Sourcing Distributed Energy Resources for Distribution Grid Services

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The DOE Office of Electricity sponsored this report as part of a broader ongoing effort to advance distribution grid transformation. This includes market and operational coordination of distributed energy resources, especially their evolving use to provide grid services. DOE Office of Electricity Program Manager Joseph Paladino oversees this work.

Abstract

The paper, Evolution of Sourcing Distribution Grid Services, examines the evolving role of distributed energy resources (DERs) in enhancing the U.S. electric distribution grid utilization to address growing electrification demands and decarbonization goals. Distributed energy resources (DER) and electric vehicle (EV) charging that provide grid services will increasingly be important to manage local distribution needs affordably. Shifting from traditional, bulk-power-focused DER use to local distribution-targeted applications is essential for deferring costly distribution infrastructure upgrades while ensuring grid reliability.

This paper proposes evolving current sourcing methods for distribution services—spanning tariffs, demand-side management programs, and procurements. Key changes include aligning the various DER sourcing methods to meet local distribution needs cost-effectively and ensuring a viable value proposition for DER service providers, including customers and aggregators.

A holistic sourcing portfolio approach, including future local flexibility markets, can enable DER service provision to address growing distribution constraints. Portfolios can be developed through a techno-econometric modeling process. The proposed method offers a comprehensive approach that addresses value certainty for all stakeholders who play a role in the cost-effective and reliable operation of the distribution grid. This includes customers, DER providers, electric utilities, and regulators.

Contents

1. Introduction

A growing number of states recognize that over the next 15 years, it will be incumbent to use distributed energy resources (DER) to reduce the cost of electrification and address load growth constraints. Distributed energy resources, including managed electric vehicle (EV) charging that provides grid services, will increasingly be important to manage local distribution needs affordably. Projections of the potential for DER services suggest an increase of 3 times current levels to reach 80-160 GW over the next ten years.[1]

The pursuit of DER services for distribution has grown significantly over the past decade. Utilities in 30 states, the District of Columbia, and Puerto Rico are increasingly sourcing these services through various methods (Figure 1). Current sourcing methods include time-varying rates, DER tariffs, programs, and procurements. DER sourcing methods refer to customer time-varying rates, retail DER tariffs (e.g., community solar and customer solar PV tariffs), geo-targeted[2] programs, procurements[3], and local flexibility markets to obtain distribution grid services from DER.

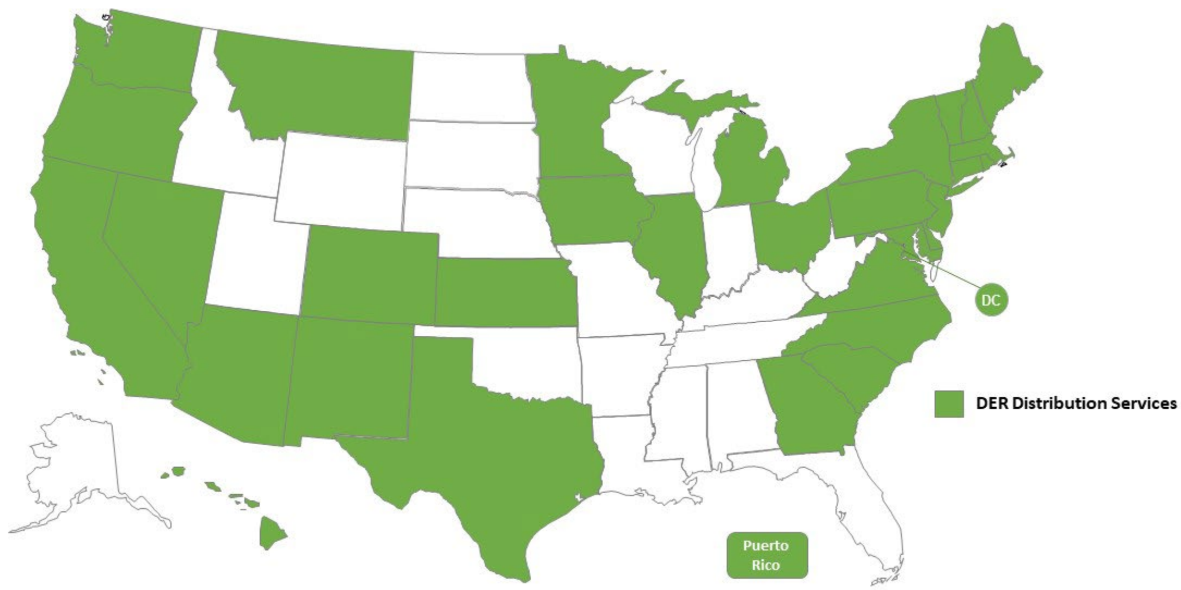

Figure 1. Jurisdictions with Distribution Grid Services and Community Solar Programs

The DOE *Pathways to Commercial Liftoff for Virtual Power Plants* (VPP) report described several challenges with scaling the use of DER for power system operational needs.[4] This paper explores evolutionary considerations for sourcing distribution grid services to facilitate discussions among regulators, distribution utilities, DER services providers, and other stakeholders. Key changes include

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[1] DOE, Virtual Power Plant Commercial Liftoff. https://liftoff.energy.gov/vpp/

[2] Geo-targeted demand flexibility programs seek to address localized capacity constraints on a distribution system at a substation, feeder, or feeder section level by aggregating customer participation and response within the constrained location.

[3] DER services may be provided by front-of-the-meter assets or behind-the-meter customer owned devices that are directly provisioned from customers or independent intermediary service providers that contract with customers.

[4] J. Downing, et al., Pathways to Commercial Liftoff: Virtual Power Plants, DOE Loan Programs Office, 2023. https://liftoff.energy.gov/wp-content/uploads/2023/10/LIFTOFF_DOE_VVP_10062023_v4.pdf

aligning the various DER sourcing methods to meet local distribution needs cost-effectively and ensuring a viable value proposition for DER service providers, including customers and aggregators.

One challenge is that many current regulatory structures and sourcing methods (i.e., pricing, programs, and procurements) are not fully aligned with the emerging distribution operational performance requirements. The current approach to front-of-the-meter and customer-owned distributed resources that may provide grid services ("flexible resources") is to primarily address bulk power system needs. For example, traditional customer time-of-use tariffs and demand-side management programs are designed to meet bulk power system needs. There have been very few instances of geo-targeted flexible demand programs to address distribution grid needs.

Further, although the use of flexible DER as a distribution non-wire alternative (NWA)[5] has been underway for nearly a decade, it remains at an early stage of maturity with mixed success.[6] This is due to several factors discussed in this paper and identified in the U.S. Department of Energy's (DOE) *Distribution Services Contract Insights* and *Distribution Grid Orchestration* papers.[7,8] As such, we are still at a relatively early stage of maturity in using flexible DER services for distribution services.

In addition to evolving the several sourcing methods, a portfolio approach to optimizing the use of all available options can yield improved cost and performance to address growing distribution constraints. Portfolios can be developed through a techno-econometric modeling process. A techno-econometric modeling process is proposed to address value certainty for all stakeholders who play a role in the cost-effective and reliable operation of the distribution grid. This includes customers, DER providers, electric utilities, and regulators.

A core issue from a grid architecture[9] perspective is where to manage net demand variability (i.e., forecasted and real-time load changes and intermittent variability of distributed renewable generation). The current approach uses DER services first to address bulk power system needs and secondarily consider distribution needs. Conversely, DER could be used first to address the distribution constraints and net demand variability within a high DER system. Doing so could have the collateral benefit of reducing bulk power system needs for operating reserves and ramping services. Focusing first on distribution constraints also increases the amount of interconnected distributed resources and the bulk power system services' operational deliverability.

This paper examines these issues considering ratepayer affordability, distribution reliability, service provider (e.g., DER customers and aggregators) value uncertainty, performance risk allocation, and complexity of orchestration mechanisms. This paper is part of DOE's Distribution Grid Transformation program's series of guides for advancing the utilization of distributed energy resources in the electric system.[10] Combined, these papers offer states and stakeholders a set of key considerations, frameworks, and methods to guide their respective pathways to achieving their energy goals.

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5 Also referred to as non-wire solution (NWS) in several jurisdictions

6 S. Succar, Navigating the complexity and challenges of non-wires solutions, ICF, 2022. https://www.icf.com/insights/energy/navigating-nwa-challenges

7 D. Murdock and R. Dahyeon Yu, Distribution Services Contract Insights, DOE, 2024

8 S. Patel and S. Viadya, Distribution Grid Orchestration, DOE, 2024

9 PNNL Grid Architecture, See: https://gridarchitecture.pnnl.gov/

10 DOE Office of Electricity's Distributed Resource Utilization project. Refer to the Distributed System Evolution, Customer Resource Flexibility, Flexible DER Connections, and DER Orchestration papers.

2. New Planning & Operating Paradigms

Significant distribution capacity upgrades may be needed if DER and EV charging are not coordinated and orchestrated.[11] However, current practices for planning, sourcing, and operation of DER for distribution are deficient in meeting this growing need. Specifically, there are a few key aspects to consider: hyper-localized distribution constraints, net load variability at the transmission-distribution interface, uncoordinated flexible DER and energy efficiency sourcing, and aggregated DER (or virtual power plants) sourcing that primarily focuses on the bulk power system needs without coordination with distribution system planning and operations. These DER sourcing methods and requirements, often developed individually, have unique influences on distribution system power flows that can be counterproductive, as illustrated in Figure 5, if not orchestrated as part of a holistic portfolio.

Underlying this discussion is a three-stage evolutionary model for U.S. electric distribution systems to enable DER and their evolving use as aggregated DER, or virtual power plants (VPP), for a broad range of grid and energy services (Figure 2). This framework assumes that the distribution system will evolve in response to top-down (public policy) and bottom-up (customer choice) drivers. Each stage builds upon the previous one due to higher levels of DER adoption and evolving policy goals. Each subsequent level requires evolving methods to source distribution services and enable distribution system functions. The orange curve represents the existing distribution system in the context of a technology lifecycle. A lifecycle will reach a point where its capabilities no longer support the evolving requirements, and its performance will decline in relation to the new uses (orange dashes). The existing distribution system was not designed with the current and planned uses in mind. The green curve represents a transformed distribution system that reliably enables electrification and DER policies. This includes the capability to utilize DER services from customers and independent service providers fully. The yellow arrow represents the institutional, business, and technical advancements needed to transition.

[11] California Public Utilities Commission (CPUC), Electrification Impacts Study – Part I, May 2023. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M508/K423/508423247.PDF

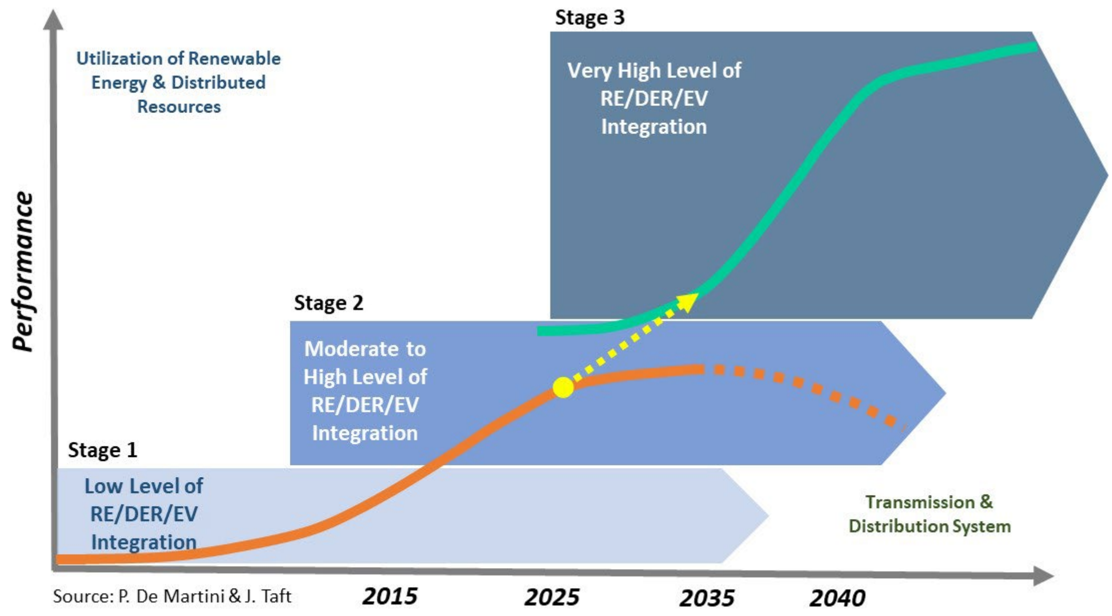


Figure 2. Distribution System Evolution[12]

Much of the U.S. has evolved into Stage 2 regarding the use of DER for bulk power systems and, to a lesser degree, distribution. This stage requires the integration of DER into system planning and operation, facilitated by advanced grid technologies to enable DER orchestration. DER orchestration is the holistic optimization and operation of DER through various dispatch (i.e., controls and price signals), autonomous (e.g., inverter setpoints), and behavioral (e.g., customer incentive rates and rebates) mechanisms to achieve a specific operational objective. For example, reduce net power flow on a distribution feeder.

