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Packages of Distributed Energy Technologies Demonstrating Demand Flexibility at Community Scale

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Packages of Distributed Energy Technologies for Demonstrating Demand Flexibility at Community Scale

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Acronyms and Abbreviations

ACEEE	American Council for an Energy Efficient Economy
AMI	Advanced Metering Infrastructure
BAS	Building Automation System
BEM	Building Energy Modeling
BESS	Battery Energy Storage System
BTM	Behind the Meter
CAISO	California Independent System Operator
DCM	Demand Charge Management
DER	Distributed Energy Resource
DERMS	Distributed Energy Resource Management System
DF	Demand Flexibility
DOE	Department of Energy
DR	Demand Response
EV	Electric Vehicle
EMIS	Energy Management Information System
EULP	End Use Load Profile
GEB	Grid-interactive Efficient Building
GHG	Green House Gases
HEM	Home Energy Monitor
HIL	Hardware-in-the-Loop
HVAC	Heating, Ventilation, and Cooling
KW	Kilawatt
HOA	Homeowners Association
HP	Heatpump
HPWH	Heatpump Water Heater
IAQ	Indoor Air Quality
LBNL	Lawrence Berkeley National Laboratory
LDERMS	Local Distributed Energy Resource Management System
LMI	Low to Moderate Income
MF	Multifamily
MLA	Machine Learning Algorithm
MW	Megawatt
NREL	National Renewable Energy Laboratory
NYCHA	New York City Housing Authority
OADR	Open Automated Demand Response
PGE	Portland General Electric
PNNL	Pacific Northwest National Laboratory
PPA	Power Purchase Agreement
PV	Photovoltaic

RFI	Request for Information
RTU	Rooftop Unit
SCL	Seattle City Light
TESS	Transactive Energy Service System
TOU	Time of Use
VPP	Virtual Power Plant
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
VRF	Variable Refrigerant Flow
WEIM	Western Energy Imbalance Market
ZERH	Zero Energy Ready Home

Executive Summary

The combination of increased electric load growth across all sectors, deferred electrical infrastructure investment, and other factors resulting in variable electric power supply, has created technical challenges to maintaining a resilient and reliable grid. Many federal, regional, and local efforts are in play to modernize the electric grid, including advancing building technologies and distributed energy resources (DERs) that are utilizing smarter controls to become responsive to both occupant and grid needs. This report reviews ten pilot projects demonstrating how groups of buildings combined with behind-the-meter (BTM) DERs such as electric vehicle (EV) charging, battery storage, flexible HVAC and domestic hot water systems, and photovoltaic systems can reliably and cost effectively provide grid services. Each of the ten pilot projects aim to deliver both energy efficiency and demand flexibility (DF) while supporting load growth.

The ten demonstration teams are piloting flexible DER packages across diverse communities of residential and commercial buildings to address a variety of regional grid needs. The outcomes of these pilot projects will be used to inform future scaling through utility program development. This paper characterizes the ten teams, showcasing the decision-making process used by each group to develop their packages (Section 2), the grid services they plan to deliver (Section 3), the types of DER packages selected for deployment within building sectors (Section 4) and trends between building sector, DER types, and grid services (Section 5).

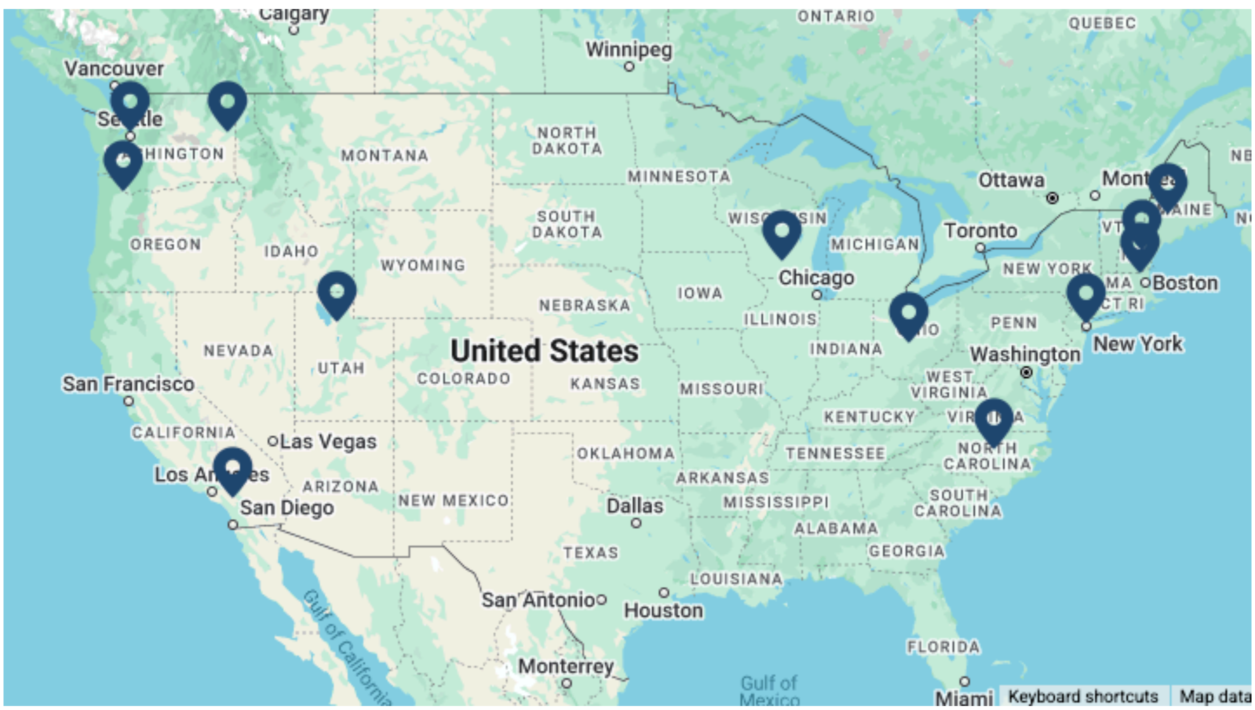

Figure ES - 1. Geographic locations of ten demand flexibility demonstration pilots

In order to achieve community scale benefits, the pilot projects must utilize aggregated control mechanisms for coordinating buildings and DERs together. Several types of coordinated control architectures have evolved amongst the teams, influenced by use type, existing market conditions, and integration type. Three coordinated controls architectures have been characterized, highlighting their use cases, benefits, challenges, and tradeoffs in their design. These insights can aid utilities, control vendors, and developers in scaling community-level energy systems (Paul, 2024).

Ultimately, the technology packages selected by the ten teams will be coordinated to provide power system services, also known as grid services. Insights from these demonstrations will be useful for grid operators, regulators, aggregators and other stakeholders as they look to deploy demand flexible resources as grid services in the future. The grid services that each team is targeting for demonstration are described in Section 3 and Section 4. Methods for evaluating the grid services have been described in the paper *Metrics for Evaluating Grid Service Provision from Communities of Grid-interactive and Efficient Buildings and other DER* (MacDonald, 2023).

To identify technology packages for demonstration, Section 2 shows that project teams used a range of analysis approaches, including building energy modeling, AMI data analysis, cost-benefit frameworks, and utility pilot data. Some teams emphasized technical modeling to quantify grid impacts and demand reduction potential, while others prioritized economic evaluations, stakeholder input, or exploratory pilots to inform deployment decisions. This diversity reflects the need to tailor selection methods to project goals, available data, and organizational context.

Section 5 discusses trends between the DER technologies deployed and the grid service provisions from each team. Residential buildings (multifamily and single family) lean towards technologies that enhance energy efficiency (e.g. weatherization upgrades, smart thermostats) and onsite power generation integration (e.g. solar PV). Commercial building demonstrations prioritize technologies that ensure operational reliability (e.g. battery storage) and centralized energy management systems and optimization solutions. Teams that are deploying controllable storage-based technologies are more likely to provide grid services that require a near real-time response. Teams incorporating load shifting technologies like smart thermostats with HEMs are likely to include energy markets participation and customer bill management offerings. Campus demonstrations are adopting diverse sets of DERs to emphasize renewable generation, paired with centralized control. This section also describes technologies that were considered during project planning but ultimately excluded from final deployment.

