Load Management Leadership

Practitioner Perspectives™

The Future of Distributed Energy Resources

A Compendium of Industry Viewpoints

Produced by
Thought Leadership and Distributed Energy Resource Integration Groups

PLMA Practitioner Perspectives:

The Future of Distributed Energy Resources, A PLMA Practitioner Perspectives™ Compendium

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PLMA (Peak Load Management Alliance) was founded in 1999 as the voice of load management practitioners and has grown to over 150 utility and allied organization members. PLMA is a community of experts and practitioners dedicated to sharing knowledge and providing resources to promote inclusiveness in the design, delivery, technology, and management of solutions addressing energy and natural resource integration. The non-profit association provides a forum for practitioners to share dynamic load management expertise, including demand response and distributed energy resources. PLMA members share expertise to educate each other and explore innovative approaches to load management programs, price and rate response, regional regulatory issues, and technologies as the energy markets evolve. PLMA will continue to maintain a forum where practical experience, ideas, and knowledge are promoted to those seeking access to a vast network of industry professionals and practitioners. It is also a place where members gather to keep abreast of the latest industry trends in load management and to inform the next generation. We offer timely subject matter and training opportunities to address key facets of our industry charge. Membership in PLMA is open to any organization interested in load management. PLMA represents a broad range of energy professionals and industries–private and publicly owned utilities, technology companies, energy and energy solution providers, equipment manufacturers, research organizations, consultants, and consumers. Learn more at www.peakload.org

Preface

Where do today's load management activities (including demand response, energy efficiency, and renewable energy programs) fit in a distributed energy resource future of non-wires alternatives, storage and more? This compendium presents eight case studies from first movers that highlight how distributed energy resource adoption is changing our industry. Key stakeholder perspectives are presented across four important business categories impacted by distributed energy resources. The compendium provides an exploration of the evolution of the energy industry from peak load emergencies and market/system economics to operational management. Other initiatives highlight how operational management considerations may precede market/system economics, that the evolution follows a path of system economics, system operations, localized economics, and localized operations.

This Compendium's primary audience is senior utility executives with distributed energy resource responsibilities, but the publication is made available for free to all who are interested. The submissions were scored and/or peer-reviewed by these PLMA Thought Leadership Planning and DER Integration Interest Group members.

- Chris Ashley, EnergyHub
- Richard Barone, Hawaiian Electric
- Nick Bengtson, CLEAResult
- Michael Brown, NV Energy
- Matt Carlson, Aquanta
- Joseph Childs, Eaton
- Patty Cook, ICF
- Beth Crouchet, Austin Energy
- Troy Eichenberger, Tennessee Valley Authority
- Brett Feldman, Navigant
- Debyani Ghosh, Navigant
- Eileen Hannigan, Illume Advising
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This Compendium was produced by the PLMA Thought Leadership Group, co-chaired by Richard Philip, Duke Energy and Jenny Roehm, Schneider Electric with the Distributed Energy Resources Integration Interest Group, co-chaired by Richard Barone, Hawaiian Electric, John Powers, Extensible Energy, and Matt Carlson, Aquanta.

Learn more about PLMA Interest and Planning Groups at www.peakload.org/groups.

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Acronyms

AMI	Advance Metering Infrastructure
ASIC	Administrador del Sistema de Intercambios Comerciales, an XM Administration Operating Unit
BES	Bulk Electric System
BESS	Battery Energy Storage System
BEV	Battery Electric Vehicle
BQDM	Brooklyn-Queens Demand Management
BYOT	Bring Your Own Thermostat®
C&I	Commercial and Industrial
CAISO	California Independent System Operator
CEC	California Energy Commission
CND	Centro Nacional de Despacho, an XM System Operations unit
CREG	Colombia Commission for the Regulation of Energy and Gas
DER	Distributed Energy Resource
DERMS	Distributed Energy Resource Management System
DLC	Direct Load Control
DoD	US Department of Defense
DR	Demand Response
EPIC	Electric Program Investment Charge
EV	Electric Vehicles
FC	Fast Charging
FERC	US Federal Energy Regulatory Commission
GW	Gigawatt
IGP	Integrated Grid Planning
IPPs	Independent Power Producer
IRENA	Colombia International Renewable Energy Agency
IRP	Integrated Resource Plan
ISA	Colombian high-voltage transmission operator

kW	Kilowatt
kWh	Kilowatt Hours
LAES	Liquid Air Energy Storage
LCOE	Levelized Cost of Electricity
LDV	Light-duty Vehicles
LV	Low Voltage
LVOE	Levelized Value of Electricity
MEM	Colombia Mercado de Energía Mayorista
MGO	Metered Generator Output
MHDV	Medium-/Heavy-duty Vehicles
MME	Colombia Ministry of Mines and Energy
MV	Medium Voltage
MW	Megawatt
MWh	Megawatt Hours
NERC	North American Reliability Council
NWA / NWS	Non-Wires Alternative / Non-Wires Solutions
PCC	Point of Common Coupling
PDR	Proxy Demand Resources
PEV	Plug-in Electric Vehicles
PHEV	Plug-in Hybrid Electric Vehicle
PNW	Pacific Northwest
PV	Photovoltaic
RPS	Renewable Portfolio Standard
T&D	Transmission & Distribution
TCO	Total Cost of Ownership
TOU	Time-of-Use
UDC	Utility Distribution Company
UPME	Colombia Planning Unit of the Mines and Energy
VRE	Variable Renewable Energy
XM	Expertos en Mercados, a division of ISA

EXECUTIVE SUMMARY

Staff of PLMA member organization — utility companies, consultants, and solution providers — have deep experience in delivering practical solutions to the operational requirement to balance resources and loads. And while the first 100 years of the energy industry was focused on matching resources (generation) to loads, the next several decades will be focused on flexible loads efficiently meeting generation output at both the transmission system and distribution (T&D) feeder level, incorporating renewable, distributed and intermittent resources. We are moving into the realm of dynamic management of the system every day. The last decade has seen a rapid increase in behind-the-meter solar installations; recent advances in battery and thermal storage, electric vehicle (EV) charging, and load flexibility resources, which are indicators of the growing importance of distributed energy resources (DERs).

The PLMA community has a history of sharing experiences that enable others in the industry to understand, learn, and embrace industry change. In keeping with this mission, PLMA asked its membership to share case studies about current DER activities and projects. Preferential consideration was given to initiatives that detail how utilities and allies are:

- Repositioning program resources designed for system-wide deployment to be targeted/locational
- Making the business process changes necessary to evolve DERs from emergency to operations
- Demonstrating where demand response (DR) fits today in a future DER construct relative to utilities that are long on generation with weak market/ regulatory signals and potentially stranded infrastructure costs
- Migrating current systems toward an enhanced distributed energy resource management system (DERMS) to manage more complex power transactions
- Balancing customer satisfaction and customer acquisition issues.

The articles selected and peer reviewed for this compendium fell into four distinct categories.

- **Planning and Foundational Category –** utilities taking bold steps to leapfrog pilots/technology straight to integrative planning and procuring, and change management
- **"DR Plus" Category –** applying customer-sited assets (with or without involvement of an aggregator) to monetize DER operations for utility/grid benefits to provide a growing spectrum of network services
- **Microgrids Category –** customer-sited assets working as an ecosystem and having great degrees of flexibility and opportunity for monetization
- **International –** DER projects implemented in other countries.

While utilities, regulators and customers are still trying to explore the value of DERs as it applies to them specifically, the reality of DERs is here to stay. If there were any questions as to the longevity of DERs one only needs to look at how utilities are weaving DERs into their Integrated Resource Planning processes.

Planning and Foundational

As DERs gain momentum they have real impacts to the grid. Utilities are currently exploring how to incorporate DER adoption and program design into the planning process. While there are many differences in how utilities address this, there are also some clear similarities:

- Reliable and consistent data, vocabulary, and standards are needed.
- Collaborative communication among departments because DER touches operations and management across the entire power system.
- Inclusion of DERs in integrated resource plans (IRPs) indicates longevity of these resources and regulatory approval documents full cycle acceptance.

In the United States (US), regulatory stability provides an environment where utilities, customers, and suppliers can invest in DERs and those investments can cost-effectively provide value. Three US utilities are showcased in case studies showing how they are integrating DERs in their planning processes.

In the Pacific Northwest (PNW), two utilities are looking at DERs and flexible loads to enhance and inform their IRPs through improved modeling, innovative rate design, and new offerings through creative partnerships.

In Hawaii, the entire approach to integrated grid planning is being reinvented. Hawaiian Electric Companies intend to meet resources and ancillary services through a competitive procurement effort that will place large independent power producers and DER aggregators on an even playing field. This process will define value for localized resources that will be used and relied upon.

As DERs become more common across utility service territories they are being used in innovative ways. Using DR as a model, market players are finding creative ways to use DERs to create value.

DR Plus

Demand response programs have been used by US utilities since the early 1980s. Initially programs offset capacity constraints and over the decades have evolved to include sophisticated solutions for ancillary services markets, frequency stabilization, and even non-wires alternatives. Many of the same techniques used to monetize demand reduction are being applied to DERs. Utility companies, their customers, and service providers are creatively adding value and stability to grid operations by stacking value from distributed generation, storage, and DR. National Grid has successfully transformed what started as a Bring Your Own Thermostat® (BYOT) program into one where other resources, specifically solar and associated storage, are coordinated to benefit the grid and return economic benefits to the asset owners. This program provides a wealth of lessons learned including aligning and closely coordinating multiple parties, contracting with short timelines, and developing a new business model. After a year of operation and some regulatory changes enabling storage exports to the grid, the Connected Solutions program will deliver even more value to National Grid and its customers.

A similar project in California is the result of collaboration between multiple agencies and private companies to show how DERs can be operated to generate multiple value streams for customers including revenue streams via participation in the wholesale electricity market. Two portfolios have been assembled, one featuring solar and storage from five public school facilities and the second featuring load resources at two hotels consisting of HVAC equipment, appliances, and lighting. Utilizing smart controls and price data provided by the California Independent System Operator (CAISO), the portfolios participate in the wholesale market. This project is designed to inform the industry on market integration steps and operational strategies for DERs participating in wholesale markets.

DER's alone provide value, but when you bring them together into a microgrid you create another level of flexibility and additional value.

Microgrids

Microgrids are an ecosystem of customer-sited resources that provide the flexibility to meet a number of grid challenges where the whole is greater than the sum of the parts — as evidenced by two case studies in this compendium. Like other long-lived resources, contracting and ownership are hurdles, but the value provided by microgrids can be well worth the effort.

For military bases, energy security is a top priority. This need is often addressed with a microgrid. However, microgrids used only as an insurance policy are expensive. The Michigan Army National Guard training facility at Fort Custer needed resiliency improvements – but also a way to recover project costs. By adding smart controls to existing DERs and upgrading outdated equipment, Fort Custer created an asset that can provide resiliency (i.e., islanded operation) as well as a cost-recovery mechanism by having the ability to export power to the utility grid showing a collaboration where both parties receive value.

In New York City, microgrids are providing resiliency and much needed relief to congested neighborhoods. Microgrids in urban areas have challenges that don't occur in places like military bases. Permitting for battery storage is more complicated because of the real concerns of how the system will react to external fire or system failure. The resource is compensated for value provided to the grid as part of an NWA, as well as shared savings from the customer's utility bill.

DER adoption is certainly not isolated to the US; rather, the vast majority of DER deployment will occur in emerging markets worldwide. Many other countries are looking to DERs to address urgent climate, energy resource, grid operational, and electrification needs. Economic growth opportunities for DERs in International markets are tremendous.

International

While each country has its own unique challenges, regulations, and market structures, we can learn from and participate in how other countries are addressing their needs. In a case study featuring DER challenges and opportunities in Colombia, we catch a glimpse of how countries worldwide are starting to embrace DERs. This article highlights the emerging opportunities due to recent regulatory reforms intended to drive further adoption of smart technologies, flexible load management, and DERs.

If senior management is asking how existing load management techniques will evolve in a world of high penetration of DERs, the following eight case studies provide a glimpse into the nature of that evolution, and a set of blueprints for increased DER adoption. Lower DER costs, new business and market participation models, and technology innovation fueled by artificial intelligence and smart contracts are already starting to make their mark. Stay tuned for PLMA members to update these blueprints as we move forward into the Future of DER.

1.0 Planning and Foundational

Hawaiian Electric's Integrated Grid Planning Soft Launch Non-Wires Alternative Solicitation

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With the Hawaiian Electric Companies' (the Companies) obligation and commitment to helping the State of Hawaii achieve its 100% renewable portfolio standard (RPS) by 2045, the Companies have determined that in order to achieve this target, fully one-half of the system's capacity of renewable energy must be derived from DERs. This realization has served as one of several drivers that resulted in the Companies' innovative initiative to define and implement their Integrated Grid Planning (IGP) effort.

The IGP process, depicted in Figure 1, incorporates the following steps:

1. Forecasts and Planning Inputs
2. Identify and Quantify System Needs
   - Bulk System
   - Distribution
3. Source Solutions
4. Solution Evaluation and Optimization

There are two elements of IGP that directly impact Distributed Energy Resources (DER)s in a meaningful way: 1) The Companies plan to source the resources and ancillary services required to meet the needs of the grid largely through a competitive procurement effort. This is particularly interesting given the fact that this procurement is competitive in the sense that both large Independent Power Producers (IPP)s and DER Aggregators will be competing to deliver the same resources to the Companies. In this respect, DERs will be on an even playing field with utility-scale resources; and, 2) The IGP effort also endeavors to determine and source distribution-level, localized resources. This means that these will need to be defined and valued – and the services derived from collections of these DERs will need to be coordinated, utilized and relied upon.

Both elements introduce degrees of uncertainty and important findings in order to achieve these objectives. Of particular note are localized resources; these are less familiar ground to utilities in general and specifically to Hawaiian Electric. As a result, the Companies have initiated an IGP Soft Launch, designed to help shape and refine the process for defining distribution-level services and executing the solicitation and selection process across multiple technology options.

