Unlocking Grid Flexibility: Understanding Challenges for Scaling Aggregated Demand Flexibility for the Distribution System

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Abstract: Accelerating load growth from domestic manufacturing and data center development is increasing pressure on distribution systems across the United States. Traditional infrastructure upgrades face long lead times and rising costs. Demand flexibility (DF) from aggregated distributed technologies can help defer costly infrastructure upgrades and address localized constraints to the energy system. This aggregated DF, operated by utilities or other organizations, can shift or reduce loads to provide reliability and alleviate costs at the distribution and bulk system levels, supporting affordability for customers. Despite recent growth in deployment of such demand flexible measures, they remain underutilized as a distribution system resource.

This paper examines how aggregators can address distribution-level grid constraints and identifies the institutional and economic barriers limiting scale. Drawing on literature review and interviews with over 15 aggregators and other market participants, the authors characterize aggregator roles, business models and revenue structures relevant to distribution grid services. Findings indicate that scaling distribution-oriented DF is constrained by access to localized grid data, procurement models that were not designed with targeting DF to areas of highest grid need, and more. Recommendations for overcoming these challenges are included, as scaling products and services will ultimately lower costs for consumers while providing valuable grid services, including for improved reliability to utilities.

Introduction

U.S. electricity demand is forecast to increase 15.8%, or 128 GW, by 2029, driven by a combination of data center and manufacturing load growth across sectors (Walton 2024). In order to sustain growth in strategic economic sectors, utilities and bulk power system operators must identify new energy capacity and develop strategies to deliver reliable and affordable service to customers. A congested interconnection queue and long lead times for critical equipment mean new generation resources can take five years to connect to the grid (Shawhan et al. 2025). DF from customer-sited distributed technologies and implementation of aggregated DF presents a large source of affordable, untapped potential that can be implemented within 12 months (Fitch 2024). While demand flexibility can provide near-term support for grid reliability and affordability, it is best viewed as complementary to investments in generation, transmission, and distribution infrastructure that will be required to meet sustained long-term load growth.

Utilities can look toward distributed technologies to increase grid capacity, creating opportunities for DF solutions to scale. A range of other organizations with varied business models can serve as intermediaries for this function, enabling distributed technologies—ranging from residential thermostats and electric vehicles to commercial and industrial assets—to participate in aggregated DF as a class of resources growing in scale and maturity (Storrs et al. 2026).

Customer-sited distributed technologies are giving consumers the capability to modify their energy consumption in response to an external signal or generate their own energy, in exchange for financial compensation (Martin-Martinez 2024). Aggregated DF harnesses the customer-sited resources to deliver benefits to many parts of the power system, from the bulk power system to the distribution and end customer level (Fitch 2024). Aggregated DF can realize financial benefits to the utility by managing voltage and reducing losses across the transmission and distribution (T&D) grid, and avoiding or delaying new capital investments (Fitch 2024). According to the U.S. Department of Energy, tripling the scale of DF by 2030 could address 10-20% of peak load while saving approximately $10 billion a year (Downing 2023).

While challenges remain, there are significant opportunities to lower the burden for aggregators aiming to scale their operations, thus allowing them to reach more customers and ultimately help lower energy costs for consumers while providing valuable grid services and reliability benefits to the distribution grid. This study aims to identify the opportunities and challenges that remain for market participants in scaling DF strategies in the distribution system. Insights can inform efforts for decision-makers to close existing gaps for providers of DF and support its effective integration, coordination, and utilization.

Growth of Aggregated DF Deployment

Aggregated DF programs have moved past the pilot scale in North America, with 37.5 GW of capacity operating or in development in 2025, with 433 unique utility and market programs (Hertz-Shargel 2025). Historically, many utility-led DF programs began with “Bring Your Own Thermostat (BYOT)” programs and have since expanded to include more customer-sited resources such as energy storage and multi-technology programs (Proudlove et al. 2024). In 2025, newer distributed technologies such as building-based batteries saw scale in demand-flexible implementations, with 61% of programs including these technologies in addition to thermostats, the most widespread flexible technology in residential buildings (Hertz-Shargel 2025).

