bidirectional charging that focuses on supplying backup power to a microgrid (for example, a utility substation, a college campus, a military base, a community center, or an evacuation center). V2M applications typically need a microgrid controller and involve sending power to more than one building. EVs have additional benefits because they are mobile battery systems and have the potential to move between microgrid sites and become flexible resilience assets.
3. **Vehicle-to-Home/Building (V2H/V2B):** V2H/V2B uses an EV to provide supplementary power to a building while connected to or disconnected from the grid. V2H/V2B is a behind-the-meter application that saves customers money by reducing the customer's peak demand from the utility and/or is used to provide backup power to a building during blackouts. V2H/V2B is non-exporting (does not send power back to the grid) and in some use cases only operates when isolated from the grid (such as backup power). While V2H/V2B use cases are non-exporting, many utilities will require customers to have an interconnection agreement for the system. V2M can be considered a variation of backup V2H/V2B, where the bidirectional charging system discharges to more than one building. In both V2H/V2B and V2M use cases, the buildings may also be receiving electricity from solar and/or stationary battery systems.
4. **Vehicle-to-Load (V2L):** V2L uses the EV battery to charge or power small, external or auxiliary loads, including construction tools, home appliances, or remote locations such as campsites. Vehicle OEMs often market V2L for resilience, in the case of weather events that cause grid blackouts, and ease-of-use, in the case of off-grid electricity usage.
5. **Vehicle-to-Vehicle (V2V):** V2V uses one EV's battery to charge another EV. Fleet managers are interested in this capability, for example, providing back-up rescue and optimizing fleet usage when away from EV charging infrastructure. V2V has mass-market applications for multi-car households to charge a smaller vehicle with the larger one as needed, and in the case of grid outages. To date, V2V has been marketed to fleets rather than for mass-market adoption.

As a baseline for all V2X use cases, customers need a vehicle that is capable of bidirectional charging. V2X use cases depend on the configuration of the bidirectional charging system and the customer upgrades needed to move from one V2X use case to the next (Figure 3).

- With the lowest level of complexity, V2L and V2V use cases are available to all customers with bidirectional-capable vehicles that have the appropriate hardware and/or software updates. Some vehicles' batteries and control systems are not equipped with the right hardware for electricity discharge. In the case of other vehicles, bidirectional charging capability is limited by software protocols, rather than hardware constraints, and may require a one-time fee to unlock the capabilities.
- V2H/V2B requires customers to have bidirectional electric vehicle supply equipment (EVSE). Installing this type of EVSE may also require the customer to upgrade their home/building panel.
- V2G requires customers to install a fully V2G-configured system, which will have additional requirements from the local utility.
- For V2H, V2B, and V2G applications, customers will need an interconnection agreement from their utility, similar to when customers install rooftop solar or battery storage systems.

The more sophisticated use cases often include capabilities for the less sophisticated use cases; V2G-configured systems often provide V2G, V2H/V2B, V2V, and V2L capabilities, while V2L configured systems can only provide V2L.

Figure 3. Overlay of V2X Configurations



Source: SEPA. (2023).

Chapter 2: Utility Perspectives on Bidirectional Charging

As the industry navigates the initial stage of bidirectional charging, each stakeholder group is assessing their respective positions. This chapter and Chapter 3 highlight perspectives from utilities, vehicle OEMs, EVSE vendors, software providers, and other industry stakeholders.

SEPA conducted a utility interview series in Q2 2023 to gain information about utility-run bidirectional charging deployments, projects, and programs. This included interviews with 37 utility subject matter experts (SMEs) spread across 25 states and territories.[5] Utility SMEs included those from 20 investor-owned utilities (IOUs), seven cooperative utilities (co-ops), seven municipal utilities (munis), two public utility districts (PUDs), and one generation and transmission company (G&T). SEPA asked utilities a series of questions on their active managed charging programs and their plans for bidirectional charging, including whether they had piloted the technology, barriers to initiating and scaling V2X programs, and what types of customer segments were of immediate interest to them.[6] Table 3 highlights the insights from the utility SMEs.

5 Ameren, Austin Energy, Baltimore Gas & Electric, Bartholomew County REMC, Belmont Light, ComEd, Concord Municipal Light Board, ConEd, Consumers, El Paso Electric, Evergy, Exelon, Heber Light & Power, Holy Cross, Hoosier, La Plata Electric Association, Los Angeles Department of Water and Power (LADWP), Littleton Electric Light and Water, Memphis Light, Gas, and Water, National Grid, NIPSCO, Nova Scotia Power, Oklahoma Gas & Electric, Orlando Utilities Commission, Pacific Gas & Electric, Pasadena Department of Water and Power, Plumas-Sierra Rural Electric Cooperative, Portland General, PSEG, Public Service Company of New Mexico, Puget Sound, Seattle City Light, Snohomish County PUD, Southern California Edison, Southern Company, TRICO, and United Power.

6 Note, views expressed by the utility respondents are uniquely theirs and not necessarily reflective of their utility's stance on these topics. Additionally, survey results are only indicative of this specific survey group and may not be reflective of utility trends and opinions throughout the U.S.

Table 3. Summary of Utility SME Perspectives on Bidirectional Charging	
Chapter Section	**About This Section**
Utilities, Customers, and the Value of Bidirectional Charging	This section includes discussions on programmatic considerations utilities will address in a bidirectional charging program. Considerations include: the types of customers in the program, interconnection processes, and the value of V2X applications for utilities and the grid.
Outlook on Utility Development of Bidirectional Charging Programs	This section includes an outlook on utilities' progress in deploying bidirectional charging projects and programs and utility perspectives regarding cases for deploying these programs.
Barriers to Utility Program Development and Adoption	This section includes an outlook on the barriers that utilities are facing when implementing and scaling bidirectional charging programs. This section includes regulatory insights and utility perspectives on where the industry should focus.

Source: SEPA. (2023).

Utilities, Customers, and the Value of Bidirectional Charging

Utilities serve a variety of customer segments, all of whom will have different motivations for adopting bidirectional charging systems. Typically utilities categorize customers as residential, commercial, or industrial. However, the utility SMEs recognized that there were more specific customer bases beyond these three and identified the following as important customer segments for a utility bidirectional charging program:

- **Residential**—Residential customers include those that live in either single- or multi-family homes and likely use light-duty vehicles.
- **Commercial**—Commercial customers include fleet operators, industrial customers, and commercial customers. These customers are typically looking to implement bidirectional charging for their business's range of light-, medium-, and heavy-duty vehicles.
- **School Districts**—School Districts are of interest to utilities due to established V2X projects with school buses. When utilities talk about school districts, they are including school districts that own their buses and those that use third-parties to own and manage the school bus fleet.
- **Transit Agencies**—Public transit agencies often use medium- and heavy-vehicles with specific schedules, and have funding available for multi-vehicle projects.
- **Workplace**—While workplace charging can occur at commercial and industrial businesses, workplace applications differ from commercial applications. Utilities characterize these customers as those seeking to implement chargers that will be available to their employees to charge their personal vehicles during work hours.
- **Public**—Public charging includes short-term and long-term parking at publicly available chargers. Publicly available chargers can be located in places such as shopping plaza parking lots, commuter parking lots, airports, street parking spots, and many others.

Target Customers

As part of the interview series, SEPA asked the utility SMEs which of these customer segments they would target for a utility program in the short- and medium-terms (Figure 4). School districts were a popular answer among the utility SMEs, in part due to established demonstration projects and federal and non-profit support.

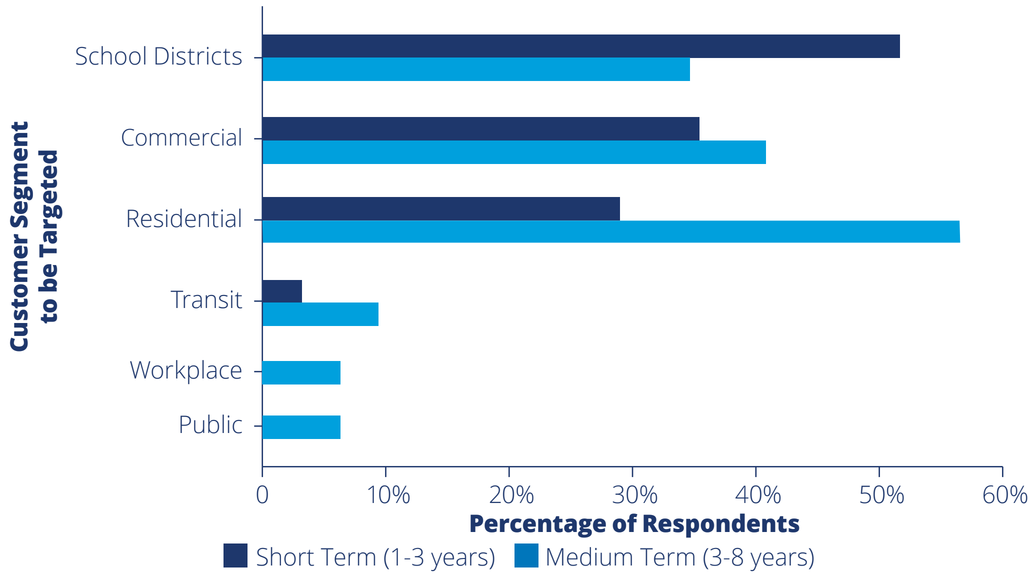
Bidirectional charging projects with electric school buses show clear value to the grid and to customers (See the National Grid and Dominion Energy Case Studies). Established and effective demonstration projects are essential to wide-scale adoption. Utilities often look to existing projects before establishing their own bidirectional charging projects (See Barriers to Utility Program Development and Adoption).

School districts and school bus fleet operators have become more aware of bidirectional charging due to federal funding for electric school buses[7] and non-profit education materials on bidirectional charging trends.[8] Many of the interviewed utility SMEs indicated that school districts in their territories were interested in bidirectional charging use cases, and in a few territories, had already begun ordering bidirectional-capable vehicles and EVSE.

7 Environmental Protection Agency. (2023). Clean School Bus Program.

8 World Resource Institute. (2022). 3 Design Considerations for Electric School Bus Vehicle-to-Grid Programs.

Figure 4. Utility Interest in Different Customer Segments for Bidirectional Charging Applications



Source: SEPA. (2023). n=37. Note: Utilities selected all that applied.

Commercial fleets and residential applications were another popular choice, with the utility SMEs favoring targeting commercial customers in the short-term and residential customers in the medium-term for a bidirectional charging program. Commercial fleets have predictable schedules and provide great potential for reducing a site's load through V2B applications. They often have fleet managers that can oversee and manage the bidirectional charging. Commercial customers usually have demand charges, and load reduction through V2B applications is financially attractive to these customers (See the North Boulder Recreation Center Case Study). Additionally, some utilities indicated that their demand response and other managed charging programs are more geared towards commercial customers (either due to a higher prevalence of commercial customers in their territories or due to limited ability to interact with residential customer devices)[9] and it would be easier for them to target commercial customers.

The utility SMEs indicated that residential uptake of bidirectional charging systems is still fairly low in their territories and that it would take some time for interest to increase enough to offer a residential utility program. While there have been a few bidirectional charging system installations in these utility territories, several utility SMEs stated that they are working on creating an interconnection process and have the bidirectional charging systems on standby for grid-tied use cases. At this point, these systems can only perform islanded (grid-isolated) operations. Additionally, several of the utility SMEs stated that they would not promote a residential bidirectional charging program until there were several residential chargers on the market so that they were not favoring one brand or model.

Utility SMEs were interested in the remaining three customer segments (transit, workplace, and public) more in the medium-term than short-term. They indicated that these applications were more nascent than the others and had fewer proven projects than commercial, residential, and school applications. The utility SMEs shared additional challenges these applications present:

- **Transit vehicles are often used throughout the day** and are less likely to be available for peak shaving and grid-tied use cases.
- **Public charging is often short and unpredictable.** V2X use cases encourage long dwell times to account for vehicle charging and discharging.
- **Workplace charging will often depend on business hours.** Many workplaces are open 9 am to 5 pm and employees may not be using the workplace charger during peak times or may not want to discharge their battery before leaving work.

9 Utility SMEs indicated that there are regulatory and/or technology barriers that prevent some of them from using residential devices in a utility program.

- **Public and workplace charging are more randomized to EVs in circulation.** Whereas customers applying for a residential or commercial program already have bidirectional charging vehicles, the same cannot be said for public and workplace charging. These use cases rely on mass-market adoption of bidirectional-capable vehicles.

These factors make it harder for a utility to predict if a vehicle will be available for a discharging event. However, some of the utility SMEs stated that long-term public parking, such as that for airports, sports stadiums, and park-and-rides, has sufficient dwelling time to allow for discharging and may provide an avenue for public bidirectional charging applications. These use cases may become more viable in the future as the bidirectional charging industry develops.

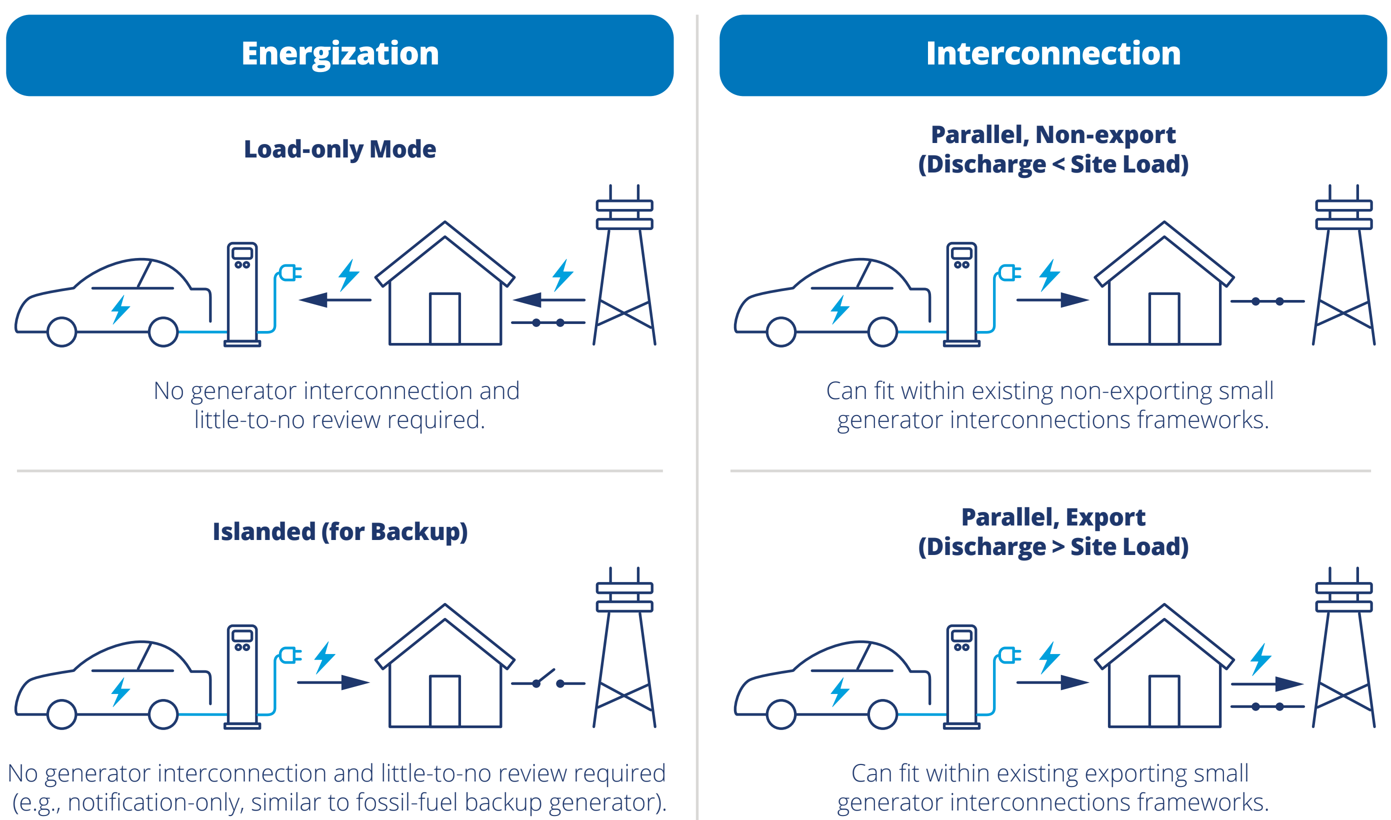
Customer Interconnection Considerations

Customer participation in a utility bidirectional charging program will depend on the configuration of their bidirectional charging system. Different bidirectional charging types have implications for the charging system's configuration and ultimately the system's interaction with the grid (Figure 5). Utilities often characterize grid-tied assets as either "energized" or "interconnected." Energized assets are those that only receive electricity from the grid (such as unidirectional EV charging), whereas, interconnected assets are those that have the ability to discharge to the grid (such as rooftop solar and stationary battery storage). Resources that discharge to the grid must undergo an interconnection process and obtain an interconnection agreement from the local utility.

