THE ROLE OF DISTRIBUTED ENERGY RESOURCES IN TODAY'S GRID TRANSITION

GRIDWORKS

GridLAB

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1 | INTRODUCTION

Electricity grids across the nation are undergoing a rapid transition. The principal contributor to this transition is the increased deployment of renewable energy resources by utilities, driven in part by declining costs of these resources relative to conventional, fossil-fired resources. A second factor contributing to the current grid transition is increased adoption of distributed energy resources (DER) by customers. This trend is driven by customers who see value in DER, which provide them with choice in their energy source and the ability to proactively manage their energy use. Effective integration of renewable resources into electricity supplies and grids is the central challenge of our industry, both from a technical and from an economic point of view. This paper is about the role DER plays in addressing that challenge.

Many view the trends of increased reliance on renewable energy resources and customer DER adoption as separate and distinct. Some even perceive DER adoption by customers as a barrier to continued large-scale renewable deployment by utilities. But a handful of utilities and policy-makers are finding a better way forward, recognizing that DER can provide key grid services, including flexibility, that will complement, not frustrate, the deployment of large-scale renewables. These regulators and utilities are showing how to strategically pivot away from legacy systems to enable a more efficient, environmentally benign energy sector.

In this paper, we define and identify the capabilities of DER, with emphasis on how those capabilities facilitate the integration of large-scale renewable deployment. Next, we identify potential services DER may provide a utility and its customers. Building on existing literature, we further consider how DER provides utilities and grid operators with new flexibility in meeting grid needs. Finally, we identify three case studies wherein utilities are embracing the capabilities of DER. Based on these case studies, we conclude DER can complement large-scale renewable energy resources and provide new services to utilities and customers.

CONTENTS

2 | DEFINITION AND CAPABILITIES

Distributed Energy Resources is a term applied to a wide variety of technologies and consumer products, including distributed generation (DG), smart inverters, distributed battery energy storage, energy efficiency (EE), demand response (DR), and electric vehicles (EVs). These resources each have distinct strengths and capabilities. Some of the most popular DER in use today include:

Distributed Generation (DG): DG refers to small-scale power resources that generate energy. DG systems are decentralized and typically connected to the distribution grid, compared to traditional centralized large-scale infrastructure which is connected to the transmission system. DG encompasses many forms of generation including, but not limited to, solar photovoltaics (PV), small wind systems, cogeneration/CHP systems, and fuel cells. The most prominent and growing technology in recent years, buoyed by falling technology costs and favorable policies, is distributed solar PV installed at the customer's location.

DG's greatest capability is the ability to generate energy locally, closer to end users compared to traditional generators. This can reduce demand for costly, large-scale utility infrastructure, such as high-voltage transmission lines. DG also reduces line losses experienced due to the transmission of power across large distances.

Finally, adoption of DG, and in particular solar PV, often catalyzes greater utility customer engagement. Utility customers who choose to install DER gain greater insight into their energy usage and often go on to install other DER technologies or utilize utility energy efficiency programs. Customers who adopt DER can be engaged on an ongoing basis in a manner that has the potential to provide additional benefits for the grid.

Battery Storage: Distributed energy storage systems can be used to both store and discharge energy. This allows batteries to act as both a generator and a source of load. Batteries can be integrated as standalone systems, used in support of other distributed resources (e.g., solar plus storage), and are becoming widely deployed in electric vehicles.

Energy storage can provide additional capabilities above and beyond distributed generation. First, batteries can provide dispatchable generation because charging behavior and battery output can be controlled. This capability allows batteries to shift energy generation by discharging at times of high demand or peak load. When energy prices vary temporally, batteries can be programmed to respond to price signals in order to both meet grid needs and reduce customer bills. For example, batteries can be programmed to charge when excess power is available and discharge at times of peak demand. Batteries can also respond instantaneously to changing load conditions, enabling battery systems to serve as a demand response resource to meet load.

Batteries can also provide important voltage regulation and frequency regulation services to improve power quality on existing grid infrastructure. In contrast to traditional utility infrastructure (e.g., transformers, regulators, etc.), storage systems can be paired with smart inverters, described in further detail below, to control the battery's energy output autonomously in response to changing conditions on the grid. Battery storage can be programmed to ramp up or down rapidly in response to voltage and frequency conditions on the grid, which can help to stabilize and manage the grid.

Smart Inverters: Inverters are devices that convert direct current produced by a generator to alternating current used by the grid. In the past, inverters used by DG and battery systems were designed to switch off when the system experienced a grid disturbance, such as the sudden loss of a large generating resource. With more DER on the system, this can amount to a large loss of generating capacity at once, further disturbing grid conditions.

Inverters are now deployed with advanced functionalities which are capable of intelligently managing the output of the DG system, which can mitigate the impact of distributed generation on the grid. In fact, smart inverters can contribute to resolving grid constraints by providing voltage support, frequency regulation, and ramp rate control. These capabilities support the grid by allowing distributed generation to help stabilize voltage and frequency on the grid, and to "ride through" a minor voltage or frequency disturbance and remain online rather than tripping offline.[1]

Energy Efficiency: Energy efficiency refers to customer-sited technologies and behaviors that reduce a consumer's end-use energy consumption. Energy efficiency can target residential, commercial, and industrial customers, and is most often focused on building efficiencies, such as lighting or insulation improvements, mechanical improvements of heating, cooling, appliance, and industrial systems, or passive measures that monitor and control energy consumption.

Energy efficiency primarily provides load and demand reductions by enabling and encouraging consumers to use less energy. Customers invest in energy efficiency measures, often supported by utility incentives or rebates, thus altering energy consumption patterns. Utilities can drive energy efficiency to achieve specific goals in two ways. First, utilities can target specific parts of the distribution network which face capacity constraints and encourage specific types of energy efficiency in response. Second, utilities can deploy energy efficiency measures broadly to reduce system peaks and avoid or defer future need for additional generating capacity.[2] Energy efficiency is also being used to reduce demand at specific times, or even to

1 Now, B.; *Smart Grid, Smart Inverters for a Smart Energy Future*, National Renewable Energy Laboratory. 2017 December. (https://www.nrel.gov/technical-assistance/blog/posts/smart-grid-smart-inverters-for-a-smart-energy-future.html).