Beginning in 2020 this IGP Soft Launch is intended to demonstrate the sourcing processes and evaluation

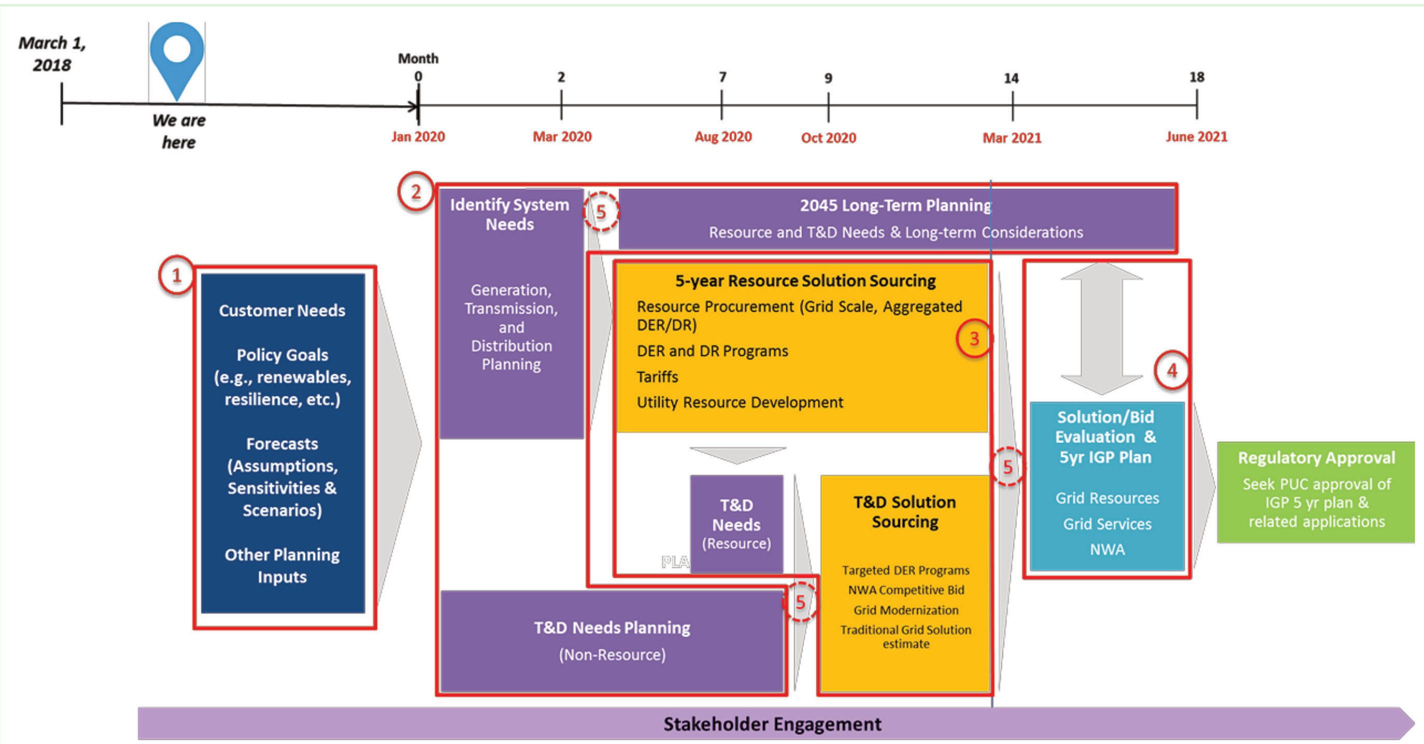


Figure 1. Hawaiian Electric Companies IGP Process.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure1.jpg

methods for distribution non-wires alternatives as part of a larger IGP effort. Solicitation will target Energy Efficiency providers, DER Aggregators and IPPs to offer solutions as a Capacity Deferral opportunity to the Companies, in lieu of expanding current substation capacity with new transformers.

While there are an increasing number of Non-Wires Alternative (NWA) projects, this is unique in the sense that it will actively seek the procurement and integration of multiple solutions – some behind the meter and others in front of the meter. These not only need to be evaluated together but operationalized. Furthermore, this is going to set the precedent for how the Company incorporates Transmission & Distribution needs identification and quantification along with bulk system needs. This reflects a truly integrative planning and sourcing process.

The identified need for the Soft Launch is an O'ahu distribution substation capacity upgrade to serve a new housing and commercial development by 2023. The Companies intend to source solutions to defer the need to expand the distribution system capacity to serve the expected load growth.

Preliminary distribution planning analysis, shown in Figure 2, identified multiple normal and contingency scenarios that must be mitigated in this area. For example, this analysis includes the need to address a peak overload of up to 4 MVA for a duration of 6 hours under normal conditions. A need to address a peak overload of up to 5.4 MVA for 11 hours duration under contingency conditions was also identified. NWA services must be operational by 2023 or additional substation capacity will need to be built.

The Companies initiated the Soft Launch in January 2019 commencing with sourcing and evaluation in 2019 and continue with anticipated solution deployment in 2020-21 and operational testing by 2022. Soft Launch will engage multiple working groups comprised of stakeholders such as internal utility personnel, Independent Power Providers, DER Aggregators, the Public Utilities Commission, the Consumer Advocate, customers, and other industry professionals ; the preliminary schedule of Soft Launch activities is shown in Figure 3.

Drivers

This project concept is not solely triggered by its importance to the IGP Work Plan, though. The Public Utilities Commission has also rejected the Companies' request for substation upgrades indicating that the Companies need to first identify what solutions or mitigation might be possible as a result of engaging customers, DERs and other NWA options. As such, this

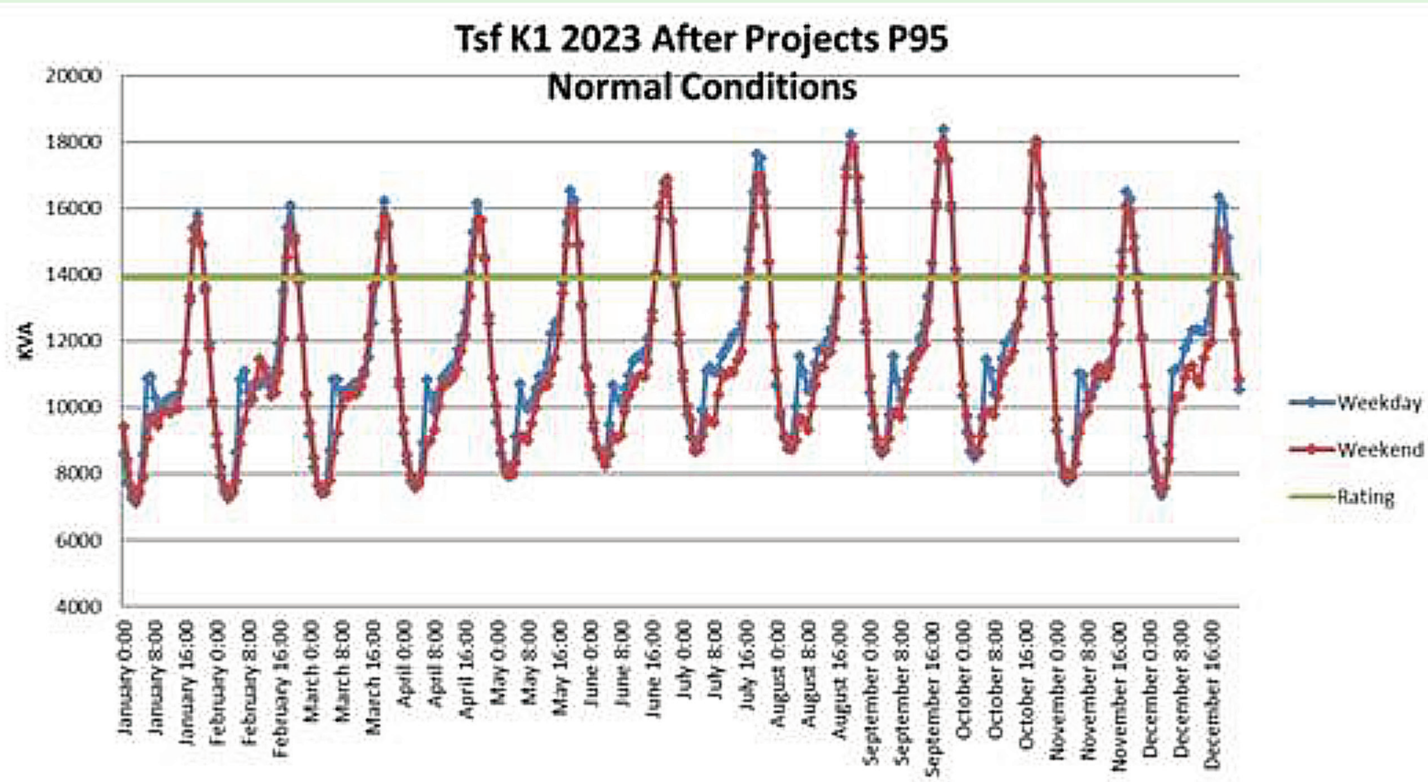


Figure 2. O'ahu Distribution Substation Capacity Upgrade Scenarios.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure2.jpg

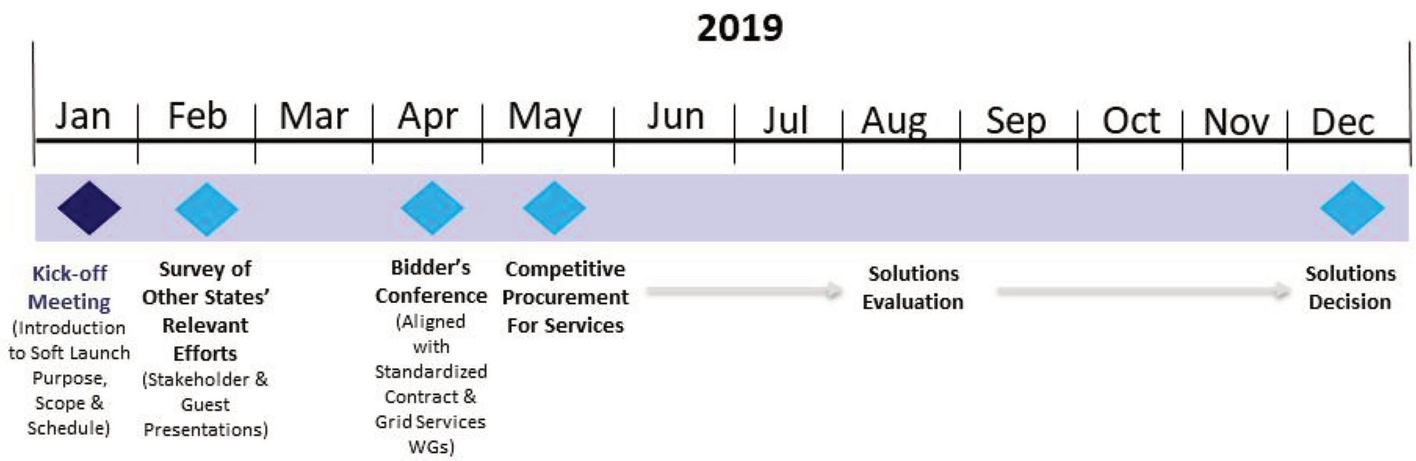


Figure 3. Soft Launch Timeline

View Figure at: www.peakload.org/assets/resources/future-DER-Figure3.jpg

project will ultimately serve two purposes: 1) Satisfy the Commission's directive to explore the prospects for the Capacity deferral to be met by these alternatives and, 2) Explore and define best practices as a scalable roadmap for a broader-reaching IGP process into the future. While the solicitation has not yet been initiated, the Companies anticipate receiving a number of bids, across a variety of solution types such as:

- Energy Efficiency packages
- Load Control via electric hot water heaters and other load management opportunities
- Load Control via behind-the-meter storage
- Load flexibility and congestion management via larger grid-tied storage or solar photovoltaic (PV) + storage projects

What Success Looks Like

A successful project will result in the development of a repeatable methodology for identifying and quantifying localized grid needs and converting these needs into a procurable product. The Companies also expect to define a process for evaluating, comparing, and selecting disparate solutions, and in turn operationalizing these solutions. In order to do this, the Companies will need to determine the appropriate contract structures for procuring these services over a long term contract horizon.

In short, the project should result in the following key learnings:

- **RFP Structure:** How to best structure an RFP for distribution resources that solicits responses from multiple counter parties and technology solutions providers.
- **Costs:** Establish a baseline for the cost of locational solutions on a $/kW or $/KVar basis. This will allow the Companies to Determine how competitive DER and EE solutions are relative to a more centralized solution.
- **Evaluation:** Establish and test an approach to evaluating different solutions. This needs to be refined and established as a blueprint for repeatable process into the future.
- **Operationalization:** Learn how to operationalize all solutions seamlessly. Identify the best approach to systematically combining disparate solutions and putting the services they can provide into the hands of system operators.
- **Requirements:** Develop an approach to quantifying the needs and convert this into a product for solicitation. Establish best practices for valuing these services.

Portland General Electric's Distributed Resource & Flexible Load Study

Authors: Shauna Jensen, Portland General Electric, Shauna.Jensen@pgn.com and Robin Maslowski, Navigant Consulting, Inc., robin.maslowski@navigant.com

Why?

Utilities typically consider the potential for DR and other DERs to help inform regulatory targets and program designs, but now utility planners need to go a step further and forecast the actual adoption of DER, often at highly granular levels. This benefits utilities as more variable energy resources require proactive management and planning. Additionally, understanding interactive effects will inform incentive structures so utilities can encourage participation of flexible loads that can help balance the variability of increased renewables.

Increasing customer adoption of DERs and flexible load (including DR), paired with an evolving regulatory model for developing and accommodating these resources, prompted Portland General Electric (PGE or the Utility) to pursue a comprehensive forecast of DERs in PGE's service area.[1]

This forecast is meant to serve the following departments and needs within the utility:

- **Integrated Resource Planning (IRP)** for long-term economic market dispatch, resource optimization, and load forecast adjustment;
- **Load Forecasting** for long-term economic energy demand planning and augment overlay;
- **Transmission & Distribution (T&D) Planning** for mid-term engineering locational planning and infrastructure design; and
- **Customer Programs** for long-term business program design and development targets.

Drivers: To-date, the penetration of DER and flexible load resources has been relatively small, with program goals that require minimal scrutiny in terms of economics and feasibility because much of the early program development is research-oriented and provides essential learning for the industry. As these resources grow, so does the need for heightened scrutiny in planning.

To support this, PGE identified two major requirements for enhanced forecasting of DER and flexible load: 1) address interactive effects between programs that may have either an enabling or a competitive effect on the resources and 2) consider the propensity for customer adoption. The objectives of these enhancements are to provide the Utility with information on how to develop multiple programs in concert and understand what is possible from a customer acquisition perspective to ensure confidence in planning commitments.

Breaking the silos: This effort involved several departments across the Utility that are relatively siloed in standard utility business processes. The effect of siloed work processes can create a disconnect between teams on planning requirements and data needs. This study created an opportunity for interdepartmental education and organization of shared development for mutually dependent goals. While understanding that data formatting needs vary widely, depending on the planning process, PGE desired for all data used by departments planning for DER and flexible load to share a common origin. PGE identified beginning with common input assumptions as the first step in working across traditional silos toward holistic planning.

Use cases: PGE plans to incorporate the results of this analysis across the organization, including in the current IRP proceeding, DR Testbed activities, Transportation Electrification planning, and Distribution Forecasting for the broader evolution of Distribution Resource Planning. This study also provides further understanding of the reasonable extent to which customers will adopt technologies that are vital to long-term decarbonization.

Furthermore, this study will stand as the foundation for a new and more coordinated planning paradigm at the Utility. PGE will build upon this work to create and implement new planning models for efficient development of programs that require interdepartmental collaboration. As shown in Figure 4, the intention is for the Customer Programs department to evaluate acquisition targets, T&D planning then locates the resources and advises on grid-related size/location specifications, and IRP then uses the aggregate trajectory to evaluate scenarios informing risk/uncertainty of investment. From there, IRP reports an economically optimized resource range as a function of portfolio design, and Customer Programs and T&D adjust planning targets if necessary. Corresponding with this process, the Load Forecasting department will also use resulting information in emergent accounting methods for DER and flexible load.

How?

PGE commissioned Navigant Consulting, Inc. (Navigant) to develop the forecasts of DER and flexible load.

1. For more information on the requirements and application of this data, refer to PGE's 2019 IRP (anticipated publication in June 2019).