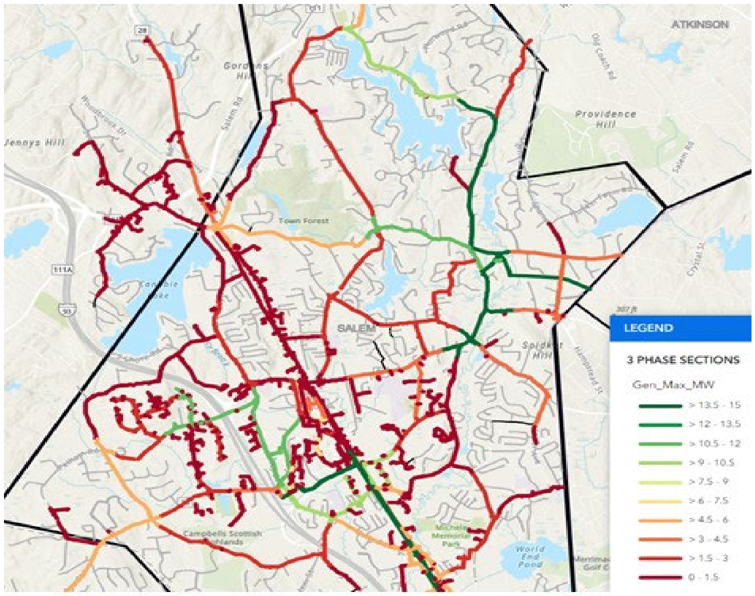
In Stage 3, DER applications and electric vehicle (EV) charging are optimized to support grid services for distribution and bulk power systems. Implementing FERC Order 2222 is a key early milestone in this stage to enable DER to participate more fully in wholesale markets. Stage 3 requires more mature DER sourcing methods and orchestration mechanisms to effectively utilize DER in a highly dynamic and increasingly decentralized energy system for distribution grid needs.[13]

Traditional power systems were designed for unidirectional flow — from generation, through transmission, to distribution, and finally to consumers. In addition, distribution networks are composed of conductors with varying capacities. Primary mainline conductors connect substations to the broader network and have higher energy delivery capacities than lateral and secondary conductors that serve individual customers. This variation in conductor sizes means that the ability to handle power flows diminishes closer to the end user. As DERs proliferate, these smaller conductors must accommodate traditional and reverse power flows from distributed generation and storage. This has contributed to increasing constraints on distribution systems across a network, from substations to customer service connections. These hyper-localized distribution constraints involve reliability issues such as overloads, service voltage violations, and potential protection relay misoperation. These constraints are commonly

[12] Note: The percentages shown are rough approximations for the threshold levels at which significant institutional, business, and grid changes are required due to consumer actions, policies, and new market models.

[13] P. De Martini and L. Schwartz, Distribution System Evolution, DOE, September 2023

included in “grid needs.” To date, these constraints have been primarily identified in utility hosting capacity analyses and distribution planning (Figure 3).



Source: Liberty Utilities

Figure 3. Hosting Capacity Map Example

Power flowing in multiple directions also complicates the management of distribution networks. Due to the source of the flows, individual constraints can occur in several locations on a single feeder and may occur at non-coincident times.[14] These non-coincident constraints also nest with one another depending on the power flow directions, creating further complexity to manage (Figure 4). The red, yellow, and green arrows in the figure indicate the direction of power flow and whether the flow exceeds an operating limit (red), nears a limit (yellow), or is reliably within a limit (green).

[14] Non-coincident refers to individual distribution line segments and equipment that experience peak loading within the same feeder at different times. For example, an individual service transformer may experience peak loading from EV charging while the feeder mainline may not be at a peak.

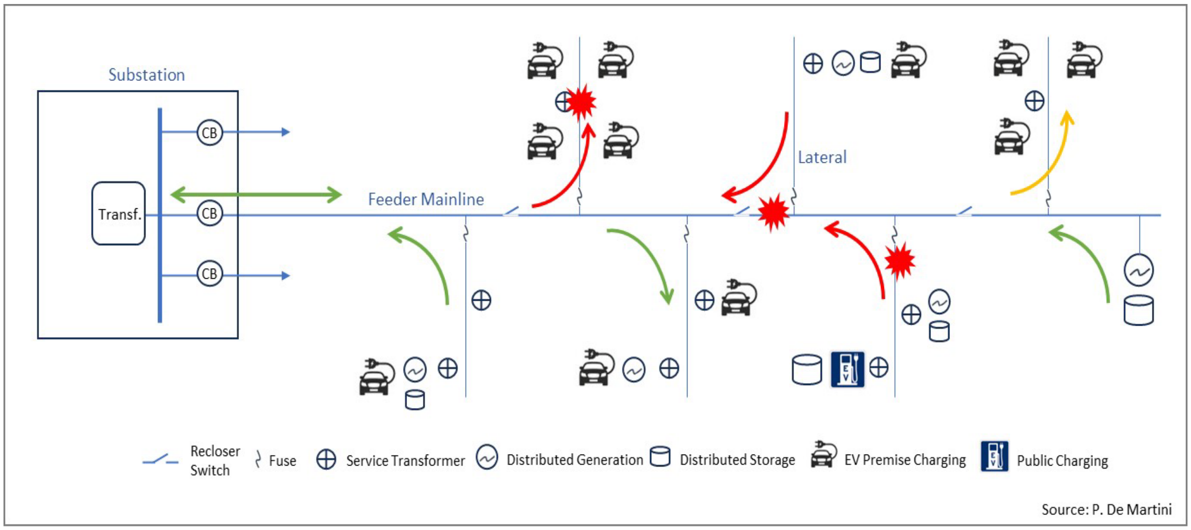


Figure 4. Multi-directional power flows on a high-DER distribution feeder

Utilities have begun to experience this phenomenon in their distribution systems.[15] This is why a growing number of states and utilities are pursuing a more detailed assessment of potential constraints across distribution networks, including the timing and factors related to specific constraints. Hosting capacity analyses today and traditional distribution planning analyses do not tell the whole story.

Integrating DER at scale — for example, solar PV, battery storage, and EV charging — transforms the operation of electrical distribution networks. This is illustrated in NREL's examination of the impact of uncoordinated DER operation on the total power flow for a small distribution substation during winter and spring (Figure 5).[16] This is analogous to larger substations and distribution feeders with high DER and EV charging levels. The power flow represented in the NREL study is a compilation of multi-directional flows across the distribution network from uncoordinated DER.

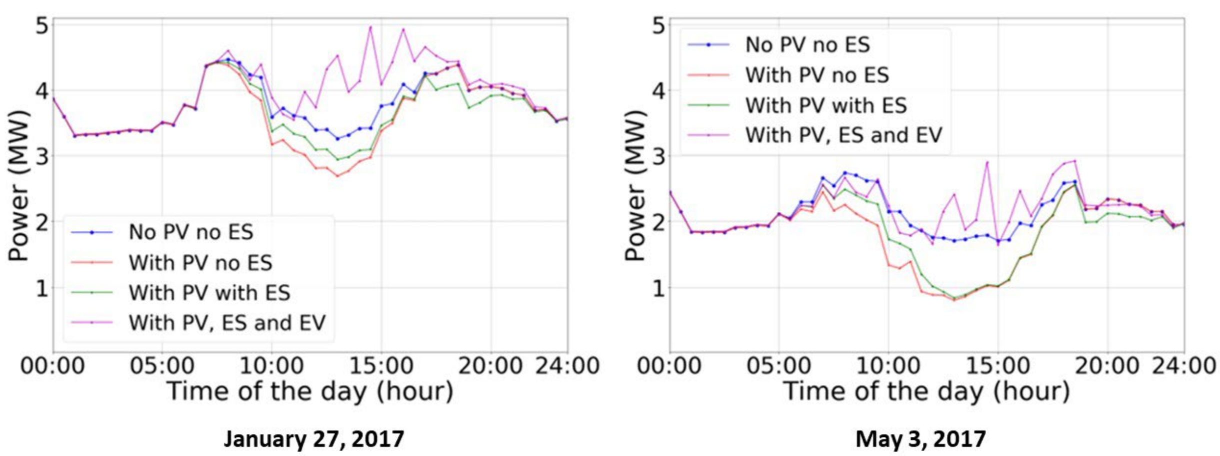


Figure 5. NREL High DER Distribution Analysis of Uncoordinated DER

This poses two issues: 1) how to address near-term hosting capacity constraints to enable DER

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[15] Based on discussions with the DOE's Distribution Grid Transformation Industry Working Group

[16] P. Paudyal, et al., The Impact of Behind-the-Meter Heterogeneous Distributed Energy Resources on Distribution Grids, National Renewable Energy Laboratory, August 2020

interconnections and EV charging service connections, and 2) how to address the time-frames and granular local capacity requirements to enable electrification and a more distributed power supply. Both issues require a better understanding of the distribution capacity availability on a forecast basis and nearer to real-time operations. This has led to using a method called the dynamic operating envelope. A dynamic operating envelope establishes the upper and lower bounds for a given time interval for allowable import or export power at a point of interconnection. These upper and lower bounds can change from one time interval to the next based on system conditions and anticipated constraints, allowing for more intelligent use of the hosting capacity.[17] Dynamic operating envelopes introduce a more sophisticated method to determine available energy export/import limits to connect new distributed generation, storage, and larger EV charging loads based on forecast and real-time grid conditions.[18]

For example, dynamic operating envelope methodology is starting to enable flexible DER interconnections and EV charging service connections to enable integration.[19] These flexible DER connection approaches are based on limiting energy export or demand at certain times to stay within the distribution grid's operation limits. This can enable more DER and EV charging connections until capacity is increased or DER orchestration mitigates the constraints. California's limited generation profile (LGP) is an example of a dynamic operating envelope applied to flexible resource interconnections.[20] A similar approach is being piloted by Southern California Edison's (SCE) flexible service connection for large EV charging facilities.[21] These examples are important steps in the evolution of the Stage 2 distribution system to enable greater DER and EV adoption and integration.

However, flexible interconnections and service connections are only an intermediate step as they employ resource and demand curtailments. As such, they will not scale as more resources and loads are added to the system, requiring greater limits (curtailments) on export and demand to remain within distribution operating limits. At some point, increasing levels of curtailments make the DER or EV charging functionally impractical. In contrast, optimizing DER energy consumption, storage, and export within the constrained distribution location can mitigate the need to curtail specific solar PV and EV charging.

3. Current Distribution Services and DER Sourcing Options

In the United States, there are three basic sourcing methods for distribution grid services: pricing (primarily time-varying tariffs), demand-side management (DSM) Programs, and non-wire-alternative (NWA) procurements ("3Ps"). Additionally, local flexibility markets are being demonstrated in a few European countries. [22] These four methods are briefly described below.

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[17] Australian Renewable Energy Agency (ARENA), On the calculation and use of dynamic operating envelopes, 2023. https://arena.gov.au/assets/2020/09/on-the-calculation-and-use-of-dynamic-operating-envelopes.pdf
[18] R. Dahyeon Yu and P. De Martini, Flexible DER and EV Connections, DOE, 2024.
[19] Ibid.
[20] CPUC, Resolution E-5296, March 2024. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M526/K988/526988970.PDF
[21] SCE, Establishment of Southern California Edison Company's Customer-Side, Third Party Owned, Automated Load Control Management Systems Pilot (Advice Letter 5138-E and 5138-E-A), January 2023. https://www.sce.com/regulatory/advice-letters
[22] Example, Norway's EuroFlex Market - https://nodesmarket.com/euroflex/

3.1. Distribution DER Services

Four fundamental distribution grid services have been identified in several jurisdictions to use for non-wires alternatives (Table 1).[23] Each service needs to incorporate a specific set of performance requirements related to a grid need identified in the integrated distribution planning analysis.[24,25] The industry is at an early stage of maturity regarding the use of DER services for distribution. To date, distribution capacity is the primary service pursued through geo-targeted energy efficiency, flexible demand programs, and contracted DER services to defer or avoid upgrades by reducing peak loading on a feeder or substation transformer. Contracted services have involved customer-owned and front-of-the-meter battery storage.[26] Distribution voltage-reactive power and power quality as services have primarily been pursued in DER interconnection and service connection requirements (including rules and tariffs), leveraging industry standards such as IEEE 1547. An early example of distribution resilience as a service includes PG&E's contract with an independent owner-operator for developing and operating a community microgrid for the City of Calistoga, California.[27]

Table 1. Currently Identified Distribution Grid Services

Distribution Capacity	The ability to inject energy or modify load as required via reduced or increased consumption reliably and consistently to manage net loading on desired distribution infrastructure within operating parameters.
Distribution Voltage Management	The ability to control leading and lagging reactive power on the system to maintain appropriate voltage levels and acceptable voltage bandwidths (ANSI C84.1), maximize the efficient transfer of real power to the load under normal and contingency conditions, and provide operational flexibility under normal and abnormal conditions.
Distribution Resilience	The ability to improve local distribution resiliency and reliability within a microgrid. This service may also involve fast reconnection and availability of excess reserves to reduce demand when restoring customers' service.
Power Quality	The ability to mitigate flicker and harmonics within acceptable levels.

Orchestrating a portfolio of DER sourced through an evolution of the several methods discussed below is a more effective next step to achieving Stage 3 capability by orchestrating all flexible DER within a distribution constraint to manage power flows optimally. This requires aligning the various interrelated aspects as all affect the resulting physical operation of distribution. This includes interconnection requirements, DER and customer tariffs, demand-side management programs, contracted distribution grid services, and grid operational and structural requirements. Such alignment is complex, integrating

[23] A. De Martini and P. De Martini, Bulk Power, Distribution, and Grid Edge Services Definitions, DOE, 2023. https://energy.gov/sites/default/files/2023-11/2023-11-01%20Grid%20Services%20Definitions%20nov%202023_optimized_0.pdf

[24] Public Service of Colorado, Weld 2978 Non-wires Alternative Request for Proposal, Attachment A–Weld2978-Project Specific Details and Information. https://www.xcelenergy.com/staticfiles/xe-responsive/Working%20With%20Us/Renewable%20Developers/WELD2978%20Feeder%20Project%20%20-%20Attachment%20A%20-%20FINAL.pdf

[25] PG&E 2023 Grid Needs Assessment (GNA) https://www.pge.com/assets/pge/docs/about/doing-business-with-pge/GNA.pdf

[26] Where allowed by law, the utility also may own and operate distribution storage in lieu of a traditional grid solution.

[27] PG&E-Vault Energy Calistoga Microgrid https://www.energyvault.com/projects/calistoga

interrelated but often discrete sourcing methods, processes, and funding sources with distinct entities and stakeholders.

3.2. Delivering Distribution Services at Scale

To achieve the scale needed to address the growing distribution grid needs, it is necessary to balance two fundamental dimensions:

a. Compelling value proposition for participating DER customers and/or third-party service providers, and

b. Value certainty for utility ratepayers based on DER services meeting performance requirements.