2 "2017 Utility Demand Response Market Snapshot." Smart Electric Power Alliance. 2017 October. (https://sepapower.org/resource/2017-utility-demand-response-market-snapshot/).

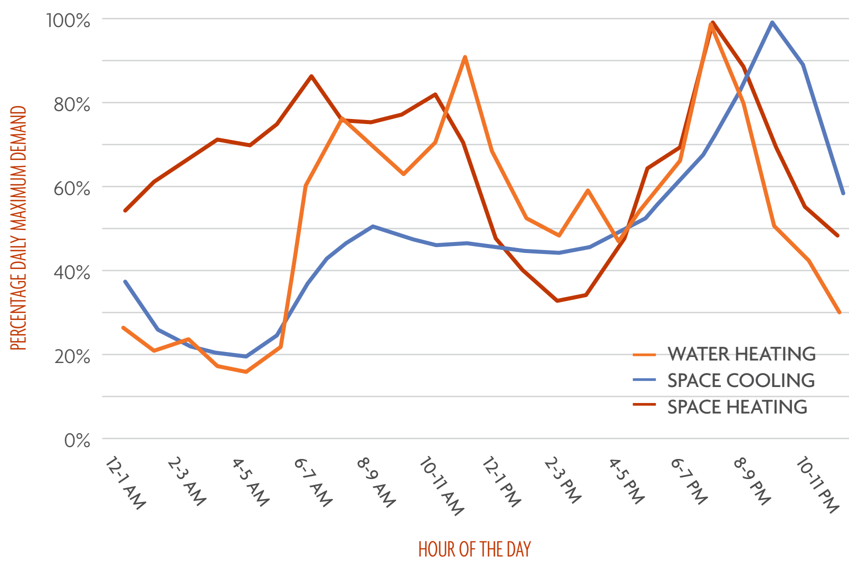


FIGURE 1. TARGETING ENERGY EFFICIENCY FOR PARTICULAR LOAD REDUCTION

Energy efficiency can be targeted to achieve load reduction during times of peak demand. This chart illustrates example load profiles for three common energy end-uses. Incentives for efficient space cooling could be used to reduce evening peak energy usage, whereas incentives for more efficient space heating contribute to morning and evening peak reduction.

Image Courtesy of ACEEE

shift demand. The chart above illustrates different energy profiles for various common energy end-uses. By targeting a specific energy end-use, utilities can choose to deploy efficiency technologies that will achieve demand reduction during a specific time period.[3] For example, incentivizing energy efficient space heaters would reduce the evening peak illustrated above.

Demand Response (DR): DR is defined as a coordinated reduction in electric load in response to specific system conditions or market incentives.[4] Demand response can be controlled by a customer, a third party or directly by the utility. Demand response capabilities allow a utility to curtail or shift load in response to a scarcity of power supplies or other various grid conditions, including changes in generating capacity, peak load scenarios, ramping requirements, transmission or distribution constraints, or voltage irregularities.

Demand response can be used to shape and shift load. DR programs can reshape customer loads over time through rate structures or energy efficiency measures that encourage better utilization of grid resources.[5] Similarly, demand response programs can shift periods of high energy demand to periods of low demand. For example, DR programs can be used to encourage electric vehicle charging or heavy appliance operation during times when power supplies are abundant. DR can also be used to shed load during peak load events, for example, by incentivizing consumers to turn down air conditioning units during system peaks. Finally, demand response can be used to provide ancillary grid services, such as rapidly smoothing load or regulating voltage in response to sudden grid disturbances.

Electric Vehicles (EV): EVs primarily provide mobility, and consumers rarely (if ever) purchase them for the additional grid services they can provide. However, intelligent EV charging enables load shaping and shifting in response to grid conditions. Such "smart charging" is expected to provide significant flexibility in the near term as EV deployment grows. Grid operators can effectively utilize an aggregated network of EVs and EV chargers to respond to certain grid events, using both real-time and day-ahead pricing, and demand signals. For example, grid operators can shape demand by encouraging charging at certain hours of the day, particularly when ample solar or wind resources are available. Similarly, operators can shed load by turning off or throttling EV chargers at peak demand hours. In just one case, experts have modeled how grid integrated vehicles can mitigate the California duck curve through peak shaving, valley filling, and ramping mitigation.[6]

In the medium- to long-term, vehicle-to-grid services could provide capabilities similar to energy storage by not only shifting charging, but allowing EVs to generate power to the grid at key times to alleviate grid stress. EVs are a particularly effective customer engagement tool that provide an added demand response resource and aggregated energy storage technology.

BETTER TOGETHER: LEVERAGING PORTFOLIOS OF DER

In addition to the individual capabilities of each DER, distributed energy resources can be combined to maximize their value to the grid and the adopting customer. For