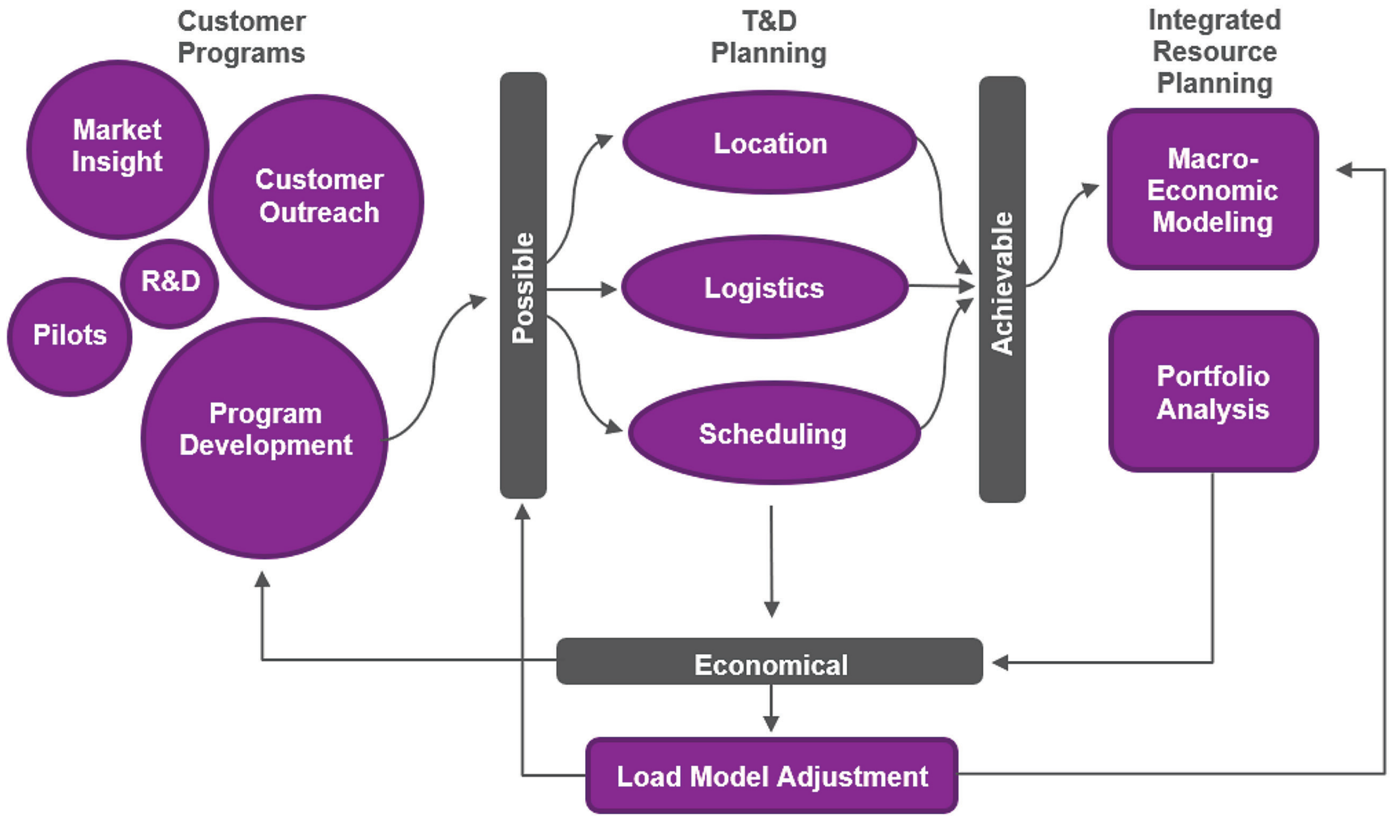


Figure 4. PGE Coordinate Planning Model.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure4.jpg

Navigant applied an integrated approach to estimating the energy and demand impacts associated with each distributed resource, with inputs and assumptions consistently applied to forecasts at both the overall system-level and a more granular feeder-level. This involved accounting for both the isolated effects of each technology or program, as well as the interactions between resources that are likely to have the greatest impact from a system planning perspective.

As shown in Figure 5, this process began with developing system-level forecasts for each resource that inherently considered the key interactive effects between the resources (e.g., the influence of TOU pricing on storage charging/discharging behavior). These system-level forecasts then served as the bases for developing scenarios, hourly load shapes, and disaggregating to the feeder-level through a combination of customer propensity analysis and allocation based on key feeder characteristics.

The advantages of this approach are the use of common inputs and assumptions throughout the process and the ability to derive deep dimensionality and multiple types of output formats from a common dataset to meet different business needs, as shown in Tables 1 and 2.

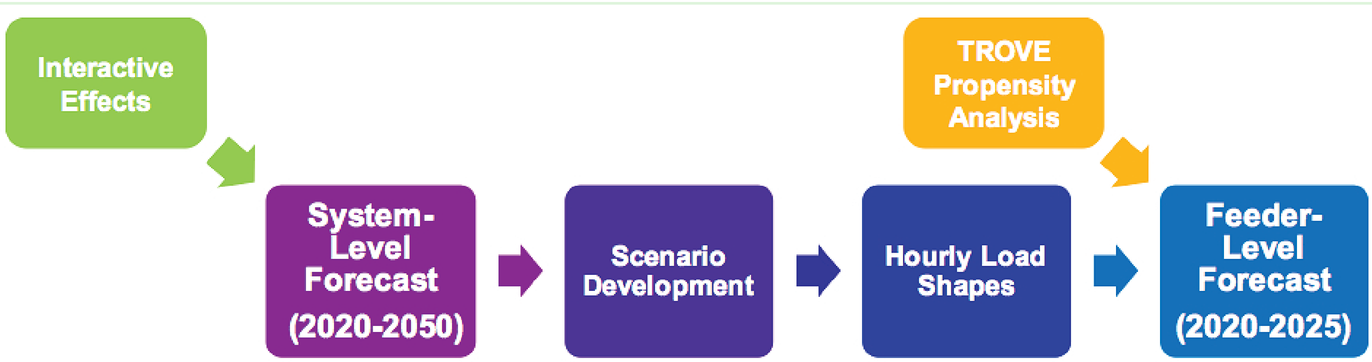
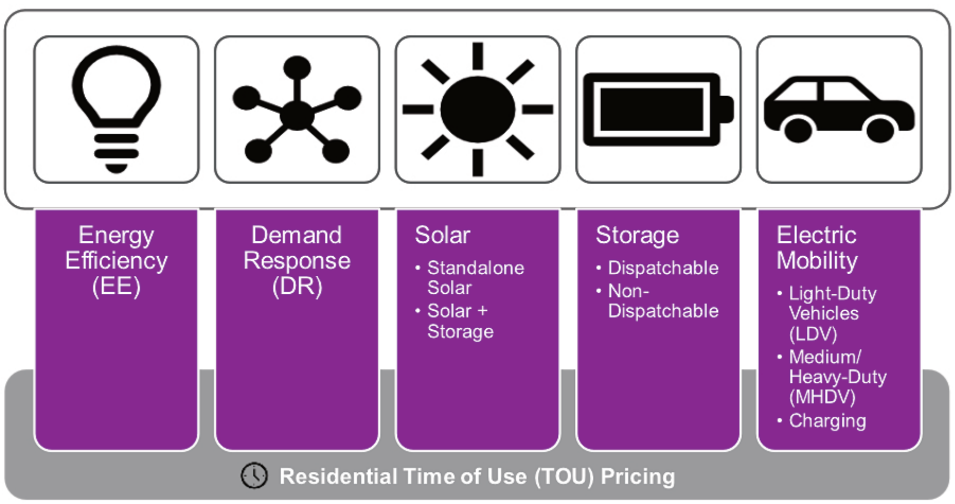


Figure 5. Overview of DER and Flexible Load Study. *Source: Navigant.*
View Figure at: www.peakload.org/assets/resources/future-DER-Figure5.jpg

Table 1. PGE Department Data and Granularity Needs. Source: PGE.

Department	Use Cases	Granularity	Study Outputs
IRP	Long-Term Economic • Market dispatch • Resource optimization • Load forecast adjustment	Aggregate system level	• Annual penetration forecasts per technology • Hourly load shapes • Interactive effects • Annual average kWh impacts • High & low scenarios
Load Forecasting	Long-Term Economic • Energy demand planning • Augment overlay	Aggregate system level	• Annual average kWh impacts • High & low scenarios
T&D Planning	Mid-Term Engineering • Locational planning • Infrastructure design	Feeder level	• Annual penetration forecasts per technology • Hourly load shapes • Confidence intervals
Customer Programs	Long-Term Business • Program design • Development targets	Aggregated from customer level	• Annual penetration forecasts per technology • Interactive effects • High & low scenarios

Table 2. Dimensionality of DER and Flexible Load Study. Source: Navigant.

Output	Dimensionality
Resources[2]	
Geography	System-level Feeder-level
Time	Annual from 2020-2050 Hourly from 2020-2025
Customer Segments	Residential Single-Family Residential Multi-Family Residential Manufactured Commercial Industrial
Impact	Energy Demand Vehicle Counts (for Electric Mobility)
Scenario	Base Low High

2. TOU pricing applies to residential customers only and is not applied to EE. This article does not cover the EE, MHDV, or charging analyses for the sake of brevity. For more information on these aspects of the analysis, refer to PGE's 2019 IRP (anticipated publication in June 2019).

Table 3 provides a high-level overview of the methodology and assumptions applied to key resources.

Table 3. Summary of Approach for Key Resources. Source: Navigant.

Resource	Approach
LDV	Forecast adoption of plug-in electric vehicles (PEV) in PGE's service area using Navigant's Vehicle Adoption Simulation Tool (VASTTM), an enhanced systems dynamics innovation diffusion model that: • Determines the long-run technology adoption potential of vehicles based on changing dynamics of competing vehicle, infrastructure, and consumer attributes • Applies a competition model driven by Total Cost of Ownership (TCO), with consideration of model availability, consumer eligibility, and consumer awareness Includes the following splits: • Ownership: Individual/Fleet • Powertrain: Battery Electric Vehicle (BEV)/Plug-In Hybrid Electric Vehicle (PHEV) Developed customer-level adoption propensities for residential LDVs to inform bottom-up feeder-level forecasts, with the support of TROVE Predictive Data Science
Solar PV and Storage	Estimated energy and capacity impacts associated with solar PV, storage, and joint solar PV + storage in PGE's service area using Navigant's Renewable Energy Simulator (RESim™) model, a systems dynamics discrete choice model for adoption forecasting that: • Uses a levelized cost, logit-decision maker approach • Accounts for the ratio of levelized cost of electricity (LCOE) to consumer offset rates (also called levelized value of electricity or LVOE), conditioned on technology acceptance and awareness Assessed the following storage use cases, both with and without solar: • Non-dispatchable customer storage: The operation (charge/discharge) of the storage is solely accessible to the customer. The customer can use the storage for demand charge avoidance, arbitrage (if on a TOU rate), and reliability purposes. • Dispatchable customer storage: PGE pays the customer an incentive to use the storage for capacity, ancillary services, and transmission and distribution benefits, while the customer can still use the storage for reliability purposes, but not demand charge avoidance or rate arbitrage.
DR	Estimated the peak demand savings available from the following DR programs for Summer and Winter: • Non-residential Direct Load Control (DLC) • Non-residential Pricing • Commercial and Industrial (C&I) Curtailment • Residential DLC • Residential Pricing/Behavioral DR • LDV DLC

Ultimately, PGE and Navigant determined the dimensionality of the study outputs based on the granularity of the input data available and PGE's different departmental needs.

For each of the distributed resources, Navigant forecasted three scenarios: Base, Low, and High. Each scenario corresponded to a different set of initial conditions for technology costs, policies, carbon prices, and pricing in each forecasting model, as agreed upon with PGE.

Another significant aspect of this study was the consideration of the interactive effects between resources. For the purposes of this study, interactive effects refer to the effects of one distributed resource on the load shape of another distributed resource, beyond the simple addition of the two resources' load shapes. For example, a standalone storage system in a residential home may be expected to operate differently from one that works in conjunction with a solar PV system installed on the roof.

Navigant focused on the interactions that were likely to impact the forecasts the most significantly in a quantifiable manner, with the acknowledgement that some interactions are still too uncertain to quantify.

Figure 6 highlights the interactions addressed in this study, which included the interactions between solar and storage; the participation of LDVs in a DLC DR program; and the influence of TOU pricing on DR, solar PV, storage, and LDV.

What?

Table 4 presents the key results from the study by resource at the system-level under the Base scenario.

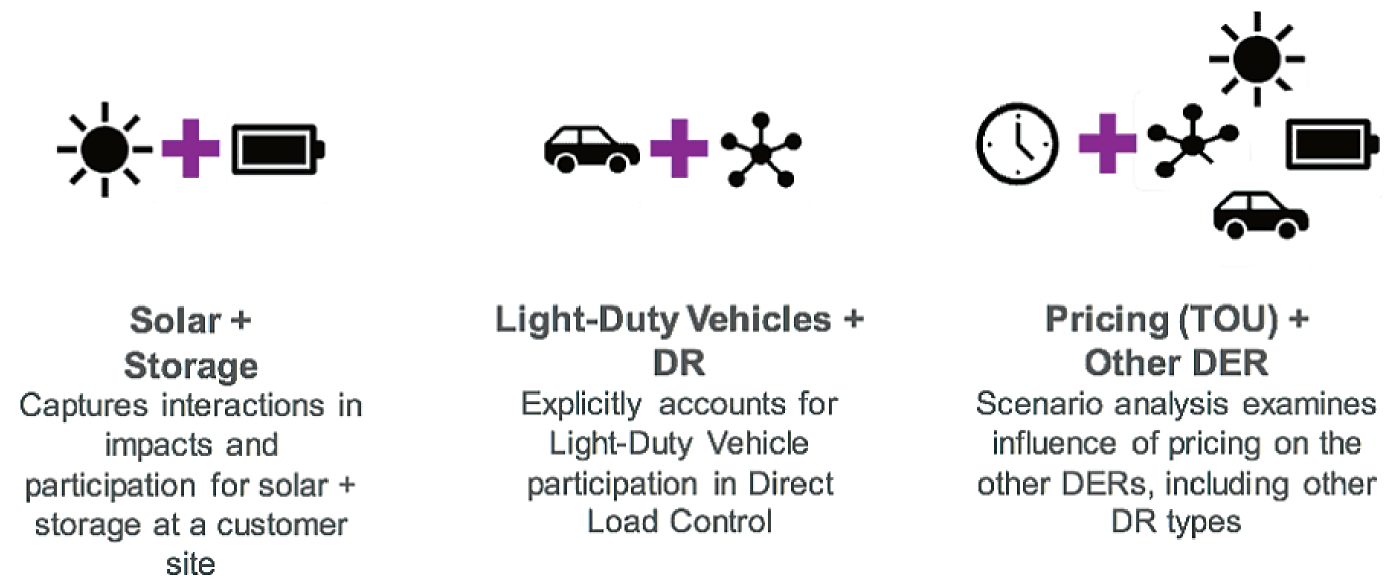


Figure 6. Interactive Effects Addressed in Study. Source: Navigant.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure6.jpg

So What?