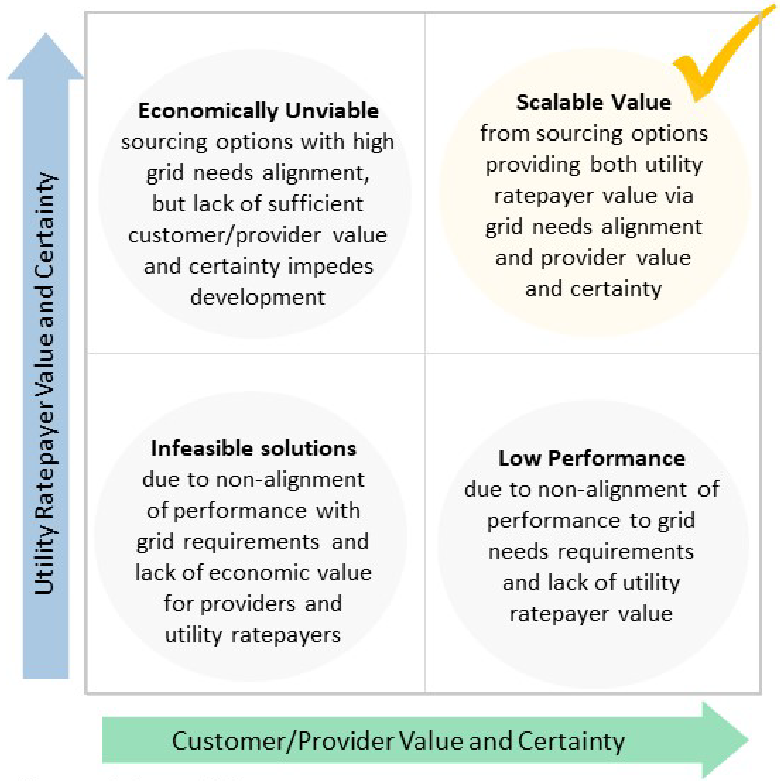
The term "service provider" refers to participating customers with DER, DER aggregators that control devices directly, aggregators-of-aggregators that manage aggregators on behalf of a utility, and program administrators that manage utility DER programs. This framework is agnostic to the choice of entity or entities in the DER service provider role.

Some current DER sourcing solutions have delivered profitability and certainty to service providers but failed to provide value certainty for utility ratepayers. Conversely, others have delivered value at a reasonable cost to ratepayers but have not been financially viable for service providers or compelling to customer participation. Figure 6 illustrates the two primary dimensions that need to be addressed to achieve scale utilization of DER services;

a) DER sourcing methods' performance and compensation alignment with distribution grid requirements to ensure utility ratepayer value (vertical axis) and

b) Sufficient risk-adjusted value ("value certainty") for DER customers and service providers (horizontal axis)

Therefore, the goal is to evolve current sourcing methods individually and through a portfolio approach to meet both requirements (top-right quadrant).



Source: S. Succar, ICF

Figure 6. DER Sourcing Method Value Framework

3.2.1.a. <u>Utility Ratepayer Value Certainty</u>

The degree to which a DER sourcing mechanism delivers a predictable level of value to utility ratepayers depends on its performance and compensation alignment with system needs. High distribution grid needs alignment indicates that the DER sourcing method's intrinsic performance capability (e.g., customer behavioral response versus control) and requirements (e.g., availability, reliability, scalability, etc.) are well-aligned to distribution grid needs in the relevant quantity, timeframe, and location. This value certainty for utility ratepayers also requires compensation for DER sourcing methods to be aligned with the performance required to meet the relevant system needs when and where they occur.

3.2.1.b. <u>Customer and Service Provider Value Certainty</u>

Equally important is active and sustained participation by DER service providers. The horizontal "customer/provider value certainty" axis in Figure 6 includes the risk-adjusted financial and non-monetary value for DER service providers, including participating customers and aggregators. Certainty and appropriate risk allocation are crucial for stimulating investment and ongoing participation. Providing certainty is essential to create an environment conducive to scalable DER service provision, fostering a stable framework to enable deployment at the scale needed to address the urgency of emerging grid needs.

3.3. DER Service Sourcing Methods

While DER growth has been robust in some jurisdictions, we have yet to see DER utilization for distribution services become an important alternative to traditional physical capacity upgrades. Examining the types and characteristics of common sourcing methods can identify what changes might be needed to enable DER to contribute to distribution system needs at scale. In the context of distribution needs, current DER services sourcing methods are identified in Figure 7. The assessment of each sourcing method follows below.

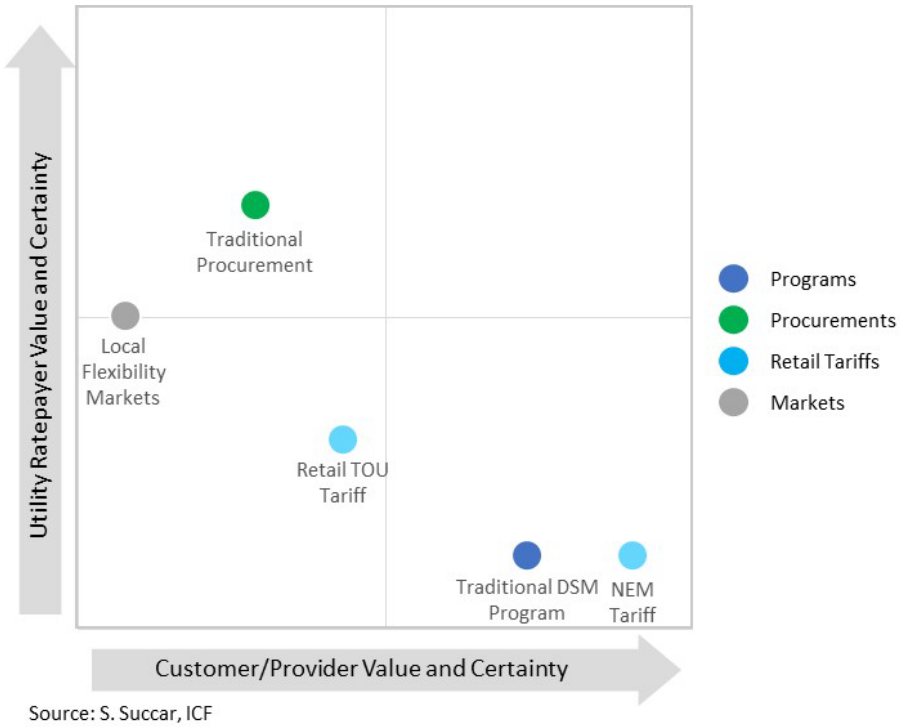


Figure 7. Current DER sourcing methods employed for distribution needs

3.3.1. Pricing (DER and Time-varying retail tariffs)

There are several approaches to providing tariff-based remuneration to DER, but these have traditionally been static and not well-aligned with distribution system needs. For example, high revenue certainty mechanisms like feed-in tariffs (FIT) and traditional net energy metering ("NEM 1.0") implementations provide resource compensation at a fixed volumetric price (e.g., cents per kilowatt-hour), irrespective of distribution grid need. While this approach offers revenue stability, providing the same compensation for output across all hours of the day in every location on the grid does not provide a mechanism to align DER production with distribution system needs. Also, most FIT and NEM 1.0 rates do not consider the distribution grid's needs and value in their design.

In contrast to these traditional DER tariff-based approaches, recent approaches vary compensation temporally or geospatially. For example, emerging DER rates align energy exports and charging demand with distribution grid needs and associated value.[28] This includes time-differentiated rates for solar PV, battery storage, EV charging, and customer-premise consumption. It also includes the potential to incorporate incentive elements into these rates to compensate for specific services provided. New York's Value of Distributed Energy Resources (VDER) tariff and Hawaii's Customer Grid Supply tariffs for solar PV and batteries were designed to address overall power system needs and initial consideration of

[28] J.P. Carvallo and L. Schwartz, The use of price-based demand response as a resource in electricity system planning, Lawrence Berkeley National Laboratory, November 2023. https://live-lbl-eta-publications.pantheonsite.io/sites/default/files/price-based_dr_as_a_resource_in_electricity_system_planning_-_final_11082023.pdf

distribution value and provide related compensation.

The challenge with time-varying rates and value compensation is that while they provide high compensation/incentive certainty for the developer/customer, they often do not align with specific distribution grid needs and performance requirements. This is partly due to a lack of locational specificity – that is, these retail tariffs are designed to be generally applicable to any customer located anywhere on the distribution system.

Also, time-varying pricing in retail consumer and DER rates may suffer from misalignment with the time-frames for distribution needs. For example, residential feeders often have demand peaks at different periods than feeders serving predominantly commercial or industrial loads. As such, designing time-varying rates based on overall system demand peaks may not address distribution level peaks. Rate designs, if aligned with grid needs and combined with other sourcing methods (e.g., procurements and programs), can be an important component of a DER sourcing portfolio.

3.3.2. Demand Side Management (DSM) Programs

Traditional DSM programs, demand response (DR) and energy efficiency (EE) have focused on bulk power system needs and can provide high value certainty. However, they typically do not specifically address local distribution needs and performance requirements.

For example, traditional EE programs are not focused on specific local distribution needs and typically involve deemed savings based on the EE solution employed to assess performance prospectively.[29] In these programs, customers either purchase an energy efficiency measure in exchange for a rebate or incentive or enroll in a demand response program and receive an incentive such as a bill credit. Compensation is based on avoided costs determined in a planning process primarily focused on the value of energy savings.

Traditional DR programs also are not designed to address local distribution needs. They are oriented more toward system peak demand management, which may not coincide with local distribution peaks and related constraints. As with NEM 1.0, these traditional DSM programs provide a high degree of value for participating customers and revenue certainty for providers but lack a high degree of alignment with the distribution system's evolving physical requirements. These sourcing options appear nearer the bottom-right corner of Figure 7. This is changing with geo-targeted programs and pay-for-performance requirements discussed below. Enhanced DSM programs that provide measured temporal and locational outcomes are important in a distribution services portfolio.

3.3.3. Procurements

Utilities that have typically used competitive procurement to source distribution grid services for non-wires alternatives[30] and microgrid resilience services.[31] Distribution grid service procurements address specific distribution needs to defer or avoid grid investments. These DER services are provided under bilateral contracts between an independent provider and a distribution utility with established

[29] Deemed Savings are pre-determined, validated estimates of energy and peak demand savings attributable to energy efficiency measures in a particular type of application. An electric utility may use these estimates instead of energy and peak demand savings estimated through measurement and verification (M&V) activities. Source: Electric Utility Marketing Managers of Texas

[30] Public Service of Colorado NWA Procurement example: https://co.my.xcelenergy.com/s/renewable/developers/non-wires-alternative-rfp

[31] Pacific Gas and Electric, CPUC Advice Letter No.6808-E , Calistoga Clean Substation Microgrid Project, 2022. https://www.pge.com/tariffs/assets/pdf/adviceletter/ELEC_6808-E.pdf

compensation for the term of the agreement.

However, these distribution services contracts involve the service provider assuming all the implementation costs, including customer acquisition and all the operational risk. These contract requirements translate into financial uncertainty for DER service providers. For example, distribution services contracts typically have stringent performance requirements for developing and operating the DER.[32,33] These typically involve significant risk exposure to the provider from liquidated damages for non-performance. In several instances in New York non-wires services procurements, the risk of liquidated damages was sufficient for service providers to abandon the contract, or when triggered by non-performance, the service firm went out of business, given the financial magnitude of the liquidated damage. This outcome does not serve the public interest or the needs of the utility, the DER service provider, or the participating customers.

Therefore, while traditional procurements might be well-intended to enable DER to meet a specified system need, they create a more challenging business model for DER service providers. As a result, such solutions occupy the top-left quadrant of Figure 7. As with the other methods, procurement and service contract improvements, as discussed below regarding evolution, can enable more effective outcomes for DER service providers and distribution utilities.

3.3.4. Local Flexibility Markets

Local distribution flexibility markets provide a platform for utilities and others to buy and sell grid services through an over-the-counter forward and day-ahead local distribution level market. This type of OTC forward market is being demonstrated in Norway, Belgium, and other European countries for distribution flexibility services.[34] These types of markets require sufficient market participation by DER service providers to create a viable competitive marketplace. Also, the competitive nature and uncertainty of distribution needs on any given day/hour, plus financial risk from non-performance, can create significant profitability/customer value uncertainty. These local markets are likely feasible at the substation level in the US when the prerequisite conditions (e.g., sufficient installed DER capacity available to provide services and participants to enable a competitive market) are present in the future.

Alternatively, local transactive energy-based markets have been pursued and piloted under research and development efforts in the US.[35] Transactive energy (TE) systems depend on automated real-time buy and sell tenders provided by consumer devices at typically short intervals (e.g., 15 minutes). These systems also require real-time distribution grid operational information that does not generally exist for distribution feeders beyond the substation circuit breaker. There are also well-known reliability issues with communicating with consumer devices over premise level Wi-Fi or narrowband home automation communications such as ZigBee and Z-wave that create operational issues for TE markets.[36] In addition, these micro-transactions (i.e., small dollar value per customer transaction) require participating service providers and utilities to have adequate billing and settlement systems to reconcile a large volume of these micro-transactions at scale. Existing utility billing systems are inadequate and will require

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[32] S. Patel and P. De Martini, Standard Distribution Services Contract, DOE, 2023. https://energy.gov/sites/default/files/2023-11/2023-11-15%20Standard%20Distribution%20Services%20Contract_optimized.pdf

[33] D. Murdock and R. Dahyeon Yu, Distribution Services Contracts Insights, DOE, 2024

[34] Example, Belgium's distribution "sthlmflex" market pilot. https://nodesmarket.com/sthlmflex/

[35] California Energy Commission (CEC), RATES Demonstration Final Report, 2020. https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-038.pdf

[36] Consumer premise-level communications with DER and load devices have been noted in a number of final reports, including by National Grid regarding connectivity to EV chargers, California IOUs with premise battery storage, and the CEC regarding their RATES demonstration.

expenditures to upgrade the capabilities.

For these reasons, both types of local flexibility markets are placed in the left quadrant of Figure 7.