These demonstrations reveal that effective DER package design should be tailored to building type, customer segment, and construction vintage. Multifamily buildings benefit from centralized HVAC upgrades and supervisory controls, while single-family homes are well-suited for individualized technologies like solar, storage, and smart home energy monitors. Commercial and campus settings prioritize EMIS integration and load optimization. New construction enables cost-effective integration of DER-ready infrastructure, whereas retrofits require deployments aligned with owner and tenant value streams. For utility program planners, early coordination with developers and building owners, paired with segmented and modular program offerings, can improve adoption, scalability, and grid impact.

1. Introducing Demonstration Teams

As this cohort of demonstrations include ten separate teams, each with multiple subcontracted partner organizations, it is worthwhile to introduce the team leads and how each team will be referenced in the body of this report. Table 1 showcases the lead project organization’s name, full project name in addition to the reference name to be used in the rest of the paper, the project’s primary location, and the building types and vintage they are demonstrating in. For the rest of this report, discussion about a project will lead with the team's reference name, though subsequent references in the same paragraph(s) may include "team", "pilot team" or "project team" until another team is introduced. Details about a project's subcontracted partners can be found in the Acknowledgments section of this report.

Table 1. Demonstration Project Team Names, Leads, and Locations

Project Lead	Full Project Name	Reference Name	Pilot Location	Building Types	Building Vintage
OpenMarket ESCO (OME)	Gateway Cities Unplugged: (em)Powering Affordable Housing	"Team OME"	New England	Multifamily	Existing
Electric Power Research Institute (EPRI)	Deep Efficiency and Smart Grid-Integrated Refrofits for Disadvantaged Retrofits (DESIRED),	"Team EPRI"	Seattle, WA and New York, NY	Multifamily	Existing
PacifiCorp	UDERMS iCommunity	"Team PacifiCorp"	Utah	Multifamily, Commercial, Light Manufacturing, Campus	Existing
Edo	Spokane Connected Community	"Team Edo"	Spokane, WA	Single family, Commercial, Campus	Existing
University of California, Irvine (UCI)	Connected Residential Communities with Enhanced Resiliency and both Customer and Utility Attributes	"Team UCI"	Menefee, CA	Single family	New Construction
IBACOS, Inc	Advanced Clean Communities Collaborative (AC3)	"Team IBACOS"	North Carolina	Single family	Existing and New Construction
Post Road Foundation	Evaluating Transactive Energy for Rural America	"Team Post Road"	Maine	Single family	Existing

Project Lead	Full Project Name	Reference Name	Pilot Location	Building Types	Building Vintage
Slipstream	Connecting Communities for Sustainable Solutions	“Team Slipstream”	Madison, WI	Commercial	Existing
The Ohio State University (OSU)	OSU Connected Community: Automated Building Control with Knowledge of Distributed Energy Resources and Electrical Systems for Grid Offerings	“Team OSU”	Columbus, OH	Campus	Existing
Portland General Electric (PGE)	SmartGrid Advanced Load Management & Optimized Neighborhood (SALMON)	“Team PGE”	Portland, OR	Multifamily, Single Family, Commercial	Existing

2. Technology Package Selection Decision Making Process

In the early phase of project development, each of the teams underwent a lengthy decision-making process to determine the DER technology packages best suited for their demonstration’s building types and grid challenges. The requirements for each project were to demonstrate improvements in energy efficiency, provide load flexibility capabilities while maintaining comfort and performance, and include at least two types of DERs (such as PV, electric vehicles, electrical or thermal energy storage) installed at the building level or community scale.

All teams developed decision-making frameworks that balanced several factors, including developing standardized solution packages for their project’s market segment(s) with cost effectiveness and future scaling in mind. Final package selection also considered the value to the grid for a given program budget. This section details some of the considerations that teams undertook in their decision making frameworks. Some teams undertook a load flexibility assessment driven by the grid challenges they were seeking to solve. Projects driven by a utility stakeholder often took a simulation modeling approach using data from their distribution networks. Other teams took a techno-economic analysis to determine which technologies could provide the most benefits compared to the cost of implementing a customer program. Projects working with existing buildings or homes also had to consider the existing infrastructure or building systems in place. Teams that did not incorporate upfront customer cost/benefit analysis as part of their selection process will assess their demonstration results from a customer cost/benefit perspective as part of their project evaluation to inform packages that would move forward to scale. Table 2 lists the project leads and the decision making frameworks utilized to arrive at their DER technology packages, which are described in detail in the following section.

Table 2. Decision Making Frameworks Used to Develop DER Technology Packages

Project Lead	Modeling / Simulation	Cost - Benefit Analysis or Economic Framework	Use of Existing Utility Pilot(s) Performance Data	Institutional Stakeholder Buy In	Pilot Learning - Exploring All DERs
OME	✔	✔			✔
EPRI	✔	✔	✔	✔	
PacifiCorp					✔
Edo	✔	✔	✔		
UCI					✔
IBACOS, Inc	✔	✔	✔	✔	
Post Road					✔
Slipstream			✔	✔	✔
OSU	✔	✔		✔	
PGE	✔			✔	✔

2.1 Modeling and Simulation-based Approach

Team IBACOS' project will demonstrate how a diverse ecosystem of DERs integrated through a virtual power plant (VPP) can be coordinated with appropriate pricing signals to support grid reliability and utility resource adequacy while delivering meaningful customer and community benefits. Team IBACOS's modeling approach looks to identify the most impactful energy intensity reduction strategies against existing equipment found in the manufactured housing population in North Carolina.

At the core of Team IBACOS' project is a database being constructed in Amazon Web Services (AWS) that will host data collected on up to 1,000 new and existing homes across North Carolina. The database will house AMI data and outputs from HEMs, smart energy panels, solar and battery inverters, and EV chargers. The database will also host information from Duke's customer programs and integrated systems operations. The AWS database will align data from all sources onto a common timestamp so analysis can be provided that shows how a fully orchestrated VPP operating in the residential market is working. The IBACOS project is in the buildout phase for both new and existing homes and is beginning preliminary analysis on data from approximately 200 homes. For example, Figure 1 shows an initial analysis of water heater use data collected from project homes comparing average use for new construction single family homes using 100% heat pump water heaters (HPWH) and existing single-family homes that are 100% electric resistance water heaters. As their project advances, Team IBACOS will use the database to complete other analyses that support Duke's business goals and grid operations, such as the impact of connected devices on the distribution grid, the economic benefits of connected devices on grid reliability and resiliency, and informing the development of new business models.