The following discussion points illustrate lessons learned from PGE's study, with suggested best practices for cross-cutting collaboration and incorporating DER into planning.

Data: The key takeaway from the data gathering phase is to **begin as early as possible**; not only assessing analytical data requirements, but also the legal processes by which data is shared. After ensuring approval for data sharing, early identification of interdepartmental points of contact with both access and understanding of source data is essential to help with any special data preparation. Moreover, there are often limitations in data availability within these nascent markets for emerging DERs, which generally requires additional time to discuss alternative data options and reach consensus on the development of inputs and assumptions.

Outputs: Within each department, it can be helpful to talk through modeling processes (both existing and evolving) upfront to **understand how the deliverables for the study can be incorporated into utility practices**. Items to consider in discussions are the format of entry data for models (e.g., row and column orientation), necessary units and their interpretation (e.g., average kW or max kW), granularity level (e.g., aggregated or distributed), reference point on the system (e.g., customer meter, busbar, feeder-breaker, net system, customer class distinction), uncertainty analysis approaches (e.g., scenarios or confidence intervals), timestep (e.g., hourly, monthly, annual), and methods for transferring and ingesting large volumes of data.

Collaboration: At the outset of this work, the contributing departments were not fully aware of the extent of each other's work. Members from different departments should spend time describing their work processes, the models they use, their planning trajectory (e.g., near-, mid-, or long-term), and the overall function they serve (e.g., reliability, innovation, economic optimization, policy compliance, etc.). During these discussions, groups will often speak using jargon terms specific to their work. This is a great opportunity for groups to become familiar with the type of language used by other departments to enhance future communication. This understanding is particularly important when making analytical decisions on other departments' behalf.

Table 4. Summary of Key Results. Source: Navigant.

Resource	Approach
LDV	• LDV adoption in PGE's system is forecasted to grow by about 60x between 2020 and 2050, with BEV adoption expected to be slightly ahead of PHEV adoption due to a more competitive TCO. • By 2050, the number of light-duty PEVs in operation is forecasted to grow to nearly 857,000 vehicles (nearly 35% of the market). • In 2050, light duty BEVs account for 54% of all PEVs, but nearly 71% of all energy consumed by PEVs.
Solar PV and Storage	• The growth of standalone solar PV is expected to be modest and continue into the future, driven by the opportunity for bill savings and net metering. • Solar + storage comprises a much smaller market share, relative to standalone solar, because of the tradeoff between the cost of adding the storage system and the relative financial benefits. • Non-dispatchable customer storage is expected to grow rapidly, but total installed capacity is limited by customer familiarity, economics, and competition with solar PV. • Overall, dispatchable customer storage is expected to gain more market share than non-dispatchable customer storage due to assumed incentive levels making dispatchable customer storage more economically attractive to customers, though this varies by sector. • Customer segments with a TOU rate are forecasted to have a higher adoption rate of non-dispatchable customer storage than other customer segments, as they take advantage of rate arbitrage opportunities.
DR	• In the near-term, Summer DR is expected to be largely driven by Residential DLC for central A/C and smart water heating. Over time, LDV DLC grows to be almost equal to Residential DLC by 2050. • Winter DR is forecast to be lower than Summer DR, given the absence of DLC for central A/C and, hence, less potential from Residential DLC. Given that LDV DLC is not expected to vary as significantly between seasons, it is forecast to be greater than Residential DLC by 2050. • Residential Pricing/BDR contributes a significant amount of potential from TOU pricing and a Peak-Time Rebate pricing program for both seasons.

INTEGRATING DER PLANNING, RESEARCH AND PROGRAM DEVELOPMENT

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Drivers

Tacoma Power is a customer-owned, hydroelectric utility located in the Pacific Northwest (PNW). Like many other utilities in the PNW, Tacoma Power has generation that greatly exceeds demand under most water conditions. This situation may change however, because about half of the resource portfolio comes from power contracts which are due to expire in the next 10 years. Given the uncertainty in the long-term resource balance, Tacoma Power has a unique opportunity to explore a wide range of resource alternatives – including traditional supply side resources as well as innovative demand-side resources. In fact, the most recent IRP identified **evolving customer expectations** and **integrating DERs** as two important factors that can help provide flexibility to meet an uncertain future.

Through the planning lens, Tacoma envisions a "Power Supply of the Future" characterized, in part, by increased resource flexibility and an actively engaged customer base. Tacoma is currently exploring grid integration of various DER solutions – in particular, DR and electric vehicles (EVs). This "Power Supply of the Future" analysis explores ways to address an increasing need for long-term storage to provide grid services during critical water conditions and/or extended periods of low wind generation.

In parallel with long-term planning efforts, Tacoma Power is also engaged in initiatives to develop practical customer-side DER solutions in the near-term. These new solutions are intended to not only be customer needs-focused, but also aligned with future resource and flexibility needs. Current projects include a public-private partnership to develop energy storage, advanced residential DR and the development of transportation electrification.

Initiatives

Summarized below are three different efforts at Tacoma Power focused on planning and enabling the future of DERs in our service territory. These efforts span three distinct categories:

- **Enhanced integrated resource planning (IRP):** This effort also includes an expanded IRP scope, new approaches to resource modeling, and new valuation methods suitable for DERs and supply-side resources alike.
- **New program offerings through creative partnerships:** Through partnerships with strategic allies (among technology, industry, academia, government, and customer advocacy groups), Tacoma Power is able to significantly improve DER value propositions by providing customers both energy and non-energy benefits enabled through utility DER integration programs.
- **Innovative rate design:** Traditional rate design practices can be a barrier to both demand response participation and to attracting new investments in public electric vehicle charging infrastructure. Creative new pilot rates that enable and incentivize DER adoption are now being developed and tested.

Enhanced Integrated Resource Planning: Battery Equivalent Modeling of DERs (Status: Under-Development)

In the past, integrated resource planning at Tacoma Power did not include detailed models of DERs beyond conservation. And even then, conservation has typically been included in the load forecast as a pre-determined quantity (all cost-effective conservation) and not as a potential resource selected for resource adequacy. Ideally, integrated resource planning should entail a process through which supply side and demand side resources can be compared on an equal basis.

In order to address and plan for a growing interest in DERs from both Tacoma Power customers as well as various other entities in the region, IRP models are being updated to include DERs – specifically, DR, distributed solar, energy storage, and electric vehicles. To model these resources, the planning group is developing "battery equivalent models". A battery equivalent model is an extensive set of resource parameters that when properly defined, can represent a wide range of customer-owned devices – not just batteries. Because the battery equivalent model has a consistent set of parameters that simply take on unique values for each device type, different DERs can be evaluated in a consistent manner and in the same planning models used for supply side resources. This is an on-going effort in conjunction with the planning group's continuous IRP modelling improvement activities.

Creative Partnerships: Liquid Air Energy Storage Project (Status: Under Development)

Recently, Tacoma Power has begun to explore a number of DERs for capacity, including liquid air energy storage (LAES) – a form of thermal energy storage. LAES uses liquefied air products, primarily nitrogen and oxygen, as an energy reserve. With liquid air products as its storage medium, LAES has several advantages over both battery storage and long-duration storage such as pumped hydro or compressed air including: 1) LAES has no geological restriction and can be sited anywhere air exists, and 2) LAES does not require the use of rare earth metal.

To explore this DER technology, Tacoma Power has proposed partnering with an industrial gas company which already has existing air liquefaction infrastructure, to construct a liquid nitrogen storage tank for use as the LAES. Combined with appropriate automation and control strategies, this thermal energy storage system would provide a number of reliability and economic grid benefits. Unlike traditional LAES which "discharges" as generation (and is currently quite an inefficient process – the first of its kind is currently being piloted in the UK), Tacoma proposes "discharging" the storage as DR. This not only eliminates the need for additional components but is also significantly more efficient: Liquid air products need not be converted to generation since the liquid air products themselves are inherently valuable to the industrial gas company which sells such products. In other words, during DR events, the industrial gas company would simply substitute grid electricity for stored liquid air products. Through such a partnership, the customer could participate in DR programs with minimal impact on normal business operations and productivity. This proposal is in the early stages and it is certain that challenges will arise– but there is also a unique opportunity for a mutually beneficial public-private partnership necessary for a DER future.

Innovative Rate Design: New Fast Charging (FC) Rate Schedule (Status: Active)

Fast chargers are necessary critical infrastructure if electric vehicles are to be adopted by the masses and creative V2G projects piloted in Tacoma Power's service territory. However, fast charging stations have an extremely high power demand and, at low levels of utilization, the utility bill alone can be prohibitively costly for investors. Since the demand charge component of the energy bill is the same whether a single car charges or an entire fleet of cars, demand charges serve as a major economic deterrent to fast charging infrastructure investments – particularly in Tacoma Power's service territory, where EV adoption is not as high as it is in more affluent cities.

In order to encourage EV adoption and promote economic development in the region, Tacoma Power developed a new Fast Charging (FC) rate; termed "Schedule FC". The new rate allows for complete cost recovery by temporarily increasing the energy charge ($/kWh) while decreasing the demand charge ($/kW) compared to the general service rate. Over the next 13 years the Schedule FC rate will gradually transition back toward the general service rate as utilization rates increase[3]. The rate was approved in 2018; in 2019 the first customer was added to the rate. In the first two months of 2019, over 26 MWh were sold through the Schedule FC rate.

These are just a few of the forward-thinking initiatives at Tacoma Power aimed at planning for and enabling a successful DER future. Because Tacoma has not yet seen adoption in DERs at a scale similar to that seen in states like California, there is a unique opportunity to plan early and be strategic about DER integration. Tacoma Power hopes to continue to take full advantage of that opportunity.

3. Tacoma Power's rate schedules, including the FC rate schedule and general (G) rate schedule can be found at: www.mytpu.org/customer-service/rates/power-rates/power-rates-schedules

2.0 DR Plus

Deriving New Wholesale Market Revenue Opportunities And Maximizing Customer Utility Savings With Behind-The-Meter Distributed Energy Resources

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Overview

California is experiencing exponential growth in customer-sited DERs. Continued adoption and grid integration of these resources is considered a strategic priority for supporting the state's aggressive energy and climate goals. Many of these resources—such as energy storage—are able to perform multiple services for customers, utilities and grid operators. However, multiple use applications and value stacking for DERs are relatively new concepts that translate into new operational strategies that need to be developed and refined to maximize the value proposition to encourage further investments. Additionally, many jurisdictions still lack the necessary physical infrastructure (e.g., Advanced Metering Infrastructure [AMI]), wholesale market access, and/or regulatory frameworks to allow DERs to provide multiple use applications to support grid and customer functions.

The Center for Sustainable Energy (CSE), Tesla, Conectric Networks, Olivine Inc, and DNV GL are collaborating on a demonstration project that aims to show how behind-the-meter DERs can operate and be paid for by multiple-use applications participating in the wholesale electricity market that is managed by the CAISO. The project resources consist of two portfolios of DERs: (1) solar PV paired with battery storage, and (2) an array of building and equipment sensors with dynamic load controls. It is supported by a grant from the California Energy Commission (CEC) Electric Program Investment Charge (EPIC). The experience and lessons learned during the project will be broadly shared with industry, utility, and regulatory representatives at the conclusion of the project in late 2019.

Project Details

The primary goal of the demonstration project is to develop operational strategies that allow behind-the-meter DERs to be bid into the CAISO day-ahead and real-time energy markets—primarily as proxy demand resources (PDR)[4]—while still maintaining their intended value and service to customers[5]. In addition to the CAISO's energy markets, the portfolios will provide spinning reserves and simulate frequency regulation. Moreover, the project will use direct metering for the energy storage systems.

The project is made of two portfolios: Portfolio 1 consists of an aggregation of five public school facilities, each with behind-the-meter solar PV paired with battery energy storage; and Portfolio 2 includes two hotels outfitted with an array of wireless sensors and dynamic controls utilizing advanced energy management software.

Portfolio 1

The five public school facilities aggregated to form Portfolio 1 are located in Chino Hills, California. Each school has behind-the-meter solar PV and Tesla Powerpack battery energy storage system (BESS) with a combined capacity of 1.1 MW/2.09 MWh and sub-metering for performance evaluation. Portfolio 1 intends to bid as a price responsive resource in the market when the potential revenue gain from wholesale market participation via discharging or charging exceeds the potential cost savings from avoided retail utility costs as dictated by the terms of the customer utility tariff[6]. In hours where the site has an opportunity to reduce load below its baseline, the battery operational strategy will evaluate when such participation exceeds the estimated marginal opportunity cost of such a dispatch. When it is economically attractive to participate, load reduction will be implemented through behind the meter dispatch of the battery. Once bids are submitted and market awards are received, Tesla can upload those economic price signals into the local optimization engine connected to the battery's controller. Under perfect 24-hour foresight when the day ahead forecasted load and market price match up with actual conditions, the battery will dispatch at each scheduled hour in the day ahead market and obtain a market award settlement in the exact amount as planned. However, as the day ahead forecasts will

4. PDR is a participation model that allows behind-the-meter resources to participate in the wholesale market as demand response. These resources are able to provide energy in both the day-ahead and real-time markets as well as spinning and non-spinning reserves. In general, the PDR model is technology agnostic and sites can use multiple resources to provide load reduction when participating in the market. The PDR model does not compensate DERs for grid export.

5. The technologies used in each portfolio were installed with the primary purpose of reducing customer electric utility bills through demand and energy reductions. As a general rule, the technologies will not participate in the wholesale market at the risk of increasing customer bills unless wholesale market participation will more than compensate customers for increased utility bills.

6. The schools' retail utility tariff is based primarily on a non-coincident demand charge, grid electricity volume assessed on bi-seasonal, time-of-use block energy rates, and a suite of non-by passable volumetric and fixed charges.

inevitably be imperfect, the battery optimization will tailor the battery dispatch from its day ahead program and use real time (15 minute interval) market information to create an optimized real time energy market bid.

In sum, the optimization solves for battery dispatch in the day ahead and real time wholesale energy markets based on the retail tariff, and forecasts of net load, potential market award, and imbalance charges (i.e. market penalty). Figure 7 shows potential wholesale market revenues for this portfolio.

Tesla receives 15 minute metering and telemetry data from a variety of system assets, which include gross customer site load, PV generation, and battery state of charge, among other signals. This data can be used to benchmark the performance of a given strategy or forecasting technique in comparison to the ex post review of perfect performance under the known net load and day ahead prices.

In addition to providing energy into the day-ahead and real-time markets, Portfolio 1 will also provide ancillary services in the form of spinning reserves and frequency regulation simulation. While the CAISO allows PDRs to provide spinning reserves, it does not allow them to provide frequency regulation; therefore, the Portfolio will bid spinning reserves into the market, and it will simulate frequency regulation by following actual regulation signals. These additional services will show how DERs can tap into multiple revenue streams in the wholesale market and the value they can provide. To date in California, few DERs have provided spinning reserves into the CAISO market, making this demonstration one of the first of its kind. Moreover, if the frequency regulation simulation is successful, this could be an opportunity to advocate for PDR to provide regulation in the market.

