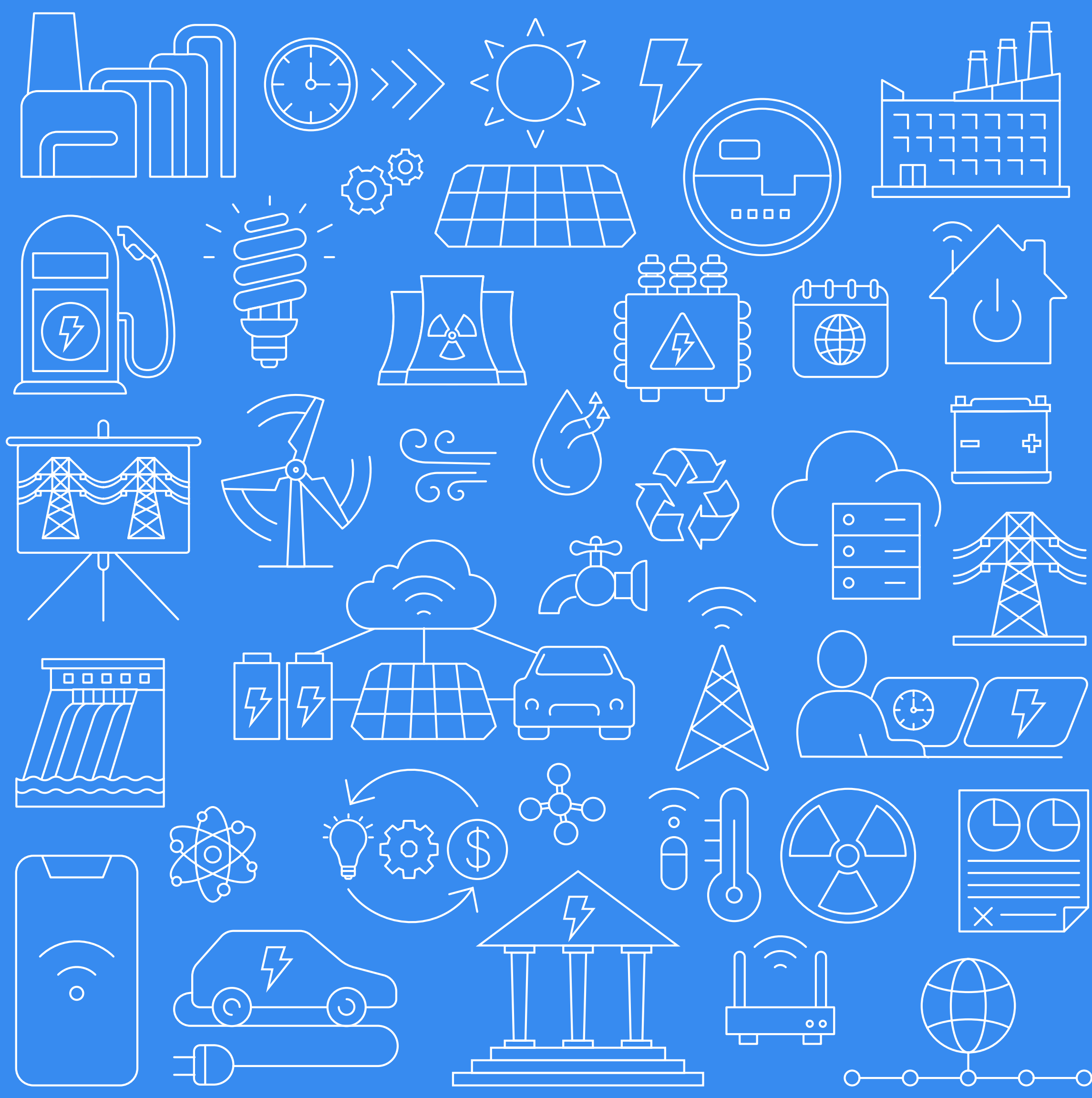
Virtual Power Plant Profiles and Inventory

January 2025

Angela Long, *Rockcress Consulting*
Ryan Long, *Rockcress Consulting*
Natalie Mims Frick, *Berkeley Lab*

Rockcress

BERKELEY LAB
Lawrence Berkeley National Laboratory



VPP Inventory

The **VPP Inventory ("Inventory")** is a publicly available database that documents key characteristics of VPPs and allows users to sort or filter for specific VPP data points (e.g., size, location). It is populated with data from two datasets:

1. The U.S. Energy Information Administration (EIA) Form 861 (EIA-861), which includes information on Demand Response (DR) programs and net energy metering (NEM) solar-plus-battery data (referred to as "NEM resources"). This data is referred to as the "EIA DER Dataset."
2. Research that details VPPs across the U.S., District of Columbia, and Puerto Rico (referred to as "VPP Programs"). This is known as the "Research Dataset."

Given that these two datasets include different types of information, we have provided a terminology crosswalk (**Table 1**) to clarify how the data is organized.

- The Data Entry Name column defines the way Inventory entries are categorized within the report. A corresponding column has also been added to the Inventory database, enabling users to filter data based on these terms.
- The Data Entry Sub-Name column outlines the classification of each entry, which contributes to the configuration of the Inventory. This structure represents the foundational architecture of the Inventory and is utilized for data filtering, program tracking, and reporting.
- The Description provides a succinct overview of the dataset.

Table 1. Report and Inventory Terminology Crosswalk

Dataset	Data Entry Name	Data Entry Sub-Name	Description
Research	1. VPP Program	1(a) Equity-focused	VPPs studied in this report
		1(b) Grid-focused	
EIA DER	1. Existing DR Programs	1(a) Traditional DR	Data from 2023 EIA-861 on Demand Response programs
	2. Existing NEM Resources	2(a) NEM Solar+Battery	Data on NEM solar-plus-battery resources

The Inventory has six high-level categories, encompassing multiple characteristics: location, implementor, entry details, VPP profile, DER type and equity attributes. A full description of all data points can be found within the Inventory. The Inventory serves as a valuable tool for understanding the current VPP landscape and identifying future VPP opportunities.

VPP Inventory Analysis

Using data from the Inventory, we analyzed four aspects of the VPP characteristics—implementer, VPP profile, Aggregated DER (ADER) type and equity to better understand current VPP trends.

During our research, we observed that some VPPs were particularly focused on equity goals. To explore this further, we chose to track these initiatives within the Inventory in order to assess whether VPPs with an equity focus differed from those primarily aimed at addressing grid needs. This comparison of design approaches, including the emphasis on equity, also contributed to shaping the approach of our VPP Profiles. Additionally, we use the Inventory as an entry point for understanding the opportunity to leverage existing DR programs and NEM resources for future VPP implementation. **Figure 1** provides our high-level findings.

Figure 1. VPP Inventory Findings

Investor-owned utilities (IOUs) are currently the primary implementors of VPPs, though equity-focused VPPs often involve a more diverse group of implementors.

VPPs primarily focus on DR or flexible load management strategies.

The 10 largest VPP programs in the U.S. aim for more than 15 GW of potential VPP capacity.

The majority of entries in the Research Dataset are classified as Integrated VPPs (see **VPP Program—VPP Type**).

Most entries in the VPP Inventory rely on demand DERs, with equity-focused VPPs showcasing more diversity by incorporating a mix of demand, generation, and storage DERs.

Over 40 VPPs, representing 8 GW of potential VPP capacity, include equity components. These include five high-level types of equity-focused VPPs: finance and funding, low-to-moderate income and disadvantaged communities, place-based, resilience, and tribal.

There are over 27 GW of existing DR programs and NEM resources, with 10 states making up the majority of capacity. These programs serve as a foundation for the design and deployment of future VPPs.

Conceptual VPP Profiles

Background

While developing our companion report, Insights into Scaling VPPs, many of our interviewees described how existing VPPs differ in DER penetration, access to scaling resources, policy support, location, market structure, and software platforms, with each model contributing value to the grid differently. However, interviewees stated that discussing these different VPP types can be challenging among regulators, utilities and stakeholders to distinguish and identify.

Additionally, during our research for both reports, we identified over 30 definitions of VPPs, influenced by audience, goals, region, perspectives, use cases, resource types, and location (see **Appendix C**). In addition, terms such as VPP, VPP platform, DERs, flexible loads, and DR are used interchangeably by various parties. The variety and use of definitions and terms can lead to confusion when parties plan and implement VPPs.

This diversity in VPP use cases and definitions led us to develop three distinct VPP profile types, which are illustrated in **Figure 2**, and summarized in **Table 2**.

Purpose

As VPPs evolve, the complexity of their dispatch strategies also increases. Initially, some VPPs may operate with manual dispatch, where the control of DERs is more straightforward, and grid operators initiate actions based on predefined criteria. However, as the system matures, collaboration with grid operations intensifies, with more dynamic coordination between the VPP and the grid. This shift leads to coordinated dispatch, where grid operators work more closely with VPPs, adjusting dispatch strategies based on real-time grid needs. As the coordination deepens, it often requires changes to the workforce structure, with the introduction of specialized roles or teams dedicated to managing VPP integration and grid operations. These changes are essential to ensure that the VPP can respond flexibly to both grid and customer needs, ultimately supporting a more efficient, resilient power system.

When deploying a VPP, it is essential to balance near-term objectives with long-term strategic planning. Initially, the focus should be on integrating DERs into grid operations as quickly and effectively as possible. At the same time, it's crucial to consider how current investments will continue to provide value to both customers and the grid in the future. For instance, a utility might begin with a basic VPP (referred to as an "Aggregated VPP" in this report) and later transition to a more complex VPP (referred to as an "Orchestrated VPP" in this report) as its needs evolve. Additionally, it's important to recognize that multiple VPP types may be deployed simultaneously, depending on the resources and grid requirements. **Table 2** guides these profile variations, ranging from simple binary events to more advanced dispatch strategies that optimize both grid-edge and bulk system operations.

Deploying VPPs can be complicated given the wide range of use cases as described above by VPP implementers and the technologies deployed within them. Each VPP is designed with specific goals, software, integration requirements, and workforce needs which vary by organization.