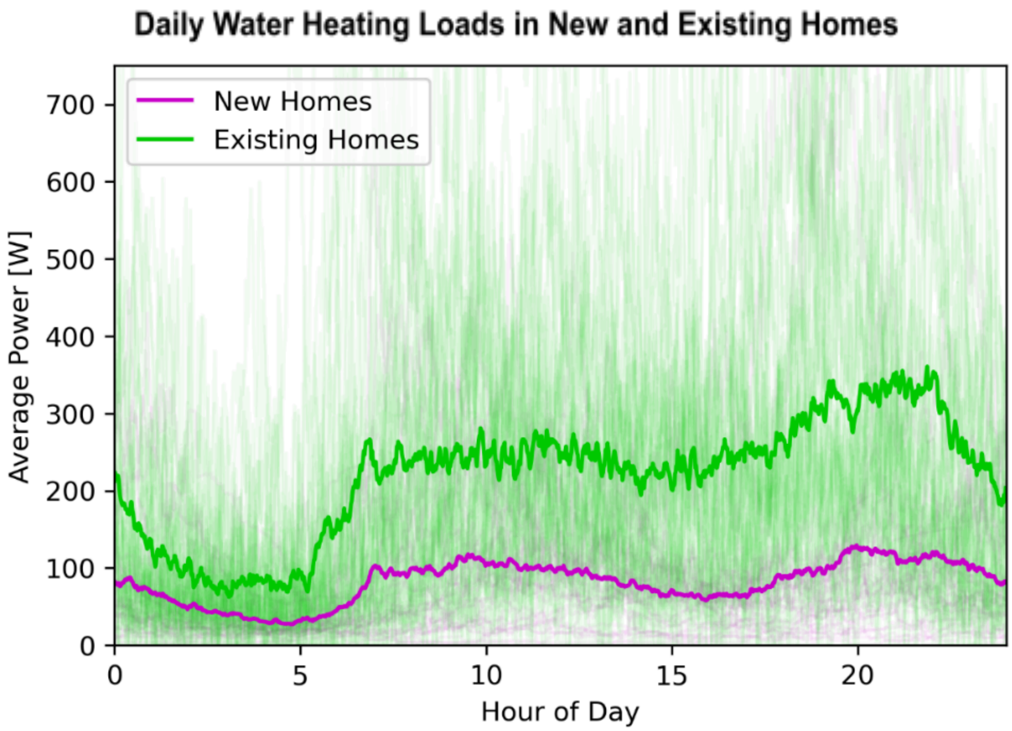

Figure 1. Preliminary analysis of data from HEM systems installed by the IBACOS' project comparing water heating loads in new construction single family homes (100% HPWHs) and existing single-family homes that are 100% electric resistance water heaters.

For assessing technology packages to deploy in the pilot, the team is leveraging a machine-learning algorithm (MLA) developed through a small pilot study conducted in 2018 on a population of 29 manufactured homes in Duke Energy's territories in North Carolina. In this pilot, HEM systems were installed in the study homes and data collected for equipment-level electricity at one-minute intervals on all HVAC and hot water heating circuits, as well as main panel usage and circuits serving other loads. After collecting data on the pilot homes for 18 months, customer AMI data was combined with each of the 29 home's HEM data. The MLA was written to define optimal retrofit packages for the existing homes based on existing HVAC equipment, the frequency of heating equipment demand spikes, and energy intensity determined by AMI data.

The calibrated MLA was then used against Duke AMI data for a larger dataset of 77,000 manufactured homes. Homes were binned according to the most beneficial upgrade measures, including 1) shell upgrades (e.g., insulation and air sealing), 2) high-efficiency HVAC equipment upgrades, or 3) a combination of both types of measures. Figure 2 provides the output from analysis that shows the recommended upgrades for the full population of manufactured homes using the MLA adapted from the smaller study.

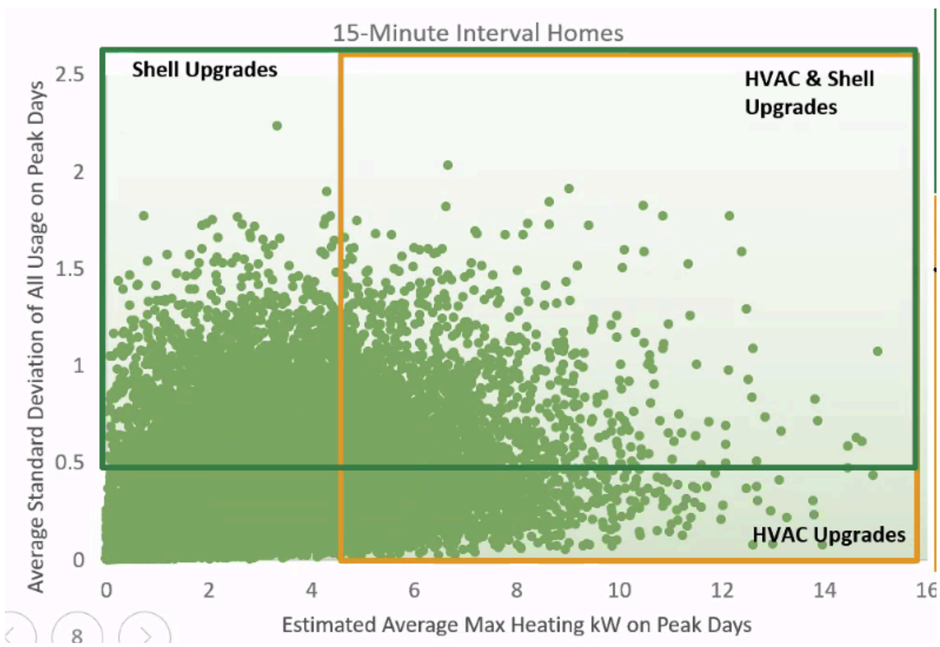

Figure 2. A residential home heating algorithm applied to Duke Energy's AMI data for roughly 77,000 manufactured homes identifies which homes are best fit for targeted retrofit packages that include shell upgrades, HVAC upgrades, or both. Source: Tierra Resources Consulting

Team PGE and its partners are taking a community modeling approach using **NREL**'s OpenDSS[1] system to assess the impact of various DER scenarios against multiple distribution feeder use cases. As the first step to their analysis, NREL built a Digital Twin-like community model that is comprised of a collection of single building OCHRE[2] models, which in aggregate will represent the customer buildings located within the two feeders that PGE plans to target for DER deployment. AMI data from PGE was used to calibrate the individual building models where data was sufficient, or else estimated from a baseline simulation.

Using the community model and a distributed energy management system (DERMS) platform implemented in a laboratory simulation, NREL is performing co-simulations to estimate the maximum

[1] https://www.nrel.gov/grid/distribution-integration.html
[2] https://www.nrel.gov/grid/ochre.html

grid benefit of a potential DER using assumptions around the number of enrolled devices as it relates to a variety of grid services. Figure 2 shows a representative community model analyzing the impact of aggregated DER impact for voltage support on the targeted feeders. Community modeling of DER benefits will be followed with field demonstrations of select DERs. PGE seeks to build 1.4MW of flexible load resources in their targeted community and will use the full co-simulation analysis paired with field study outcomes to determine the final DER packages and grid services to scale to market.

In parallel to the co-simulation analysis, PGE's customer program team has been engaging customers and identifying steps needed to update or begin new programs to prepare for deployment at scale. They are focused on providing additional incentives to increase participation and enable efficiency projects to be no or low cost to all. PGE's target audience includes residential customers, small to medium business owners, and large commercial. The neighborhood, however, is primarily residential, so significant consideration toward home owner education and activation is necessary for the success of the project.

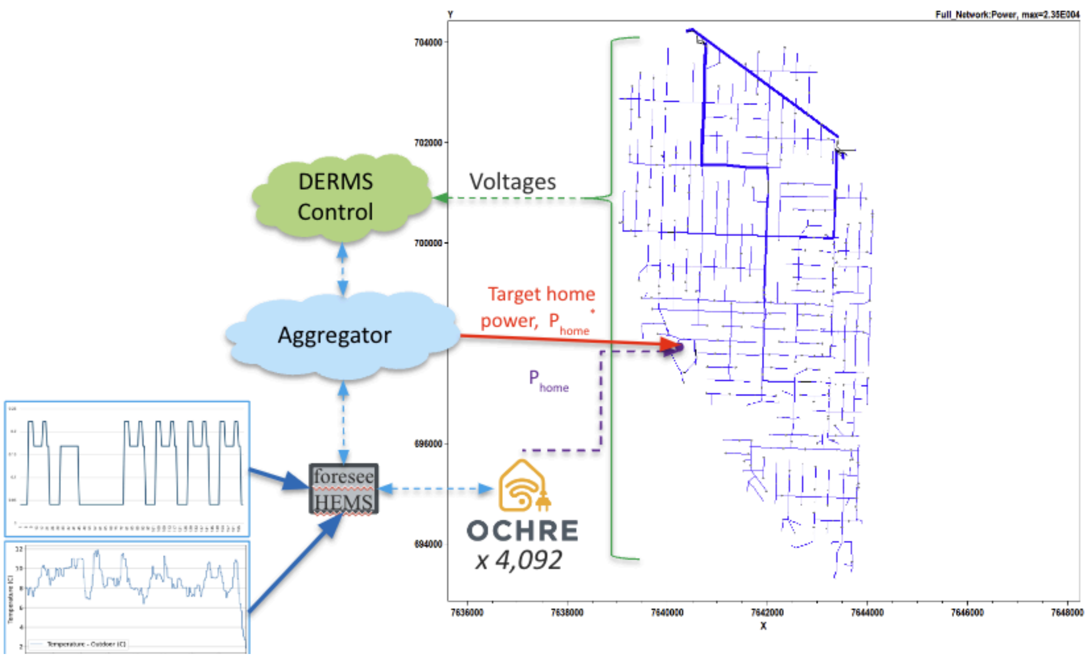

Figure 3. NREL developed a community model based on aggregated OCHRE models to analyze how voltage support will be impacted by a variety of DERs in PGE's two targeted feeders. Other grid services will be evaluated using a similar approach. Source: NREL

