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Introduction

Demand flexibility[1] (DF)—the ability of buildings and equipment to adjust energy use dynamically in response to grid conditions—and its application in ***grid-interactive efficient buildings*** (GEB)—energy efficient, smart buildings that provide demand flexibility co-optimized to serve occupants and the grid—offer important capabilities for managing an increasingly complex electricity system. They will be key to address imperatives of energy affordability and equity, reliability and resilience, and environmental protection, including energy system decarbonization. The potential to align energy use in buildings and facilities with grid conditions to mutually support customer, grid, and societal needs has far reaching electricity policy, regulatory, and investment implications for State Energy Offices, Public Utility Commissions, utilities, and building owners and investors. This document provides a high-level overview of DF and GEB for decisionmakers and stakeholders and a glossary of selected terms. It also offers additional resources for deeper exploration of the topics.

Context

The electricity system is changing rapidly, presenting challenges and opportunities for the delivery of reliable, clean, and affordable power to the nation's homes, businesses, and institutions. The rapid growth of variable renewable generation, utility energy storage, and ***distributed energy resources*** (DERs)—including ***energy efficiency***, ***demand response*** (DR), and onsite generation and storage—is making electricity system management more complex. This is particularly so as ***electrification*** of transportation,[2] buildings, and industrial processes accelerates.

State Energy Offices and Public Utility Commissions increasingly need to consider these trends and developments in energy and electricity system planning and understand their implications for achieving state energy, economic, and environmental policy objectives, The Offices and Commissions have vital roles in creating policies, developing regulations, and providing market contexts that can help channel DF and DERs amidst the palette of technological advances to help states achieve their policy goals. (More discussion of policy, regulatory, and market matters appears later as well as references for deeper consideration.)

Fortunately, new technologies offer prospects for orchestrating utility, customer, and third-party energy resources to simultaneously meet grid and customer needs. DF, also called load flexibility, and its application in GEBs can:

- Lower costs, enhance ***reliability*** and ***resilience***, and reduce emissions;
- Reduce ***peak loads***, moderate the ramping of demand, and provide ***grid services***; and
- Enhance energy efficiency and integrate distributed and renewable energy resources.

The combination of these flexible and distributed resources can support building performance and resilience, improve utility distribution systems (including as "***non-wires solutions" or "non-wires alternatives***" to traditional utility upgrades), and, when aggregated, serve as ***virtual power plants*** (VPPs), supplementing and at times supplanting conventional generation.

Demand Flexibility and GEB Capabilities and Benefits

As illustrated in Figure 1, DF capabilities include:

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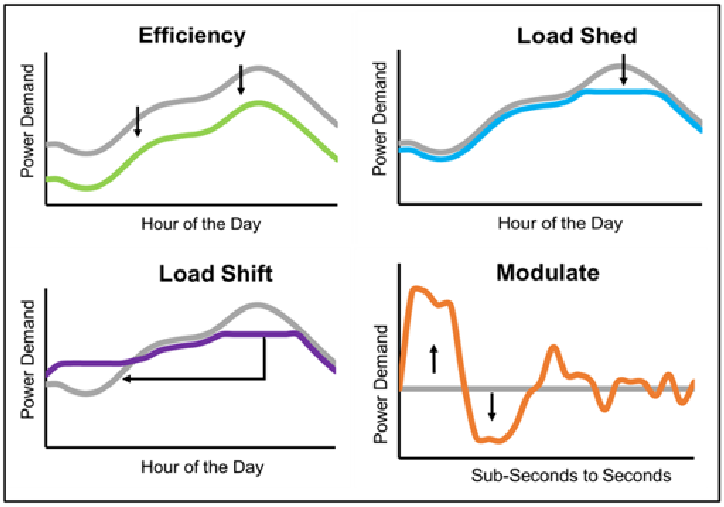
[1] Terms first appearing in italics and bold can be found in the glossary.

[2] Electric vehicles (EVs) and their chargers are sometimes regarded as DERs.

- *energy efficiency*, which provides ongoing reductions in energy use and power demand,
- ***load shedding*** through curtailment of energy use during periods of very high demand,
- ***load shifting*** to shift usage from periods of high demand to those of lower demand, which sometimes entail use of batteries or thermal energy storage, and
- ***modulation*** to provide rapid adjustments to regulate frequency and voltage and assure power quality.