Depending on the configuration of the bidirectional charging system, some systems will be considered energized, while others will be interconnected (Table 4). From a utility standpoint, V2L, V2V, V2M, and islanded V2H/V2B are all considered energization because they are not sending electricity to grid-connected loads. These types of systems have the same impact on the grid as unidirectional (also known as V1G) charging systems.

V2G sends electricity directly to the grid and always needs an interconnection agreement. Grid-tied V2H/V2B will also need an interconnection agreement because these systems send electricity to a home or building, which

Figure 5. Common V2X Bidirectional Charging System Configurations



Source: Vehicle Grid Integration Council. (2022). V2X Bidirectional Charging Systems Best Practices for Service Connection or Interconnection. Recreated by SEPA.

Table 4. Summary of Energized vs Interconnected Bidirectional Charging Systems

Category	Types of Bidirectional Charging Configurations
Interconnected	▪ V2G ▪ Grid-tied V2H, V2B, V2M
Energized	▪ Backup / Islanded V2H, V2B, V2M ▪ V2L ▪ V2V

Source: SEPA. (2023).

are interconnected to the grid. In this case, while the bidirectional charging system is not designed to send electricity to the grid, there is still a utility safety concern because there is a bidirectional power flow occurring, which can have impacts on the utility system.

Utility Target Applications for Bidirectional Charging Programs

Utilities can utilize customer's bidirectional charging systems in a variety of applications. SEPA asked the utility SMEs what types of bidirectional charging applications they were interested in pursuing. The responses fell into six broad application categories (Table 5).

The utility SMEs indicated that peak shaving and grid export were the most popular bidirectional charging applications (Figure 6). They stated that peak shaving and grid export applications have significant economic benefits due to the cost savings from peak shaving. Peak shaving and grid export applications also alleviate distribution congestion, and provide the ability to defer infrastructure upgrades. One utility SME indicated that because of their location in a small territory, they have limited ability to install new peak generation units, and solutions that can reduce their system peak are great for their operations. Many utility SMEs stated that cost reduction and reliability improvement through discharging to the grid are primary motivations for their interest in bidirectional charging.

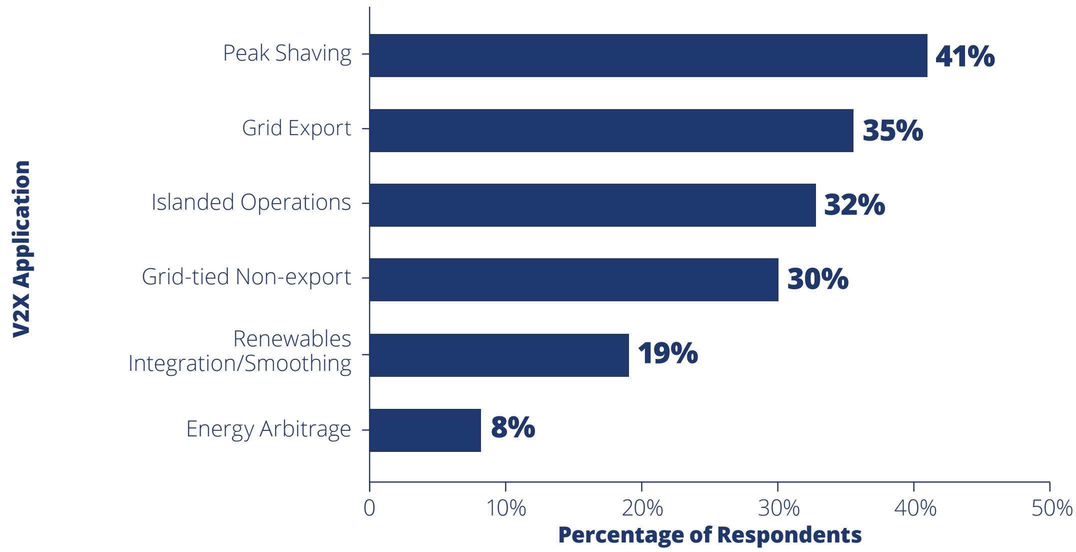
Islanded operations (backup generation and microgrids) was also a popular application. Much of the utility interest in this application was related to their customers' need for more resilience options. Whole-home backup for grid outages and extreme weather events is a growing motivation for customers adopting bidirectional charging systems. However, resilience was only a primary motivator for utilities in territories that experience extreme weather events (such as hurricanes, wildfires, and ice storms) that cause widespread grid outages. For utilities in areas with high levels of reliability, backup generation was a less popular application.

Table 5. Categories of Bidirectional Charging Applications

Application	Description
Peak Shaving	Peak shaving is the process of reducing peak load. Peak load reduction can be done for system-wide peaks, distribution-level, and/or a customer's site level. V2H, V2B, and V2G configured bidirectional charging systems can conduct peak shaving at the customer-site level, and V2G can contribute to peak shaving at the distribution- and system-wide levels.
Grid Export	Grid export is also known as parallel export (Figure 5, part d). Grid export includes using a bidirectional charging system for V2G, ancillary services, and distribution congestion relief. Grid export is grid-tied and requires utility notice and an interconnection agreement.
Grid-tied Non-export	Grid-tied non-export is also known as parallel, non-export (Figure 5, part c). Grid-tied non-export includes V2H and V2B applications where the charging system discharges to meet only site load. While grid-tied non-export should not be discharging to the grid, this application often requires utility notice and an interconnection agreement.
Islanded Operations	Island operations are also known as non-parallel, islanded operations (Figure 5, part b). Islanded operations occur when the customer site is no longer connected to the grid, usually due to grid outages or scheduled disconnection. Islanded operations are V2B, V2H, and V2M applications that often include backup generation during grid outages.
Renewables Integration	Renewables integration often involves pairing renewable generation such as solar and wind with EV charging. By pairing EV charging with renewable and carbon-free electricity and discharging that storage during peak events, utility systems can better orchestrate and improve the use of intermittent renewable generation on their system.
Energy Arbitrage	Energy arbitrage is the ability to charge and discharge a battery based on market signals.

Source: SEPA. (2023).

Figure 6. Utility Interest in Different Types of Bidirectional Charging Applications



Source: SEPA. (2023). n-37. Note: Utilities selected all that applied.

Utility Program Design—Managed Charging's Influence on Bidirectional Charging

In the case of managed charging programs, utilities interact with customers by offering incentives for changing charging habits (such as charging during the night instead of during peak times). Common managed charging programs and their incentives include:

- **Rebate programs** that cover the cost of the charger and/or a portion of a customer's panel upgrades. Utilities often require customers receiving the rebate to register their EV in a demand response, time-of-use (TOU) program, or other type of managed charging program.
- **Whole-home and EV-specific TOU programs** that incentivize customers to charge during non-peak times.
- **Demand response programs** that incentivize customers to participate in demand response events and often have requirements for customers to participate in a minimum number of events during the peak season.

Utilities structure these programs to reflect the value that the EV resources provide the grid and to compensate customers for that value. Utilities identify that value through these steps:

1. Determine the service they want EVs to provide and determine if other resources currently provide that same service. For example, if a utility wants an EV to discharge to the grid during peak times through a demand response program, the utility would examine how other resources (such as stationary batteries) are valued in that program.
2. Evaluate to what extent EV participation would provide the same service as other resources and if the EV participation has the same degree of reliability and performance.
3. Apply the existing or modified compensation mechanism to the managed charging program where applicable.

Utilities are in the process of determining how they want to use EV discharging for provision of grid services and how EVs compare to other resources. There currently are few examples of utilities compensating customers for discharging their EVs. Utilities are in the early stages of determining how to compensate customers for participating in bidirectional charging programs (Table 6).

Table 6. Existing Utility Mechanisms for Compensating Bidirectional Charging

Utility	Program Description and Incentive Structure
Consolidated Edison (ConEd)	ConEd has approved bidirectional-capable systems to interconnect to their grid through a variation of their stationary storage interconnection process. Customers can participate in ConEd's Value of Distributed Energy Resources (VDER) tariff that compensates customers through different value streams, including demand reduction, capacity participation, location system relief, and others. (See Revel Case Study).
National Grid and Eversource	Through National Grid[10] and Eversource's[11] ConnectedSolutions demand response programs, customers can be compensated for their EV discharge during demand response events. Customers are compensated for the average amount of kilowatt hours (kWh) they discharge to the grid over the event period. (See National Grid Case Study).
Pacific Gas & Electric (PG&E)	PG&E is implementing three customer pilots: V2X Residential, V2X Commercial, and V2X Microgrids. Customers receive an upfront incentive and additional incentives for participating in the program. The program also provides additional incentives for customers in Disadvantaged Communities. (See PG&E Case Study).
Dominion Energy Virginia	Dominion Energy provides funds to schools to offset the additional costs of purchasing an electric school bus over a diesel one (including charging infrastructure costs) and provides extra assistance for schools to navigate installing the systems. The program requires that the buses and charging equipment be V2G-capable and to give Dominion Energy Virginia the V2G rights and ownership of the bus batteries after 15 years.[12] (See Dominion Energy Virginia Case Study).
Duke Energy	Duke Energy is piloting a V2G customer program with 100 customers leasing Ford F-150 Lightnings.[13] The financial incentive is structured to reduce lease payments for program participants. Through the program, Duke Energy uses the customer's vehicles three times per month during peak winter and summer months and one time during each of the remaining months of the year.
Xcel Energy	Commercial customers in Xcel's Colorado territories have demand charges that can be reduced through on-site peak demand reduction. Customers can use V2B-configured systems to reduce their peak demand and generate monthly savings (See North Boulder Recreation Center Case Study).
New Hampshire Electric Co-op (NHEC)	NHEC has a transactive energy rate that allows customers to conduct energy arbitrage using day-ahead price signals. Customers can participate in the program with bidirectional charging systems. (See Plymouth State University Case Study).

Source: SEPA. (2023).

Utility Perspectives on Customer Participation

Customer adoption of bidirectional charging systems is a prerequisite to them participating in a utility program. During the interviews, the utility SMEs were asked to identify what types of barriers they believe customers experience when adopting bidirectional charging systems (See Chapter 4 for more on customer perspectives). The majority of utility SMEs (57%) indicated that they viewed lack of education as the most significant barrier to customer adoption (Figure 7). Customer education involves informing consumers on topics including:

- Battery degradation from battery cycling
- Implications of bidirectional charging on battery warranties
- Types of bidirectional charging use cases and their monetary, resilience, and noneconomic benefits to the customer

"In their everyday lives, people are deciding on whether to spend more money or not, the dollars and cents are important to people."—UTILITY SME

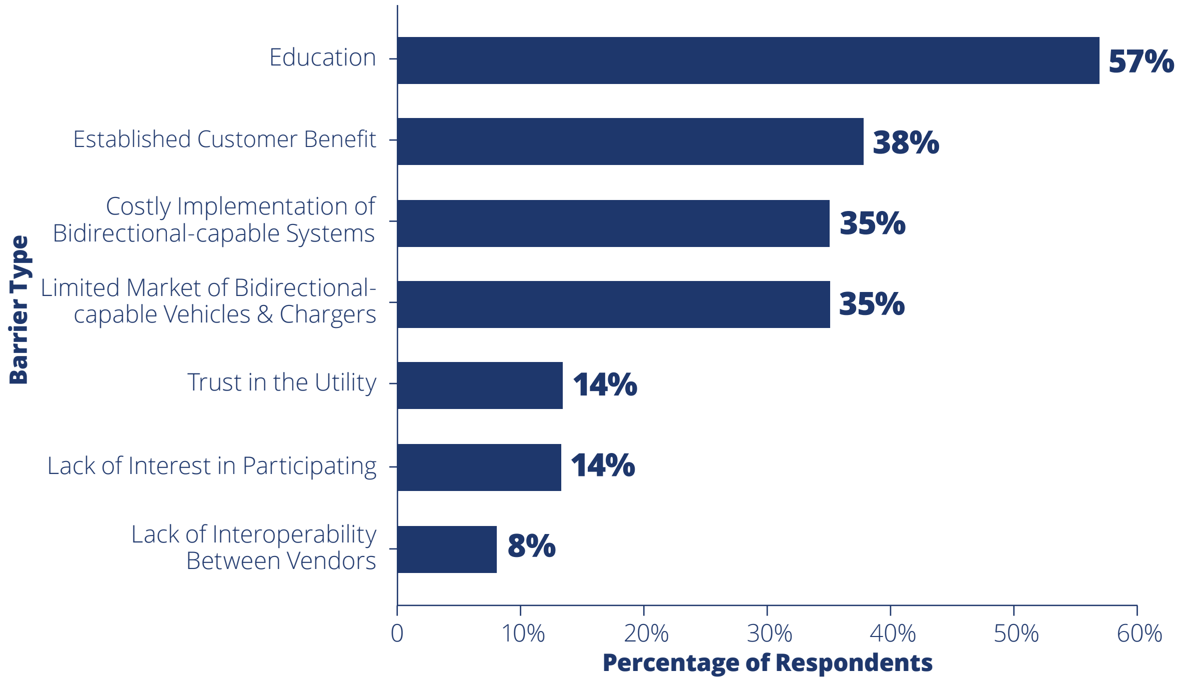
10 Fermata Energy (Jan. 2022). Revenue and Energy Savings Paving the Way for Mainstream Adoption of Vehicle-to-Everything (V2X) Technology.

11 Fermata Energy (Sept. 2022). FirstLight Power, Fermata Energy, and Skyview Ventures Partner to Launch First Ever Vehicle-to-Grid Charging Platform in Western Massachusetts.

12 Dominion Energy Virginia (July 2022). Electric School Bus Infrastructure Program.

13 Duke Energy. (Aug. 2022). Illuminating possibility: Duke Energy and Ford Motor Company plan to use F-150 Lightning electric trucks to help power the grid.

Figure 7. Utility Perspectives on Barriers to Customer Bidirectional Charging Adoption



Source: SEPA. (2023). n=37. Note: Utilities selected all that applied.

- Education around how the utility will perform the bidirectional charging
- General education around EVs, charging, and vehicle range as well as rates including TOU, demand response, and EV-specific rates
- Working with utilities early and often, especially when planning the required EVSE

The utility SMEs viewed economic considerations as the next two most important barriers for customers. The utility SMEs stated that customers would need to understand what types of benefits they could derive from implementing a bidirectional charging system. Some of the benefits would be derived from backup generation and resilience benefits, which are difficult to quantify, and another part would be derived from utility program incentives including peak load reduction savings and program participation incentives. The utility SMEs indicated that customers need a clear understanding of the benefit and value of bidirectional charging to justify the extra costs associated with implementing a bidirectional system. Most installations of bidirectional charging systems come with costs associated with interconnection studies and panel upgrades, and the bidirectional EVSE is often more expensive than the unidirectional counterparts.

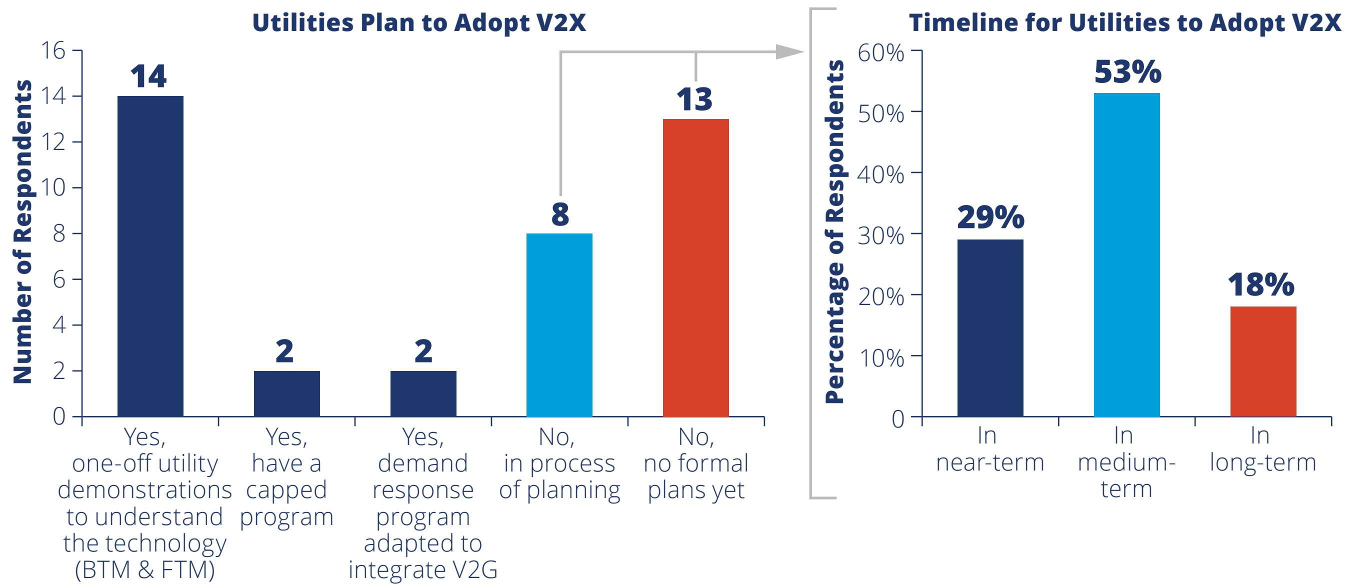
Outlook on Utility Development of Bidirectional Charging Programs

Utility Adoption of Bidirectional Charging Programs

During the discussions with the utility SMEs, several indicated that they viewed bidirectional charging as a continuation of their managed charging programs and could see themselves adding a bidirectional charging program as a later phase to those programs. As a precursor to developing and adopting full-scale bidirectional programs, 16 of the utility SMEs indicated that their utility had already been testing bidirectional charging systems to understand how they would impact grid operations (Figure 8).