This project is also using a newly-developed metering methodology at the CAISO, known as Metered Generator Output (MGO) to directly meter the energy storage systems for performance and settlement purposes. MGO is an alternative to traditional retail DR programs that utilize whole-premises metering (typically the electric utility distribution company's (UDC) revenue/billing meter) to baseline the performance of load curtailment during an event. A counterfactual framework such as a "10-in-10" is established based upon the difference between a historical baseline value and the actual usage during the event period[7].

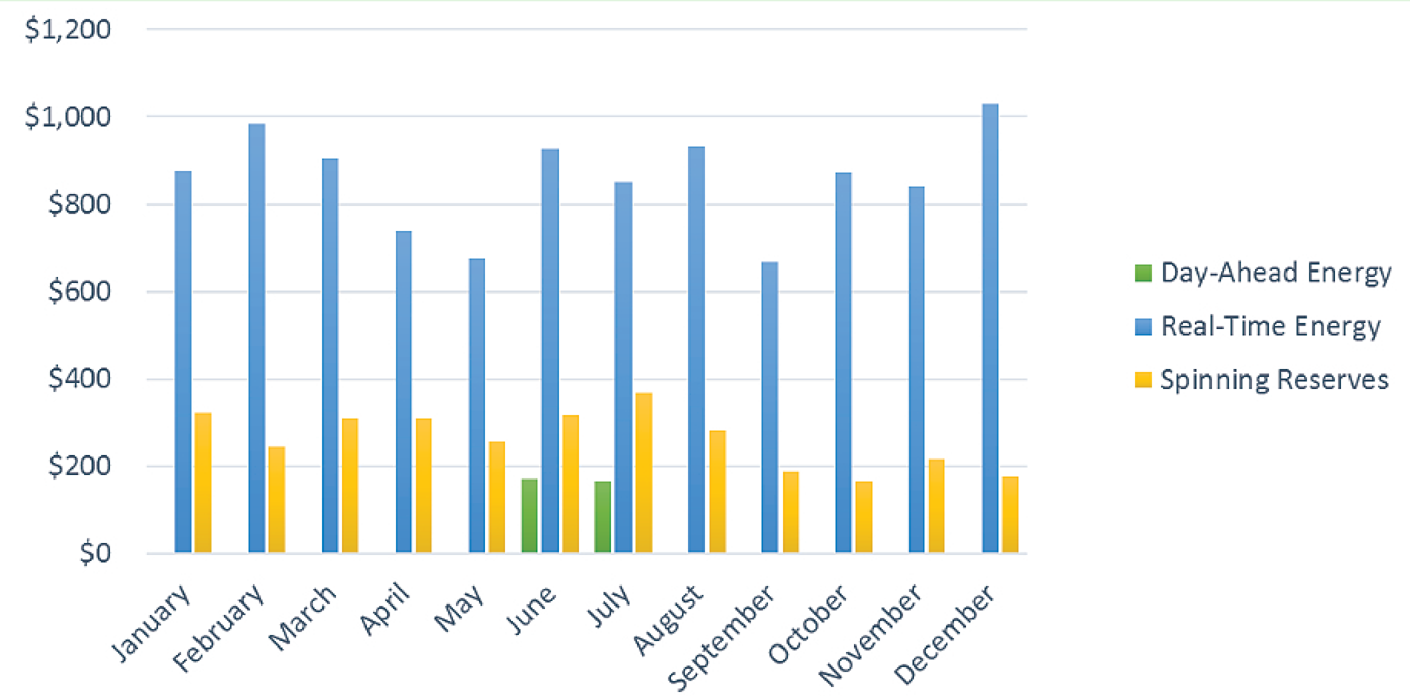

Figure 7. Portfolio 1 Potential Wholesale Market Participation Revenues.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure7.jpg

7. A "10-in-10" baseline can be commonly described as a baseline settlement method that establishes a counterfactual baseline by averaging a given facility's ten most recent similar non-event days hourly load — immediately before, during and after a particular demand response event window — and then subtracting out the event period curtailed energy demand.

The MGO method calculates DR performance by relying on a sub-meter that directly measures the contribution (energy delivered) by the registered generation device located behind the whole-premises revenue meter. Under this configuration, the Tesla Powerpack storage devices are sub-metered to determine performance during a DR event. A feature of this demonstration project will be to test the ability of MGO as a mechanism to ensure accurate compensation of behind-the-meter (BTM) storage for its contributions to a DR event dispatch.

Portfolio 2

Portfolio 2 consists of two hotels located in San Diego, California and uses advanced energy management software developed by Conectric Networks to evaluate whole-premises metered performance. The two sites combined can reduce onsite load by up to 215 kW/ 1,300 kWh. Both hotel facilities are outfitted with thousands of lighting, thermal, and occupancy sensors throughout the common areas and hotel rooms that are WiFi-connected to Conectric's dedicated local area network (LAN) gateway hubs, along with automated smart controls placed 'over the top' on HVAC equipment (that had preexisting equipment management system controls of their own) and lighting switches – see Figure 8.

Portfolio 2 anticipates following a "price taker" strategy when participating in the CAISO energy markets, meaning that the resource does not have a set price that wholesale markets must reach to submit a bid[8]. Rather, the portfolio plans to submit bids during time periods when the flexible capacity available is sufficiently large enough to make cost effective bids. Figure 8 provides an overview of potential monthly revenues from wholesale market participation.

To provide both retail and wholesale services, Portfolio 2 includes load management strategies, a list of necessary data points to collect, a data collection and load control protocol, and protocols to perform automated load management responses to varying grid conditions. Portfolio 2 has two primary methods[9] to strategically manage site loads when participating in the wholesale market (see Figure 9):

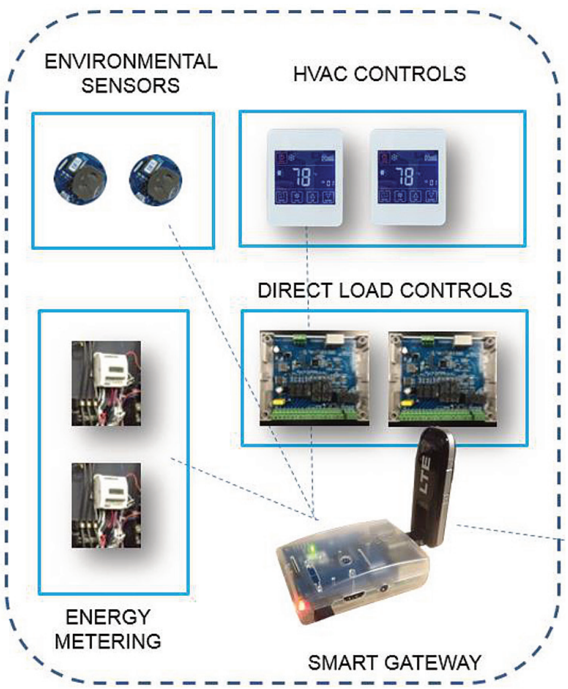

Figure 8. General View of the WiFi-enabled Sensors and Controls (Via Dedicated Smart Gateway Hubs) That Are Outfitted in Portfolio 2 Hotel Facilities.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure8.jpg

8. "Price taker" has limited range for demand response resources in the wholesale market due to FERC Order 745 Net Benefits Test (NBT), which establishes a bid price floor for demand response resources. More information is available on CAISO website at: www.caiso.com/informed/Pages/StakeholderProcesses/CompletedClosedStakeholderInitiatives/DemandResponseNetBenefitsTest.aspx.

9. This demand response terminology was established in the 2025 California Demand Response Potential Study (2017) by Lawrence Berkeley National Laboratory and adopted into the record of the Demand Response Proceeding at the California Public Utilities Commission (Rulemaking 13-09-011), available online at: http://www.cpuc.ca.gov/General.aspx?id=10622.

1. **Load Shift** by primarily using the building's thermal mass as passive thermal energy storage[10].
2. **Load Shed** when peak-demand economic conditions merit additional reductions.

Specific load management strategies that Conectric Networks plans to implement to deploy both load shift and load shed across both hotel facilities include:

- **Occupancy forecasting:** Using detailed analysis of historical occupancy patterns provided by the hotel, probabilities will be assigned to the occupancy of a specific use area. For example, only 1% of rooms are occupied between 3pm and 4pm, increasing to 48% between 4pm and 5pm and 74% between 5pm and 6pm. The amount and duration of cooling load shifting in guestrooms can be matched to the occupancy probability.
- **Pre-cooling strategies:** The thermal characteristics of each zone and of each building as an aggregate compared to weather data and available heating and cooling capacity can determine the amount and duration of pre-cooling that is required to deliver a certain reduction in cooling requirement at a later time. This fits with the demand shifting or thermal energy storage function.
- **Ventilation control:** Ventilation is often left uncontrolled or based on schedules that are not regularly updated. By adding occupancy information to ventilation control, it may be possible to manage ventilation to perform energy load-shift, -shed or -shimmy functions.
- **Pump control:** Hotel buildings have sizable water management systems designed to pump, distribute, heat, cool and treat water. Some of the many water features include swimming pools, chillers for air conditioning, and boiler systems for hot water and heat; nearly all of which can be managed for energy load optimization. For example, it may be economically favorable to turn off water pumping functions for a certain period to perform load shift or shed if the forecasted wholesale market price crosses a certain threshold. Or another example may be that if rooms are unoccupied for multiple hours it may be unnecessary to pump as much hot water through portions of the facility.
- **Lighting controls:** Customers typically find it difficult to control common area lighting. A user interface can be developed to make it easier to create individual lighting branch control. Additionally, dimmable lights may be controlled to produce energy load-shift or shed functions.

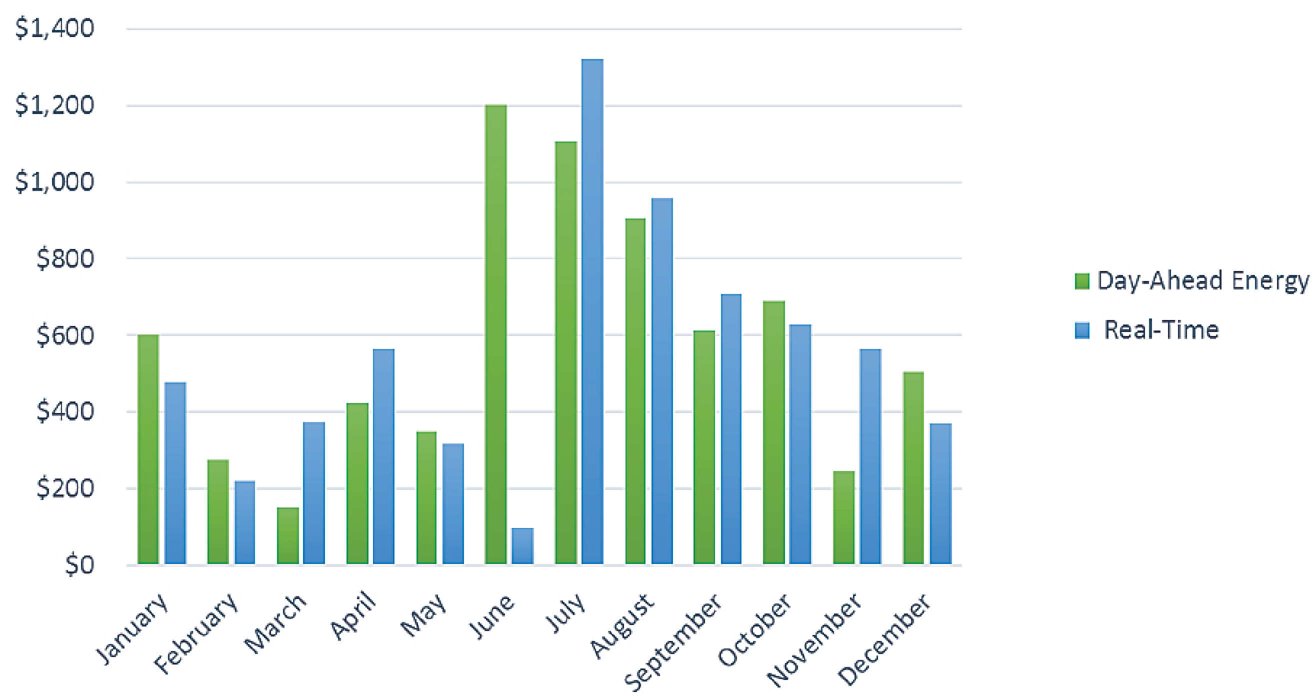

Figure 9. Portfolio 2 Potential Wholesale Market Participation Revenues.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure9.jpg

10. The buildings' concrete walls and floors can hold and store heat, acting as passive thermal energy storage. No actual thermal storage device will be installed on the properties.

Timeline

Portfolio 1 is currently in the wholesale market registration process. The project team anticipates that it will be ready to begin market participation in May 2019. Portfolio 2 is in the customer agreement phase, and the project team is hoping to begin market participation by Summer 2019.

The project team will observe and analyze both portfolios participation in the market into early 2020.

Conclusion

Through this pilot, the project team hopes to inform the industry and market on the market integration steps and operational strategies of multiple use application DER portfolios participating in wholesale markets. Additionally, the project will test innovative uses of DERs by providing spinning reserves into the CAISO market and simulating frequency regulation. Lastly, the project will demonstrate the use of direct metering and compare the performance and settlement impacts with those of traditional DR baselines. With these lessons learned the project team plans to inform regulatory agencies on policies and practices that can allow DERs to provide greater benefits to customers and the overall energy grid.

EXPANDING NATIONAL GRID'S CONNECTEDSOLUTIONS PROGRAM TO INCLUDE ENERGY STORAGE

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Background

National Grid added a battery energy storage component to its successful ConnectedSolutions Bring Your Own Thermostat® (BYOT) program in 2018. The utility planned to use the program to bolster its DR portfolio while creating another touchpoint for positive customer engagement.

This case study covers the process for standing up the storage component of the program, the key results and learnings from DR events in the summer of 2018, the optimizations based on those results, and takes a look ahead at the potential of ConnectedSolutions as it continues to scale.

About ConnectedSolutions

National Grid's ConnectedSolutions program started as a BYOT DR program meant to reduce stress on the grid during times of peak demand, lower the cost of electricity for ratepayers, and curb pollution. In 2018, National Grid announced it was adding energy storage to ConnectedSolutions, evolving from BYOT into an innovative Bring Your Own Device (BYOD) program. The utility partnered with DERMS provider EnergyHub and solar and storage vendor Sunrun (collectively "the team") to deploy and manage behind-the-meter solar and storage systems in homes across National Grid's utility service area in Massachusetts and Rhode Island.

From program design to launch and measurement and verification (see Figure 10), the team leveraged their respective strengths to create a program that would benefit National Grid's and Sunrun's customers while increasing the value of the ConnectedSolutions program to the grid.

Standing Up the New ConnectedSolutions Program

The team came together to launch the storage element of ConnectedSolutions in early 2018 with the goal of launching the program that summer. A contracting process that included short timelines, innovative technology, new business models, and multiple parties required alignment and close coordination.

Designing a BYOD Program

The team committed to maintaining flexibility in program design to anticipate step changes in market dynamics, asset deployment, storage technology, and grid services software improvements. They also considered the shifting regulatory environment over the ensuing program years.

Sunrun was able to create customer-centered terms & conditions designed for the pilot season. This allows for expedited signup of these same customers for the longer-term future program seasons under new and expanded terms. This approach was in line with medium-term policy expectations of the launch of the SMART Incentive[11] and capability of energy export, and higher DR value in future seasons.