To aid in advancing discussions among various parties and to support the understanding of why VPPs may differ, we developed simplified conceptual profiles, with a summary table as described below:

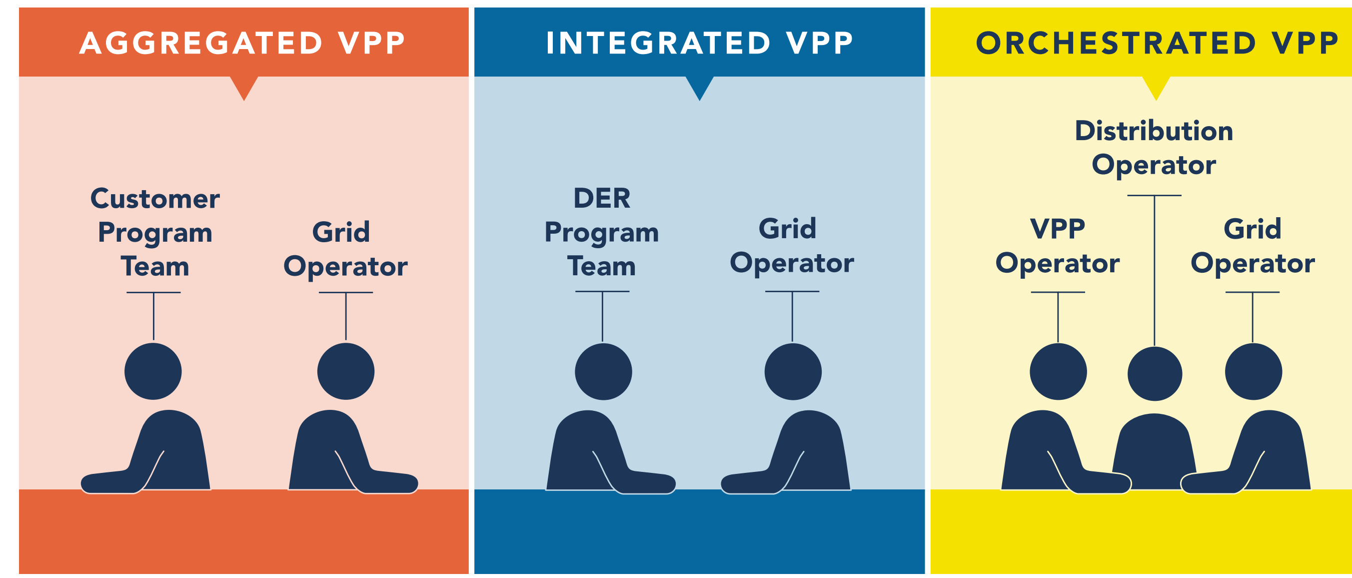
1. **VPP Profiles** consisting of three VPP types—**Aggregated, Integrated, and Orchestrated** (**Figure 2**). These profiles represent different stages of VPP deployment and highlight the varied approaches to integrating DERs with grid operations.
2. **VPP Profile Summary Table** that utilizes the VPP Profiles and incorporates key design considerations such as DER adoption, ownership, coordination, grid services, and notice requirements (**Table 2**).

In the following sections, we provide a more detailed discussion of these resources, starting with the VPP Profiles, followed by a summary table of the VPP Profiles. A description of each design characteristic within **Table 2** can be found in **Appendix B**, and **Appendix C** includes definitions of key terms used throughout the report.

VPP Profiles

Below we present three VPP profiles intended to represent the different stages of VPP design and deployment and highlight the varied approaches to integrating DERs with grid operations.

Figure 2. VPP Profiles



Aggregated VPP

Aggregated VPPs represent the simplest and most basic type of VPP, typically utilizing demand-side resources like DR or flexible loads. The primary purpose of an Aggregated VPP is to shape or shift load on the grid, making it a useful tool for demand-side management. These VPPs generally operate with homogenous DERs (e.g., smart thermostats program) under fixed tariff schedules, which may be limited to specific grid need such as reducing overall system peak demand. The coordination of these DERs is minimal, and communication is often one-way.

Aggregated VPPs are typically managed by a single DER management system such as a distributed resource management system (DRMS) or Edge distributed energy management system (DERMS), enabling manual dispatch of DERs. Due to their simplicity, Aggregated VPPs are responsive to grid needs with longer dispatch lead times, often hours or days.

The DERs in Aggregated VPPs are typically smaller and contribute a lower percentage (less than 5%) of the distribution system's peak load.[2] This low level of integration means that these systems are typically managed manually, with limited coordination between the bulk power and distribution systems. These VPPs are often used for energy and capacity management at the bulk system level, but they rarely engage in coordination with the distribution system.

In **Figure 2**, Aggregated VPPs are composed of a customer program team and a grid operator, facing back-to-back, because the program team and grid operator are working together, but not in close alignment. It represents a VPP where the program is focused on customer satisfaction, while meeting forecasted grid capacity needs such as day-ahead events.

Key Takeaways:

Aggregated VPPs represent the simplest and most basic type of VPP, characterized by the following:

- Simple to implement, with basic load-shifting capabilities.
- Typically utilize demand-side resources like DR or flexible loads to shape and shift load.
- Have minimal DER coordination, mainly manually dispatching DERs.
- Primarily for energy and capacity services at the bulk system.

[2] De Martini, P. *Distribution System Evolution*. Nov. 2023.

Integrated VPP

Integrated VPPs represent an intermediate evolution of VPPs, where the focus shifts to enhanced control and visibility. By leveraging advanced communication controls and software for near real-time visibility, Integrated VPPs can manage large volumes of DERs, enabling them to operate similarly to traditional grid resources. These VPPs combine diverse DER types (e.g., demand response, generation, storage) into a unified resource that can meet intraday grid needs, such as hour-ahead dispatches. They are operated through a single VPP platform that manages multiple other energy management systems such as DRMS and Edge DERMS. The VPP platform interfaces with other enterprise-wide systems and is integrated into a centralized DERMS.

These VPPs have a level of DERs that typically contribute between 5-15% of the distribution system's peak load,[3] and can provide energy, capacity, and essential reliability services at the bulk system level. Their dispatch processes are partially automated (meaning that some manual processes may still exist in dispatching VPP events) based on grid needs and operations, making it more dynamic, adapting to grid conditions with two-way communication that allows for near real-time responses. Additionally, Integrated VPPs enable more frequent dispatches and rely on integrated systems to coordinate with both the bulk power system and distribution operations.

A key characteristic of Integrated VPPs is the integration of both homogeneous and heterogeneous DERs, supported by advanced operational capabilities, and are generally operated based on grid needs. These VPPs can accommodate smaller DERs such as "bring your own device" (e.g., batteries) to medium-sized DERs such as microgrids.

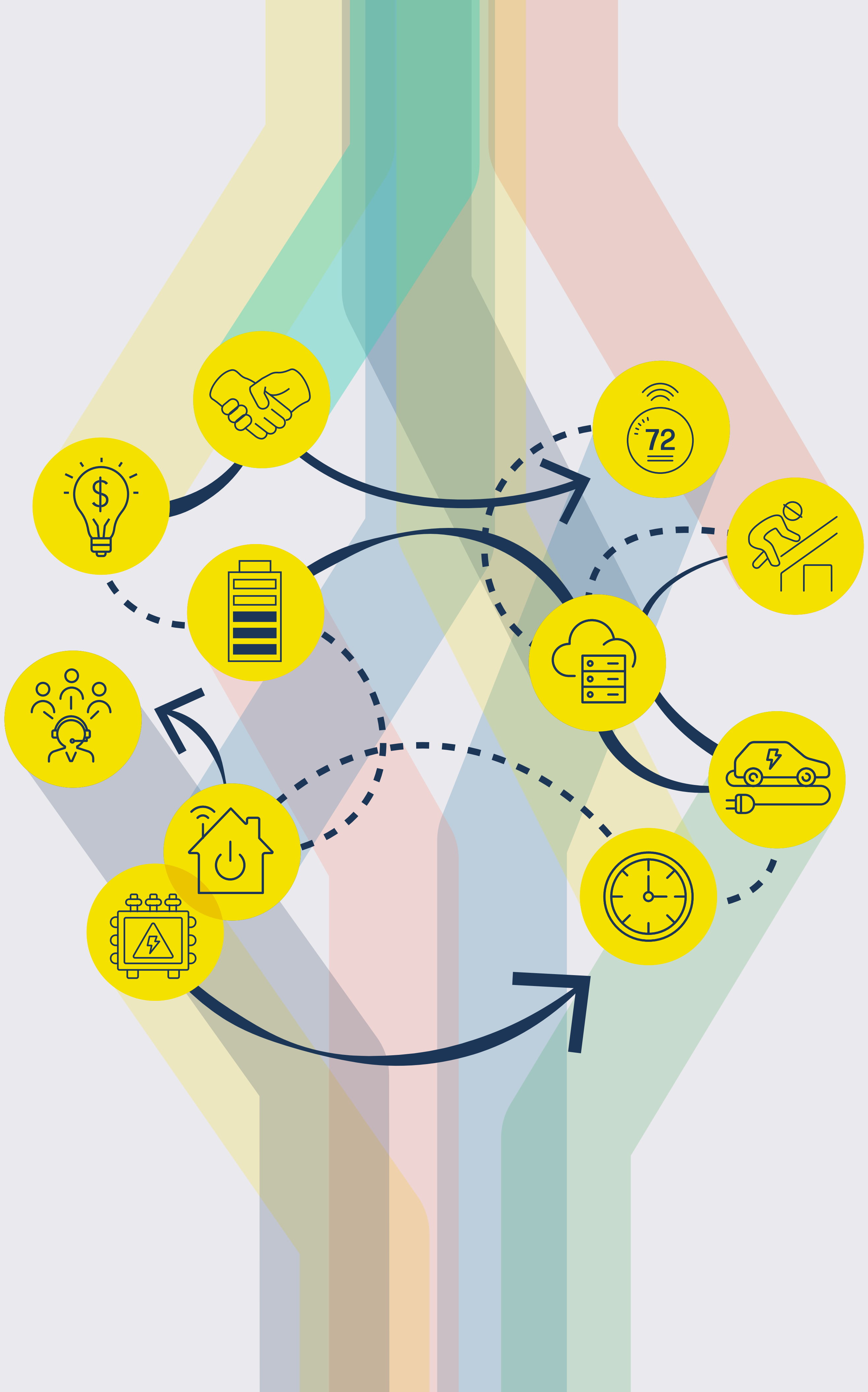
The Integrated VPP creates the need for enhanced workforce functions, including the establishment of a dedicated DER program team, as seen in **Figure 2**. This team oversees solution providers, Edge DERMs, and customer experience, while the grid operator ensures the VPP delivers the required grid services. Effective coordination with grid operations is crucial, requiring frequent interaction between the two teams to maximize benefits for both consumers and the grid. Although partially automated, the VPP still relies on strong collaboration between the DER program team and grid operations to ensure the smooth execution of VPP events, as illustrated in **Figure 2**.

Key Takeaways:

The key difference from an Aggregated VPP to an Integrated VPP is the shift in increased control, visibility and enhancements to workforce such as a dedicated DER program team within a utility. These VPPs:

- Combine homogenous and heterogeneous DERs, with the ability to utilize increasingly larger DERs such as microgrids.
- Typically shape, shift and shed load.
- Provide bulk system energy, capacity and reliability services while offering more dynamic control and near real-time responsiveness.
- Involve closer integration between DER program teams, grid operators and solution providers.

[3] De Martini, P. Distribution System Evolution. Nov. 2023.



Orchestrated VPP

Orchestrated VPPs represent the most advanced level of VPP deployment, utilizing a sophisticated VPP platform, typically actively controlled through an Advanced Distribution Management System (ADMS) that is integrated into a centralized DERMS. The primary goal of Orchestrated VPPs is to provide a comprehensive range of services: not only energy, capacity, and reliability at the bulk system level, but also services at the distribution system and local grid edge, including energy, capacity, resilience. These VPPs leverage a broad range of heterogeneous DERs, such as batteries, microgrids, and other distributed energy resources, and can have very high levels of DERs (contributing more than 15% of the distribution system's peak load).[4]

These VPPs enable active transacting DERs to respond dynamically to grid fluctuations, retail and market signals. The dispatch process is continuous, allowing for real-time control (within seconds) and dynamic participation in economic dispatch such as responding to market signals. Orchestrated VPPs enable locational dispatch, optimizing DERs at the grid edge. Additionally, their two-way communication ensures seamless integration with both the distribution system and the bulk power system.