2.2 Modeling Paired with a Utility Program Administration Cost Benefit Analysis Framework

Team Edo and utility partner **Avista** used building energy modeling (BEM) to inform the development of solution packages for different customer building segments, in addition to experiences from Avista's prior customer program pilots. BEM was used to inform the development of solution packages for each customer group. The team utilized customer metadata and AMI data to develop a set of customer building segment demand curves to represent a peak demand event on the Spokane substation of interest. Using AMI interval data, the team then evaluated the impact of individual buildings on the overall substation's load profile, temporal impacts of electric demand, feeder congestion during extreme weather events, and the role of different building types and their contribution to the substation's overall load profile.

To estimate the demand reduction for various technology solution packages for each customer segment, the team selected stock models from NREL's End-Use Load Profiles for the U.S. Building Stock (EULP) dataset[3], which consists of approximately 900,000 Openstudio models created with ComStock[4] and ResStock[5] tools.

Models were used to compare the demand reduction for potential technology solution packages and differing levels of active control on demand reduction for a particular stock building. Model results were aggregated to understand the representative load reduction on Avista's target substation.

A decision-making simulation framework was then developed to evaluate the cost to deploy the technology packages across the customer base, considering Avista's program recruitment budgets. Cost estimates were provided for each solution package, including both installation and Avista incentive program administration costs to inform calculation of the overall program performance. This framework was used for Edo's initial assessment of the solution packages and recruitment strategy and will be continuously assessed as necessary by the project team.

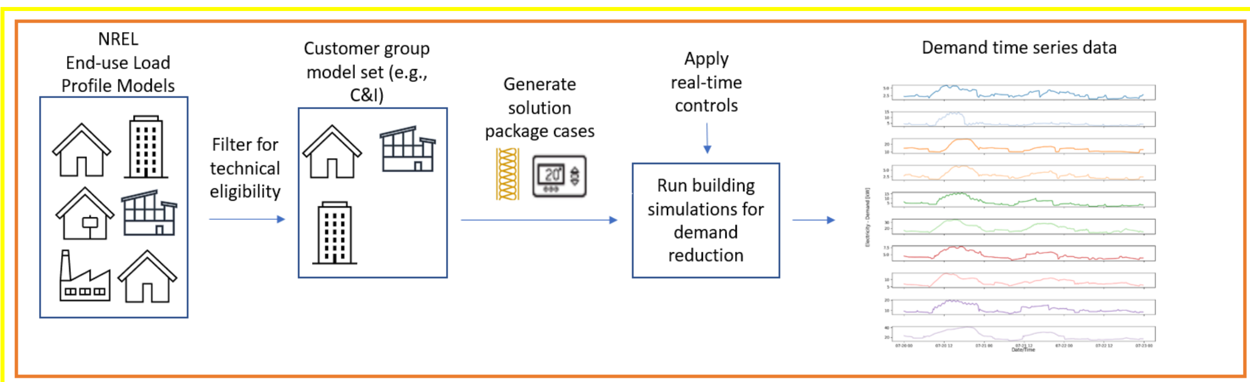

Figure 4. Edo's simulation framework for evaluating DF controls for solution packages applied to varying building characteristics using NREL's Comstock and Restock models developed for the Spokane, WA region.

In addition to the technical evaluation, Edo and Avista worked together to develop a new tariff, approved by the Washington Utilities & Transportation Commission, to allow payment of direct financial benefits to customers for participating in DF programs. Residential and small commercial buildings will

[3] https://www.nrel.gov/buildings/end-use-load-profiles.html#dataset
[4]Data includes information from the ComStock™ dataset developed by the National Renewable Energy Laboratory (NREL) with funding from the U.S. Department of Energy (DOE)
[5] Data includes information from the ResStock™ dataset developed by the National Renewable Energy Laboratory (NREL) with funding from the U.S. Department of Energy (DOE)

receive a monthly participation credit and additional performance credits. Large commercial participants are eligible for a DF capacity payment and additional performance credits.

2.3 Modeling Paired with Multi-Stakeholder Cost Benefit Analysis Framework

Team EPRI also took a BEM approach to develop technology packages for each of their multifamily housing communities in Seattle City Light's territory. Data used to progressively calibrate the model included monitored public data (e.g. benchmarking disclosure data), AMI data, and weather data scaled from field demonstration to the portfolio level, and then to city scale.

A cost-benefit framework was then used to identify the technology options that drive value for the customer (building owners), the utility, and to society at large (Sankaranarayanan, 2024). In EPRI's value assessment framework (Table 3), cost and benefits includes first costs, operating costs, primary value dimensions, and decision tradeoffs. For the customer, building owners of the communities, first and operating costs include equipment and labor costs to implement electrification measures, followed by the utility bill costs following the retrofit.

For Seattle City Light (SCL), their first cost parameters included costs to upgrade distribution systems to accommodate load growth, plus the additional on-bill revenue from switching customers from gas to electrified systems. The decision matrix is a function of the tradeoff between the primary lifetime values for all three stakeholders. EPRI aimed to identify solutions that provided positive values for all 3 stakeholders on a site-by-site basis. Details for how the models were calibrated can be found in an ACEEE Summer Study 2024 paper authored by S. Sankaranarayanan called *Techno-economic Analysis of High Efficiency and Connected DERs for Connected Communities: A Case Study in Seattle, WA*.

Table 3. EPRI's Value Assessment Framework for Cost-Benefit Analysis

	Utility	Customer	Society
First cost parameters (-)	Distribution upgrades needed to accommodate electrification Customer acquisition (incremental administrative costs)	Equipment and labor cost of electrification measure Retrofit cost to enable electrification (wiring, panel upgrade, disposal of old equipment)	Federal and state incentives
Operating cost parameters (-/+)	On-Bill Revenue	Increase/decrease in bills	Rates for electricity and natural gas Societal benefits

	Utility	Customer	Society
Primary value dimension	Lifetime value of Infrastructure Upgrade Investment	Lifetime value of Electrified End-Use	Projected grid performance gains such as reliability improvements
Decision Tradeoff	Incremental peak demand, On-bill revenues	First cost, operating costs	Societal benefit

Assessment about which technologies to deploy required consideration of tradeoffs between the 3 stakeholders. First costs were compared to operating cost savings, in addition to peak load changes due to the increased electric loads. Three of the five apartment communities in Seattle performed at high energy efficiency with packages of heat pump measures electrifying HVAC load. Higher potential operating costs for HPs for the customer, however, will require more active load management to help reduce customer cost increases. EPRI measured demand flexibility (DF) potential using an approach that helps flatten peak loads. Most of the communities considered have high DF potential with heat pumps and heat pump water heating in the winter. In cases when the addition of an electrified heating load increases the building's peak load, active load management is needed to reduce impacts to the grid and customer bill. Almost all communities will need to include community solar PV paired with virtual net metering to improve overall operation costs for the owner and relieve customer energy burden.

To inform decision making, EPRI also used data from existing utility pilots in CA and WA for assessing the performance of 120V retrofit ready technologies such as monoblock HPs and centralized HPWH systems. They received additional institutional stakeholder buy-in by referencing SCL's assessment studies for their city-wide buildings and transportation electrification program(s), and their grid modernization studies employing the use of DF and distributed energy resource management systems (DERMS) as enablers for distribution upgrade deferral and non-wires solutions.