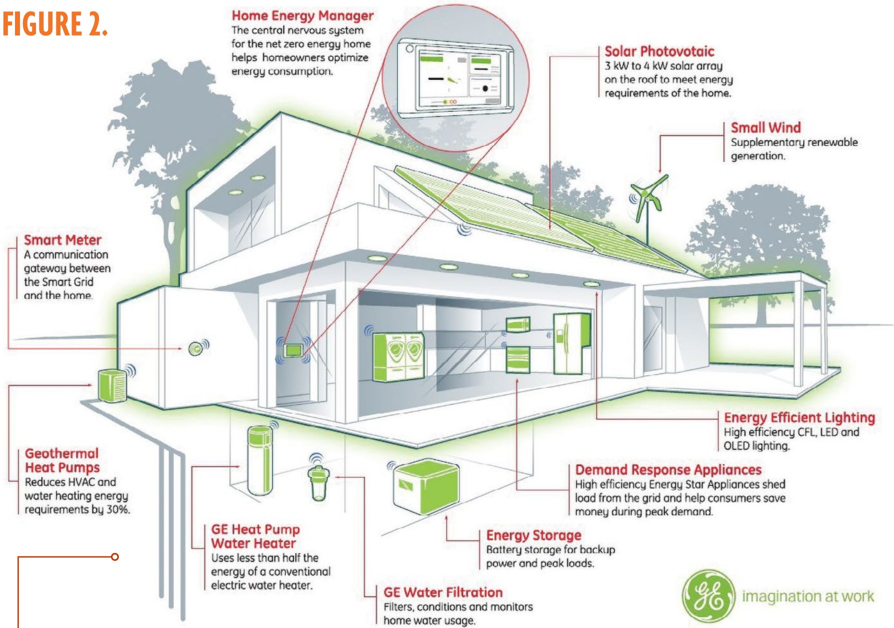
3 *Beyond the Meter, Distributed Energy Resources Capabilities Guide*, Smart Electric Power Alliance. 2017 June. (http://www.ourenergypolicy.org/wp-content/uploads/2017/09/SEPA_AEE_RMI__BTM-Recommended.pdf)

4 "2017 Utility Demand Response Market Snapshot." Smart Electric Power Alliance. 2017 October. (https://sepapower.org/resource/2017-utility-demand-response-market-snapshot/).

5 *2015 California Demand Response Potential Study*, Lawrence Berkeley National Laboratory. 2016 November. (http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=644245154).

6 Jonathan Coignard et al 2018 Environ. Res. Lett. 13 054031. (http://iopscience.iop.org/article/10.1088/1748-9326/aabe97/meta).

FIGURE 2.



A portfolio of interconnected distributed energy resources can provide enhanced value and services compared to each resource in isolation.

Image Courtesy of GE

example, a customer-sited solar and storage installation, paired with an electric vehicle and regulated by a smart inverter, can generate power when needed, store and discharge that power in response to grid conditions, energize the transportation needs of the customer, and contribute to the grid operator's regulation of voltage at the point of interconnection. In this way, individual distributed energy resources complement one another to provide greater service to the adopting customer while also contributing to grid needs.

DER can also be deployed in portfolios where large aggregations of DER are coordinated to meet grid needs. In such cases, the DER adopted by customers — in some cases hundreds of thousands of customers — are brought together by utilities and third parties. Aggregating resources in this way provides new opportunities. First, drawing on the relative strengths of different technologies, these portfolios offer services to the grid which exceed services that each technology can offer on a standalone basis. Additionally, a portfolio approach allows for risk management strategies that are not possible for single DER resources. As is the case with an investment portfolio, risk can be managed through diversification. For example, to meet new capacity needs, a utility can combine energy efficiency, demand response, and distributed storage, engaging a range of residential, commercial and industrial customers. Aggregated, the technologies and customers can contribute to a whole which is greater than the sum of the parts.

3 | DER SERVICES

DER are capable of providing a wide range of services to the grid whether they are used as individual resources (like DG or EE), combinations (such as solar and storage), or aggregated into portfolios of diverse technologies and customers. The following section identifies services DER can provide and describes how the capabilities of DER match both traditional and new grid needs. Building on existing literature, this paper contributes new perspectives on a growing grid need, flexibility.

AVOIDED TRANSMISSION AND DISTRIBUTION SYSTEM INVESTMENTS

DER can avoid or defer investments in the transmission and distribution system. They accomplish this in at least two ways: by reducing dispersed demands on the grid, as might be the case with an energy efficiency program that reduces future growth in peak demand, or by serving as a non-wires solution, as might be the case when solar and storage deployment targets specific grid upgrades. Each path may lead to avoided upgrades to transformers, conductors, capacitors, and in select cases, substations.

Determining avoided Transmission and Distribution (T&D) value requires quantification of the costs that would otherwise be incurred by utilities and ratepayers with traditional "wires" infrastructure. The cost of a business-as-usual (traditional utility infrastructure) approach must be quantified with sufficient transparency and locational granularity to allow consideration of DER as non-wires solutions. This includes cost information as well as sufficient information about the type of infrastructure or upgrade needed (e.g., how often upgrades are needed, or by what magnitude voltage is considered out of range). Locational granularity is particularly important to accurately understand avoided distribution costs, as the ability of DER to avoid traditional upgrades is dependent on local infrastructure needs. Once quantified, DER can be sourced to avoid expected T&D costs.

DER is largely valuable for meeting local distribution needs, but it also has an impact on transmission costs and needs, particularly as high DER adoption levels change load shapes and reduce the need for additional transmission infrastructure. At the transmission level, it is highly important to consider DER in aggregate. It is also important to consider additional factors, including aligning load forecasting and planning efforts between the distribution and transmission sides of operations.

AVOIDED GENERATION

DER can avoid new generation investments by providing both energy and capacity. Distributed generation can meet local load needs, while load-modifying DER (EE, storage, DR, and EVs) can shift load to avoid system peaks at specific times of the day and reduce the need for additional capacity investments. Together, a coordinated portfolio of DER can avoid the need for high-polluting peaker plants. Furthermore, DER can reduce transmission congestion issues and line losses, representing the avoided cost of delivering energy, if appropriate price signals are present.

As avoided generation, DER can provide both energy and capacity value. In order for DER to provide capacity value, certain performance requirements may be needed. DER are demonstrating their capabilities to meet those performance requirements, as evidenced by the case studies cited in the next section.

FLEXIBILITY

While the deployment of DER is changing the distribution grid, the wider grid is going through its own transformation. Increased deployment of renewables and retirement of traditional thermal units has increased the need for flexibility. DER are emerging as a way to provide this flexibility. At both the distribution and wholesale level, DER

7 *Non-Wires Alternatives,* Navigant Research. 2017. (https://www.navigantresearch.com/reports/non-wires-alternatives).

WHAT IS A NON-WIRES SOLUTION?

