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VGI Valuation Method

Below is an updated version of the six-step VGI Valuation Method, originally proposed by PG&E.[1] Upon achieving consensus within this sub-group A, we shall refer to this updated Proposal as the ***California VGI Valuation Method***, and it shall be used primarily to answer the three main questions of this Vehicle Grid Integration Working Group (VGI WG):

a. What VGI use cases can provide value now, and how can that value be captured?
b. How does the value of VGI use cases compare to other storage or Distributed Energy Resources?
c. What policies need to be changed or adopted to allow additional use cases to be deployed in the future?

The method is presented sequentially in this section. The steps are:

Step 1: Define A VGI Framework
Step 2: Identify Hypothetical VGI Use-Cases
Step 3: Screen Out Impractical VGI Use-Cases
Step 4: Assess Each VGI Use-Case's Potential Benefits and Costs
Step 5: Rank VGI Use-Cases by Practical Net Benefits
Step 6: Make Recommendations on Policy, Market, or Technology in Order to Capture and/or Improve the VGI Use-Cases' Value

Step 1: Define A VGI Framework

This first step identifies six key *Dimensions* along which VGI use-cases can be designed, and their value subsequently quantified. The Dimensions are illustrated in Figure 1 and summarized below, and a detailed description is included in Appendix A.[2]

- **Sector**:
  - Pinpoints where the vehicle is used and charged/discharged
  - Could be broadly grouped into *residential* and *commercial* categories, or subsets thereof (e.g. commercial school bus, or commercial public destination)
  - Determines the loadshapes – both in "reference" and "optimized" forms – that are to be associated with the VGI use-case
  - Determines the plug-in schedule that is to be associated with the VGI use-case

- **Application:**
  - Refers to the service(s) VGI aims to provide
  - Could be broadly grouped into *customer-centric* and *system-centric* services

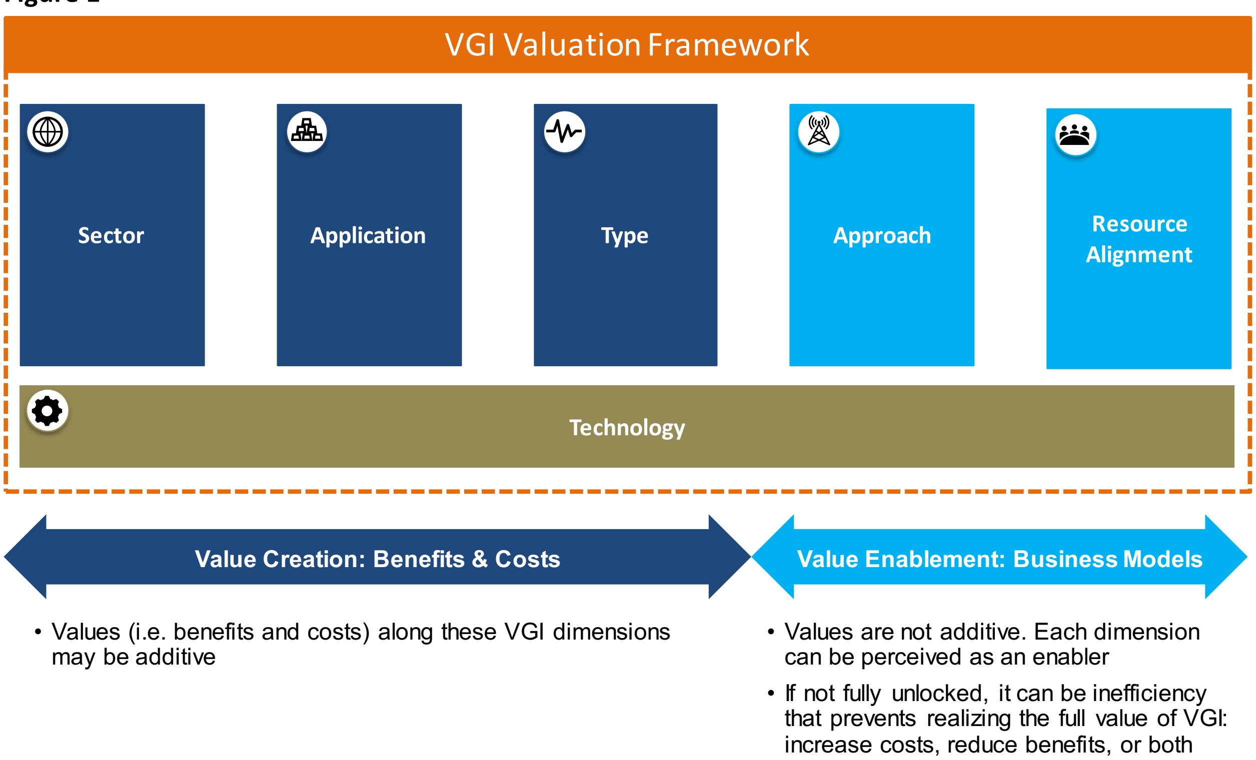
[1] Karim Farhat. PG&E VGI Valuation Method. Gridworks VGI Framing Doc. August 2019.
[2] Karim Farhat. PG&E's VGI Valuation Framework, as originally published in "*A Comprehensive Guide to Electric Vehicle Managed Charging*" SEPA, May 2019.