Team OME also took a BEM approach by developing a grid-interactive buildings (GEB) calculator designed to identify and optimize load flexibility and demand charge management (DCM) revenue opportunities by measure at the site level. This calculator is a rules-based model for determining near-optimal monthly dispatch strategies for flexible loads, which includes central HVAC equipment, serving both common area and resident units, as well as solar and battery storage (BESS). The calculator factors in details from utility programs in Connecticut, Massachusetts, and New York. The approach involves determining the storage required to achieve incrementally increasing levels of demand reduction each month and calculating the implied value per kWh of DCM at each level of demand reduction. It also identifies the inflection point at which DCM becomes less valuable than other competing operational value streams, thereby determining the target monthly demand reduction and resource allocation for each value stream by month. Hourly dispatch commands are generated to ensure that the target site-level demand is achieved, performance in non-DCM value streams is maximized, and the BESS can recharge prior to the day's performance period. Finally, the resulting annual revenue is calculated based on these optimizations. The GEB calculator was utilized for all six of Team OME's properties and can be scaled up to provide a simplified GEB evaluation tool for other multifamily building owners and operators interested in implementing DF and battery strategies.

2.4 Modeling Paired with Institutional Stakeholder Decision-making Input

Team OSU, like other campus settings, faced a complex decision making structure, and other institutional challenges common to large university complexes, when planning for their demonstration. Multiple leadership bodies meant a distributed and overlapping decision making process. Unique cybersecurity requirements also meant special consideration for any type of software solution. The physical energy infrastructure of a higher education campus is also complex, with responsibility for maintaining comfort for occupants distributed among multiple decision makers. Due to the enterprise level of effort required to manage the project, OSU took a stakeholder-driven approach to get buy-in from all potential stakeholders for the project. They first conducted interviews with key potential decision makers and found occupant comfort as a primary concern for energy related projects.

While individual buildings on campus have smart meters for their utility usage, OSU's electric utility recognizes a single meter for the campus' participation in demand response programs. The project team used OpenStudio[6], an open-source building simulation tool, to build characterization models of individual campus buildings to predict thermal conditions and model the impacts of various energy optimization. This reduced concerns due to unfamiliarity of the approaches, and helped secure stakeholder buy-in for the pilot program participation. Additional optimization strategies were modeled to understand impacts on energy consumption and demand reduction.

To help facilitate the implementation phase of the project, a stakeholder advisory board was formed to coordinate all key players required for a successful demonstration, which includes the VP of Facilities, various university-level leadership groups, student life staff who manage residence halls, the Office of IT who leads cybersecurity and the business unit of OSU that manages portfolio energy use.

As it is often not immediately clear in the higher education sector where authority is to make policy changes necessary for widespread adoption of an effort like DF demonstration, there is a clear need for universities to have a champion for such efforts.

2.5 Utility Pilot Approach, Paired with Utility/Customer Cost Benefit Analysis

Team Slipstream and its building owner partner, the **City of Madison** (CoM) worked with the local utility **Madison Gas & Electric (MG&E)** to develop a Request for Information (RFI) for energy management and information system (EMIS) technology providers that could implement their platforms in a two-phased pilot. Solution providers are first required to demonstrate the ability to integrate to the City's existing building automation system (BAS) infrastructure, plus integrate and potentially command a variety of DERs, including EV managed charging, smart inverters, and battery systems.

[6] https://www.energy.gov/eere/buildings/articles/openstudio

The first phase of the pilot focuses on deploying the EMIS to the CoM municipal buildings and evaluating its ability to integrate to the pre-selected DERs, their performance in providing load flexibility capabilities, plus cost effectiveness. For the second phase of the pilot, Team Slipstream will use lessons learned from phase one about cost effectiveness, kW impact, and stakeholder satisfaction to decide which technology packages to include in a utility pilot targeting privately owned, large commercial buildings.

2.6 Pilot Learning Approach - Exploring All DER Options

Some teams opted to deploy and assess many possible DER technologies types as part of their demonstrations, given some of the more unique aspects of their projects and applications. Similar to the other pilot projects, they will use performance evaluation from the outcomes of the demonstration to determine which technologies to scale in the future.

Team UCI's project objectives were to demonstrate that residential neighborhoods can be deployed as individual and community-scale microgrids while providing resilience benefits to customers and the grid, and provide other grid services. They worked with a developer to build connected and all electric homes certified by DOE's Zero Energy Ready Home (ZERH)[7] program, which reflect high standards for energy efficiency, air quality, and water efficiency. DERs deployed include solar, battery energy storage systems (BESS), flexible heating loads, and "vehicle-to-home" enabled electric vehicles.

Team PacifiCorp's demonstration in Salt Lake City is using a hierarchical, utility-managed DERMS control approach that integrates multiple behind-the-meter, aggregated flexible energy loads via open communication protocols that can provide bulk system grid services. They focused on enrolling fully electrified buildings and coupled distributed DERs like solar and battery energy storage to optimize energy and demand profiles.

PacifiCorp worked with several key community stakeholders as part of the project development and conceptualization phase to build upon work from existing production programs, minimize hardware deployment costs, and integrate and optimize multiple DER types. Technology selection and decision-making was handled via multiple approaches. Energy modelling was used to evaluate the baseline of the participating buildings including any existing measures present and determine if there is need for additional measures within each of the properties. Grid modelling and power flow analysis was also performed using a distribution system modelling tool to fully analyze the comprehensive impact of each participating building to ensure that the full technology packages present at each participating building do not create distribution-level violations for voltage, short-circuit analysis, or loading. Hardware-in-the-Loop (HIL) simulation is being performed to understand the impact of adding new DERs (i.e., water heater and HVAC control) at some participating buildings and to understand the impacts of the various grid services events and any associated device-level control parameters (kW reduction, % load reduction, pre-cooling, etc.). Financial analysis is also being leveraged as part of the device selection process with high consideration for minimized integration requirements by leveraging existing PacifiCorp systems or integrations. As some of the technology at the participating locations

[7] https://www.energy.gov/eere/buildings/zero-energy-ready-home-program

was existing, and part of the location selection process, there is a certain amount of existing program performance data that the team can leverage as part of the analysis (i.e., BESS, solar inverter, and EV chargers at Utah State University). Institutional stakeholder buy-in is also critical for Team PacifiCorp's community for the consideration of new devices at each customer location.

Team Post Road's transactive energy platform will enable a "prices-from-devices" coordination strategy to enable load flexibility in residential homes. As such, their project is vendor and DER-type agnostic and their system can be used to orchestrate a diverse mixture of EVs, HVAC loads, controllable water heaters, batteries, thermal storage, and solar. Their efforts in the pilot include lab tests to ensure that qualified DERs can successfully integrate into their software before deploying a field pilot in rural Maine.

In conclusion, the cohort of ten pilot teams reveal that successful DER package selection requires a highly contextualized and often multi-pronged approach, influenced by building type, existing infrastructure, utility engagement, and customer demographics. Teams used diverse methods ranging from advanced building energy modeling, (e.g., Team Edo), techno-economic assessments (e.g., Team EPRI), stakeholder-driven processes (e.g., Team OSU), and pilot-based exploratory learning approaches (e.g., Team UCI and Team Post Road). A key takeaway is that utility-involved teams were more likely to leverage granular AMI data and incorporate grid modeling to target specific constraints, while community or institution-led projects prioritized stakeholder alignment and retrofit compatibility. Across the board, DER package development benefited from integrating past pilot data, especially where existing systems or customer relationships could be leveraged for deployment at scale.

3. Demand Flexibility Demonstrations and Grid Services

Each pilot team will be demonstrating and evaluating the ability of their DER packages to provide select grid services, shown in Table 4. The potential grid services include bidding their communities' assets into wholesale energy markets, providing bulk system transmission services, providing distribution-grid services, and strategies to manage customer bills. Wholesale energy market programs include day-ahead markets, imbalance or real time markets, capacity markets, and ancillary services. Transmission grid services include economic energy dispatch, forward capacity, voltage support, frequency regulation, and frequency response programs. Distribution grid services include emergency load transfer, voltage management, and capacity relief programs. Customer bill management strategies include proactive management of peak loads and optimizing billing in reference to time-of-use (TOU) rates. These grid services are further described in MacDonald 2023.