4. Evolving DER Sourcing Considerations for Distribution Services

4.1. Utility Ratepayer Value Certainty

Achieving a high degree of certainty in utility ratepayer value requires effective alignment between sourcing methods and distribution grid needs such that the probability of meeting the relevant grid need is high. Distribution grid needs should be clearly articulated in technical and operational requirements, as required in several states that have pursued non-wires alternatives.[37]

Distribution grid needs have traditionally been in terms of relatively straightforward metrics such as static substation transformer thermal ratings. However, this is becoming more complex, given the changing use of and loads on distribution systems. Also, unlike the wholesale market with operating reserve capacity requirements, no DER service capacity reserves are currently employed for distribution grid services. The amount of grid services sourced is often the quantity specified in the engineering analysis that defined the grid need.[38] For example, a distribution grid need related to increasing the capacity of a feeder by 2 MW to accommodate electric vehicle charging will involve sourcing 2 MW of DER service from a single provider.[39] This creates significant operational dependence on the DER performance, related customer participation and responsiveness, and DER technologies (e.g., thermostats, control systems, communications).

For context regarding performance, the operational response times required for grid services vary. For example, distribution voltage and power quality response are needed in less than a minute. Required performance periods for managing distribution peak loading have been approximately an hour, scheduled a day in advance unless required for emergencies. This type of peak load management has shaped traditional demand response programs (DR 1.0). Over the past decade, demand response has evolved into flexible load management (DR 2.0)[40] using smart thermostats and battery systems that enable responses in shorter time frames and over longer performance durations of 4–6 hours.[41] This

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[37] CPUC, Decision 18-02-004 Order Instituting Rulemaking Regarding Policies, Procedures and Rules for Development of Distribution Resources Plans Pursuant to Public Utilities Code Section 769. Feb. 8, 2018. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M209/K858/209858586.PDF

[38] For example, PG&E's 2023 Distribution Grid Needs Assessment, Aug. 15, 2023. https://www.pge.com/assets/pge/docs/about/doing-business-with-pge/GNA.pdf

[39] For example, Xcel Energy's Public Service Company of Colorado Non-Wires Alternative Solicitation Attachment A – Project Specific Needs of WELD2978 Feeder Project. https://www.xcelenergy.com/staticfiles/xe-responsive/Working%20With%20Us/Renewable%20Developers/WELD2978%20Feeder%20Project%20%20-%20Attachment%20A%20-%20FINAL.pdf

[40] P. De Martini, *DR 2.0: A Future of Customer Response*, Lawrence Berkeley National Laboratory, July 2013. https://s3.amazonaws.com/fonteva-customer-media/00Do0000000Yi66EAC/DR%202.0%20A%20Future%20of%20Customer%20Response.pdf

[41] "Reshaping the future of the electric grid through low-cost, long-duration discharge batteries" Argonne National Laboratory. Mar. 17, 2021. https://www.anl.gov/article/reshaping-the-future-of-the-electric-grid-through-lowcost-longduration-discharge-batteries

capability enabled the initial limited use of DER as distribution non-wire alternatives.

Growth in electric vehicles and distributed solar is expected to create increased distribution power flow dynamics over extended portions of each day. This also includes, for example, using batteries for non-distribution purposes and uncoordinated inverter operation. The result will involve a complex portfolio of aggregated customer behavioral incentives and dispatched and autonomous resources operating continuously for distribution grids to stay within safety, reliability, and service quality operating parameters (Figure 8).

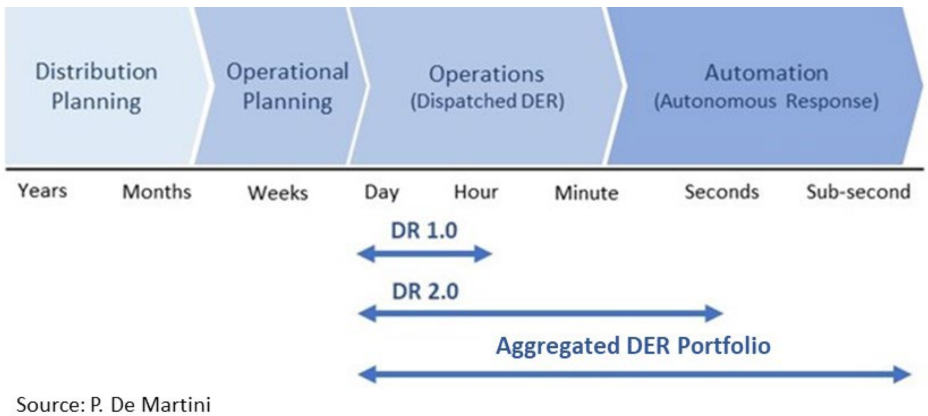

Figure 8. Planning and operational periods with DER utilization

Using DER services as an alternative to traditional distribution infrastructure investment (e.g., wires, transformers) means a utility does not plan to pursue an infrastructure investment for the same grid need. This requires the reliability of the individual or aggregated DER solution to be minimally equivalent to the physical option, or the operational reliability will be reduced. Therefore, distribution grid services must be reliable on a comparable basis to the distribution grid average of 99.98%.[42] Distribution operators must have confidence in DER performance regarding availability and response in real-time. To address this need, non-performance and liquidated damages provisions have been reflected in distribution services contracts.[43] These contracts have typically been adapted from power purchase agreements (PPA) that have been used for decades. However, the sophisticated suppliers under a PPA provide services from generation and battery storage assets explicitly developed and operated for bulk power system use. This is not the case for services from customer DER. While aggregators may be sophisticated, the customers who own the DER or will shift their energy usage are not. Also, customers can almost always opt out at their discretion. Achieving the contracted quantity of service is also very different from building a power plant or battery. Customer acquisition has a high level of uncertainty regarding marketing and any installation costs and time needed to obtain sufficient customer participation. These differences between a PPA for utility-scale generation and a DSC for DER services have created unsymmetrical risk/reward issues for service providers, as discussed below. Conversely, tariffs and DSM programs do not have similar stringent performance requirements or non-performance

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[42] Distribution reliability in reference to the national Customer Average Interruption Duration Index (CAIDI) for 2021 and 2022. See: https://www.eia.gov/electricity/annual/html/epa_11_01.html

[43] For example, Non-Wires Alternative Services Agreement between Public Service Company of Colorado and Xcel Energy. https://www.xcelenergy.com/staticfiles/xe-responsive/Working%20With%20Us/Renewable%20Developers/PSCo%20NWA%20-%20Attachment%20B%20-%20Model%20Contract%20for%20NWA%20Services%20-%20FINAL.pdf

consequences.

Additionally, suppose a DER sourcing method does not include performance requirements closely aligned to the distribution need, and/or the method inherently cannot perform one or more of the requirements. In that case, the DER service provider may be compensated despite their inability to deliver the requisite service.

These factors lead to distribution operators' lack of confidence in DER services, which has been a significant challenge to the expanded use for distribution. Changes to distribution planning can include reserve margins for DER services and behind-the-meter DER resource accreditation.[44] A portfolio approach employing more than one DER sourcing method, like ConEdison's Brooklyn Queens Demand Management (BQMD) project, could be more effective.[45]

To address these evolving distribution grid needs, defining and operationalizing services that meet specific grid needs becomes increasingly important. This requires a focus on four core elements:

- Clearly defined services and performance attributes,
- Appropriate sourcing methods (e.g., pricing, programs, procurements, and flexibility markets) that match service requirements
- Adopting enhanced planning methods and tools, including techno-econometric analysis, to assess and create effective DER sourcing portfolios and
- Integrate operational capabilities (e.g., Advanced Distribution Management Systems and Grid Distributed Energy Resource Management Systems) for DER to deliver the needed services.

DER can be leveraged to enhance grid performance and potentially defer costly infrastructure upgrades by addressing these aspects. As DER adoption grows, it will be necessary to intentionally integrate the sourcing methods to create effective DER portfolios to maximize their potential and ensure a reliable and efficient distribution system.

4.2. Customer and 3rd Party Service Provider Financial/Value Certainty

High financial/value certainty means that the revenue/incentives to the DER service providers, including the DER customer and aggregator, are dependable, and performance risks are manageable. Low financial/value certainty may reflect some combination of revenue volatility, significant performance risk penalties, customers' failure to realize benefits, or other sources of uncertainty and risk. The risks for customers and service providers are significant.

4.2.1. DER Customer Participation Considerations

As described in the Customer Resource Flexibility paper, customers weigh several risk factors when considering allowing the use of their resources for grid services:[46]

- **Functional Risk** – a consumer's calculation of whether the service will function as planned or will create customer equipment issues such as a shortened product life or malfunction; also,

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[44] P. De Martini and J. Taft, DER Utilization for Distribution Reliability (final draft), NETL-DOE, 2024.

[45] https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B5B4091D0-ED09-44DF-8C56-D0A40459298D%7D

[46] A. De Martini and P. De Martini, Consumer Resource Flexibility, DOE, Nov. 2023. https://www.energy.gov/sites/default/files/2023-11/2023-11-01%20Consumer%20Resource%20Flexibility%20nov%202023_optimized.pdf

cybersecurity risks regarding personal and confidential information may be a factor for consumers

- **Physical Risk** – a consumer analysis of personal health and safety as it relates to a potential flexible load management program or grid service during extreme weather events, for example
- **Financial Risk** – a consumer's assessment of the specific financial benefits of a program/offer, which includes both the perceived personal financial benefits from cost savings and/or incentives or market-based payments; financial risk also includes consideration of the consumer's cost to acquire the DER
- **Social Risk** – a consumer's perception of their contribution, through providing grid services, in creating societal value, which studies have shown to be an important motivation for sustained participation[47]
- **Complexity Risk** – retail time-varying electric rates, demand response programs, and market designs introduce significant complexity; also, consumers have varying levels of technology literacy, which can be a barrier to their willingness to participate in providing grid services from their DERs

Addressing these five customer risks holistically can improve the reliability of aggregated customer DERs and shape a mutually beneficial partnership between customers, the DER service providers, and OEMs that is viewed as a fair and reasonable exchange for all parties. A reliability assessment of proposed tariffs, programs, and independent DER portfolios should include consideration of the customer engagement plan and whether these five customer risks are adequately addressed.

4.2.2. DER Aggregator Considerations

DER service providers also have a set of business risk considerations regarding financial certainty:[48]

- **Customer Acquisition & Sustained Participation** - DER service providers need to acquire customers willing to participate in flexible load and resource programs and/or market-based provision of distribution grid services for the program/service contract duration. Aggregating enough customers to provide sufficient resource capacity and availability is an expensive challenge.[49] Distribution needs are very localized, with a relatively small number of customers with available DER flexibility that are physically located to affect the constraint.
- **Limited Profit Potential**- DER service providers face competition among themselves and from other market players, such as DER manufacturers. This competition can reduce a service provider's revenue and profit potential for services. Service providers may outsource a DERMS solution[50] and customer acquisition marketing. As a result, the total dollar value of any individual service can be modest, and profitability can be quite low.[51] Distribution capacity service requirements can also preclude the ability to sell wholesale services so that value-

[47] Portland General Electric, Smart Grid Testbed final evaluation https://edocs.puc.state.or.us/efdocs/HAD/um1976had9321.pdf

[48] P. De Martini and J. Taft, DER Services for Distribution Reliability (final draft), NETL-DOE, 2024.

[49] Small commercial and residential customer engagement (acquisition and ongoing engagement) is a significant cost for DER service providers. See: https://www.nwcouncil.org/sites/default/files/SixthPowerPlan_Appendix_H_1.pdf

[50] For example, Virtual Peaker, EnergyHub, OATI, and others provide software-as-a-service solutions for aggregator DERMS.

[51] Over the past decade DER Aggregators, such as Advanced Microgrid Solutions, Comverge, EnerNoc, Sunverge, Swell, and others, have closed, exited, or pivoted to provide other services.

stacking opportunities may be limited.[52]

- **Non-performance Risk**—Retail flexible load management programs and distribution service contracts typically include pay-for-performance, performance assurance, and/or liquidated damage provisions to address the risk of non-performance. While performance assurance may be prudent, it adds costs and other financial issues for DER service providers that can create revenue recognition issues and erode profit margins.
- **DER Technology Risk**—DER service providers must manage various devices, including smart thermostats, water heaters, EV charging, battery storage systems, and distributed generation. This requires sophisticated monitoring and control software and hardware systems and the ability to collect and manage large amounts of data securely. The lack of interoperability and using customers' Wi-Fi and internet connections to communicate with devices can pose material performance risks.
- **Regulatory Complexity** - Service providers must navigate complex regulatory landscapes, which involve compliance with unique wholesale market rules, retail regulations, programs, tariffs (pricing mechanisms), and utility procurements.

Customer engagement costs, opportunity costs, technology risks, and non-performance penalties can effectively erode a service provider's value of providing distribution services sourced from a relatively small number of customer DERs within the distribution-constrained location. This is why many DER service providers do not pursue distribution grid services (e.g., through NWA procurements) in primarily residential areas.

5. DER Sourcing Methods Evolution

Changing distribution grid needs necessitates evolving sourcing methods toward the top-right quadrant of high alignment and scalability, as shown in Figure 9. This requires solutions and portfolios to meet physical distribution needs cost-effectively and mitigate the attendant value uncertainty and risk for DER customers and third-party service providers. It also requires DER solutions to reliably meet the variability and hyper-locality of emerging distribution constraints. This means moving "up" toward a greater alignment with distribution grid needs and improving DER service provider financial and value certainty that move toward the "right."

To find options in the top-right quadrant of these alignment-scalability axes, we can explore a two-fold evolution in DER sourcing that involves (1) improving DER sourcing options toward distribution need alignment and sustained viability for providers and (2) combining sourcing options into integrated portfolios that consider the relative contributions and cost of each option to address distribution grid needs. No sourcing method alone can address the evolving distribution grid needs, as illustrated in Figure 9 below.

[52] This is because a resource cannot sell the same capability simultaneously (in the same time period) to two different buyers, such as a distribution utility and an ISO. This is the case for wholesale market participation under FERC Order 2222.