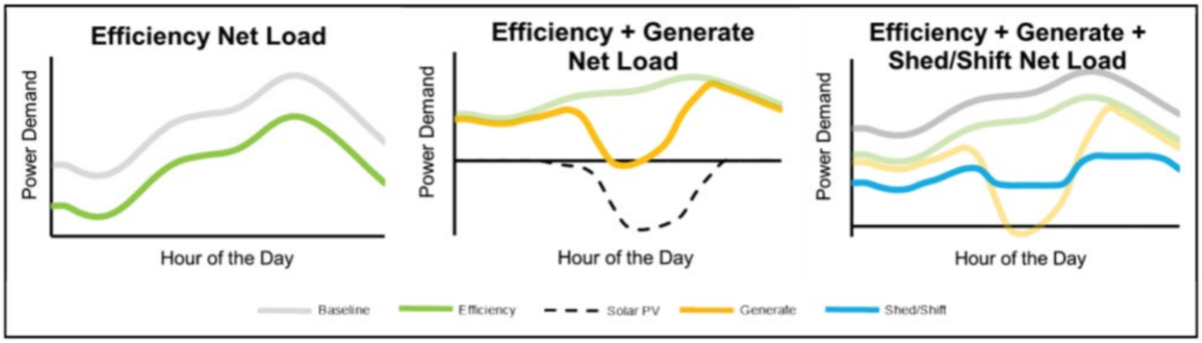
Figure 1. Demand Flexibility Capabilities



Source: U.S. Department of Energy (DOE)

These can be accompanied by onsite power *generation* (Figure 2) too. DF can make a building or facility more "grid friendly" by reducing system costs and stresses (thus supporting reliability and resilience, especially during periods of very high demand or constrained electricity supply) and by improving renewable energy utilization. DF, energy storage, and generation can also be configured as a ***microgrid*** to provide resilience at a building, facility, or community level by allowing critical operations to continue to operate should an outage occur.

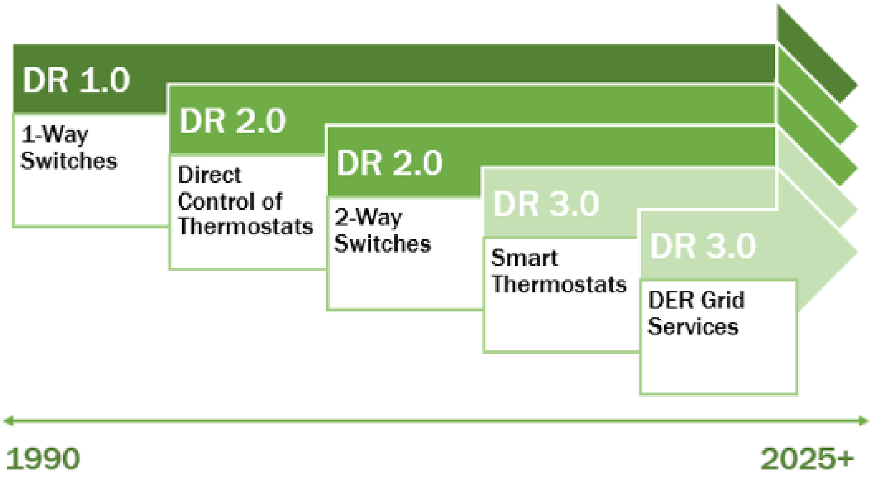
Figure 2. Additional Demand Flexibility Features



Source: U.S. Department of Energy.
Note: Left graph shows reduced demand or load (green line) from baseline load (gray) due to energy efficiency. Center adds solar generation which appears as negative power demand (dashed line) leading to a net load curve (yellow). Right graph then adds in shed and shift impacts to yield the blue net load curve.

