Best Practices on E-Bus and Grid Integration: A Guide for California Transit Fleets

A Product of the Advanced Transit Bus VGI Project

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Table of Contents

List of Acronyms

AC	Alternating Current
ARFVTP	Alternative and Renewable Fuel and Vehicle Technology Program
AVTA	Antelope Valley Transit Authority
BEB	Battery Electric Bus
CAISO	California Independent System Operator
CARB	California Air Resources Board
CEC	California Energy Commission
CNG	Compressed Natural Gas
CPUC	California Public Utilities Commission
DAC	Disadvantaged Community
DC	Direct Current
DER	Distributed Energy Resource
DoD	Department of Defense
DRIVE	Development of Rates and Infrastructure for Vehicle Electrification
EMP	Energy Management Platform
EMS	Emergency Management System
ERCOT	Electric Reliability Council of Texas
EV	Electric Vehicle
EV-PCS	Electric Vehicle-Power Conditioning System
EVSE	Electric Vehicle Supply Equipment
FC	Fast Charging
GO-Biz	California Governor’s Office of Business and Economic Development
HVIP	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project
IEPR	Integrated Energy Policy Report
ISO	Independent System Operator
LCFS	Low Carbon Fuel Standard
LD	Light Duty
LTE	Long-Term Evolution

MD	Medium Duty
MHD	Medium- and Heavy-Duty
MW	Megawatt
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturer
OIR	Order Instituting Rulemaking
O&M	Operations and Maintenance
ORNL	Oak Ridge National Laboratory
PFE	Power Flow Entity
PG&E	Pacific Gas & Electric
PHEV	Plug-in Hybrid Electric Vehicle
PV	Photovoltaic
RTO	Regional Transmission Organization
SCE	Southern California Edison
UPS	United Parcel Service
V1G	Smart Charging, or Managed Charging
V2B	Vehicle-to-Building
V2G	Vehicle-to-Grid
VGI	Vehicle-Grid Integration
VTA	Santa Clara Valley Transportation Authority
ZEV	Zero Emission Vehicle
ZNZ	Zero- and Near-Zero Emission

1 Introduction to E-Bus and Grid Integration

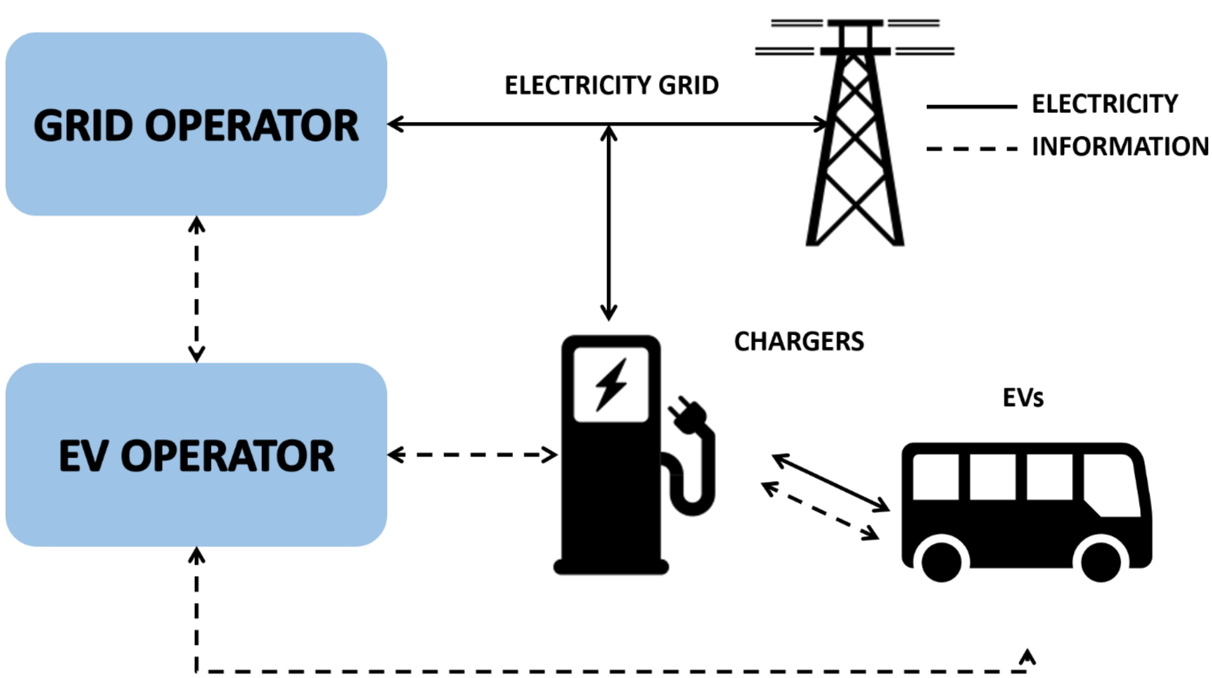
1.1 Objectives of This Guide

The number of electric buses in operation around the world has grown significantly over the last 10 years, and they are currently the fastest growing part of the electric vehicle (EV) market[i]. Electric buses have changed how transit agencies move people and have become a forefront topic for the future of public transportation. When managed effectively, battery electric buses (BEBs) can offer benefits to both the fleets that operate them and the power grid that supports them. One of the more recently explored methods of reaping some of those benefits is vehicle-grid integration (VGI), an umbrella term that describes methods for both using EVs as grid assets and smartly managing EV charging. Using two electric transit bus case studies – the California E-Bus to Grid Integration Project at Antelope Valley Transit Authority (AVTA) and the Advanced Transit Bus VGI Project at Santa Clara Valley Transportation Authority (VTA) – this guide will provide information to help other transit fleets in California better understand VGI and how they can implement it into their own operations. As such, the guide will provide information on what VGI is, what its current status is from technological and policy standpoints, and it will summarize a few best practices for transit fleets that are interested in implementing VGI.

1.2 What is Vehicle-Grid Integration?

Understanding VGI means understanding how the electric vehicle interacts with the power grid and the benefits that can be reaped from its implementation. According to the California Public Utilities Commission (CPUC), "VGI can harness the usage characteristics of and technologies within [electric vehicles] to allow them to serve as a grid asset."[ii] Figure 1 shows a simplified diagram of how VGI works with EVs, charging infrastructure, the EV operator, and the broader electric grid.

Figure 1 Simplified Vehicle-Grid Integration Diagram[iii]



In traditional EV charging scenarios, electricity is generated and distributed to the EV operator's facilities and fed through electric vehicle supply equipment (EVSE), otherwise known as the charger, ultimately reaching the EV and charging its battery with needed energy. As you can see in Figure 1, however, VGI can make it possible to open up a bi-directional flow of electricity and information, offering an opportunity for the fleet to earn revenue by supplying the grid operator with electricity when needed, or to minimize charging costs by charging under the most optimal cost scenarios.

The bi-directional flow of electricity falls under a subset of VGI called Vehicle-to-Grid, or V2G. Figure 2 shows V2G along with two other subsets of VGI called managed charging (V1G) and Vehicle-to-Building (V2B). Figure 2, adapted from a figure created by Olivine[1], also summarizes which technologies are often used in VGI systems, the areas on which VGI has an impact for fleets and grid operators, various streams of value that could be tapped into via VGI, and several ways to measure the impact of VGI systems.

Figure 2 VGI Subsets and Related Analyses[iv]

VGI SERVICES		
V1G	V2G	V2B

VGI TECHNOLOGIES AND STRATEGIES				
E-Buses/Chargers	+ Storage	+ Solar PV	+ Solar PV + Storage	+ Demand Response

VGI IMPACT ANALYSIS			
Energy	Capacity	Grid Services	Environmental

VGI VALUE STREAM ANALYSIS			
Demand Charge Management	TOU Price Arbitrage	Demand Response Revenue	Grid Resiliency / Backup Power
Solar PV Self Consumption	Distribution/Transmission Infrastructure Deferral	LCFS Credit Trading	Other Indirect & Societal Benefits

VGI USE CASE PRO FORMA ECONOMIC ANALYSIS RESULTS		
Lifecycle Cash Flow	Net Present Value	Average Annual Cash Flow
Years to Cash Flow Positive	Benefit-Cost Ratio	Internal Rate of Return

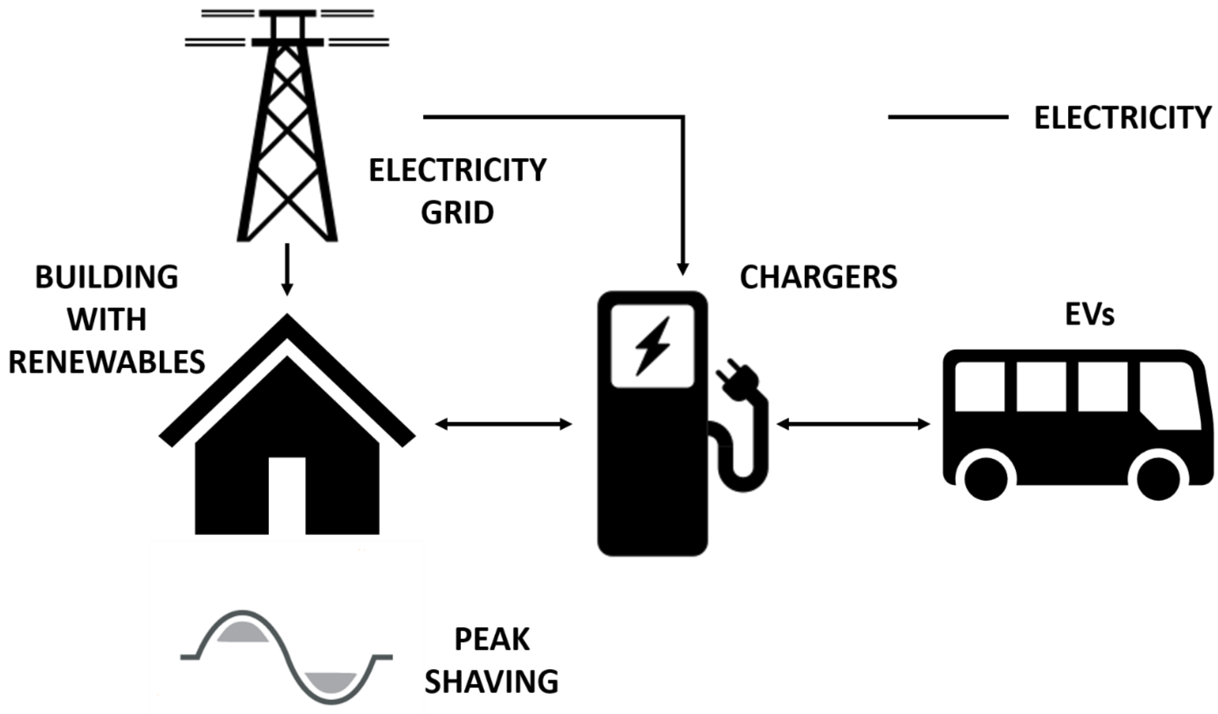
[1] Olivine is a company specializing in enabling DERs to offer grid services.

Simply put, V1G, or managed charging, is the process of using 'smart' charging software and data to make decisions on how and when to charge vehicles. Those decisions can range from using data on utility time-of-use rate structures to determine what time of day is optimal to charge vehicles, to throttling charging power up and down across multiple vehicles, and quite a lot in between. Ultimately, V1G is a technique that can enable fleets to use data and the flow of information to manage their charging routines in ways that are most cost effective for them. This can lead to less wasted energy and a more informed ability to charge at lower-cost times-of-day, both having the potential to cut charging costs for fleets.

As explained above, V2G refers to the interaction between EVs and the electric grid. For a simplified diagram of how V2G works, refer to Figure 1. V2G is characterized by a two-way flow of electricity, enabling both traditional charging of EVs as well as the ability to return electricity from EVs to the grid. One way that EV fleets can apply V2G and potentially realize financial benefits from its use is by taking advantage of existing electricity market programs provided by grid operators and utilities. Like many other products, electricity can be bought and sold on either wholesale or retail terms, and there are several electricity market programs offered by grid operators, like the California Independent System Operator (CAISO), and utilities, like Southern California Edison (SCE). Typically, electricity is sold to resellers (e.g. utilities) in the wholesale market, while the sale of electricity to consumers (e.g. electric bus fleets) occurs in the retail market. In addition to these energy markets, grid operators also solicit Ancillary Services. Ancillary services are those that grid operators must provide in order to maintain reliable transmission of electric power to consumers, and EV fleets may be well-positioned to benefit from them. Due to the grid operator's need to maintain balance between power generation and power demand, EV fleets may sell excess electricity to the operator, helping the grid operator to maintain reliability in the grid and providing the fleet with an opportunity to earn revenue. The term grid operator refers to the entity that is entrusted with transporting electricity through the grid and maintaining the grid's reliability. Grid operators can take multiple forms and they vary by region. Often, Regional Transmission Organizations (RTO) like the PJM Interconnection or Independent System Operators (ISO) like the Electric Reliability Council of Texas (ERCOT) manage the grid. California's electric grid is managed by CAISO, which provides multiple ancillary services and other electricity markets in which EV fleets could theoretically participate. The three primary services that V2G-capable vehicles can provide include bulk energy storage, operating reserves, and frequency regulation.[v] More on these services will be shared in later sections of the guide.

In addition to V1G and V2G, another subset of VGI is V2B. V2B includes the bi-directional transfer of electricity between the vehicle and a building that is tied to the local electrical system. In this system, the vehicle may store energy and serve as a backup generator of sorts, offering power during outages or to reduce the building's dependence on grid-supplied electricity during peak demand. V2B systems may also benefit from the addition of microgrids, allowing the vehicle to store excess electricity generated by other distributed energy resources (DERs) such as photovoltaic (PV) solar panels or wind power, and release that electricity when needed. V2B differs from V1G in that it allows a bi-directional flow of information and electricity, while V1G does not. V2B differs from V2G in that it constrains the flow of electricity between the vehicle, a building, and other local energy asset like a microgrid, while V2G opens the flow to the broader electrical grid. Figure 3 below depicts how V2B works in a simplified form.