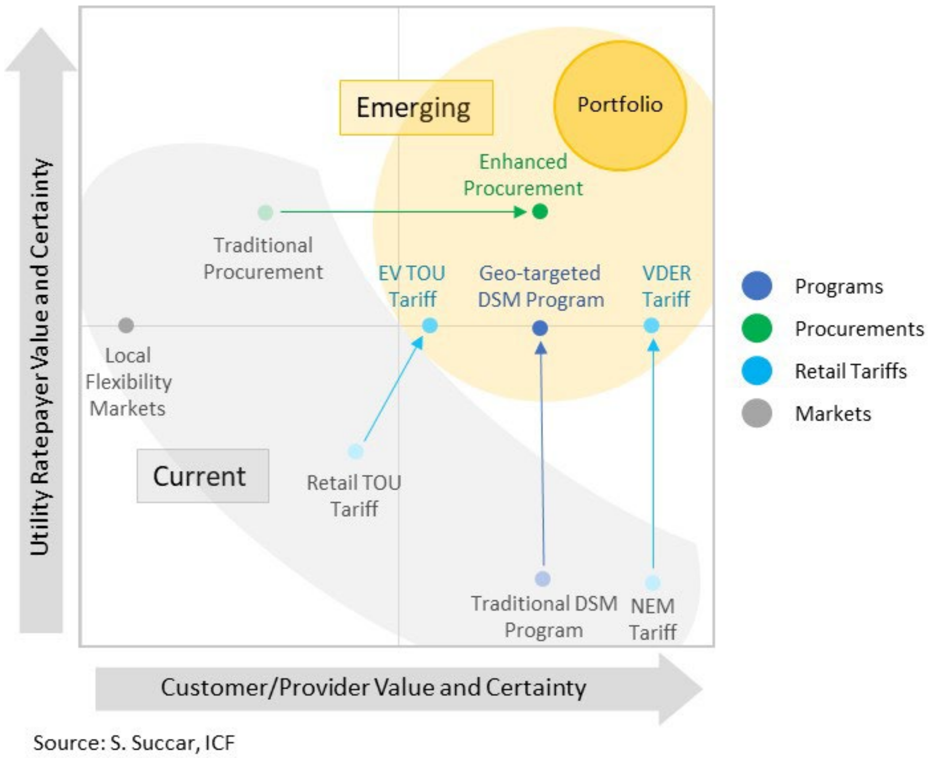

Figure 9. Evolution of DER sourcing methods employed for distribution needs

5.1. Improving Sourcing Methods

Each sourcing method presents challenges to achieving scalable grid value from DER services. Existing tariffs and legacy DSM programs significantly shape customer net load and energy exports from solar PV and batteries. The following discussion suggests evolutionary changes for each method.

5.1.1. Retail & NEM Tariffs

Commercial and residential time-of-use rate (TOU) periods can also better align with distribution constraint timing. Tariffs for solar, batteries, and EV charging could include locational and temporal attributes aligned to related specific distribution constraints. The Value of DER (VDER) tariff in New York includes a Locational System Relief Value that differentiates compensation based on location (Figure 10).[53] These tariffs may mitigate the need for curtailment programs for distributed solar and batteries and EV charging.

[53] See: https://www.nyserda.ny.gov/All-Programs/NY-Sun/Contractors/Value-of-Distributed-Energy-Resources

Figure 10. ConEdison's Locational System Relief Value Map for King's County, New York

5.1.2. DSM and DER Programs

Traditional DSM programs require more location and temporally-based, geo-targeted designs to better align with distribution grid needs. These program designs would also reflect geo-targeted local distribution needs using performance requirements and compensation based on results (e.g., pay-for-performance programs). This shifts customer programs toward more direct alignment with distribution grid needs, as reflected in the vertical position of the geo-targeted DSM programs sourcing option in Figure 9. Programs benefiting from the declining cost of battery storage offer significant opportunities for effective distribution services. Overall, DSM and DER programs could enable greater alignment with grid needs by leveraging their scalability with the locational specificity of geo-targeted solutions.

5.1.3. Procurements

New approaches for procurement can similarly help address some of the drawbacks of traditional non-wires approaches. For example, risk allocation between a utility and service provider is an important factor in the success of contracted service provision. Reconsidering the roles and responsibilities of the utility and service provider regarding costs and risk assignment can help identify significant improvements. For example, today, most distribution service contracts (DSC) reflect an arm's length relationship between the utility and the DER services provider, with no joint responsibilities for costs or implementation and operational risks.

This is not how utilities contract for DSM programs. Utilities engage DSM program administrators effectively as utility partners with a shared cost and operational risk approach based on the comparative capabilities of each party. For example, utilities could share the responsibility and expense of soliciting customer participation as they do for DSM programs. Also, distribution NWA procurements typically involves a single DER services provider for each need. This creates significant supplier risk. Instead, the utility could take responsibility for sourcing an additional quantity of service desired as an operating reserve instead of having the aggregator assume that responsibility. This can benefit the utility by diversifying supplier risk and the aggregator that must incur additional costs for reserves and associated financial liability.

DSM program administration models are very mature and employed at a very high scale. They can provide lessons for improving the effectiveness of procuring and contracting DER services. Incorporating best practices into standard DSCs can provide the basis for simplifying the contracting process and administration. Also, contract mechanisms that can more flexibly manage and mitigate unforeseen circumstances could help mitigate some of the challenges associated with traditional procurement and contracting approaches.[54]

5.2. Integrated Sourcing Portfolio

To scale the utilization of DER services for distribution, a portfolio of sourcing methods cost-effectively addressing the distribution grid needs alignment/performance certainty, and provider profitability/value realization is needed (top-right quadrant). Therefore, the overall objective is to align the technical orchestration mechanisms with the economic value methods to achieve the required operational performance and thus facilitate efficient growth and success in integrating DER into the distribution grid. However, getting to this top-right quadrant has been challenging, partly because the nature of distribution value is increasingly complex.

For example, the variable timing and hyper-locality of emerging distribution needs mean that certain distribution grid services, described earlier in this paper, might require continuous dispatch of resources located in a segment of a distribution feeder for up to 8 hours. Today, however, no single sourcing method can cost-effectively provide that type of long-duration continuous response for a distribution grid need.[55]

The opportunity is to identify the potential to create a portfolio of DER solutions that are cost-effective in addressing each distribution constraint. A prominent example is ConEdison's Brooklyn-Queens Demand Management (BQDM) program portfolio, employing various sourcing methods and technologies to reduce net load to avoid a $1.2 billion distribution substation upgrade (Figure 11). This same portfolio of DER solutions also has collateral benefits to the bulk power system.

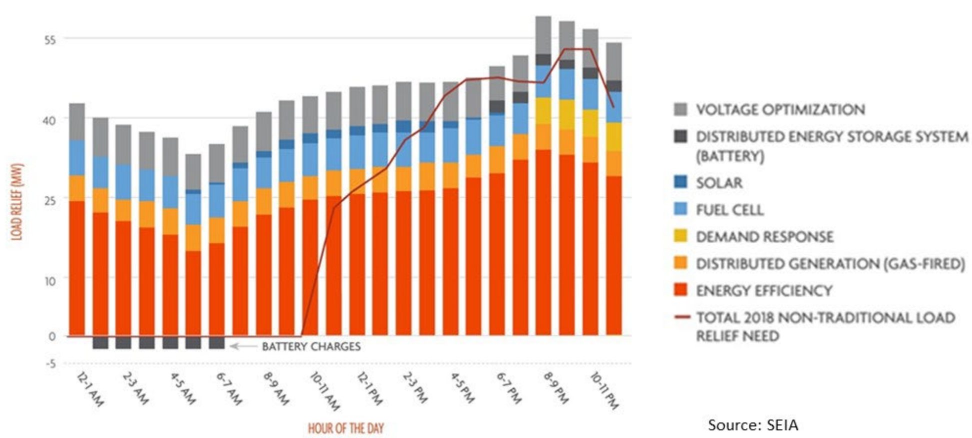

Figure 11. ConEdison's BQMD Program Portfolio of DER Solutions

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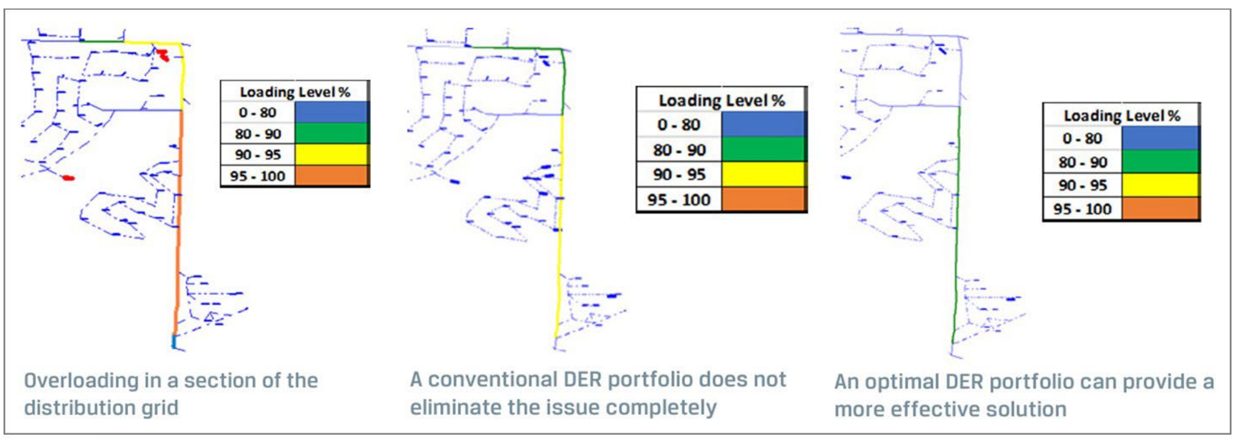
[54] D. Murdock and R. Dahyeon Yu, Distribution Services Contract Insights, DOE, 2024

[55] Cost-effective in the context of the deferral or avoidance value of a physical distribution grid upgrade alternative. This has been identified in several unsuccessful utility non-wires alternative procurements.

Orchestration of DER and EV charging will also require a holistic approach to coordinating all these sourcing methods to optimize distribution grid utilization and maximize customer benefits while maintaining grid reliability and safety. However, DER sourcing methods are typically developed and implemented independently and not operationally coordinated or co-optimized today. The path forward to achieve the scale of DER services envisioned will necessarily need to address the cost of DER services to ratepayers holistically, the performance of various sourcing methods and orchestration mechanisms for DER services, and provider business model viability and customer value. Appendix A provides an overview of the various orchestration mechanisms described in greater detail in two DOE companion reports.[56,57]

The incremental cost of deploying retail rate tariffs is relatively low. Likewise, many existing DSM programs can readily be reshaped into geo-targeted solutions that better align with distribution needs without incremental cost to ratepayers. Conversely, NWA procurements and flexibility markets involve incremental costs to ratepayers as they typically involve compensation related to the value of the avoided distribution upgrade.

While enhancements to the approaches used with each sourcing method can improve the overall effectiveness for all parties, it is not practical to think that only one method will address a distribution need. For example, a comparative analysis of the current non-wires DER solution identification approaches versus an optimized portfolio designed through a techno-econometric approach was conducted for a North American utility.[58] The identified grid need involved feeders experiencing voltage violations and overloading during peak and off-peak periods, with peak demand projected to exceed feeder capacity (Figure 12). A set of DER solutions was identified using the utility's conventional approach. This conventional portfolio provided some demand reduction but did not fully address the grid need requirements. An optimized DER portfolio was developed to meet the distribution needs fully. This optimized portfolio of geo-targeted DSM programs, pricing strategies, and DER services procurement proved to be a more reliable and cost-effective alternative to feeder and substation transformer upgrades.



Source: ICF

Figure 12. Conventional DER Solution versus Optimal DER Portfolio for Distribution

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56 R. Dahyeon Yu and P. De Martini, Flexible DER and EV Connections, DOE, 2024.

57 S. Viayda and S. Patel, Distribution Grid Orchestration, DOE, 2024.

58 H. Safiullah, S. Succar, et al., Using Optimization to Drive Your DER Strategy and Build Value, ICF, 2017. https://www.icf.com/-/media/files/icf/white-paper/2017/energy-using-optimization-drive-der-strategy.pdf?rev=1a943b8197b2404db07cda0c341dc1d0

5.3. Ratepayer Cost Implications

When evaluating DER sourcing methods in this portfolio approach, the incremental cost to ratepayers of the various options is an important consideration. For example, the incremental cost of adding an EV TOU rate is relatively low if a general TOU rate is in place. Also, DER tariff rates, such as the value of DER tariffs that align pricing to avoided costs, could have minimal cost impacts on customer rates.[59,60] Similarly, realigning existing DSM budgets to include geo-targeted programs may not involve incremental costs to ratepayers.

By contrast, DER services procurements add material incremental costs for ratepayers regarding the specific NWA evaluation and procurement processes and the compensation for the service(s) provided. This is because the service provided is to offset the incremental distribution upgrade expense that would otherwise also be an incremental cost to ratepayers. Compensation under these procurements is typically on par with the avoided distribution cost. Additionally, the cost recovery mechanism employed for NWA services compensation (e.g., utility operating expense) can have a greater near-term rate impact than the avoided utility distribution capital expense that is typically amortized over the asset's life.

With local flexibility markets, the cost implications for ratepayers are like procurements in that the level of compensation is set relative to the avoided distribution cost. Still, like any competitive market, the price may vary depending on demand and service availability. There are also non-trivial costs to establish the distribution level marketplace, ongoing market operational costs, and any related regulatory proceedings to establish the distribution market and determine cost allocation for development and ongoing maintenance.[61,62]

Distribution energy markets are not considered viable yet. This is because nearly all distributed generation and storage are either under retail tariffs (e.g., community solar tariffs, New York's VDER tariff, Hawaii's CGS+ tariff) that do not allow the sale for resale[63] by the customer, wholesale-related power purchase agreements, or front-of-the-meter resources interconnected under wholesale market participation rules/tariffs.

The incremental ratepayer cost implications for each sourcing method are summarized in Table 2 below.

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[59] Cappers, P. and A. Satchwell. 2022. EV Retail Rate Design 101.

[60] Cappers, P., A. Satchwell, C. Brooks, S. Kozel. 2023. A Snapshot of EV-Specific Rate Designs Among U.S. Investor-Owned Electric Utilities.