Ideally, GEBs combine these capabilities to be *efficient*, *connected* (with two-way grid communication), *smart* (utilizing analytics to co-optimize building performance and grid service), and *flexible*. However, different degrees of DF, grid interaction, and "smartness" still offer grid and building owner benefits. For example, building operators can pre-cool buildings during off-peak periods and stage heating, ventilation, and air conditioning (HVAC) equipment and other onsite loads to reduce ***demand charges*** and peak loads even in the absence of a grid signal. Also, traditional one-way DR signals to reduce "non-smart" building loads at certain times provide significant benefits. A continuum exists, progressing from traditional one-way DR through automated DR of smart, efficient equipment and appliances to highly dynamic, flexible, and interactive management of multiple DERs in real time. (See Figure 3)

Figure 3. Evolution of Demand Response to Demand Flexibility



Source: Smart Electric Power Alliance, 2017, 2017 Utility Demand Response Market Snapshot, https://sepapower.org/resource/2017-utility-demand-response-market-snapshot/

DF can provide cost savings by helping customers reduce their electricity use during high demand periods or low resource availability, when prices are higher. For example, Massachusetts data for 2015 found that one percent of hours that year accounted for eight percent of electricity spending; 10 percent of hours accounted for 40 percent of electricity spending.[3] Thus, shedding or shifting loads from peak periods can lead to significant monetary savings not only for owners of buildings implementing DF measures but system-wide for all electricity consumers. The Brattle Group estimated that a U.S. nation-wide demand flexibility portfolio could deliver over $16 billion of annual savings in 2030 from avoided generation capacity, energy cost savings, avoided transmission and distribution (T&D) capacity, and grid ***ancillary services*** (frequency regulation only in this study).[4]

From a building owner perspective, the Rocky Mountain Institute (RMI) and the U.S. General Services Administration (GSA) projected that flexible HVAC, lighting, plug-load, renewable energy, and storage measures across the GSA-owned office portfolio could yield 165 megawatts (MW) of peak demand

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[3] E. Friedman, 2019, "The Role of Grid-Interactive Efficient Buildings," Better Buildings Summit. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/Grid-Modernization.pdf

[4] R. Hledik, A. Faruqui, T. Lee, and J. Higham, 2019, *The National Potential for Load Flexibility: Value and Market Potential Through 2030*, The Brattle Group. https://www.brattle.com/wp-content/uploads/2021/05/16639_national_potential_for_load_flexibility_-_final.pdf

reduction and 180 gigawatt-hours (GWh) per year of energy savings, reducing energy bills by $50 million annually or about 20 percent of GSA's annual energy spending.[5] Presumably, such potential savings apply to other types of buildings too. The same study also projected up to $70 million in annual grid cost savings from avoided generation and T&D while also supporting resilience, load balancing, and emission reduction.

By shifting the time of electricity use to decrease peak loads and ***ramp rates*** (rate of change in generation to meet changing demand), DF can reduce wear-and-tear and stresses to the grid. During periods of very high demand or when there are generation or transmission constraints, shifting and curtailing loads can help avert or reduce the extent of disruptions and outages, thus supporting system reliability and resilience. DF could possibly help with orderly restoration of service should an outage occur by supporting staging of loads. As noted, DF with onsite energy storage and generation can provide facility-level or local energy resilience.

DF can also lower greenhouse gas and other emissions through several means: (1) reducing combustion-based generation that would otherwise be used to meet peak demand and as spinning reserves (generation operating to meet rapid changes in demand), (2) lowering energy wasted as heat from congested T&D lines during peak periods[6] and, increasingly important, (3) enabling better use of excess renewable power that would otherwise be curtailed. In 2020, California, with its fast expanding renewable power generation base, averaged about 4.3 gigawatt-hours (GWh) of daily renewable (mainly solar) generation curtailment, projected to increase to 15 GWh by 2030.[7] Using DF to significantly shift customer loads and reduce renewable generation curtailment can "(a) increase[e] renewable integration and reduc[e] GHG emissions, (b) reduc[e] system ramping requirements and improv[e] system reliability, and (c) reduc[e] or minimiz[e] cost of service system-wide."[8]

Figure 4 showing the (in)famous "duck curve," first manifested in California but arriving elsewhere as solar generation increases, illustrates the previous points. At times of high solar generation (belly of the duck), wholesale power prices can turn negative and renewable generation may be curtailed. But as evening comes, solar power generation declines as evening demand grows, leading to a steep ramp rate (neck of the duck), often met by higher emitting generation, such as natural gas combustion turbine units. Regions with high levels of wind generation also face operational, economic, and environmental challenges of variable renewable supply sometimes not matching patterns of power demand. DF, including shifting demand and energy storage, can smooth the net demand curve to utilize cleaner energy resources more economically and reliably.