Orchestrated VPPs are implemented by three entities (as seen in **Figure 2**) that apply system operator functions, traditionally managed by Independent System Operators (ISOs), at the distribution level. This VPP introduces the role of the VPP operator, which integrates distribution and grid operations. This role represents an evolution of the DER program team and oversees all aspects of DER planning and operations at the grid level.

Orchestrated VPPs offer significant additional benefits beyond those created by an Integrated VPP, such as enhanced local resilience, improved power quality, and better voltage and reactive power control all the way to the grid edge. An Orchestrated VPP administers a transparent market for DERs, where VPPs openly transact and participate in economic dispatch.

Key Takeaways:

The key difference between an Orchestrated VPP and an Integrated VPP lies in the VPP Platform—Orchestrated VPPs leverage an Advanced Distribution Management System (ADMS) to seamlessly integrate the VPP platform into centralized grid operations. Additionally, it integrates the ADMS into a centralized distributed energy resource management system (DERMS), which may also be referred to as a grid DERMS or an enterprise DERMS. This technology enables system actors—such as ISOs, utilities, solution providers, producers, and customers—to interact at the distribution-level.[5] Orchestrated VPPs are characterized by the following:

- Sophisticated, continuously operating VPPs with real-time, locational dispatch.
- Typically shape, shed, shift and shimmy load.
- Can manage and operate high levels of DER integration, with the ability to leverage diverse interconnected DERs and third-party resources.
- Provides local resilience and integrates with both bulk power and distribution systems.

[4] De Martini, P. *Distribution System Evolution*. Nov. 2023.
[5] Black & Veatch Management Consulting. DSO Models for Utility Stakeholders: Organizational Models for a Digital, Distributed Modern Grid. Accessed in Jan. 2025.

VPP Profile Summary Table

Table 2 summarizes the three VPP profile types, followed by descriptions of defining program and system characteristics. This table serves as a quick-reference guide—essentially a "cheat sheet"—to help novice to intermediate audiences understand differences in VPPs and facilitate discussions among various stakeholders. It was developed based on frequently asked questions and topics identified during interviews conducted while preparing our companion report.

The three VPP profile types are not mutually exclusive and do not necessarily represent linear progression. Rather, they are meant to distinguish different VPP configurations. For instance, depending on the specific VPP goal, available resources, or grid requirements, an implementor may choose to deploy an Aggregated VPP for one customer segment and an Integrated VPP for another.

Given the evolving nature of VPPs, design considerations should be seen as a spectrum rather than rigid categories. Not all VPPs will align perfectly with the descriptions here, but these profiles provide a starting point for discussion. As VPP deployment continues to evolve, these profiles will likely be updated to reflect new developments.

Table 2. VPP Profile Summary Table[6]

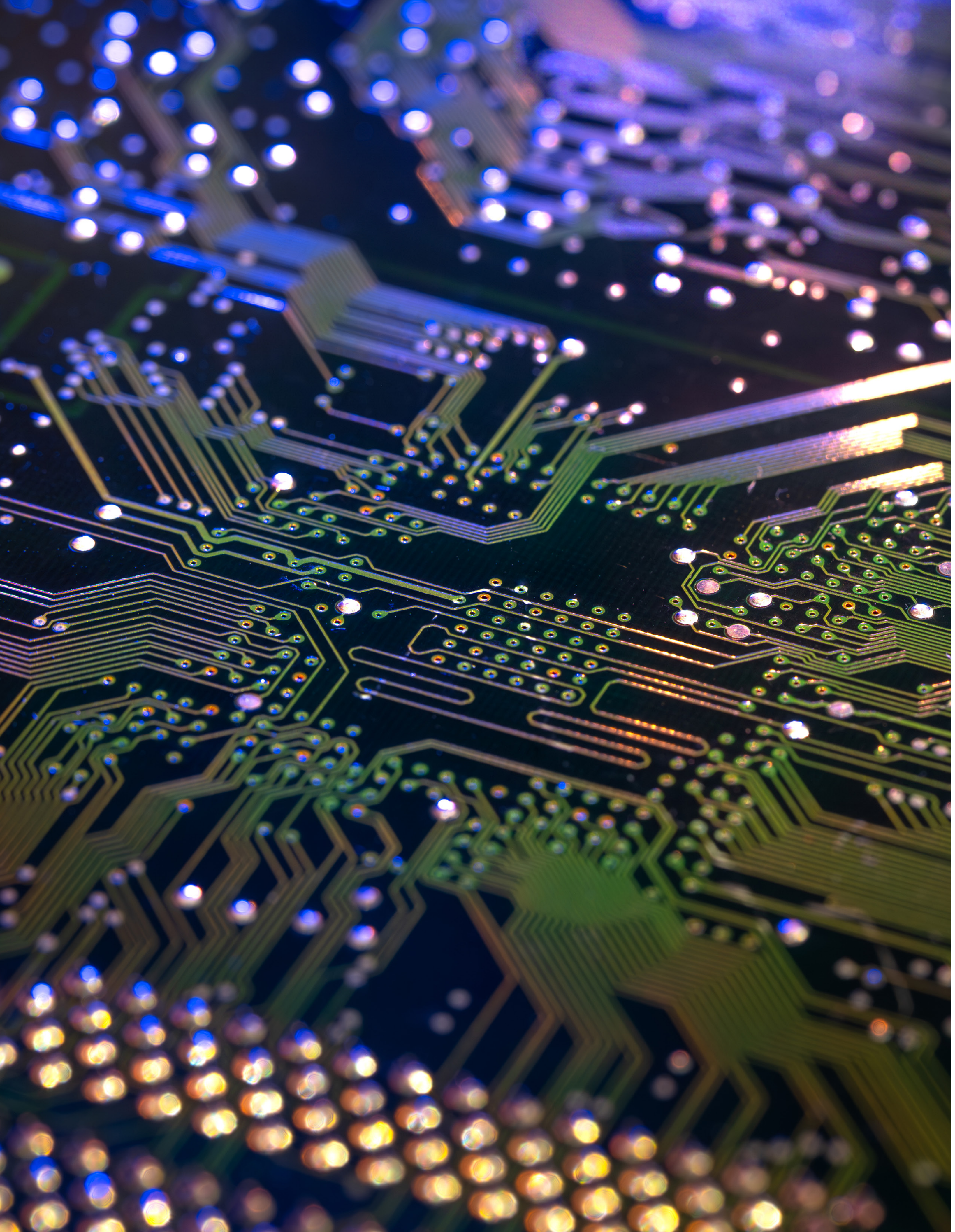
	Aggregated	Integrated	Orchestrated
	Aggregated VPPs are the most basic type of VPP in terms of the grid services it provides.	**Integrated VPPs support increased control and visibility of DERs.**	**Orchestrated VPPs actively control and monitor DERs at all levels of the grid.**
Program Characteristics			
Purpose	Shape, shift	Shape, shift, shed	Shape, shift, shed, shimmy
DER Type(s)	Homogenous DERs in a program; Homogenous aggregations	Homogenous DERs in programs; Heterogenous aggregations	Heterogenous DERs in programs; Heterogenous aggregations
Design Parameters	Based on tariff schedules	Based on grid need and operation	Based on grid need and operation or retail and market need and operation
Example Program	Smart thermostat program	Bring your own device (e.g., batteries) or microgrid	Texas ADER, PacifiCorp Wattsmart Program, National Grid's Connected Solutions Program[7]

[6] Refer to **Appendix C** for terms in this table.
[7] Additional information on PacifiCorp's and National Grid's VPPs can be found in our *Insights into Scaling VPPs* report.

Table 2. VPP Framework Characteristics (continued)

	Aggregated	Integrated	Orchestrated
	Aggregated VPPs are the most basic type of VPP in terms of the grid services it provides.	**Integrated VPPs support increased control and visibility of DERs.**	**Orchestrated VPPs actively control and monitor DERs at all levels of the grid.**
System Characteristics			
Grid Services	Energy and capacity at the bulk system	Energy, capacity, essential reliability services at the bulk system	Energy, capacity, essential reliability services at the bulk system and distribution system; energy and local resilience at the grid edge
Bulk Power and Distribution System Coordination	Limited, if any, bulk power system and distribution system coordination	Integrated with the bulk power system, limited distribution system coordination	Active within the bulk power system and locational distribution system coordination
Power Flow & Interconnection	One-way; minimal interconnection to ensure DERs safely connect to the grid	Two-way; enhanced to ensure DERs safely interact with the grid	Two-way; enhanced to ensure DERs safely interact with the grid
Responsiveness	Forecasted (day-ahead or days before event)	Near real-time (hour-ahead)	Real-time (within seconds)

	Aggregated	Integrated	Orchestrated
	Aggregated VPPs are the most basic type of VPP in terms of the grid services it provides.	**Integrated VPPs support increased control and visibility of DERs.**	**Orchestrated VPPs actively control and monitor DERs at all levels of the grid.**
System Characteristics			
Dispatch Frequency	Discrete events	Daily events	Continuous operation
Dispatch Control	Manual	Partially automated	Fully automated
Platform Type	DRMS, Edge DERMS	DRMS, Edge DERMS, Centralized DERMS	ADMS, Centralized DERMS that coordinate with DRMS, Edge DERMS
Platform Description	No platform; use single DER management system	Capable of interfacing multiple systems	Capable of dynamically and actively transacting DERs