Figure 3 Simplified Vehicle-to-Building Diagram



1.3 Benefits of VGI to Transit Fleets and the Grid

VGI is still a relatively new concept, and as such its full suite of benefits to transit fleets, grid operators, and utilities requires further definition. Nevertheless, there are several potential benefits to speak of for both of those stakeholders. The potential benefits of VGI to fleets include but are not limited to those listed in Table 1 below.

Table 1 Potential Benefits of VGI to Fleets

Subset of VGI	Potential Benefit to Fleets
V1G	Avoided energy costs and demand charges from peak shaving and/or demand response
V1G	Cost savings from more efficient energy use and charging patterns
V1G	Improved operations from the use of enhanced data collected by deployed V1G systems
V2G	Revenue from participating in electricity markets, like ancillary services markets
V2G	Cost savings from participating in electricity markets, like ancillary services markets
V2G	Opportunity to swiftly adjust power demand in response to signals and information received from utilities or other grid operators (Demand Response)
V2B	Avoided demand charges for the building
V2B	Backup power available for the building from a zero-emission source

Through implementation of V1G, fleets have the potential to better manage charging their fleet of electric vehicles, especially as they scale-up the number of EVs in their fleet. V1G can do this by providing robust and important data to fleet managers regarding the vehicles' operations, charging needs, scheduling and dispatch needs, and more. Using this data wisely offers an opportunity for fleets to save money through cost avoidance, and it may also improve the efficiency of EV operations. In addition to this, fleets could benefit from V1G by avoiding high-cost charging at peak hours, as well as costly demand charges. By combining the data mentioned above with information about the utility's time-of-use rate structure, fleets can make more informed decisions about how and when they charge, potentially saving them money in the process. The technology associated with V1G may also help fleets conduct demand response activities in cooperation with their utility to lower power demand when needed.

Through V2G, fleets can participate in electricity markets, such as by providing ancillary services to their grid operator in return for revenues. As stated above, V2G-capable fleets can help grid operators maintain optimal frequency of the grid, and they can potentially serve as an operating reserve to help the grid operator maintain balance between power generation and demand. This could involve both throttling the power to a fleet's electric chargers up or down, depending on what the grid operator requests, as well as sending electricity back to the grid operator, both of which could provide the fleet with revenues that may be used to offset charging costs. More detail will be given on these options later in the guide.

Finally, fleets could benefit from V2B through shifting electricity between their vehicles and their facilities. For example, if it works with their operations, a fleet could use excess energy stored in the vehicles' batteries as a power source for certain functions of a building during peak hours, potentially lowering costs. Also, having a fleet of V2B-capable electric vehicles on hand could provide backup power in the case of an outage.

Fleets are not the only group that can benefit from VGI technologies. Grid operators and utilities also stand to benefit. The potential benefits of VGI to grid operators and utilities include but are not limited to those in Table 2 below.

Table 2 Potential Benefits of VGI to Grid Operators and Utilities

Subset of VGI	Potential Benefit to Grid Operators
V1G	More stable and predictable demand from V1G-capable EV fleet customers
V1G	Ability to lower power demand via demand response
V2G	Help from V2G-capable EV fleets in maintaining grid frequency (regulation up and regulation down services)
V2G	Help from V2G-capable EV fleets in maintaining balanced power generation and power demand (operating reserves)
V2B	Potential to lower peak demand from V2B-capable EV fleet customers
VGI (in general)	Potential to avoid costly grid capacity upgrades

By servicing EV fleets that are V1G-capable (see Section 2 for a description of what makes fleets V1G-capable), utilities stand to benefit through more stable and predictable demand curves from these customers, which then also benefits grid operators managing regional grid assets. They can also implement demand response actions with V1G-capable fleets, requesting the fleets to lower power demand when needed. As EV fleets stabilize their own energy demands and load profiles, utilities and grid operators will be better able to predict the needs of these fleets. As discussed above, EV fleets can potentially benefit from V2G by helping grid operators with frequency regulation and by serving as an operating reserve. The benefit of this to the utility and grid operator is a more stable and reliable electric grid. Additionally, as V2B-capable EV fleets can lower their peak demand, grid operators and utilities could benefit by being able to devote resources to other loads that need power during peak hours. Finally, VGI in general may benefit utilities and grid operators by reducing the need for costly grid capacity upgrades to meet increasing demand, instead relying on EV fleets for some of those demands.

As stated above, VGI is still a relatively new concept and so the benefits listed above remain to be tested and quantified in depth. However, it is important for fleets, grid operators, and utilities to keep these potential benefits in mind as they start to consider VGI. The remainder of this Best Practices Guide will be devoted to explaining how California transit fleets may start implementing VGI as well as recommended best practices in doing so. Section 2 provides a high-level overview of readiness criteria which transit fleets should plan to meet for each form of VGI discussed above. Section 3 explains a detailed list of best practices and recommendations based on the learnings from the Advanced Transit Bus VGI Project and the California E-Bus to Grid Integration Project. Section 4 provides some information on the current status of VGI in California from both a policy and technological standpoint. Finally, Section 5 includes concluding remarks and a list of key takeaways for California transit fleets.

2 Transit Fleet Readiness for VGI

Before adopting any form of VGI, transit fleets must be sufficiently prepared, making sure certain prerequisites are met and fleets are adequately equipped. At the most basic level, this includes certain types of hardware and software, a certain level of systems and software integration, and certain external partners. In addition to these prerequisites, fleets should also consider the relative level of difficulty and commercial feasibility for each type of VGI. Of the three types of VGI, V1G is the most widely applicable to fleets and easily adopted with relatively little prior preparation and the fewest prerequisites. V1G is also the most commercially feasible VGI technology at the time of writing this guide. V2G is more complex and requires a significant amount of coordination among partners, as well as significant investment in setting-up the needed infrastructure to implement it. At the time of writing this guide, the commercial feasibility for this form of VGI is challenging given the lack of defined policies, programs, fully-defined value, and the nascent associated technology which still requires refining (see Section 4.3.1). An additional issue regarding V2G commercialization is the relatively low electric bus penetration rates among transit fleets, however, this challenge is somewhat self-solving as public transit fleets in California are mandated to be zero-emissions by 2040. Finally, V2B is arguably more complex than V1G but less complex than V2G. It is commercially feasible at the time of writing this guide, but like all other forms of VGI it will require significant time and resources to set-up the technology. This section will briefly summarize the minimum prerequisites that transit fleets must meet to implement each form of VGI before going into more detail on the best practices for implementation in the following section.

V1G has the fewest prerequisites out of the three forms of VGI. At the most basic level, V1G requires an electric vehicle (or plug-in hybrid - PHEV) and charging infrastructure. Additionally, a suite of integrated software must be procured to monitor several different assets and attributes of the fleet and its charging. First, scheduling software is needed to manage the optimal times for charging and how much charging is necessary for each vehicle to complete its daily duty cycle. This may allow for reduced power demand and increased charging efficiency by preventing fleets from overcharging their vehicles. Secondly, telematics software must be installed in order to monitor basic information from the vehicles and chargers, such as the energy the vehicles consume, the distance the vehicles travel, and how long they are in operation, allowing fleet managers to properly assess the needs of each vehicle. This is supported by other data and software, such as maintenance databases to monitor vehicle downtime and energy flow information from the power provider. Advanced metering is also useful to enable real-time capture of utility power readings, which is an enabling feature of VGI systems that works to manage demand. In the Advanced Transit Bus VGI Project, these pieces of software were developed separately but managed by one overarching system, which VTA and its partners call an Energy Management Platform (EMP). An EMP of this sort can allow fleet managers to manage the flow of electricity to the buses, making sure charging is done efficiently and effectively, building a foundation for fleets upon which further integration can be completed.

V2G builds onto the infrastructure that is required for V1G. V2G also requires an electric vehicle or PHEV, charging infrastructure, and an integrated software platform to manage certain parameters like telematics, charging data, scheduling, and metering, but there are a few additional hardware and software components. The V2G system must be able to covert power from direct current (DC) to alternating current (AC) of the correct frequency before transferring that power back to the grid.[vi] This can be done using an inverter. Additionally, independent system operators (ISO) tend to require a minimum amount of power before an electric vehicle is eligible to participate in electricity markets. What this value is will depend on the ISO, market conditions, and the electricity market that is bid into. V2G also requires sophisticated software that can give real-time control to fleet managers over charging and discharging balance in order to maximize the energy generated and the energy discharged. These load-management tools are important for communicating with the electric grid and were not entirely necessary with unidirectional integration.[vii] Lastly, there are duty cycle requirements. The longer a vehicle is parked and plugged in, the longer the grid will have access to the energy stored on the electric vehicle.[viii]

Implementation of V2B has similar requirements to V2G. Like V2G, all the infrastructure required for V1G is also required. This includes an electric vehicle, adequate charging infrastructure and an integrated software platform to manage charging, telematics, and scheduling.[ix] In addition, many of the issues and requirements specific to V2G are also required for V2B. This includes power conversion hardware and more sophisticated charging management software. These specific tools need to be modified to more adequately communicate with the building's electric infrastructure as opposed to the broader electric grid.

To summarize the guidance given above, Table 3 outlines the basic hardware and software needed for each type of VGI. It is important to note that every transit agency may have its own unique considerations as they pursue VGI implementation, but the items listed in Table 3 represent a common set of hardware and software required.

Table 3 Basic Hardware and Software Needed for VGI

VGI Type	Hardware or Software	Basic Necessary Items
V1G	Hardware	Electric Bus
	Hardware	EVSE
	Hardware	Advanced Metering
	Hardware	Communications Technology
	Software	Route Management
	Software	Bus Telematics
	Software	Maintenance
	Software	Tracking Charge Events
	Software	Integration Across Software (Where Possible)
V2G	Hardware	Electric Bus
	Hardware	EVSE
	Hardware	Advanced Metering
	Hardware	Bi-Directional Inverter
	Hardware	Communications Technology
	Software	Route Management
	Software	Bus Telematics
	Software	Maintenance
	Software	Tracking Charge Events
	Software	Load Management
	Software	Grid Communications
	Software	Integration Across Software (Where Possible)
V2B	Hardware	Electric Bus
	Hardware	EVSE
	Hardware	Advanced Metering
	Hardware	Bi-Directional Inverter
	Hardware	Communications Technology
	Software	Route Management
	Software	Bus Telematics
	Software	Maintenance
	Software	Tracking Charge Events
	Software	Load Management
	Software	Building Communications
	Software	Integration Across Software (Where Possible)

In addition to acquiring and installing the right hardware and software, transit fleets will find that VGI implementation requires collaboration with several external partners. In order to successfully implement any type of VGI, fleets should be in continual dialogue with their utility, their software providers, the original equipment manufacturers (OEMs) providing their buses and chargers, and CAISO if needed. Communication with the utility is necessary for the fleet to assess which electric rates are best suited for their operations, to ensure they have adequate power to meet their charging needs, to collaborate on any demand response activities, and to discuss any electricity market participation. Collaboration with software providers and OEMs is crucial, as VGI-implementation is largely an integration problem. As will be discussed further in Section 4.2, the Advanced Transit Bus VGI Project at VTA required the collaboration of several software providers and OEMs. Integrating the disparate pieces of software and hardware was a major milestone for that project, and other transit agencies should expect similar experiences. Finally, communication with CAISO may be required for VGI implementation if a fleet wishes to bid into any ancillary services or other electricity markets offered by CAISO. It is recommended that transit fleets interested in implementing VGI technology communicate with these partners early and often. The following section will expand on these points, as well as other best practices for implementing VGI.

3 Best Practices for Transit Fleets Implementing VGI: Learnings from the Advanced Transit Bus VGI Project and the California E-Bus to Grid Integration Project

The Advanced Transit Bus VGI Project at VTA, and the California E-Bus to Grid Integration Project at AVTA were both California Energy Commission (CEC)-funded projects to examine VGI implementation in California transit fleets. As will be discussed in Section 4.2, both projects had similar scopes but different approaches. Broadly, both projects aimed to demonstrate various VGI systems in real-world operations. As a product of the former project at VTA, this section of the guide provides recommendations and best practices for transit fleets pursuing VGI implementation based on the learnings of both projects

3.1 Partners

The several project partners which provided the authors of this guide with feedback on best practices for VGI implementation offered many different considerations for fleets. However, one of the most frequently expressed sentiments was the importance of partnership for successfully implementing VGI. VGI implementation is a complex and multi-faceted technical challenge consisting of problems to be solved regarding hardware, software, operations, cost-effectiveness, and project management. Fleets that collaborate well with their partners are likely to be more successful as they develop VGI systems. Project partners range multiple vocations. Table 4 on the next page shows the multiple partners on the projects at VTA and AVTA, along with descriptions of their roles on those projects.

Table 4 Partners on the VTA and AVTA VGI Projects

Partner	Roles and Responsibilities
Prospect Silicon Valley	A nonprofit cleantech innovation hub that focuses on for mobility and energy solutions for urban communities. ProspectSV managed the VTA project.
CALSTART	A national non-profit focused on clean transportation. CALSTART led knowledge transfer efforts on the VTA project, including this guide.
VTA	A fleet demonstrating VGI technology, located in San Jose, CA.
AVTA	A fleet demonstrating VGI technology, located in Lancaster, CA.
Proterra	Electric bus manufacturer.
National Renewable Energy Laboratory (NREL)	A national lab that conducted analysis and modeling on business case and fleet electrification planning for VTA.
ChargePoint	Electric charger manufacturer and provider of ChargePoint Cloud Services, tracking data on charge events. ChargePoint helped design the EMP for VTA.
ZNE Alliance	A non-profit that conducts projects on energy services, the built environment, and sustainable mobility. ZNEA managed the AVTA project.
Pacific Gas & Electric	The utility supplying power to VTA.
Southern California Edison	The utility supplying power to AVTA.
Energy Solutions	A company that designed and implemented a bus operator driving efficiency incentive program.
NOVA	A Bay Area workforce development organization that worked with CALSTART and ProspectSV on translating project learnings into curriculum for students in California.
Clever Devices	A software provider that provided telematics software to track bus performance and operations.
Trapeze	A software provider that provided route management software.
Kisensum	A software provider that helped integrate each disparate software system into a combined EMP. Acquired by ChargePoint.
Olivine	A company that provided analysis on VGI valuation, use cases, and demonstration planning on the AVTA project.