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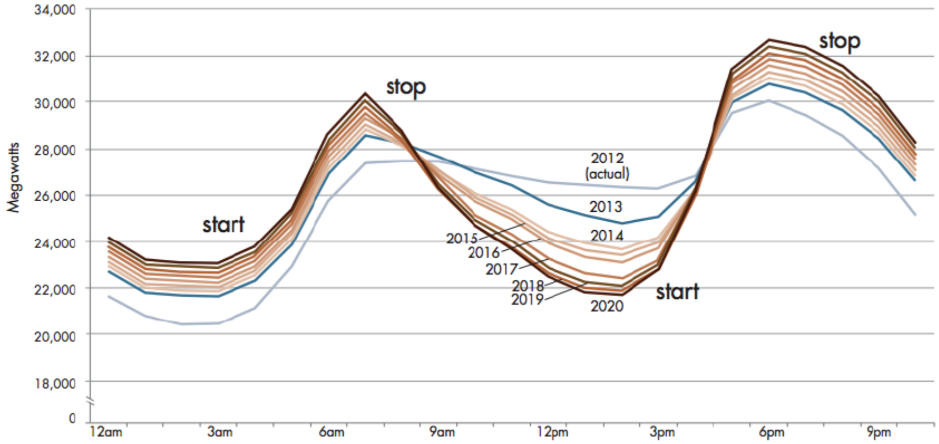
[5] C. Carmichael, M. Jungclaus, P. Keuhn, K. Porst Hydras, 2019, *Value Potential for Grid-Interactive Efficient Buildings in the GSA Portfolio: A Cost-Benefit Analysis*, Rocky Mountain Institute and U.S. General Services Administration. https://rmi.org/insight/value-potential-for-grid-interactive-efficient-buildings-in-the-gsa-portfolio-a-cost-benefit-analysis/

[6] Line losses from electrical resistance grow exponentially with load. Marginal line losses during system peaks can be much larger than average losses in the utility system. J. Lazar and X. Baldwin, 2011, *Valuing the Contribution of Energy Efficiency to Avoided Marginal Line Losses and Reserve Requirements*, Regulatory Assistance Project, https://www.raponline.org/knowledge-center/valuing-the-contribution-of-energy-efficiency-to-avoided-marginal-line-losses-and-reserve-requirements/

[7] California Public Utilities Commission, 2022, *Advanced Strategies for Demand Flexibility Management and Customer DER Compensation*, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/demand-response/demand-response-workshops/advanced-der---demand-flexibility-management/ed-white-paper---advanced-strategies-for-demand-flexibility-management.pdf

[8] Ibid.

Figure 4. The Duck Curve (Example from a January 11th Net Load)



Source: California Independent System Operator

Challenges

Realizing the benefits offered by DF and GEBs will require addressing various challenges. Some of the challenges are technical, including advancing sensors and control hardware and software, improving data management and analytics, addressing standards and interoperability, and assuring cybersecurity and customer privacy, among others.

Some challenges have technical bases or aspects but are important for informing and implementing policies, planning, regulation, and market operations, such as applying appropriate performance metrics, valuing DF-provided services, and integrating DER impacts into state and utility planning.

Policies, regulation, administration, and market design are critical, including employing frameworks to align public policy goals with private benefits. Utilities and customers both must see value and benefit to implementing DF. There can also be valuable roles for third-party firms to aggregate grid services. Do regulations and bases for compensation encourage or discourage utilities from tapping DERs, including DF, to provide grid services? Are building owners and operators compensated through rates, markets, or program incentives to operate flexibly while meeting owner and occupant needs? Are there markets and compensation mechanisms to enable third-party service providers to make a business of aggregating DERs and DF to provide grid services while offering customer benefits?

Policies, programs, and financial mechanisms that traditionally have been oriented toward energy efficiency and DR "1.0" can be extended to better align and integrate dynamic DF and grid-interactive capabilities. This can include utility programs, building energy codes, appliance standards, building performance standards, and energy performance and "as-a-service" contracting structures, among others.[9] This means that policies, rate design, incentive mechanisms, regulations, and market structures are as or more important to achieving the benefits of DF than particular technologies.