Era of Large Load Growth

Load growth in recent years spurred by customer technology adoption at the grid edge, domestic manufacturing and data center development is driving up electricity demand forecasts and increasing interconnection queue times (Lutz et al. 2026). Utilities are grappling with meeting growing demand while maintaining affordability for existing customers. As of late 2025, several dozen utilities have adopted large-load tariffs, with a few tailoring them specifically to data center customers (Penrod 2025). Some state regulators have introduced more stringent interconnection rules for new large loads, while others are exploring ways for large customers to connect to the grid faster by incorporating DF strategies (Lutz et al. 2026). For example, Arizona Public Service's 2024 Demand-Side Management Plan includes funding to prepare for large facility DF initiatives beginning in 2027 (Proudlove and Haynes 2026). Virginia's General Assembly recently introduced a bill that would require establishing DF programs for high energy demand customers (loads greater than 25 MW and load factor of at least 75%) by 2028 (Virginia General Assembly 2026).

New business models are emerging to serve data center customers in capacity-constrained regions. For example, in 2026, DF provider Voltus is partnering with Google on a "Bring-Your-Own-Capacity" framework. Through this partnership, Voltus will provide 100 MW of aggregated DF per year for three years. DF from distributed technologies will be sourced from customers in the PJM region, who will receive payment for responding to capacity needs associated with Google's capacity demand (Voltus, 2026). DF industry groups like the Flex Coalition include commercial and residential DF providers, aiming to increase energy affordability for customers while supporting the grid (Flex Coalition 2023). This introduces yet another business model for aggregators.

Another emerging model uses distributed grid-edge hardware itself as the compute-hosting capacity for data center demand. In 2026, SPAN launched XFRA, which places NVIDIA GPU compute nodes at residential and small commercial sites behind its smart electrical panels, letting hyperscalers and AI cloud providers tap underutilized headroom in the existing grid instead of waiting years for new interconnection. In exchange, homeowners receive a SPAN Panel, battery backup, and discounted electricity and internet rates in exchange for hosting the capacity (SPAN, 2026).

Methodology

The objectives of this paper are to expand upon a forthcoming Berkeley Lab report titled "*Demand Flexibility Aggregators Industry Landscape: Business Models and Market Characteristics"* with additional context and discussion for distribution system operations and related challenges and constraints (Zhu 2026). This report includes literature review findings that characterize how aggregators are commonly understood to interact with distribution grid services and related utility programs. Throughout Summer and Fall 2025, the authors conducted stakeholder interviews with over 15 aggregators and related market participants to understand the current landscape of products and services, and market opportunities. Table 1 shows the companies that participated in interviews and the stakeholder category they fall under, which is further characterized in this study.

Table 1. Aggregated DF stakeholders interviewed and their product offering categories

	CSPs	Virtual Flexibility Resource (VFR) [1] Providers	OEM Aggregators	OEMs	Data or Platform Enablers	Other Ecosystem Players[2]
CPower	✓	✓				
Voltus[3]	✓	✓				
ERock	✓			✓		
Uplight		✓				
Resideo Grid Services[4]		✓				
Renew Home		✓			✓	
ChargeScape		✓				
EnergyHub[5]		✓				
sonnen			✓			
Budderfly[6]			✓			
Harvest Thermal				✓		
Span				✓		
GE Electronics				✓		
GridPoint[7]			✓			

[1] Virtual Flexibility Resources (VFR)are also known as virtual power plants (VPPs).
[2] This group's offerings are focused on novel methods for utilities to offer distributed technologies or DF capabilities directly, either through advanced metering or procurement.
[3] Voltus did not participate in stakeholder interviews, but was frequently referenced by other vendors as a critical ecosystem player for market access
[4] As of December 2025, Resideo Grid Services was acquired by EnergyHub, https://www.energyhub.com/news/energyhub-acquires-resideo-grid-services
[5] EnergyHub did not participate in stakeholder interviews, but was frequently referenced by other vendors as an aggregator/Edge-DERMS partner
[6] Budderfly primarily provides energy efficiency measures through investing in high-efficiency equipment upgrades in HVAC, refrigeration, and more, and through patented building controls. Budderfly has developed aggregated DF capabilities, enabling 8,500+ commercial sites to become active, grid-responsive assets.
[7] GridPoint primarily provides energy efficiency measures through advanced building controls, has developed aggregated DF capabilities, and partners with aggregators for grid service capabilities. GridPoint offers both the