Other fleets pursuing VGI implementation may not need all the same partners shown in Table 4. Consultants and non-profit organizations on the AVTA and VTA projects provided valuable analyses and insights as the technology was in a demonstration phase. However, fleets interested in VGI should be most concerned with the technology providers, utilities, and grid operators that they must interact with to successfully implement the technology. As explained in Sections 3.2 and 0, VGI is largely a technical challenge requiring significant resources put toward integrating separate pieces of hardware and software, and cooperation among these partners is key. As with the rest of the technology deployment processes, fleets are recommended to plan collaboratively, and communicate with partners early and often.

3.2 Hardware Requirements and Considerations

VGI technologies require certain hardware to be installed and tested before operations can start. This includes the obvious electric bus with adequate battery capacity and charging infrastructure, but also additional VGI-enabling equipment. For all forms of VGI, the charging infrastructure must be 'smart' and able to be monitored and controlled by software, so energy and information flow can be controlled and set to the most optimal level.

From the Advanced Transit Bus VGI Project and the California E-Bus to Grid Integration Project, several best practices relating to hardware installation were recommended by multiple partners, most notably ChargePoint. ChargePoint noted that hardware installation requires ongoing cooperation with each partner and thorough planning. Each issue related to infrastructure development should be considered and thoroughly understood before installation takes place. Importantly, time must be given to understand and abide by any building codes and city permits, and make sure any infrastructure installation is properly abiding by local regulations. Additionally, when allocating space for new hardware, consideration should be given to future expansion as the fleet scales-up. As the basic EV charging infrastructure is installed, fleets must also plan to integrate VGI-enabling hardware, which can vary based on VGI type.

Table 5 shows a list of basic hardware required for each type of VGI.

Table 5 Basic Hardware Required for VGI

VGI Type	Basic Necessary Hardware
V1G	Electric Bus
	Networked Charging Equipment
	Advanced Metering
	Communications Technology
V2G and V2B	Electric Bus
	Networked Charging Equipment
	Advanced Metering
	Bi-Directional Inverter
	Communications Technology

As explained in Section 2, V1G has the fewest pieces of basic required hardware, but not by much. Due to the bi-directional flow of electricity, both V2G and V2B will require a bi-directional inverter that can convert DC power to AC power and vice versa. Importantly, fleets are advised to install chargers that are networked, have charging management capabilities that will enable the fleet to manage things like power delivery, and chargers should have the ability to integrate with other systems such as telematics and route management. Chargers with these capabilities allow the fleet to utilize data to make smart charging decisions.

The table above represents the minimum hardware requirements for VGI. Fleets may find that additional equipment is cost effective and suits their operations, including other DERs like solar PV panels and battery storage. Fleets are encouraged to assess their own circumstances to determine if such additional equipment is necessary and adds value to their VGI goals. Additionally, fleets are encouraged to keep scale in mind as they deploy VGI technologies. As the number of electric buses in a fleet grows, the power demands for that fleet will grow, and so will the case for VGI, as well as the amount of information that must be processed.

Section 3.3 will outline recommendations for software that must be implemented to enable VGI, and as fleets consider software requirements, they are advised to consider the interactions between hardware and software as well.

Table 6 outlines VGI-enabling hardware functionalities and communication protocols for EVSEs, as found in a September 2020 CEC grant solicitation for zero-emission transit fleet infrastructure deployment (GFO-20-602), explained further in Section 4.1.

Table 6 Recommended Hardware Functionalities and Communication Protocols to Enable VGI[x]

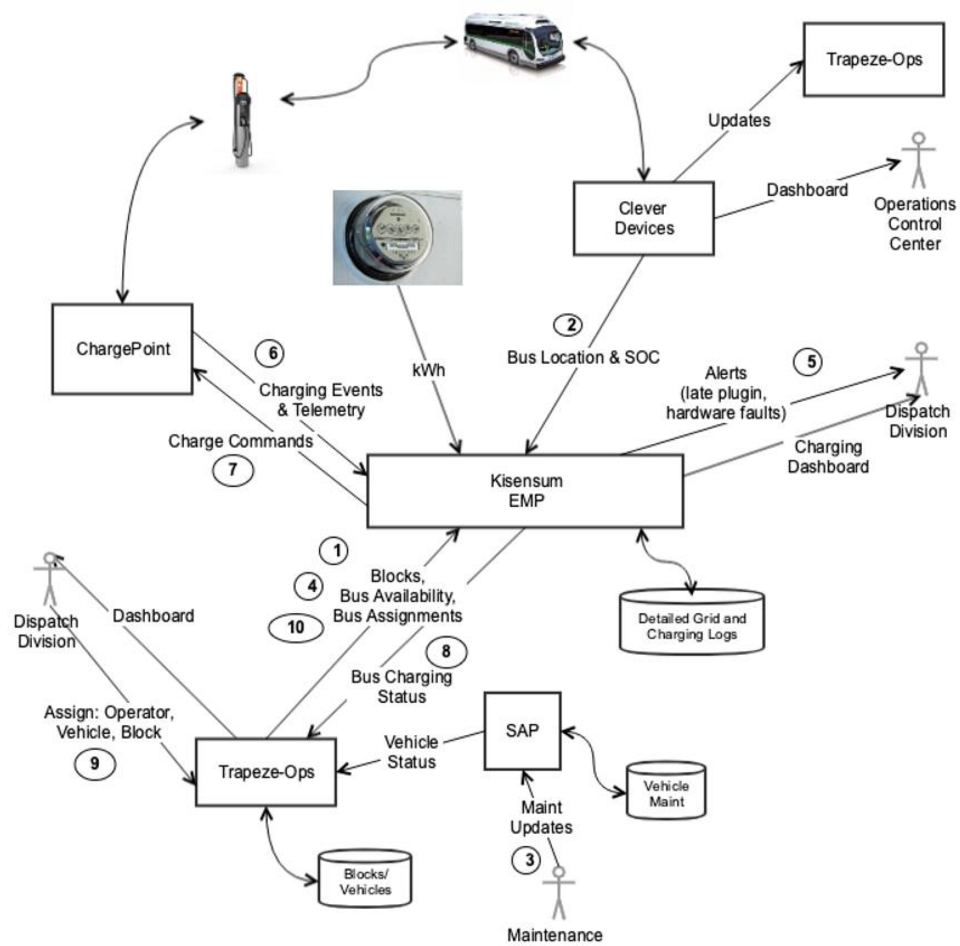
Functionality Type	Functionality Description
Facilitate vehicle-charger interoperability	Utilize connectors and interfaces which are compatible with MHD vehicles, including but not limited to J1772, CCS1, and J3105
Leverage open standards-based network communications	Enable the EVSE to communicate with electric vehicle service providers (EVSP), local fleet energy management system, and/or the utility by using IEEE 802.11n for high-bandwidth wireless networking, or IEEE 802.3 for Ethernet connectivity for Local Area Network and Wide Area Network applications
	Comply with Transmission Control Protocol (TCP)/IP and IPv6, or its successor version(s)
	Leverage Open Charge Point Protocol (OCPP) version 1.6 or later, Open Automated Demand Response (OpenADR, IEC 62746-10-1 ED1), or those outlined by the Smart Grid Interoperability Panel (SGIP) Catalog of Standards, the NIST Smart Grid Framework, the American National Standards Institute (ANSI), or other well-established international standards organizations such as the International Organization for Standardization (IDO), International Electrotechnical Commission (IEC), International Telecommunication Union (ITU), Institute for Electrical and Electronics Engineers (IEEE), or Internet Engineering Task Force (IETF)
Receiving signals	Be capable of receiving energy management signals from an EVSP, EMS, or a utility
Automatically adjusting charging load	Be capable of automatically adjusting charging load in consideration of the energy management signal
Bi-directional power flow	If V2G or V2B is desired, be capable of bi-directional power flow

This table, produced by the VGI Communications Protocol Working Group led by the CPUC, provides fleets with recommended hardware design functions that may help to enable VGI technologies. In summary it suggests ensuring interoperability, that updates and modifications can be made remotely, and that technologies which are in-line with industry standards be used. As fleets pursuing VGI implement the appropriate hardware and software, they are advised to test their technology prior to commencing operations. This is especially important for V2G systems, which are recommended to be tested for functionality well in advance of starting live CAISO market participation.

3.3 Software Requirements and Considerations

For VTA and the other Advanced Transit Bus VGI Project partners, getting software implemented and integrated correctly was one of the most important facets of deploying VGI. Figure 4 shows the schematic for the EMP developed by partners on the Advanced Transit Bus VGI Project.

Figure 4 Schematic of the ChargePoint Energy Management Platform Developed for VTA[xi]



This EMP was developed by integrating multiple disparate pieces of software with the aim of managing the charging of VTA's growing electric bus fleet. Clever Devices provided software that inputs telematics data on vehicle location and energy consumption. Trapeze-Ops provided software that inputs data on fleet route management. And, ChargePoint's Cloud Services inputted information on bus charging events. Also, ChargePoint installed a metering device at VTA's utility connection to capture a continuous stream of real-time utility power readings and relay them via a long-term evolution (LTE) uplink to the EMP. When properly integrated the EMP allows for each one of these different pieces of software to work together. For example, the EMP may allow charging management software to work with route scheduling software to know exactly when the buses are available and how much energy they will need to complete certain routes. Taken together, the system works by providing VTA with robust information across each of these items, enabling communication between technologies, further enabling the fleet to manage its charging more efficiently.

As VGI technology matures over time, fleets may have more off-the-shelf software options to accomplish what this EMP aims to do, but at the time of writing this guide no such solution was known to be on the market. Thus, software integration is a critical step in deploying VGI in California's transit fleets, and fleets are advised to work closely with their technology providers in deploying VGI-related software. As was the case with the Advanced Transit Bus VGI Project, below is a list of recommended software for transit fleets to consider:

- **Telematics Systems:** Data from telematics systems gives fleets the ability to monitor and keep track of general performance data, such as speed, distance traveled, and energy consumed. This allows fleet managers to keep track of how buses are performing and identify any issues that may arise.
- **Route Scheduling Software:** Integrated route scheduling software allows fleets to know exactly where each vehicle is always , and perhaps more importantly, where each vehicle is going to be. This allows fleet operators to understand how much energy each vehicle will need each day, when each vehicle will be at the depot for charging, and the departure time for the next route that each vehicle will drive.
- **Charging Management Software:** EVSE-related software allows fleet managers to closely manage vehicle charging, and to know exactly when a vehicle is charging, how much energy it needs, and when it may be available for other VGI-related services like demand response. This software is critical for both V1G and V2G, and allows for direct control over vehicle charging, maximizing efficiency.
- **Maintenance Logs and Tracking Software:** Knowing when a vehicle is unavailable due to maintenance is vital for the smooth operation of an electric fleet. A simple database that communicates with other systems should suffice, and this addition can help a fleet adjust when a bus is out of service.
- **Communication with Grid Operators and Utilities:** Fleets that are considering V2G will need to be able to communicate with grid operators and respond to their signals for service. Setting up systems that can accomplish this while also communicating with the other sub-systems discussed above will contribute to enabling V2G for interested fleets.

In order to successfully integrate all these disparate pieces of software, the proper communication protocols must be put in place by the fleet and their partners. As discussed in Table 6 of Section 3.2, and explained further in Section 4.1, certain communication protocols are recommended. Refer to Table 11 and its surrounding text for more information.

Lastly, partners on the Advanced Transit Bus VGI Project highlighted the importance for each technology provider to collaborate, as multiple groups will be involved with software development and integration. Partners also mentioned how important it is to develop manual fail safes and workarounds in case any issues arise with software. This keeps fleets running if any issues do arise. Finally, as discussed in Section 3.2, fleets pursuing VGI implementation are advised to test their technology prior to starting operations. This is especially important for V2G systems, which are recommended to be tested for functionality well in advance of starting live CAISO market participation. Taken together, these best practices may help transit fleets get started in solving VGI software problems.

3.4 Operational Procedures and Best Practices

As fleets consider deploying any form of VGI, be it managed charging or a V2G pilot project, operational changes may be worth evaluating. Transit fleets that adopt electric buses can often reduce their operating costs by doing so, but the deployment process adds a few new considerations to contend with, including bus range, charging duration times, and charging schedules. Fleets are encouraged to look at their standard operating procedures early on in an electric bus deployment, and to identify ways they can ensure that they are accommodating the electric buses. The following are practices that may help them see to it that their electric fleet benefits them.

3.4.1 Optimizing Routes and Schedules

Often, transit fleets use plug-in chargers and charge their electric buses overnight due to the lack of service during those hours. However, some fleets may opt for different charging schedules that require on-route fast chargers, if they work best with their operations. As fleets adopt electric buses, it is important for them to keep in mind the amount of time that it is expected to take for the buses to charge, which depends on their battery sizes and the power level of the fleet's chargers. In addition to this, fleets adopting electric buses will be tasked with considering utility electricity rates that vary per time-of-day in combination with their route requirements. Fleets considering V2G must also consider the market conditions for ancillary services and other electricity markets that they may want to bid into. VGI can be used as a tool to help fleets in navigating the decisions that accompany these considerations. By tracking and processing the fleet's charging needs, their operations, and surrounding market conditions, VGI can help the fleet decide what adjustments may benefit them as they deploy electric buses. Fleets are encouraged to assess their typical fueling and route schedules early on in an electric bus deployment, and to consider their options when it comes to scheduling, using VGI to help.