"An electricity grid investment or project that uses non-traditional solutions to transmission and distribution (T&D) problems, such as distributed generation, energy storage, energy efficiency, demand response, or 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."[7]

WHAT IS FLEXIBILITY?

The flexibility the grid requires can be described as:

- **Ramp -** the ability to respond rapidly and over sustained periods to changes in load or generation.
- **Overgeneration -** the grid needs to be able to absorb or shift excess generation.
- **Frequency -** the grid needs to keep generation and load in balance at all times.
- **Voltage -** maintain voltage within acceptable limits. While the other flexibility needs are required at a larger system level, voltage is a local requirement and must be managed at a circuit level.

are increasingly relied upon to serve the grid's need for flexibility.[8]

The majority of DER currently deployed are rooftop solar, which generates on an as-available basis (i.e., when the sun shines). In this context, DER are viewed as "negative load" by most system operators and therefore considered inflexible resources. Demand response has been one of the few DER considered to provide system flexibility.

Today utilities are beginning to use DER as a solution to these grid needs, calling for new recognition of DER value. We believe that DER contribution to system flexibility has been undervalued, and new technologies and rate structures will increase the value of DER on the system and improve grid flexibility. These technologies are led by storage, but include solar with smart inverters, targeted energy efficiency, sophisticated demand response, and flexible loads like smart charging of electric vehicles.

For example, Rocky Mountain Institute recently completed a study on how flexibility provided by DER not only better matches demand to variable supply, but can lead to a system with lower overall costs and carbon emissions. This overall system is better, and increasingly cheaper, than the traditional approach of using only gas-fired generation to balance renewables and meet peak load. As the table below details, the adjusted net load is considerably smoother with the utilization of flexible resources. Flexibility in this case reduces ramps, reduces curtailment (lost excess generation), and increases the value of renewable energy on the system.[9] Flexible resources can be used to reduce system peaks and flatten net load.

8 Dyson, M., Lovins, A.; *The Grid Needs a Symphony, Not a Shouting Match*, The Rocky Mountain Institute. 2017 June. (https://rmi.org/news/grid-needs-symphony-not-shouting-match/).

9 *Demand Flexibility: The Key to Enabling A Low-Cost, Low-Carbon Grid*, The Rocky Mountain Institute. 2018 February. (https://www.rmi.org/wp-content/uploads/2018/02/Insight_Brief_Demand_Flexibility_2018.pdf).

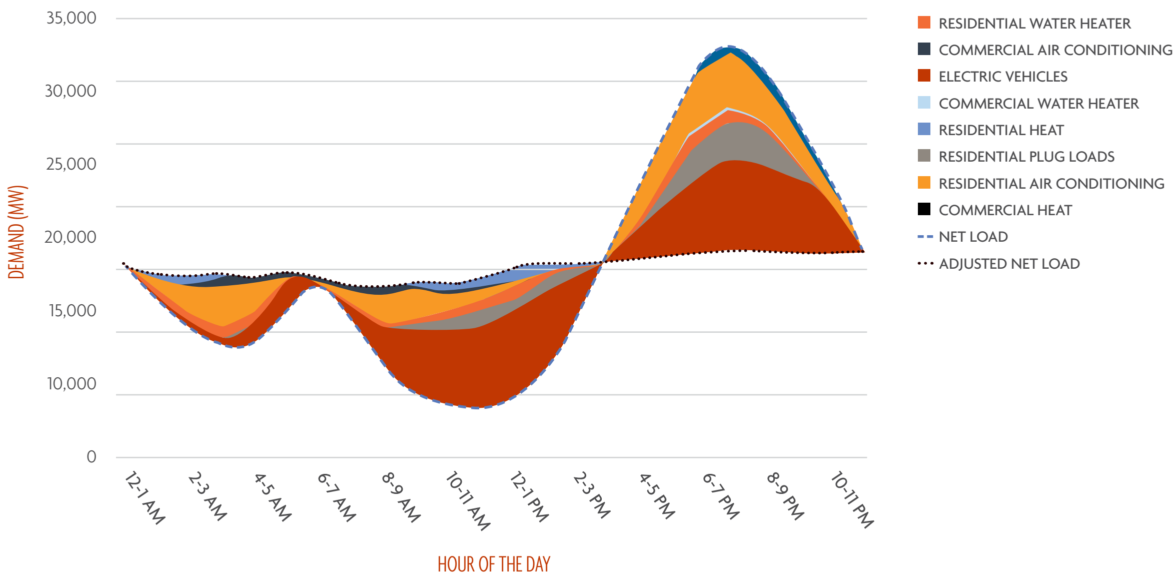
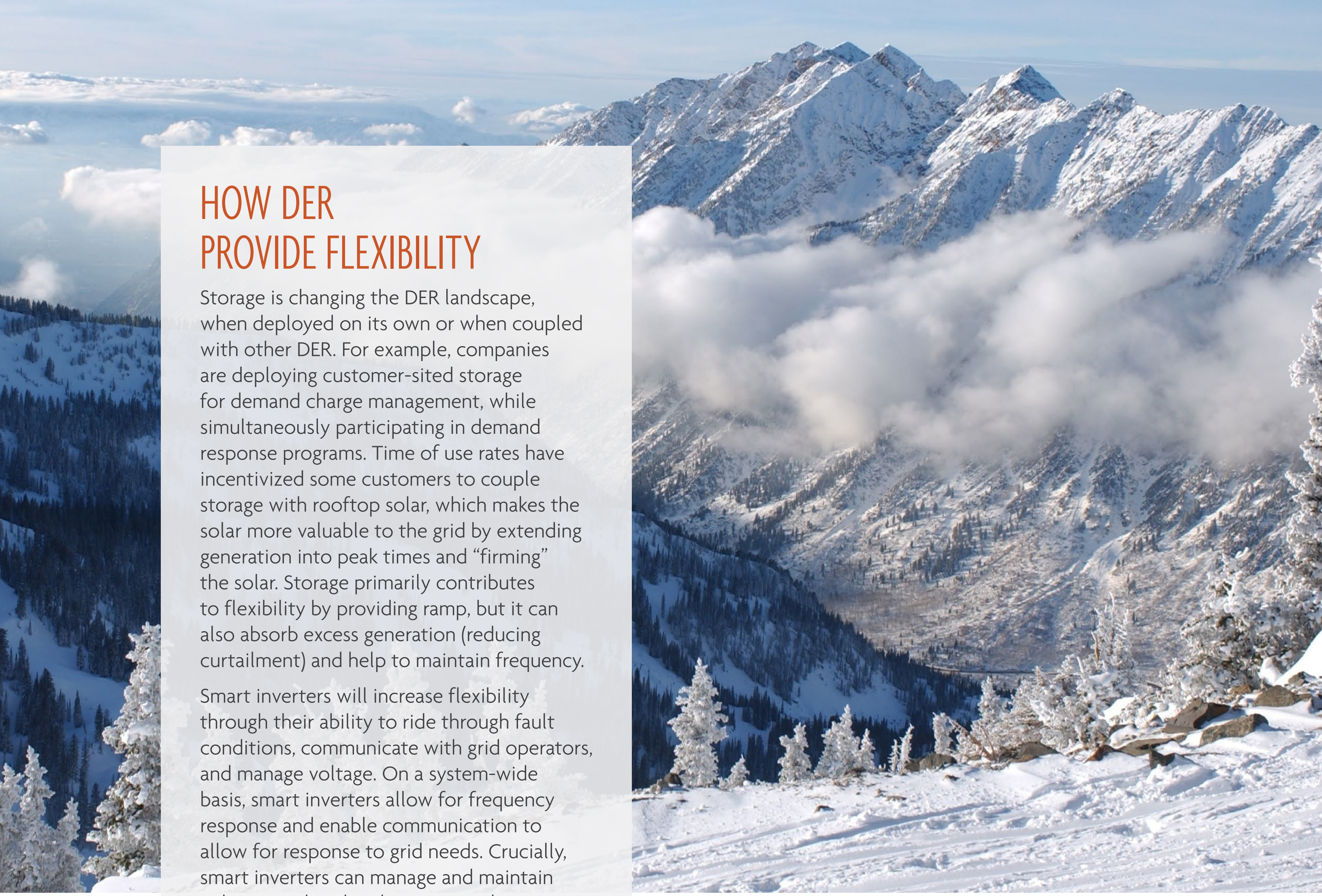