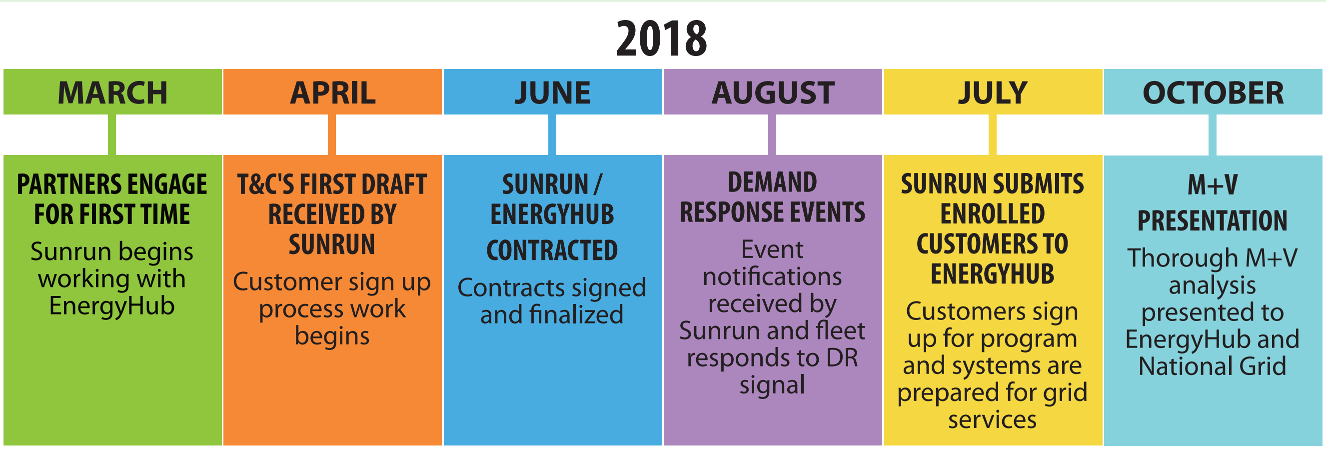

Figure 10. ConnectedSolutions Time Line.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure10.jpg

11. www.mass.gov/solar-massachusetts-renewable-target-smart Residential customers with renewable charged energy storage units would be required to discharge under the SMART Tariff and the expectation would be that permission for all energy storage units in the state would be allowed to discharge to the grid following the SMART rollout.

The team created cohesive marketing collateral used to recruit customers. Sunrun worked closely with National Grid to create unique go-to-market collateral for their joint customer base. The marketing messages highlighted the value of backup power and the benefits that utilizing energy storage for DR could yield for greater communities and the grid.

Cohesive marketing is an important factor in utility programs that are marketed by residential solar + storage partners. Customers are put at ease when trusted consumer brands and electric utilities work together to provide them with an attractive offer, so presenting a unified vision for the program was critical. There is evidence, based on post-program interviews with program participants, to suggest that co-marketed programs of this nature increase customer opinion of their utility partners over time.

When it came to designing the energy storage control strategy, the team knew ConnectedSolutions customers would be sensitive to "sharing" their battery with the utility. Many storage customers paid a high upfront cost solely to have backup power when the grid was down. This backup-only product was a result of the previous utility position regarding residential energy storage, which in 2018 was prevented from exporting energy directly to the distribution grid[12]. Sunrun's expertise in residential energy storage allowed the teams to adequately prepare customers to change from only using their battery for backup during grid outages to utilizing them to maximize load reduction during program events.

Given the limitations on exporting power, Sunrun prioritized a control structure that utilized the battery only to cover a home's immediate energy consumption during DR events. This helped in crafting conversations for enrollment into the program. Customers would participate in three-hour demand response events from 2-5 p.m., with the option of opting out of individual events, or the program as a whole, by contacting Sunrun at any time during the summer.

The team launched battery storage as part of the ConnectedSolutions program in June 2018 and were able to actively recruit customers until August 1, 2018.

The initial pilot period and customer terms in 2018 were limited to a one-year time frame, allowing stakeholders across the team to step into operations quickly and use the results from the pilot phase to influence longer-term designs in later program years.

BYOD Program Performance in 2018

The impact of the DR events was somewhat limited. With the previous Massachusetts landscape preventing customers from exporting batteries to the grid and the DR window occurring during peak solar production, there was a very limited amount of possible reduction under the rules of the program on a per-unit and aggregate basis. As shown in Figure 11, demand response was limited to net load of the home (the difference between actual load and the rooftop solar output), which greatly reduced the kW per battery delivered during demand response events. In fact, many customers saw net negative load during event windows, seriously limiting DR results.

One of the main takeaways demonstrated by Figure 11 — illustrating performance of an individual system during a demand response event in the 2018 season — is that the inability to export from the battery critically limits the load reduction potential for utilities from these assets, as well as limits the revenue share possible for customers who are enrolled. The "Without Export" graph shows a battery only discharging 2401 Wh when in the non-export (maximize self-consumption) mode, while the "With Export" graph shows the battery could have discharged 7,840 Wh had it been able to export at the same time during the same event.

Key Learnings of the 2019 BYOT to BYOD Pilot

Program Design Learning

The pilot demonstrated that it was possible to rapidly ramp up a successful behind-the-meter energy storage program without launching at-scale. Key learnings are summarized in Table 5. The team gathered a broad set of internal stakeholders that were given the leeway to quickly stand up the program while relying on the expertise of the team. Launching the program with a cohesive marketing message on an abbreviated timeline was a major victory for all parties involved.

Integrating a residential solar + storage aggregator into a utility DR program brings a fundamentally different set of requirements than adding additional device vendors to a BYOT program. The costs for customer acquisition and the timelines for installing and interconnecting devices require more lead time and planning.

Thorough collateral, materials, and trainings are necessary to successfully navigate the complex customer acquisition process of residential storage with the added complexity of DR event management — specifically for

12. The Department of Public Utilities has since ruled that under net metering, residential storage can export to the grid when charged by a net metered solar system.

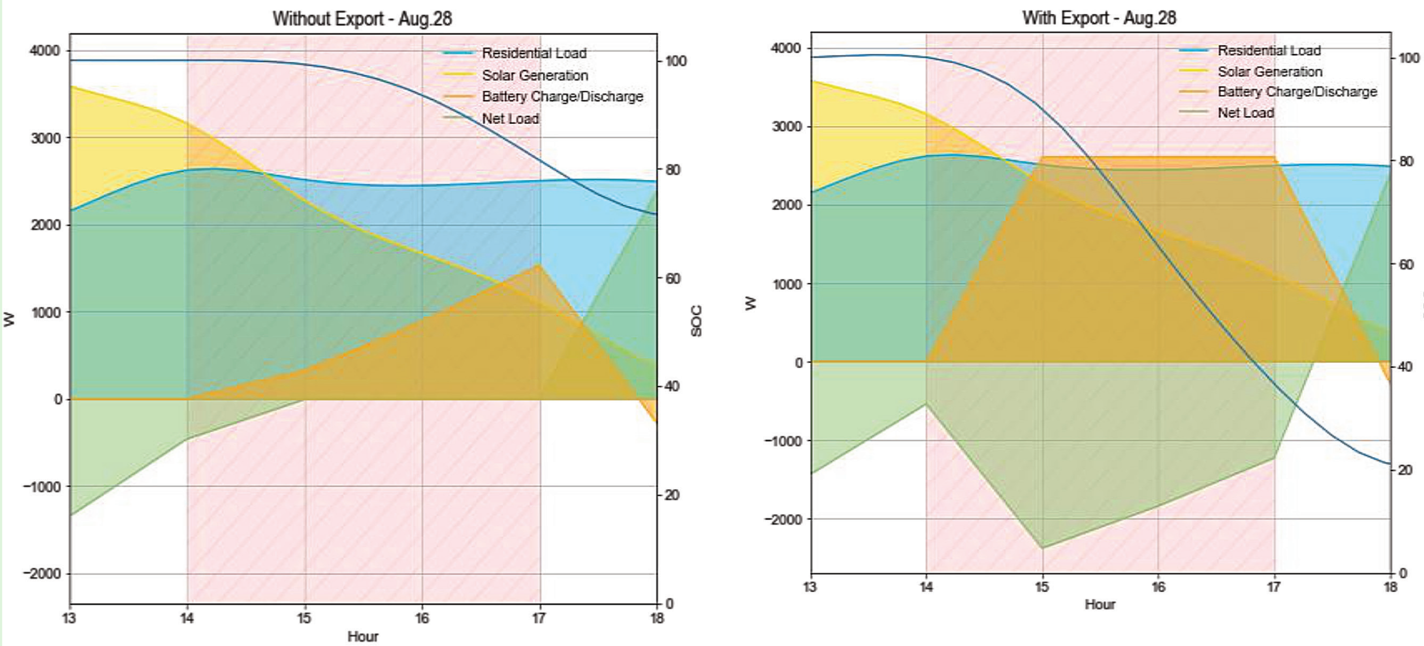

Figure 11. Head to Head Comparison — Without Export | With Export.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure11.jpg

Table 5. Summary of Key Learnings

Program Design	Energy Storage Performance	Future Improvements
Create pilot-specific terms and conditions that allow for updates in later seasons and flexibility in implementation	Limit integrations to those necessary for deployment and event notification and management to work within tight deadlines and schedules.	Clarification in Massachusetts allows for batteries to export to the grid
Create a cohesive marketing message used by both the utility and the device vendors to increase customer acceptance.	Batteries exporting to the grid creates the potential for massive demand response results while the opposite can be said from limiting exports.	Daily demand response events in July and August will create significant value for National Grid in future seasons
Clearly articulate the control strategy and event parameters to the customers.	Predictable seasons and event parameters help customers understand changing energy storage operations.	More control time leads to a larger customer incentive, which is a net-positive for the customer and the utility

a customer segment whose sole priority in purchasing energy storage was for backup power. Alignment on the management of the assets to optimally perform and protect customer value are critical.

Program Performance Learning

Customers responded well to transitioning from a backup-only solar and energy storage paradigm to one in which they contributed to a BYOD program construct.

The energy storage fleet of devices responded to external demand response event triggers from National Grid, passed through EnergyHub's DERMS platform to Sunrun.

Despite the quick timelines for operations setup there was adequate communication and performance due to limiting the depth of partner integration to only those that were needed for dispatch.

The team provided thorough and detailed measurement and valuation analysis to regulators and stakeholders to help articulate the case for changes to energy export rules in future seasons. Allowing the team access to performance data allowed each to bring their own expertise to the analysis of performance and best recommendations for future seasons.

A Look Toward the Future

In February 2019, the Massachusetts Department of Public Utilities clarified that customer-owned batteries could export to the grid. This regulatory certainty should improve the effectiveness of the ConnectedSolutions program, allowing for significantly more load reduction from each individual system on a per event and per season basis.

National Grid also determined there is significant value in reducing peak load across all days in July and August, allowing them to step away from the more infrequent dispatch strategy for a traditional peak-shaving DR program. Daily DR using batteries for these peak summer months is both a utility- and customer-friendly solution, as the only constraint is the need to recharge, and using the battery for DR does not impact customer comfort. With that in mind, National Grid increased the incentive for customers to join the program in 2019. Customers will now receive $275/kW-year based on the average load shed they deliver — a massive increase compared to 2018's $120 per customer for a single summer season.

Overall, the first season of the ConnectedSolutions program was a success. In standing up one of the first programs of its kind, National Grid, EnergyHub, and Sunrun developed new processes that allowed the team to deploy new residential energy storage assets, enroll them in a demand response program, and have them participate in demand response events within less than two quarters. In 2019 with more favorable rules around exporting batteries to the grid, and the tailwind of beneficial state incentives through the SMART Tariff, the ConnectedSolutions program promises to deliver tremendous value to both National Grid and its customers.

3.0 Microgrids

Microgrid Enables Military Facility To Participate In Utility Services

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Summary

The Michigan Army National Guard training facility at Fort Custer required improvements in its resiliency with a microgrid. The requirements also included a cost recovery mechanism and an economic way of installing a microgrid. The microgrid solution required the management of a mix of geographically distributed energy resources across the facility (Figure 12). To build this microgrid, the large solar PV plant with intermittent output and the wide load variation required an advanced microgrid technology including the addition of energy storage and an upgrade to the existing backup diesel generators and a smart controller.

The key accomplishment for this project is the optimal management of diesel generator, solar PV, and battery storage assets in real time to maintain demand or export power at the utility connection – Point of Common Coupling (PCC). Optimal management solutions during an emergency include: managing the solar PV supported by the storage and regulating the demand while using all the solar power; enabling Fort Custer to export power to the utility-owned distribution grid so that the utility can support closely sited critical facilities. This across-the-fence powering of facilities allows the leverage of all existing resources in the region, reducing the investment required for additional assets in the region. This implementation of microgrid control as dispatchable microgrids (as against dispatchable DER) is an advancement on the state of the art in microgrids and allows military facilities with microgrid installations to participate in utility ancillary services while meeting their energy security needs. The modifications carried out to realize the goals were the upgrade of legacy equipment, specifically legacy backup distributed generation (DG) (to make them dispatchable) and upgrade manual PCC switches to enable automation

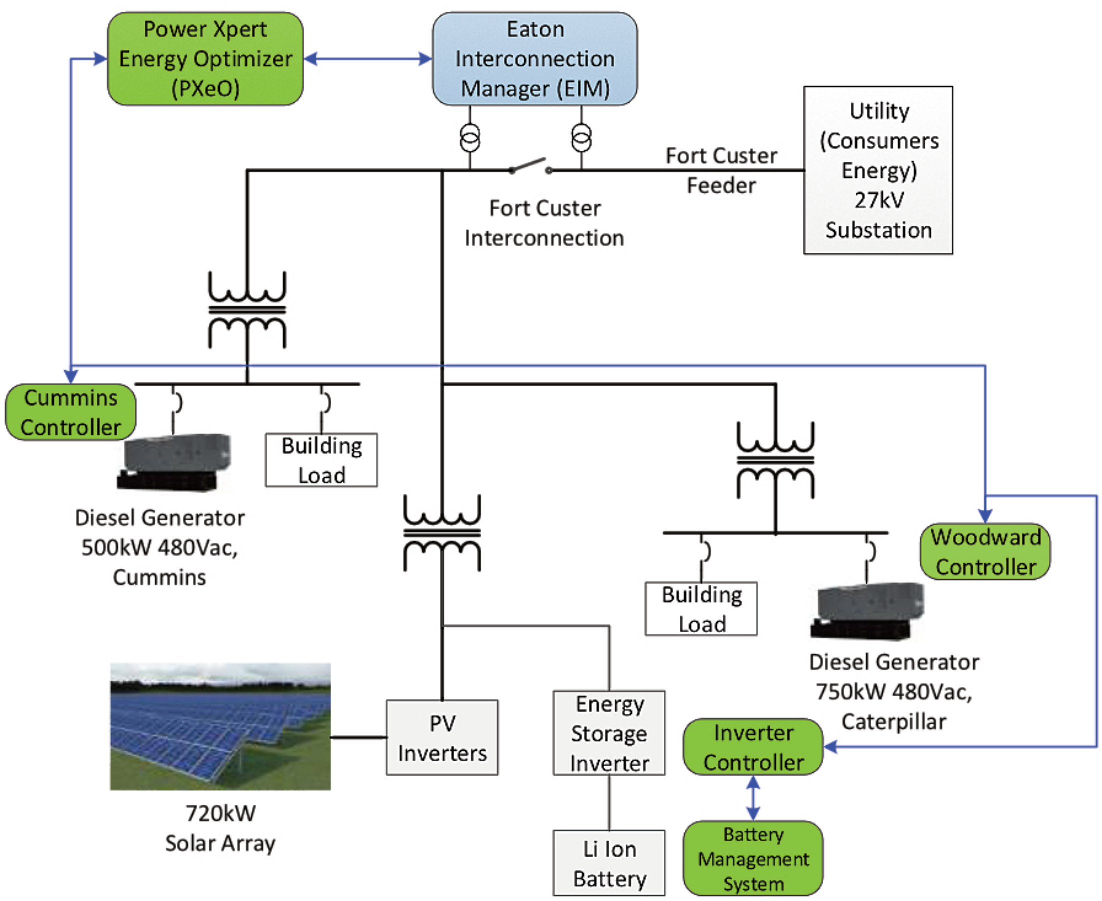

Figure 12. Schematic Diagram Illustrating Fort Custer Microgrid Layout.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure12.jpg

and seamless disconnection and reconnection at the utility PCC. Additional energy storage was also deployed for mitigating PV intermittency and for managing peak power demand.