VPP Inventory

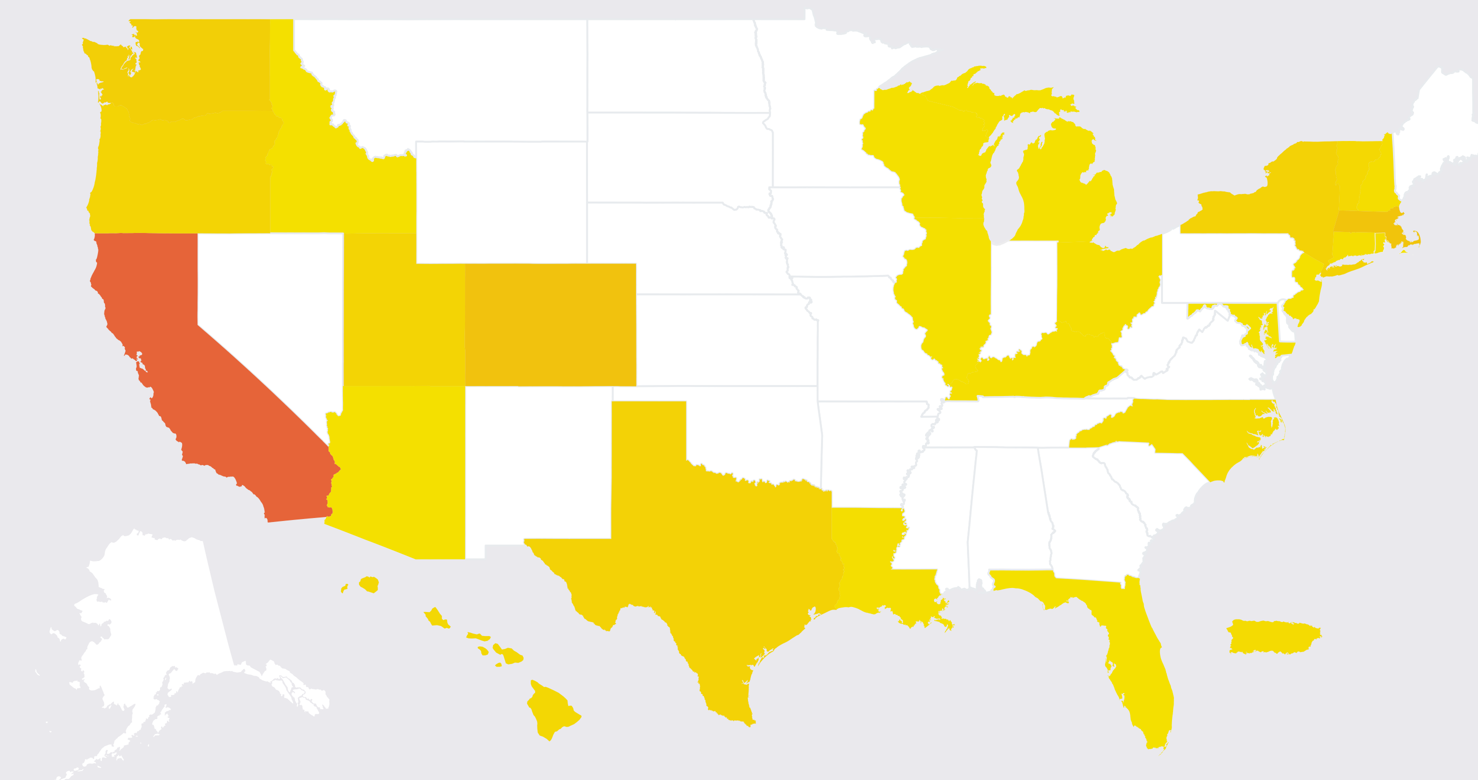
While conducting research and interviews for our companion report Insights into Scaling VPPs, the project team identified an information gap on current VPP trends. Despite the rapidly growing body of work on VPPs, there is not a publicly available resource that documents their key characteristics and allows users to sort or filter for specific VPP attributes (e.g., size, location). To address this gap, we created the Inventory, a publicly available database, using information from our research and 2023 EIA-861 data.[8] However, it remains a starting point, and future efforts are needed to refine this data and create a more robust, publicly available resource.

There are two datasets in the Inventory, named the Research Dataset and EIA DER Dataset. For simplicity, we use the following broad terms to describe entries within each dataset. Please refer to **Appendix A** for additional terms used throughout this report.

- DR in the EIA DER Dataset is referred to as "existing DR programs."
- NEM solar-plus-battery in the EIA DER Dataset is referred to as "existing NEM resources."
- VPPs in the Research Dataset are referred to as "VPP programs."
- When discussing entries in the Inventory, we refer to them as "Inventory entry" or "entry."

[8] U.S. EIA. *Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files*.

Figure 3. Research Dataset by State and Count



Count of VPPs Researched (1 – 62)

Arizona	1	Illinois	1	New Jersey	1	Texas	8
California	62	Kentucky	2	New York	8	Utah	7
Colorado	16	Louisiana	2	North Carolina	4	Vermont	5
Connecticut	3	Maryland	1	Ohio	2	Washington	9
Florida	1	Massachusetts	15	Oregon	7	Wisconsin	1
Hawaii	6	Michigan	1	Puerto Rico	4		
Idaho	1	New Hampshire	3	Rhode Island	3		

The Research Dataset includes approximately **180** VPP programs with a potential VPP capacity of **19** GWs

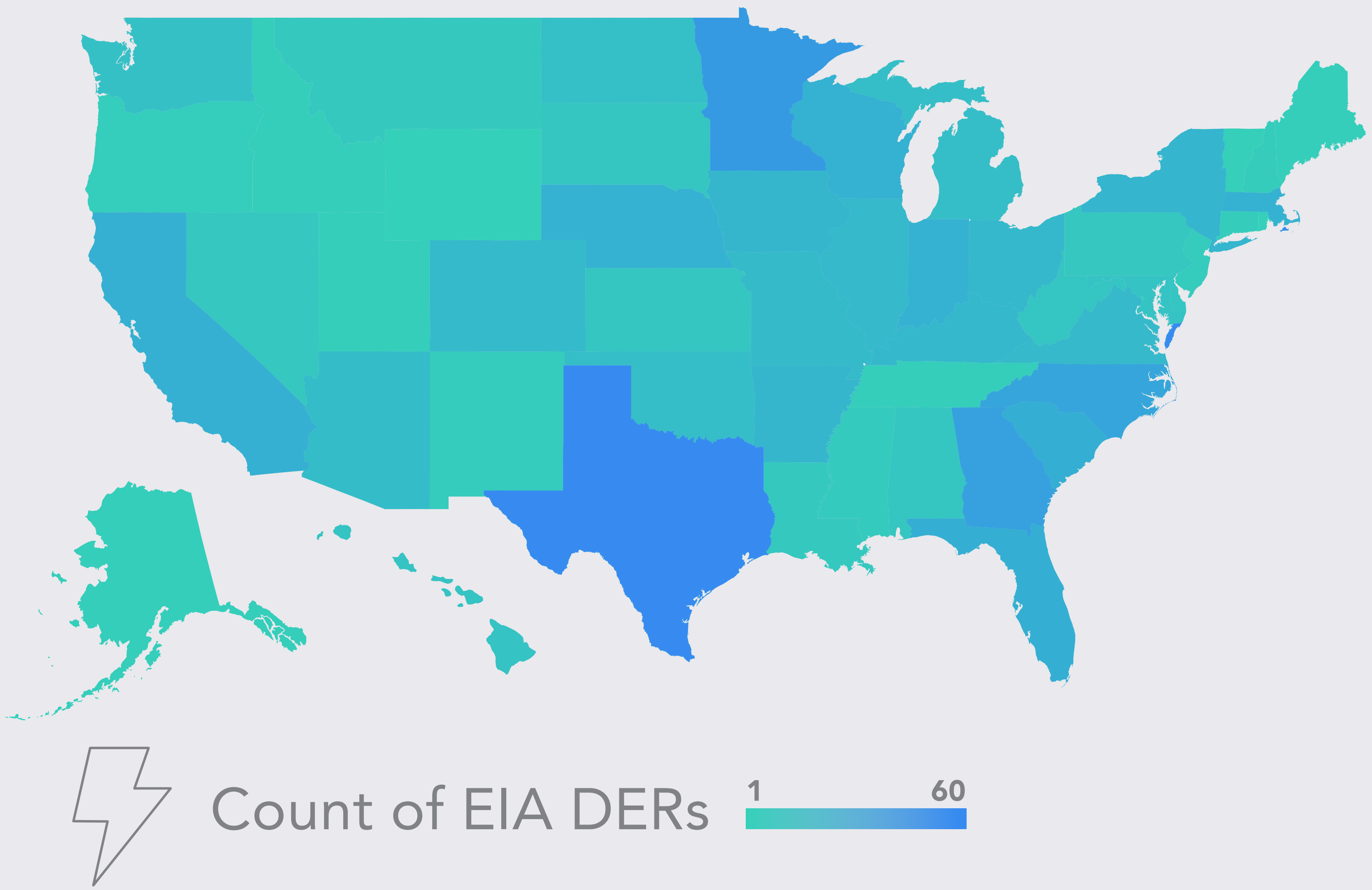
Research Dataset

The Research Dataset was developed using publicly available data and information from sources including utility filings, industry reports, news articles and press releases. This information serves as a novel, publicly available dataset of VPPs in the 50 states, District of Columbia, and Puerto Rico, enabling stakeholders to explore and understand the current landscape of VPPs.

During our research, we observed that some VPP programs were particularly focused on equity goals. To explore this further, we chose to track these initiatives within the Inventory in order to assess whether VPPs with an equity focus differed from those primarily aimed at addressing grid needs. Unlike the EIA DER Dataset, which does not include equity related data, this dataset contains adequate information to analyze high-level findings related to VPPs with equity attributes. Each VPP in this dataset is categorized as either an equity-focused or grid-focused VPP, based on its primary driver of design.

The Research Dataset includes 180 VPP programs with a potential VPP capacity of 19 GWs. **Figure 3** illustrates the location and number of VPPs we researched. We chose to highlight the count of VPP programs due to the lack of publicly available data on potential VPP capacity for some of the VPP programs within this dataset.

Figure 4. EIA DER Dataset by State and Count



Alabama	9
Alaska	2
Arizona	17
Arkansas	23
California	28
Colorado	20
Connecticut	4
Delaware	10
District of Columbia	1
Florida	29
Georgia	41
Hawaii	12
Idaho	2
Illinois	20
Indiana	26
Iowa	23
Kansas	9
Kentucky	21
Louisiana	7
Maine	3
Maryland	12
Massachusetts	26
Michigan	16
Minnesota	47
Mississippi	6
Missouri	19
Montana	7
Nebraska	26
Nevada	8
New Hampshire	4
New Jersey	5
New Mexico	5
New York	24
North Carolina	37
North Dakota	15
Ohio	21
Oklahoma	16
Oregon	3
Pennsylvania	8
Rhode Island	1
South Carolina	29
South Dakota	9
Tennessee	2
Texas	60
Utah	2
Vermont	1
Virginia	20
Washington	14
West Virginia	10
Wisconsin	27
Wyoming	1

The EIA DER Dataset includes approximately

790

existing DR programs and NEM resources with a capacity of

27 GWs

EIA DER Dataset

The EIA DER Dataset includes data on existing DR programs and NEM resources from the 2023 EIA-861 data. EIA-861 collects self-reported data from utilities on their DR programs and NEM resources through its Annual Electric Industry Report, Form 861 annually. This data includes information such as utility, sector(s), megawatts of capacity, and costs, but does not include details on the included technologies, how the DERs are operated, or other aspects such as equity attributes and grid benefits. EIA-861 does collect data on both the potential and actual DR capacity by state and utility, and for consistency we use the same terms when describing the existing DR programs.

The EIA DER Dataset includes approximately 790 existing DR programs and NEM resources with a capacity of 27 GWs.[9] **Figure 4** illustrates the location and count of DERs within the EIA DER Dataset.

[9] See **Appendix A** for how capacity is described within the EIA DER Dataset.

Data Selection, Cleaning and Limitations

The project team reviewed publicly available data such as 2023 U.S. EIA-861 data, utility filings, industry reports, news articles, and press releases. U.S. EIA-861 data was used because it is the only publicly available data collected from distribution utilities and power marketers of electricity, which creates a survey census of all US electric utilities on existing DR programs and NEM resources.

To prevent duplicate entries in the Inventory, the datasets were cleaned after being merged. If an entry appeared in both the Research and EIA DER Datasets, it was removed from the EIA DER Dataset. To be conservative in identifying potential duplicates, entries were generalized into residential and non-residential customer segments, and each entry was classified by the types of DERs included (**Figure 5**). Potential duplicates were removed from the EIA DER Dataset if another entry matched three characteristics—utility name, generalized customer sector(s), and DER type.