[61] Baringa Partners, DER Market Design & Implementation, Consolidated Edison Company of New York, Inc., November 2022.

[62] Maine Governor's Energy Office, Distribution System Operator (DSO) Feasibility Study Update, Nov 26, 2024 https://www.maine.gov/energy/sites/maine.gov.energy/files/meetings/DSO%20study%20webinar%20slide%20deck%2011.26.24.pdf

[63] Energy sales for resale are considered FERC jurisdictional transactions.

Table 2. Sourcing Method and Ratepayer Incremental Cost Summary

Sourcing Method	Incremental Ratepayer Cost
Tariffs/Price Signal (DER, TOU)	Relatively low cost for billing changes and customer communications
DSM/Demand Flexibility Programs (Geo-targeted and temporal)[64]	None if the existing authorized program funding is redirected to geo-targeted /temporal needs
Procurement/Bi-lateral Contract	Cost is based on competitive proposals but typically capped at the deferred/avoided distribution value.
Local Flexibility Market	Market implementation cost + cost of purchased flexibility service at market prices

5.4. Manage Bulk Power System Variability from DER at the Edge

In addition to the distribution challenges described above, distributed solar and consumer EV charging introduce operational variability into the bulk power system primarily due to their inherent characteristics of intermittency and unpredictability that impact both supply and demand dynamics. Industry capability and experience in forecasting these distributed resources and EV charging is evolving to address these issues; however, it is not particularly mature for most utilities and others. Also, the error between forecast net demand and actual demand in real-time remains a concern.

For example, the North American Electric Reliability Corporation (NERC) has expressed concerns about the operational challenges of distributed solar PV and EV charging on the bulk power system. Specifically, NERC highlights that the rapid growth of distributed solar and the increasing adoption of EVs contribute to increased net load variability, which impacts the bulk power system's reliability.[65,66]

Distributed solar power output varies with weather conditions, time of day, and seasonal changes. Solar generation can fluctuate significantly within short periods (e.g., cloud cover moving across a region). This intermittent nature creates challenges in maintaining a steady power supply to the grid, as the bulk system needs to respond to sudden drops in generation by ramping up other generation sources. For example, Midcontinent Independent System Operator (MISO) and other ISO/RTOs have reported that distributed solar PV (both community and behind-the-meter installations) variability makes it difficult to forecast net load accurately, exacerbating the challenges of managing supply and demand in real-time.[67]

Consumer EV charging creates another emergent layer of variability in the bulk power system, primarily on the demand side. EV charging demand can be highly unpredictable, depending on consumer behavior, such as when and where consumers charge their vehicles. This variability could lead to significant fluctuations in demand, particularly during peak demand periods when many EVs may be plugged in simultaneously. The combined effects of distributed resources and EV charging on net

[64] Demand Flexibility Programs include geotargeted and temporal programs. Integrated Demand Side Management (EE + DR) is an early manifestation of Demand Flexibility programs. EE and DR (1.0 and 2.) have sometimes been artificially separated by funding but should be considered holistically as demand flexibility.

[65] https://www.nerc.com/comm/RSTC/Documents/Grid_Friendly_EV_Charging_Recommendations.pdf

[66] https://www.rtoinsider.com/30444-nerc-wecc-examine-ev-charging-risks-grid-reliability/

[67] https://www.misoenergy.org/meet-miso/media-center/miso-matters/misos-latest-reliability-imperative-report/

demand variability are increasingly significant.

The New York Independent System Operator (NYISO) reported that day-ahead net load forecast errors have become "*significant in magnitude and duration*." NYISO found that based on a historical analysis of 2021-2022, there were several hourly instances where the day-ahead net load forecast errors exceeded the size of the largest generator contingency.[68] The distribution system, including connected distributed resources and EV charging, effectively creates demand variability in the bulk power system.[69]

The question is, how can this net load variability be managed best? Optimally managing DER for distribution could significantly mitigate the residual load variability in the bulk power system. For example, during midday, when solar generation is high, there may be low overall grid net demand that can create distribution protection and related safety issues, in addition to unwanted "duck curve" effects in a bulk power system. A managed EV charging and battery storage program or DER aggregation could address the distribution issue and mitigate net demand variability at the bulk power system. This would reduce the demand variability and associated need for bulk power system flexibility services.

Today, however, the focus is mainly on using DER to solve bulk system needs primarily or concurrently to solve distribution challenges through traditional top-down planning processes. These approaches often miss the synergistic benefit realized by managing DER at the edge for distribution and then considering the resulting net load changes at the bulk power system. Also, the timing of distribution and bulk power system needs are not always aligned (Figure 13). If the bulk system and distribution grid needs are divergent, "DER services for the respective uses may cancel each other out or exacerbate the need in the other domain."[70]

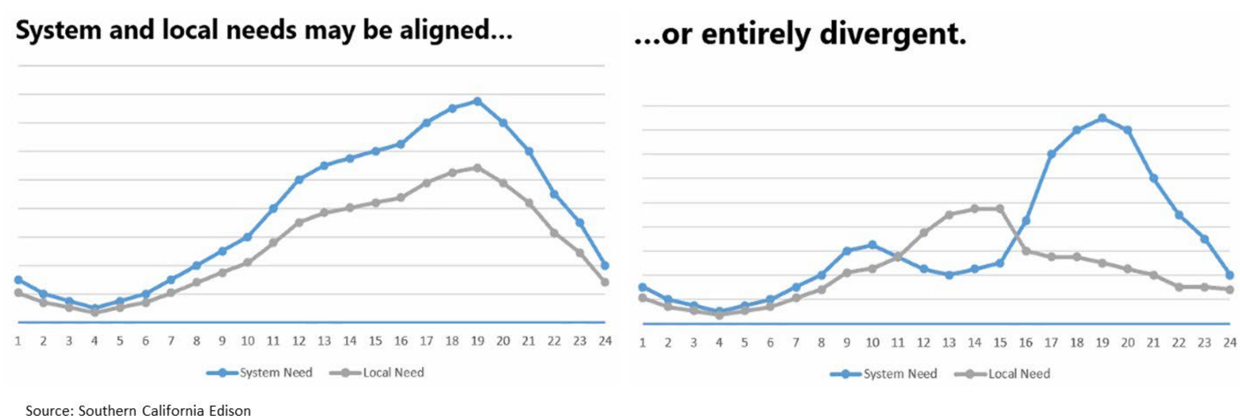

Figure 13. Coordinating/Optimizing DER Services for Distribution and Bulk Power System

For these reasons, a distribution to bulk power system-oriented "bottom-up" paradigm shift is important when developing strategies to manage and value DER integration and utilization, particularly in high DER and electrification scenarios. This will also allow for better optimization of DER integration and utilization across the power system.

[68] A. Myott, et al., Balancing Intermittency: Initial Analyses, NYISO, July 19, 2023.

[69] Note: DER may also export energy from distribution into the bulk power system, as has been increasingly occurring in utility systems over the past decade.

[70] SCE presentation, Moving Toward More Dynamic Markets, CPUC R. 22-11-013 Data Working Group, December 16, 2024.

6. Techno-Econometric Decision Model for DER Services

Many sourcing combinations are possible, given the diversity of pricing, program, and procurement options that may be implemented using various dispatch and autonomous mechanisms for a wide range of DER technologies. This requires a multi-factor evaluation approach (“techno-econometric”) to address the considerations discussed above. Particularly when addressing capacity constraints and resilience, distribution grid needs will benefit from considering an integrated portfolio of DER solutions. Therefore, a systematic approach to developing a portfolio of DER solutions involves the following:

- Modeling a distribution system under various scenarios to determine grid needs and related operating requirements,
- Assessing technical capabilities of specific DER technologies individually and in aggregate,
- Determining the key performance factors related to developing the requisite quantity needed and operational response,[71]
- Determining (e.g., through a model-based analysis) an optimal mix of DER solutions based on expected performance and cost to ratepayers (both participating and non-participating customers), sourced from the various pricing, programs, and procurement options, and
- Evaluating DER portfolio performance to ensure distribution reliability and continuously improve program performance in near real-time and methods in subsequent planning cycles.

Techno-econometric models are appropriate for such complex decision-making because they provide a structured and integrated approach to analyzing technical and economic factors. When applied to DER sourcing methods and orchestration mechanisms, these models enhance the quality of decisions by ensuring that all relevant aspects are considered, risks are identified, and DER solutions are optimized.

The DER Orchestration Techno-Econometric Decision Model in Figure 13 is designed to identify, evaluate, and select the most appropriate DER solutions based on technical feasibility and economic viability. The model comprises two primary analyses, technical and economic, each containing several key steps that collectively guide the decision-making process from understanding grid needs to selecting optimal DER solution portfolios.

[71] P. De Martini and J. Taft, Utilizing DER Services for Distribution Reliability, National Energy Technology Laboratory, 2024

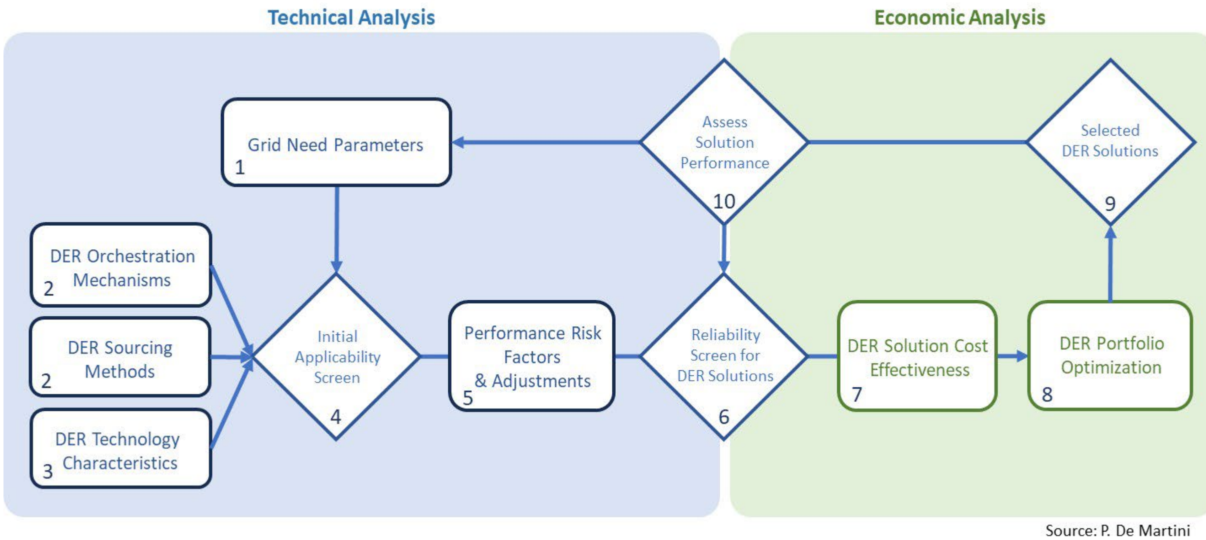

Figure 14. DER Orchestration Techno-Econometric Decision Model

These steps form the basis for a robust techno-econometric decision model that holistically assesses and crafts cost-effective DER solution portfolios to address distribution grid needs. The process is analogous to the factors and methods employed in integrated resource planning to create cost-effective resource portfolios but focuses on unique distribution considerations. This decision support model facilitates stakeholders' understanding of the trade-offs and synergies that lead to selected DER solutions. This decision model is described in detail in Appendix B.

7. Conclusion

The evolving landscape of power systems necessitates a paradigm shift in managing distribution systems, particularly when using DER services to defer physical upgrades or enhance performance and operational efficiency. As customer dependency on reliable electricity increases, distribution grids become more dynamic, with multi-directional power flows and greater variability in demand and energy exports from distributed generation. The business-as-usual approach to system upgrades, relying primarily on large-scale distribution infrastructure investment, is costly for ratepayers and not sustainable.

At the same time, status quo acquisition approaches for DERs are not a scalable solution. Siloed sourcing efforts focusing primarily on bulk power system needs lead to detrimental, uncoordinated customer behavior and device response at the distribution level. Additionally, technology-neutral approaches can overlook the specific performance capabilities required to manage the dynamic flows at the distribution level, further complicating grid management. Recognizing that non-wire alternatives are not the sole solution, given the performance and cost considerations is also important. Further, today, no single sourcing method or technology can serve as a "silver bullet" to address emerging distribution needs affordably. Instead, a portfolio of DER solutions and a holistic approach to orchestrating DER offers a better approach. Such a portfolio can be developed using the comprehensive techno-econometric model detailed in Appendix B.

From a financial perspective, achieving scale in distribution grid services depends on carefully balancing ratepayer affordability with effective risk allocation between utilities, service providers, and customers.

Standardization across technology interoperability and sourcing methods (e.g., standard services contracts) can help reduce costs and barriers, making DER services more reliable and scalable.

Ultimately, relying on DER services for the distribution grid requires new planning and operating paradigms. Integrated system planning, with a bottom-up approach that begins at the edge of the grid and integrates DERs in forecasting, hosting capacity analysis, and non-wires solutions, can enable the optimization of distribution and customer layers of the grid. This includes consideration of distribution operating reserves and behind-the-meter DER resource accreditation in planning. By embracing these new strategies, the distribution grid can evolve to meet future challenges while maintaining customer reliability and affordability.

Recommendations

Examine enhancements to Integrated System Planning processes, including:

- Employ a bottom-up approach to consider DER optimization first at the distribution level before use for bulk power systems.
- Determine distribution operating reserve margins and behind-the-meter DER resource accreditation for DER services for each type of DER technology and related orchestration and sourcing methods to ensure distribution grid reliability.

Integrate DER sourcing approaches to holistically consider the use of pricing, programs, and procurements:

- Explore the integration of regulatory dockets to examine retail rate designs, geo-targeted/temporal demand flexibility programs, and NWA procurement processes that can yield more effective utilization of DER services for distribution.
- Examine geo-targeting DER programs to address distribution needs by considering temporal and locational needs, including performance requirements, to provide cost-effective grid solutions.
- Consider using public purpose funds, as applicable, to enable geo-targeted energy efficiency and demand flexibility to help meet distribution system needs.
- Revisit NWA procurement approaches to consider enhancements that address service provider cost and risk factors to improve participation and viability. This includes considering a cost- and risk-sharing partnership between the utility and service providers, such as the model for DSM between the utility and program administrators.