3.4.2 Incentivizing Efficient Driving

One of the levers that can be pulled to improve operational efficiency for electric transit bus fleets is driving efficiency in kWh consumed per mile. While fleets with conventionally-fueled buses must maintain proper fuel economy in miles per gallon, fleets with electric buses will find that driving efficiency has an additional layer of importance due to the interaction of vehicle range and efficiency. Refueling stations for buses running on diesel or CNG are abundant compared to electric charging stations. Added to this is the need to consider utility electricity rates and possible demand charges. The more efficient the buses, the less the buses may need to charge overall, potentially lowering operating costs. Fleets should encourage their drivers to maintain driving efficiencies at reasonably high levels, and one option for doing this is incentivizing efficient driving. As an example, partners at the California E-Bus to Grid Integration Project at AVTA developed a driver incentive program as part of project scope. As will be discussed in Section 4.2.2, a company called Energy Solutions worked with AVTA to train its bus operators on efficient electric bus driving practices, and they created an incentive-based system that rewarded top performing operators complete with a dashboard made available to track and report staff scores. Fleets may consider this option as well as other ideas to improve driving efficiencies.

3.4.3 Training Needed Staff on VGI

In addition to driving efficiency, necessary transit agency staff must be trained on each facet of the fleet's VGI system. Operators, dispatchers, maintenance staff, and management need to know how the VGI system works, how to operate it, and how it may have changed standard operating procedures. This training may include but is not limited to the following: understanding and operating each part of the VGI-related software and hardware, electric bus maintenance, new operating procedures resulting from deployment of electric buses, and proper charging protocol. Fleets are encouraged to assess the training needs across their staff and to conduct training as appropriate.

3.4.4 Be Flexible

Adopting electric buses may require changes to a fleet's operations simply due to the differences between electric bus operations, charging, and maintenance compared with diesel or CNG buses. Transit agencies are encouraged to be flexible and open to change, especially as they scale-up the number of electric buses in their fleets. While modifying operating procedures that have long been successful may feel counterintuitive, it may very well benefit the fleet to adjust in ways that accommodate efficient electric bus operations. As stated above, multiple facets of bus operations may change as fleets adopt electric buses: maintenance requirements will likely be different, driving practices may change, refueling practices will change, and fleets may also have a new need to use VGI-related software. Fleets are encouraged to be flexible with these changes, and to look to case studies from early-adopting transit fleets for best practices and lessons on adapting to such changes.

3.5 Cost Considerations

As will be discussed further in Section 4.4, Table 7 shows a simplified list of costs that transit fleets may need to consider as they pursue VGI implementation.

Table 7 Simplified VGI Cost Considerations

Category	Cost Consideration
Basic Capital Costs	Electric Bus
	Electric Bus Battery Capacity Upgrades
	Charging Equipment
	VGI-Related Software Material Costs (bus telematics, route management, tracking charge events)
DER Capital Costs	Solar PV Panel Material Costs
	Battery Storage Material Costs
Installation Costs	Charging Equipment Installation Costs
	VGI-Related Software Installation Costs
	Labor Costs for Integrating Disparate VGI-Related Software
	Solar PV Panel Installation Costs
	Battery Storage Installation Costs
Operations & Maintenance (O&M) Costs	Bus Charging Costs
	Bus Maintenance Costs
	Solar PV Panel O&M Costs
	Battery Storage O&M Costs
Other Miscellaneous Cost Considerations	Fleet Staff Training Costs
	Cost of Participating in Electricity Markets
	Battery Degradation and Replacement Resulting from Discharging
	Cost of Working with an Aggregator

It is important to reiterate that each fleet will have its own set of circumstances that dictate which costs they incur in setting up VGI. While all fleets that are pursuing VGI implementation will incur costs to purchase buses, chargers, and VGI-related equipment and software, some may not need to deploy renewables and battery storage, for example. Fleets are advised to evaluate their own needs and conduct a benefit-cost analysis to better understand the cost-effectiveness of their VGI goals.

In addition to the costs outlined in Table 7, there are a few additional considerations that fleets must keep in mind as they pursue VGI. Those additional considerations include the following:

- The costs associated with ancillary service programs and other electricity markets offered by CAISO and utilities;
- The multiple utility rate programs that may be available to your fleet;
- Incentive funding options available to you, such as the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP), other grant funding opportunities, and California's Low Carbon Fuel Standard (LCFS) program; and,
- The levers that fleets may pull regarding their fleet charging operations.

Section 4.4 will describe each of the above in more detail.

The costs of deploying electric transit buses, associated infrastructure, and setting-up VGI technologies can be extensive, but it can also be cost-effective in the medium- to long-term despite any high upfront costs. Fleets are encouraged to consider the details above as a starting point from which they can evaluate their own costs, along with the potential benefits that the technology will provide them.

3.6 Timeline Considerations

VGI implementation is a process that can take a significant amount of time, with many moving parts and different sections that need to be managed properly in order to make sure implementation occurs smoothly and on schedule. Each process is highly integrated, and delays in any one process can compound upon each other and cause delays in other areas as well. To minimize these delays, fleets should begin planning VGI implementation early and make sure each partner is involved in each step as needed. This includes the utility, all infrastructure providers, software developers, fleet operators and dispatchers, and anyone else that may be involved. It is also recommended that the implementation be sequential, beginning with smart charging and expanding to other types of VGI as needed or desired. As stated previously, the VGI needs of fleets will vary: some may desire V2G while others may only have a need for V1G. Fleets are advised to determine this early and use it to start their timeline planning.

VGI is not the only part of electric bus deployment that can take time. According to the engineering firm, Black & Veatch, the whole process of electric bus and charging infrastructure deployment can range as low as three months up to two years, depending on the infrastructure upgrade needs at a given site. Table 8 outlines information from Black & Veatch on the expected time ranges associated with deploying medium- and heavy-duty (MHD) EV charging infrastructure under 1 megawatt (MW) in power, and with no needed grid upgrades.

Table 8 Expected Time Ranges for Medium- and Heavy-Duty EV Infrastructure Deployment (No Distribution Upgrades) [xii]

Project Phase	Typical Ranges (Months)	
Engineering / Design	0.50	2.00
Permitting / Land Use	0.50	3.00
Construction	1.75	2.50
Commissioning	0.25	0.50
Total Project Schedule	3.00	8.00

As fleets scale-up their electric vehicle fleet, their power needs increase, which may necessitate some form of grid infrastructure upgrade. Table 9 outlines information from Black & Veatch on the estimated time ranges for various types of power delivery upgrades.

Table 9 Expected Time Ranges for Medium- and Heavy-Duty EV Infrastructure Power Delivery Upgrades[xiii]

Potential Power Delivery Upgrades	Typical Ranges (Months)	
Supply Conductor (Service Extension)	0	2
Medium Voltage (Service Provisioning)	0	5
Feeder Re-Conductor	6	36
Feeder Additional Conductor	6	36
New Feeder	9	48
Substation Upgrade Required	18	36
New Substation Required	24	48

As you can see, grid upgrades, if extensive, can take up to 48 months in the case of a new substation requirement. This type of upgrade is not always necessary, of course, and it depends on the amount of power demanded by the fleet to charge their electric buses. Table 10, also from Black & Veatch, shows the range of power levels at which certain power delivery upgrades may become necessary. Importantly, these upgrades may not always be necessary if fleets require additional power as they scale-up, but since they might be, the MW ranges in Table 10 are important for fleets to consider. As fleets deploy electric bus charging infrastructure, they are advised to contact their utility early in order to evaluate any needed upgrades and to plan accordingly. If needed, fleets are encouraged to explore which of these upgrades may be done in parallel with other items in the EV and infrastructure deployment process. Doing so can cut down on the time it takes to accomplish deployment.

Table 10 Potential Grid Upgrades and Associated Charging Power Needs[xiv]

Potential Power Delivery Upgrade	MW
Supply Conductor (Service Extension)	0 – 1
Medium Voltage (Service Provisioning)	3 – 5
Feeder Re-Conductor	1 – 5
Feeder Additional Conductor	3 – 5
New Feeder	5 – 10
Substation Upgrade Required	5 – 10
New Substation Required	10 – 20

The time estimates above are related to the EV charging infrastructure deployment process that will largely precede VGI implementation. Nevertheless, fleets are advised to start planning for VGI early as they are planning for their broader infrastructure needs. The timeline for VGI implementation will be interlinked with the timeline for infrastructure development. As fleets are planning to deploy electric buses and charging infrastructure, and as they are planning for scale, they are encouraged to consider the hardware and software needed to implement VGI technologies, the partners they will need to collaborate with to implement VGI, and to account for the additional work required to implement VGI that is in addition to standard charging infrastructure deployment.

3.7 Best Practices for Minimizing Costs and Maximizing Value

As transit fleets pursue VGI implementation, there are a number of important considerations of which they must be mindful. This section provided selected best practices stemming from the literature on VGI to-date, and from the lessons learned on the Advanced Transit Bus VGI Project and the California E-Bus to Grid Integration Project. Transit fleets in California may use these best practices to get started on VGI implementation, but they should also expect to face unique and nuanced challenges based on each of their own circumstances. VGI implementation is a multi-faceted problem that requires strong partner collaboration, thorough planning, a strong understanding of hardware and software requirements, an openness to change business processes when beneficial, and preparation for the costs and time fleets are anticipated to expend in setting-up these systems. By following the best practices outlined above, fleets may start on a path toward minimizing costs and maximizing value associated with VGI.

4 Current Status of VGI in California

While electric vehicles have been around for some time, VGI is a relatively new concept, and California has taken an active posture in figuring out how to enable its implementation in fleets statewide. In particular, as transit agencies across California begin the transition to zero-emission buses, VGI is being considered as a supporting technology that may serve to assist these fleets in managing their vehicle charging, especially as they scale-up. To further enable the commercialization of VGI in California, State agencies and organizations like the CPUC, CAISO, California Air Resources Board (CARB), and CEC are working to better define the technology and break down policy barriers to its implementation. Likewise, the private sector is continuing to refine VGI technology so that it may be adopted by EV fleets throughout the State. This section will review the current status of VGI in both policy and technology, as well as review its current market barriers, drivers, and opportunities.

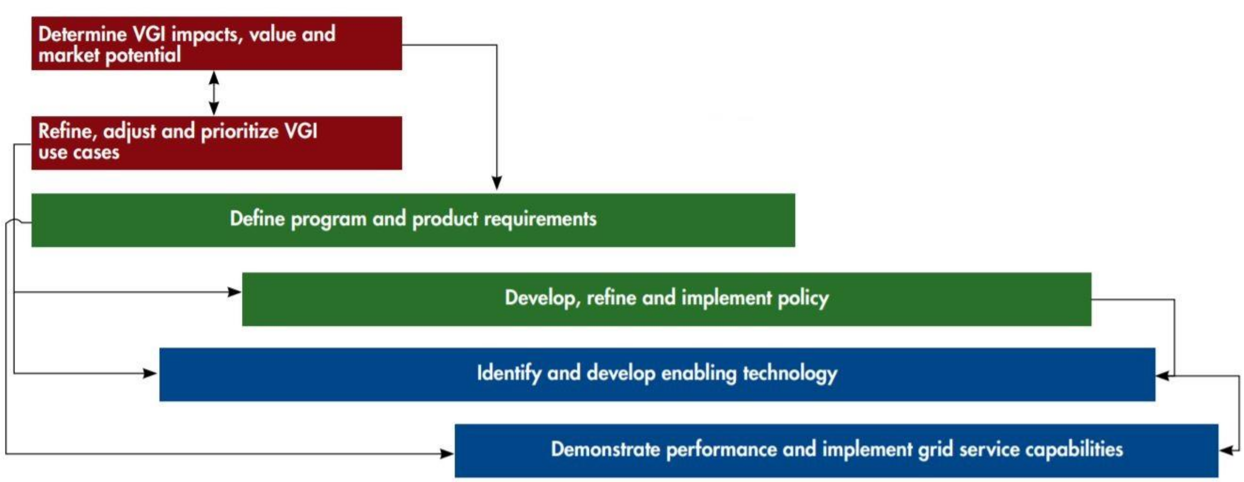
4.1 Current Regulatory Environment and Policy in California

Since the release of the 2013 Zero-Emission Vehicle (ZEV) Action Plan, which lays out goals and strategies for accelerating the adoption of EVs in California, several state agencies and organizations have worked together to refine understanding of VGI technology and its current policy needs. As an introduction, below is a list of roadmaps, reports, and regulatory documents related to VGI that have been released since 2013 in the State of California:

4.1.1 CAISO California VGI Roadmap[xv]

In response to the 2013 ZEV Action Plan, CAISO led the development of the California VGI Roadmap and released it in February 2014 with collaboration from the Governor's Office, CEC, and CPUC. The purpose of this roadmap is to chart a way toward enabling EVs to provide grid services while still meeting the needs of drivers. Figure 5 below shows the roadmap that the group developed.

Figure 5 2014 California VGI Roadmap



As you can see, the roadmap is organized into three interdependent tracks, each showing two actions that must be accomplished to realize the benefits of VGI in California. As deemed by CAISO, these tracks are as follows: determine VGI value, develop enabling policy, and support enabling technology development. Per the roadmap, determining the value of VGI will include understanding its impacts on the grid, quantifying value streams and costs, and estimating the market potential for VGI use cases. The process of developing enabling policies will include creating retail and wholesale programs, explaining settlement processes, and outlining the signaling and messaging between actors implementing VGI activities. Finally, supporting enabling technology development will require creating standards that enable VGI aggregation, developing communication requirements, and supporting research and development for VGI technology.

At the time of writing this Guide, the roadmap is currently being updated by the CEC to incorporate new complexities related to enabling VGI in California.