Table 4. Pilot Teams by Grid Services Provision

	Energy Markets				Transmission Services						Distribution Services			Customer Bill Management	
	Day Ahead Energy	Imbalance (Real TIme)	Capacity	Ancillary Services	Economic Energy Dispatch	Forward Capacity	Voltage Support	Frequency Regulation	Frequency Response	Contingency Reserves	Emergency Load Transfer	Voltage Mgmt	Capacity Relief	Peak Load Mgmt	Tariff Optimization (TOU Rates)
OME	✔				✔	✔							✔	✔	✔

	Energy Markets				Transmission Services						Distribution Services			Customer Bill Management	
	Day Ahead Energy	Imbalance (Real TIme)	Capacity	Ancillary Services	Economic Energy Dispatch	Forward Capacity	Voltage Support	Frequency Regulation	Frequency Response	Contingency Reserves	Emergency Load Transfer	Voltage Mgmt	Capacity Relief	Peak Load Mgmt	Tariff Optimization (TOU Rates)
EPRI		✔	✔		*exploring all bulk system services*							✔	✔	✔	✔
PacifiCorp									✔	✔			✔	✔	
Edo													✔		✔
UC Irvine	✔			✔			✔	✔			✔		✔	✔	✔
IBACOS, Inc				✔			✔		✔				✔	✔	✔
Post Road				✔		✔							✔	✔	✔
Slipstream					✔							✔	✔	✔	✔
OSU	✔			✔						✔			✔	✔	
PGE	✔	✔			*exploring all bulk system services*							✔	✔	✔	✔

4. DER Technology Packages by Building Types

As utility customer programs are typically segmented into customer sectors by building type, it is worth discussing the technologies being deployed based on their market segment and the challenges and opportunities unique to each segment. Table 5 shows the building types each team is focused on, which include multifamily residential, single family residential, commercial, light manufacturing, and university campus.

Table 5. Teams Demonstrating in Multiple Building Types

	Multifamily Residential	Single Family Residential	Commercial	Light Manufacturing	Campus
OME	✔				
EPRI	✔				
Pacificorp	✔		✔	✔	✔
Edo		✔	✔		✔
UC Irvine		✔			
IBACOS, Inc		✔			

	Multifamily Residential	Single Family Residential	Commercial	Light Manufacturing	Campus
Post Road		✔			
Slipstream			✔		
OSU			✔		✔
PGE	✔	✔	✔		

4.1 Multifamily Residential

Five of the ten pilot teams are deploying DER technologies in multifamily (MF) residential buildings. Multifamily is a challenging sector to implement energy projects in as landlord-tenant split incentives often make it difficult to align value streams between owners and residents and overcome first cost barriers. Multifamily represents 17% of residential energy use in the U.S., but it is difficult to quantify the value of opportunity for DF in this sector (ACEEE, 2020). Gaining visibility into energy use and load flexibility opportunities in MF buildings are unique challenges for landlords when tenants are directly metered for their electricity use. Several of the MU demonstrations are also focusing on Low to Moderate (LMI) communities or have significant units of affordable housing. Limited technology integration and lack of smart meters and access to real time data are additional challenges.

The pilot teams deploying in MF communities are identifying technology packages that can demonstrate a significant scale of DER implementation in a challenging sector and benefit their tenants, for whom energy bills can be a significant cost burden.

Team OME is designing GEB packages for six (6) existing affordable and mixed-income multifamily housing communities representing 1000 homes in Connecticut, Massachusetts, and New York. OME is a subsidiary within WinnCompanies (Winn), a national developer, owner, and manager of multifamily housing. OME was founded in 2009 as a vehicle to develop and manage energy related projects for their real estate portfolio. Winn's demonstration focuses on master metered buildings, where the landlord takes on the cost of utilities, paying a significant amount of money for electricity. Without the complexity of landlord-tenant split incentives, and higher/larger demand use profiles to manage, Winn can more directly make financial decisions about technology adoption, maximize the full value of demand response participation, and collect data to quantify the impact of demand flexibility in the MF sector. Team OME’s goals focus on the building operators as the core customer and aim to demonstrate that financial pathways exist for affordable MF housing to adopt grid flexible technologies to reduce energy costs and explore new approaches for resilience and load flexibility in vulnerable communities.

At the building level, OME will deploy:

1. Supervisory controller to receive demand signals and send control signals to downstream flexible technologies
2. Solar PV and smart inverters to modify overall load shapes

3. Battery energy storage systems
4. EV charging stations
5. BAS to enhance and optimize central HVAC load including a central chiller and make up air units for conditioning common areas and apartments
6. Smart thermostats to control central HVAC loads by adjusting in-unit fan coil units

Within the residential unit level, OME will deploy:

1. Smart thermostats to adjust in-unit heating and cooling

For grid services, OME will utilize its supervisory controller to participate in ISO-New England's **forward capacity, economic energy dispatch, and day ahead markets**, utility demand response programs from Eversource and National Grid, and **peak shaving** for bill reductions.

Team EPRI is leading a bi-coastal effort to retrofit multifamily housing communities in diverse climate zones while efficiently aggregating and increasing the availability of DERs to provide multiple grid services. The focus on multifamily housing communities in New York City and Seattle means overcoming split incentives between decision makers (building owners) and those who benefit from energy upgrades (occupants), a challenge when deploying energy projects in this sector. Their goals for determining good fit technology packages are to reduce overall operational costs for the building operators and reduce energy burdens for the building occupants. For these projects to succeed, EPRI understands that robust customer engagement is needed to help with resident participation, in addition to prioritizing the reduction of impact to residents as part of the controls design.

In NYC, Team EPRI is working with **New York Power Authority (NYPA)**, which provides power for all public buildings in the State of New York, including the affordable housing stock owned and operated by the **NYC Housing Authority (NYCHA)**. NYCHA's energy load is a large portion of NYPA's overall usage and both can benefit from improving energy efficiency within the building stock and reducing capacity. As NYC has passed a local law that enforces energy performance for large buildings based on their size and usage type, the team aims to address these targets by including HPs and HPWHs in their community retrofits. Multifamily buildings, especially public housing entities, are financially constrained, making investing in new technologies especially difficult as they can have significantly high first costs.

At two master-metered NYCHA demonstration sites where HVAC loads are submetered, EPRI will deploy new technologies that can also provide load shedding:

1. Variable refrigerant flow (VRF) system, with dedicated outdoor units per tenant space, and in unit packaged heat pumps (HP)
2. Heat pump water heater (HPWH)
3. Energy management system for supervisory aggregated control of HVAC units, thermostats, and water heating loads

In addition, a local controller with EPRI's open-source DERMS software installed will control EV fleet charging at the NYCHA Long Island City office. For grid services, EPRI will explore **bulk system**

services through flexible load aggregation, load shifting, and optimal DER management using day-ahead pricing as a control signal.

In Seattle, EPRI is partnering with **Seattle City Light (SCL)**, the local power provider that maintains an extensive distribution network across the city along with hydropower generators in the Pacific Northwest. SCL is focused on addressing their increasing load growth needs, particularly with heating loads. As a nonprofit municipal utility, SCL seeks to limit rate increases by avoiding or deferring distribution upgrades by deploying more demand flexibility to encourage customer adoption of technologies such as HPs, HPWHs and EVs.