> **"V2X or bidirectional flow is an aspect of managed charging, and within the family of programs." —UTILITY SME**

Figure 8. Utilities Adoption of Bidirectional Projects



Source: SEPA. (2023).

The utility demonstration projects varied from testing utility-owned/operated bidirectional charging systems and light-duty vehicles to one-off agreements with customers to pilot specific applications. The one-off agreements included those with schools to study V2B and peak shaving, with commercial customers to study V2B and peak shaving, with community colleges and universities to test a variety of V2X use cases, and with microgrid owners to test using V2G in islanded, microgrid settings. Of note, some of these agreements are still in the initial phases of development, in large part due to logistical delays in receiving either the charging equipment or the bidirectional-capable vehicles. Across the 16 utilities, from small co-ops to large IOUs, these demonstration projects and pilots were important for:

- Testing the technology and understanding the reliability and responsiveness of bidirectional charging systems[14]
- Understanding the grid impacts of bidirectional charging systems[15]
- Developing utility confidence in bidirectional charging systems to support customers as they adopt this technology
- Understanding the efficacy of different bidirectional applications and beginning to assign value to peak shaving, V2B, V2G, and other use cases.

Four of the interviewed utilities had deployed programs beyond one-off agreements that were available to customers with bidirectional charging systems (Figure 8).[16] Two programs are capped customer programs where the utilities are examining how V2X applications work with multiple customers (See the PG&E Case Study for an example on customer V2X programs). The other two are programs where the utilities have opened their demand response program to bidirectional charging systems. These two programs already allow stationary storage to participate in the demand response program and were able to leverage that knowledge and value proposition to allow bidirectional-capable EVs to participate (See the National Grid's Case Study for an example on a demand response program).

Of the 14 utilities with demonstration pilots, two also had a deployed program, and among the remaining 12, nine stated that they wanted to understand the lessons from their demonstration projects before planning for a fully-fledged program, five stated that they were planning for more projects in the near-term, and two stated they were planning for more projects in the medium-term.

The majority of the utilities did not yet have demonstration projects or a full program. However, eight of the utilities had plans to file proceedings in the next several years

14 Utilities did not discuss metrics or measurements for reliability and responsiveness during the interviews.

15 Utilities did not discuss metrics or measurements for grid impacts during the interviews.

16 Note, this number is indicative of the survey group. There are more utility V2X programs in the U.S. than the four reviewed here. See Table 5 for more V2X programs.

to allow them to test the technology and prepare for widespread adoption. Of the 21 utilities that currently do not have bidirectional charging projects, 17 indicated the approximate timeline they would probably begin to conduct bidirectional charging projects. The majority of which are planning for its adoption in the medium-term (medium-term is loosely defined as a period between three to eight years).

Reasons cited for this timeline include:

- Plans to run managed charging programs first, then look at adopting bidirectional charging after these programs are established
- Desire for bidirectional charging programs to be proven at other utilities first
- The need for more EV adoption in the area
- Lack of urgency to adopt bidirectional charging
- Desire for more bidirectional-capable EVSE and vehicles to be on the market

Barriers to Utility Program Development and Adoption

All utility SMEs were asked about the barriers they face in implementing a bidirectional charging program. During the interviews, each utility SME identified barriers around:

- Implementing a bidirectional charging project or program
- Scaling a bidirectional charging program
- Regulatory barriers to exploring and scaling a bidirectional charging program
- Industry barriers

While each utility SME identified their utility's specific barriers, many of the SMEs shared similar barriers including:

- Programmatic design and determining program values and incentives
- Funding programs and gaining regulatory or board approval
- Technology barriers including standardization, interoperability, and certification
- Interconnection and costly implementation of the charging systems

Implementing and Scaling Bidirectional Charging Programs

Utilities may face different challenges depending on whether they are in the early stages of studying bidirectional charging technologies and piloting with select customers or if they are in the later stages of scaling a bidirectional charging program. SEPA asked each utility SME to identify their barriers to implementing an early-phase bidirectional charging project or program and to identify the types of barriers that exist in scaling that program to a wider customer base (Figure 9).

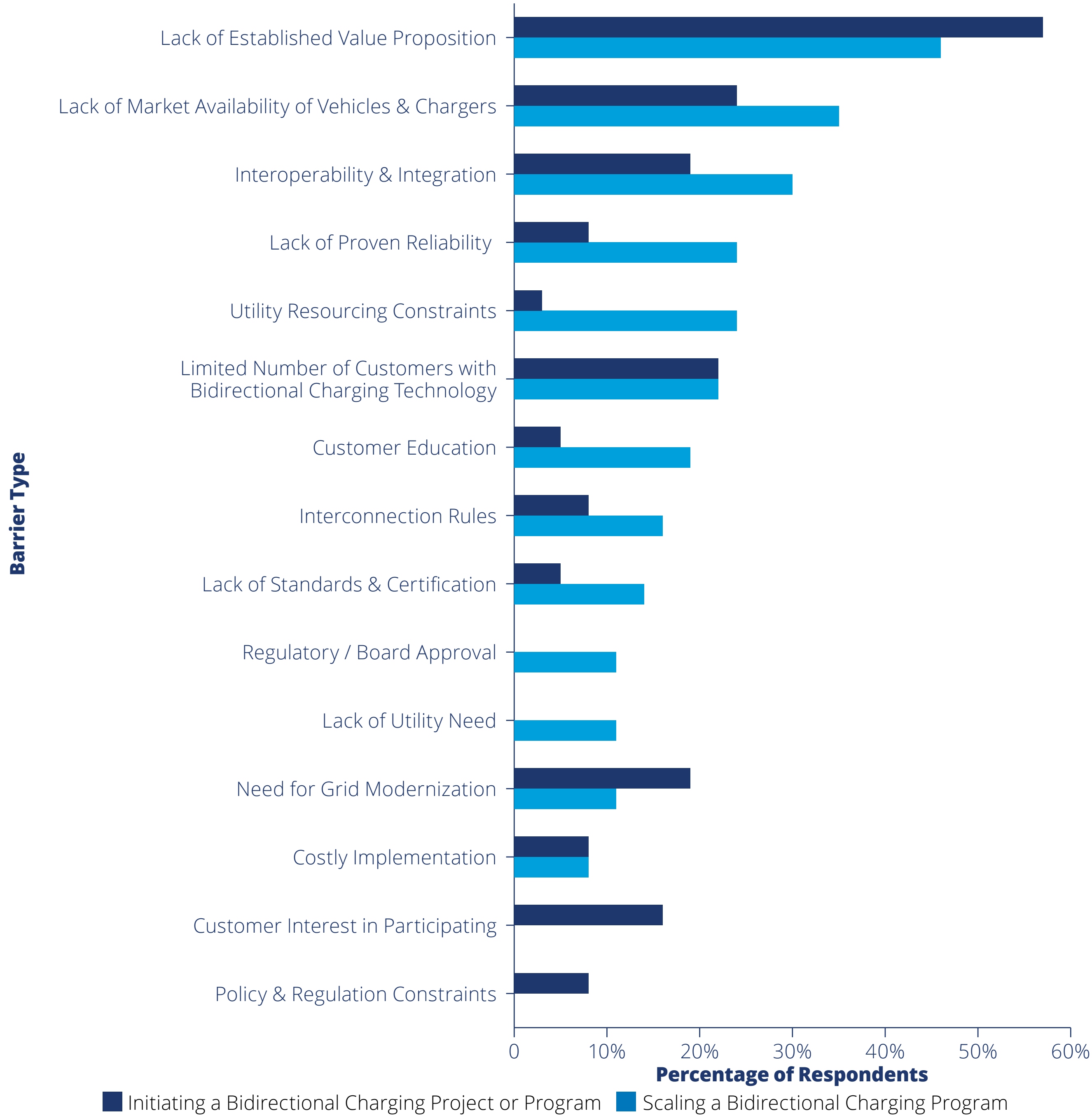
In both the implementation and scaling phases, the utility SMEs predominantly responded that the value proposition of bidirectional charging needs to be established before they would implement a program. The value proposition affects the types of rate structures a utility would test, whether or not the program has sufficient monetary and grid value for the utility to make the investment, and whether or not a customer would gain benefit from participating in a utility program. The different types of bidirectional charging applications (including V2H, V2B, V2G, ancillary services, peak shaving, resilience services and others) all have different values to the grid and to the customer.

Many utility SMEs felt that the industry was in the early stage of determining value for V2X applications and achieving that value at scale. Some SMEs indicated that they would wait and see how other utilities design bidirectional charging programs, while other SMEs indicated they would be the front-runners in implementing and testing these programs and their value structures.

The utility SMEs also felt that there is a lack of market availability of vehicles and chargers. The low number of bidirectional-capable vehicles and chargers has significant implications for overall customer adoption. Most of the interviewed utilities said that they have very few customers that have bidirectional charging-capable systems and that it is difficult for a utility to justify the cost of implementing a bidirectional charging program if there are a lack of participants. Associated program costs can include:

- Budgeting employee hours to the project and allocating funds to run the program
- Producing educational resources for customers to participate in a pilot or program
- Infrastructure upgrades that may be required, including distribution lines, transformers, etc.
- Software requirements including energy orchestration and control systems

Figure 9. Barriers to Utility Implementation and Scaling of Bidirectional Charging Programs



Source: SEPA. (2023). n=37. Note: Utilities selected all that applied.

- Integration requirements including developing protocols to interconnect customer systems to utility control systems
- Paying customers large enough incentives to participate in the program without cross-subsidizing from other utility programs

Additionally, several utilities responded that they are more worried about customers adopting EVs in general and are focused on ensuring that the transition from fossil fuel vehicles to EVs is smooth and easy for their customers.

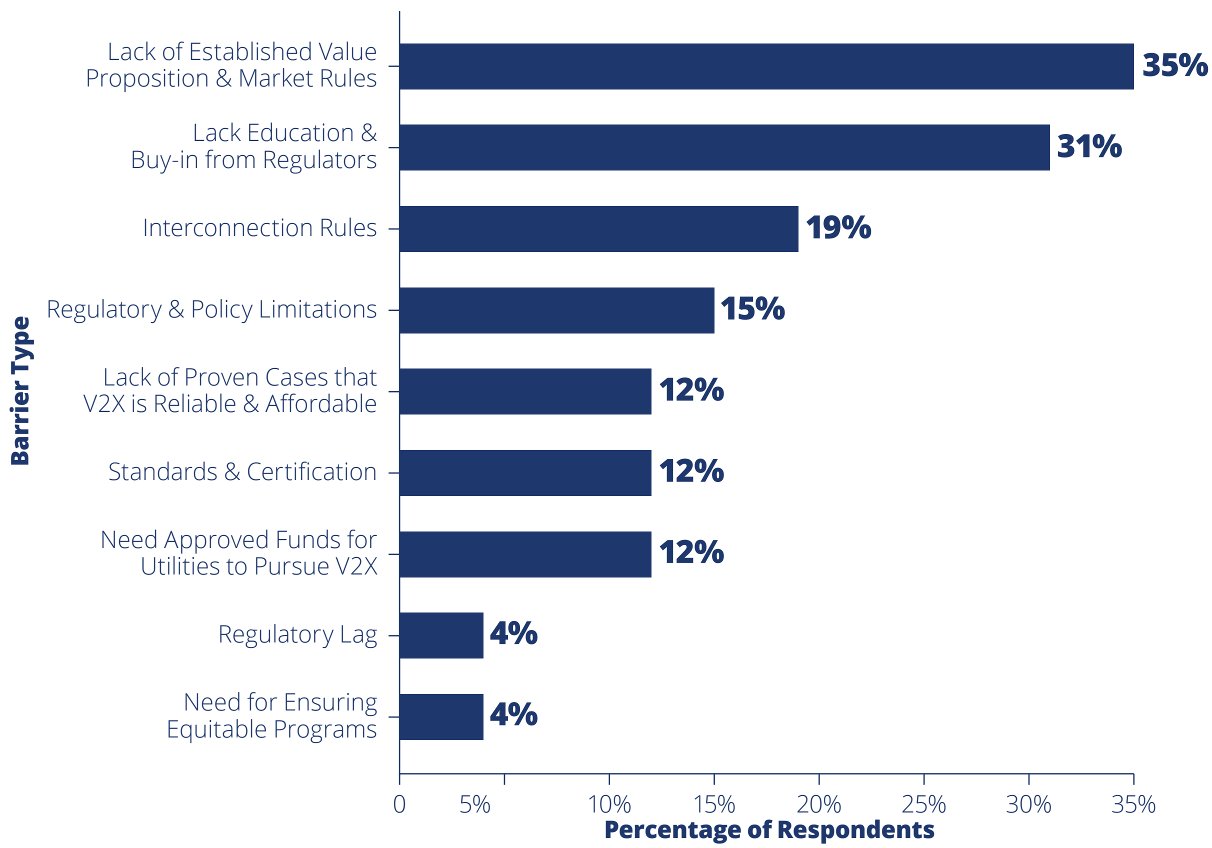
As one utility SME summed it up "People should focus on the reliability of the charging network before we get into more complex V2X plays." Utilities first and foremost want to prioritize positive customer relationships that benefit both parties. EV adoption is still in the early stages for mass adoption and requires customer education and support.

Other prominent barriers include interoperability among the EVSE, vehicles, and the utilities and the overall integration of these systems to the grid. As will be discussed in the Interoperability and Standardization section, bidirectional charging systems rely on a complex communication system that sends signals between the vehicles, the EVSE, the utilities, and sometimes other systems such as building management systems. The current fragmentation and lack of interoperability in the bidirectional charging market makes it more challenging to interconnect to a utility system.

Regulatory Barriers

SEPA also asked interviewees if there were any regulatory barriers that were influencing their adoption of bidirectional charging programs (Figure 10). More than 10 of the utility SMEs indicated that they did not have any regulatory barriers; either they were not subject to a regulatory body or they had supportive regulatory bodies. Among the utility SMEs with regulatory barriers, the need for established value propositions and clear market rules was the primary concern as well as a lack of regulator buy-in and understanding of the benefits of bidirectional charging programs. Some of the utility SMEs stated that they wanted their regulatory bodies to open bidirectional charging tariff proceedings to begin the process of determining the value of V2X applications. Others stated

Figure 10. Regulatory Barriers to Utility Adoption of V2X Programs



Source: SEPA. (2023). n=26. Note: Utilities selected all that applied.