4.1.2 CPUC Vehicle – Grid Integration Report[xvi]

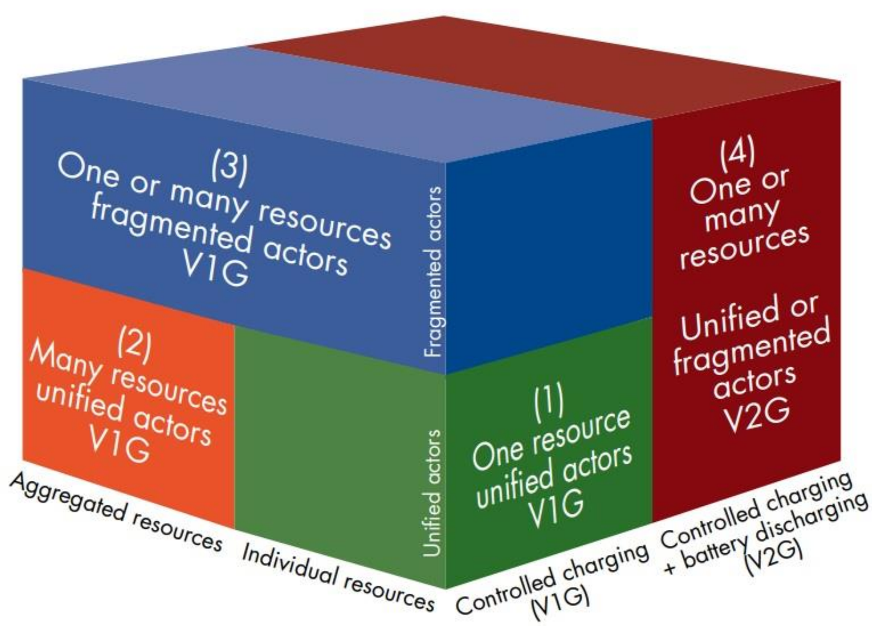
In 2014, the Energy Division of the CPUC released its report, Vehicle – Grid Integration: A Vision for Zero-Emission Transportation Interconnected throughout California's Electricity System. This report accomplishes three things: it outlines regulatory barriers to VGI's statewide adoption, it identifies four use cases for VGI technology, and it characterizes those use cases using three characteristics.

Following are the four regulatory barriers to realizing VGI's benefits to grid operators and fleets, which CPUC puts forth.

1) "The Commission should define where the resource is located;
2) The Commission should determine which entities (utilities and/or third-party aggregators) are able to aggregate resources and the point at which it occurs;
3) The Commission and other agencies should define a primacy among different grid benefits; and
4) The utilities need to develop methods to capture and return to customers the value that VGI provides to their distribution infrastructure."[xvii]

To define VGI use cases and characterize them, the CPUC developed the figure shown in Figure 6.

Figure 6 VGI Use Cases and Their Characterization[xviii]



According to the CPUC, there are four primary use cases for VGI, and the CPUC recommends that they be implemented sequentially, starting with the first and simplest use case and moving toward more complex uses cases over time.

1. Unidirectional Power Flow (V1G) with One Resource and Unified Actor Objectives (Simplest)
2. V1G with Aggregated Resources
3. V1G with Fragmented Actor Objectives
4. Bi-directional Power Flow (V2G) (Most Complex)

Further, the CPUC characterizes each of these use cases on three characteristics.

- "The capability of the [VGI] resource to provide power to the grid in addition to managing its power draw"
- "The alignment of objectives of the various actors (a vehicle owner, an electric charging station operator, and the facility at which they are located) involved with provision of power to or from the resource"
- "The provision of grid services from an individual or an aggregation of resources"[xix]

Thus, V1G with one resource and unified actor objectives would represent a case in which one vehicle owner seeks to manage the charging of its EVs and that goal is aligned with the goals of the EVSE provider, the facility at which the EVSEs are located, and the grid operator. This is the opposite of fragmented actor objectives, in which case the goals of each actor in the system may not be exactly aligned. Further, an example of aggregated resources may include managed charging for multiple fleets via an aggregator.

4.1.3 CEC 2017 Integrated Energy Policy Report (and Subsequent Yearly Updates)[xx]

On a yearly basis, the CEC releases its Integrated Energy Policy Report (IEPR), which provides guidance on solving a number of prioritized energy issues throughout the State, including VGI. In the 2017 IEPR the CEC summarized key takeaways from multiple IEPR workshops on VGI, as well as other agencies' work on the topic. This included a call to update the 2014 VGI Roadmap discussed above with the following priorities, which came from participants of the June 29, 2017 IEPR Workshop:

- "Establish interoperability capabilities so that these [VGI-related] vehicle resources can be certified and operated as a dispatchable demand response or eventually storage device and grid resource…"
- "Promote the return of value of ancillary services and controlled charging grid integration investments to drivers, automakers, charging providers, and utilities and provide clarity for business planning and component and equipment manufacturing decisions."
- "Coordinate vehicle technology research and development plans with charging infrastructure deployment plans…"[xxi]

In the 2018 and 2019 IEPRs that have been published since then, the CEC has called for continued research on VGI. This includes more specific recommendations as well, such as using cost and grid impact mitigation strategies learned from light-duty vehicle research to inform research in the MHD space, and assessing how VGI technologies can address other state goals.[xxii]

4.1.4 2017 VGI Communication Protocol Working Group Energy Division Staff Report[xxiii]

In 2017, the CPUC, CEC, CARB, CAISO, and the Governor's Office of Business and Economic Development (GO-Biz) formed the VGI Communication Protocol Working Group. This working group resolved to determine whether or not the CPUC should require a certain communication protocol or set of protocols for the EV infrastructure that IOUs rate-base. Additionally, the working group set a goal to collect data that would help the State determine what policies are needed to enable VGI. The CPUC's Energy Division released a Staff Report in October 2018 to communicate the working group's recommendations.

Ultimately, the group decided not to require IOUs to use either a single protocol or a specific set of protocols for the infrastructure they support. They did provide hardware recommendations and recommended protocols that would help enable VGI in Level 2, Alternating Current (AC), conductive EVSEs developed within the state. However, because transit fleets typically do not use Level 2 EVSEs for their electric buses, the recommendations within this Staff Report are not completely applicable for transit agencies. The CEC's Clean Transportation Program has identified the following list of hardware functionalities and communication protocols that are applicable to transit vehicles.

Table 11 Recommended Hardware Functionalities and Communication Protocols to Enable VGI[xxiv]

Functionality Type	Functionality Description
Facilitate vehicle-charger interoperability	Utilize connectors and interfaces which are compatible with MHD vehicles, including but not limited to J1772, CCS1, and J3105
Leverage open standards-based network communications	Enable the EVSE to communicate with electric vehicle service providers (EVSP), local fleet energy management system, and/or the utility by using IEEE 802.11n for high-bandwidth wireless networking, or IEEE 802.3 for Ethernet connectivity for Local Area Network and Wide Area Network applications
	Comply with Transmission Control Protocol (TCP)/IP and IPv6, or its successor version(s)
	Leverage Open Charge Point Protocol (OCPP) version 1.6 or later, Open Automated Demand Response (OpenADR, IEC 62746-10-1 ED1), or those outlined by the Smart Grid Interoperability Panel (SGIP) Catalog of Standards, the NIST Smart Grid Framework, the American National Standards Institute (ANSI), or other well-established international standards organizations such as the International Organization for Standardization (IDO), International Electrotechnical Commission (IEC), International Telecommunication Union (ITU), Institute for Electrical and Electronics Engineers (IEEE), or Internet Engineering Task Force (IETF)
Receiving signals	Be capable of receiving energy management signals from an EVSP, EMS, or a utility
Automatically adjusting charging load	Be capable of automatically adjusting charging load in consideration of the energy management signal
Bi-directional power flow	If V2G or V2B is desired, be capable of bi-directional power flow

4.1.5 The 2019 DRIVE OIR VGI Working Group[xxv]

Following on the 2017 VGI Communications Protocol Working Group, the CPUC, CEC, CARB, and CAISO formed the 2019 Development of Rates and Infrastructure for Vehicle Electrification (DRIVE) Order Instituting Rulemaking (OIR) VGI Working Group to discuss policies which need to be adopted or changed to enable VGI in California. This group met regularly from August 2019 to June 2020, and are currently working on a Final Report to disseminate their findings and recommendations, however, they did release a draft version of that report on May 19, 2020. In the report, the group identifies 310 use cases which were deemed able to provide value in the short term, now through 2022. These use cases range in their applications which include the following, as defined by the working group: backup power and resiliency, bill management, renewable self-consumption, upgrade deferral, day-ahead energy services, frequency regulation, greenhouse gas reductions, flexible grid capacity, local capacity, system capacity, real-time energy services, renewable integration, and voltage support. The working group has compiled a database of all use cases, on which you can see much more detail here[xxvi].

The group also put forward 31 policy recommendations to be considered from now through 2022, all of which garnered "strong agreement" from the group's constituents, as well as longer-term policy considerations. These policy recommendations range in category which include the following, as defined by the working group: reform retail rates; develop and fund government and utility customer programs, incentives, and DER procurements; design wholesale market rules and access; understand and transform VGI markets by funding and launching data programs, studies, and task forces; accelerate use of EVs for bi-directional non-grid-export power; develop EV bi-directional grid-export power including interconnection rules; fund and launch demonstrations and other activities to accelerate and validate commercialization; develop, approve, and support adoption of other non-interconnection technical standards; fund and launch market education and coordination; enhance coordination and consistency between agencies and state goals; and, conduct other non-VGI-specific programs and activities to increase EV adoption. The working group has compiled a database of policy recommendations, on which you can see much more detail here[xxvii].

4.1.6 CPUC Order Instituting Rulemaking to Consider Streamlining Interconnection of Distributed Energy Resources and Improvements to Rule 21 (Decision 20-09-035, Rulemaking 17-07-007)[xxviii]

Issued on September 30, 2020, CPUC Decision 20-09-035 (R.17-07-007) modifies Electric Tariff Rule 21 which applies to Pacific Gas and Electric (PG&E), San Diego Gas & Electric (SDG&E), and Southern California Edison (SCE). Rule 21 is a tariff which defines the requirements regarding interconnection, operation, and metering that generation facilities must follow in order to be connected to a utility's distribution grid. By way of background, the CPUC adopted Rulemaking (R.) 17-07-007 on July 13, 2017 to consider multiple modifications to Rule 21. Thus, working groups conferred and put forth several proposals to the CPUC, including those related to the interconnection of electric vehicles and related charging infrastructure. Based on comments from relevant stakeholders, the CPUC then made decisions on which proposals to adopt and which to decline. As stated in Decision 20-09-035 (R.17-07-007), the CPUC adopted proposals 23a, 23b, 23c, 23d, 23e, 23f, and 23i, and they declined to adopt proposals 23g and 23h. Below is an explanation of each proposal:

- 23a (Adopted): This proposal recognizes that Rule 21 does not apply to unidirectional charge-only V1G, but Rules 2, 15, and 16 are applicable.

- 23b (Adopted): This proposal would modify Rule 21 by clarifying that it applies to the interconnection of stationary and energy storage systems. In response to this proposal, the CPUC directed the utilities to develop clarifying language for Section B.4 of Rule 21.
- 23c (Adopted): This proposal clarifies that Rule 21 allows the interconnection of V2G DC EVSE systems, as long as the EVSE meets all relevant Rule 21 requirements.
- 23d (Adopted): This proposal would allow V2G DC EVSE systems with bidirectional capabilities to connect as V1G, load-only systems, and operate in unidirectional mode upon confirming that the EV will not discharge if the EVSE is in unidirectional mode, that the EVSE will not switch to a bidirectional mode, and that factory settings are in unidirectional mode. In response to this proposal, the CPUC directed utilities to meet and decide upon appropriate language changes to Rule 21.
- 23e (Adopted): This proposal would require permission from the utility to be obtained before bidirectional capabilities are enabled for V2G DC EVSE systems. In response to this proposal, the CPUC directed utilities to create a set of consistent implementation steps for V2G DC EVSE systems.
- 23f (Adopted): This proposal would alter utilities' interconnection portals to track V2G interconnections. In response to this proposal, the CPUC directed utilities to develop the costs, cost recovery methods, and timelines needed to carry out this proposal.
- 23g (Declined): This proposal would create a group to develop technical recommendations for enabling V2G AC interconnection. The CPUC deemed this unnecessary as R.18-12-006 has already established a Vehicle to Grid Alternating Current Subgroup.
- 23h (Declined): This proposal would change Section N of Rule 21 to permit a streamlined study process for V2G DC EVSE interconnections. The CPUC deemed this to be unnecessary as the definition of a generator in Rule 21 already includes V2G DC capabilities.
- 23i (Adopted): This proposal would clarify a pathway for interconnection of V2G AC systems in a time-efficient manner for pilots and/or temporary use until more finalized rules are created in the future. Additionally, this proposal would provide V2G AC system pilots with a temporary exemption from Rule 21 smart inverter requirements. In response to this proposal, the CPUC directed utilities to create a temporary interconnection pathway for V2G AC interconnection in pilots.

4.1.7 Electricity Market Programs and Ancillary Services Provided by CAISO[xxix]

As discussed in previous sections of this guide, California fleets with V2G-capable EVs may participate in a variety of electricity markets offered by CAISO or their utility. Examples of wholesale electricity market programs offered by CAISO include Proxy Demand Resource (PDR) and Reliability Demand Response Resource (RDRR). Examples of retail electricity market programs offered by California utilities include Base Interruptible Program (BIP), Capacity Bidding Program (CBP), Peak Day Pricing (PDP), and more. Within the wholesale market programs offered by CAISO, fleets may provide Ancillary Services to help the grid operator maintain reliability of the grid, offering the potential to earn revenue by doing so. This section will explain those services in more depth.

CAISO is a nonprofit organization that is tasked with managing the electric grid for much of California. As an ISO, CAISO must meet the power demands in its territory while also balancing the amount of electricity generated with the amount of electricity demanded at any given time. To do this, CAISO provides a number of Ancillary Services, which include several business operations that extend beyond the generation and transmission of electricity. These services are required to maintain stability and security of the grid.

The main ancillary services that CAISO offers are included in the bulleted list below.[xxx] CAISO creates a competitive market for these services on which Scheduling Coordinators, or market participants that have an impact on the grid (e.g. power plants, electricity off-takers that can regulate demand, etc.), can bid. Scheduling Coordinators can participate in these services for a price determined by that market.