- The prospect of "stacking" these services, and their values, is important and relevant not only to VGI but also to other DERs such as battery energy storage

- **Type**:
  - Determines the power flow to and/or from the vehicle
  - Could be uni-directional (*V1G*) or bi-directional (*V2G*)

- **Approach:**
  - Refers to the control mechanism through which the vehicle's charge and/or discharge is managed
  - Could be either *indirect (i.e. passive) or direct (i.e. active).* Fundamentally, *indirect (passive)* control involves adjusting the EV charge/discharge by responding to a "signal" only, without prescribing what the charge/discharge adjustment entails. The receiver of the signal chooses how exactly to respond to that signal, including possibly not responding at all. On the other hand, *direct (active)* control involves adjusting the EV charge/discharge by responding to both a "signal" as well as "dispatching instructions" that prescribes what the charge/discharge adjustment entails. In this case, the receiver of the signal is provided clear instructions on the requirements to respond to that signal. For both *direct* and *indirect* control, the signal can be economic (e.g. time-of-use price), environmental (e.g. GHG intensity), or reliability-based (e.g. distribution-grid congestion). Utility time-of-use rates are a good example of *passive control* mechanism, whereas Demand Response programs (based on CAISO market clearing prices) are a good example of *active control* mechanism.
  - Embedded in this dimension is also the role of aggregation

Figure 1



- **Resource Alignment:**
  - The framework distinguishes between two important actors: "EV actor" is the party that controls and/or operates the electric vehicle, and "EVSE actor" is the party that controls and/or operates the electric vehicle charger under the utility meter.
  - Based on that, the framework views the EV-EVSE combination as the Resource.
  - If the EV and EVSE are controlled and/or operated by the same actor, the EV-EVSE Resource is *unified*. Alternatively, if the EV and EVSE are controlled and/or operated by different actors, the EV-EVSE Resource is *fragmented*.
  - Furthermore, if the EV actor and EVSE actor are aligned in their intentions and actions, the EV-EVSE Resource is *aligned*. Alternatively, if the EV actor and EVSE actor are not aligned in their intentions and actions, the EV-EVSE Resource is *misaligned*.
  - By default, if the EV-EVSE Resource is *unified*, it must also be *aligned*, since the EV and EVSE are controlled and/or operated by the same actor. However, in the case the EV-EVSE Resource is *fragmented*, it may be either *aligned* or *misaligned.* Among other factors, incentive design may be an important consideration to achieve alignment between the EV actor and EVSE actor, and to guarantee the delivery of the VGI service.
  - Ultimately, the Resource Alignment dimension yields three potential prospects: (1) *EV-EVSE Unified, Aligned*; (2) *EV-EVSE Fragmented, Aligned*; (3) *EV-EVSE Fragmented, Misaligned*.

- **Technology:**
  - Identifies the hardware and software needed to realize the VGI opportunity
  - Technology considerations include, but are not limited to:
    - electric vehicle type (e.g. battery electric vehicle, plugin-hybrid electric vehicle)
    - charging rate (e.g. L1, L2, fast-charge)
    - charging type (e.g. AC with mobile inverter, DC with stationary inverter)
    - communication requirements and pathways to EV and/or EVSE
  - Technology solution sets are diverse and span across the other five VGI Dimensions

The VGI framework treats *Sector*, *Application*, and *Type* as "value creation" Dimensions, since they determine how VGI value (both benefits and costs) is created and where it comes from. Value along these Dimensions may be additive. For example, residential charging can be added to commercial charging; wholesale ancillary services can be added to capacity services, and managed charging can be added to managed discharging, resulting in additional benefits and/or costs.

The VGI framework also treats *Approach* and *Resource Alignment* as "value enablement" Dimensions, since they determine how VGI value (both benefits and costs) can be unlocked and effectively captured. Value-enablement Dimensions compliment value-creation Dimensions to accurately characterize benefits and costs. For example, no matter how significant the potential net-benefits may be from leveraging managed charging of EV fleets for distribution-grid upgrade deferral, that value may never be realized in real life if the approach is inappropriate, or the EV and EVSE actors are fragmented and misaligned.

As Technology spans across the other five Dimensions, it has the potential to impact benefits and costs, in terms of both "value creation" as well as "value enablement." In this Working Group, to maintain a delicate balance between simplicity and accuracy, reasonable assumptions on Technology will be made along the other five Dimensions, whenever needed, to valuate and quantify VGI benefits and/or costs.

Step 2: Identify Hypothetical VGI Use-Cases

Together, the aforementioned six *Dimensions* constitute the main pillars of a VGI framework by which use-cases are scoped and defined. Under each Dimension, several options can be identified; we refer to those options as *Elements*. For example, as shown in Figure 2, *Customer - Bill Management* and *System - Day-Ahead Energy* are Elements of the Dimension *Applications*. Some of the key Dimensions, such as *Sector* or *Application*, could have many potential Elements. Table 1 and Figure 2 document the Elements for each of the value-relevant Dimensions: *Sector, Application, Type, Approach,* and *Resource Alignment*.

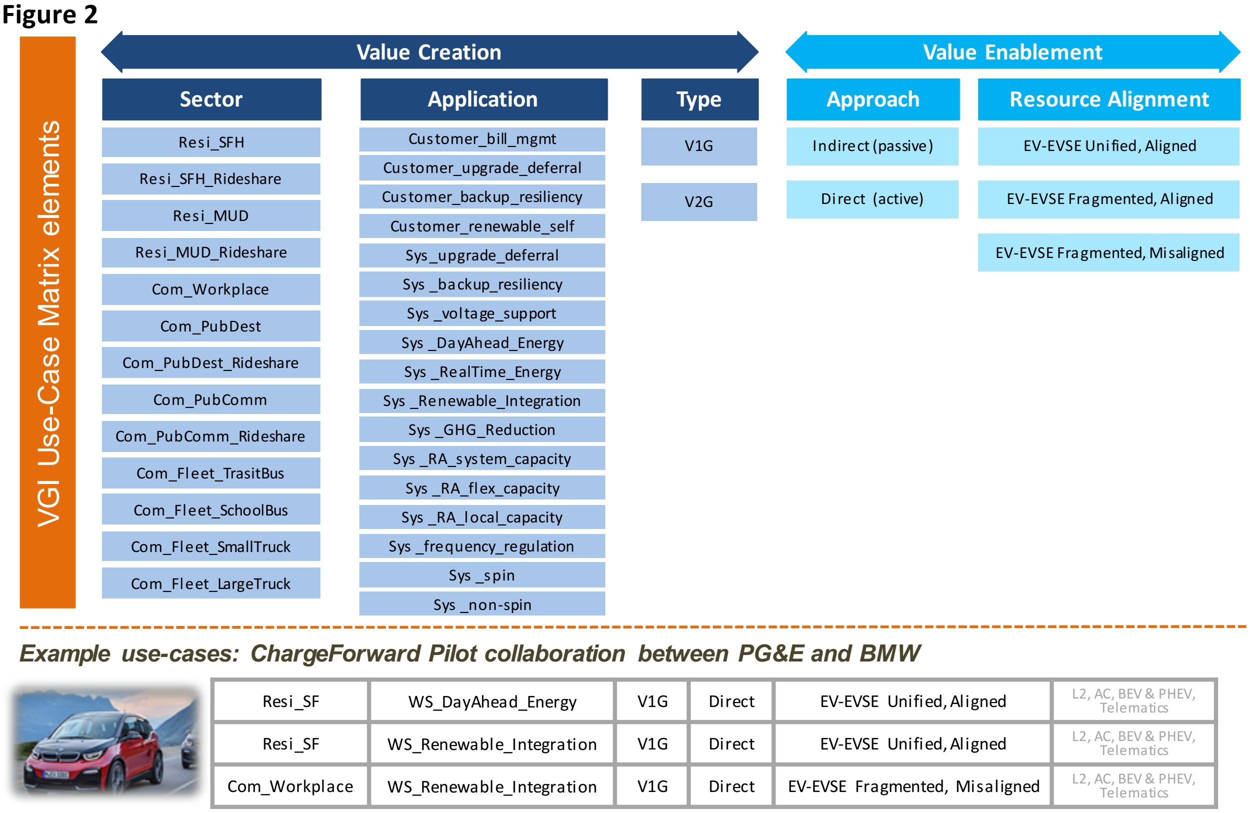
Table 1.