	CSPs	Virtual Flexibility Resource (VFR) [1] Providers	OEM Aggregators	OEMs	Data or Platform Enablers	Other Ecosystem Players[2]
WeaveGrid		✓				
Piclo					✓	
Texture					✓	
Enode					✓	
Leap[8]		✓			✓	
Utilidata						✓
Sparkfund						✓

Interview discussions covered the following themes:

1. Product and Service Offerings
2. Active market opportunities, understanding market entry, including heavy lifts and research areas of industry interest that support scaling
3. Customer value creation, key segments, contract structures, strategic partnerships
4. Business models and key revenue drivers
5. Gaps and challenges related to scaling

Insights from stakeholder interviews are synthesized in the following sections, including aggregator and other service provider roles and value propositions, business and revenue models, and key challenges and considerations for scaling services.

Roles and Benefits of Aggregators in the Distribution System

The primary role of an aggregator is to coordinate and manage a portfolio of customer-sited DF technologies, serving as the facilitator between the devices and the utility that requires the load flexibility offered by the customer resources (Matsuda-Dunn et al. 2023). Through this role, the aggregator provides the utility with program administration support and the

hardware and software to aggregate distributed technology assets into a centralized platform. GridPoint also has HVAC and lighting capabilities.

[8] Leap did not participate in stakeholder interviews, but was frequently referenced by other vendors as a critical ecosystem player for market access

management of DF devices and dispatch. The provider typically handles all aspects of customer enrollment while managing the distribution of incentives to customers after providing a single point of settlement from the utility (Bieler et al. 2024).

Infrastructure-Deferring Investments

Infrastructure-deferring investments, also called infrastructure-deferring solutions, is an umbrella term for operating practices or technologies[9] that can postpone the need to invest in the construction or upgrade of physical components of the distribution or transmission systems. Aggregators can leverage the DF of customer distributed technology assets, deferring the need for infrastructure upgrades by shifting or reducing electricity usage during specific times, which utilities can procure as a grid service in the form of capacity relief (Bieler et al. 2024). When used in this manner, such assets may also allow the utility to better understand the most appropriate size of grid upgrades required through the use of more accurate demand forecasts during the deferral period. The primary value of infrastructure-deferring investments is the near-term avoided cost. As a result, utilities and other aggregators contribute to system and customer affordability by avoiding capital expenses for infrastructure investments, which would otherwise be passed down to ratepayers (Bieler et al. 2024). Additionally, aggregators contribute to system reliability by easing system constraints (Frick and Schwartz, 2024).

To estimate the system savings potential of these infrastructure-deferring investments, one study estimated that without DF strategies deployed, the infrastructure upgrades required of the U.S. distribution grid to accommodate a modeled scenario representing a load growth future could cost between $350 and $790 billion nationwide, or approximately $2,800-6,400 per household. When demand-side management and coordination strategies are implemented by aggregators to manage system peaks, grid reinforcement costs could be reduced by up to 43% (Priyadarsha et al. 2025).

Distribution System Grid Services

Grid services for the distribution system include energy resources that produce active power in the system and capacity resources that supply energy or reduce load to reduce net load where necessary on the network. Aggregators can serve their customers through aggregation of DF generation and storage technologies. Capacity services can be provided through the aggregation of generation, storage, and DF technologies.

Essential reliability services, sometimes also referred to as ancillary services, include reactive power and voltage support that maintain voltage levels at the distribution level. Aggregators can support these services, e.g. through aggregating smart inverters that can regulate voltage and provide reactive power (Bieler et al. 2024). For example, an aggregator can

[9] Examples include batteries, gas generators, microgrids, time-varying rates, geotargeted load management programs, and dynamic phase balancing

participate in frequency response programs, dispatching distributed technologies to inject or absorb power within seconds to stabilize grid frequency.

The value of DF is highly dependent on the availability of DF assets and the potential upgrade costs it can defer in a specific location. Aggregators provide the most value in areas where current distribution capacity is constrained and insufficient to meet future peak demand needs. Integrated distribution planning processes are increasingly used to identify these high-value locations where infrastructure-deferring strategies such as DF can be deployed cost-effectively (Frick 2021).