- **Regulation Up & Down:** Regulation is used to correct minor deviances in the balance between electricity generation and electricity demand. This is done on both sides of the balance, by either signaling resources to increase or decrease generation or increase or decrease demand.
- **Spinning Reserves:** Reserves help CAISO maintain the balance between generation and demand in the case of a significant generation deficiency (e.g. if a generator that was expected to generate electricity is down for any reason, or if there is an unforeseen increase in demand). Spinning reserves are generators (e.g. power plants) that are already connected to and synchronized with the grid. For CAISO, Spinning Reserves must ramp-up within 10 minutes and must run for at least two hours.
- **Non-Spinning Reserves:** Similar to Spinning Reserves, Non-Spinning Reserves also provide extra generating capacity in the event of a deficiency on the grid. These differ from Spinning Reserves in that they are not already connected to the grid, but can be after a short delay. For CAISO, Non-Spinning Reserves must also be synchronized to the grid and ramped up within 10 minutes and must run for at least two hours.

CAISO regularly determines minimum and maximum quantity limits for ancillary services they wish to procure in each of the regions they manage. Those limits are dependent on a number of factors related to grid conditions, including the following, as reported by CAISO:[xxxi]

- **Transmission-Related Factors:** Network constraints, transfer capacity, regional limitations, outages, forecasted path flows, largest single contingency, de-ratings
- **Generation-Related Factors:** Locational mix, operating constraints, historical availability, outages, largest single contingency
- **Load-Related Factors (Power Demand):** Locational mix, load pockets, CAISO forecast of CAISO demand

Similarly, there are a number of requirements for resources that participate in the ancillary service markets described above. According to CAISO, resources that wish to bid into the markets are assessed on the following criteria:[xxxii]

- Ramp rate increase and decrease (MW/minute)
- Power factor (leading or lagging)
- Maximum output (real and reactive)
- Minimum output (real and reactive)
- Capability to respond immediately to CAISO's Emergency Management System (EMS) control
- Minimum length of time the resource can provide ancillary services

For Scheduling Coordinators that do use their resources to provide ancillary services to CAISO, they are compensated using the following formula:

(Ancillary Service Quantity in Megawatts X Time) X (Ancillary Service Marginal price in $/MW/Time)

As it relates to VGI, transit bus fleets that are V2G-enabled can theoretically bid into CAISO's ancillary services markets, however, there currently are no specific guidelines for V2G-enabled EV fleets to be Scheduling Coordinators. More information on CAISO's ancillary services can be found on CAISO's website[xxxiii], in this Business Practice Manual for Market Operations[xxxiv], and in this FERC Electric Tariff[xxxv].

4.1.8 Summary of the Current State of VGI-Related Policy and Regulation in California

As you can see from the subsections above, VGI-related policy in California is still being developed. While identifying, prioritizing, and implementing policies that will enable VGI adoption in the State is clearly a priority for agencies like the CEC, CPUC, CARB, and other relevant stakeholders like CAISO and utilities in the State, more work is needed to move the needle on this front. Agencies have made great strides in characterizing VGI and identifying barriers that need to be addressed, and they have started to address those barriers through working groups and technology research and development. Further, the recent Decision 20-09-035 (R.17-07-007) issued by the CPUC has provided needed clarity on which VGI system interconnections are applicable to Rule 21, and it has directed utilities to take needed measures to provide further direction on VGI implementation. While progress has certainly been made since the release of the 2013 ZEV Action Plan, more is still needed. Namely, the value and market potential for VGI must be further refined; the programs, processes, and policies needed to effectively and smoothly enable VGI activities are still to be thoroughly developed; more specific guidance needs to be provided to VGI-enabled fleets on how to participate in electricity markets; and, the technology itself still requires further development and validation. This is all to be expected given how new VGI is, and given the relatively nascent EV market compared to conventional vehicles. As the organizations mentioned above start to consider and implement policy recommendations like those produced by the 2019 DRIVE OIR VGI Working Group, they will also benefit from continued technology demonstrations and pilot projects, which will help improve VGI and provide needed input for policymakers.

4.2 Brief Review of Selected Case Studies

There have been multiple VGI-related demonstrations and pilots across the country in recent years, and they have ranged from light-duty (LD) passenger vehicles to transit buses to school buses, and even work trucks. To briefly showcase how VGI technology is being studied, this section will highlight a few of these case studies and their findings as available. To start, this section will discuss the first two transit bus VGI projects in the United States.

4.2.1 Advanced Transit Bus VGI Project[xxxvi]

Funded with grant dollars awarded by the CEC, AVTA, located in Lancaster, California, and VTA, located in San Jose, California, are the first two transit agencies to participate in VGI-related demonstration projects in the United States. VTA's project, the Advanced Transit Bus VGI Project, is led by Prospect Silicon Valley, a nonprofit cleantech innovation hub in San Jose. It includes advanced energy management and services for 5-10 electric buses, as well as a state-wide scaling analysis for VGI in California's transit buses. The project started on June 01, 2017 and is set to end on December 31, 2020. At the time of writing this guide, VTA has deployed five electric transit buses, six VGI-enabled chargers, have developed an EMP to conduct V1G activities, and have integrated the EMP with vehicle telematics systems. They are in the process of integrating the EMP with other software, including fleet route management software and maintenance data, and they will be expanding the EMP with an additional five electric buses when they are deployed.

While still in progress, this project has already gleaned a number of important takeaways. First, the development of the EMP took the collaboration of 10 companies and multiple disparate pieces of software that had to be carefully integrated to provide VTA with V1G capabilities. This integration process took a good amount of time and had to be done carefully to ensure success. With the EMP now deployed, VTA is working with those partners to demonstrate V1G capabilities that can smooth the fleet's demand for electricity as they plan to scale-up their BEB fleet. The NREL is in charge of assessing BEB operating scenarios for VTA, determining opportunities for electric bus scale-up, and conducting a state-wide scale-up analysis. So far, NREL has concluded the following on this project at VTA, reported directly from an NREL presentation on February 26, 2020:[xxxvii]

- 70% of VTA's fleet is eligible for electrification assuming 60kW chargers and 40'/60' buses with 350/550 kWh usable stored energy;
- There are a variety of solutions for achieving further electrification: increase charger power, purchase larger vehicle batteries, on-route charging, purchasing additional buses (or batteries) and swapping them to enable the existing routes/blocks to be met, route-block redesign to align with electric bus needs;
- Compared to immediate charging, smart charging can reduce maximum site power consumption by 31-65%;
- Smart charging can reduce the number of chargers needed without impacts to service. One 60kW charger may be used for 2.5 buses or one 120kW charger may be used for 3.8 buses;
- For VTA, adding PV can increase renewable incentives from California programs (e.g. Low Carbon Fuel Standard); and,
- The flexibility that smart charging provides mitigates much of the need to install batteries; however, there are still potential benefits for reliability and resiliency, which should be considered.

4.2.2 California E-Bus to Grid Integration Project[xxxviii]

AVTA's VGI project, The California E-Bus to Grid Integration Project, is similar in scope to the VTA project but takes a different approach. This project aimed to include 80 BEBs, multiple wireless charging pads, vehicle telemetry, and data transfer to develop both V1G and V2G capabilities. Olivine, a company specializing in enabling DERs to offer grid services, was the project partner that led development of The E-Bus Platform. This Platform aims to integrate data from the vehicles, route information, chargers, utilities, and CAISO to optimize charging and grid services. As of February 26, 2020, the date on which the latest project-wide update was given prior to writing this guide, real-time charging control had not yet been established. However, Olivine has completed some AVTA-specific and statewide modeling and analysis that yielded the following results for AVTA and the CEC, reported directly from a presentation Olivine gave on February 26, 2020:[xxxix]

- Olivine's E-Bus Platform demonstrates a 40% reduction in energy cost from smart charging;
- Savings potential in Southern California Edison (SCE) and Pacific Gas & Electric (PG&E) territories equals $11,460 per bus per year from smart charging;
- Olivine estimates $50-$70 million in statewide savings are available assuming the deployment of 6,112 e-buses by 2030; and,
- Olivine estimates $250 million per year in statewide MHD savings are available per a 2030 market forecast put forth by ICF and E3.

In addition to Olivine's work on energy management and grid services, the project also features work to improve BEB driving efficiency, conducted by a company called Energy Solutions. Energy Solutions has developed driver training materials, conducted multiple training sessions, and has developed a dashboard to track operator efficiencies. In parallel, they have developed an incentive program whereby the most efficient operators are awarded. The program has been relatively successful, showing a 0.04 kWh/mi improvement in efficiencies after training and operator feedback.

4.2.3 Los Angeles Air Force Base Vehicle-to-Grid Demonstration[xl]

The CEC's Alternative and Renewable Fuel Vehicle and Technology Program (ARFVTP), in collaboration with the Department of Defense (DoD), funded this project at the Los Angeles Air Force Base to demonstrate V2G. The project consisted of over 40 EVs that ranged in use and size, including LD and medium-duty (MD) vehicles. The focus of this project was to demonstrate the ability for these EVs to participate in CAISO ancillary market services and to measure the effect of V2G activity on EV battery health. The vehicles successfully provided frequency regulation services to CAISO when plugged-in to charging stations on the base, and in sum they were able to provide more than 700 kW of power.

4.2.4 Bidirectional Wireless Charging on Hybrid UPS Truck by Oak Ridge National Laboratory[xli]

Another VGI-related project that is ongoing is being led by Oak Ridge National Laboratory (ORNL) with the collaboration of United Parcel Service (UPS). These partners have developed a bi-directional, wireless, charging apparatus that enables one of UPS' MD PHEVs to transfer power over an 11-inch air gap. At the time of writing this guide, the project is still on going, but so far, the partners have had successful demonstration runs for the technology, with power being transferred from the vehicle through the charger and reaching the grid at more than 92% charging efficiency. As the project continues, UPS and ORNL will focus on how the technology may be used to enable energy storage, which can be of benefit to UPS if it scales-up its EV fleet.

4.2.5 JUMPSmart Maui[xlii]

A final case study on VGI is the JUMPSmart Maui project, funded in part by the Japanese organization NEDO, which aimed at demonstrating smart grid technologies to enable the efficient use of renewable energy on the island of Maui, Hawaii. This project focused only on LD passenger EVs, setting up 13 FC stations across the island and deploying 200 level-2 chargers to be installed at study participants' homes and businesses. The project provided participants with Hitachi's EV-Power Conditioning System (EV-PCS) to be used at their homes in order to discharge power from their EVs to their facilities or to the local electric grid, which is managed by Maui Electric. As one might expect, the study found that the amount of battery capacity which could be discharged varied by time-of-day. 14-31% of the total capacity across EV batteries was available to discharge during peak hours, 8-30% was available during night-time charging, only 2-4% was available during daytime charging, and 6-16% was available in the early afternoon.[xliii]

VGI-related studies continue to be developed and executed as interested stakeholders seek to better understand the concept, and to refine it as it matures and charts a path toward deeper market penetration. The above case studies are only a selection of those that have been done, and they provide valuable insights into both how VGI technology can be improved and how fleets can better prepare themselves for implementing VGI. As fleets consider the latter, it is also important to be cognizant of what barriers exist to the proliferation of VGI, what is driving a market for VGI, and what opportunities exist for VGI to advance and for transit fleets to benefit.

4.3 VGI Market Barriers and Drivers

4.3.1 Market Barriers

According to the California VGI Roadmap led by CAISO, the following are the high-level barriers to VGI in California:[xliv]

- The value of VGI is not clear;
- VGI-eligible policies and programs must be better defined and implemented; and,
- VGI technology must be refined and improved, including technical standards and specifications.

While efforts to overcome these barriers are underway in California, they still remain, and the remainder of this section will address each individually.

Unclear Value of VGI

V1G arguably has a clearer value proposition than V2G. Transit fleets that invest in V1G technology are likely to see benefits in the form of reduced electricity demand, avoided demand charges, avoided charging costs, and more seamless electric bus fleet management. While these benefits have been demonstrated through the few V1G demonstrations and pilots that have occurred to-date, much more work still needs to be done to ensure that transit agencies will actually realize these benefits. As transit fleet operations vary from agency to agency, V1G requires more pilot projects and demonstrations to refine the technology so that it is flexible enough to meet the needs of each agency while also delivering the benefits that fleets expect. In addition to the flexibility needed to meet an array of use cases, the itemized costs of deploying V1G are not fully apparent, and in order for the value of this technology to be realized those costs will need to be made clear.