Dimension	Element
Sector	Residential - Single Family Home
	Residential - Single Family Home - Rideshare
	Residential - Multi-Unit Dwelling
	Residential - Multi-Unit Dwelling - Rideshare
	Commercial - Workplace
	Commercial - Public, Destination
	Commercial - Public, Destination - Rideshare
	Commercial - Public, Commute
	Commercial - Public, Commute - Rideshare
	Commercial - Fleet, Transit Bus
	Commercial - Fleet, School Bus
	Commercial - Fleet, Small Truck (class 2-5)
	Commercial - Fleet, Large Truck (class 6-8)
Application	Customer - Bill Management
	Customer - Upgrade Deferral
	Customer - Backup, Resiliency
	Customer - Renewable Self-Consumption
	System - Grid Upgrade Deferral
	System - Backup, Resiliency
	System - Voltage Support
	System - Day-Ahead Energy
	System - Real-Time Energy
	System - Renewable Integration
	System - GHG Reduction
	System - RA, System Capacity
	System - RA, Flex Capacity
	System - RA, Local Capacity
	System - Frequency Regulation Up/Down
	System - Spinning Reserve
	System - Non-Spinning Reserve

Type	V1G	
	V2G	
Approach	Indirect (passive)	
	Direct (active)	
Resource Alignment	EV-EVSE Unified, Aligned	
	EV-EVSE Fragmented, Aligned	
	EV-EVSE Fragmented, Misaligned	

One particular aspect to note in the Elements under the *Sector* Dimension is the simplified representation of medium-duty and heavy-duty (MDHD) electric vehicles. The MDHD space covers a wide range of vehicle classes and vocations. While each MDHD vehicle class and/or vocation may contribute a unique set of VGI use-cases, the electrification in the MDHD space is still in its early stages. Therefore, to maintain simplicity while still honoring inclusivity, the proposed Method carves out four distinct MDHD Elements in *Sector*: *Transit Bus*, *School Bus*, *Small Truck (Class 2-5)*, and *Large Truck (Class 6-8)*. *School Bus* and *Transit Bus* are highlighted due to their distinct charging behavior as well as to special emphasis in California and around the country on accelerating their electrification. Overall, understanding and articulating the value for the VGI use-cases associated with these four simplified MDHD Elements will provide sufficient clarity into their associated value of VGI, without adding too much complexity.

Figure 2



This method defines a use-case as a unique combination of Elements under the six Dimensions identified in the framework. To illustrate, below we present an example VGI use-case by choosing a *Sector*, an *Application*, and a *Type*, then selecting an *Approach* and identifying the nature and degree of the *Resource Alignment*; we also highlight the relevant Technology components:

Example: Amazon Delivery Fleet
Sector: Commercial – Fleet, Small Truck (Class 2-5)
Application: Customer – Bill Management
Type: V1G
Approach: Indirect
Resource Alignment: EV-EVSE Unified, Aligned
Technology: Electric Vans; OpenADR Communication Standard; DCFC

VGI use-cases can be simple or advanced. A simple use-case consists of only one choice for each dimensional Element, as in the example provided above. An advanced use-case may consist of multiple choices for each dimensional Element, as would be the case if the commercial fleet in the above example provided both energy and capacity services in the wholesale market.

In theory, hundreds of combinations of Elements in the framework could be made, resulting in hundreds of hypothetical VGI use-cases with distinct values.

Step 3: Screen Out Impractical VGI Use-Cases

Fundamentally, all VGI use-cases are intended to be voluntary in nature, aiming to complement and not jeopardize the primary objective of electric vehicles, which is meeting the customer's mobility needs. Given that overarching principle, the next important step is to identify *Screens* that can be applied to the full range of hypothetical use-cases in order to filter out "impractical" use-cases. Applying those screens yields a focused set of use-cases that can be further characterized and quantified. Screens may emerge from technological feasibility, market rules, customer preferences, or data availability, among other considerations.

Screens should also be articulated and applied within a clearly defined and agreed upon timeframe for evaluation (hereby referred to as the "Timeframe"). For this Valuation Method, the Timeframe is defined as follows:

- For VGI value "now": the Timeframe extends from 2019 up to and including 2022.
- For VGI value "in the future": the Timeframe extends from 2023 up to and including 2030.

Given the Timeframe specifications above, the following list of Screens can be applied for refining VGI use-cases:

- **Technological feasibility**:
  - Screen 1: Filter out use-cases that can only be achieved using hardware and/or software technologies or solutions that have not been either developed or tested in California, within The Timeframe. For clarification: technologies that are being piloted in California today are considered feasible and should not be filtered out within the “now” timeframe.