Beyond distribution deferral, DER orchestration can layer additional value streams onto the same enrolled assets, including generation and transmission capacity deferral, wholesale energy savings, frequency regulation and other ancillary grid services, that are not captured when a program is evaluated on distribution benefits alone (SEPA 2025). Demonstrations of multi-stack demand response events, in which several DR services are called from the same fleet in succession, further show how orchestration platforms can monetize a single DER across multiple use cases simultaneously, improving overall program cost-effectiveness (SEPA 2025)

Resilience

Aggregators can help reduce the physical strain on grid infrastructure and increase reliability for customers by providing resilience at the grid-edge. The most direct route toward this improved resilience is through managing distributed technologies to provide backup power during outages related to natural disasters and/or aging energy infrastructure. At the grid-edge, aggregators managing battery assets and other islanding technologies can allow a home or community microgrid to disconnect from the main grid during an outage and continue operating critical loads independently. For example, during a historic heat wave in September 2022, California's Emergency Load Reduction Program and Demand Side Grid Support programs leveraged activation of distributed technologies for nine consecutive days to avoid rolling blackouts (Brehm and Tobin 2024). Through deployment of aggregated DF programs and coordination of distribution at the grid-edge, aggregators also reduce risks of system failure through lowering peak demand during periods of extreme weather conditions, thus preventing the distribution grid from exceeding its physical limits.

Aggregators and their Business and Revenue Models

Diverse Ecosystem of Providers

There is currently no single standard or definition of virtual flexibility resources (VFR), but there are different varieties and implementation concepts. Of the models that are capable of delivering distribution system grid services, the Smart Electric Power Alliance (SEPA) characterizes three distinct participation structures emerging in the U.S (Proudlove et al. 2025):

1. Third-party in contract with a utility
2. Utility-led using a third party platform
3. Utility-owned and operated

A multi-layered value chain of hardware and software providers make up the aggregated DF value chain, as shown in Figure 1 (Hertz-Shargel 2025). The same provider may play multiple roles within the same value chain in order to deliver capacity to an offtaker, such as a distribution utility or a wholesale market program.

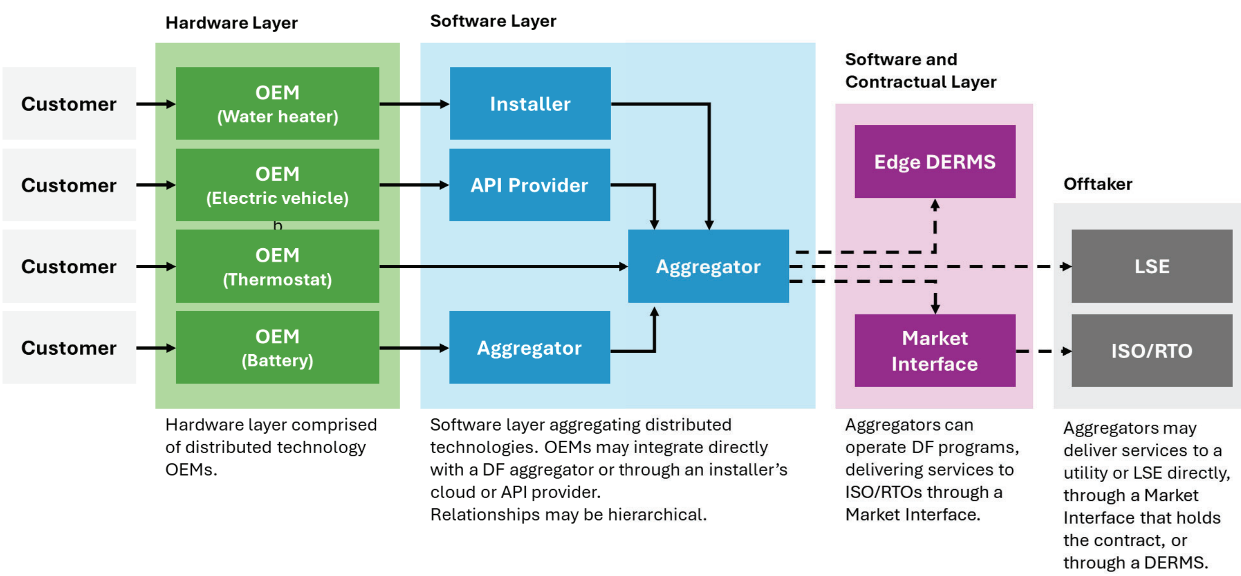

Figure 1. Aggregated DF value chain
The aggregated DF value chain consists of multiple layers of hardware and software providers, sometimes acting in multiple roles within the same value chain.
Source: Adapted from Wood Mackenzie, 2025