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[9] Among pertinent references: Smart Electric Power Alliance, 2022, *Accelerating Coordinated Utility Programs for Grid-Interactive Efficient Buildings: Practitioners' Perspectives*, https://sepapower.org/resource/accelerating-coordinated-utility-programs-for-grid-interactive-efficient-buildings-practitioners-perspectives/; NASEO, 2021, *State and Local Building Policies and Programs for Energy Efficiency and Demand Flexibility*, https://www.naseo.org/data/sites/1/documents/publications/NASEO%20BldgPolicies%20EE%20and%20DF%20Fe

Resources: Dig Deeper

There is a rapidly growing literature on DF, GEBs, and related and complementary topics of DER integration and VPPs. To delve beyond this "101" level brief, the following may be useful:

- NASEO, 2019, *Grid-interactive Efficient Buildings: State Briefing Paper*, https://naseo.org/data/sites/1/documents/publications/v3-Final-Updated-GEB-Doc-10-30.pdf
- State and Local Energy Efficiency Action Network, 2020, *Grid-Interactive Efficient Buildings: An Introduction for State and Local Governments, https://www.naseo.org/Data/Sites/1/see-action-gebs-intro-report_april-2020.pdf*
- U.S. Department of Energy, 2021, *A National Roadmap for Grid-interactive Efficient Buildings*, https://gebroadmap.lbl.gov/
- American Council for an Energy-Efficient Economy, 2019, *State of the Market: Grid-Interactive Efficient Buildings Utility Programs*, https://www.aceee.org/white-paper/gebs-103019
- NASEO-NARUC Grid-interactive Efficient Buildings Working Group https://www.naseo.org/issues/buildings/naseo-naruc-geb-working-group and GEB Resources https://www.naseo.org/issues/buildings/naseo-geb-resources
- U.S Department of Energy, Grid-interactive Efficient Buildings https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings

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b%202021.pdf; NASEO, 2021, *Wringing More Value from Building Energy Operations and Upgrades: Monetizing Demand Flexibility in Public and Institutional Buildings*, https://naseo.org/data/sites/1/documents/publications/Wringing%20More%20Value%20Monetizing%20DF%20Feb%202021.pdf.

Glossary

This glossary gathers and derives definitions from a variety of sources to some terms commonly encountered in discussing DF, GEB, DERs, and related areas. (Not all of the terms below appear in the foregoing text.) As an evolving topic undergoing marked technological, policy, and regulatory changes, definitions and usage can vary and at times be indistinct. Various reports and organizations have their own glossaries. Many of the glossary terms here are from the U.S. DOE, *A National Roadmap for Grid-interactive Efficient Buildings*.[10] Some are modified from their original sources. Others have been substantially altered or developed for this document. The Indiana Utility Regulatory Commission offers a comprehensive *2022 Glossary of Electric and Natural Gas Industry Terms and Concepts* that some readers may find useful.[11] A Canary Media article also provides a short, useful guide to relevant terms and concepts.[12]

Aggregator: Any marketer, broker, public agency, city, county, or special district that combines the loads of multiple end-use customers in negotiating the purchase of electricity, the transmission of electricity, and other related services for these customers. (National GEB Roadmap) Often used to mean a firm that aggregates customer-side DR, DF, and DERs to provide grid services. Sometimes referred to as a "curtailment service provider" based on traditional load shed DR.

Ancillary services: A variety of operations beyond generation and transmission that are required to maintain grid stability and security. These services generally include frequency control, spinning reserves, and operating reserves. Traditionally, ancillary services were provided by generators and other equipment (e.g., capacitors) on the utility system. However, the development of smart building technologies has broadened the types of equipment that can be used to provide ancillary services. (National GEB Roadmap)

Behind the meter (BTM): Resources, capabilities, and equipment on the customer's side of the utility electric (or gas) meter. It can include energy-using (including grid-interactive) appliances and equipment, customer sited generation (solar, fossil fuel, and others), and energy storage (batteries and thermal). BTM resources may be owned by customers, third-parties, or utilities. Their control may be by customers or via utilities, other grid operators, or third-party aggregators.