- **Market rules**: from a market perspective, VGI use-cases can be broadly divided into three categories: (A) use-cases that can be implemented under existing market participation rules; (B) use-cases that are not possible to implement under existing market participation rules, but are possible to implement under updated rules in the specified Timeframe (e.g. within the “now” Timeframe, this includes market rules under consideration in active regulatory proceedings such as IDER and DDOR); (C) use-cases that are not possible to implement under existing market participation rules, and also not possible to implement under updated rules in the specified Timeframe (i.e. require substantial rule changes that will take longer than the duration of the specified Timeframe).
  - Screen 2a: Filter out use-cases (C) involving applications and services that cannot be offered through existing or reformed/updated CAISO market participation rules within the Timeframe.
  - Screen 2b: Filter out use-cases (C) involving applications or services that cannot be offered through existing or reformed/updated utility program participation rules within the Timeframe.

- **Customer preferences:**
  - Screen 3a: Filter out use-cases that significantly conflicts with or compromises customer mobility needs or lifestyle preferences, within the Timeframe.
  - Screen 3b: Filter out use-cases that are likely to have significantly low customer adoption rate and/or participation rate, within the Timeframe.

- **Data availability:**
  - Screen 4a: Filter out use-cases where data needed to quantify VGI value does not exist, and cannot be reasonably and reliably inferred or simulated, within the Timeframe. Necessary data could include, but is not limited to, the following:
    - Reference unmanaged charging profiles, including total mobility energy need as well as charging behavior
    - Plug-in schedule that shows when the EV is connected and available to interact with the grid
    - Operational specifications of the offered service
    - Economic/monetary value of the offered service
  - Screen 4b: Filter out use-cases that can only be characterized and/or valuated using private data not publicly available within the Timeframe

The outcome from this Step is a short-list of use-cases that pass all the Screens.

Step 4: Quantify Each VGI Use-Case's Potential Benefits and Costs

Having identified potential use-cases and screened them for impracticalities, this method turns next to quantifying the potential benefits and costs of use-cases.

To simplify this complex task, this Step shall be composed of two sub-steps: Step 4a focusing on quantifying benefits, and Step 4b focusing on quantifying costs.

Step 4a: Quantifying Benefits

This sub-step shall focus only on the three "value creation" Dimensions of the VGI Valuation Framework: Sector, Application, and Type. Effectively, this means that this sub-step shall aim to quantify what the total benefit potential is for each unique combination of VGI sectors, applications, and types, but it will not address how, and the extent to which, that benefit is captured via different forms and degrees of control mechanisms (Approach), or EV-EVSE resource fragmentation & alignment (Resource Alignment).

To be clear, all VGI Dimensions remain important for valuating VGI benefits. After this Step 4a addresses the total value of benefits, Step 6 shall make recommendations on the best means to capture as much of that value as possible. This is explained in more detail in Step 6.

The process in this sub-step goes as follows:

- The short-list of screened VGI use-cases from Step 3 are grouped together into *3D use-cases* that account for the Sector, Application, and Type elements only, but drop and disregard the Approach and Resource Alignment elements.

- A 3D use-case's benefit can be modelled and optimized by considering six broad sets of inputs related to the three "value creation" Dimensions, within the applicable Timeframe:
  - Inputs for Sector:
    - (1) some form of a "reference" EV charging profile. The "reference" profile should focus on average market conditions related to unmanaged EV charging
    - (2) plug-in schedule that shows when the EV is connected and available to interact with the grid
  - Inputs for Application:
    - (3) an economic signal (e.g. price of service) to maximize or minimize charge/discharge over time
  - Inputs for Type:
    - (4) V1G versus V2G
    - (5) battery characteristics or constraints (e.g. battery capacity in kWh)
    - (6) EV-EVSE characteristics or constraints (e.g. energy demand for mobility needs, level of charging, etc.)
  - The output from inputs (2)-(6) is an "optimal" EV charging profile. Comparing the optimized output to the reference allows deducing the quantitative benefits of the investigated 3D use-case.

Sub-Step 4b: Quantifying Costs

To account for the full range of VGI costs, all VGI Dimensions should be considered.

The process in this sub-step goes as follows:

- Every use-case in the short-list of screened VGI use-cases from Step 3 shall be assigned a unique cost figure, which shall consider two broad categories of costs, within the applicable Timeframe:
    - Admin costs: Includes any of the following quantifiable costs:
        - Design and development
        - Operations and maintenance
        - Marketing and sales
        - IT
        - Evaluation, measurement, and verification
        - Reporting
    - Capital costs: Includes any of the following costs:
        - Hardware (equipment)
        - Software (IT)

Net-benefits: Accounting for both benefits and costs would then determine the use-case's value in terms of net-benefits.

An example demonstrating Steps 4a and 4b is presented in Table 2 below.

Table 2.

Step 3: Screened Use-Cases (illustrative examples)					
Sector	**Application**	**Type**	**Approach**	**Resource Alignment**	
Commercial - Workplace	System - Grid Upgrade Deferral	V1G	Direct	EV-EVSE Fragmented, Aligned	
Commercial - Workplace	System - Grid Upgrade Deferral	V1G	Direct	EV-EVSE Fragmented, Misaligned	
Commercial - Workplace	System - Grid Upgrade Deferral	V1G	Indirect	EV-EVSE Fragmented, Aligned	
Commercial - Workplace	System - Grid Upgrade Deferral	V2G	Direct	EV-EVSE Fragmented, Aligned	
Commercial - Workplace	System - Grid Upgrade Deferral	V2G	Direct	EV-EVSE Fragmented, Misaligned	
Commercial - Workplace	System - Grid Upgrade Deferral	V2G	Indirect	EV-EVSE Fragmented, Aligned	
Step 4a: 3D Use-Cases to quantify benefits (illustrative examples)					
Sector	**Application**	**Type**	**Benefit**		
Commercial - Workplace	System - Grid Upgrade Deferral	V1G	$A		
Commercial - Workplace	System - Grid Upgrade Deferral	V2G	$B		
Step 4b: Use-Cases to quantify costs (illustrative examples)					
Sector	**Application**	**Type**	**Approach**	**Resource Alignment**	**Cost**