Appendix A: DER Orchestration Mechanisms

DER orchestration mechanisms are broadly classified into signaling-based orchestration and autonomous orchestration. The control location and types of intermediation/interfaces between distribution operators and DER devices further distinguish each category (Figure 14).

Dispatch Signaling—This category includes mechanisms where a signal (either price or control) is sent to initiate a response from DERs. Centralized orchestration means that signals are sent from a central entity like a utility or grid operator, while Decentralized orchestration involves more localized control systems or automation near the DER. Signals are classified into:

- Price Signals: DERs respond to market-based pricing for distribution
- Control Signals: DERs respond to dispatch instructions from control systems (i.e., utility direct control and/or through intermediaries)

Autonomous—This category refers to systems in which DERs operate independently based on predefined engineering parameters or dynamic conditions without needing real-time communication from a grid operator. Autonomous orchestrations are classified into:

- Fixed Parametric: DERs operate based on pre-set standards (e.g., IEEE 1547-2018) or engineering parameters.
- Dynamic Parametric: DER automatically adjusts its operation based on parameters provided the day ahead or the day of (e.g., CPUC Limited Generation Profile).

Behavioral- This category refers to customer response to retail tariffs and incentives to encourage customer demand management and energy conservation:

- Responsive Demand: Customers manually control energy demand or automate response based on time-varying rates or incentives.
- Energy Conservation: Customers reduce energy consumption through energy efficiency measures and awareness of energy use.

Interface Levels- Several different levels of interface may be employed between the utility operator and DER device to affect a response, including aggregators and manufacturers as may be applicable:

- Direct Interface: Utility dispatch is communicated directly to the DER device.
- 1-Level Indirect Interface: Utility dispatch is intermediated by either an aggregator or a device manufacturer (e.g., comms interface/device software). For example, utility distribution services are provided by aggregated smart thermostats via an aggregator such as RenewHome.
- 2-Level Indirect Interface: Utility dispatch involves two or more entities (an aggregator and a device manufacturer) for the utility to initiate device response. For example, utility-managed EV charging is done through an EV's onboard charging system (see National Grid pilot).

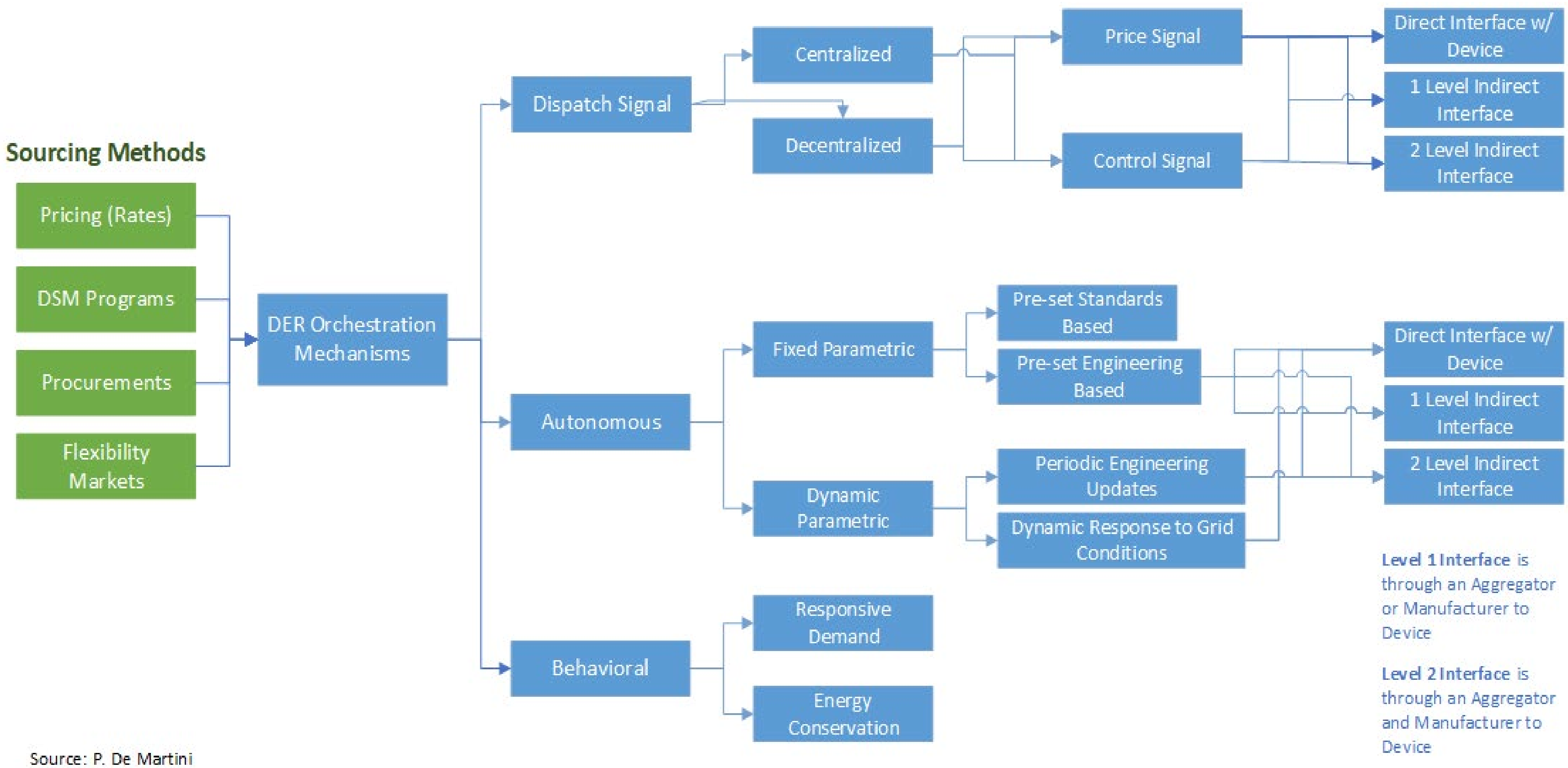

Figure 15. DER Services Sourcing Methods and Orchestration Mechanisms[72]

[72] S. Vaidya, S. Patel, and P. De Martini, Distribution Grid Orchestration, DOE, 2024

Appendix B: DER Services Techno-Econometric Decision Model

The DER Services Techno-Econometric Decision Model (Figure 15) identifies, evaluates, and selects the most appropriate DER solutions based on technical feasibility and economic viability. The model comprises two primary analyses: technical and economic analysis, each containing several key steps that collectively guide the decision-making process from understanding grid needs to selecting optimal DER solutions.

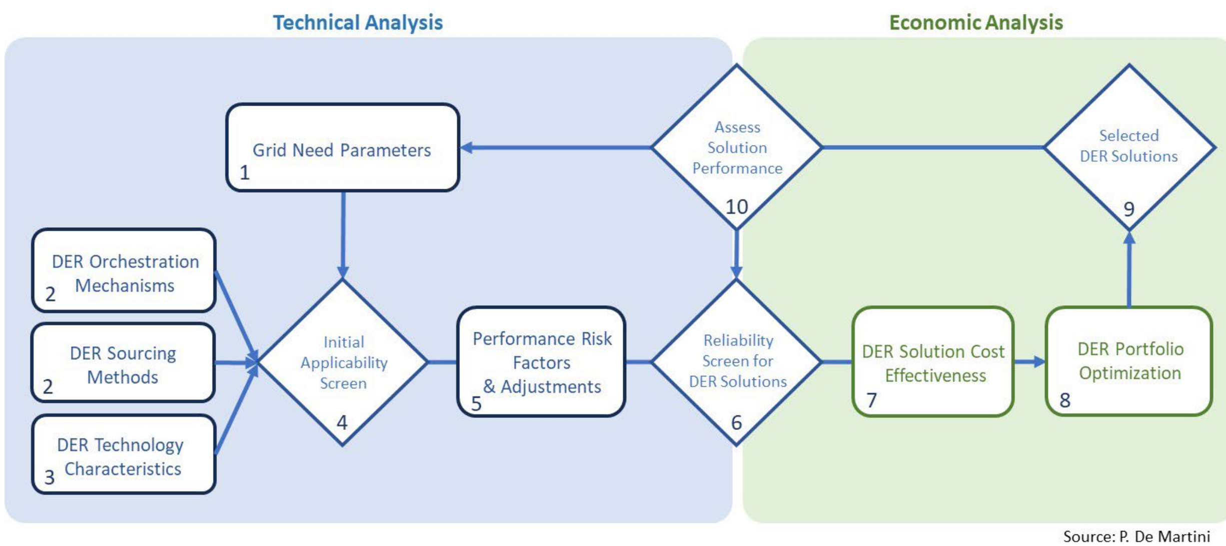

Figure 16. DER Orchestration Techno-Econometric Decision Model

The following is a brief description of the model and its steps:

Technical Analysis

1. Grid Need Parameters - The first step involves identifying the specific distribution grid constraints and related engineering requirements to be addressed by DER solutions. Utility grid needs assessments produce this information, and several states require utilities to publish the information[73]. This includes parameters such as temporal power flow-thermal capacity limits (i.e., ampacity), voltage limits, and protection relay criteria.

2. DER Orchestration Mechanisms - This involves identifying and assessing the commercial viability and technical considerations associated with the various dispatch signaling through price and/or control and/or autonomous mechanisms for orchestrating DER.

2. DER Services Sourcing Methods – This involves identifying the specific sourcing approach within the rates, programs, procurement, and/or flexibility markets categories. Each candidate approach is assessed regarding, for example, customer participation potential, implementation considerations, competitive market viability, and other relevant factors associated with each approach.

[73] San Diego Gas & Electric, Grid Needs Assessment, 2023. https://www.sdge.com/sites/default/files/regulatory/R21-06-017%20SDGE%202023%20IPE%20DPAG%20Report.pdf

3. DER Technology Characteristics - This step involves evaluating various DER technologies' technical specifications, capabilities, and limitations, including integration potential with existing grid infrastructure. Understanding these characteristics is essential for assessing their applicability and performance.,

4. Initial Applicability Screen - This is the first screening process to determine which DER technologies are potentially applicable based on the grid needs and DER characteristics. It filters out technologies that do not meet the basic requirements.

5. Technology Performance Risk Factors & Adjustments - In this step, the model assesses potential performance risks associated with the applicable DER technologies, such as technology maturity and reliability, implementation, and operational risks. Adjustments are made to account for these risks, ensuring a more reliable evaluation.

6. Reliability Screen for DER Solutions - This step involves a more detailed reliability assessment of the various DER sourcing options to employ for the identified DER technologies that passed the initial applicability screen. Specifically, this step assesses the performance risks associated with developing and operating each sourcing and operational mechanism. It ensures that the selected solutions are dependable and meet the grid's reliability standards and requirements.

Economic Analysis

7. DER Solution Cost Effectiveness—This step calculates the cost and benefits associated with the shortlisted DER solutions to help quantify each option's economic viability from a ratepayer perspective. It includes both capital and operational expenses, identified benefits such as direct utility cost avoidance/savings, and direct and indirect ratepayer and societal benefits that may accrue.

8. DER Portfolio Optimization - This step involves the creation of an optimal portfolio for a specific grid need. This also involves co-optimizing DER services across multiple concurrent grid needs that apply to sets of DERs that are locationally relevant to those grid needs. A comprehensive analysis integrates the technical performance and economic evaluations. It provides a holistic view of the viability of each DER solution, considering both engineering and economic aspects, and involves a detailed cost-benefit analysis and comparison of the solutions to determine the most economically advantageous portfolio of options[74].

9. Selected DER Solutions—This is the result of Step 8 - selecting the most suitable DER solutions based on the combined results of the technical and economic analyses. These solutions best meet the grid's needs based on risk-adjusted performance while providing a cost-effective portfolio. This is the set of solutions to implement for distribution grid needs.

Assess Solution Performance

10. Assess Solution Performance—This step involves assessing the operational performance of the solution portfolios against the specific grid need(s) prospectively through model-based simulations and ex-post, typically annually, to determine operational performance and inform the next planning cycle. This analysis would involve evaluating performance at different levels of locational granularity and for multiple time horizons.

Techno-econometric models, like the DER Orchestration Techno-Econometric Decision Model, are becoming essential approaches for complex decision-making due to their ability to integrate technical

[74] An example of this DER optimization portfolio modeling tool is ICF's DER Insight.

and economic analyses to provide a comprehensive view. This decision model ensures a structured and thorough approach to selecting DER solutions, balancing technical feasibility with economic considerations to achieve the best grid management and optimization outcomes. The model also incorporates implementation and performance risk factors, enabling decision-makers to identify and mitigate potential risks associated with different options. This leads to more reliable solutions to address operational needs.

Evaluation Screens

Each evaluation screen in the model shown in Figure 15 (Steps 4, 6, 9, and 10) narrows the many potential DER solutions that apply to the grid need and related performance requirements toward developing an optimal portfolio.

Applicability Screen (Step 4)

This first screening step is to determine which DER technologies and operating mechanisms are potentially applicable based on the grid needs and DER characteristics. This screen involves a structured evaluation to assess the compatibility of DER orchestration mechanisms and technologies for specific distribution services requirements. For example, energy efficiency measures such as a home insulation program cannot address distribution voltage violations. Still, it may contribute to a base level of energy reduction to address forecast distribution overloads. This is intended to filter out non-viable options early in the process to focus on those most appropriate for given distribution grid needs parameters. For many potential solutions, this screening may only need to be done once to create a reference catalog and update it as needed in response to technological advancements. Steps 1 and 2 provide the information necessary for this initial viability assessment (Figure 16).

The evaluation considers both the applicability of the DER technology and the various operational mechanism options that may be used.