FIGURE 3. FLEXIBLE RESOURCES CAN BE USED TO REDUCE SYSTEM PEAKS AND FLATTEN NET LOAD

A typical energy load profile can be shifted and flattened through deployment of DER. In this case, a combination of a variety of DER could be used to shift energy usage from times of peak demand, from 5PM - 9PM, to times when demand is low. This results in a flatter load curve throughout all hours of the day, and allows for better utilization of solar resources that are producing energy during the middle of the day. Image Courtesy of RMI.



HOW DER PROVIDE FLEXIBILITY

Storage is changing the DER landscape, when deployed on its own or when coupled with other DER. For example, companies are deploying customer-sited storage for demand charge management, while simultaneously participating in demand response programs. Time of use rates have incentivized some customers to couple storage with rooftop solar, which makes the solar more valuable to the grid by extending generation into peak times and "firming" the solar. Storage primarily contributes to flexibility by providing ramp, but it can also absorb excess generation (reducing curtailment) and help to maintain frequency.

Smart inverters will increase flexibility through their ability to ride through fault conditions, communicate with grid operators, and manage voltage. On a system-wide basis, smart inverters allow for frequency response and enable communication to allow for response to grid needs. Crucially, smart inverters can manage and maintain voltage on their local circuit. Leading states, including California, Hawaii, Illinois, and Minnesota are deploying smart inverters today, and the new IEEE smart inverter standard will mandate that smart inverters have these capabilities and go into wider adoption in 2020.

Finally, utilities and grid operators are developing rules to allow DER to participate in wholesale markets. Although there are barriers, DER participation in wholesale markets unlocks additional flexibility from customer sited storage, distributed generation, demand response, and flexible loads like electric vehicles. Allowing for DER participation in the larger system addresses many of the concerns grid operators have with DER today, and "unlocks" the flexibility that DER can provide the wider grid. This includes enabling flexible loads to absorb excess generation, reducing ramps, and providing incentives and signals for DER to respond to grid needs. These developments are occurring in both deregulated markets and in vertically integrated utilities. The example of Hawaii (a vertically integrated system) is detailed below.

4 | CASE STUDIES: EMBRACING DER SERVICES

The services DER can provide in supporting today's grid transition are being realized by utilities now, as the following three case studies demonstrate.

CASE STUDY
MEETING LOAD GROWTH WITH DER

Consolidated Edison's Brooklyn-Queens Demand Management Project (BQDM)

ConEd in New York was one of the first utility projects to successfully proactively source local DER and develop creative solutions to defer traditional utility investment and manage load growth. Following an increased focus on climate resiliency due to Superstorm Sandy, plus a projected 69 MW overload, ConEd was forced to consider $1.2 billion of grid upgrades, including a new substation, in order to mitigate the overload. Instead, ConEd pursued a mix of traditional grid upgrades and distributed solutions that in total cost one-fifth of the traditional "wires" solution. The solution included a portfolio of DER such as distributed generation, energy efficiency, demand response, and battery storage.