Commercial - Workplace	System - Grid Upgrade Deferral	V1G	Direct	EV-EVSE Fragmented, Aligned	$X
Commercial - Workplace	System - Grid Upgrade Deferral	V1G	Direct	EV-EVSE Fragmented, Misaligned	$Y
Commercial - Workplace	System - Grid Upgrade Deferral	V1G	Indirect	EV-EVSE Fragmented, Aligned	$Z
Commercial - Workplace	System - Grid Upgrade Deferral	V2G	Direct	EV-EVSE Fragmented, Aligned	$W
Commercial - Workplace	System - Grid Upgrade Deferral	V2G	Direct	EV-EVSE Fragmented, Misaligned	$V
Commercial - Workplace	System - Grid Upgrade Deferral	V2G	Indirect	EV-EVSE Fragmented, Aligned	$T
Step 4: Use-Cases to quantify net-benefits (illustrative examples)					
Sector	**Application**	**Type**	**Approach**	**Resource Alignment**	**Net-benefit ($)**
Commercial - Workplace	System - Grid Upgrade Deferral	V1G	Direct	EV-EVSE Fragmented, Aligned	$A-X
Commercial - Workplace	System - Grid Upgrade Deferral	V1G	Direct	EV-EVSE Fragmented, Misaligned	$A-Y
Commercial - Workplace	System - Grid Upgrade Deferral	V1G	Indirect	EV-EVSE Fragmented, Aligned	$A-Z
Commercial - Workplace	System - Grid Upgrade Deferral	V2G	Direct	EV-EVSE Fragmented, Aligned	$B-W
Commercial - Workplace	System - Grid Upgrade Deferral	V2G	Direct	EV-EVSE Fragmented, Misaligned	$B-V
Commercial - Workplace	System - Grid Upgrade Deferral	V2G	Indirect	EV-EVSE Fragmented, Aligned	$B-T

Additional guidance for quantifying VGI value:

1. Distinction between use-cases with “Customer” Application and use-case with “System” Application:
The procedures outlined in Step 4a and 4b can be applied to all screened use-cases from Step 3. However, the resulting values (benefits, costs, and net-benefits) for uses-cases with “Customer” Application shall not be compared to the resulting values (benefits, costs, and net-benefits) for use-cases with “System” Application. Fundamentally, this is because these two sets of use-cases assess value from different perspectives, consistent with guidelines provided in the PUC’s Standard Practice Manual[3], and in alignment with the recent Decision Adopting Cost-Effectiveness Analysis Framework Policies For All Distributed Energy Resource (Rulemaking 14-10-003)[4].

- Customer-Application use-cases: The benefits and costs associated with these use-cases are computed from the participant(s) perspective. These use-cases may use “retail” and other economic signals (e.g. utility rates or incremental LCFS credits) to compute the benefits.
- System-Application use-cases: The benefits and costs associated with these use-cases are computed from a California-wide perspective, which examines whether the cost to California of a use-case is less than the benefit to California of that use-case.

[3] https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/CPUC_STANDARD_PRACTICE_MANUAL.pdf
[4] http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M293/K833/293833387.PDF

Subsequent steps of this Methodology shall not compare Customer-Application use-cases to System-Application uses-cases based on value.

2. The application of "cost-effectiveness (CE) tests" and "least-cost, best-fit (LCBF) principles" for VGI valuation: It is very important to clarify that the proposed simplified procedure in Step 4a and Step 4b to quantify VGI benefits and costs shall only be used to help address the three PUC questions in this Working Group. Accordingly, the proposed procedure is not intended as a replacement or substitute to existing CE tests or LCBF principles for evaluating VGI as a Distributed Energy Resource (DER). Both the CE tests (e.g. Total Resource Cost test) and the LCBF principles (e.g. Portfolio Adjusted Value metric) shall continue to be used, as relevant and per guidance in existing DER regulatory proceedings, to evaluate current or future VGI initiatives. The CE tests shall continue to be applied to evaluate any and all potential VGI initiatives within a Demand Response construct or program, and the LCBF principles shall continue to be applied to evaluate offers for any and all potential VGI procurement initiatives.

3. Leveraging publicly available information and data: To ensure transparency, to the extent possible, publicly available data sources and information should be used to quantify the benefit and cost items. A good example is leveraging the PUC's Avoided Cost Calculator[5] to quantify some of the System benefits such as the avoided cost of supplying electricity, potentially adjusted to take into account stakeholders' input.

4. Data granularity: Where granular data may not be available or sufficient, but aggregate data is, simplifying the relevant 3D use-case(s) may be necessary and beneficial in order to make use of the available aggregate data.

5. Uncertainty assessment: It is important to account for the various degrees of uncertainty in quantifying VGI value, especially when making assumptions due to significant data gaps/limitations. A high-low or high-medium-low probabilistic scenario-analysis can be conducted, when necessary and on case-by-case basis, to account for uncertainties.

6. Avoided cost of transmission and distribution: To the extent possible, it is important to account for the locational dependency of benefits from deferred grid upgrades, especially for distribution grid.

7. Timeframe:

- Data used to quantify benefits and costs should refer to the same Timeframe. To the extent possible, data should also refer to the same year within the Timeframe. For example, it is not favorable to quantify benefits for *System – Day-Ahead Energy* based on forecasts for year 2022 while quantifying benefits for *System – RA, System Capacity* based on forecasts for year 2020.
- To quantify VGI value "now" within the timeframe extending from 2019 to 2022: to the extent possible, use data for year 2019.
- To quantify VGI value "in the future" within the timeframe extending from 2023 to 2030: to the extent possible, use data for year 2025.

The outcome from this Step is a clear and quantified net-benefit for each of the 3D use-cases.