Curtailment Service Providers

Curtailment service providers (CSP) typically engage large commercial & industrial customers with large loads and sophisticated energy procurement and management strategies to enter DF markets. CSPs usually have in-house expertise and software technology with control capabilities for aggregating and dispatching flexible loads.

Virtual Flexibility Resource Providers

As characterized in Zhu et al. and shown in Table 1, there are several different types of third-party aggregators that can interact with the distribution system grid, in addition to several related stakeholders that are critical to the successful deployment of aggregated DF. Some providers are distributed-asset specific, focusing on aggregating thermostats, batteries, or charging stations. Others target customer segments, such as specifically focusing on large commercial and industrial loads. Service providers here may also identify as Distributed Energy Resource Management System (DERMS) platforms, integrate multiple distributed asset types into their platforms, either integrating directly or partnering with another third-party provider.

Original equipment manufacturers (OEMs) Providers

OEMs are a critical component of the aggregated DF value chain as their distributed assets provide the critical generation, storage, and load shifting and shedding functions that can provide grid services to the distribution system. A growth area in the aggregator landscape sees OEMs developing their own internal software capabilities to directly aggregate and dispatch their assets for load flexibility (Zhu et al. 2026). This allows them to capture additional revenue to help their customers offset capital expenses, in addition to diversifying their own value streams.

Grid-Edge OEMs

Some OEMs are developing grid-edge controls at the customer meter level to address the need for localized grid services at the distribution level. SPAN, manufacturer of residential smart electric panels announced a partnership with Pacific Gas and Electric Company (PG&E) in early 2026, introducing the SPAN Edge device which will provide real time load management at the customer meter without requiring costly electric panel or service upgrades, a significant hurdle for serving home loads (PG&E 2026).

Utilidata is a software company that provides a distributed AI module embedded into electric meters with the compute power to handle distributed controls, monitoring, and throttling of integrated energy assets. As utilities think toward the next generation of AMI meters, embedding these functions into the meter can provide the visibility needed for localized grid services at the distribution level.

Data or Platform Enablers

Another critical segment of DF service providers are software developers that serve as digital intermediaries between utilities and aggregate DF platforms, providing critical data integration services that enable the integration of customer-sited distributed technologies for responding to and optimizing distribution system constraints (Zhu 2026). Companies in this space are providing digital solutions to help utilities integrate existing utility IT and OT systems with external customer energy data and distributed systems/assets. For DF platform providers, this segment includes critical partners who develop and maintain the data connectivity to OEM assets that are aggregated for load flexibility. Other use cases for such companies include assigning locational data to customer-sited assets, cleansing and standardizing energy data and providing real time visibility of distributed technologies to utility systems.

Aggregator Revenue Models

There are multiple revenue model frameworks for aggregators participating in the distribution system. As utilities across the nation seek solutions to address the growing electric demand, nascent revenue models and partnerships are emerging to meet the challenge. This section discusses a few examples.

Revenue Sharing

Aggregators in this model are compensated based on a contracted upon percentage of the total revenue of load flexibility their customer portfolios provide in DF markets. In programs targeting distribution grid needs, the value of load flexibility is often determined by the maximum duration of a DF event and the expected frequency of events within a season.

Utility Contracts / Volumetric Enrollment

In this model, utilities contract aggregators to deliver a volumetric amount of flexible load via a customer program. Customer programs may be structured to provide event-based load management, as well as to provide continuous optimization of distributed technologies. For event-based programs, customers opt to be notified of future flexibility events, which may include an incentive component to reward customer participation. In continuous optimization programs, customers set their preferences at enrollment, which are used to manage their load in response to grid conditions. Aggregators may be paid by the utility based on aggregated capacity enrolled (MW) or per device enrolled, as is currently the industry standard for thermostat programs. This encourages competition amongst aggregators to identify and recruit new customers, particularly in areas with grid capacity constraints that are frequently targeted by DR events.