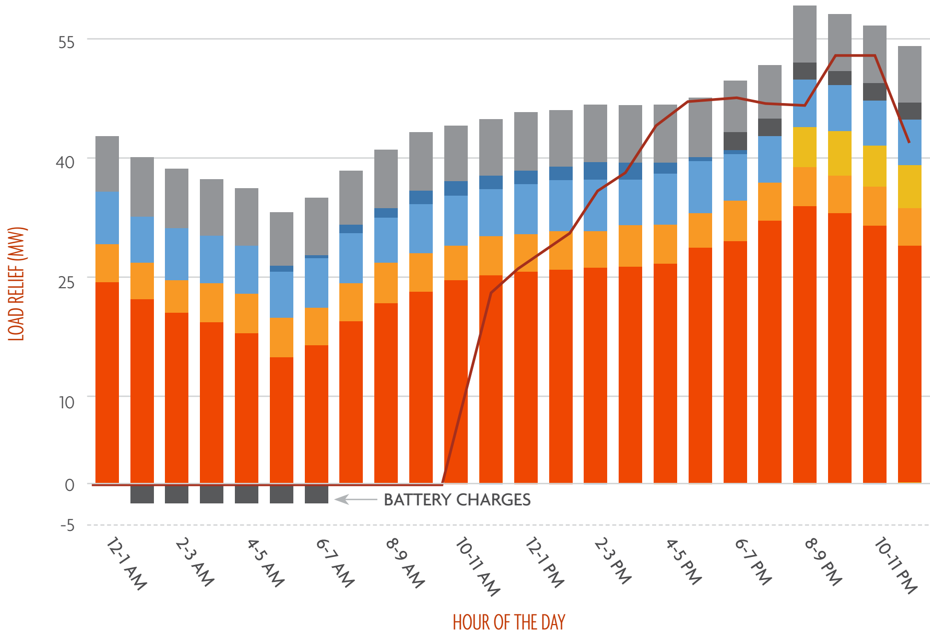


FIGURE 4. BQDM SOLUTION PORTFOLIOS

The Brooklyn Queens Demand Management Program used a portfolio of a variety of DER to provide significant needed load relief and avoid $1.2 billion in grid upgrades.

Image courtesy of SEIA

The development of BQDM resulted in two successful lessons learned. First, that utilities can successfully and proactively engage in conversation on non-wires solutions within their traditional distribution planning process. And second, in aggregate, DER technologies spread across diverse customers can add up to address big grid needs.

CASE STUDY
SOLVING TRANSMISSION RELIABILITY ISSUES WITH DER

Pacific Gas & Electric's Oakland Clean Energy Initiative Project

The retirement of a 40-year old peaking plant in Oakland, California posed risks to local transmission reliability. To replace the plant, which operated under a Reliability Must-Run contract, the California grid operator (CAISO) and local utility (PG&E) evaluated whether a portfolio of DER could replace traditional investment options, such as building new gas turbines or transmission lines. The resulting proposal, approved by CAISO, allows PG&E to procure 20-45 MW of clean energy and DER. The resource portfolio includes at least 19.2 MW of demand response, 10 MW of battery storage, a mix of local generation and energy efficiency upgrades, and some traditional grid upgrades to transformers and substations for a total cost of $102 million — a significantly lower cost than the traditional wires upgrade of $537 million for a 230 kV transmission upgrade. This innovative solution is a landmark example of DER serving transmission reliability needs.

CASE STUDY
ADDRESSING VOLTAGE REGULATION AND FREQUENCY RESPONSE WITH DER

Hawaiian Electric Companies' Successors to Net Metering, Smart Inverter Standards, and Demand Response

After a surge in solar adoption by customers between 2012 and 2015, the Hawaiian Electric Companies began to experience overvoltage conditions at the circuit-level and frequency disruptions at the system-level, as depicted in Figure 5.[10]

Hawaii regulators and the utilities enlisted DER to help address this challenge. Through a combination of advanced inverter requirements on new solar installations and a suite of tariffs to encourage on-site consumption and shifting of system exports to periods of greater scarcity, the Hawaiian Electric Companies can enjoy the benefits of distributed solar energy by stabilizing the grid impacts.[11] While solar adoption dipped dramatically following the expiration of net energy metering, a policy which pays the customer their full retail rate for all energy exported back to the grid, the market has begun to stabilize and solar and storage installations are increasing significantly.

Hawaii has also launched an innovative Demand Response program to provide grid services. Through this initiative, customer loads will be aggregated to meet grid needs under performance-based contracts, an agreement between the utility and DER owner which specifies grid-friendly performance expectations. Services solicited by the Hawaiian Electric Companies include capacity, fast frequency response, regulating reserve, and replacement reserve. These services may be provided through changes in energy consumption, use of traditional measures such as programmable thermostats and time of use rates, or through new technologies, such as batteries coupled with solar. Finally, it bears emphasis that Hawaii remains a vertically integrated market, demonstrating that the provision of grid services by DER is not limited to deregulated wholesale markets.[12]

10 Power Supply Improvement Plans: Update Report, Hawaiian Electric Companies. 2016 December. (http://www.hei.com/CustomPage/Index?KeyGenPage=1073751924).
11 HPUC Order 34924, Hawaii Public Utilities Commission. 2017 October. (https://puc.hawaii.gov/wp-content/uploads/2017/10/2014-0192.ORDER_34924_10-20-17.pdf).
12 *HPUC Order 35238*, Hawaii Public Utilities Commission. 2018 January. (https://cca.hawaii.gov/dca/files/2018/02/HECO-Docket-2015-0412.pdf).