[5] The CPUC's Avoided Cost Calculator: https://www.cpuc.ca.gov/general.aspx?id=5267

Step 5: Rank VGI Use-Cases by Practical Net Benefits

Step 5 shall be implemented separately for:

- *Customer-Application use-cases*
- *System-Application use-cases*

The results of Step 3 and Step 4 feed into Step 5, which aims to rank the VGI use-cases. Customer-Application use-cases can be compared for representative customers under specific utility retail rates. System-Application use-cases can be ranked by aggregate net-benefits.

Two criteria are proposed for ranking the VGI use-cases:

Ranking Criterion #1 – Net-benefit: the complete short-list of screened VGI use-cases in Step 3 shall be ranked, from the most to least valuable, based on two metrics computed in Stage 4:

For Customer-Application use-cases:

- Yearly net-benefits per EV: $ per EV per year

For System-Application use-cases:

- Yearly net-benefits per EV: $ per EV per year
- Yearly net-benefits per Sector: $ per year (for total EV population in the Sector)

Ranking Criterion #2 – Implementability: the complete short-list of screened VGI use-cases in Step 3 shall also be ranked based on their easiness to be implemented and to commercially scale-up. Each VGI use-case shall be assigned a discrete numerical score from 1 to 5, with score 1 referring to “most difficult to implement and scale” and score 5 referring to “easiest to implement and scale”. The stakeholders shall work collaboratively and strive to obtain the score assigned to each use-case through consensus.

Table 3 illustrates the ranking of an example list of VGI use-cases. Both Ranking Criteria should be assessed within the same relevant Timeframe.

The outcome from this Step is a clear ranking of the screened and quantified VGI use-cases, based on their analyzed value in Step 4 as well as on their easiness to be implemented and scaled up.

Table 3.

Step 4: Use-Cases ranking (illustrative examples)						
Sector	**Application**	**Type**	**Approach**	**Resource Alignment**	**Value ($/EV/Yr)**	**Implementability**
Commercial - Workplace	System – Grid Upgrade Deferral	V2G	Direct	EV-EVSE Fragmented, Aligned	$XXX	3
Commercial - Workplace	System – Grid Upgrade Deferral	V2G	Direct	EV-EVSE Fragmented, Misaligned	$XXX	1

Commercial - Workplace	System – Grid Upgrade Deferral	V2G	Indirect	EV-EVSE Fragmented, Aligned	$XXX	2
Commercial - Workplace	System – Grid Upgrade Deferral	V1G	Direct	EV-EVSE Fragmented, Aligned	$XX	4
Commercial - Workplace	System – Grid Upgrade Deferral	V1G	Direct	EV-EVSE Fragmented, Misaligned	$XX	1
Commercial - Workplace	System – Grid Upgrade Deferral	V1G	Indirect	EV-EVSE Fragmented, Aligned	$XX	3

Step 6: Make Recommendations on Policy, Market, or Technology in Order to Realize and/or Improve the VGI Use-Cases' Value

Step 6 shall be implemented separately for:

- *Customer-Application use-cases*
- *System-Application use-cases*

This final step draws on all previous steps to infer recommendations on how to capture and/or improve the value of VGI use-cases. Recommendations made in this step may be related to policy, market, or technology needs.

Leveraging the ranking in Step 5, unique recommendations can be carved out for four distinct sets of well-articulated, screened, and quantified VGI use-cases:

i. **For VGI use-cases with *high* net-benefit and *high* implementability:**
   - Recommendations should focus on means to prioritize and scale up these use-cases
     - Insights into value attribution to the various parties?
   - Recommendations should advise on best ways to capture value:
     - What Approach (direct vs. indirect) facilitates capturing the highest value?
       - Specific recommendations on utility rate design, load management programs, and wholesale services?
     - What Resource configuration facilitates capturing the highest value? How to ensure highest level of alignment between the EV and EVSE actors?

ii. **Recommendations for VGI use-cases with *high* net-benefit and *low* implementability:**
   - Recommendations should focus on potential ways to enable further testing and overcoming implementation barriers
     - Insights into value attribution to the various parties?
   - Recommendations should advise on best ways to capture value:
     - What Approach (direct vs. indirect) facilitates capturing the highest value?
       - Specific recommendations on utility rate design, load management programs, and wholesale services?
     - What Resource configuration facilitates capturing the highest value? How to ensure highest level of alignment between the EV and EVSE actors?

iii. **Recommendations for VGI use-cases with *low* net-benefit and *high* implementability**
   - Recommendations should focus on potential ways to improve value

iv. **Recommendations for VGI use-cases with *low* net-benefit and *low* implementability**

- Recommendations should focus on potential need for further R&D

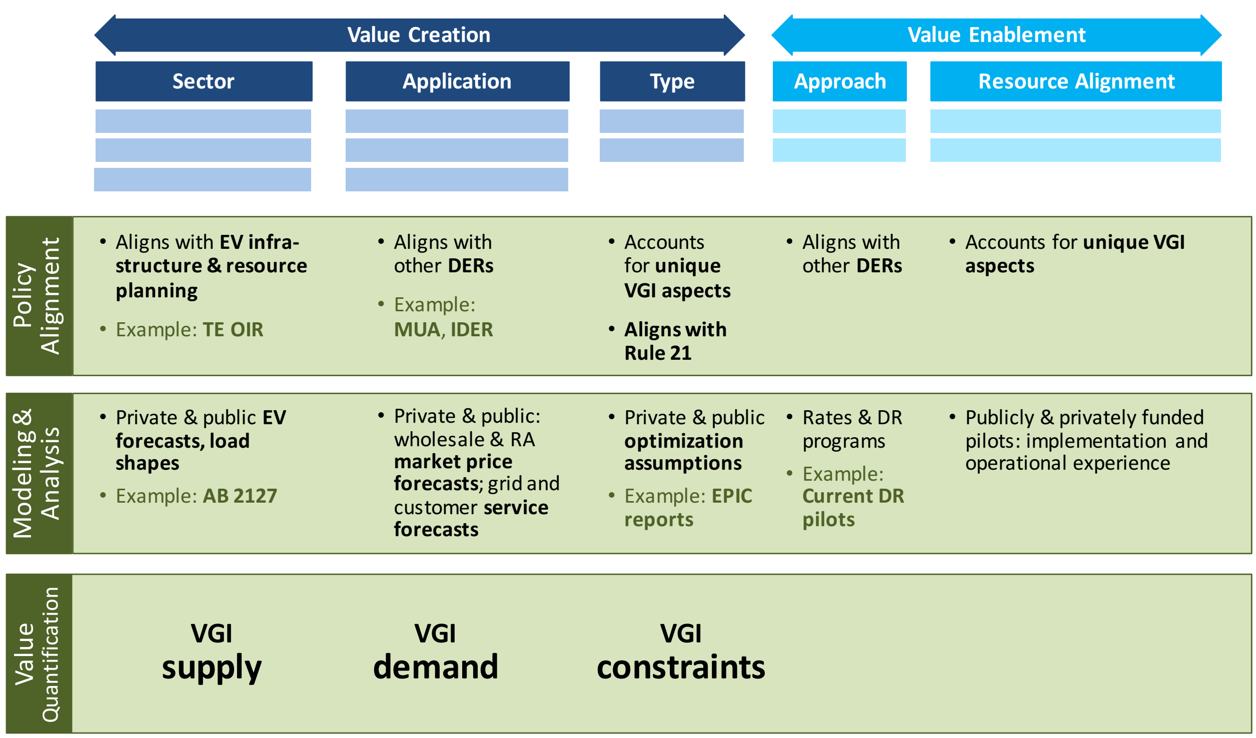
As with Steps 3-5, recommendations in this Step should be tailored to the relevant Timeframe.