Challenges and Opportunity

The project involved integrating separately located DERs from different manufacturers, having individual asset-level control requirements, to operate in a coordinated manner and make Fort Custer a dispatchable microgrid. The challenge lies in the brownfield design of the Fort Custer microgrid. Extensive effort was required to make existing backup diesel generators operate in grid-parallel mode and make them dispatchable. Typical backup generators have limited protection and switching hardware (i.e., automatic transfer switch), and are not suitable for paralleling with the grid. Upgrades were made to the generator controllers and the switchgear for the generators to ensure safe and reliable power export. The upgraded controls allow isochronous and base-load operations as well as load-sharing by the generator. The manual switch at PCC also required an upgrade with a control-plus-protection integrated switchgear to enable point of connection power export or demand management, blink-less islanding/reconnection, and advanced protection requirements, in lieu of the new grid-parallel operation and power export features. The over-the-fence connection of the microgrid also required extensive interaction with the region's utility provider, Consumers Energy, because of right-of-way concerns. An amendment was made to the existing interconnect agreement to allow power export to the utility grid. Successful implementation of the microgrid establishes a whole new level of regional energy resiliency available on demand to the military and the utility company.

Solutions Provided

The technology solution provides a microgrid control architecture composed of scalable commercial-off-the-shelf controllers, protection relays, and switchgear suitable for all medium- voltage (MV) distribution with MV / LV (low-voltage) generation assets. The ability to seamlessly island, control the demand to a set point, and even export into the utility to support other loads on the MV distribution can be used by the military post or Consumers Energy working with Fort Custer. Onsite PV can reduce a significant portion of the demand. The demand can be regulated to a set point despite changes in PV power output. The short-time fluctuations in PV are met with battery storage and larger deficits with diesel generation. In an emergency or for maintenance the entire military post can go completely off-grid. The demonstrated controls are applicable to any US Department of Defense (DoD) facility with excess generation capacity for sale to the regional ancillary and demand services markets available while retaining the capability of islanding and use of the same assets for energy surety during contingencies.

Key Results

The microgrid operation was demonstrated in different modes utilizing the developed control framework; islanded mode illustrating resiliency; grid-parallel mode (non-export mode) illustrating demand management; grid-parallel export mode for participating in ancillary functions like reserves. The demonstration involved continuous 48 hours of islanded operation as well as 4 hours of grid-parallel operation of the military base with active management of the on-site resources to perform different functions (Figures 13 and 14). The islanded operation can offer renewable support and load-source

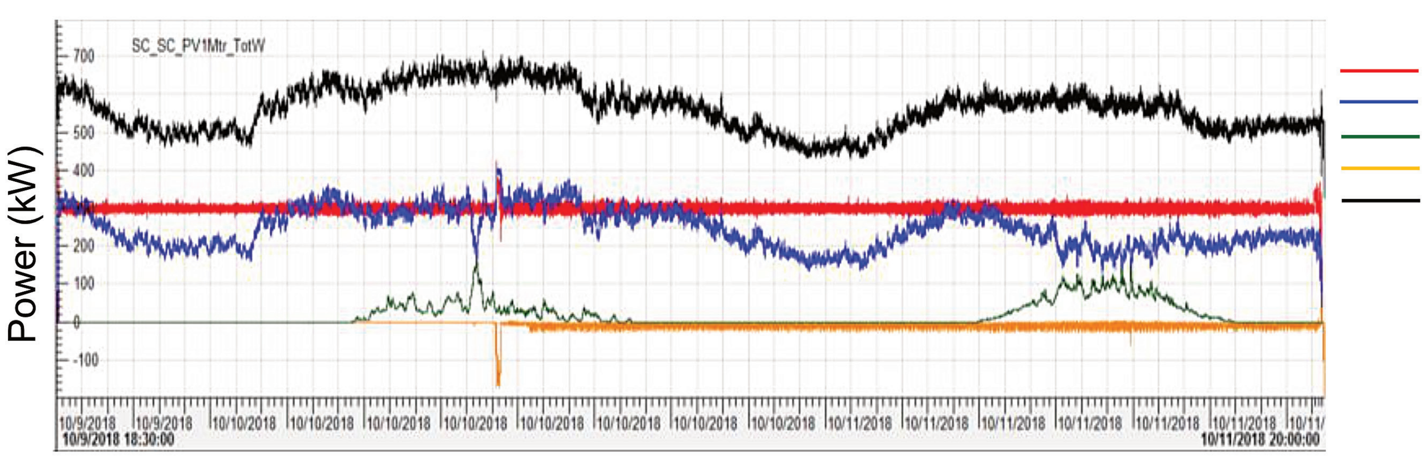

Figure 13. Real Power Output for 48 Hours of Islanded Operation.
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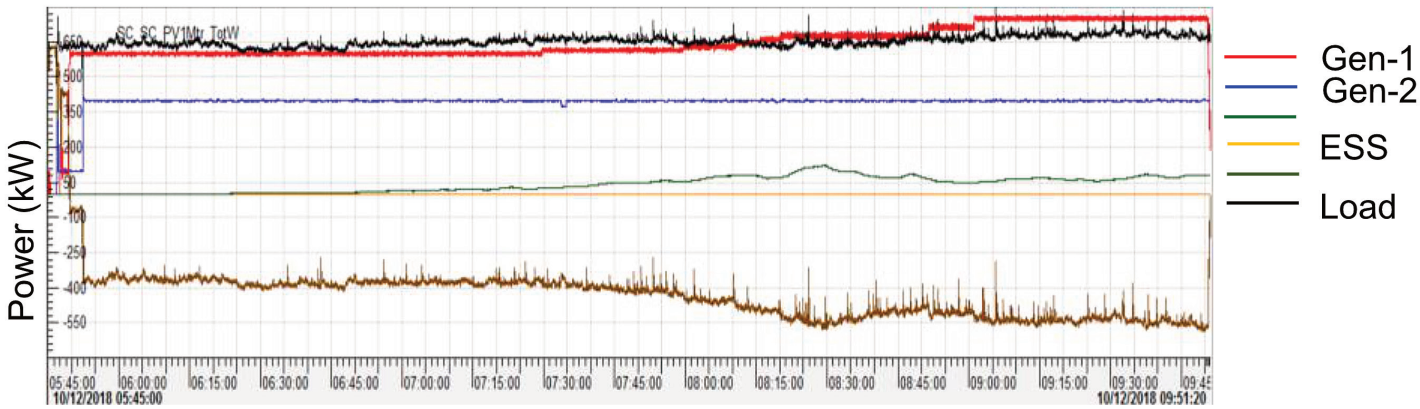

Figure 14. Real Power Output for 4 Hours of Grid-Parallel Operation.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure14.jpg

balancing to maintain power quality. The grid-parallel operation can perform net zero operation at PCC, operator-issued dispatch setpoint following, as well as optimization of generation mix for dispatch. Some of the results from the demonstration are described below.

- **Islanded Operation:** Gen-1 (CAT) is operated as the isochronous generator while Gen-2 (Cummins) runs in the grid-following mode. PV output is dictated by its MPPT controls and energy storage is primarily responsible for mitigating fast PV ramps. This demonstrates a reliable control framework and upgrades.
- **Grid-Parallel Operation:** Both generators are operated in the grid-following mode. The dispatch settings of the generators are optimized for different scenarios, such as net zero export and demand response. The set points of the individual generators within the microgrid are also managed internally to utilize better fuel economy of different generator operation, without affecting the net export to the utility.
- **Demand Response and Ancillary Services:** Because of grid-parallel operation capability, Fort Custer can sell energy through an aggregator into the Real-Time and Operating Reserves market and the developing demand response market. The value of the exported energy will be determined based on the $/MWh to monetize the available generation capacity from Fort Custer.

The islanded operation is beneficial to the base for resiliency purposes. The grid-parallel operation allows revenue generation by offering utility services. However, the base needs to consider the trade-off between the lifetime of generators and market participation. Considering the aggregate of Fort Custer DG assets were available for dispatch by Consumers Energy to sell into the Reserve Energy Market, an estimated ROI is 20,447 hours (2.5 years) of export operation. This estimate is based on an average price from the MISO Reserve Energy Market of $30.57/MWh with the Fort Custer asset aggregation of 2 MW.

Key Learnings

Solution Modeling and Simulation: The complete solution including operator controls was built and tested in a virtual microgrid ahead of the installation. This virtual environment allowed the team to operate the system at the factory prior to the deployment phase, reducing costly and time-consuming commissioning time and field changes, which only required controller fine-tuning.

DER Simulators: All distributed resources (generators, solar PV, battery, and inverter) were modeled as a complete entity including the control I/O points. This approach considerably reduced the field commissioning, as the controller configuration and software was already validated in a simulation environment.

Ease of Operation for Base Personnel: The installed microgrid is designed such that the assets can operate independently, even if the microgrid controller was turned off. It provides Fort Custer, if needed, the option to operate the military post in a non-microgrid mode as originally designed. Features such as backup operation of generators through ATS function does not need microgrid control of generators. The PCC switch is also made accessible to the onsite electrician to manually operate for grid power interruption/restoration, without the need of the microgrid in operation.

Emission Consideration: The state of Michigan allows operating backup generators for extended duration. However, this extended operational time for diesel generators will be an issue for this technology implementation in other states with stricter EPA regulations. This may require larger renewables and battery capacity.

Interconnect Agreements: An additional risk includes communication and coordination between grid operators and microgrid operators, especially in the context of power export to nearby facilities and ownership of infrastructure and equipment. If nearby microgrid facilities coordinate with each other, they must keep in mind the electrical infrastructure separating their facilities is generally owned by the local utility which will seek to mitigate risk to its own equipment. Measures such as directional protection element for fault detection and power export limits at PCC can help in this regard.

Modular Expansion: The modeling and simulators allow Fort Custer an additional value for future operations of the facility. The effects of facility expansion can be modeled with high fidelity to determine the impact on standalone and grid parallel operation. Also, any new DER resources to be added at the facility can be modeled allowing tuning and testing of the control algorithms prior to commissioning.

Acknowledgment

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Energy Storage And Microgrid Performance In Brooklyn-Queens Demand Management And Other Demand Management Programs – A System Operator's Perspective

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Background

Enel X's predecessor, Demand Energy Networks, began developing customer-sited energy storage control systems in 2009. Enel X recognized that energy storage could add the most value in the areas of greatest grid congestion. This is because, ideally, the congestion is reflected in customer demand charges and demand response opportunities that could support the system, financially.

The versatility, round-the-clock availability, and absence of fatigue with energy storage create a high value for it in the setting of a non-wires solution (NWS). Con Edison's (Con Ed's) first Brooklyn-Queens Demand Management (BQDM) program gave Enel X the opportunity to deploy its first microgrid.

The BQDM-participating system is a 300kW/1200kWh microgrid control / energy storage system at the Marcus Garvey Apartments in Brooklyn. The system is also responsible for keeping a 400-kW fuel cell and 400 kW of distributed PV from injecting generation back on to the grid. It was installed at no cost to the customer and is paying for itself through a share of the savings generated on the power bill. It also supplies resilient, backup power for the security office and a community room. Success is measured through its ability to reduce energy bills and to provide this resilience.

Enel X energy storage / microgrid systems have participated in three Con Ed demand reduction and NWS projects since 2015 in New York City. These systems have executed well over 1,000 DR events for Con Ed. Like other DR programs, success is measured on percentage of dispatch. Enel X dispatched at 105% of contracted load reduction during summer 2018 in the BQDM program for the 15 events.

Challenges

Challenges have centered around the pioneering use of energy storage technology and the 10-month window between contract award and program operation.

1. **Permitting:** Permitting mechanisms for energy storage systems as DR tools did not exist prior to these projects in New York City. Understandably, in an urban environment as dense as New York City, permitting bodies (specifically the NYC Department of Buildings and the Fire Department of New York) required certitude that the systems were a good fit with the people and building infrastructure of New York City. Enel X worked closely with both Authorities Having Jurisdiction (AHJs) and was the first project developer to receive Letters of No Objection from the FDNY for both valve-regulated lead acid energy storage systems and lithium-ion energy storage systems.

FDNY in particular, is taking extensive steps to develop an understanding of how energy storage systems will react to either an external fire or a system failure. This research is still on-going and will play an important role in developing standard procedures for the permitting of energy storage systems.

The City University of New York has worked closely with FDNY, Con Ed, Enel X, and other parties, to develop and disseminate procedures for the permitting of energy storage systems in the city.

Since utilities typically have good relationships with fire departments and other permitting bodies, they are encouraged to take a "seat at the table" as permitting processes for energy storage systems are developed in their communities.

2. **Customer Recruitment:** NWS customer recruitment is not simply a matter of making an economic case to customers in a specific geographic region. Customers need to have an openness to new technologies and innovation.

The same customer segmentation principles being used in other utility programs apply to identifying energy storage customers (although this segmentation is typically more advanced when looking at residential customers than C&I customers).

Those segments are (with applicable ones in bold): **Pioneers, Early Adopters,** Followers, Economic Buyers, and Laggards.

3. **Customer Retention:** Because energy storage and microgrids are capital-intensive, they require a long-term relationship with the customer during the 10- to 20-year life of the system. Managing this relationship well is a key to a successful project for the long-term.

Good communication, integrity, and respect are key qualities for the project operator to have.

Multiple Benefits for Utilities

The success of these projects provides a great example of the multiple benefits that microgrids and energy storage can provide for DR-type services, both for system-wide demand reduction and in targeted geographic areas.

- "Swiss army knife" benefits to the utility, particularly through its ability to provide load reduction at any time, its reliability, and the elimination of participant-fatigue issues.
- Enhancing local grid reliability by shifting load and reducing peak demand
- Maximizing hosting capacity for local generation
- Providing resilience to a community center and security office at Marcus Garvey Apartments

Utility Application

Energy storage is a powerful tool for NWS and DR because of its flexibility, reliability and persistence Con Ed is embracing this power and expects future programs to make even greater use of its effectiveness. This is a critical, because it is more expensive and difficult to deploy than EE and DR savings created by turning off loads.