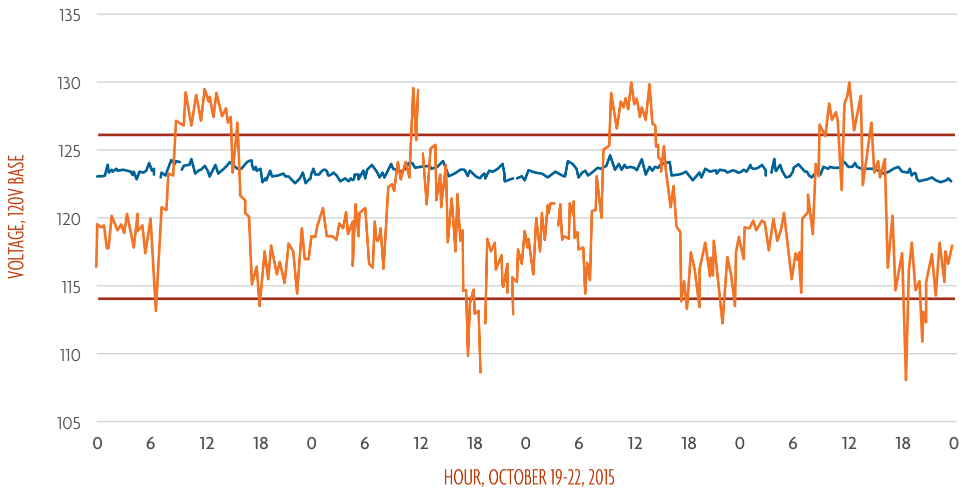


FIGURE 5. CUSTOMER METER VOLTAGE READINGS AND SERVING DISTRIBUTION TRANSFORMER

High penetration of distributed solar PV on some Hawaiian Electric Company distribution circuits drove voltage beyond design limits, prompting policy-makers to adopt smart inverter standards.

Image Courtesy of HECO

5 | RECOMMENDATIONS

As demonstrated in this paper, properly leveraged Distributed Energy Resources can provide significant benefits to the grid and utility customers. There are initial steps that utilities, regulators, and policy makers can take to capture the benefits of DER for the grid.

1 | The first step towards capturing the benefits of DER is to develop a full understanding of DER technologies, capabilities, and the various value streams they provide. This understanding is important to ensure DER continued growth in a manner that benefits the grid. There are an ever increasing number of publications about DER and non-wires solutions. Included with this document is an annotated bibliography describing relevant recent studies.

2 | Transparent Integrated Distribution Planning processes will allow utilities and regulators to evaluate the full implications of all available energy resources, including DER such as energy storage projects, demand response initiatives, and energy efficiency measures. Clear and proper evaluation of non-wires solutions, including detailed cost-benefit analyses that compare traditional utility investments with DER, are necessary to ensure customers are receiving the benefits from the full range of energy options available to them at the lowest cost. Non-wires solutions, such as adoption of solar with smart inverters or demand response programs in place of expensive transformer or transmission upgrades, often provide a multitude of grid services at lower cost. Non-wires solutions, in the context of effective Integrated Distribution Planning and avoided T&D, will often deliver a greater combination of services to the grid than a traditional infrastructure upgrade while also reducing costs for end-use consumers.

3 | Regulators can urge the adoption of smart inverters for new distributed energy sources. Smart inverters enable a host of additional services to support the grid, as highlighted above. Not only do smart inverters provide a number of ancillary grid services, such as voltage support or soft-start capabilities, but they similarly help avoid costly T&D investments. Increasing the adoption of smart inverters will inevitably lead to a more flexible, resilient electric grid.

6 | CONCLUSION

Distributed energy resources offer a means to leverage private investment to the benefit of the grid while satisfying the desire among some customers to choose the source of their power and proactively manage their energy usage. Not all customers wish to make such a choice, but the number is growing due in large part to decreasing costs and increasing availability of DER. This trend is likely to accelerate as EVs become more mainstream, and as the cost of solar, battery storage, and smart energy management devices continues to fall.[13]

As shown through the case studies highlighted in this paper, utilities and their regulators are increasingly recognizing the capabilities of DER to address challenges emerging from the grid transition. DER are demonstrating their capability to provide services to reduce peak demand, avoid transmission and distribution investments, and provide voltage and frequency support. DER also provide an important new service, flexibility. In doing so, they provide enhanced value to utilities and their customers. This progress invites policymakers to think of DER as a complement to the grid transition, rather than a frustration. Once the full capabilities of DER are recognized, policymakers can value the resource accordingly, and consider approaches to incentivizing DER to unlock that value.

13 *Electric Vehicle Outlook 2018*, Bloomberg New Energy Finance. 2018 May. (https://about.bnef.com/electric-vehicle-outlook/).

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INTEGRATED DISTRIBUTION PLANNING

Volkmann, Curt. "A Path Forward: Integrated Distribution Planning." GridLab, July 2018.

https://gridlab.org/s/IDP-Whitepaper_GridLab.pdf

This GridLab publication provides a synthesis of existing literature on Integrated Distribution Planning and activity in various states, a summary of anticipated changes and new required capabilities, and recommendations for regulators on potential next steps for beginning the transition to IDP.

DISTRIBUTED ENERGY RESOURCES

"2017 Utility Demand Response Market Snapshot." Smart Electric Power Alliance, October 2017.

https://sepapower.org/resource/2017-utility-demand-response-market-snapshot/

An overview of both the distributed and wholesale demand response market, analyzing demand response capabilities, services, and trends overtime. Included in this market analysis is a discussion on advanced DR capabilities and how DR responds in wholesale markets.

"2015 California Demand Response Potential Study." Lawrence Berkeley National Laboratory, November 2016.

http://www.cpuc.ca.gov/General.aspx?id=10622

This report utilizes data from hundreds of thousands of smart meters throughout California to characterize how electricity is consumed throughout the state. The paper then models how a suite of possible demand response tools can complement the needs of the grid.

"Beyond the Meter, Distributed Energy Resources Capabilities Guide." Smart Electric Power Alliance, June 2017.

http://www.ourenergypolicy.org/wp-content/uploads/2017/09/SEPA_AEE_RMI__BTM-Recommended.pdf

SEPAs Beyond the Meter series provides an in-depth look at the next generation of grid modernization strategies. This particular resource, created in conjunction with Rocky Mountain Institute and Advanced Energy Economy, provides a detailed examination of the services that DER provide, as well as recommended reading for a variety of technologies and DER solutions.

Deora, Tanuj, Jamie Mandel, Lisa Frantzis. 2017. "Distributed Energy Resources 101: Required Reading for a Modern Grid." Smart Electric Power Alliance, February.

https://sepapower.org/knowledge/distributed-energy-resources-101-required-reading-modern-grid/

A short primer on the basics of DER, with insights into how different DER technologies provide varying types of services, effective benefit-cost frameworks, proper DER valuation, and how DER may affect existing or new markets. This report primarily provides a list of resources that explore these topics.