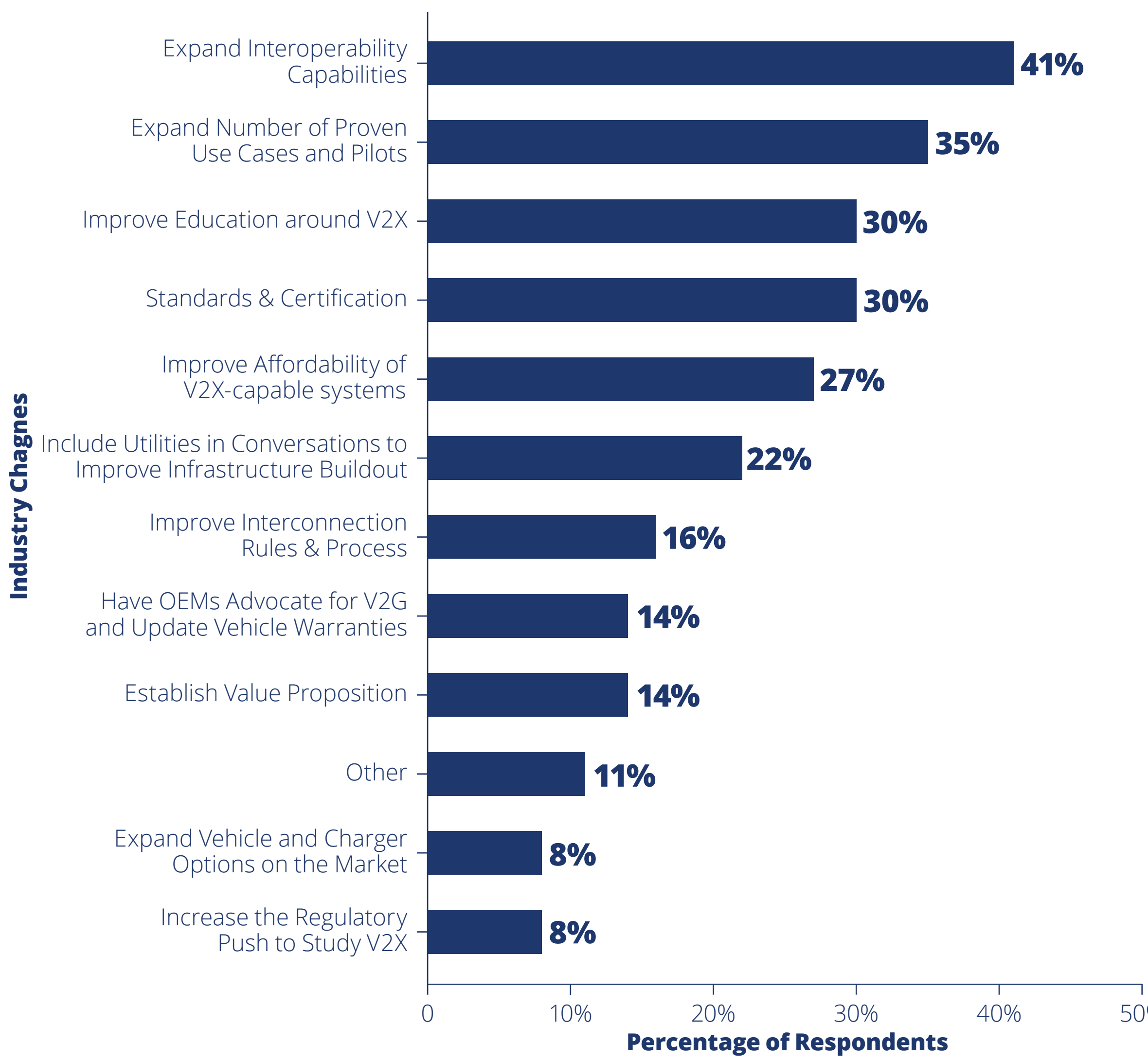
that they are beginning to incorporate EV planning into their integrated resource plans (IRPs) and will likely include bidirectional charging programs in future plans.

Desired Industry Changes

The final interview question pertained to what utilities wanted to see from the bidirectional charging industry, including from regulators, vehicle OEMs, EVSE manufacturers, software providers, and other stakeholders. The top suggestion was to expand the interoperability capabilities of vehicles and chargers so that customers could pick and choose among different brands and to expand the number of proven demonstration projects (Figure 11). These answers corresponded to the barriers that utilities saw for both their own adoption and for widespread customer adoption. Other suggestions from utilities included:

- **Include utilities early and often** in planning for bidirectional charging projects. Utilities need sufficient lead time to ensure that sites have sufficient distribution infrastructure to handle EV charging and discharging
- **Host more forums** in which different stakeholders can all come to the table and create holistic approaches to bidirectional charging solutions
- **Promote standards and regulations** across all stakeholder groups. Customers should be able to implement bidirectional charging consistently regardless of geographic area

Figure 11. Utility Suggestions for Industry Priorities



Source: SEPA. (2023). n=37. Note: Utilities selected all that applied.

Chapter 3: Manufacturer and Non-Utility Perspectives on Technology and Interconnection Considerations

Manufacturers and service providers are critical stakeholders in the development and mass market adoption of bidirectional-capable technologies. These industry stakeholders include vehicle OEMS, EVSE manufacturers, network and software service providers, and program implementation partners. As highlighted in SEPA's 2022 report "Customer-centric Pathways to V2X Adoption," industry stakeholders are all at different stages in developing their offerings and have different perspectives on how customers will adopt the technology. Alongside the utility interviews, SEPA conducted in-depth interviews with 16 non-utility SMEs to hear insights on how the bidirectional charging industry is developing (Table 7).

Table 7. Alphabetical List of Non-utility SME Interview Participants

Company Name	Type of Organization
CharIN	Non-profit, supports EV standards development
CLEAResult	Project implementation partner
dcbel	EVSE hardware provider, software service provider
Enphase	EVSE hardware provider, software service provider
ev.energy	Software service provider
Fermata Energy	EVSE hardware provider, software service provider
ICF	Project implementation partner
InCharge Energy	Project implementation partner
Kaluza	Software service provider
SunPower	EVSE installer, project implementation partner
Sunrun	EVSE installer, project implementation partner
Vehicle-Grid Integration Council (VGIC)	Non-profit, supports vehicle-grid integration research and industry education
Virtual Peaker	Software service provider

Source: SEPA. (2023). Disclaimer: The opinions expressed in this report are not attributed to any one stakeholder nor reflective of any specific organization. SEPA also conducted three interviews with vehicle OEM SMEs, who wished to remain anonymous.

The State of Bidirectional Charging in 2023

"The state of the industry is that we are very early."
—PROJECT IMPLEMENTATION PARTNER SME

Industry stakeholders are excited to provide bidirectional charging technologies to the marketplace. So far 2023 has seen notable progress in EVSE and vehicle OEMs increasing industry participation and in the partnerships among different providers. While there has been increased momentum, industry stakeholders have indicated that there are some primary barriers that still need to be addressed. Through the non-utility SME interview series, the SMEs discussed several key technology and project implementation areas that are being addressed by the industry (Table 8).

Table 8. Summary of Non-Utility SME Perspectives

Chapter Section	About This Section
State of the Industry	Non-utility SMEs are directly involved in developing bidirectional charging solutions and have keen insights into the development of the industry. This section will cover how non-utility SMEs consider the state of the industry and the collaborations that have occurred.
Interoperability and Standardization	Interoperability and standardization are required for bidirectional charging systems to work at scale and for utilities to approve interconnection agreements. This section will cover regulatory and standards bodies that approve standards, the types of standards and certifications required for bidirectional charging systems, and other key considerations.
Technology Differences: V2G-AC Versus V2G-DC	There are two main configuration types for bidirectional charging systems: V2G- alternating current (AC) and V2G- direct current (DC). This section will briefly cover the two types.
Lessons Learned from Utility Interconnection Processes	Interconnection is frequently cited by the utility and non-utility SMEs as a primary barrier for customers implementing bidirectional charging systems. This section will cover key interconnection considerations.

Source: SEPA. (2023).

"There is excitement over the potential to offer new value to customers (drivers, fleet owners, operators), but there is still a lot that needs to be figured out."—NON-PROFIT SME

State of the Industry

Bidirectional charging is an early market technology, and there is near unanimous consensus that bidirectional charging will bring benefits to utilities, customers, and industry stakeholders. During the interviews, the non-utility SMEs shared their thoughts on the state of the industry, the types of vendors in the space, technology considerations, and customer implications.

The Bidirectional Charging Market

Prior to 2023, few vehicle and EVSE manufacturers offered bidirectional-capable devices to the U.S. market, and even fewer were approved for utility interconnection (See Appendix for a summary of vendors). Fermata Energy, Proterra, Nuuve, and Coritech bidirectional EVSE manufacturers were among some of the original vendors in the U.S. market. Their initial product offerings were commercially available three-phase DC chargers, seen most frequently in fleet and commercial applications. Most often, these chargers were paired with Nissan LEAFs, which for nearly a decade was the only U.S. light-duty vehicle allowing bidirectional charging. They have also been paired with electric school buses, often manufactured by Blue Bird, Lion Electric, and Thomas Built Buses.

The 2021-2023 time period has seen a major increase in new vendors entering the bidirectional charging market. Among the vehicle OEMs, the bidirectional charging market started to expand beyond Nissan and select school bus manufacturers, with Ford's 2021 announcement of the

Ford F-150.[17] In 2022, GM followed with its announcement that its 2024 Chevrolet Silverado EV would be bidirectional capable and that the company would expand into energy management products.[18] Hyundai and Kia also released the Ioniq5 and EV6, which both have V2L capabilities.

Among EVSE manufacturers, Q4 2022 - Q2 2023 saw a suite of announcements. In 2022, Ford announced that its Level 2 Ford Charge Pro Station was listed to Underwriters Laboratories (UL) Solutions bidirectional charging standards.[19] UL listing means that a product meets the U.S.'s nationally recognized safety standards and is often a requirement for utility interconnection. In Q2 2023, dcbel announced that its residential DC r16 Home Energy Station met all UL requirements.[20] Other EVSE manufacturers, including Enphase, Autel Energy, Emporia, and Wallbox announced that they plan to release bidirectional-capable chargers in the 2023 to 2024 time range.[21]

Many of the bidirectional-charging manufacturers and software service providers have developed specific customer and application niches. Niches include targeting residential vs. commercial customers, focusing on light-duty vs. medium- and heavy-duty vehicles, integrating proprietary AI-driven software for market participants (charger manufacturers, auto OEMs, universal aggregators), and specializing in different levels of EV charging including Level 1, Level 2, and direct-current fast-charging (DCFC).

Bidirectional charging is a complicated technology that often benefits from collaboration. It can be challenging for manufacturers to transition from unidirectional-capable systems to bidirectional-capable. Vehicle OEMs have an advantage of decades of expertise researching, developing, and manufacturing new vehicles at scale and distributing those vehicles to dealerships throughout the country. However, as vehicle OEMs enter the EV space and include bidirectional charging capabilities, they are being challenged to expand their hardware and software knowledge. They must integrate software capable of interacting and communicating with bidirectional-capable EVSE, energy management systems, and/or universal aggregators into vehicles.

"There is a broad spectrum of capability and capacity to engage with V2X. It is also the broader EV story. Some companies have different strategic investments and different in-house capabilities to pursue different value streams. There is no single approach."
—NON-PROFIT SME

Some vehicle OEMs are also choosing to expand their capabilities into new product offerings. GM announced its new business unit, GM Energy, and has been advertising its home energy management software systems.[22] Other vehicle and charger OEMs are choosing to partner with software service providers; Fermata Energy is integrating its bidirectional software with V2G-capable chargers produced by other charger manufacturers and auto OEMs, and Ford worked with Siemens to develop the Ford Pro Charging Station.

Technology Considerations

Interoperability and Standardization

Interoperability and well implemented standards are required for bidirectional charging to function efficiently and safely. Standardized communication protocols, safety certifications, and properly-defined interconnection (and standardized) requirements continue to be a focus of the industry and are often pointed to as a top priority. This section provides an overview of the common standards and certifications directly associated with bidirectional charging. This list is not comprehensive and represents the standards that were mentioned in the industry and utility SME interview series. This report does not attempt to suggest a path to achieving industry agreement on standards nor does it aim to offer a comprehensive description of the standards or how to best implement them. For more in-depth discussions on standards, see the Interstate Renewable Energy Council's (IREC) 2022 report "Paving the Way: Vehicle-to-Grid (V2G) Standards of Electric Vehicles."

17 Ford. (2021). FORD TO REVEAL ALL-ELECTRIC F-150 LIGHTNING MAY 19.

18 GM. (2022). General Motors' New Energy Ecosystem Will Give Customers Control of Their Energy Needs and Help Mitigate Effects of Power Outages.

19 Electrive. (2022). Ford and Siemens present wall box for Ford F-150 Lightning Truck.

20 dcbel. (2023). dcbel's residential bidirectional DC charger first to achieve certification in the US.

21 Clean Energy Reviews. (2023). Bidirectional Chargers Explained - V2G vs V2H vs V2L.

22 GM Energy. (2023). Ultium Home.

This report loosely groups standards into three categories: Grid Connection Standards, Communication Protocols, and Safety and Functionality Standards.

- **Grid Connection Standards:** These standards outline the technical specifications for connecting V2G systems to the power grid (see Table 9). They define parameters such as voltage levels, frequency, power quality, and safety considerations for bidirectional power flow. In the U.S., the National Electrical Code (NEC) and IEEE 1547 provide guidelines for grid interconnection of distributed energy resources (DERs) and the safe operation of power systems.
- **Communication Protocols:** Communication protocols establish the rules and formats for data exchange between V2G systems and the grid (see Table 10). They enable the coordination of charging and discharging operations, real-time monitoring, and grid services.
- **Safety and Protection Standards:** Safety and protection standards aim to minimize the risks associated with V2G operations (see Table 11). They define the necessary safety measures, equipment protection, fault detection, and isolation procedures. In North America, equipment manufacturers list their equipment to standards published by UL Solutions in the U.S. and Mexico and by the Canadian Standards Association (CSA) in Canada. In the utility interviews, utility SMEs frequently stated that UL certification was either an important or required condition before they would approve the interconnection of bidirectional EVSE. Early versions of UL 1741 followed the initial requirements of IEEE 1547 that specified that utility interactive inverters disconnect quickly from the grid during excursions from normal grid conditions. Later updates to IEEE 1547 modified this requirement and specified that DERs should provide support to the grid during abnormal voltage and frequency events. This requirement is one of the items in IEEE 1547 updates in 2014 and 2018 that are reflected in UL specifications.

Table 9. Grid Connection Standards

Standard Name	Description
IEEE 1547	The Institute of Electrical and Electronics Engineers (IEEE) Standards Association advances global standards and promotes interoperability. The standard IEEE 1547 establishes criteria and requirements for the interconnection of DERs with electric power systems (EPS), and associated interfaces. The root IEEE 1547 standard describes the functional requirements for the interconnection itself, while IEEE 1547.1 describes the testing procedures for conformance with the root standard.
J3072	J3072 is produced by SAE International, which develops mobility standards. J3072 establishes interconnection requirements for a utility-interactive inverter system, which is integrated into a plug-in hybrid electric vehicle (PHEV) and connects in parallel with an EPS by way of conductively-coupled EVSE. This standard also defines the communication between the PHEV and the EVSE required for the PHEV onboard inverter to be configured and authorized by the EVSE for discharging at a site. These requirements are intended to be used in conjunction with IEEE 1547.[23]

Source: SEPA. (2023).

"Most car and device companies are underestimating how complicated it is. When you have utility regulations, permitting, UL and other certifications, it's really complicated." —SOFTWARE PROVIDER SME

23 SAE (2020). SAE J3072 Update for V2G-AC.

Table 10. Communication Protocols	
Standard Name	**Description**
ISO 15118	ISO 15118 is an international communication standard for both AC and DC charging. It is primarily used for unidirectional charging, but the International Organization for Standardization (ISO) is adding bidirectionality in the newest edition of the communications protocol (15118-20) as of 2023.
CHAdeMO	CHAdeMO is a standard for DC charging (protocol and equipment) that supports both unidirectional and bidirectional charging (since 2014).
Open Charge Point Protocol	Open Charge Point Protocol (OCPP) is an open and widely adopted communication protocol for managing charging stations and EV charging networks. It supports basic bidirectional charging functions, but the extent of bidirectional capabilities varies depending on the specific version of OCPP implemented.
IEC 61850	IEC 61850 is a communication standard primarily used for substation automation in the power industry. IEC 61850 was produced by the International Electrotechnical Commission. It is not specific to EV charging but can be utilized for bidirectional EV charging as well. IEC 61850 offers a robust and standardized communication framework for control, monitoring, and protecting electrical systems, including bidirectional power flow between EVs and the grid.
IEEE 2030.5	2030.5 is an application layer standard based on web services with built-in security, and is designed to use the internet to transport messages between devices. The standard has recently been updated to incorporate the CA Rule 21 and IEEE 1547-2018 functionality. Due to its mandate in California, IEEE 2030.5 is emerging as a preferred industry standard for DER communications. This is also the core messaging protocol for the SAE V2G J3072 series of standards. The standard supports V1G and demand response applications.[24]
Open Automated Demand Response (OpenADR)	Open Automated Demand Response (OpenADR) provides a non-proprietary, open, standardized and secure demand response (DR) interface that allows electricity providers to communicate DR signals directly to existing customers using a common language and existing communications such as the Internet.

Source: SEPA. (2023).

Table 11. Safety and Protection Standards	
Standard Name	**Description**
UL 1741 Supplement SA	UL 1741 Supplement SA is used to test and certify inverters and other utility interconnected DERs for grid support functions enabling smarter, safer, grid interconnection. There are five primary grid support functions that are expected with UL1741 Supplement SA. ▪ Provide predictable, soft start ramp rates of power production when initiating grid-connected operation ▪ Apply a specified power factor to the grid ▪ Apply reactive power to help control grid voltage ▪ Apply real power to help control grid voltage ▪ Apply real power to help control grid frequency These functions allow inverters to function without a direct communications link to utility companies, while actively helping support the grid during abnormal conditions of voltage and frequency.
UL1741 Supplement SB	UL1741 Supplement SB is an updated specification for DER performance that includes the updated requirements of IEEE 1547-2018 and test methods of IEEE 1547.1-2020.
UL 9741	UL 9741 is an Outline of Investigation for Electric Vehicle Power Export (EVPE) equipment. This document includes performance requirements for a variety of both AC and DC power export from EVs and also allows for bidirectional operation (in the form of EV charging). UL 9741 was originally drafted as a specification for bidirectional EV charging (not specifically power export) and combined aspects of EV charging (UL 2202, UL 2594, UL2231) as well as EV discharge as a DER (UL 1741).