Across a portfolio of 6 buildings that have in-unit metering, Team EPRI will deploy:

1. Rooftop Solar PV to 5 of 6 buildings to help improve customer bill savings
2. 4 of 6 communities will have weatherization upgrades
3. 4 of 6 communities will have 120V HPs
4. 2 buildings will replace gas boilers with HPWH
5. V2G-enabled EV charging equipment at 2 properties
6. An EMIS installed, enhanced with EPRI's local DERMS (L-DERMS) for grid controls

In this project, Team EPRI will demonstrate **congestion relief** through reducing baseline energy consumption and control strategies with flexible loads and EV charging to **reduce coincident peaks** driving feeder level peak loads. SCL will also be testing **Time-of-Use** (TOU) rates as part of the study. The study will also help to develop more realistic models of demand flexibility-based generation capacity availability for contribution to SCL's participation in the Western Imbalance Market (WEIM), a wholesale energy market operated by the California Independent System Operator (CAISO).

Team PacifiCorp, a vertically integrated utility and its Utah-based teaming partners are delivering a project that is targeting a diverse set of approximately 7 buildings, including a large market rate suburban apartment building and a mixed-income urban multifamily complex. PacifiCorp is hosting a **DERMS** that will communicate via open standards such as Open Automated Demand Response (OADR) and DNP3/IEEE2030.5 to integrate with a downstream Aggregator, a battery grid management system, and the various participating buildings. A hierarchical communication structure using OADR and DER-specific protocols eliminates the need for the utility to communicate directly with devices.

Team PacifiCorp is deploying energy efficiency measures at three of its mixed-income all-electric MF properties (Citizens West, Project Open I, and Project Open II), allowing the owners to offer lower energy costs to tenants. These projects provide additional proof that high density, all-electric buildings can lower energy costs for residents and be more cost effective than traditional construction.

At the building level, Citizens West will deploy the following technologies to deliver grid services and optimize local loads:

1. Solar PV
2. Battery storage
3. Community EV charging

4. Centralized HPWH

Within the residents' units, Citizens West will have:
1. Smart thermostats
2. Mini-split HP controllers

At Project Open I and II, Team PacifiCorp will deploy:
1. EV charging

Soleil Lofts, a high-performance all-electric luxury MF residence, will participate in Rocky Mountain Power's WattSmart battery program, allowing the landlord to earn bill credits for common area electricity use flexibility. Soleil Lofts will have:
1. 12.4MWh of a BESS located in a common area of the complex and within 600 individual resident units, integrated into a VPP for grid dispatch
2. 5 MW of rooftop solar panels

This demonstration will help Team PacifiCorp evaluate the viability of strategic aggregation and deployment of DER bundles in wholesale markets to support the potential for inclusion of this model in the utility's future Integrated Resource Planning. The grid services targeted include **peak load management**, **frequency support,** and **contingency reserves**. The objective is to effectively integrate intermittent renewable resources, enhance resiliency and outage response at the distribution level and ensure resource adequacy during periods of disruption.

Team PGE and its partners are taking an in-depth community modeling approach to assessing the impact of various DER scenarios for its bulk system and/or distribution use cases. The targeted demonstration area is a low-to-moderate income block of Portland that features a diverse mix of building types, including multifamily properties. DERs being assessed for load flexibility include batteries, EV charging, smart thermostats, and heat pump water heaters. PGE will use the scenario analysis to determine the final DER packages and grid services to bring to market.

Once DERs are selected and deployed, PGE aims to demonstrate that DERs can be used as a resource for **voltage management**, **frequency response**, and **bulk service provisioning**. PGE is working with Energy Trust of Oregon to support enrollment of multifamily water heaters.

4.2 Single Family Residential

Single family homes are the greatest sector by quantity of buildings represented across the ten demonstration projects. Two of the ten teams are addressing single family new construction homes, one in a market rate setting on the Southwest climate and another in a low-to-moderate income (LMI) setting on the east coast. These teams require strong partnerships between the DER providers, local utilities and the home builders in order to develop business models where a flexible, smart home can scale cost effectively during construction, valuation and purchase, and during occupancy. Another two teams are looking to demonstrate load flexibility in existing single family homes where local grid constraints are requiring utilities to deploy demand side customer programs. In both newly constructed and existing homes, single family residential pilot teams are developing methods and tools to engage and educate homeowners and other market stakeholders around grid flexibility.

Team UCI are demonstrating resiliency and load flexibility at two communities of new construction homes, located in southern California where wildfire risk is high. The communities feature 219 all-electric homes and will host a connected microgrid with both behind and front of meter DERs capable of islanding at multiple levels (neighborhood and home). The team aims to demonstrate a highly efficient and resilient community and lower DER capital costs for homeowners.

Each home is built to meet the requirements of **DOE's Zero-Energy Ready Home**[8] standards, which includes efficient envelope measures, HP heating and smart HPWHs. Residents can monitor their energy use with a home energy monitoring (HEM) system and manage their comfort levels with a smart thermostat. Each home is also equipped with a smart electrical panel that combines DER technologies. Homes are outfitted with 5-6 kW PV and a home battery storage system. Residents can customize and track energy usage and storage in their homes through a mobile app. All homes are level 2 EV charger-ready and a bidirectional EV system will be deployed in 6 homes to demonstrate and evaluate **Vehicle-to-Home (V2H)** services, where a vehicle's battery can power loads in the home.

This project will demonstrate capacity relief from **demand response**, **emergency load transfer capabilities**, and **voltage and frequency regulation**. Home owners have the opportunity to enroll their flexible loads into a VPP program to earn revenue and provide grid services to the CAISO for bill credits. At the community level, a front of the meter BESS will connect to the CAISO market.

The combination of energy efficiency measures, VPP participation, and DER integration are expected to result in significantly reduced energy bills for residents. Once the costs to build and operate residential microgrids and the value propositions to customers become clearer, this demonstration will help evaluate if microgrids should be funded by the local HOA or via utility rates.

Team IBACOS and **Duke Energy** in North Carolina are identifying the best approaches for delivering flexible distributed capacity at scale, targeting newly constructed and existing mobile and manufactured homes. Duke Energy aims to address emerging winter peak capacity challenges, which is primarily driven by electric heating in the residential sector. This sector is a significant customer base for the utility and across the country. Most mobile home residents in NC are low-income residents in rural locations, and many are single family renters as well. Team IBACOS is working closely with several home builders to deploy technology packages and recruit future customers, and seeks to help builders provide value to future home buyers. For Duke, developing close long-term relationships with builders is critical to this effort as demand flexibility is a relatively novel concept to the new homes market and the value of DF is still not very clear for builders.

Homes will be connected through a **DERMS** platform to serve utility peak capacity and resource adequacy needs. The following builders are deploying these packages:

[8] https://www.energy.gov/eere/buildings/zero-energy-ready-home-program

Mattamy Homes at Riverfall features:
1. Battery storage
2. Smart electrical panel
3. EV charging system
4. High efficiency HP
5. Smart thermostats
6. Managed HPWH

Meritage Homes at Harper Landing features:
1. Smart thermostats
2. HPWH
3. HEM devices

American Homes 4 Rent (AMH) is retrofitting 45 homes with:
1. Smart thermostats
2. Water heater controllers
3. HEM devices

This project aims to demonstrate that flexible electrified HVAC and hot water can reliably support grid related issues. Smart thermostat providers will provide daily **load shifting** and **peak demand reductions**, and customers will receive incentives when thermostats make small adjustments during Duke DR events. The hot water controllers will provide daily load shifting and peak demand reductions while ensuring the home owners always have hot water available through preheating strategies. HEMs will offer load shifting through a behavior modification strategy where appliance use will align with off-peak periods. The battery management system will **support TOU rates** by charging during off-peak hours, and discharging during on-peak hours.

Team Post Road is working with **Efficiency Maine Trust** and other stakeholders in Maine to develop and deploy a "prices from devices" transactive energy market to coordinate load flexibility from BTM DERs in existing rural homes. This project will build a custom DERMS-like software called the **Transactive Energy Service System (TESS)** which will coordinate a vendor agnostic, heterogenous mixture of DER types via a real time auction market, much like organized real-time wholesale energy markets. TESS allocates building-level consumption based on the preferences of each building occupant, expressed via a mobile app, which is also being developed as part of the project. At scale, TESS can provide feeder-level and wholesale-level **peak and constraint management** and has the potential to lower energy costs for Mainers in two ways. First, Maine is looking for cost effective mechanisms to manage bulk system peaks which are typically in the summer, but may be in the winter in future. These peaks are expensive and drive the costs of the transmission system. Without management, these peaks are also expected to grow due to transition from fuel oil to heat-pumps for HVAC (most of Maine does not have natural gas infrastructure), increased air conditioning load, and Maine's aggressive transportation and building electric growth goals. Second, and relatedly, many distribution circuits are near capacity and more circuits are expected to reach capacity as load grows. Electricity rates have doubled in the past few years so the appetite for additional rate increases to spend on distribution infrastructure is low and Maine is looking for cost effective mechanisms to manage distribution-level peaks.