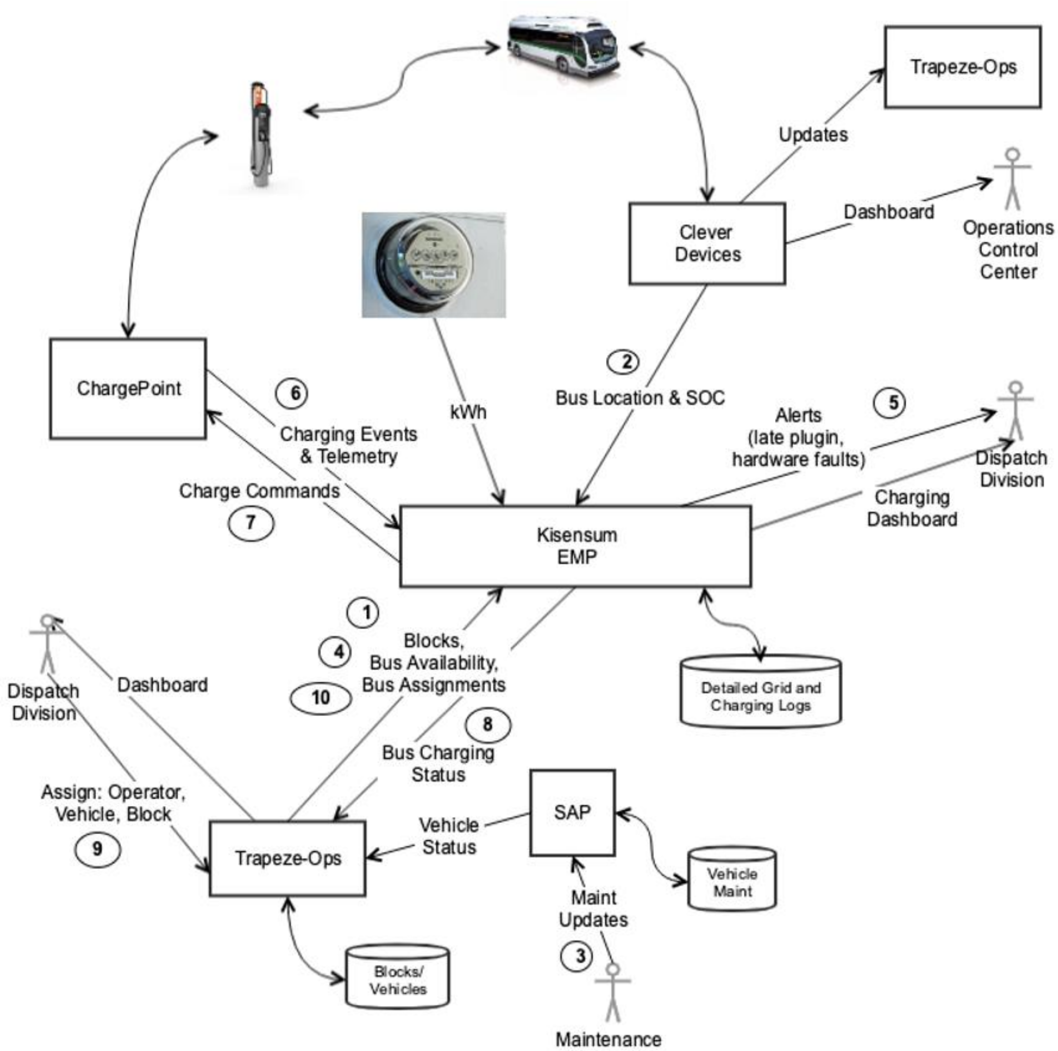
The value of V2G is even more undefined. Again, while there have been and continue to be, a few demonstrations and pilots of this technology, the benefits remain underdeveloped and not completely proven. This is partially due to the relatively low penetration rate of BEBs in California. While all public transit fleets are mandated to be completely zero-emissions by 2040[xlv], many fleets with BEBs currently only have a handful of them at the time of writing this guide. In order to adequately provide power to the grid, fleets must reach a certain level of scale that most transit fleets have not yet reached, and therefore the opportunities to assess the true value of V2G have so far been limited. However, more opportunities will arise as transit fleets scale-up the number of their BEBs. As this scale-up occurs, fleets will require a clearer picture of the both the costs and benefits associated with V2G, as also discussed with V1G above.

The same may hold with V2B as well. V2B may be a slightly simpler technology to deploy than V2G, since V2B does not necessarily require the BEBs to respond to signals for services sent by the grid operator or utility. With V2B, any one BEB can shift electricity to and from a building through a properly-equipped EVSE. However, a scaled-up fleet of BEBs will likely be more effective in shifting loads between the bus and the building simply due to scale. As with V1G and V2G, more data is needed on the benefits and costs associated with V2B to better understand the value it can bring to transit fleets across multiple operating scenarios.

Nascent VGI Technology and the Need for Improvement

The second barrier to VGI technology adoption is that the technology itself is still nascent and stands to improve. V1G is currently in pilot stages, being tested by fleets ranging in vehicle type, while V2G is still largely in research and development stages. There are certainly some V2G tests happening in the field, like in the California E-Bus to Grid Integration Project at AVTA, but as mentioned above, continued testing of V2G technology will require scaled-up fleets. As more demonstrations and pilots are conducted, VGI technology will have an opportunity to improve, specifically in the areas of communication, controls, bi-directional flow of energy, and integration of disparate software programs into combined VGI-focused solutions. The last of which is notable as the authors of this guide found no off-the-shelf VGI software solutions similar to VTA's EMP that are available to fleets quite yet. Figure 7 below shows a schematic of the EMP that project partners developed on the Advanced Transit Bus VGI Project at VTA. This schematic shows the multiple, disparate pieces of software that had to be integrated to enable V1G for VTA's BEB fleet.

Figure 7 Schematic of the ChargePoint Energy Management Platform Developed for VTA[xlvi]



As explained in Section 3, the inputs to this EMP were collected through software developed by Clever Devices, Trapeze-Ops, and ChargePoint, as well as the electric meter. Clever Devices provided software that inputted telematics data on vehicle location and energy consumption; Trapeze-Ops provided software that inputted data on fleet route management; and, ChargePoint's software inputted information about bus charging events. Also, ChargePoint installed a metering device at VTA's utility connection to capture a continuous stream of real-time utility power readings and relay them via an LTE uplink to the EMP. Together, this software was combined to develop the EMP that enabled V1G at VTA. Notably, the integration of these disparate pieces of software and hardware was a major milestone for this project. As VGI technology is refined, technology providers may aim to package it as one combined software solution rather than the combination of multiple solutions.

As stated in CAISO's California VGI Roadmap, refining VGI-enabling technology is interdependent with developing VGI-enabling policy. To that end, VGI technology improvement will both impact and be impacted by developments in policy and regulation. Take the need to refine VGI technology control systems as an example. For a fleet to send electricity to a grid operator through V2G systems, the fleet will need to respond quickly to signals from that grid operator. As the controls to do this are improved, the codes and regulations surrounding those signals will need to be in sync. Continued coordination between manufacturers, grid operators, utilities, fleets and policymakers will help to ensure that advances in VGI-related technology and policy are well aligned.

The Need for Further Definition of VGI-Related Policies

The last barrier to VGI adoption in California is the need for further definition of VGI-enabling policies. As you can see in Section 4.1, several state agencies have committed to VGI research and development. CARB, CEC, CPUC, CAISO, and others have all published reports on the topic and are working together to identify, prioritize, and implement VGI-enabling policies. However, the State isn't quite there yet. A number of policy-related items require further development. As stated in CAISO's VGI Roadmap, the business flows and rules governing VGI stand to be further defined.[xlvii] The recent CPUC Decision 20-09-035 with respect to Rulemaking 17-07-007 provides clarity on the applicability of V1G and V2G system interconnections under CPUC Rule 21, which governs CPUC-jurisdictional interconnections, but several other components of V2G processes remain somewhat unclear, including signaling processes, compensation approaches, and broader program requirements. These facets of VGI must be better defined in order for stakeholders of all relevant types to use the technology.

To make progress on this front, the 2019 DRIVE OIR VGI Working Group focused on identifying and prioritizing VGI-enabling policy. The group has put forward 31 "strong agreement", short-term, policy recommendations to be considered through 2022, as well as longer-term policy considerations. These recommendations vary in category, but they address a number of gaps identified by the CAISO VGI Roadmap and discussed above. For more detail on the policy recommendations put forward by the 2019 DRIVE OIR VGI Working Group, please visit this website. Further, as discussed above, CPUC Decision 20-09-035 (R.17-07-007) has provided needed clarity on which VGI system interconnections are applicable to Rule 21, and it has directed utilities to take needed measures to provide further direction on VGI implementation.

4.3.2 Market Drivers

Proliferation of Electric Vehicles throughout California and the Need for Managed Charging

EV adoption throughout California is increasing, and with that trend comes new electric loads for fleets and utilities to manage. Transit fleets, especially, have a need for smart charging management solutions and opportunities to offset the costs of charging. As discussed previously, all public transit agencies in

California have been mandated to have completely zero-emission fleets by 2040, with all bus purchases in 2029 and after required to be zero-emission buses. In many cases this will require transit agencies to manage hundreds of electric buses, a new challenge that may require VGI to ensure cost-effective charging.[xlviii] V1G has the potential to reduce power demand for transit fleets, as well as the potential to optimize charging procedures and minimize costs. V2G offers an opportunity for transit fleets to earn revenue that may offset charging costs, as well as an opportunity to support the larger power grid. And, V2B offers an opportunity for fleets to connect their buses and their facilities in ways that provide an additional method of managing energy flows and charging.

V2G Revenue Potential for Fleets and Ancillary Services for Grid Operators

As discussed previously, there are two potential benefits from V2G that serve as drivers for adoption of the technology by fleets and grid operators. As fleets scale-up they have an opportunity to earn revenue by bidding into electricity markets offered by grid operators, including bulk energy storage, operating reserves, and frequency regulation. This revenue opportunity is attractive to electric vehicle fleets due to the potential it has to offset costs associated with charging. While charging electric buses can often be less costly than refueling diesel buses, demand charges can throw a wrench in that business case.[xlix,l,li] Demand charges are fees that utilities levy upon their non-residential customers based on the amount of power they require in a typical billing cycle. These charges can be quite costly for transit agencies that are using BEBs due to the additional power needs of the buses, especially as fleets scale-up. Theoretically, V2G-related revenues could offer opportunities to offset those costs.

For grid operators and utilities, VGI is a tool that can help them to balance electricity demand and generation. As discussed in previous sections, each subset of VGI can be of benefit to grid operators and utilities in various ways. V1G can enable more stable and predictable demand from EV fleet customers that use it. V2G offers a pathway for grid operators to garner support from fleets in maintaining grid frequency and balancing power demand. And, V2B offers an opportunity to lower peak demand from V2B-enabled fleet buildings. This opportunity that VGI brings for improving the efficiency of California's power grid is quite a significant driver, especially as EV adoption rises.

California Agencies are Taking an Active Posture on VGI

California state agencies are proactively examining opportunities to advance VGI technology. As you can see in Section 4.1, CARB, CEC, CPUC, CAISO, and GO-Biz have all committed, in one way or another, to studying VGI and working together to pave a path forward for the technology. This favorable attitude toward VGI is good for transit fleets that are adopting BEBs, as well as the grid operators and utilities that provide those fleets with electricity. These state agencies are doing a number of things to support VGI development: they are proactively examining VGI-enabling policies, investing significant dollars into VGI research and development projects, and continually benchmarking progress against VGI roadmaps developed to chart a path toward VGI technology commercialization. As transit agencies in California continue to address the challenge of managed charging and V2G, it is reasonable for them to expect continued support from these agencies in the years to come.

4.4 Cost Effectiveness of VGI for Transit Fleets

Ensuring cost-effectiveness is critical for any fleet that is interested in implementing VGI as they procure EVs. Determining cost-effectiveness will require fleets to thoroughly assess the benefits and costs associated with the VGI technology they pursue, as well as any other related considerations such as which utility rate structure is most optimal or which electricity market in which to participate. As VGI is still a nascent concept, little data is available on the cost-effectiveness of this technology at the time of writing this guide. Nevertheless, transit fleets in California can benefit from knowing what considerations to include in their cost-effectiveness assessments going forward. Importantly, these assessments will be very case-specific, as each transit agency will have unique costs and considerations depending on a variety of factors, including but not limited to their buses' duty cycles, their fleet makeup, the utility service territory they fall in, and so on. This section will outline some of the key considerations that transit fleets in California should keep in mind as they assess the cost-effectiveness of VGI.

As outlined in Section 1.3, transit fleets can anticipate several benefits from each type of VGI. Table 12 below outlines the main benefits for fleets by VGI type.

Table 12 Potential Benefits of VGI to Fleets

Subset of VGI	Potential Benefit to Fleets
V1G	Avoided energy costs and demand charges from peak shaving and/or demand response
V1G	Cost savings from more efficient energy use and charging patterns
V1G	Improved operations from the use of enhanced data collected by deployed V1G systems
V2G	Revenue from participating in electricity markets, like ancillary services markets
V2G	Cost savings from participating in electricity markets, like ancillary services markets
V2G	Opportunity to swiftly adjust power demand in response to signals and information received from utilities or other grid operators (Demand Response)
V2B	Avoided demand charges for the building
V2B	Backup power available for the building from a zero-emission source

Section 1.3 describes each of these potential benefits in detail, and so this section will not repeat. In summary, however, fleets may benefit from VGI through savings on charging costs, avoided costs (e.g. demand charges), improved efficiencies in operation from enhanced data, revenue from electricity market participation, and by having a source of backup power if buses are V2B-enabled.

These benefits offer potential for significant revenues and cost savings, but to fully assess the cost-effectiveness of VGI, fleets must consider the costs associated with their own unique circumstances. Table 13 shows simple list of cost considerations for transit fleets to consider as they pursue VGI implementation, some of which may or may not be necessary based on their own circumstances.

Table 13 Simplified VGI Cost Considerations

Category	Cost Consideration
Basic Capital Costs	Electric Bus
	Electric Bus Battery Capacity Upgrades
	Charging Equipment
	VGI-Related Software Material Costs (bus telematics, route management, tracking charge events)
DER Capital Costs	Solar PV Panel Material Costs
	Battery Storage Material Costs
Installation Costs	Charging Equipment Installation Costs
	VGI-Related Software Installation Costs
	Labor Costs for Integrating Disparate VGI-Related Software
	Solar PV Panel Installation Costs
	Battery Storage Installation Costs
Operations & Maintenance (O&M) Costs	Bus Charging Costs
	Bus Maintenance Costs
	Solar PV Panel O&M Costs
	Battery Storage O&M Costs
Other Miscellaneous Cost Considerations	Fleet Staff Training Costs
	Cost of Participating in Electricity Markets
	Battery Degradation and Replacement Resulting from Discharging
	Cost of Working with an Aggregator

As fleets consider both the potential benefits and costs of VGI technology, it is also important to consider the operating environment that each fleet is in. There are a few considerations for transit bus fleets in California to be cognizant of here:

- The multiple ancillary service and other electricity market programs offered by CAISO and utilities;
- The multiple utility rate programs that may be available to your fleet;
- Incentive funding options available to you, such as HVIP, other grant funding opportunities, and California's LCFS program; and,
- The levers that fleets may pull regarding their fleet charging profiles.