Building automation system (BAS): An energy management system, usually with additional capabilities, relating to the overall operation of the building in which it is installed, such as equipment monitoring, protection of equipment against power failure, and building security. (National GEB Roadmap)

Coincident peak demand or load: Refers to the electricity (or gas) demand of one or more buildings or customers during the time of the electricity (or gas) system's peak demand. Coincident peak demand is a

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[10] U.S. Department of Energy, 2021, *A National Roadmap for Grid-interactive Efficient Buildings*, https://gebroadmap.lbl.gov/, referred to as the National GEB Roadmap in the glossary entries.

[11] Indiana Utility Regulatory Commission, 2022, *2022 Glossary of Electric and Natural Gas Industry Terms and Concepts*, https://pubs.naruc.org/pub/DD7DB67E-1866-DAAC-99FB-36526B06C7C6

[12] A. Takemura, 2022, "The Power Grid Explained – Plus Demand Response, Virtual Power Plants and More," Canary Media (June 2, 2022), https://www.canarymedia.com/articles/guides-and-how-tos/the-power-grid-explained-plus-demand-response-virtual-power-plants-and-more

measure of customer contributions to overall system peaks which determine the system's capacity needs.[13]

CTA-2045: A Modular Communications Interface for Energy Management standard published by the Consumer Technology Association (CTA) and dual-listed by the American National Standards Institute (ANSI). The standard defines a physical interface, also referred to as a socket or port, with pins that carry digital information. (National GEB Roadmap)

Demand charge: That portion of the consumer's bill for electric service based on the consumer's maximum electric capacity usage and calculated based on the billing demand charges under the applicable rate schedule. Traditionally, demand charges have been determined as a customer's maximum usage without regard to the time of use or the customer's contribution to the utility's maximum demand (coincident demand). As a result of demand being determined by a customer's non-coincident demand, some customers might establish their maximum usage at a time when the utility would benefit from additional use. (IURC) [14]

Demand flexibility (DF): Capability provided by DERs to reduce, shed, shift, modulate or generate electricity; **energy flexibility** and **load flexibility** are often used interchangeably with demand flexibility. (National GEB Roadmap)

Demand response (DR): Change in the rate of electricity consumption in response to price signals or specific requests of a utility or grid operator. (National GEB Roadmap) Some construe DR narrowly to consist of an active change in energy use or demand in response to specific command or price signals on a limited-time, episodic basis (a DR "event"). Others view DR more broadly to include, for example, application of time-of-use rates to incentivize routine time-differentiated energy management rather than in response to specific DR events.

Demand-side management: The modification of energy demand by customers through strategies, including energy efficiency, demand response, distributed generation, energy storage, electric vehicles, and/or time-of-use pricing structures. (National GEB Roadmap)

Dispatchable: Means that the timing and level of response is under the control of the utility or grid operator, either through technical control or by the terms of a contract, or both. (NSPM for DERs)[15]

Distributed energy resource (DER): A resource sited close to customers that can provide all or some of their immediate power needs and/or can be used by the utility system to either reduce demand or provide supply to satisfy the energy, capacity, or ancillary service needs of the grid. (National GEB Roadmap) These include energy efficiency, demand response, distributed generation, storage, plug-in electric vehicles, strategic electrification technologies, and more. (NSPM for DERs)

Distributed energy resource management systems (DERMS): Navigant Research defines DERMS as "a control system that enables optimized control of the grid and DERs, including capabilities such as Volt/

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[13] Derived from Enerdynamics, Energy KnowledgeBase, Coincident Peak Demand https://energyknowledgebase.com/topics/coincident-peak-demand.asp

[14] IURC refers to Indiana Utility Regulatory Commission, 2022, op cit.