While the Inventory database is a valuable resource, it also points out a key challenge: there is currently no distinct data source that differentiates between existing DR programs, NEM resources, and VPP programs that utilize DERs for demand, generation, and storage. This means that utilities and states may consider existing DR programs and NEM resources as part of their VPP programs, but the distinction between the three is not clearly made within EIA-861 as well as within VPP programs, which can create confusion or challenges in measuring the actual impact and effectiveness of VPPs.

Please note that some data points in the Inventory may be missing due to the unavailability or difficulty in obtaining publicly accessible information. In certain cases, data could not be found or was not readily accessible at the time of this research. For example, not all public sources reported capacity for VPPs we researched; however, they may have reported device counts, homes, participants or energy saved. While we made considerable efforts to ensure the data is accurate and up-to-date, users should exercise discretion and caution when using the dataset. We do not make any guarantees about its completeness or reliability, and we recommend users independently verify any insights or decisions they make based on this data.

Structure

The Inventory has six high-level categories, encompassing multiple characteristics: location, implementor, entry details, VPP Profile, DER type and equity attributes (**Figure 6**). The VPP Inventory allows users to sort all data using various characteristics. A full description of all data points can be found within the Inventory database. In addition to the six categories, the project team included additional data points to help filter data based on potential VPP configurations (such as traditional DR, equity-focused), data source type (such as EIA-861 data or researched), and EIA utility name and number.

Figure 5. ADER Configurations and Examples of Technologies[10]

Demand	Generation	Storage
Demand DERs include EV chargers, smart thermostats paired with electric heating, ventilation, and air conditioning systems (HVAC), such as heat pumps, electric water heaters, and C&I equipment.	**Generation DERs** include distributed solar (which becomes dispatchable when paired with storage systems such as batteries) and fuel-based generators.	**Storage DERs** include BTM batteries and EV batteries.

[10] Sourced from the U.S. DOE's *Pathways to Commercial Liftoff Report: Virtual Power Plants*. Sept. 2023.

Figure 6. VPP Inventory High-level Categories

The six categories of the Inventory are summarized as follows. A full description of all data points can be found within the Inventory.

Location

Provides information on the location of the Inventory entry.

Implementor

Categorizes Inventory entries based on implementor type. We utilized four categories: utilities (such as IOUs, municipalities, public power, cooperatives and retail providers), solution providers (aggregators, which can include utilities, and Original Equipment Manufacturers), local (community choice aggregators, cities or communities), and state or national (state or national-led initiatives such as California's Demand Side Grid Support Program).

Entry details

Provides multiple high-level data points such as sector, DER(s), capacity, energy, incentive, customer count, dispatch time and months.

VPP Profile

Categorizes Inventory entries as Aggregated, Integrated or Orchestrated, based on the VPP Profiles. Specifically, EIA DER Dataset entries were classified as Aggregated VPPs (see Leveraging the EIA DER Dataset section). The Research Dataset entries were classified as an Integrated VPP unless it was specifically noted that the VPP was used for wholesale market participation, in which case they were classified as an Orchestrated VPP.

DER type

Provides the composition of Aggregated DERs (ADERs) in the Inventory entry and categorizes the entry as Demand, Generation or Storage DERs (**Figure 5**).[11]

Equity attribute

Identifies if the VPP program has an equity attribute.

[11] We incorporated DER configurations from NARUC's *Aggregated DER in 2024: The Fundamentals*, Tables 5 through Table 7, into the VPP Inventory needed to identify the potential grid services VPPs may provide across the bulk power system, distribution, and grid edge. Based on these configurations, the VPP Inventory categorizes ADERs such as demand, generation, and storage. Accessed in Jan. 2025

Inventory Analysis

The project team used the data in the Inventory to identify VPP trends. This chapter reports on the results of analysis using the Research Dataset and includes several Inventory categories—implementor, DER capacity, VPP Profile, DER type and equity attribute.

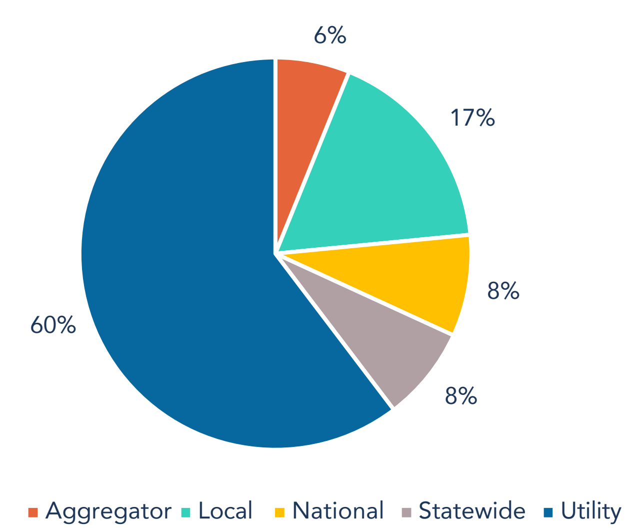
We use both datasets for some, but not all of our analyses, because we wanted to understand the current state of VPP programs compared to the ability to scale VPPs using existing DR programs and NEM resources. For each section of this report, we note the dataset that is used for the findings. We use the Inventory to begin to analyze the opportunity to use existing DR and NEM resources as VPP resources as seen in the **Examining Potential to Scale VPPs** section.

Leveraging the Research Dataset

VPP Program—Implementor Type

Using the Research Dataset within the Inventory, we explored which types of implementers are leading VPP deployment. We found that utilities are the main drivers of adoption, with large IOUs playing a central role. These deployments are typically focused on DR or flexible load management. **Figure 7** highlights the diversity of VPP implementors, each shaped by different organizational motivations and objectives. .

Figure 7. VPP Program—Distribution of Implementor Types[12]



[12] Data from the Research Dataset.

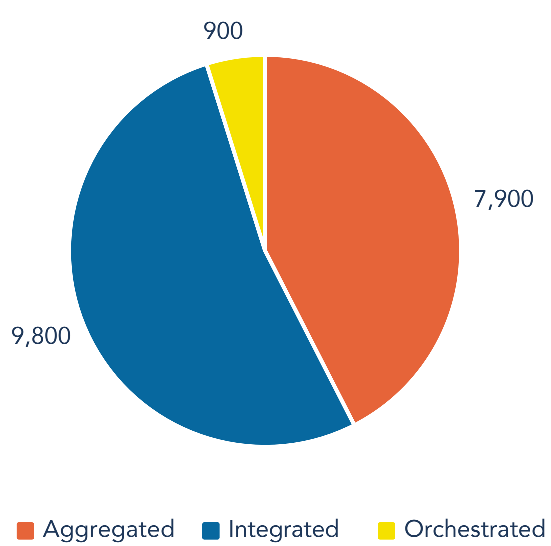
VPP Program—VPP Type

Guided by the VPP Profiles, we cataloged VPP programs in the Research Dataset (**Figure 8**). The majority of the VPP programs in the Inventory fall into the Integrated VPP category because they focus on combining diverse DERs types (e.g., demand, generation, storage) to function as a unified grid resource.[13] Aggregated VPPs also represent a significant portion, as many VPP programs are primarily composed of demand DERs. We also classified VPP programs as Aggregated VPPs when there was insufficient data to confirm whether the VPP would operate as an Integrated or Orchestrated VPP. Orchestrated VPPs in this dataset include programs that have stated goals for participation in retail or wholesale markets.

Finding Sourced from the Research Dataset

Programs or VPPs with an equity focus tend to include a more diverse group of implementors. Approximately 25% of organizations are national, 15% are local and 10% are statewide. In contrast, when looking at all VPPs in the Inventory, utilities are the predominant implementer.

Figure 8. VPP Program—VPP Type by Potential Capacity (MW)[14]



[13] Bieler, S., Cara Goldenberg, Avery McEvoy, et al. Jul. 2024. *Aggregated DER in 2024: The Fundamentals*.
[14] Data from the Research Dataset with capacity numbers rounded to the nearest hundredth.

VPP Program—Potential VPP Capacity

Using the Research Dataset, we identified organizations with the largest potential VPP capacity goals in the US. Understanding who implements VPPs provides an understanding of where VPP deployment opportunities may emerge, enabling grid optimization, and advancing demand flexibility and system modernization through DERs. **Table 3** presents the top 10 VPP implementers based on potential VPP capacity goals, ranked by capacity.

Many VPP programs aim to address various energy and grid challenges while pursuing specific goals, such as aligning with community and state objectives, supporting grid modernization, balancing renewable energy and energy storage, enhancing resilience, promoting energy equity, and advancing decarbonization. For example, Tri-State Generation Association, a cooperative utility, plans to procure 1.3 GW of renewable energy and storage by 2031. This effort aligns with Colorado's clean energy and efficiency goals, including a 4% DR target launching in 2025, with similar initiatives extending to New Mexico and Wyoming.[15]

Another notable VPP program is Nimiipuu Energy's, a Tribe-to-Tribe Utility Cooperative, which has plans for a 5.3 GW VPP that would be the largest in the nation, providing pathways to energy sovereignty and cultural revitalization for tribal communities.[16]

[15] Tri-State Generation Association. Dec. 2023. *Tri-State Accelerates Clean Energy Transition and Bolsters Electric System Reliability*.
[16] Nez Perce. *Nez Perce Tribe to Reveal Plans for Virtual Power Plant at RES2022*.

Table 3. VPP Programs—Top 10 VPP Implementers Ranked by Potential Capacity[17]

Organization	Implementer Type	State(s)	Driver	Capacity (MW)
Nimiipuu Energy	Local	Idaho, Nevada, Utah, Wyoming, Arizona	Enabling energy independence and cultural restoration through clean energy	5,300
PSE&G	Utility	New York, New Jersey	Regulatory filings, including the VPP Petition in New Jersey and Utility 2.0 Long Range Plan & Energy Efficiency Plan in New York	1,300
SMUD	Utility	California	Zero carbon goals, including customer-owned resources and customer-focused programs that can help contribute between 360 and 1,300 MW of capacity to the grid	1,300
Southern California Edison	Utility	California	Clean energy goals, reliability, wholesale market participation, including multiple programs aimed at VPP solution provider agreements, emergency load reduction, demand-side support, microgrids, local/community-level VPPs, and other DER initiatives	1,300
Tri-State Generation Association	Utility	Colorado, Nebraska, New Mexico, Wyoming	Clean energy and reliability, which accelerates the clean energy transition across the West and bolsters electric system reliability	1,300
Con Edison	Utility	New York	Clean energy goals, non-wire solutions, demand response programs and enhanced grid operations enabled by VPPs	1,200
National Grid	Utility	Massachusetts, New York	Connected Solutions, Electric Sector Modernization Plans, transportation electrification demand response, non-wires solutions, DERMS, and demonstration projects such as Fruit Belt Neighborhood	1,000
NRG Energy	Utility	Texas	AI-dispatched thermostats in partnership with Renew Homes and Google Cloud technology	1,000
Xcel Energy	Utility	Colorado	Existing DER programs, with focus on LMI/DAC, EV programs and enhanced grid operations through VPP	700
CEC	Statewide	California	Statewide programs such as Demand Side Grid Support Program, Electric Program Investment Charge (EPIC), VPP-Approaches for Demand Flexibility (VPP-FLEX)	700
Total Potential Capacity (MW)				**15,100**

[17] Data from the Research Dataset with numbers rounded to the nearest hundredth.