<u>Evaluate Which DER Technologies May Be Appropriate</u>

Potential DER technologies are evaluated in terms of their inherent capabilities to affect energy imports/exports, voltage, and other parameters specific to the grid need that is being addressed. This recognizes that a wide range of DER technologies are available today. Each DER technology has unique characteristics that may be combined with other technologies applicable to specific grid needs. Understanding the integration and coordination effects of various DER technologies is also important, as some technologies may provide synergistic results, and others may be detrimental. For example, it has been demonstrated that combining time-of-use rates with smart thermostats creates a synergic benefit greater than the TOU rate or thermostat yield individually.[75] A technology-neutral approach is ineffective when building a DER solution portfolio for specific grid needs. The granularity of distribution grid needs and the related reliability criteria require a more precise alignment of DER technology capabilities to distribution grid needs.[76] This is also important when considering the development of an optimized portfolio of solutions later in the process.

<u>Evaluate Which Operational Mechanism(s) May Be Appropriate</u>

Potential operational mechanisms associated with specific DER technologies are evaluated to determine

[75] Nexant, Inc. and Research Into Action, “California Statewide Op-in Time-of-Use Pricing Pilot,” final report prepared for the TOU Working Group, March 30, 2018.

[76] D. Murdock and R. Dahyeon Yu, Distribution Services Contract Insights, DOE, 2024

their suitability for the distribution service. Several factors are considered:

- Operational Latency Requirements: The time sensitivity of the service delivery.
- Scale of Mechanism: The scope and intricacy of implementing the mechanism.
- Availability of Required Information: The necessary data and its accessibility to execute the mechanism.
- Technical Maturity of the Mechanism: The commercial availability of the mechanism technologies and level of standards-based interoperability employed.
- Robustness of Mechanism: The reliability and complexity of the operational mechanism.

All these factors are sensitive to the degree of locational granularity needed to make the mechanism function effectively.

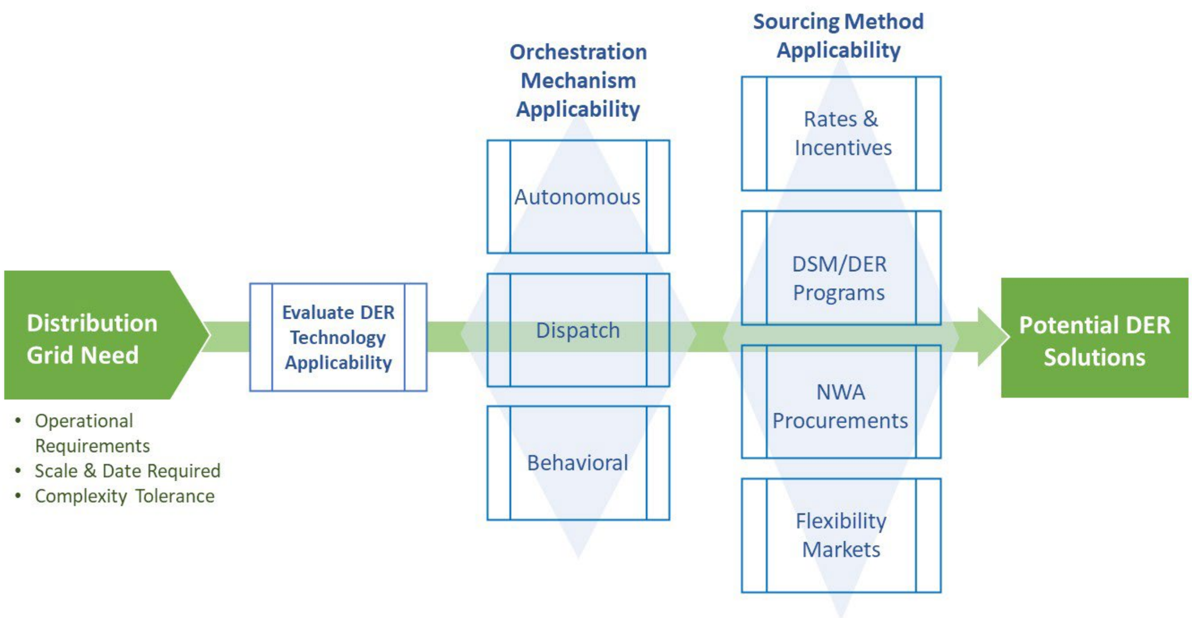

Figure 17. Initial Applicability Screen

Reliability Screen for DER Solutions (Step 6)

The DER solution reliability assessment process involves a detailed evaluation of operational requirements, compensation methods, and coordination mechanisms for specific grid services. By systematically distinguishing compensation methods, evaluating operational mechanisms, identifying coordination structures, and resolving conflicts, this process ensures that DER solutions are effectively integrated and managed within the grid. This step involves a more detailed reliability assessment of the DER solutions that passed the initial applicability screen.

The Performance Risks and Adjustments identified in Step 5 are developed using a DER Services Risk Assessment Framework, which provides a structured approach to identifying, evaluating, and identifying potential mitigations to manage the various risks associated with different DER technologies, operational mechanisms, and sourcing methods. This approach also helps stakeholders understand potential challenges and make informed decisions to address these risks effectively. A comprehensive risk assessment is crucial for successfully deploying and integrating DER services for distribution grid needs. The following are key implementation and operational performance risk factors:

Cost Risk

The likelihood of DSM program implementation or independent aggregator and developer proposals exceeds planned costs. The probability of implementation cost overruns is the risk that the actual costs incurred during the implementation of DER services will surpass the authorized budget. Cost overruns can delay DER services implementation and potentially jeopardize the financial viability of the DER solution, including the developer walking away from the project. Exceeding planned costs can lead to overall budget overruns, require additional funding, and incremental rate impacts.

Volumetric Risk

Volumetric risk involves four aspects related to the quantity and timing of service provided in relation to the performance requirements described below:

- The expected performance capability for a specific DER type – is its resource accreditation. Resource accreditation determines the DER's performance capabilities (i.e., probability of performance) to deliver its intended services reliably and efficiently within all necessary technical, safety, and operational criteria.
- The probability of not reaching the scale needed is the likelihood that a DER aggregation will not obtain sufficient customer DER participation to meet the specific grid needs requirements. Failure to reach the needed participation level can limit the DER solution's overall effectiveness and value, impacting financial and operational targets. Not reaching sufficient scale may result in not deferring grid investment, creating cost overruns, and diminished distribution grid reliability. For example, there may not be a sufficient number and type of customer premises in the target locale to implement DER solutions to address the need. Insufficient customer DER can limit the effectiveness of DER services to address specific local distribution needs. For example, this has been an issue for aggregated DER solutions for distribution needs within a section of a distribution feeder.
- The probability of volumetric degradation faster than expected is the risk that customer participation in a DER aggregation will degrade more rapidly than anticipated. This leads to decreased DER service provision over time, affecting the viability of distribution investment deferral or avoidance.
- The probability of not matching the needed hourly profile is the risk that the DER solution will not align with the expected profile associated with the grid need. This affects grid reliability and the ability to address specific distribution constraints, potentially leading to reliability issues and increased operational costs.

Operational Performance Risk

Operational performance risk includes aspects other than quantity considerations that can impact distribution reliability and cost-effectiveness.

- Resource availability is the availability of the necessary resources to operate the DER service and meet the performance requirements. Managed EV charging is a unique example. The availability to manage charging in a target locale may be compromised given that EVs are mobile and may not be in the target location or charging when load reductions or exports (V2G) are needed.
- Non-performance is the potential for DER to fail to perform as expected when called upon. Non-performance can lead to potential DER service provider financial damages and increased costs for pursuing alternative solutions.

- Service provider failure is the risk that the provider will fail to deliver the expected services for non-technical issues. For example, a DER services provider may choose not to perform due to immature business processes and financial considerations, abrogate a services contract, or exit the business.

Technology Maturity Risk

The probability of failure due to technology issues is the risk that DER will fail due to technological problems or limitations. Three prominent issues continue to persist in the orchestration of DER:

- Telecommunications failures connecting with customer devices at their premises.[77,78]
- Lack of device and system interoperability among device manufacturers and software providers can lead to more fragile complex integrations, which can result in operational failures.
- Unstable DER device application interfaces (API) that change with frequent software updates that cause information and data disruptions.

Considering these risk factors in assessing the reliability screen in Step 6 provides a robust approach to assessing the operational performance of DER solutions in relation to the identified distribution grid need. Figure 17 illustrates a simple summary qualitative scoring method informed by a documented detailed examination of the issues above. The scores can determine minimum acceptable risk thresholds for any category and overall risk. This assessment is conducted for each identified grid need. However, it may be simplified through experience to determine a subset of solutions that best apply to specific distribution needs. This would allow a more focused evaluation. This risk factor assessment also enables the development of mitigation measures to enhance the performance of a solution as it is further assessed in this process.

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[77] J. St. John, "What California Utilities Have Learned from Their Smart Inverter Pilots", GreenTech Media, November 8, 2018. https://www.greentechmedia.com/squared/dispatches-from-the-grid-edge/what-california-utilities-have-learned-from-their-smart-inverter-pilots

[78] National Grid, National Grid Petition Seeking Certain Modifications to EV Managed Charging Program, New York Public Service Commission, Case 18-E-0138, 2024. Available online: https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BF0D6798D-0000-CC11-BE20-7BC34F9C0DB1%7D

Distribution Implementation & Operational Risk Factors	Time Varying Rates (Premise)	Time Varying Rates (EV Charging)	EE (deemed savings)	Geotarget EE (Pay for Performance)	Traditional DR	Geotarget Utility DR (PfP)	Geotarget 3rd Party DR (PfP)	Geotarget 3rd Party EV Fleet/Public managed charging	Geotarget 3rd Party LDV EV managed charging	FTM Grid Battery	BTM Battery	Community Solar PV	BTM Rooftop Solar PV
Cost Risk													
Probability of 3rd party proposals exceeding planned cost													
Probability of implementation cost overruns													
Volumetric Risk													
Resource Accredidation													
Probability of not achieving scale needed													
Probability of volumetric degradation is faster than expected													
Probability of not matching the needed profile (shape risk)													
Performance Risk													
Availability of resource/s													
Probability of non-performance when dispatched													
Probability of service provider failure													
Location Risk													
Availablility of sufficient customer DER in target locale													
Availability of mobile EV charging in target locale													
Technology & Business Maturity Risk													
Probability of failure due to technology issues													
Probability of failure due to immature business processes													
(Scale: 1- Low, 5 - High) **Totals:**													

Source: P. De Martini

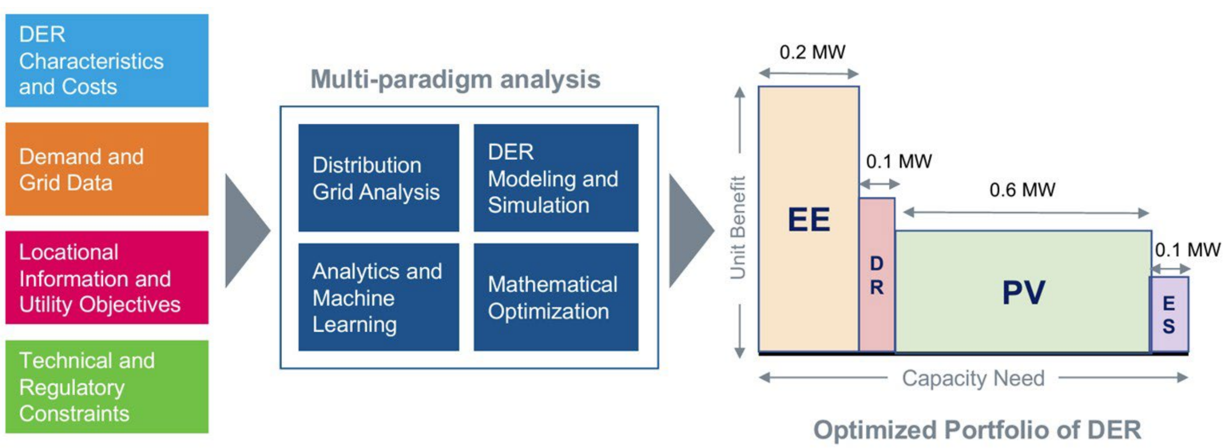
Figure 18. DER Solution Reliability Screen

DER Portfolio Optimization – Step 9

DER portfolio optimization is a bottom-up engineering-economic analysis of the potential DER solutions identified in the prior steps to address distribution grid needs. The objective is to create optimal portfolios that combine the various DER types, operating mechanisms, and sourcing methods to create an integrated portfolio that is highly likely to successfully and cost-effectively address specific distribution needs.

This type of engineering-economic analysis uses distribution system topology and the grid constraints identified in Step 1 at the outset of the techno-econometric modeling process. Customer data, including past program participation and performance, is used to inform the assessment of DER solutions. This engineering-economic analysis also uses historical data and market trends to incorporate forecast adoption of various DER technologies, such as smart thermostats, EVs, PV, battery storage systems, and heat pumps. This allows for impact assessments of DER adoption, providing insights into how increased DER adoption will support the scale of flexible DER needed.

This bottom-up analysis leverages public data sources and analytical techniques to develop individualized digital twins for each building in the target locations. These digital twins can be created using the DOE's OpenStudio[79] software and commercial DER modeling tools to serve as virtual representations of premises. New 8,760 load profiles are generated for each premise and multi-unit building, capturing the anticipated impacts of simulated flexible DER technologies on energy export/import profiles at individual premises, enabling precise and localized flexible DER management strategies. For example, this type of analysis quantifies how flexible DER, time-varying rates, demand response (DR), managed EV charging, and/or energy efficiency (EE) measures contribute to addressing distribution grid needs. This analysis also provides the financial implications for customers, considering potential savings from reduced energy usage or participation in DER services. The portfolio analysis approach is illustrated below in Figure 18.



Source: ICF

Figure 19. DER Solution Portfolio Development

[79] See: http://openstudio.net/

Assess Solution Performance – Step 10

This step involves a prospective model-based simulation to conduct a preliminary performance assessment in distribution simulation tools[80] to conduct a preliminary assessment of performance and adjust before implementation. This step also includes assessing the implemented DER portfolios' subsequent operational performance results. The results are also fed into the planning process to inform the next planning cycle and opportunities to improve the decision-making process and solutions.

[80] An example is PNNL's set of GridLab-D power system software, and distributed controls and transactive simulation tools.