[15] NSPM for DERs refers to National Energy Screening Project, 2020, *National Standard Practice Manual for Benefit-Cost Analyses of Distributed Energy Resources*, available at https://www.nationalenergyscreeningproject.org/national-standard-practice-manual/

VAR optimization (VVO), power quality management and the coordination of DER dispatch to support operational needs."[16]

Electrification: Increased electrification of end-uses, including building and transportation electrification. Building electrification measures include switching from fuel-consuming to electric appliances and equipment for such functions as space heating, water heating, cooking, and clothes drying. Electrification can be "partial," where some but not all fuel consumption is replaced by electricity (e.g., a plug-in hybrid electric vehicle), or "complete" (e.g., a battery electric vehicle). (Derived with significant modification from NSPM for DERs) **Beneficial electrification** adds criteria that electrification meet at least one of the following without compromising the others: (1) save consumers money over time, (2) benefits the environment and reduces greenhouse gas emissions, (3) improves product quality or consumer quality of life, and (4) fosters a more robust and resilient grid.[17]

Energy efficiency (EE): Ongoing reduction in energy use to provide the same or improved level of function. (National GEB Roadmap)

FERC Order No. 2222: An order of the Federal Energy Regulatory Commission that directs regional grid operators to revise their tariffs to establish DERs as a category of market participant. These tariffs will allow aggregators to register their resources under one or more participation models that accommodate(s) the physical and operational characteristics of those resources. The order's intent is to remove barriers preventing distributed energy resources (DERs) from competing on a level playing field in the organized capacity, energy and ancillary services markets run by regional grid operators.[18]

Grid-interactive efficient buildings (GEB): An energy efficient building that uses smart technologies and on-site DERs to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences in a continuous and integrated way. (National GEB Roadmap)

Grid services: Services that support the generation, transmission, and distribution of electricity and provide value through avoided electricity system costs (generation and/or delivery costs); this report focuses on grid services that can be provided by DF, DERs, and GEB. (Derived from National GEB Roadmap)

Integrated demand side management: Term used to represent an integrated or coordinated delivery of three or more of: (1) energy efficiency (EE), (2) demand response (DR), (3) distributed generation (DG), (4) storage, (5) electric vehicle (EV) technologies, and (6) time-based rate programs to residential and commercial electric utility customers.[19]

Integrated distribution system planning: An assessment of the physical and operational changes to the electric distribution system necessary to enable safe, reliable, and affordable service that satisfies

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[16] Microgrid Knowledge, 2020, "What are Distributed Energy Management Systems (aka DERMS)?" (June 18, 2020) https://microgridknowledge.com/derms-next-generation-grid/

[17] Beneficial Electrification Leagues, https://be-league.org/

[18] Federal Energy Regulatory Commission, 2020, *FERC Order No. 2222: Fact Sheet*. https://www.ferc.gov/media/ferc-order-no-2222-fact-sheet

[19] J. Potter, E. Stuart and P. Cappers, 2018, *Barriers and Opportunities to Broader Adoption of Integrated Demand Side Management at Electric Utilities: A Scoping Study*, https://emp.lbl.gov/publications/barriers-and-opportunities-broader

customers’ changing expectations and use of DERs, generally in coordination with resource and transmission planning. (National GEB Roadmap)

Integrated resource plan (IRP): A utility plan for meeting forecasted annual peak and energy demand, plus some established reserve margin, through a combination of supply-side and demand-side resources over a specified future period. (National GEB Roadmap)

Load profile: A building’s load profile describes when – time of day or hour of the year – the building is consuming energy (typically used to refer to electricity consumption but can also describe on-site fuel use); load shape and load curve are often used interchangeably, but all refer to the timing of energy use. (National GEB Roadmap) Load profiles can also be derived at other levels of analysis, such as by type of equipment or operation (e.g., heating, cooling, lighting), customer class, geographic area, and utility system as a whole.

Load shed: The ability to reduce electricity use for a short time period and typically on short notice. Shedding is typically dispatched during peak demand periods and during emergencies. (National GEB Roadmap)

Load shift: The ability to change the timing of electricity use to minimize demand during peak periods or to take advantage of the cheapest electricity prices. A shift may lead to using more electricity during the cheapest time period and using thermal or battery storage at another time period when electricity prices increase. (National GEB Roadmap)

Localized coincident peak demand: Demand of one or more buildings or customers during the period of peak demand in a localized area, such as that served by an electrical substation, and can be pertinent to distribution system operations and planning.

Microgrid: A group of interconnected loads and DERs within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid and can connect or disconnect from the grid to operate in both grid-connected or island-mode.[20]

Modulating: The ability to balance power supply/demand or reactive power draw/supply autonomously (within seconds to sub-seconds) in response to a signal from the utility during the dispatch period. (National GEB Roadmap)

Non-coincident peak demand or load: Refers to the highest electricity (or gas) demand of one or more buildings or customers irrespective of demand on the system.