VPP Program—DER Types

Utilizing the Research Dataset, we examined the different types of ADERs using the DER configurations shown in **Figure 5**. This allowed us to examine the potential grid services that ADERs can provide and understand how these resources influence VPP performance. **Table 4** provides the DER Type by potential VPP capacity.

Table 4. VPP Program—ADER Type by Count and Potential Capacity[18]

DER Type	# of ADER Type	Capacity (MW)
Demand only	59	4,600
Generation only	4	100
Storage only	26	1,300
Any combination of Demand, Generation, and Storage	90	12,700
Total	**179**	**18,700**

Finding Sourced from the Inventory

Almost all VPPs with an equity focus use a combination of demand, generation and storage. This is in contrast to all of the VPPs in the Inventory, where the majority use demand only.

[18] Data from the Research Dataset with capacity numbers are rounded to the nearest hundredth.

VPP Program—Equity Attributes

The Research Dataset identifies over 40 VPP programs with equity attributes, representing a collective goal of 8 GWs of potential VPP capacity. For these VPP programs, we identified five high-level primary types of equity-focused VPP. These primary types are not meant to encompass all the equity attributes of these VPPs. Many equity-focused VPP programs share overlapping goals. For the purposes of this research, we classified VPP programs based on what we considered to be the primary equity attribute, while considering other equity attributes as goals as seen in the examples below. In the following sections, we provide a description of each equity type along with an example, presented in order of their percentage share within the total equity-focused VPP programs.

Low- to Moderate-income and Disadvantaged Communities (LMI/DAC)

VPPs that are designed to serve low-to moderate income and disadvantaged communities compose more than half of the VPP equity entries. Design goals include decarbonization, targeted outreach, support for rural communities, financial assistance for renters and multifamily housing, and enhancing incentives or affordable housing elements. **Table 5** provides an example of an LMI/DAC VPP program using Public Service Company of Colorado (Xcel Energy) service territory-wide solar plus storage program.[19]

Table 5. Example LMI/DAC VPP Program

Renewable Battery Connect—Xcel Energy	
Location	Colorado
Description	Xcel Energy's Renewable Battery Connect Program provides income-qualified customers with up to 75% of the cost of equipment. In addition, income-qualified and disproportionally impacted community residents qualify for up to 35% higher annual incentives.
Goals	Resiliency, low-cost equipment

[19] *Senate Bill 24-218* was signed into law on May 22, 2024, by Gov. Jared Polis requiring Xcel Energy to create a VPP program that includes a performance-based compensation tariff for its Colorado customers by Feb. 2025.

Place-Based

VPPs that focus on deployment in specific areas such as neighborhoods or communities, or groups of buildings (e.g., university campuses, multifamily housing) are categorized as place-based, and represent more than a third of the equity entries. These VPPs have goals that include environmental benefits, low-cost equipment, accessibility, and resiliency. They tend to focus on grid interactive buildings, efficient multifamily and rental units, and access to low-cost equipment. **Table 6** provides an example of a Place-Based VPP program using Green Mountain Power's McKnight Lane Redevelopment in Waltham, Vermont.[20]

Table 6. Example Place-Based VPP Program

McKnight Lane Redevelopment Project—Green Mountain Power	
Location	Waltham, Vermont
Description	Revitalized a previously abandoned mobile home park in rural Vermont, turning it into the nation's first resilient, zero-energy, affordable modular housing development equipped with resilient solar and battery storage systems for low-income renters in a rural community.
Goals	LMI/DAC assistance, affordable housing, low-cost equipment, rural community support

Resiliency

VPPs that focus the deployment of DERs for the purpose of community resiliency are categorized as resiliency and make up less than 10% of the equity entries. These VPPs have goals for grid-interactive buildings, low-cost equipment, and increased access to clean energy. **Table 7** provides an example of a Resiliency VPP program using Together Louisiana's microgrid project in LaPlace, Louisiana.[21]

Table 7. Example Resiliency VPP Program

Statewide Microgrid—Together Louisiana & U.S. DOE	
Location	LaPlace, Louisiana
Description	Leveraging U.S. DOE GRIP grants to develop a large solar plus storage microgrid in LaPlace, a community vulnerable to climate change. These microgrids serve as resilience hubs, providing essential services during power outages. This program was created in response to the devastation caused by two major hurricanes and the need to optimize and integrate clean energy resiliency hubs throughout the electric grid system.
Goals	Grid interactive buildings, community resilience hubs, grid innovation

Finance & Funding

VPPs that provide direct funding to consumers—such as financing for renters and those with lower credits scores, funding for community microgrids, or donations to women-, minority-, and veteran-owned businesses—are categorized as finance and funding. These represent 5% of the equity driven VPPs and are usually led by utilities or state VPP programs. **Table 8** provides an example of a Finance & Funding VPP program using ERCOT's Project TexFlex initiative at 2410 Waugh Apartments with PearlX Infrastructure and supported by SolarEdge equipment.[22]

Table 8. Example Finance & Funding VPP Program

Project TexFlex—ERCOT	
Location	Houston, Texas
Description	Provides solar and battery systems to renters and those with low credit scores, as well as community solar and battery storage in apartment complexes. Aims to achieve significant energy savings and power reliability during outages.
Goals	Grid interactive buildings, renter and multifamily assistance

[20] CleanEnergy Group. *McKnight Lane Affordable Housing Development Project Fact Sheet*. Accessed in Jan. 2025
[21] U.S. DOE Grid Deployment Office. Oct. 2023. *Grid Resilience and Innovation Partnership Programs Fact Sheet: Building Energy Resilience in Louisiana*.
[22] SolarEdge. Apr. 2022. *SolarEdge and PearlX Bring Affordable Community Solar to Texas*.

Tribal

The Tribal equity type represents VPPs within tribal communities and are less than 2% of the equity driven VPPs. This VPP has goals such as energy independence, cultural preservation, and benefits for natural resources and the environment. **Table 9** provides an example of a Tribal VPP program using Nimiipuu Energy's native-led VPP with Tesla.[23]

Table 9. Example Tribal VPP Program

VPP—Nimiipuu Energy	
Location	Lapwai, Idaho
Description	Aims to generate 5 GW of electricity, promoting energy independence and environmental restoration as part of a broader initiative to remove the Lower Snake River dams. Nimiipuu Energy is working with the Nez Perce Tribe to achieve its goals and plans to install a range of energy projects totaling 500 MW by 2027.
Goals	Energy independence, cultural preservation, natural resources and environment

[23] Nimiipuu Energy. *News*. Accessed in Jan. 2025.

Leveraging the EIA DER Dataset

The EIA DER Dataset offers a foundation for understanding existing DR programs and NEM resources. We used this dataset to explore the top 10 states with existing DR programs and NEM resources and present our findings below.

Existing DR Programs—Top 10 States

Table 10 presents the top 10 states with existing DR programs, based on actual peak demand savings, ranked by capacity. These 10 states alone have almost 15 GWs of existing actual peak demand savings, making up over 200 existing DR programs.

Table 10. Existing DR Program—Top 10 States by Count and Actual Peak Demand Savings[24]

State	# of Existing DR Programs	Actual Peak Demand Savings (MW)
Florida	19	2,900
Alabama	9	2,000
Minnesota	35	1,600
Georgia	31	1,400
New York	16	1,200
South Carolina	23	1,200
Illinois	17	1,200
North Carolina	29	1,100
Arkansas	18	1,100
Michigan	9	1,000
Total	**206**	**14,700**

[24] Data from the EIA DER Dataset with capacity numbers rounded to the nearest hundredth.

Existing NEM Resources—Top 10 States

Table 11 highlights the top 10 states with significant existing NEM resources, ranked by total NEM capacity. States like New York, Arkansas, and Florida stand out as Top 10 performers in both existing DR programs and NEM resource capacity, highlighting their well-rounded progress toward DER integration and potential for scaling VPPs.

Table 11. NEM Resources—Top 10 States by Count and Total NEM Capacity[25]

State	Count of Existing NEM Resources	Total NEM Capacity (MW)
Massachusetts	1,854	140
Hawaii	15,634	120
New York	990	70
Arizona	4,669	30
Nevada	2,499	20
Arkansas	39	20
Texas	1,970	20
Florida	2,253	20
New Jersey	1,230	10
Ohio	1,503	10
Total	**32,641**	**460**

25 Data from the EIA DER Dataset with capacity numbers rounded to the nearest tenth.

Examining Potential to Scale VPPs using the Inventory

By advancing design and deployment approaches, existing DR programs have the potential to increase VPP capacity by up to 30 GW.[26] This strategy—quickly leveraging resources that participate in DR to form the foundation of a VPP—appears in utility Bring Your Own Device (BYOD) programs. For example, in Massachusetts, utilities leveraged customers with batteries to participate in the ConnectedSolutions program. The utilities' evaluation found that 25% of customers, prior to enrolling in the ConnectedSolutions program, were using their battery for daily or near daily dispatch (e.g., DR).[27] National Grid, one of the utilities participating in the ConnectedSolutions program, was able to launch and rapidly deploy the VPP in under four months and now has 250 MW of peak shaving capacity in Massachusetts and New York.[28]

To explore how existing DR programs and NEM resources may be leveraged to create VPPs, we combined the EIA DER Dataset with the Research Dataset (see **Figure 9**). We assumed that existing DR programs and NEM resources can quickly evolve into Aggregated VPPs, similar to Massachusetts's ConnectedSolution program, with enhancements as seen in the **VPP Profiles** section and **Table 2**.

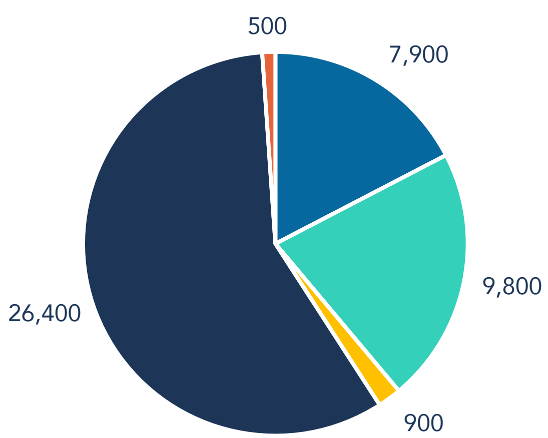
Additionally, combining existing DR programs and NEM resources within the Inventory with the Research Dataset offers valuable insights for policymakers and regulators regarding the potential for these existing resources to support VPPs within their state or to integrate VPPs into planning processes, such as integrated resource and distribution system planning.

26 Long, A., Ryan Long, Natalie Mims Frick. Jan. 2025. Insights into Scaling VPPs.
27 Guidehouse. Mar. 2024. Massachusetts Residential Energy Storage Demand Reduction Offering.
28 Razdan, S., J. Downing, L. White. Jan. 2025. Pathways to Commercial Liftoff: Virtual Power Plants 2025 Update.