Over time, Con Ed's use of the systems has varied. It appears that usage has increased as confidence in the effectiveness of the systems has grown.

1. Dispatch approximately 100 times annually, every summer week day (Demand Management Program I);
2. Usage only coincident with other day-ahead system peak reduction programs, less than 5 times per season (Demand Management Program II);
3. Usage only coincident with other day-ahead system peak reduction programs, but in a targeted network and, utilized less than 5 times per season (BQDM Program, 2017 execution);
4. Usage many times more than other day-ahead system peak reduction programs, still in a targeted network. The systems were called upon 15 times this past season BQDM Program, 2018 execution).

4.0 International

First Movers in DER in Colombia

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Background

Colombia has had a competitive electricity market since 1994, when Law 143 established the Mercado de Energía Mayorista (MEM), literally translated as the Wholesale Energy Market. As a result of the economic reforms in the 1990s, Colombia opened markets to the private sector and allowed for the investment, both foreign and domestic. All of the energy which passes through Colombia's interconnected market, is traded via the spot market, using bilateral contracts, or through government-administered auctions. Like the US, there are many parties which play a role in managing the electricity markets in Colombia, including:

- **Policy:** Ministry of Mines and Energy (MME)
- **Planning:** Planning Unit of the Mines and Energy (UPME)
- **Regulation:** Commission for the Regulation of Energy and Gas (CREG)
- **Surveillance:** Superintendency of Public Utility Services
- **Operations:** Expertos en Mercados (XM), a division of ISA with two operating units for:
- **Market Administration:** Administrador del Sistema de Intercambios Comerciales, (ASIC)
- **System Operation:** Centro Nacional de Despacho (CND)

These reforms were so effective that further reforms were not seen as a priority until more recently with the increase in the frequency and severity of El Niño weather patterns. Unlike many countries in the region, the Niño brings reduced rainfall to Colombia. Severe droughts are common in Niño years which leads to a direct reduction in the output of hydroelectric generation, which accounts for nearly 11 GW of capacity out of a total of almost 17 GW (Figure 15). During the last Niño period in the first half of 2016, hydroelectric power declined to below 50% percent of electricity generation in Colombia as compared to roughly 70% during the same period in 2015.

Challenges

Concerns about possible shortfalls of electricity have been strengthened by recent problems with the Ituango Hydroelectric Project which was planned to cover nearly 20% of Colombia's electricity demand once operational. Unfortunately, recent heavy rains contributed to a catastrophic collapse of a diversion tunnel and forced Empresas Publicas de Medellín to flood the machine house. The project has a new target completion planned for 2021 (HydroReview, 2019).

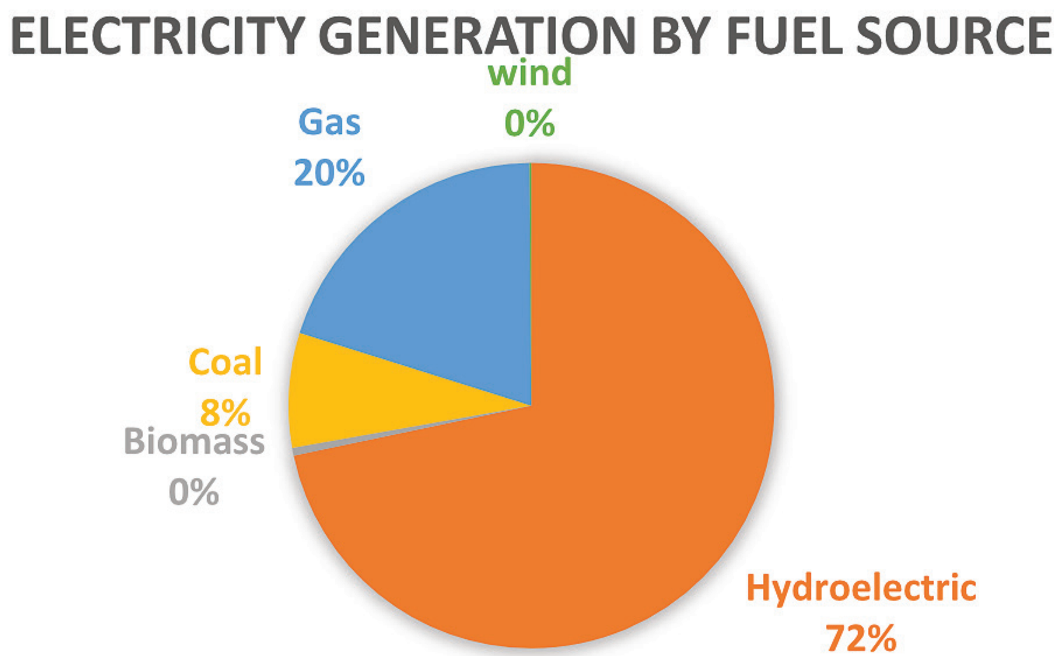

Figure 15. Electricity Generation by Fuel Source. Source: UPME, 2018.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure15.jpg

This reliance on hydroelectricity with major negative impacts during Niño years — coupled with concerns that Ituango has the potential to remain a volatile electricity source — has spurred a new round of reforms in Colombia aimed at diversifying Colombia's energy mix. These efforts have been given further impetus by a recent study from UPME that foresees peak demand increasing to 15 GW by 2030 from 10 GW currently, a roughly 50% increase in only 12 years (UPME, 2018).

Planning

Colombia plans to satisfy a large share of this increase in demand with variable renewable energy (VRE). UPME expects VREs to account for 17% of the 24 GW of installed capacity it expects by 2030, with biomass accounting for an additional 3% (Figure 16). It expects gas to maintain its share of generation, while coal use for generation is expected to decline slightly, from around 7.5% currently to under 4.5% by 2030. However, coal and gas are still expected to retain sufficient capacity to ramp up in a Niño year. In contrast, a recent analysis by International Renewable Energy Agency (IRENA) outlines a pathway under which Colombia could achieve 100% renewable energy production by increasing solar PV to 18.5 GW of solar PV together with 12.5 GW storage, possibly pumped hydro (IRENA, 2018).

The North American Electric Reliability Corporation (NERC, 2017) defines DER as any resource on the distribution system that produces electricity and is not otherwise included in the formal NERC definition of the Bulk Electric System (BES). Such resources can include:

- distributed generation such as solar panels,
- combined heat and power turbines, or combined cycle turbines;
- behind-the-meter generation such as solar panels, either at a single location or aggregated;
- energy storage facilities; and
- micro-grids, which may combine various of the previously-mentioned elements.

The US Federal Energy Regulatory Commission (FERC, 2018) adds energy efficiency and demand response to this definition.

The high level of hydroelectric production puts Colombia in a very advantageous position with respect to renewables in general, and renewable DER in particular. Since hydroelectricity can be a great resource for balancing load, this advantage could allow Colombia to incorporate greater amounts of renewables, including DER, compared to countries that rely more on fossil fuels and nuclear for baseload. This, plus the government's desire to diversify the generation fuel mix, have made renewables a natural focus for government electricity-sector reform plans. Photovoltaic solar systems are particularly attractive since Colombia gets an average solar irradiance of 194 W/m2 or 4.5 kWh/m2, well above

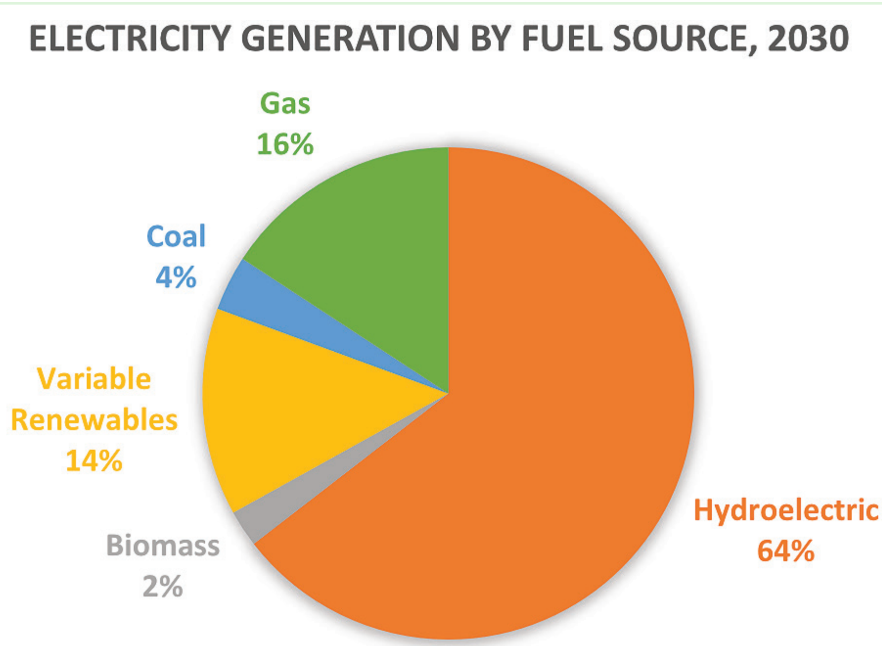

Figure 16. Electricity Generation by Fuel Source, 2030. Source: UPME, 2018.
View Figure at: www.peakload.org/assets/resources/future-DER-Figure16.jpg

global averages (i.e., solar irradiance measures the amount of power received by the sun in a particular area).

One of the outcomes of this recent round of reforms was Law 1715 passed in 2014 which established a basis for incorporating renewable energy (solar, wind, and mini and micro-hydro) into the national energy system. This law established the legal framework and instruments for the use of these energy sources, generally referred to as non-conventional energy sources in Colombia and created tax incentives for investments in this sector. More recently, in February 2018, the electricity-sector regulator CREG issued a ruling, Resolution 030, which set out the regulations under which electricity customers are allowed to generate up to 1 MW of electricity for self-consumption with the option to sell any surplus power into the system.

The current level of both utility scale and behind-the-meter variable renewables is quite low, although it is expected to grow quickly. UPME, has identified 0.7 GW of distributed solar generation and 0.6 GW of smaller plants and cogeneration. When added to the current 1.1 GW of smaller plants connected to the national electricity system this means that 2.4 GW of DER will be connected to the Colombian Electric System in the coming years without taking into account distributed residential generation which will likely grow substantially due to CREG Resolution 030 (UPME, 2018).

DER is an important feature of Smart Grids Colombia's Visión 2030 (InterAmerican Development Bank [IDB], 2016), a report carried out by the IDB for UPME which outlines a pathway to smart grids for Colombia. The report calls for development of behind-the-meter distributed generation, energy storage, and telemetered demand response capabilities, as well as electric-vehicle-to-grid capabilities. If the 3-phase timeline of this plan is followed, Colombia will have 20-60 MW of behind-the-meter distributed generation by 2020, 90-120 MW by 2025, and 240-600 MW by 2030, at which point DER will have reached between 1 and 2.5% of its potential. During this third phase, some storage capabilities will also be added, between 0.1 and 0.3% of total potential. DR for C&I users is planned for this first phase, TOU rates are planned for the second phase, and residential DR is planned for the third phase.

Current plans are that by 2030, 95% of all customers in the cities will have AMI and in the rural areas, 50% of users will have AMI. Within the next year the Government plans to issue public policy and guidelines for CREG and to develop measures to develop dynamic and feasible plans to implement AMI and DER. Recently, Colombian Government sources stated that while there is no current discussion on DER; and that existing DER is primarily focused on either self-generation or off-grid support, new initiatives are expected shortly. (USEA-USAID Course, 2019)

Progress

Some initial efforts were begun in 2016, including a pilot program that CODENSA, an energy distributor, conducted between 2016 and 2017, therein which 1,813 smart meters were installed for a group of large users (Comunicados/Co, 2016). Since this pilot was begun during a Niño year, it is probable that these smart meters were used for DR, and there is no evidence that it was combined with any other form of DER, such as solar panels, to produce electricity and sell any excess production. Furthermore, there are no signs that CODENSA is planning to continue this pilot program, or to make it available to all of its customers any time soon. Indeed, without government incentives or requirements, it is difficult to see why distributors would want to set up such a program, which will only reduce their billable demand.

Another distributor, Celsia, has been somewhat more active in promoting DER, and their efforts appear to be focused on behind-the-meter solar panels. But with solar installations on 15 roofs, and another 23 in development, they have a long way to go before these installations begin to have a measurable impact on demand. Their model, in which they sign PPAs with the companies acquiring such panels; and Celsia installs and maintains the panels, is more likely to be of interest to large users, which would exclude most residences, and indeed their promotional material is aimed at businesses, rather than residences (Celsia, 2017b and 2018).

The lack of programs aimed at residential customers means that solar installations so far are being installed mostly by larger electricity customers such as shopping malls or factories with space enough to install a significant number of solar panels and electricity bills large enough to make the needed investments worthwhile. These investments have been given a push by Resolution 0549, implemented by Colombia's Ministry of Housing in 2017 which mandates a 20% reduction in net billable energy consumption for all new low-income housing developments, and for shopping centers, hospitals, schools, hotels, and offices over a certain size. One of the options for achieving this reduction is the use of solar panels. For the moment, this requirement plus the fiscal incentives offered by Law 1715 are the only government incentives for solar panels in Colombia (Celsia, 2017a).

In the area of DR, progress was initially much quicker. During the last Niño in 2016, CREG released Resolution 029 establishing a program of electricity tariffs to promote voluntary reductions in energy consumption. This program, called "Apagar paga" (turning off pays), brought consumption down from levels of around 5% **above** the previous year in January and February, to almost 6% **below** during that period. Broken down by regulated vs non regulated customers, the level of demand response is even more impressive: while regulated consumption **increased** by 1%, non-regulated consumption **decreased** by 1.7% (Portafolio, 2016). At least one of the demand response efforts, on the part of EMCALI, a distributor in the Northwestern part of Colombia, included a smart grid pilot program with provider Innovari to test demand response for a number of large users (EMCALI, 2019).

The battery storage market is not well developed; however, the government has recently begun planning a pilot project in the service territory covered by Electricaribe, a distribution utility with chronic delivery issues, which led to the government taking receivership of the company. This pilot program will provide practical experiences with battery storage which should help incorporate this electricity resource into regulations and planning, and onto the grid.

Potential

The potential for DER in Colombia is huge. The cost advantages of solar panels in a country with a high level of solar irradiance make behind-the-meter solar a good investment for Colombia, although careful monitoring of high levels of solar penetration may lead to additional challenges such as large ramp requirements as seen in the western US. Initial efforts with DR have been promising and the next Niño (or the threat thereof) should give new impetus to DER efforts in Colombia and jump start the kinds of policies needed to encourage the installation of smart meters, advanced metering infrastructure, storage, and solar panels that experts have been advocating for years. It is probable that DER in general, and DR in particular, will then follow the route they seem to be taking in other markets, where they will be increasing integrated into the grid as additional resources for balancing the grid rather than being seen mainly as a means of avoiding load shedding during Niño years. That said, there remains a big opportunity for demand response to get into the Colombia market early and create meaningful impacts.

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