Non-dispatchable: Means that the timing and level of response is under not under the direct control of the utility or grid operator through technical or contractual means but depends on price mechanisms, such as time-varying rates to encourage customers to alter their energy usage during particular hours. The IURC glossary defines *non-dispatchable resources* an any system resource that does not have active power management capability such as Automatic Generation Control (AGC) or cannot respond to

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[20] Derived from DOE definition appearing in D. Ton and M. Smith, 2012, “The U.S. Department of Energy’s Microgrid Initiative,” *The Electricity Journal*, 25(8), pp. 85-94. https://www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy%27s%20Microgrid%20Initiative.pdf

dispatch signals. These may include some nuclear generating units, geothermal generators, older utility-scale renewable generators, and DERs.

Non-wires solution or non-wires alternative: An electricity grid investment or project that uses nontraditional transmission and distribution (T&D) solutions, such as distributed generation, energy storage, EE, DR, and grid software and controls, to defer or replace the need for specific equipment upgrades, such as T&D lines or transformers, by reducing load at a substation or circuit level. (National GEB Roadmap)

OpenADR: An open, secure, and two-way information exchange model and global Smart Grid standard. OpenADR standardizes the message format used for automated DR and DER management so that dynamic price and reliability signals can be exchanged among utilities, ISOs, and energy management and control systems. (National GEB Roadmap)

Peak demand or peak load: The maximum load during a specified period of time. The electric load corresponding to a maximum level of electric demand in a specified period (also called peak load). Utilities try to forecast their peak load in order to plan for adequate power supplies and demand-response. (IURC)

Ramp rate: Speed at which generators increase (ramp up) or decrease (ramp down) generation in response to changing demand.

Rate design or rate structure: The design and organization of billing charges by customer class to distribute the revenue requirement among customer classes and rating periods. At the retail level, these may include flat rates, declining block rates, inverted block rates, economic development rates, and time-differentiated rates such as seasonal rates, interruptible rates, real-time pricing time-of-day rates, critical peak pricing rates, and rates to promote demand response and customer-owned generation. (IURC)

Reliability: The ability to maintain the delivery of electric power to customers in the face of routine uncertainty in operating conditions. (GMLC)[21]

Resilience: The ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents. (Presidential Policy Directive 21)[22]

Smart Home Energy Management System: A combination of devices and services that manages the energy use of connected devices in a home. (National GEB Roadmap)

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[21] Grid Modernization Laboratory Consortium in Eto, J., K. Hamachi-LaCommare, M. Yue. 2020. Grid Modernization: Metrics Analysis (GMLC1.1) – Reliability, https://gmlc.doe.gov/sites/default/files/resources/GMLC1.1_Vol2_Reliability.pdf

[22] White House, 2013, Presidential Policy Directive—Critical Infrastructure Security and Resilience (PPD-21), https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil

Smart technologies for energy management: Advanced controls, sensors, models, and analytics used to manage DERs. Grid-interactive efficient buildings are characterized by their use of these technologies. (National GEB Roadmap)

Time-varying rates: Rates that allow the price to vary over some time period to reflect seasonal, diurnal, or hourly changes and designed to modify patterns of electricity usage, including the timing and level of electricity demand. Designs may include time of use (TOU), real-time pricing (RTP), variable peak pricing, and critical peak pricing (CPP). (National GEB Roadmap)

Transactive Energy: An intelligent, multi-level communications method that coordinates energy generation, consumption, and delivery. Under the transactive energy scenario, electricity suppliers, energy markets, the power grid, homes, commercial buildings, and distributed energy resources (DERs), such as electric vehicles and batteries, would "talk" directly or indirectly with each other to negotiate energy needs and costs. The electronic process would rapidly and automatically harmonize energy availability, consumer needs, cost preferences, and other factors, enhancing overall energy system efficiency.[23]

Virtual Power Plants (VPP): A coordination of power produced and grid services provided by many individual DERs using software and advanced communication networks into an aggregated electricity source that can offer grid services that prevent supply variability and strain on the main electric grid.

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[23] Pacific Northwest National Laboratory, Transactive Energy, https://www.pnnl.gov/explainer-articles/transactive-energy

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