Software-as-a-Service (SaaS)

Data or platform enablers developing data integration into utility IT and OT systems are often operating under a SaaS model and seeking to sign multiyear contracts with the utilities that procure their services. While utilities are their direct customers, these providers form partnerships with OEMs and aggregated DF to deliver flexible loads. Many platforms allow utilities to create custom resource groups that can be dispatched together for load shifting or shedding. For instance, utilities can leverage this to implement load management focused on specific system locations and assets during times of stress. Some providers also use a mix of a SaaS model for baseline annual costs paired with cost per device volumetric pricing.

Resiliency-as-a-Service

Providing resilience during periods of critical need has benefits for both the grid and customers with critical operations, such as hospitals. This model, as exemplified by ERock, provides a utility-sponsored gas-power generation solution for commercial customers that require year-round backup generation. The utility takes on all the balance sheet risk for purchasing small-scale distributed generators sited onto customer properties. The customer pays the utility $/kW for the resilience benefit and program enrollment. Through ERock's DF platform, the utility is able to dispatch grid services events to targeted locations when needed.

Energy as a Service (EaaS)

Similar to a traditional energy service company (ESCO), the EaaS provided by Budderfly, a company that provides energy management solutions and financing for small to medium-sized commercial buildings. They become the customer of record for the utility on behalf of their end client buildings. Using historical utility data, they establish a site's historical utility baseline, which is then used to establish a new, predictable electric rate that the customer pays directly to Budderfly.

Distributed Capacity Procurement

In this emerging approach to aggregated DF deployment, a utility invests in and directly procures the hardware capable of providing dispatchable flexible loads, treating the assets like capital infrastructure. The utility leases the land where the assets are located from customer host sites and directly controls the devices when grid constraints require action. Xcel Energy's Capacity*Connect plan, unveiled in October 2025, is taking this approach to developing flexible capacity across the congested parts of its grid in lieu of working with third party suppliers and service providers (St. John 2026). Google is providing $50 million in funding for this program to develop distributed capacity in Pine Island, Minnesota, where a new data center will be located (Google, 2026).

Bring Your Own Capacity

As mentioned earlier, the Bring Your Own Capacity model has emerged to meet the needs of hyperscalers seeking to develop new data centers in capacity-constrained regions. This model is an evolution of a contracting framework that large energy buyers have used to transfer capacity directly into a utility's portfolio to satisfy reliability requirements (Allsup 2026). For example, through partnerships with Voltus and Octopus Energy, a data center's owner will finance an aggregated DF program, paying for others to provide DF that offsets the new data center's load and allows it to potentially bypass the years-long interconnection queue for new generation (Allsup 2026).

Insights and Challenges for Scaling Distribution System DF

Locational Value of DF

One of the biggest challenges for utilities is integrating the value of infrastructure-deferring solutions into existing business models. Historically, such investment opportunities and the increase of distributed technology adoption presented interesting opportunities for distribution system planners, but uncertainties around real-time visibility, resource reliability, output, and costs posed technical and economic challenges. To evaluate how infrastructure-deferring solutions such as an aggregated DF portfolio can be incorporated into distribution system planning, utilities require information related to (Coley, et al 2018):

- **Locational characteristics**: Siting of assets and their relation to localized grid constraints
- **Temporal characteristics:** resource availability, output variability, sustainability of response, and resource lifetime
- **Design:** Size of DF aggregation, eligible technologies, compensation structure, reliability, customer participation, third-party contractual agreements, and impacts of portfolio-level shifting against transformer or feeder-level constraints
- **Economic impact:** Costs and benefits of infrastructure-deferring solutions, including distributed technology performance and lifetime considerations, cost savings of reducing, deferring, or mitigating distribution system operating costs and capital investment

From the aggregators perspective, many stakeholders interviewed for this study discussed the ongoing challenge of gathering granular data about where customer-sited resources are located in the distribution system, their real-time performance, and customer identification information necessary to value DF at the distribution system level. Access to such information should be implemented in a manner consistent with utility cybersecurity requirements, customer privacy protections, and applicable state and federal regulations. As described in this study, many data and platform enabling providers are emerging in the marketplace to provide data-related solutions to deploy DF at scale.