As described in Section 4.1.7, CAISO and utilities provide several electricity market programs in which EV fleets could theoretically participate. Relatedly, CAISO provides three main ancillary services into which Scheduling Coordinators may bid: regulation up & down, spinning reserves, and non-spinning reserves. Each of these services, along with other market programs, will have different requirements and different financial impacts to the fleets that consider them. As discussed previously, CAISO is collaborating with other California agencies to better understand opportunities for enabling V2G, but has not yet provided any specific guidance to VGI-enabled fleets for participating in these programs, and so any financial impact assessment of these programs on transit fleets would be speculative without demonstration. Nevertheless, it is important for fleets to keep in mind that these programs would likely have varying financial impacts, and a thorough analysis is recommended.

Utilities typically offer multiple rate structures to their customers, and fleets are recommended to thoroughly assess each of the applicable rate structures and their financial and operational impacts. Several utilities are starting to offer EV-specific rate structures, such as PG&E's BEV1 and BEV2 rates[lii]; SCE's TOU-EV-7, TOU-EV-8, and TOU-EV-9 rates[liii]; and, San Diego Gas & Electric's (SDG&E) proposed EV-HP rate[liv]. To fully assess the cost-effectiveness of any VGI solution, fleets must evaluate the potential impact each of their utility's applicable rate structures may have on their operations and choose the one best suited for their circumstances.

The third consideration is focused on incentive funding. There are multiple financial incentive programs available for transit bus fleets in California. The first is California HVIP, which offers point-of-sale vouchers that lower the upfront purchase price of MHD zero- and near-zero emission (ZNZ) vehicles. At the time of writing this guide, HVIP offers vouchers of $80,000 to $315,000 per bus, depending on the size of the bus and whether or not it operates in a Disadvantaged Community (DAC). In addition to HVIP funding, other entities in the State may also offer grant funding for MHD, ZNZ vehicles and infrastructure, such as air quality management districts. Additionally, the California LCFS is a state-level rule that aims to reduce the carbon intensity in transportation fuels used throughout the state. It includes a market-based system on which entities can conduct emissions trading, which can benefit fleets with clean vehicles. For transit agencies that operate electric buses, LCFS can provide significant revenues based on the amount of electricity they charge into their vehicles. Transit agencies can earn a certain dollar amount per kWh charged into their buses, which fluctuate based on LCFS market prices. This revenue can in turn be used to offset operating costs, such as the cost to charge buses.

The final consideration that fleets must be cognizant of as they implement VGI is the structure of their charging practices. There are several sub-considerations here that are important for fleets to have in mind. First, electricity rates often vary based on time-of-day, with the most expensive rates occurring at peak hours when demand is highest. Transit fleets should consider when their buses charge, and if those schedules are flexible in order to reduce costs. Second, charger power in kilowatts is important. Transit buses can often charge overnight, allowing them several hours to reach a full-charge, but this may not be the case for all buses. If a bus can stand to be plugged-in to a charger for longer periods of time, lower power (and less expensive) chargers may be adequate. Fleets should consider their operations carefully and choose the most optimal charger. Third is the potential impact of smart charging (or, V1G) on the number of chargers needed for a fleet. In the Advanced Transit Bus VGI Project at VTA, NREL estimated that smart charging has the potential to reduce the number of chargers needed to meet the needs of a fully electrified VTA fleet.[lv] This calls into consideration the importance of scale. Fleets should consider how the combination of scale and V1G may impact their charging equipment needs. Finally, fleets should consider their DER needs, if any. If a fleet needs additional power on-site it may consider installing renewables like PV solar. Similarly, if a fleet needs battery storage it may consider purchasing and integrating that technology into its charging ecosystem. Each of these DERs come with a cost which should be assessed carefully, as they may or may not necessarily make business sense. For example, in the same project discussed above, NREL found that adding storage where buses could perform intraday charging with V1G capabilities may increase costs for VTA as it pursues fleet electrification. They attributed this to the expected effectiveness of V1G to spread electricity needs throughout a given day.

This section provided a very simplified set of considerations for fleets that are interested in VGI implementation. As more VGI technology demonstrations are carried out, the clean transportation research community will gain more data from which to draw valuable insights into the cost-effectiveness of VGI for fleets. Until then, fleets are advised to thoroughly outline the anticipated benefits, costs, and other related considerations for their VGI goals, and to evaluate a number of operating scenarios with those items in mind. Through this planning activity, fleets will come to a better understanding of their own operations, which will equip them with the knowledge necessary to make wise decisions as they relate to implementing VGI technologies.

4.4.1 Estimated Value of VGI to Fleets

The potential dollar value of VGI to any transit fleet is going to vary due to a number of fleet-specific circumstances. For that reason, it is difficult to make any sweeping statements on what dollar value transit fleets in California can expect to receive from VGI. However, the two transit bus VGI demonstration projects funded by the CEC can provide some insight into how those specific fleets may benefit from the VGI systems they have implemented.

Multiple organizations estimated the potential value of VGI as part of the California E-Bus to Grid Integration Project at AVTA and the Advanced Transit Bus VGI Project at VTA. Olivine estimated the potential benefits of V1G and V1G with demand response for AVTA using a model they call the E-Fleet Energy Model. NREL conducted a preliminary analysis on the potential for VTA's electric buses to provide grid services through V2G. Finally, VTA conducted some of its own analysis to see the real impact that its Energy Management Platform had on energy usage and charging costs.

Olivine's analysis used their E-Fleet Energy Model to optimize yearly charging costs under multiple utility rate scenarios. Using rates from AVTA's two utilities, Lancaster Choice Energy and SCE (specifically, SCE's TOU-EV-8 and TOU-EV-9 rate structures), Olivine estimated that AVTA could save 40% of total charging costs per bus per year. This includes both regular energy costs from bus charging as well as demand charges. AVTA also modeled the potential value of V1G with demand response compared to a non-managed charging scenario, and they found that the benefits did not outweigh the costs, yielding an estimated benefit cost ratio of 0.58.[lvi]

NREL's analysis was conducted preliminarily, before VTA's EMP was implemented, and it examined the potential for VTA's electric buses to provide grid services under a number of electricity market programs. NREL found the following results through this analysis:

- Availability is the primary challenge for VTA's buses when it comes to V2G. A number of examined energy market programs were deemed valuable if the buses were to charge between 2 PM and 9 PM, but VTA's buses are not usually charged when grid services are most valuable, instead being charged when value for those services is little to none.
- VTA could earn as much as $315/kW per bus per year by participating in CAISO spinning and non-spinning reserve markets, assuming the bus travels an average of 130 miles per day.
- Theoretically, VTA could increase its yearly per bus revenue up to a total of $659/kW if the Proxy Demand Resource (PDR) program offered by CAISO allowed demand response resources to provide regulation within that program. However, this is only hypothetical as the PDR program does not currently allow this.[lvii]

It is important to note a couple things about this analysis from NREL. First, as mentioned above, the analysis was conducted preliminarily before VTA's EMP was implemented. Second, NREL's estimates only show potential revenues from the electricity market programs mentioned above; they do not include costs associated with providing ancillary services, nor do they include infrastructure costs that are required to enable VGI. At the time of writing this guide, NREL was underway in updating their analysis to include in-use data from the VTA VGI demonstration but it was not available by the time this guide was finished.

Finally, VTA collected a few months of energy use data after its EMP was activated in December 2019 and used it to assess the impact that the EMP's V1G capabilities have had on energy usage and charging costs. VTA found that the EMP has helped in the following ways:

- The EMP allowed VTA to move charging sessions from on-peak hours to off-peak hours;
- The EMP mitigated rises in peak energy usage despite significant increases in total energy usage, spreading energy use throughout the day; and,
- The EMP reduced overall cost per kWh.

To illustrate the points above, consider VTA's comparison of energy usage in December 2018 versus December 2019 when the EMP was activated. Total energy use reportedly increased by 85% in December 2019 compared to 2018, but peak energy use increased by only 17%. Further, the cost per kWh for both months remained at about $0.22 despite the increase in total energy use.[lviii]

As stated above, the exact value of VGI to transit fleets will vary depending on a number of fleet-specific circumstances. Both VTA and AVTA showed significant cost savings from V1G, but the value of V2G was less certain. In the case of VTA, V2G has potential to provide revenues for the agency, but their current bus driving patterns are a barrier. VTA will have to assess by how much, if at all, it may shift those driving schedules in order to capture benefits from a V2G system. For AVTA, V1G alone was estimated to yield cost savings, but the incorporation of demand response did not appear to be cost effective. These results are specific to VTA and AVTA. Every transit agency is recommended to assess their own circumstances carefully in determining whether V1G, V2G, V2B or a combination of any of the three may be beneficial to them.

5 Conclusions

Vehicle-grid integration has the potential to offer several benefits to fleets, utilities, and grid operators. If implemented properly, it can minimize charging costs, contribute to cost avoidances, and reduce electricity demand among fleets. Utilities and grid operators may benefit through more stable power demand, the potential to receive support from V2G-enabled fleets in maintaining grid reliability and stability, and the potential to avoid costly grid upgrades by relying on VGI-capable EV fleets to meet some peak power demands. As stated previously, VGI is currently underdeveloped and is still being defined in California. Broadly speaking, the value of VGI is not completely clear as of yet; VGI-enabling policies and programs require more definition and implementation; and, VGI technology requires further refinement. To overcome these barriers, multiple state agencies in California are collaborating to better understand opportunities to advance VGI through policy development, as well as demonstrations and pilot programs aimed at refining VGI technologies. As these agencies continue working on grid integration over time, fleets can expect more solid ground to be established on which they may stand to experiment with VGI.

Fleets that are interested in pursuing VGI implementation are recommended to start with V1G due to its commercial readiness compared to V2G. As stated previously, V2G is theoretically possible but is still in research, development, and demonstration phases. V2B is also an option for fleets that are interested, and much of the technology that enables V1G will help in enabling V2B. In addition, fleets are advised to learn from the Advanced Transit Bus VGI Project at VTA and the California E-Bus to Grid Integration Project at AVTA. Partners on those projects provided several best practice suggestions for California transit fleets interested in VGI, including the following:

- Get the right partners on-board early, and collaborate with them often;
- Thorough planning is crucial, and it should be done as early as possible. See Sections 2 and 3 for considerations to include in planning stages;
- VGI requires specialized hardware and software, and integrating all of it will be a major milestone for any transit fleet interested in VGI implementation. Plan accordingly for this;
- Be flexible in adjusting your operations to allow electric buses and VGI to benefit your organization;
- It is recommended to conduct a benefit-cost analysis to thoroughly assess the potential cost effectiveness of VGI;
- Timing of EV infrastructure and VGI deployment can vary, and in some cases, it can take many months depending on how extensive the project is. Plan ahead for this; and,
- Fleets new to VGI are recommended to speak to other transit fleets that have implemented it, in order to understand best practices and lessons learned.

The authors of this guide have provided several resources, considerations, and best practice suggestions to California transit fleets interested in VGI. It is their aim that by using this guide as a starting point and a resource, those fleets will have more success in deploying VGI systems and better managing their electric buses.

6 Appendix A: Resources

2019 DRIVE OIR Vehicle-Grid Integration Working Group

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Advanced Transit Bus VGI Project

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CAISO Ancillary Services

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CAISO Business Practice Manual for Market Operations

California Independent System Operator. March 2020. Business Practice Manual for Market Operations. CAISO. https://bpmcm.caiso.com/BPM%20Document%20Library/Market%20Operations/BPM_for_Market%20Operations_V65_redline.pdf

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CAISO Fifth Replacement FERC Electric Tariff

California Independent System Operator Corporation. June 2020. Fifth Replacement FERC Electric Tariff. CAISO. http://www.caiso.com/Documents/ConformedTariff-6-1-2020.pdf

California E-Bus to Grid Integration Report

California Energy Commission. (n.d.). California E-Bus to Grid Integration Project.

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CEC 2017 Integrated Energy Policy Report

California Energy Commission (CEC). February 2018. 2017 Integrated Energy Policy Report. CEC. https://efiling.energy.ca.gov/getdocument.aspx?tn=223205

CPUC Vehicle – Grid Integration Report

Langton, A. & Crisostomo, N. March 2014. Vehicle – Grid Integration: A Vision for Zero-Emission Transportation Interconnected throughout California's Electricity System. California Public Utilities Commission – Energy Division. https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=7744

CPUC VGI Communication Protocol Working Group

California Public Utilities Commission (CPUC) – Energy Division. October 2018. VGI Communication Protocol Working Group Energy Division Staff Report. CPUC. https://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442460144

IEEE 2030.5

The Institute of Electrical and Electronics Engineers Standards Association. (2018, December 21). 2030.5-2018 – IEEE Standard for Smart Energy Profile Application Protocol. https://standards.ieee.org/standard/2030_5-2018.html

ISO 15118 v1

International Organization for Standardization. (n.d.). ISO 15118-1:2019(en). https://www.iso.org/obp/ui/#iso:std:iso:15118:-1:ed-2:v1:en

JUMPSmart Maui

EV Ohana. (n.d.). Our Story. http://evohana.com/story/

Los Angeles Air Force Base Vehicle-to-Grid Demonstration

Black, D., MacDonald, J., DeForest, N., & Gehbauer, C. October 2018. Los Angeles Air Force Base Vehicle-to-Grid Demonstration. California Energy Commission. https://ww2.energy.ca.gov/2018publications/CEC-500-2018-025/CEC-500-2018-025.pdf

Oak Ridge National Laboratory Bi-Directional Wireless Charging on Hybrid UPS Truck

Oak Ridge National Laboratory. April 2020. Successful Delivery: ORNL Demonstrates Bi-Directional Wireless Charging on Hybrid UPS Truck. https://www.ornl.gov/news/successful-delivery-ornl-demonstrates-bi-directional-wireless-charging-hybrid-ups-truck

OCPP 1.6

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OpenADR 2.0b

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7 Appendix B: Endnotes

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