Source: SEPA. (2023).

24 IEEE (2018). IEEE Standard for Smart Energy Profile Application Protocol.

The State of Bidirectional Charging in 2023

Widespread adoption of specific standards allows EVSE, vehicles, and energy management software systems to communicate with one another, optimize data from a variety of sources, and manage the bidirectional charging functions. Bidirectional EV charging is an evolving field, and new standards and requirements will continue to emerge as the technology advances. These interoperability standards play a crucial role in enabling seamless communication, ensuring safety, and facilitating the integration of bidirectional charging into the existing EV ecosystem. By adhering to these standards, manufacturers, charging infrastructure providers, and utilities can collaborate effectively to unlock the full potential of bidirectional EV charging.

> **"It doesn't make sense for one organization to own standards. Guiding principle is that you need all of this technology to work across the board."**
> **—SOFTWARE PROVIDER SME**

Several of the non-utility SMEs have noted that widespread adoption of any one communication standard is still in early development. Recent announcements by major OEMs about adding the North American Charging Standard (NACS) charging port to the EVs indicates that the industry continues to evolve and that regulators may be mistaken in selecting certain standards over others.

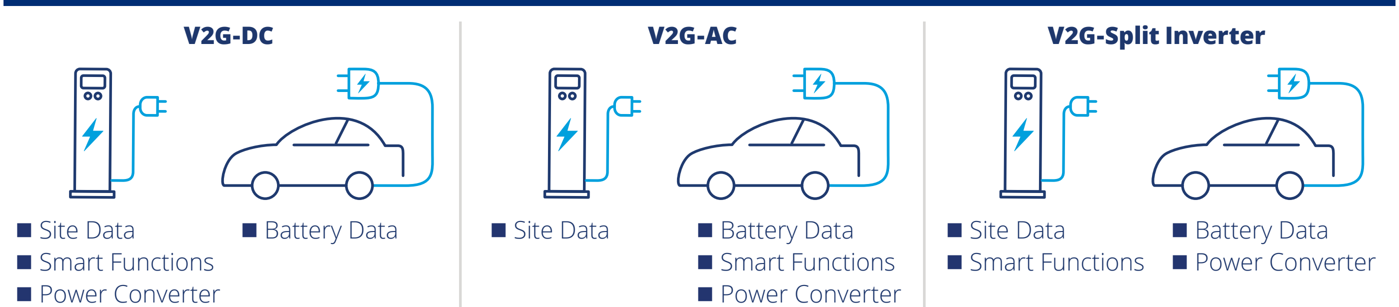
One such standard, ISO 15118, is built for the Combined Charging System (CCS) ecosystem. EVSE manufacturers have already begun to uptake ISO 15118.[25] Vehicle OEMs are still in the process of integrating the ISO 15118 protocol into their systems, and some vehicle OEMs have indicated that they will adopt it in the 2025 timeframe and beyond. The non-utility SMEs noted that the slow adoption of protocols by vehicle OEMs is due to their long timelines for design-to-market (often seven to ten years) and the implementation timeline for OEMs to move from an older version of a protocol to its updated version. While there has been slow uptake of ISO 15118 by vehicle OEMs, some non-utility SME interviews highlighted that the protocol will likely become the new minimum standard due to the National Electric Vehicle Infrastructure (NEVI) funding requirements. Chargers funded by NEVI grants have to utilize ISO 15118 and include hardware capability for implementation of ISO 15118 -2 and -20.[26]

Several of the non-utility SMEs also noted the importance of the industry working together to create these open standards and protocols. These non-utility SMEs warned against the industry stakeholders creating their own protocols and standards and advocated for bidirectional charging demonstration projects to move beyond pilots using proprietary standards towards projects that align with market-adopted, open standards. Interoperability among the different vendors helps improve the integration of software systems and allows customers more freedom of choice to select the vehicles, EVSE, and service providers that they desire.

Technology Differences: V2G-AC Versus V2G-DC

Bidirectional charging can occur either through on-board or off-board DC charging. This has implications for the cost of the bidirectional charging system, interconnection to the utility grid, and the vehicle and EVSEs' standards and certifications. On-board or off-board DC charging refers to the placement of the AC/DC inverter and where the smart functions need to reside (Figure 12).

Figure 12. V2G Inverter Configurations



Source: Interstate Renewable Energy Council. (2022). Paving the Way. Vehicle-to-Grid (V2G) Standards for Electric Vehicles. Recreated by SEPA.

25 SEPA. (2021). The State of Managed Charging in 2021.
26 Federal Highway Administration. (2023). National Electric Vehicle Infrastructure Standards and Requirements.

In V2G-DC, the inverter resides in the EVSE, and the EVSE needs to conform to UL 1741 SA and SB to be sufficient to meet utility grid requirements, such as California's interconnection Rule 21.[27] In V2G-AC, the inverter resides in the vehicle, and the vehicle would need to conform to UL 1741 SC, which is still at least one-to-two years down the road from being finalized and another one-to-three years from being adopted by the OEMs. In the V2G-AC configuration, the vehicle OEMs would need to submit their vehicles to UL 1741 testing and certification, which is an additional requirement for the OEMs compared to the V2G-DC scenario, in which only the EVSE needs to be certified.

The non-utility SMEs noted that vehicle OEMs are not yet favoring either V2G-AC vs V2G-DC and that the market is still determining what configurations the vehicle OEMs will adopt in the long-term.

Lessons Learned from Utility Interconnection Processes

Most of the non-utility SME interviewees noted that interconnection is among the most significant challenges in deploying bidirectional charging systems because many utilities are either in the process of designing their bidirectional charging interconnection process or have not yet begun. As discussed in Chapter 2, many of the utility SMEs noted that their customers have not adopted bidirectional charging, and as a utility they have not yet interconnected a customer system.

> **"Doesn't matter how big the utility is or where it is located, the lift is the same for the first customer in the territory."**
> **—PROJECT IMPLEMENTATION PARTNER SME**

As with any new technology, integrating their first customer bidirectional charging system with the distribution grid will be an important milestone for utilities. Utilities of all sizes have special interest in their first bidirectional charging interconnection, and there will be some level of utility preparation needed to update the interconnection process to allow the bidirectional charging systems to be connected to the grid.

In utility territories that already have stationary storage interconnection tariffs, the customer portals, smart inverter requirements, and customer support teams that are already in place can be used for V2G and other grid-tied EV charging applications. In these jurisdictions, there is less utility effort needed to adapt interconnection processes to include bidirectional charging systems (See National Grid and Revel Case Studies). In contrast, utility territories that do not have any stationary storage may have to design an entirely new process or use its rooftop solar interconnection process as a starting point. Interconnection rules are different in every utility jurisdiction, making it difficult for utilities to copy other utility interconnection processes.

On the project implementation side, it is difficult for vendors to scale their operations because vendors have to learn to navigate different interconnection processes in each utility territory. Project implementation companies such as Sunrun and SunPower have experience installing PV solar across the U.S. and have partnered with Ford[28] and GM[29] respectively to help them overcome challenges associated with interconnection processes. In the early stages of adoption, companies and utilities will need to work closely to interconnect bidirectional charging systems.

Energization Versus Interconnection

The non-utility SMEs noted that it is becoming increasingly important that all stakeholders have a common understanding of terminology when it comes to interconnection requests. Not all bidirectional charging systems will need interconnection agreements, usually depending on whether the system is grid-tied or not (Figure 13).

Interconnection

To be interconnected has the specific connotation that the customer has applied to the utility for an interconnection agreement and has proven that they have sufficient infrastructure in place to meet the utility's safety requirements (such as having a transfer switch, power control system, and/or smart inverter) and that the bidirectional charging system meets specific certification and standards requirements (such as meeting UL 1741

27 Greentech Renewables. (2018). UL 1741 & Rule 21: Advanced Inverter Tests.

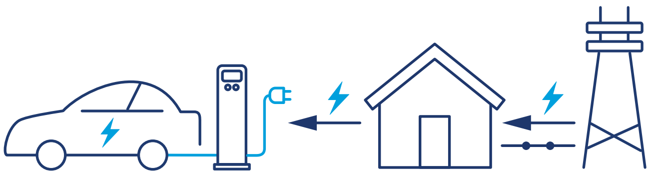
28 Sunrun. (2021). Sunrun Partners with Ford to Provide Seamless Installation.

29 PR Newswire (2022). SunPower and General Motors to Power Homs of the Future with Electric Vehicles.

Figure 13. Common V2X Bidirectional Charging System Configurations

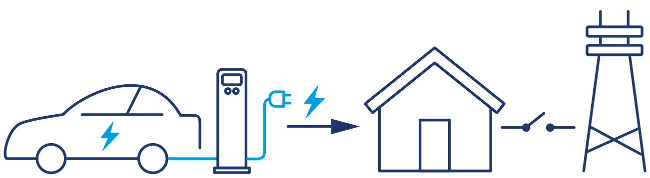
Energization

Load-only Mode



No generator interconnection and little-to-no review required.

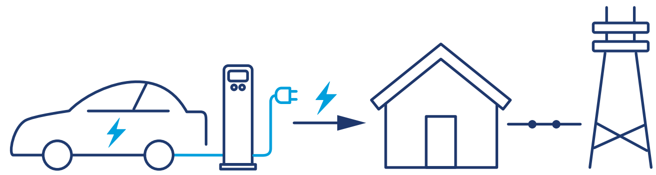
Islanded (for Backup)



No generator interconnection and little-to-no review required (e.g., notification-only, similar to fossil-fuel backup generator).

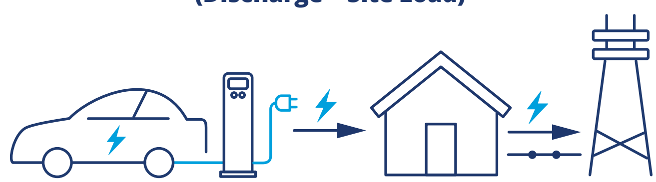
Interconnection

Parallel, Non-export (Discharge < Site Load)



Can fit within existing non-exporting small generator interconnections frameworks.

Parallel, Export (Discharge > Site Load)



Can fit within existing exporting small generator interconnections frameworks.

Source: Vehicle Grid Integration Council. (2022). V2X Bidirectional Charging Systems Best Practices for Service Connection or Interconnection.

and IEEE 1547-2018). Obtaining the interconnection agreement can be challenging in many utility jurisdictions and some of the non-utility SMEs noted that meeting requirements such as California's interconnection Rule 21 still remains challenging for EVSE manufacturers. Utility interconnection requirements have been cited as a barrier for V2G and other grid-tied use cases.

Energization

Both the non-utility and utility SMEs brought up the distinction that non-parallel applications (V2L, V2M, and V2H/V2B backup generation) should be categorized as energization rather than interconnection. If utilities consider these use cases to be energization and thereby do not require an interconnection agreement, customers can adopt these systems while utilities work on creating their interconnection rules and processes for grid-tied bidirectional charging systems. For these reasons, several of the non-utility SMEs indicated that they thought V2H/V2B backup generation would be the first use case adopted by many customers, particularly residential and commercial customers concerned about grid outages.

Some industry stakeholders have also advocated for allowing bidirectional systems to be implemented in energization mode until they can obtain an interconnection permit. By allowing bidirectional chargers to be installed through the energization process, customers can more expeditiously deploy the system and use the chargers in V1G modes until the interconnection is approved or rejected. This process allows customers to deploy bidirectional charging assets initially for use as a charger while utilities review the implications of bidirectional operation and later approve or reject the bidirectional interconnection request.

Additionally, islanded V2H/V2B applications may be less costly to residential customers; existing interconnection permits for distributed renewables can range between $0 and $800,[30] and the need for smart inverters and other power control systems can quickly increase the deployment cost of the bidirectional charging system.

30 NREL. (2018). Review of Interconnection Practices and Costs in the Western States.

Costly and complicated interconnection processes can be overwhelming to customers, potentially preventing some customers from upgrading their systems to be grid-interconnected.

However, one non-utility SME did note that V2G and grid-tied V2B applications are not necessarily more complicated than backup generation. The ease of implementing these systems will depend on the customer's site and any needed infrastructure upgrades.

New Business Models and Value Streams

There is widespread consensus that bidirectional charging has value to all of these stakeholders and the industry is still in the early days of determining how to capture and monetize that value. In large part, bidirectional charging value will be determined by the V2X use case; V2H backup generation has a very different value than that for peak shaving and V2G applications. Backup generation was identified as being among the easiest use cases to determine value. V2H/V2B backup generation can be compared to the price of other backup generation options and/or stationary storage and gives clearer value to the customers. Several non-utility SMEs noted that the vehicle OEMs are examining new ways in which they can earn on-going revenue from selling bidirectional charging systems. There is overall interest in exploring this new business model beyond just selling vehicles to customers. Chapter 4 will explore bidirectional charging value alignment in more detail.

> **"Bidirectional charging—What is the business case for it and how does it help us sell more cars" —EVSE HARDWARE PROVIDER SME**

Chapter 4: Opportunities for Wide-scale Adoption

As bidirectional charging transitions from early adopters to wide-scale adoption, there are major opportunities for industry stakeholders to build customer relationships, establish the value of bidirectional charging, and support policy and regulatory changes that aid bidirectional charging adoption. This chapter will cover SME insights on these topics (Table 12).

Table 12. Summary of Opportunities of Wide-scale Adoption

Chapter Section	About This Section
Customer Adoption	Utilities, vehicle OEMs, EVSE manufacturers, and other industry stakeholders have an opportunity to interact with new customer bases and address customer concerns and questions around adopting bidirectional charging systems. This section will highlight how these stakeholders can engage with customers, address warranty issues, and improve customer adoption.
The Value of Bidirectional Charging	Bidirectional charging has numerous values for utilities, manufactures, software providers, and customers. This section will cover how these stakeholders share the value and cost of bidirectional charging systems.
Policies and Regulations	Policy and regulatory bodies can support the adoption of bidirectional charging systems by helping utilities establish customer programs, approving funding for bidirectional charging programs, and addressing utility needs.

Source: SEPA. (2023).

Customer Adoption

Widespread adoption of bidirectional charging technologies will rely on customer demand for the products. While portions of the EV and utility industries have been exploring bidirectional charging for over a decade, more widespread customer awareness and desire for the technology has only occurred over the last several years. One notable change in customer awareness has been the vehicle OEM marketing campaigns around V2L and backup V2H capabilities. Many of the utility and non-utility SME interviews stated that Ford's F-150 commercials have greatly increased customer interest in bidirectional charging. Other interviewees brought up GM's promotion of whole-home integrated solutions as another driver of customer interest. As customers become more familiar with solar, home battery storage, and other DERs, they are becoming more open to the idea of using their vehicle as another type of energy resource.

"We've established a track record to make them more comfortable. You have to build that reputation." —UTILITY SME

Leverage Existing Education Programs

Some of the utility SMEs indicated that bidirectional charging programs can utilize learnings from other types of utility programs. Many utilities have long-standing TOU and DR programs and have already begun working with customers to help them understand these programs. That knowledge can be leveraged to introduce bidirectional charging to customers and to strengthen the relationship between the utilities and their customers. Utility SMEs indicated that building trust and a good reputation with customers is an important aspect of their long-standing programs.

"Part of a utility's role will be that of a change agent for both residential customers and fleet managers." —UTILITY SME

Additionally, as utilities establish fleet advisory services, they can utilize those departments to help commercial and fleet customers understand the value of bidirectional charging technologies. Several utility SMEs indicated that it is important to engage in these conversations early with fleet owners, transit agencies, and school districts so they understand their bidirectional charging options and can make more informed decisions on the types of vehicles and EVSE they will be purchasing.

Industry stakeholders have emphasized using solar installers and their project management abilities to engage with customers. Both Ford and GM have announced partnerships with Sunrun[31] and SunPower[32] respectively to install their systems on customer's properties. Part of the benefit of these partnerships is leveraging these solar installers years of experience working directly with customers to understand DER technologies and to understand how they benefit from having onsite energy generation.

Additionally, findings from the United Kingdom (UK) indicated that customers expect to hear about bidirectional charging from their vehicle dealership and their charger manufacturer (Figure 14). Customers had lower expectations to learn from their home energy supplier or utility, but still expected to have some education from this stakeholder group.