"Innovation Outlook: The 2017 State of Energy Efficiency." CLEAResult, April 2017.

https://www.clearesult.com/insights/whitepapers/innovation-outlook-the-2017-state-of-energy-efficiency/

An outlook on the state of energy efficiency measures throughout the country, and where the industry is headed. Included in this report are analyses focused on customer empowerment, innovative technologies, the utility business model, and the future of efficiency advancements.

SMART INVERTERS

Mow, Benjamin. "Smart Grid, Smart Inverters for a Smart Energy Future." National Renewable Energy Laboratory, December 2017.

https://www.nrel.gov/technical-assistance/blog/posts/smart-grid-smart-inverters-for-a-smart-energy-future.html

A short blog post from NREL explaining what a smart inverter is, how it is utilized, the values it provides, and how this technology contributes to the advancement of smart grids.

FLEXIBILITY

Aydin, Mariko, Judy W. Chang, et al.. "Advancing Past "Baseload" to a Flexible Grid." The Brattle Group, June 2017.

http://files.brattle.com/system/publications/pdfs/000/005/456/original/advancing_past_baseload_to_a_flexible_grid.pdf?1498246224

This Brattle paper explores the emerging framework of resource planning, highlighting the antiquated nature of a baseload power resource, and the evolving nature of the grid that undermines this thought process. The paper includes new definitions, an analysis of the economics of baseload and flexible power, and market structures to encourage proper resource planning.

"Demand Flexibility: The Key to Enabling A Low-Cost, Low-Carbon Grid." The Rocky Mountain Institute, February 2018.

https://www.rmi.org/wp-content/uploads/2018/02/Insight_Brief_Demand_Flexibility_2018.pdf

This insight brief from RMI provides an overview of demand

flexibility, and how flexibility compliments the increasing penetration of renewables. The report covers the role of demand flexibility in the market, as well as a short summary of existing demand flexibility programs throughout the U.S. The report includes a simulation of a high-renewable Texas power system, detailing how the use of demand flexibility in eight end-use loads can shift demand and increase the value of renewables on the grid.

Goggins, Andrew, David Nelson, Brendan Pierpont, et al. "Flexibility: The Path to Low-Carbon, Low-Cost Electricity Grids." Climate Policy Initiative, April 2017.

https://climatepolicyinitiative.org/wp-content/uploads/2017/04/CPI-Flexibility-the-path-to-low-carbon-low-cost-grids-April-2017.pdf

An in-depth analysis of the economics of flexibility costs. The paper examines how to properly ensure that the grid has a sufficient amount of flexible resources at the lowest-cost available to consumers. The paper covers cost mechanisms, as well as the value of a set of flexibility services, such as spinning, short-term reserves, and ramping.

ELECTRIC VEHICLES

"Electric Vehicle Outlook 2018." Bloomberg New Energy Finance, May 2018.

https://about.bnef.com/electric-vehicle-outlook/

A BNEF look at the 2018 market for electric vehicles. Includes a current snapshot and trends to date, plus a future projection of the EV market.

Jonathan Coignard et al 2018 Environ. Res. Lett. 13 054031.

http://iopscience.iop.org/article/10.1088/1748-9326/aabe97/meta

This paper attempts to model the system-wide benefits from EVs charging or discharging on the grid to mitigate the intermittency of renewables. The paper specifically examines how modular charging mitigates unique challenges on the California grid, highlighting principles that can then be applied elsewhere throughout the country.

ADDITIONAL PUBLICATIONS AND ARTICLES

Dyson, Mark, Amory Lovins. "The Grid Needs a Symphony, Not a Shouting Match." The Rocky Mountain Institute, June 2017.

https://rmi.org/news/grid-needs-symphony-not-shouting-match/

This blog post challenges the outdated notion of baseload power, encouraging the need for more flexibility from a diverse set of resources.

IRENA and CPI (2018), Global Landscape of Renewable Energy Finance, 2018, International Renewable Energy Agency, Abu Dhabi.

https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_Global_landscape_RE_finance_2018.pdf

A snapshot of the existing market for renewable energy finance, which finds that while renewable energy capacity has reached record highs, investment in dollars dipped slightly in 2016. Includes insight around private versus public investment, technology sector specifics, and technology costs.

***Non-Wires Alternatives*, Navigant Research. 2017.**

https://www.navigantresearch.com/reports/non-wires-alternatives

This report examines the global non-wires alternatives market, including market drivers and global trends. Additionally, the report includes definitions, trends analysis, and detailed NWA spending information by region and sector.

Pyper, Julia. "Smart Inverters in Action: Initial Findings From APS' Utility-Owned Solar Program." Greentech Media, August 2016.

https://www.greentechmedia.com/articles/read/smart-inverters-in-action-initial-findings-from-aps-utility-owned#gs.9ZIdvUI

A Greentech Media article detailing the nuances of smart inverter use and adoption through a rooftop-solar program rolled out by Arizona Public Service. Inverters installed along the rooftop-solar program have allowed APS to test new technology to support DER growth on the grid.

Walton, Robert. "Utilities Target Marketplace for Customer Interaction, Energy Savings." Utility Dive, June 2018.

https://www.utilitydive.com/news/utilities-target-marketplace-for-customer-engagement-energy-savings/525308/

A short Utility Dive article that details how various utilities and third-party energy companies are engaging customers to help reduce energy use, gain deeper customer insights, and further engagement down the value chain.

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ABOUT UTAH CLEAN ENERGY

Utah Clean Energy is Utah's leading expert public interest organization working to expand renewable energy and energy efficiency in a way that is beneficial not only for Utah's environment and health, but also our economy and long-term energy security. Utah Clean Energy is committed to creating a future that ensures healthy, thriving communities for all, empowered and sustained by clean energies such as solar, wind and energy efficiency.

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