The results of this Step are recommendations to policy makers, market participants, or technology and solution providers that can enable capturing and improving VGI value.

Conclusion

Combined, these six steps break the inquiry on VGI evaluation into manageable pieces, addressed in a sequence that allows for transparent, efficient, and inclusive consideration of use-cases. More broadly, as highlighted in Figure 3, the proposed *California VGI Valuation Method* helps achieve three key objectives: (1) aligning VGI policy and regulations with those impacting the broader transportation electrification goal and other DERs; (2) identifying and gathering the necessary information and data – including leveraging existing information and data – needed for VGI valuation; (3) developing a robust analytical tool to quantify VGI benefits and costs.

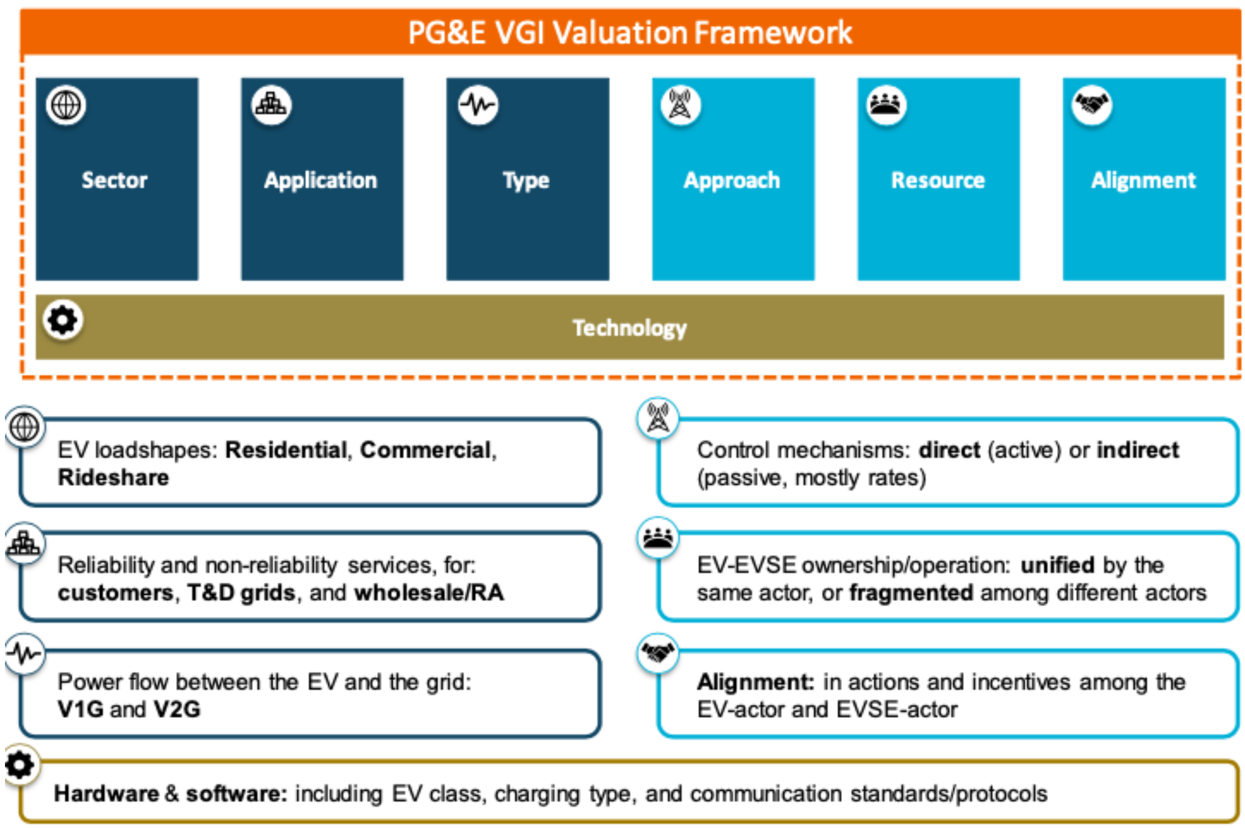
Figure 3



Appendix A

PG&E VGI Valuation Framework [6]

Building on the progress achieved during the California Public Utilities Commission VGI Working Group, PG&E took the initiative to develop a VGI framework that can help advance the work on VGI valuation. PG&E's VGI Valuation Framework identifies seven key dimensions along which VGI use-cases can be designed, and their value subsequently quantified. While this framework may still evolve as the industry progresses, it can significantly help different stakeholders think and communicate with clarity and accuracy about VGI.