Inventory Entries—VPP Type (EIA DER and Research Datasets)

Guided by our VPP Profiles, we cataloged VPP programs by VPP Type (**Figure 9**). We then combined the EIA DER Dataset with the Research Dataset in the Inventory. When combining these datasets, it shows the potential to expand VPP capacity from nearly 8 GW of VPP programs (see **Figure 8**) to over 34 GWs (**Figure 9**). This highlights a significant opportunity to scale VPPs with existing DR programs and NEM resources (see **Figure 4**).

Figure 9. Inventory Entries—Potential Capacity Growth (MW)[29]



Inventory Entries—ADER Types (EIA DER and Resource Datasets)

Utilizing the Inventory, we examined the ADER types within the Research Dataset and EIA DER Dataset using the DER configurations shown in **Figure 5**. This allowed us to examine the potential grid services that ADERs can provide and understand how these resources influence VPP performance. **Table 12** provides the ADER Type by reported capacity for all entities in the Inventory.

Table 12. Inventory Entries—ADER Type by Reported Capacity[30]

DER Type	# of ADER Type	Reported Capacity (MW)
Demand only	610	31,000
Generation only	4	100
Storage only	26	1,300
Any combination of Demand, Generation, and Storage	327	13,300
Total	**967**	**45,700**

[29] Data derived from all datasets within the VPP Inventory with capacity numbers rounded to the nearest hundredth.

[30] Data derived from all datasets within the VPP Inventory with capacity numbers rounded to the nearest hundredth.

Future Research

Our goal was to understand the current state of VPPs in addition to their potential to scale. In doing so, we developed VPP Profiles based on existing VPPs to guide the transition from traditional DR programs to Aggregated VPPs, or from Aggregated VPPs to Orchestrated VPPs. These profiles outline key characteristics that can inform the design and deployment of VPPs. It has the potential to be developed into a comprehensive tool that not only supports technical and operational advancements but also guides policy, equity, and public engagement efforts essential for deploying VPPs effectively.

The potential for VPPs to operate as a grid resource depends on their ability to effectively leverage DERs as a technological solution for grid management. Several factors, including transparency, influence how effectively VPPs are designed. To address this, we developed the Inventory, with the goal of supporting the replication of well-designed VPPs and identifying opportunities to scale future VPPs. While the Inventory is a valuable starting point, it can be further refined by enhancing the data it contains, expanding its scope, and improving its usability. Aligning the Inventory with national energy strategies and policies will strengthen its role as a comprehensive tool for understanding and scaling VPPs, ultimately supporting informed decision-making and advancing the integration of VPPs into the grid.

Although this report provides foundational insights, further research, new tools, and additional data will be needed to better understand the full potential of VPPs. We hope that our work can serve as a steppingstone toward the development of a more robust, publicly available data source to explore the opportunities and potential of VPPs, both now and in the future.

Figure 10 provides key areas for future research and initiatives that could expand upon the work presented in this report.

Figure 10. Key Areas for Future Research

Update VPP Profile Summary Table (Table 1): Refine existing characteristics and include new ones, such as operator revenue, wholesale market participation, DER size (such as MW, number of devices or customer enrollment).
Dataset Enhancements: Refine the Inventory by working with utilities and solution providers to ensure VPP programs are correctly captured within the dataset, such as identifying actual capacity versus aspirational goals for future capacity. Add new data points to the Inventory such as the capacity by DER type and Effective Load Carrying Capacity.
Enhancing Data Sharing: Utilize the Inventory as a foundational dataset for the U.S. DOE's efforts by integrating it with federal databases to improve data accessibility and transparency for stakeholders involved in national energy planning.
Aligning Profiles with Other Efforts: Compare and align the three VPP Profiles (Aggregated, Integrated, Orchestrated) with other initiatives to ensure consistency in terminology and approach across federal initiatives.
Policy Development Collaboration: Work with DOE to develop policies that support the scaling of VPPs, ensuring that federal funding and incentives are integrated to buy down the cost of VPPs to consumers.
Joint Research Initiatives: Propose joint research initiatives with DOE to explore advanced DR capabilities and their integration into VPPs, focusing on real-time grid operations and enhancing grid resilience.
Public Engagement Strategies: Develop public engagement strategies in collaboration with DOE to raise awareness about the benefits of VPPs, particularly in promoting clean energy access and community empowerment through equitable energy solutions.
Creating VPP Playbooks: Use the VPP Profiles to create detailed operating manuals for all stages in the VPP lifecycle (from building operators to solution providers to utilities to the market). These manuals will help stakeholders understand the requirements for DERs to be effectively utilized as grid resources, including the software needed for real-time control and monitoring of devices.
Expand Equity-Focused Data: Categorize all Inventory entries by the equity components they provide, if any. This will help to identify VPPs that may need support through policy to enable non-traditional utility use cases for DERs such as equity, decarbonization or resiliency.

Appendices

Appendix A. Report Terms

Bulk Power and Distribution System Coordination: Level of coordination between bulk power system and distribution system. Ranges from limited coordination to VPPs that transact in wholesale markets.

A **customer program team** is a group within a utility company or energy organization dedicated to managing and executing initiatives specifically designed to engage, retain, and enhance the experience of the organization's customer base.

A **DER program team** refers to a group of individuals within a utility company or energy organization focused on developing and managing programs that encourage the adoption of DERs, like rooftop solar, battery storage, and electric vehicle chargers, by customers, aiming to improve grid reliability, reduce peak demand, and promote clean energy usage.

A **distribution operator** manages the dynamic, two-way nature of DERs on the distribution grid (from where the distribution system starts at the circuit breaker and high-side disconnect of the substation distribution transformer) and ensures grid services at the grid edge.

DR program capacity is defined by EIA-861 as such:

- Potential peak demand savings is the "total demand savings that could occur at the time of the system peak hour assuming all demand response is called."
- Actual peak demand savings is the "demand reduction actually achieved by demand response activities and is measured at the time of the company's annual system peak hour."

Existing DR programs refers to EIA-861 DR that is captured in the EIA DER Dataset.

Existing NEM resources refers to EIA-861 NEM solar-plus-battery in the EIA DER Dataset.

A **grid operator** manages generation and transmission assets as well as transmitting electricity across long distances through the power grid to distribution points, essentially overseeing the entire flow of electricity from its creation to its delivery to consumers, often through high-voltage transmission lines.

Inventory entry refers to a data entry within the Inventory.

Potential VPP capacity refers to the capacity of a VPP program.

- We chose to use the term "potential VPP capacity" when describing VPP program capacity. We chose this term as a recognition that the VPP programs within the Inventory may be at various stages of development, and whether their goals are aspirational or based on current enrolled capacity.

Reported capacity refers to the capacity of an Inventory entry, regardless of whether its potential or actual capacity.

Shape captures DR that reshapes customer load profiles through price response or behavioral campaigns—"load-modifying DR"—with advance notice of months to days.

Shed describes loads that can be curtailed to provide peak capacity reduction and support the system in emergency or contingency events with a range in dispatch advance notice times.

Shift represents DR that encourages the movement of energy consumption from times of high demand to times of day when there is a surplus of variable renewable energy (VRE) generation.

Shimmy involves using loads to dynamically adjust demand on the system to alleviate short-run ramps and disturbances at timescales ranging from seconds up to an hour.

Total NEM capacity refers to capacity as it is reported at the state-level for EIA-861.[31]

- EIA-861 also contains cumulative installation count and capacity of generators that are net metered by technology, state, sector, and balancing authority. Storage systems that are paired with net-metered photovoltaic are also captured. For NEM Resources, we use the term "total NEM capacity" because capacity is reported at the state-level for EIA-861. This provides consistency with how EIA-861 makes a state-level adjustment for missing PV capacity and converts state total capacity to AC units for those respondents who report data in DC units.

A **VPP operator** refers to the entity that manages electricity supply and demand for businesses and handles enrollment and participation in energy market programs.

VPP program refers to a VPP researched as part of this project and is captured in the Research Dataset.

31 EIA-861 uses 0.8256 as a conversion factor to change DC to AC.

Appendix B. VPP Summary Table Descriptions

Design: Describes the mechanism for designing the VPP, from customer programs based on utility tariffs to VPPs that dispatch DERs in response to fluctuating energy, capacity, or locational prices to meet grid or market needs.

DER Types: Single or multiple DERs, homo- or heterogenous aggregations. Ranging from single DER programs in homogenous aggregations to multiple DER programs in heterogenous aggregations.

Dispatch Control: This refers to how a VPP dispatches DERs for grid services. Ranging from manual dispatch to increasing collaboration with grid operations. For example, a manual dispatch will call events where DERs turn on and off (similar to a light switch). Increasing DER dispatch allows events to be orchestrated to co-optimize grid edge and bulk system benefits.

Dispatch Frequency: Operational timing of DERs. Ranging from discrete events to continuously operating DER for events such as frequency response.

Example Program: A common example of the type of program that may be used within this VPP profile that can be used by grid operators as a resource option for balancing supply and demand.

Grid Services: Refers to the grid services ADERs can provide by receiving grid service signals through a VPP and responding by adjusting customer demand, storage, and/or generation.[32] The mechanisms for controlling ADERs vary by grid service type and ADER technical capabilities. ADER control can be carried out by different parties dependent on the state context and grid service design.

Responsiveness: Describes how the software or platform monitors energy production and consumption of each DER, sending control signals to adjust output based on grid needs, such as reducing power usage during peak demand. It ranges from limited visibility with manual dispatch to real-time visibility, enabling grid operators to track DER impacts instantly.

Platform Description: Description of VPP platform, if applicable. Ranges from no platform to real-time monitoring and control through a centralized DERMS and an ADMS.

Power Flow & Interconnection: Describes the power flow between the grid and DERs as well as the interconnection process needed to connect the device, ranging from one-way power flow from centralized generation to customers, to bi-directional flow with increasing demand for DER interconnection.

Purpose: Purpose(s) of operating the VPP. Ranges from shift to shimmy.[33]

Technology Platform: The type of software system that connects and manages a network of DERs.

32 Bieler, S. C. Goldenberg, A. McEvoy, et al. Jul. 2024. *Aggregated DER in 2024: The Fundamentals*.
33 Alstone, P., Jennifer Potter, Mary Ann Peitte, et al. 01 Mar. 2017. *2025 California Demand Response Potential Study - Charting California's Demand Response Future: Final Report on Phase 2 Results*.

Appendix C. VPP Definitions

Organization/Program	Sector	Definition
APS - 2022	Utility	APS' demand-response programs use a virtual network of smart home products, like thermostats, water heaters and pool pumps, to reduce energy use on Arizona's hottest summer days and shift energy demand to when more solar power is available. Chief among the programs connected to the APS VPP is the company's signature residential thermostat program, APS Cool Rewards.
APS - 2024	Utility	APS's VPP is a partnership with customers, a network of thousands of customer-owned devices, like smart thermostats and home battery storage, that act as an energy resource and a collaborative way to reduce energy demand at peak times to balance supply and demand. The energy production this connection of smart technology avoids reduces the need to start up or build a traditional, physical power plant.
Autogrid	Provider	A VPP is an aggregated network of DERs that can be remotely controlled and operated to balance the supply and demand of electricity on the grid. A VPP combines devices that store, generate, and shift electricity to help meet peak demand in place of a conventional power plant.
Baker Home Energy - California	Installer	VPPs are a connected network of energy resources, typically home batteries, used to reduce stress on the grid. They can also include networks of electric vehicles or smart thermostats.