Clarify Messaging on Battery Degradation and Warranties

The utility and non-utility SME interviews indicated that warranty issues are a top-of-mind issue for customers. Historically, discharging vehicles to support external loads would void the warranty of the vehicle batteries, with special exemptions made for demonstration projects. In 2022, Nissan was among the first vehicle OEMs to allow bidirectional charging without voiding the battery warranty.[33] However, Nissan limited this warranty allowance to customers using Fermata Energy's FE-15 charger. As more vehicle OEMs enter the bidirectional charging space, they

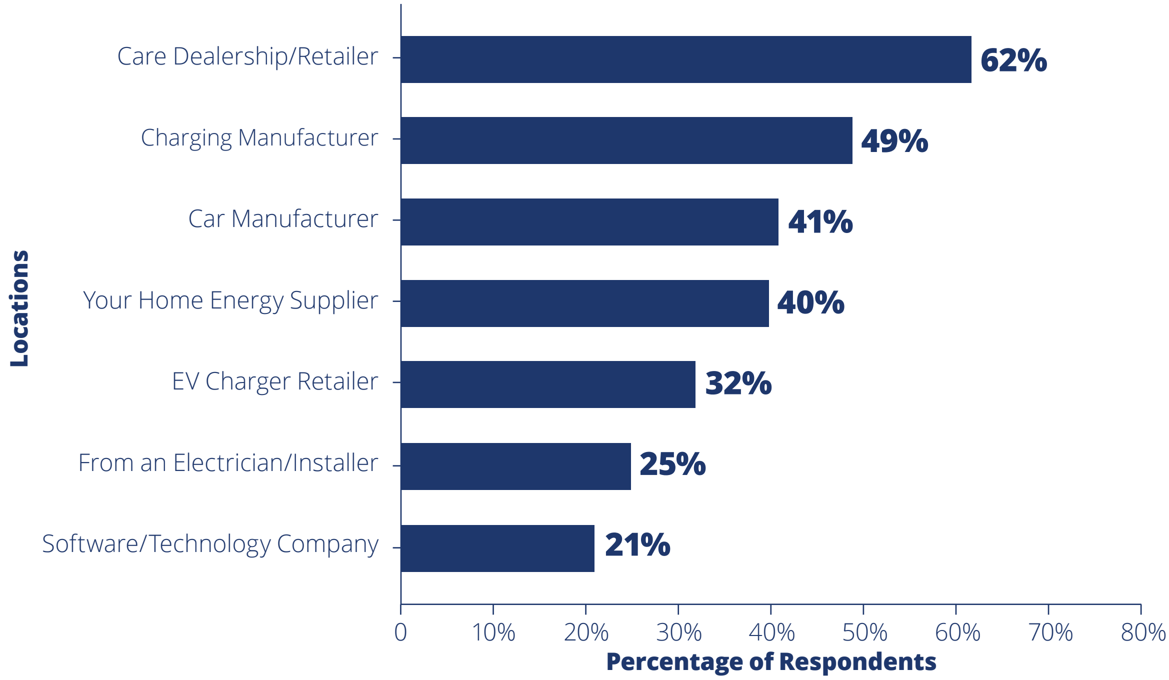
"We have had TOU-based rates for a while, and we had to do some education and that might help us with education in the future. We could leverage that for helping customers understand how to use their battery for V2X."—UTILITY SME

31 Sunrun. (2021). Sunrun Partners with Ford to Provide Seamless Installation.

32 PR Newswire. (2022). SunPower and General Motors to Power Homes of the Future with Electric Vehicles.

33 Fermata Energy. (2022). Nissan Approves Fermata Energy's Bidirectional Charger as First for Use with Nissan LEAF in the U.S.

Figure 14. Where Customers Expect to Learn about Bidirectional Chargers



Source: Kaluza. (2023). Recreated by SEPA. Base: EV drivers with dedicated charger (358).

will need to clarify battery warranties with customers and the parameters in which they can do bidirectional charging. Many vehicles currently doing bidirectional charging support V2L and V2H/V2B scenarios, and there is less clarity on the impacts of V2G and grid-tied cycling for the battery and the battery warranty. Some education around bidirectional charging applications will need to occur so customers stay within the warranty parameters.

Alongside education around warranties, the utility interviews highlighted that customers will likely have concerns around their batteries and degradation. EVs are a significant purchase for many customers, and customers will be reluctant to adopt bidirectional charging if it has too great of an adverse impact on the battery. Utilities and industry stakeholders can provide education materials to customers to assuage their fears and to understand how to manage their EV to decrease the rate of battery degradation. The reality for EV drivers is that their battery will degrade over time, even if they are not driving the vehicles, and there may even be some benefit to discharging the EV battery every once in a while. Additionally, bidirectional charging has different impacts on battery degradation depending on the frequency of discharging. If customers are participating in peak events that only occur a dozen times a year, then the degradation will be minimal.

Decrease Hardware and Installation Costs

The cost of purchasing and installing bidirectional charging systems remains expensive, especially compared to unidirectional systems. Price estimates for residential bidirectional systems are frequently quoted between $5 to $20 thousand dollars, a price point that is cost-prohibitive for many customers. The hardware and installation costs include interconnection permit fees, panel upgrades, the cost of the charger, and sometimes additional costs if a home energy management system, transfer switch, smart inverter, or other infrastructure is needed. Guidehouse conducted an analysis of the price premium for implementing bidirectional charging systems in Colorado (compared to unidirectional systems) and found that the price premium was between $8,500 and $9,000 for residential systems and $16,500 and $34,000 for commercial systems (Table 13).

"In their everyday lives, people are deciding on whether to spend more money or not. The dollars and cents are important to most people." —UTILITY SME

Table 13. V2H and V2B Deployment Cost Premiums Compared to Comparable V1G EVSE

V2H Deployment		
Deployment Cost Component	**Ford-Sunrun V2H Solution**	**Level 2 V1G EVSE**
Charger	$1,310	$380-$689
Power Management Equipment	$3,895	NA
Installation Cost	$5,505	$1,325-$1,427
Deployment Total	$10,710	$1,705-$2,116
V2H Premium	$8,594 – $9,005	
V2B Deployment		
Deployment Cost Component	**Commercial Level 2 V2B EVSE**	**Commercial Level 2 V1G EVSE**
Charger	$10,000	$4,900-$7,210
Power Management Equipment + Installation	$18,000-$33,000	$4,173
Deployment Total	$28,000-$43,000	$9,073-$11,383
V2B Premium	$16,617-$33,927	

Source: Guidehouse. (2023). The Potential of V2X. Challenges and Opportunities for V2X, and how to accelerate market maturity in Xcel Energy's Colorado service territory. Modified and recreated by SEPA.

Utility and non-utility SME interviewees alike stated that until the hardware and installation costs decrease, it will be difficult for bidirectional charging to become widely adopted. So long as unidirectional charging stations are significantly cheaper than bidirectional systems to install, it will be harder to transition customers to adopting bidirectional charging. Not only do the two product offerings need to achieve cost parity, but also the savings and economic gain from using bidirectional charging systems needs to be further established.

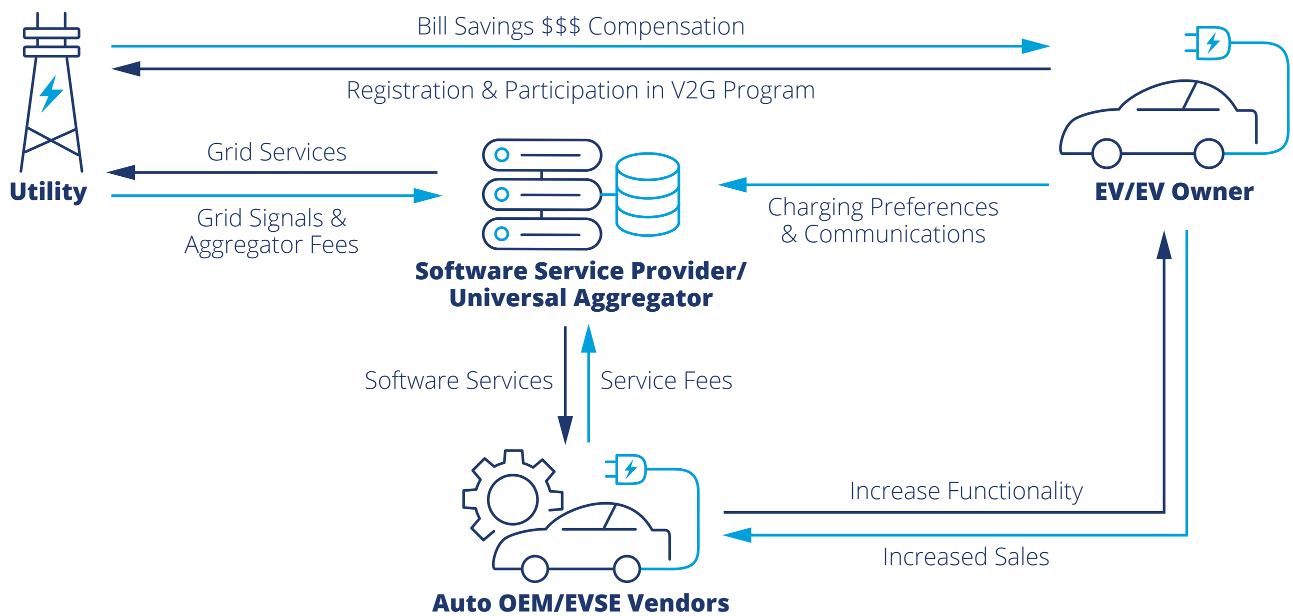
The Value of Bidirectional Charging

In order for bidirectional charging to be adopted at scale, the market needs to support compelling economic and other non-monetary benefits for utilities, customers, and OEMs. The value of bidirectional charging has been nearly universally accepted among these parties. However, the magnitude of value and the beneficiary of that value needs to be defined by utilities, OEMs, and regulatory bodies.

Specifically, these stakeholders need to determine the magnitude of value provided to each stakeholder and determine the costs associated with enabling that value. For example, bidirectional charging may increase the usage of an EV's battery, and the increased usage could have impacts to the battery's lifetime and warranty. The market will need to determine who takes on that added cost and risk. Customers may be willing to take on the added risk in exchange for the value of a specific V2X use case (such as backup V2H) but not want the greater risk of degradation that may come from providing another use case (such as frequency response). Alternatively, an OEM may include some bidirectional charging applications in the warranty (such as V2L and backup V2H) but not others (such as V2G) based on their understanding of a customer's willingness to pay a premium for certain applications.

When the proper compensation mechanisms are in place and the economics pencil out for OEMs, EV owners, and utilities, the market for bidirectional charging can scale organically. Figure 15 represents an illustrative example of how services and economic costs and benefits may be shared among stakeholder groups. Each stakeholder will receive a different slice of the value stack depending on the bidirectional charging application and degree to which the stakeholder engages in upholding that application. For example, vehicle OEMs may partner with a software provider to enable V2H and V2G applications and will share their portion of the value stack with that partner. In other cases, the vehicle OEM may develop their own software and will retain that portion of the value stack.

Figure 15. Illustrative Example of Value Streams of Different Stakeholder Groups



Source: SEPA. (2023).

Table 14. Value Streams for Utilities, OEMs, and Customers

Stakeholder Group	Value Streams
Utilities	▪ Bulk energy services (capacity, energy arbitrage) ▪ Transmission services (mitigate congestion, upgrade deferral) ▪ Distribution services (mitigate congestion, upgrade deferral, voltage control) ▪ Ancillary services
Vehicle OEMs and EVSE Manufacturers	▪ Product differentiation (e.g., can sell vehicles and EVSE at a higher price) ▪ Revenue from an energy management system
Software Service Providers	▪ Product differentiation (e.g., can appeal to universal aggregators, vendors, and utilities) ▪ Revenue from playing a virtual power plant aggregator role
Customers	▪ Backup power ▪ Utility bill reduction ▪ Compensation for providing utility services

Source: SEPA. (2023).

The Value of Virtual Power Plants

Software service providers that capture grid intelligence and data from devices such as EVs and other DERs (smart water heaters, stationary battery storage systems, smart thermostats, and others) amplify the value of bidirectional charging. Device data includes device status, availability for program participation, and available capacity. Software service providers have helped utilities evolve demand response events into demand flexibility programs that control these devices with more sophistication based on real-time grid conditions and market price signals.

Virtual power plants (VPPs) are a type of utility program that aggregates DER services to provide distribution grid services in a flexible and rapid manner. The VPP ecosystem is enabled by technology manufacturers, utilities, program implementation service providers and consultants, and software providers such as Virtual Peaker.

VPPs allow utilities to address peak needs, reduce utility reliance on fossil fuel peaking plants, and provide reliability and resilience services.[34] VPPs are considered a streamlined way for utilities to implement non-wires alternatives (NWAs) and to reduce and/or defer grid infrastructure costs. VPPs are:

- **Dispatchable**—through reliable and real-time controls
- **Firm capacity**—VPPs serve a volume of load rather than focusing on a number of participants
- **Long duration**—VPPs can serve beyond traditional DR windows of 10-15 three-hour events per year
- **All resource types**—VPPs consist of a diverse portfolio of DERs, including bidirectional charging assets.

VPPs can address grid impacts caused by wide-spread EV adoption and large-scale transportation electrification by providing distribution and locational relief. Upgrading grid infrastructure to accommodate new loads from transportation electrification is a slow process for utilities. VPPs can help reduce the need for grid upgrades and improve utilities' ability to serve a growing EV population.

Customer Buy-in

Even with widely-available technology and sound unit economics, bidirectional charging will not be possible at scale without consumer buy-in. Software providers are often the interface between a utility program and a customer, and these industry stakeholders frequently survey consumers to understand their desires, concerns, and preferences on managed charging and bidirectional charging programs. ev.energy is a V1G/V2G software provider that surveyed a portion of its 150,000 customer base to gain insights into these customer preferences.[35] The recent survey polled both commercial and residential customers (Figure 16).

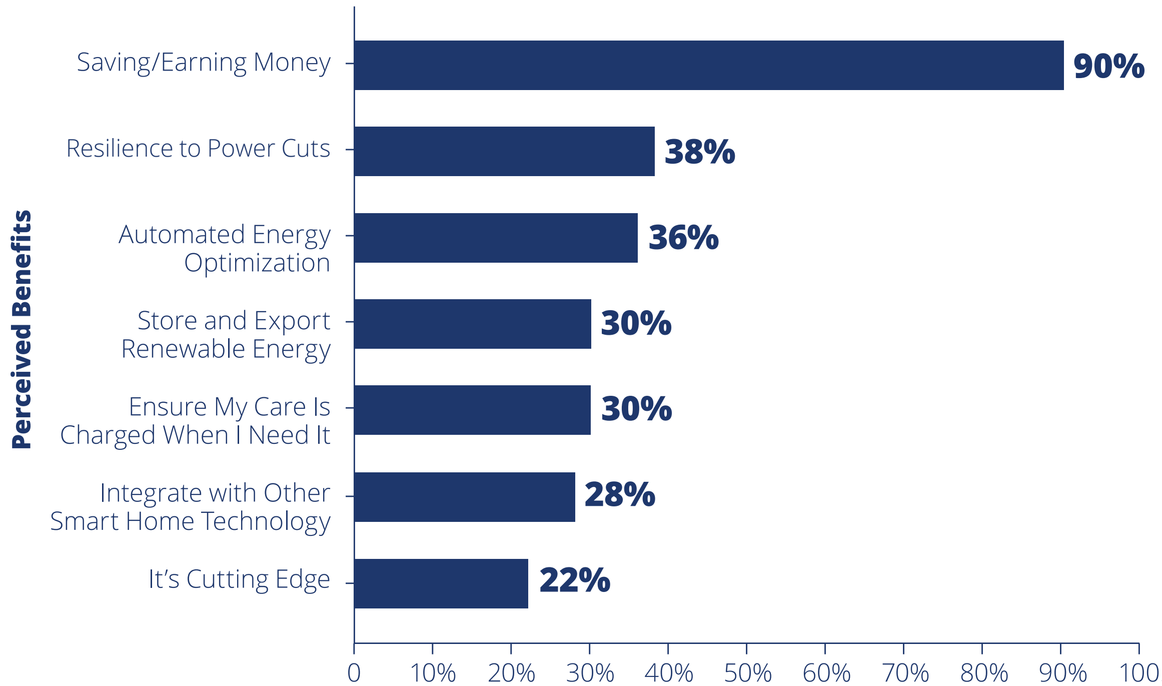
At a high level, commercial customers (for example, EV fleet operators and municipalities) were more likely than residential customers to find V2X use cases appealing; commercial customers were more strongly motivated by financial benefits while residential customers were motivated not only by energy-bill savings but also the appeal of backup power and bidirectional charging as part of a holistic smart home energy management system.