Industry decision makers are increasingly focused on assessing cost-effectiveness and the value of distributed technologies in the distribution planning process. Two methods for valuation include (1) area-specific avoided distribution costs and (2) marginal cost of service studies (Frick 2021). State guidance to utilities about which method to use and how to procure a DF strategy for distribution system needs continues to evolve. Industry groups like the Smart Electric Power Alliance (SEPA) are documenting notable new statewide policies annually, informing decision-makers on the range of options available to enable DF (Proudlove and Haynes 2026).

Misaligned Incentive Models

The difficulty in gathering locational data on distributed technologies also makes it challenging for utilities and aggregators to accurately quantify the value of DF below the substation level, thereby limiting their ability to understand the value of distributed technologies in supporting grid needs at a granular level. Current procurement structures may not fully capture the locational value of demand flexibility resources, particularly in areas experiencing localized grid constraints. In the current model of customer program management, utilities often carve out special incentives for grid constrained areas to drive customer enrollments. Most aggregators are contracted to provide flexible load through volumetric enrollment of distributed assets. Often, such enrollment does not distinguish if an asset is in a grid-constrained location, creating a misaligned incentive for targeting DF customer enrollment to areas of critical grid need.

While the current model may encourage competition among aggregators to identify and recruit new customers, these models will need to evolve as DF strategies mature to ensure that consumers able to provide a high frequency of load flexibility in high grid constraint areas that may be frequently targeted by demand-response events are compensated fairly. Furthermore, dual participation rules for resources providing DF services to one or more retail programs (e.g., bulk and distribution energy services) are largely undefined, and will be decided individually by states and grid operators, creating the need for aggregators to design DF programs that comply with a range of market designs and operating rules (FERC 2020).

Infrastructure-deferring solutions provide multiple stakeholders with opportunities to avoid costs. While many of these implications are beyond the scope of this work, multiple decision makers are in active discussions or making decisions consistent with this priority.

Stakeholder Education

There is a patchwork of market rules and requirements across wholesale market operators and states that aggregators must navigate when entering DF markets to provide services. Pertaining to distribution system services, aggregators are interested in more clarity on which distribution system and wholesale energy programs can be combined for maximizing value for customers. Utilities will want to continue seeing evidence that aggregated DF resources can provide reliable capacity and granular data required for consideration during distribution operations and planning processes.

While best practices for utilizing aggregated DF for distribution-system constraints will emerge as this market matures, collaboration to overcome barriers could reduce challenges to participation, improve program confidence, and accelerate implementation. These actors include aggregators, utility program developers, trade associations, research organizations, and other decisionmakers.

Conclusions

Rapid load growth and increasing distribution system constraints are forcing utilities to reconsider how capacity is planned, procured, and deployed. Aggregated DF from distributed technologies is one of several tools available to utilities for addressing distribution-system constraints, providing targeted capacity relief, operational support, and resilience benefits, and affordability benefits where cost-effective. As aggregated DF moves beyond pilot programs, aggregators are demonstrating the technical capability to coordinate diverse portfolios of customer-sited assets to respond to grid needs.

This research characterizes existing challenges to scaling distribution-oriented DF. Access to granular, feeder and transformer-level data limits the ability of aggregators to target constrained locations and demonstrate the locational value of DF. Prevailing procurement models based on volumetric enrollment or per-device incentives conflict with the need to deliver

DF to areas of highest system need.

The market for DF is evolving, with diverse business models emerging to address distribution system needs, including utility-contracted DF, resilience-as-a-service offerings, and "bring-your-own-capacity" frameworks for large loads. Aligning clearer valuation mechanisms, data access protocols, and procurement mechanisms with distribution system planning processes will help aggregate DF scale with projected load growth.

To support projected load growth, utilities may benefit from leveraging technology and aligning planning across the DF value chain to identify where demand flexibility can complement traditional investments in generation, transmission, and distribution infrastructure while helping reduce costs to consumers.

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