Organization/Program	Sector	Definition
Bakers Home Energy - Solar	Provider	A solar virtual power plant (SVPP) generates PV power from sunlight, but is not limited by a central distribution station. Just as the virtual computing cloud is made up of multiple data storage units (computers), a SVPP refers to a group of energy storage units—or batteries—all interconnected via the cloud.
Brattle - Real Reliability: The Value of VPP report	Research	A VPP is a portfolio of DERs that are actively controlled to provide benefits to the power system, consumers, and the environment.
Canary Media, Austin Texas	Media	A VPP is a network of small-scale distributed energy sources — such as solar-plus-battery systems, smart thermostats or electric vehicles — that are remotely controlled using software to help balance the main electrical grid, much like a traditional power plant.
CEC	Government	VPPs consist of a network of decentralized, medium-scale power generating units and flexible loads, such as batteries, EVs, smart appliances, and flexible heating and cooling loads that can be effectively managed to the benefit of grid operators.
CEC	Government	VPPs are portfolios of DERs such as smart thermostats, rooftop solar PV, EVs, batteries, and smart water heaters that are actively controlled by software to benefit the power system, consumers, and the environment. While these resources have the potential to meet grid needs as reliably as conventional alternatives such as gas-fired generators, their advantages extend further, offering greater affordability and substantial decarbonization benefits. However, research and development of both technologies and business models is needed to fully capitalize on and understand VPPs' potential, especially the systems that feature predictive controls and require minimal consumer engagement. The examples of predictive controls relevant to this research include, but are not limited to, the use of artificial intelligence or model predictive controls for EV load shifting or building pre-cooling applications.

Organization/Program	Sector	Definition
CEC	Regulator	A network of decentralized power generating units, flexible loads, and energy storage systems that respond to a signal or coordinated set of signals to benefit the electric grid.
ConEd	Utility	A platform that provides aggregated control of individual residential resources, converting them into a "virtual power plant" (VPP), resulting in grid-scale impact and benefits to Con Edison and all its customers.
DOE	Government	A VPP is a virtual aggregation of DERs like PV, energy storage, EV chargers and demand-responsive devices (such as water heaters, thermostats, and appliances). VPPs do more than provide decarbonization and grid services—they increasingly give grid operators a large-scale and utility-grade alternative to new generation and system buildout through automated efficiency, capacity support, and non-wire alternatives. By deploying grid assets more efficiently, an aggregation of distributed resources lowers the cost of power for everybody, especially VPP participants.
DOE - LPO	Government	Virtual power plants, generally considered a connected aggregation of DER technologies, offer deeper integration of renewables and demand flexibility, which in turn offers more Americans cleaner and more affordable power.
DOE – Commercial VPP Liftoff (Sept. 2023)	Government	VPPs are aggregations of DERs that can balance electrical loads and provide utility-scale and utility-grade grid services like a traditional power plant. DOE uses a broad definition of VPPs that includes a variety of mechanisms for aggregating and orchestrating DERs. Fundamentally, VPPs are a tool used for flexing distributed demand and supply resources with a level of dexterity that has historically only been possible in flexing centralized supply.

Organization/Program	Sector	Definition
DOE – Commercial VPP Liftoff 2025 Update	Government	VPPs are aggregations of DERs such as rooftop solar with BTM batteries, EVs and electric water heaters, smart buildings and their controls, and flexible C&I loads that can balance electricity demand and supply, as well as provide utility-scale and utility-grade grid services. VPPs are solutions that can be deployed at scale in a short timeframe to maximize the use and value of existing grid infrastructure, minimize costs to ratepayers, and ensure a resilient, reliable, and secure grid for all Americans.
ERCOT (Tesla)	Government	Typically refers to a combination of generation, storage and demand response under software control.
Telsa	OEM	A VPP is a network of distributed energy sources such as homes with solar and battery systems, working together as a single power plant. The combined energy of these sources is used to support the electrical grid. Participating members can give the VPP program permission to use their energy as a resource during high demand events and generate value through their participation.
Generac	Provider	A VPP is a cloud-based network of Distributed Energy Resources (like battery storage devices, backup generators, and smart thermostats) that can be utilized to reduce stress on the electrical grid during times of peak energy use.
GridWise Alliance	Research	VPPs utilize digital technology to integrate multiple decentralized energy resources into a single network. VPPs allow for the aggregation and coordination of various energy sources, such as solar panels, wind turbines, battery storage systems, and even demand response programs, to function as a unified power plant. Through advanced software systems and real-time monitoring, VPPs can optimize the dispatch and distribution of electricity, effectively balancing supply and demand, and maximizing the utilization of renewable energy sources.

Organization/Program	Sector	Definition
International Electrotechnical Commission - IEC TS 63189-2:2023	Quasi-government	VPPs are parties or systems and standardize the aggregation of objects into three categories: controllable loads, energy storage devices, and distributed generation. At the same time, it emphasizes that the basic functions are aggregation, optimization, and control. In addition, the definition provides two explanations to highlight features: "aggregating resources can break free from network topology constraints" and "aggregated entities support power system operation and power market operation."
Marin Clean Energy - VPP Pilot in Richmond	CCA	Like a traditional power plant, VPPs provide electricity to the grid, but a few key differences set them apart. A traditional power plant consists of one large central power source located in an individual location such as a gas-fired power plant. In contrast, a VPP consists of several small-scale distributed energy resources that are connected on a virtual network. Examples of distributed energy resources include rooftop solar, home batteries, and smart thermostats. A VPP can remotely coordinate these independent technologies to respond to grid needs.

Organization/Program	Sector	Definition
Marin Clean Energy - What is a VPP	CCA	A VPP is a bidirectional energy source. It provides electricity to the grid, and, when there are market opportunities, it can also receive energy. However, instead of being sited in one place like a physical power plant, a VPP harnesses energy resources that are distributed across an entire participating community. By coordinating these devices, VPPs can quickly supply power to the grid, take power from the grid, or lower energy consumption during critical times to reduce grid-strain. With enough smart-homes, a utility can reduce costs and pass savings on to customers in the form of direct payment, credits, or reduced rates, saving people money while supporting efficient and grid-smart energy usage. The VPP's bidirectional flow capabilities provide a unique ability to participate in practically all markets of the CAISO and capture value from those markets in a way previously unexplored by the Community Choice movement. This ability makes MCE's VPP an innovative, cutting-edge approach to local energy production and consumption.
MIT	Research	A virtual power plant is a system of DERs—like rooftop solar panels, electric vehicle chargers, and smart water heaters—that work together to balance energy supply and demand on a large scale. They are usually run by local utility companies who oversee this balancing act.
Navigant	Provider	VPP is a system that relies upon software and a smart grid to remotely and automatically dispatch and optimize DERs via aggregation and optimization platform linking retail to wholesale markets.
Nimiipuu Energy	Utility	A VPP is a network of distributed power, generating units and/or storage systems that can be interconnected through software management. Each system is independently owned and operated, but the network is controlled centrally allowing dispersed resources to respond to energy supply and demand.

Organization/Program	Sector	Definition
PGE	Utility	PGE's VPP is a combination of resources, technologies, infrastructure, and operations. To clearly articulate these discrete components and describe how they are integrated to scale the size and capabilities of the VPP, PGE defines its VPP as "the orchestration of DERs and Flexible Load, through technology platforms, to provide grid and operations services." The VPP is how PGE integrates and operates the distribution system with increasingly distributed resources, flexible loads, and technology in an optimized manner to deliver value to customers.
PSE	Utility	A VPP establishes a platform by which aggregated DERs can be forecast, controlled, and dispatched by PSE. It is a software tool that enables PSE to utilize diverse types of DERs at desired magnitudes meaningful for the Load Office, Market Dispatch, and System Operations. It is being used and recommended by other utilities to operate and control expanding DER infrastructure.
RMI - Flipbook	Research	A VPP is a collection of small-scale energy resources that, aggregated together and coordinated with grid operations, can provide the same kind of reliability and economic value to the grid as traditional power plants.

Organization/Program	Sector	Definition
RMI - VPP, Real Benefits	Research	We define VPPs as grid-integrated aggregations of distributed energy resources. There are three key parts to that definition: • DERs: At its core, a VPP is comprised of hundreds or thousands of devices located at or near homes and businesses. Some of these assets (e.g., behind-the-meter batteries) are readily dispatchable. Other assets (e.g., solar photovoltaic [PV], or passive energy efficiency investments) are less likely to be flexibly dispatched but still can be aggregated and provide value to the grid. • Aggregation: A VPP brings these DER assets together into aggregations. In some instances, these aggregations can be collectively and directly controlled by a grid operator. At other times, the aggregation is much looser, with less direct control by a grid operator. • Grid-integrated: Finally, VPPs provide value to the grid, and they are compensated for the value they provide. Properly integrated into long-term grid planning and real-time operations processes and/or markets, VPPs can add value alongside other, traditional grid assets like large-scale generating facilities.
Rocky Mountain Power	Utility	A VPP refers to a collection of decentralized DERs that are aggregated to enhance power generation and dispatch of power on the grid.
Rural Electric Magazine	Media	VPP plant refers to the collection of decentralized DERs that are aggregate resources such as solar panels, batteries and devices like smart thermostats into a controllable combination of load, storage and distributed generation that can reduce the need for additional physical generation.

Organization/Program	Sector	Definition
SCE	Utility	Aggregator programs that send a single control signal to dispatch the aggregator that has been contracted to provide a certain amount of capacity to the grid.
SEPA	Research	A VPP relies on software and advanced communications systems to aggregate, control, dispatch, plan and optimize a suite of DERs to provide services similar to a conventional power plant.
SMUD	Municipal	A VPP consists of many small devices often owned by customers and located at their homes and businesses. When operated and managed together in a coordinated way, they can become an alternative to a conventional utility-scale power plant. VPPs can include electric vehicles, batteries, thermostats and electric water heaters. By aggregating their capacity and flexibility, a VPP can mimic a power plant and provide services that help reduce electric peak demand during hot summer days or cold winter nights, potentially reducing the need for the utility to build or buy other resources, freeing resources to more aggressively invest in renewable energy.
Sunverge	Provider	A VPP is a grid-aware and dynamic power source built from the aggregation of behind-the-meter DERs. The Sunverge real time DER control and aggregation platform is unique in providing dynamic multi-objective optimization of services on both sides of the meter, helping customers with intelligent management of their own renewable energy generation and utilities with greater flexibility in managing their infrastructure investments, reducing generation costs, increasing system reliability, and meeting their renewable energy goals. Together with the Sunverge Infinity edge controller, the Sunverge VPP platform provides intelligent dynamic near real-time control over decentralized energy resources that is efficient, reliable, and responsive to utilities and their customers.

Organization/Program	Sector	Definition
Swell Energy	Provider	A VPP combines the power of hundreds or even thousands of distributed solar and energy storage systems like the one on your home to create a new kind of power plant. A Virtual Power Plant can reduce stress on the grid, limit the need for expensive new energy infrastructure, and even replace a traditional fossil fuel powered or nuclear plant.
Northwest Power & Conservation Council	Quasi-government	A VPP is a network of decentralized energy resources that are aggregated to provide utility-scale and utility-grade grid services like a traditional power plant.