The seven dimensions are described in more detail below:

1. **Sector:** It is important to define the sector where the vehicle is used and charged, because that most often determines the corresponding EV load shape and therefore the load management opportunity. Broadly speaking, the three main sectors with unique load shapes are residential (e.g. single-family or multi-unit dwellings), commercial (e.g. workplace, fleet, or public) and rideshare. For example, a residential light-duty vehicle charging profile looks very different from that of a

[6] PG&E's VGI Valuation Framework, as originally published in "*A Comprehensive Guide to Electric Vehicle Managed Charging*" SEPA, May 2019.

commercial-fleet medium- or heavy-duty vehicle. Different load profiles result in different load management actions and yield different VGI values, depending on the needs.

2. **Application**: Refers to the service(s) the EV is used to fulfill. PG&E breaks down applications into reliability and non-reliability services, which are further characterized at the customer-level (e.g., customer bill reduction), transmission and distribution grid level (e.g., capacity investment deferral), and the broader wholesale market level (e.g., ancillary services, capacity, renewable integration, etc.). An EV may fulfill, and therefore may get compensated for, one or more of these services. The prospect of "stacking" these services, and their values, is important and relevant not only to VGI but also to other DERs such as battery energy storage.

3. **Type:** This defines the power flow between the EV and the grid. A uni-directional flow (V1G) results in charging modulation (increase or decrease load) only, whereas a bi-directional flow (V2G) also allows discharging the EV back to the facility or all the way back to the grid. These different types have different associated capability sets and therefore result in different values.

PG&E's framework treats Sector, Application, and Type as "value creation" dimensions, since they determine how VGI value (both benefits and costs) is created and where it comes from. Value along these dimensions is additive: residential charging can be added to commercial charging; wholesale ancillary services can be added to capacity services, and managed charging can be added to managed discharging, resulting in additional benefits and/or costs from VGI.

4. **Approach:** Managed charging can be defined as both active (e.g. through demand response) and passive (e.g. through time-of-use rates). The control mechanisms by which load management is enabled have different associated costs and benefits. For example, DR events may result in limited load shifting during specific time periods on specific dates, whereas TOU rates may result in consistent load shifting on daily basis throughout the year. DR participation may result in high benefits per event while necessitating nontrivial investment in technological upgrades. On the other hand, TOU rates may result in consistent savings over time while imposing modest administrative costs to setup and run the program.

5. **Resource:** Defines whether the EVSE-EV actors are unified (e.g., a fleet operator that owns the vehicle and the charger) or fragmented (e.g., a workplace charger that doesn't control how EV-driving staff use the asset). When EVSE-EV actors are unified, it is easier to fulfil the VGI application and capture its value. When EVSE-EV actors are fragmented, further effort may be needed to ensure their alignment, which is the focus of the next VGI dimension.

6. **Alignment:** Alignment and Resource are tightly linked. When the EVSE and EV actors are unified, they are aligned by default. In the case that the EVSE and EV actors are fragmented, they may be either aligned or misaligned. Among other factors, incentive design is an important consideration to achieve alignment and guarantee the delivery of the VGI service. Absent this alignment, managed charging/discharging may never get to fulfill its purpose, and the value of VGI would be eroded.

PG&E's framework treats Approach, Resource, and Alignment as "value enablement" dimensions, since they determine how VGI value (both benefits and costs) can be unlocked and effectively captured. Value-enablement dimensions compliment value-creation dimensions to accurately characterize benefits and costs. For example, no matter how significant the potential net-benefits may be from leveraging managed charging of EV fleets for distribution-capacity deferral, that value may never been realized in real life if the approach is inappropriate, the resource is fragmented, and/or the actors are misaligned. Effectively, the value-enablement dimensions help inform the design of successful business models for the VGI use-cases, and they help identify any technological, policy, or market gaps that need to be resolved for that purpose.

7. **Technology:** includes the hardware and software to bring about the necessary capabilities to fulfill a VGI offering. Technology solution sets are diverse and span across the other six VGI dimensions. Examples of technology considerations could include the type of EV (e.g., light-duty vehicle versus heavy-duty vehicle, or plug-in hybrid vehicle versus battery electric vehicle; a battery electric vehicle typically has a larger battery capacity than a plug-in hybrid electric and therefore more opportunity for load shifting), the charger type (e.g., a networked L2 charger may be more expensive but allow higher charge/discharge rate than a networked L1 charger), and the corresponding communications protocols to pass information and commands between the vehicle and ultimately the grid.

PG&E sees the VGI landscape as a decision tree that keeps branching out, with each branch ultimately characterizing a unique use-case. A VGI use-case is defined by choosing a Sector, an Application, and a Type, then selecting a direct or indirect Approach, a unified or fragmented Resource, and the corresponding degree of Alignment.

The following are two examples of a VGI use-case:

• Residential (Sector) EV load decrease (Type) in the afternoon to avoid peak pricing and minimize monthly energy bill (Application) by setting charger timer based on TOU rate schedule (Approach), where both the charger and EV are owned by the meter customer (Resource and Alignment).

• Workplace (Sector) EV load increase (Type) to soak up excess renewable energy during the day (Application) via DR (Approach), where the EVSE and EV are operated by different actors (Resource and Alignment).

Ultimately, this framework yields hundreds of possible VGI use-cases. While all use-cases may be worthy of consideration, some will likely be more valuable and/or market-ready than others.
PG&E's approach helps clarify the granularity of the VGI use-cases while inclusively accounting for all of them, and then gathering the necessary information and data to quantify benefits and costs and to design successful programs. While some industry stakeholders can – and tend to – focus their business offerings on a limited set of use-cases, the utility needs to be able to assess, compare, and plan across the full range of feasible and implementable use-cases since they all eventually impact the grid.

Overall, the VGI Valuation Framework PG&E developed helps achieve three objectives: (1) defining a comprehensive list of VGI use-cases, (2) quantifying their value, and (3) aligning VGI policy and regulations with those impacting the broader transportation electrification goal and other DERs. Simply put, the framework serves as an accounting mechanism that charters a clear path for VGI valuation.