The commercial EV fleet operators surveyed were located entirely in the U.S., and ranged in fleet size from approximately 20 to 500 vehicles. Findings from the survey included:

- **The appeal of bidirectional charging:** 100% of fleet operators surveyed found bidirectional charging appealing. Fleet operators indicated that their primary benefit highlighted was financial (82% of respondents), while the remainder were motivated by on-site load balancing (V2L).
- **Required financial compensation:** Fleet respondents responded that an average of approximately $870 of compensation per EV per year made V2G export financially worthwhile. However, this value was highly dependent on the nature of the fleet and vehicle downtime.
- **Business model influenced the required financial compensation:** Fleet operators with minimum downtime between shifts (such as ride-hail/taxi fleets) required much higher levels of financial compensation (an average of $1,200 per EV per year) to recoup

34 Brattle. (May 2023). Real Reliability. The Value of Virtual Power.
35 ev.energy and Energy Systems Catapult. (2023). Consumer study.

Figure 16. Perceived Consumer Benefits of V2X



Source: ev.energy, Energy System Catapult. (2023).

for battery discharge and shorter potential routes. Fleet operators with sufficient downtime for battery discharge and recharge (municipal fleets and buses) required an average of just $470 per EV per year.

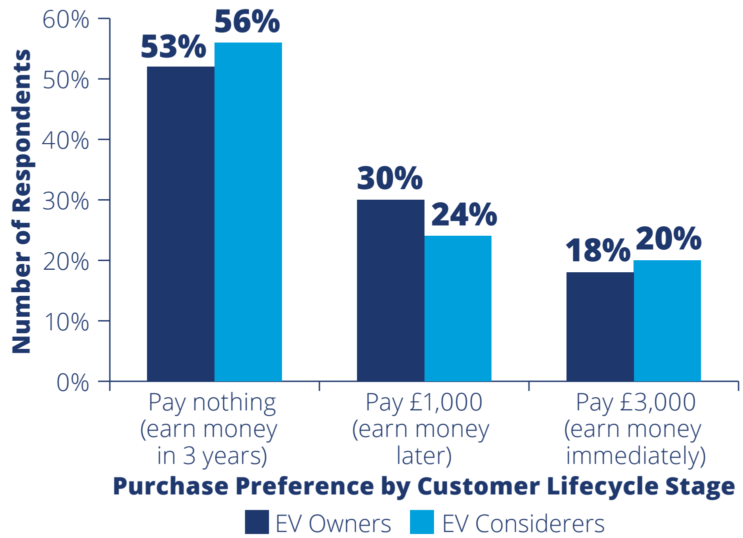
- **Concerns related to bidirectional charging:** When surveyed about their concerns around bidirectional charging, fleet operators most commonly cited reduced range/shorter routes (72%), high upfront costs (66%), and potential battery degradation (43%) concerns.

ev.energy. and its partner Energy Systems Catapult, also surveyed residential EV drivers across the U.S. and Europe. These companies presented residential consumers with both V2G and V2H propositions. V2G was framed as grid export for financial gain, with the ability to charge an EV battery using self-generated solar for those with rooftop systems and V2H as a resiliency tool during power outages. Residential consumers surveyed had between one and two EVs per household. Findings from the residential survey included:

- **The appeal of bidirectional charging:** Overall, 77% of EV drivers surveyed found bidirectional charging appealing and felt they could benefit from bidirectional charging in some way.
- **Relationship between other DER adoption and customer interest in bidirectional charging.** Among the residential customers surveyed, those with electric heating were nearly twice as likely to adopt bidirectional charging as those with gas or oil central heating. The primary motivation for customers with electric heating was to reduce energy bills (especially during peak hours), and these customers were willing to receive about 15% lower compensation for grid export than those with gas or oil central heating. Interestingly, customers who already had home battery systems were about 50% more likely to be willing to adopt bidirectional charging as those without residential battery systems; the primary motivation was to further reduce their energy bills while also generating income from grid export. There was no significant difference in bidirectional charging interest or adoption among customers with and without rooftop solar.

Kaluza, another software provider working with customers on bidirectional charging, also conducted a European consumer survey and has published findings on consumer behaviors. One such finding indicated that EV customers prefer lower upfront costs compared to earning money in a utility bidirectional charging program (Figure 17). Kaluza asked customers to compare implementing a bidirectional

Figure 17. Findings on Customer Purchase Options



Source: Kaluza. (2023). Recreated by SEPA.

charging system with no upfront costs, a £1,000 (approx. $1,300), and a £3,000 (approx. $3,900) system, all with different annual incentive streams. Customers were significantly more interested in having no upfront costs than annual incentives.

Policies and Regulations

As with any new technology, the legislative and regulatory landscape occasionally needs to adapt their rules and regulations to allow grid integration of bidirectional charging. Regulatory and legislative bodies can support wide-scale adoption of bidirectional charging by addressing existing regulatory barriers and by passing supportive legislative and regulatory rulings. Supportive rulings give utilities more ability to examine bidirectional charging and to prepare for customers adopting this technology. Supportive rulings can include mandating that utilities study bidirectional charging technologies, approving funds for utilities to pilot bidirectional charging programs, and approving new tariffs that incentivize customers to participate in bidirectional charging programs. Supportive legislation can include measures that help increase the adoption of bidirectional charging stations such as creating funds for public chargers to be bidirectional-capable.

Depending on the jurisdiction, customers will have more or less ability to install and/or interconnect their bidirectional charging system to the grid. Current challenges that were noted by the utility SMEs included:

- Regulations that prevent customers sending electricity back to the grid from any form of customer energy storage, which prevents customers from interconnecting their bidirectional charging system to the grid.
- Regulations that do not recognize EV batteries as a form of customer battery assets. While very similar in function, the mobility of the batteries as well as the need for using an EVSE means some jurisdictions see bidirectional charging systems as a new type of asset rather than a subclass of battery assets.
- A lack of established compensation mechanisms for bidirectional charging systems. It is unclear how to classify electricity received from bidirectional charging systems. These systems do not function quite like solar (so they would not benefit from net energy metering (NEM) rates) and they do not function quite like stationary storage (so they are more difficult to add into existing DR and battery storage rates).
- Data restrictions that make it difficult for utilities to work with third-party vendors. Many jurisdictions have strict data privacy standards to protect customer data, which makes it hard for utilities to share the customer data with vendors and to gain access to customers' DER assets.

"Our level of understanding is great. Which is different from a regulatory body that needs to know all things about all things. We need greater education of the regulatory body to get them in the same space to understand what needs to be done." —UTILITY SME

Some of these barriers will need to be addressed by commissions across the country, while others will need to be addressed through state legislative sessions. Many of the utility SMEs indicated that they felt that the regulatory barriers to bidirectional charging were relatively minimal and could be remedied to promote widespread adoption. In part, many of the above issues can be addressed by taking learnings from solutions developed for other DERs:

For interconnection, there have been suggestions to use the same interconnection processes that are used for solar and battery storage. For example, the same interconnection requirements of using IEEE 1547-2018 and smart inverters can be adapted from solar and battery programs to be used for bidirectional programs.

For compensation mechanisms, some utilities are adapting their DR programs to include EVs as a form of battery storage. Other utilities are talking about including bidirectional charging systems in their VPP and existing DER programs. See the "State of Bidirectional Charging in 2023: Case Study Booklet" for examples of compensation mechanisms in practice.

For hosting capacity analysis (HCA), some state legislatures are directing regulatory bodies to open new dockets on interconnection and distributed generation systems. These directives open new pathways for commissions and IOUs to study bidirectional charging, incorporate it into their IRPs, and to examine ways to consider it in HCA. The Michigan Public Service Commission (MPSC) is one such commission that has opened a Distribution System Data Access (DSDA) workgroup to examine the distribution impacts of DERs, including bidirectional charging. As part of its studies, DSDA worked with the National Renewable Energy Laboratory (NREL) to consider how to update its HCA tools to include bidirectional charging. Previously, hosting capacity studies were either conducted on a generation-dimension (in the case of solar PV) or on a load-dimension (in the case of unidirectional EV charging). DSDA's Q2 2023 filing, proposed a new bidirectional charging methodology by merging generation- and load- hosting capacity methodologies.[36]

For IRPs, some utilities are evaluating how to incorporate bidirectional charging use cases (such as V2G) into their IRP planning processes. In its 2022-2023 IRP cycle, the California Public Utilities Commission (CPUC) included V2G as a distinct aspect of its vehicle-grid integration modeling.[37] As of this publication, the CPUC was in the process of soliciting stakeholder input on modeling V2G.[38]

For data restrictions, some utilities have suggested that the learnings they have gathered from deploying advanced metering infrastructure (AMI) and managed charging programs will help them apply those same techniques to bidirectional charging programs.

Education for Policymakers and Regulators

Several utility SMEs indicated that it is difficult for regulatory commissions and legislative bodies to know enough about bidirectional charging and its implications to create new rules quickly enough to adapt to the market. Several utility SMEs stated that there needs to be more educational resources for regulatory bodies so that they can quickly come up to speed on bidirectional charging and understand the topic enough to make decisions.

36 Michigan Public Service Commission. (2023). Grid Integration Study Report.

37 CPUC. (June 2023). Inputs & Assumptions: 2022-2023 Integrated Resource Planning (IRP).

38 VGIC. (June 2023). Informal Comments of the Vehicle Grid Integration Council Regarding the Draft 2022-20223 Integrated Resource Planning Inputs and Assumptions.

Conclusion: Bidirectional Charging—A Valuable Resource for Grids and Customers

Bidirectional charging has potential to transform the role of vehicles and create new business models. The technology allows vehicles to transition from an energy consumption resource to a flexible grid asset opening new revenue streams for customers, utilities, and industry partners. In the early stages of wide-scale adoption, the bidirectional charging industry must address technology, regulatory, interconnection, and customer barriers. However, these barriers present new opportunities for utilities and industry partners to engage with one another and to redefine their relationship with consumers.

Recommendations for Utilities

- **Utilize existing interconnection processes and learnings to streamline interconnection of bidirectional charging systems.** Utilities and regulators can use existing interconnection guidelines from other (such as solar, battery storage, and backup generation) to allow interconnection of bidirectional charging systems. Streamlined interconnection processes help customers and installers to more easily implement bidirectional charging systems.
- **Develop bidirectional charging programs that allow for customers to energize bidirectional systems more expeditiously.** Bidirectional-capable chargers are first and foremost chargers for the vehicle. Consider bidirectional charging programs that allow and/or accommodate for customers more expeditiously deploying their system in charging only mode while they wait for additional interconnection studies or applications to be processed. Additionally, some V2X applications fall entirely under energization (such as backup V2H/V2B and V2M configurations) and will not need to undergo a full interconnection process.
- **Develop bidirectional charging programs.** Bidirectional charging has great potential to provide flexible grid services to utilities and provide customers with additional value streams. To access this value, utilities will need to develop bidirectional charging programs so they can use customer assets and provide customers incentives to participate in those programs.
- **Utilize existing managed charging programs to engage with and educate customers on bidirectional charging.** As utilities offer TOU, DR, and other managed charging programs, they can use those programs to educate customers on bidirectional charging. Customer education will be a critical component to increasing customers' understanding of bidirectional charging and willingness to participate in utility programs.

Recommendations for Manufacturers

- **Engage with and educate customers on bidirectional charging.** OEMs and retailers are expected to be a significant source of education for customers. Engaging with customers at the point-of-purchase can promote customer adoption of bidirectional charging systems and promote customer participation in utility programs.
- **Be clear on warranties and battery degradation.** Customers are often concerned about voided warranties and increased battery degradation after using bidirectional charging functionalities. OEMs need to be clear about which V2X applications a customer can use without impacting the warranty and need to educate customers about the impacts of bidirectional charging on batteries. Customers need to understand how some applications have minimal (or even beneficial) impacts on the battery while others applications will have more significant battery degradation.

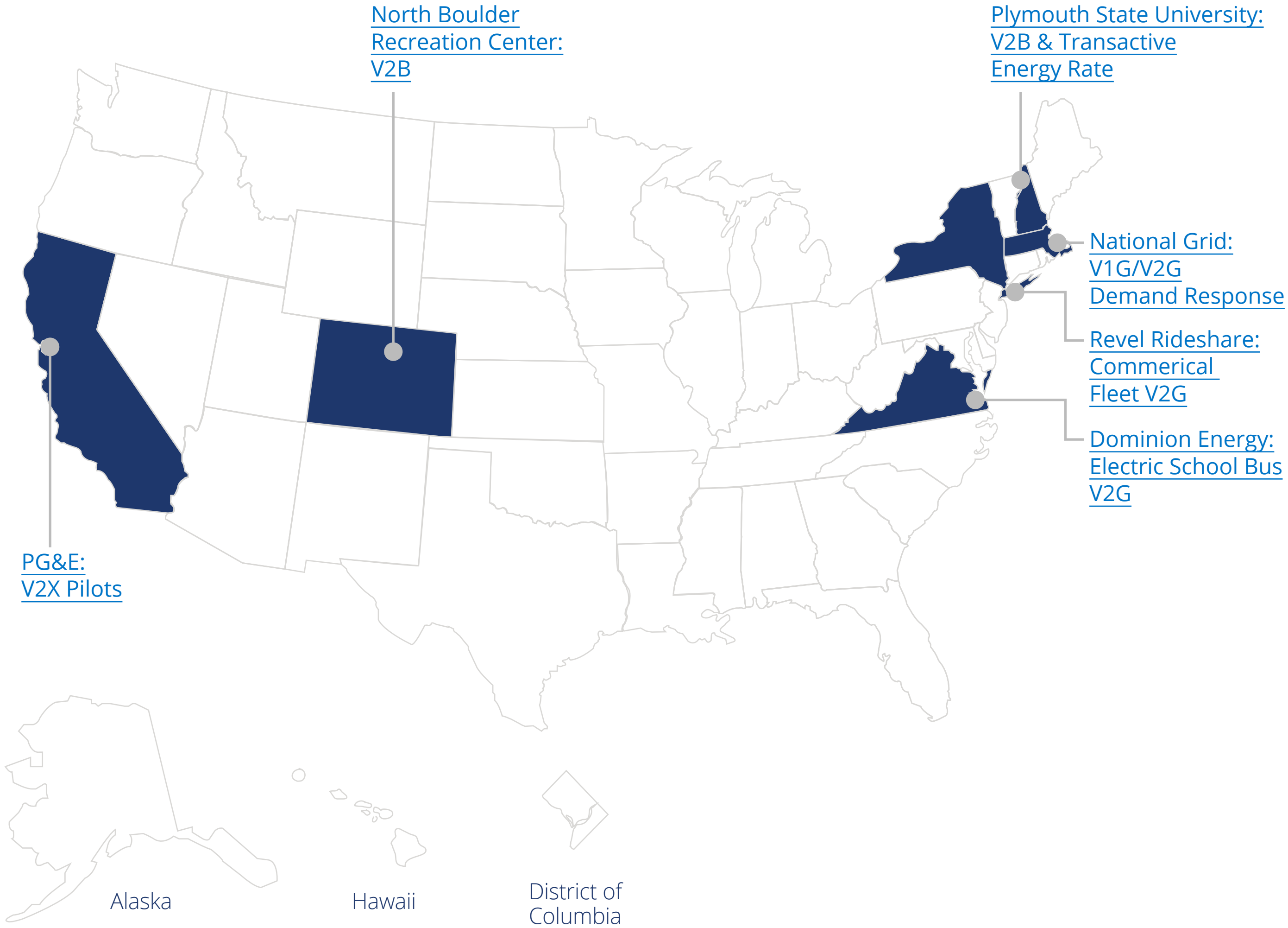
- **Bring more products to market.** Bringing more bidirectional-capable vehicles and EVSE to market improves wide scale adoption. Many utilities are waiting for more offerings to enter the market before they promote a bidirectional charging program.
- **Decrease hardware and installation costs.** Bidirectional charging systems have a price premium over their unidirectional counterparts. Decreasing the price premium will allow more customers to adopt bidirectional charging systems.

Recommendations for the Industry

- **Establish clear and fair compensation mechanisms for V2X services and market them to customers.** It is difficult for customers to make a purchase decision if they do not know what the payback will be on their investment, and it is hard for utilities to justify implementing a new program if there is no clear customer benefit.
- **Promote standardization and interoperability.** Bidirectional charging relies on many different types of hardware and software technology, and effective interoperability allows for easier implementation and scalability for bidirectional charging. Product standardization would also help customers de-risk their investments in the case where proprietary hardware/software vendors exit the market.
- **Engage with regulators and legislators to educate them on bidirectional charging.** The industry can utilize its knowledge to educate regulators and legislators about this technology. OEMs, utilities, and other stakeholders can engage in rulemaking proceedings to ensure regulators and legislators understand the potential for bidirectional charging.
- **Engage in cross-stakeholder partnerships and coalitions.** Wide scale adoption of bidirectional charging relies on a variety of stakeholders and benefits from cross-stakeholder collaboration. Industry stakeholders should participate in regular gatherings to promote interoperability, to progress policy, and to further develop the technology.

The bidirectional charging industry will continue to see many changes as this product matures and is adopted by consumers. As the industry develops, bidirectional charging will continue to expand and evolve beyond current predictions (Figure 18).

Figure 18. Geographical Locations of the Bidirectional Charging Case Studies Referenced in This Report



Source: SEPA. (2023). Note: This is not a comprehensive map of all bidirectional charging projects/programs in the U.S.

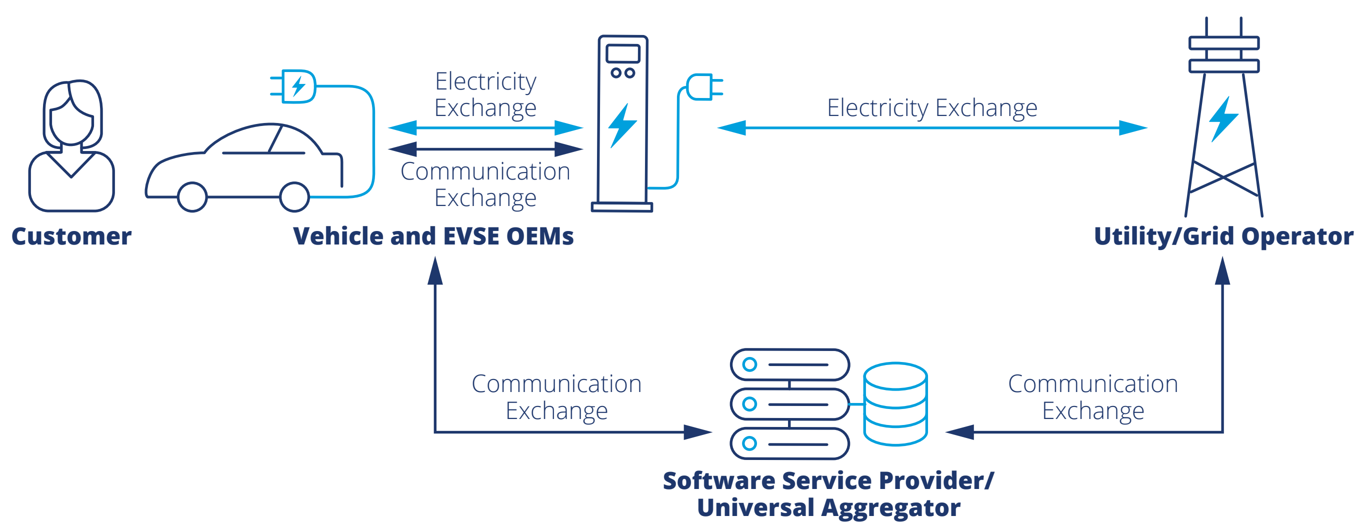
Appendix: Bidirectional Charging Technology and Vendor Landscape

The bidirectional charging ecosystem includes vehicle OEMs, EVSE vendors, network service and software providers, and project implementation partners. Figure 19 illustrates these industry partners' roles in the market. Vehicle OEMs integrate bidirectional charging capabilities and protocols into their light-, medium-, and heavy-duty EVs. EVSE vendors bring residential Level 2, commercial Level 2, and DCFC chargers to market. Network service and software providers develop software systems that can manage, control, and optimize bidirectional power flow between the EVs and the desired load (including individual loads, buildings, and the grid). Project implementation partners are a broad category of consultants, project managers, installers, and other partners that help implement bidirectional charging systems. Project implementation partners bring all of the bidirectional charging components together in a timely cost-effective manner to help customers adopt these systems and to help customers and utilities alike implement new business models. While customers are not industry partners, they are the most important component of the industry ecosystem because they are the ones paying for and using the bidirectional charging technology. It is important that industry stakeholders keep customers in mind when designing their bidirectional charging offerings.

Bidirectional charging relies on robust coordination and partnerships among these different players. At a minimum, bidirectional charging systems require advanced hardware, communications systems, and software systems. Software systems enhance the value of bidirectional charging by orchestrating EV charging and discharging for individual vehicles and for millions of EVs in aggregate. Collaboration across partners and software providers will help integrate bidirectional charging solutions and make it easier for grid operators, planners, and customers to utilize EVs as a reliable DER.

This chapter includes an examination of companies operating in North America with any of the above product offerings. The bidirectional charging space is changing rapidly, and more OEM and EVSE vendors are expected to announce bidirectional offerings in the near future. The lists included in this chapter are not comprehensive given the rapid change in the industry and instead show the increasing breadth of offerings in the marketplace. The following sections include lists of vendors, their offerings, and the role that they play in the broader bidirectional charging ecosystem.

Figure 19. Illustrative Ecosystem of Industry Stakeholders



Source: SEPA. (2023).

Vehicle OEMs

In recent years, more vehicle OEMs have announced and promoted new EV bidirectional charging capabilities. Vehicle OEMs can loosely be categorized as those that manufacture light-duty vehicles and those that manufacture medium- and heavy-duty vehicles. Customers will need to consider the vehicle's battery size and output power to determine if the vehicle is sufficient for their use case.

Light-Duty Vehicle OEMs

Light-duty vehicle OEMs help shape both the personal and small-scale commercial transportation sectors. These manufacturers are increasingly incorporating bidirectional charging capabilities into their EV offerings, helping open the residential and small commercial spaces to bidirectional charging and increasing customer acceptance and demand. Not all vehicles can support the full variety of V2X applications. Many of the vehicles available today only support V2L applications and have a maximum rated output of 1.8-3.6 kW while others can support V2V, V2B, and V2G applications and have a maximum rated output of 9.6-15 kW (Table 15). For customers only desiring extra supply for small electric loads (such as in the case of camping or temporary grid outages), a smaller battery and a 1.9-3.6 kW output can be sufficient. For customers desiring V2B applications (such as for long-term grid outages during weather events) larger batteries and a higher output capacity will be needed.

Medium- and Heavy-Duty Vehicle OEMs

Medium- and heavy-duty vehicle OEMs cater to distinct market segments including larger vehicles such as electric buses, school buses, public transit, delivery vans, refuse trucks, and others. The OEMs' customer bases include larger commercial customers, industrial, and public transit agencies. These customers tend to have fleets of vehicles and more capital available for larger charging systems. They are also often subject to utility tariffs with demand charges. Thus, fleet customers are increasingly likely to adopt bidirectional charging systems to reduce vehicle operating costs and benefit from leveraging any potential

Table 15. Alphabetical List of OEMs Selling Bidirectional-Capable Light-Duty Vehicles on the North American Market

Manufacturer	Model	Battery Size	V2X Max Output Power	V2X Application
Ford	F-150 Lightning	98-131 kWh	9.6 kW	V2L, V2V, V2B, V2G
Genesis	G80 EV	87.2 kWh	1.9 kW	V2L
	GV60 EV	77.4 kWh	3.6 kW	V2L
	GV70 EV	77.4 kWh	3.6 kW	V2L
General Motors (GM)	Silverado EV RST	200 kWh	9.6 kW	V2L, V2B, V2G
	Hummer EV Pickup	212 kWh	6 kW	V2L, V2V, V2B, V2G
Hyundai	Ioniq 5	58-77.4 kWh	3.6 kW	V2L
	Ioniq 6	58-77.4 kWh	3.6 kW	V2L
Kia	EV6	77.4 kWh	1.9 kW	V2L
	Niro EV PHEV	64.8 kWh	1.8 kW	V2L
Mitsubishi	Outlander Plug-In Hybrid	20 kWh	1.5 kW	V2L
Nissan	LEAF	40-62 kWh	15 kW	V2L, V2B, V2G
Ram	1500 REV	168-229 kWh	7.2 kW	V2L, V2V, V2B, V2G

Source: SEPA. (2023). Note: Data on battery size and V2X output capacity was gathered from publicly available vehicle specifications sheets and/or projects stating real output capacities.

savings from V2B demand reduction. Furthermore, with the ability to send significant levels of power back to the grid, these customers can extend their value proposition beyond cost savings and gain an additional revenue stream from their vehicles.

In contrast to the light-duty vehicle market, medium- and heavy-duty vehicles have larger batteries and are more often capable of V2B and V2G applications. Table 16 includes a list of common manufacturers of bidirectional-capable medium- and heavy-duty vehicles.

Other Vehicles OEMs

While few examples exist today, this category encompasses manufacturers that will eventually explore the potential of bidirectional charging in various specialized vehicles beyond those discussed above. Alternative vehicles are often non-road vehicles and include:

- **Agricultural vehicles** such as electric tractors and harvesters that have seasonal use patterns and may be good resources for utilities with winter peaks.
- **Heavy duty equipment** such as snowcats and excavators that have limited work windows and potentially large downtimes .
- **Maritime vehicles** including electric boats, yachts, and port equipment that have long periods of downtime when not in use.
- **Recreational vehicles** that are used for leisure on the weekends such as campervans, all-terrain vehicles, and golf cars.

Most of these vehicles are characterized by large battery capacities and predictable downtimes. While these sectors have yet to adopt bidirectional charging, their potential is promising. Vehicles with substantial battery capacities and significant downtimes can be ideal candidates for grid support services and provide new customers revenue streams for idle assets.

Bidirectional EVSE

Bidirectional charger vendors, which include both L2 and DCFC EVSE, cater to a broad range of customers. Across the board, bidirectional EVSE vendors have product offerings that can be installed in homes, commercial establishments, fleet yards, industrial centers, and more. As discussed in Chapter 3, bidirectional-capable EVSE needs to have AC/DC inverters and additional certification in order to connect to the utility grid. Prior to 2023, there were few vendors offering bidirectional-capable EVSE, but the market has begun to expand as more vendors announce their offerings. Q1 and Q2 2023 saw several EVSE vendors announcing their plans to release bidirectional EVSE in 2023 and 2024. As of this report, Table 17 shows a list of common vendors with EVSE offerings currently available in North America.

Table 16. Alphabetical List of OEMs Selling Bidirectional-Capable Medium- and Heavy-Duty Vehicles on the North American Market

Manufacturer	Model	Battery Size	V2X Max Output Power	V2X Application
Blue Bird[39]	BlueBird Vision Electric	155 kWh	Not specified	V2B, V2G
	BlueBird All American RE Electric	155 kWh	Not specified	V2B, V2G
BYD	BYD Type A	156 kWh	Not specified	V2B, V2G
	BYD Type D	255 kWh	Not specified	V2B, V2G
Lion Electric	Lion Electric LionA	84-168 kWh	Not specified	V2B, V2G
	Lion Electric LionC	126-168 kWh	Not specified	V2B, V2G
	Lion Electric LionD	126-168-210 kWh	25-60 kW	V2V, V2B, V2G
Thomas Built Buses	Saf-T-Liner C2 Jouley	226 kWh	60 kW	V2B, V2G

Source: SEPA. (2023). Note: Many of these OEMs do not list V2X output limitations on their specification sheets. However, existing V2X use cases often limit the max output to the size of the EVSE and frequently use 60 kW as a maximum.

39 Blue Bird has participated in V2X projects with 60 kW and 125 kW rated systems.

Table 17. Alphabetical List of Vendors Selling Bidirectional-Capable EVSE on the North American Market

Manufacturer	EVSE	Maximum Rated V2X Output Power
Autel	MaxiCharger V2X	7/12 kW
Borg Warner	RES-DCVC60-480 EV DC Fast Charging Power Conversion System (PCS)	60 kW
	RES-DCVC125-480 EV DC Fast Charging Power Conversion System (PCS)	125 kW
	RES-D3-CS20 Electric Vehicle DC Fast Charger Dispenser	60 kW and 125 kW
Corritech	Electric Vehicle DC V2G Fast Charger	30 kW
dcbel	dcbel r16	15.2 kW
Delta	V2H/V2G Bi-directional EV Charger	10 kW
Emporia	EMV2X1	11.52 kW
Enphase	Enphase Bidirectional Charger	Not specified*
Fermata Energy	FE-15	15 kW
	FE-20	20 kW
Ford	Ford Charge Station Pro	9.6 kW
General Motors	Ultium Home	9.6 kW**
Nuvve	Nuvve PowerPort	19.2 kW
	Nuvve PowerPort 3	52.3 kW
	Nuvve DC Heavy Duty Charging Station	60 kW
	Nuvve DC Rapid HD Charging Station	125 kW
Proterra	Proterra Industrial Charging System Suite	60, 90, 120, 150, and 180 kW
Rectifier Technologies	Highbury DC bi-directional	7-11 kW
SETEC Power	V2H 6kVA Charger	4.2 kW
SolarEdge	Bi-Directional DC EV Charger	24 kW
Wallbox	Quasar	7.2 kW
	Quasar 2	11.5 kW

Source: SEPA. (2023).
*Expected release in early 2024 based on public announcements.
**Based on GM's press release, not yet available on the market

Software Service Providers

The success of bidirectional charging depends on software-based, technology platform vendors that interface between charging stations, their operators, and EV drivers. They form the backbone for interoperability between the electric grid, EV charging stations, and electric vehicles, providing necessary software and communication protocols for the seamless exchange of energy and data. These vendors include optimization and control software providers whose products predict patterns, manage demand, and balance loads as well as DERMS and other aggregator providers that manage the operation of aggregated EVSE and EVs. There are opportunities for software providers to leverage EV telematics insights (such as data on battery status and the location of the EV) and EV charging data (such as utilizing granular charging controls to change the rate of charge). Combining existing insights with new advancements can increase the optimization of electricity consumption and export from millions of EVs across the grid.

Table 18 includes a list of software providers with explicit announcements on their V2X capabilities and includes software providers that have joined the Department of Energy's Memorandum of Understanding (MOU). Software providers that join the MOU are proven V2X software solutions. However, this list includes other software providers that have been cited in demonstration projects and that actively market their V2X capabilities. For brevity, this list does not include EVSE manufacturers that provide a software system along with their EVSE offerings.

Note, this list does not examine the effectiveness of a company's V2X software offerings. Additionally, there may be software providers beyond this list that have the ability to optimize and communicate with bidirectional charging systems but were not included if they did not have clear public marketing around those capabilities.

Table 18. Alphabetical List of Software Service Providers Offering Products with V2X Capabilities on the North American Market

Software Provider		
AmpUP	AutoGrid	BorgWarner
Doosan GridTech	EnergyHub	ev.energy
Fermata Energy	GE Digital	Generac Grid Services
Hitachi Energy	IoTecha	Kaluza
OATI	Octopus Energy	Peak Power
Proterra	SolarEdge	Synop
The Mobility House	Virtual Peaker	WeaveGrid

Source: SEPA. (2023).

Project Implementation Partners

Program implementation partners offer expertise to utilities, energy providers, aggregators, fleet managers, and others interested in developing bidirectional charging projects (Table 19). These partners help utilities and commercial customers navigate business transformation, customer engagement strategies, and launch and manage programs. Program services may include:

- Grid impact studies
- Interconnection design
- Program design and planning
- Equity and justice prioritization and categorization
- Rate and incentive design
- Program implementation
- Outreach and education
- Stakeholder engagement
- Technical assistance
- Data collection and reporting
- Evaluation and continuous improvement

Table 19. Alphabetical List of Program Implementation Partners Offering Services for V2X Projects on the North American Market

Program Implementation Partner		
CLEAResult	EPRI	Highland Electric Fleets
ICF	InCharge Energy	NineDot Energy
Schneider Electric	Siemens e-mobility	SunPower
Sunrun		

Source: SEPA. (2023).
Note: This is not a comprehensive list of program implementation partners.

Cross-Stakeholder Partnerships

Industry stakeholders have created coalitions and memorandums of understanding to discuss advancing bidirectional charging technologies and create interoperable solutions. These industry gatherings promote productive conversations, progress policy, and develop requirements for bidirectional charging systems. Industry gatherings include:

- Virtual Power Plant Partnership (VP3): VP3 is an industry initiative led by RMI and has 23-member organizations at the time of this publication. Member organizations include technology OEMs, software providers, and implementation partners including Sunrun, SunPower, General Motors, Ford, Virtual Peaker, and others. The organization will catalog, research, and communicate VPP benefits as well as develop industry-wide best practices, standards, and roadmaps.
- Department of Energy Memorandum of Understanding (MOU): The MOU establishes the intent of utilities, EVSE vendors, vehicle OEMs, program partners, and other industry stakeholders to create a Vehicle-to-Everything Collaboration. In Q3 2023, the MOU announced its third round of signatories.
- California's Regulatory Vehicle-Grid Integration (VGI) Working Group: The Energy Division of the CPUC launched the VGI working group that brought together 85 participants, including California's governmental and energy agencies, the California ISO, the state's IOUs, community choice aggregators (CCAs), vehicle OEMs, battery manufacturers, charging network and energy service providers, advocacy and research groups, ratepayer advocates, and other industry groups. This group provides policy recommendations to advance VGI use cases, including bidirectional charging.

Cross-stakeholder coalitions unite efforts across vehicle OEMs, EVSE vendors, software providers, and implementation partners. As bidirectional charging develops into a mass-market technology, these partnerships will be critical to ensure the technology becomes easy to adopt and is interoperable among the different systems.

Smart Electric Power Alliance

1800 M STREET, NW FRONT 1
#33159
WASHINGTON, DC 20036
202-857-0898