Once the TESS is developed, Post Road aims to enroll between 100 and 400 existing homes. Enrolled homes are expected to feature a variety of DERs such as smart thermostats, HPs, HPWH, batteries, and EV charging, to be deployed with rebates and incentives from Efficiency Maine Trust.

Team Edo and **Avista Utilities** are leading a demonstration in Spokane, WA focused on a non-wires alternative to defer or avoid capital upgrades for a local 55MW-peak substation in Avista territory that is facing grid congestion. Their goals are to mitigate congestion, and improve resilience and efficiency at a substation that powers nearly 5,000 residential dwellings, 3 university campuses, over 900 commercial businesses, and 5 public schools. The diverse customer mix will allow Edo to pilot adoption across different customer classes and understand the price points for bringing DF technologies to residential, large commercial, and small business customers. Edo plans to create targeted VPPs from recruited buildings that can schedule and dispatch flexible loads to **relieve congestion**. Edo's cloud-based control architecture will provide aggregation services such as forecasting load flexibility and scheduling downstream DER controllers. This demonstration will enable Avista to combine the benefits of energy efficiency and demand flexibility in programs across their service territory, and Edo to work with other utilities to implement similar targeted VPPs.

Team Edo's targeted substation in Spokane serves over 5,000 residential homes, including a significant number of single family homes. Edo will seek to deploy the following packages in Table 4, for which residents will be eligible to earn bill credits for engaging in load flexibility events:

Table 6. Technology Package Options for Edo's Single Family Residential Customers

	Envelope weatherization	Smart thermostats	Battery storage
Package 1	✔	✔	
Package 2	✔	✔	✔

Team PGE's project area also includes single family residential homes. Residential customers will be able to take advantage of incentives from existing smart thermostat DR programs, plus any new customer programs that are developed as part of this pilot. Participants will also be eligible for a free home energy score and financial incentives for installation of eligible equipment and participation to provide grid services. Low-income customers may be eligible for low or no cost installation and configuration of eligible equipment.

The majority of residential sites use gas for space heating. Around a quarter of the sites (24%) use electricity for space heating (approximately 1,200 homes). It is estimated that around 1/3 of residential sites could have an existing electric water heater and could be good candidates to install heat pump water heater measures.

The community's roughly 2,800 buildings are a mix of single-family (76.2%), multifamily (14.4%), and commercial (9.4%) buildings. The single-family stock is largely pre-war (68% built before 1940), with an average size of ~1,500 ft. The multifamily stock consists primarily of smaller developments (2-4 units), however most of the multifamily residents (63%) live in larger complexes with 16 or more units. The non-residential stock is primarily small businesses dispersed throughout the community.

4.3 Commercial

The commercial building pilots being demonstrated range in building end use type, size, and existing systems but face similar challenges in having to navigate across multiple decision making stakeholders while balancing the needs of building occupants. Public sector buildings benefit from being able to make top down decisions for owner-occupied buildings, but will still need to navigate gathering input from different departments and lengthy legal reviews. Smaller commercial buildings often lack a centralized control system, so additional technology solutions are required to develop DF strategies. The lessons learned from these demonstrations are critical for scaling future DF in the commercial sectors.

Team Slipstream and the **City of Madison (CoM), WI** are planning a two-phase pilot, with the first phase focusing on seven publicly owned buildings before expanding up to ten additional medium-to-large private or public commercial buildings. The CoM building types range from municipal office to transportation depots with critical fleets, such as fire station vehicles and winter snow plows. This team's objectives include deploying a turnkey solution under a single EMIS vendor and developing a scalable business model with **Madison Gas & Electric (MGE)**, where demand response and energy efficiency incentive programs are bundled together for grid flexible measures. This effort also reveals some unique challenges with deploying in publicly owned buildings, where services and goods rendered require a Request for Information (RFI) and Request for Proposal (RFP) bidding process.

The seven CoM municipal buildings have a BAS that will be integrated to an EMIS platform. The EMIS will provide continuous demand management with load shedding of advanced HVAC and lighting controls.

Rooftop solar is already deployed at each CoM building. The project team will deploy smart inverter functionality at these buildings. A battery management system will be integrated to the EMIS platform at two buildings, providing load shifting to minimize monthly peak demand charges while maintaining required battery charge for backup power. A portion of the battery will also be available to participate in demand response (DR) events.

Deployment in the first phase with public buildings will inform the technologies that will be demonstrated in the second phase of the pilot with MGE commercial customers, utilizing a similar communication structure where an EMIS platform is integrated to command-and-control building loads and integrated DERs. The utility hopes to understand how feasible facility-level control is with an EMIS, and whether it can also control EV charging and batteries. They also hope to understand the minimum requirements needed for a BAS to work within this model of controls.

The grid services demonstrated by this project in MGE's territory include distribution **capacity relief, economic energy dispatch**, and distribution **voltage management**.

Team Edo's Spokane project is piloting demand flexibility in the commercial buildings sector at the South Landing EcoDistrict, a development featuring a large cross-laminated timber office and academic building called The Catalyst Building and the adjacent Scott Morris Center for Energy Innovation. Team Edo's energy management and aggregation system will integrate to a variety of flexible loads at South Landing, including a central plant for optimization, 260 kW rooftop solar PV, battery storage systems, and thermal storage.

For small to medium sized buildings (SMB) that lack a BAS, Edo is partnering with **Pacific Northwest National Lab (PNNL)**, who have developed a common SMB technology package which uses its open source **Volttron gateway**[9] to control temperature setpoints from rooftop units (RTUs) via **smart thermostats**.

Team PGE's demonstration area also targets businesses in small commercial buildings. Business customers will also be eligible for incentives related to installation of specified equipment and delivery of energy services, in support of various grid services. Their commercial building stock mainly consists of food service, office and retail sites. There is also a school, a major retail brand campus and a grocery store in the project area. Small users make up 77% of total, with food service dominating the small usage (<100,000 kwh or <3,500 therms annually) market. The sites are well established (34% in business for 6-10 years).

Team PacifiCorp is also demonstrating load flexibility in commercial and light industrial manufacturing building types, in addition to their work in multifamily communities. Their DERMS will communicate with an EV aggregator to control charging systems at Rocky Mountain Power's headquarters, an electric bus depot at Utah Transit Authority Depot, and at a light industrial manufacturing facility in Salt Lake City.

4.4 Campus

Team OSU's demonstration will include 22 retrofitted education buildings with a variety of use cases ranging from offices to classrooms and student dormitories. According to the U.S. Energy Information Administration (EIA), academic buildings account for 7% of U.S. commercial buildings but occupy 14%

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[9] https://www.pnnl.gov/sites/default/files/media/file/EED_2716_FLYER_ControlSystems_FINAL.pdf

of total commercial floor space[10]. Campuses are natural candidates for connected approaches considering their large utility expenses, and tendency to have centralized systems and controls. They also present unique challenges, such as distributed and often overlapping decision making across multiple stakeholders, stringent cybersecurity requirements, plus a diverse and complex vintage of physical building infrastructure. With this project, the team aims to understand how to deploy grid technologies and services in university or other campus settings.

The barriers OSU and other higher education institutions face include cybersecurity concerns, comfort levels of campus building occupants, and a lack of unified decision making for infrastructure projects. OSU aims to understand these challenges and transfer their value propositions to other campuses.

OSU will deploy a cyber secure supervisory control system to interface with the campus's existing BAS and with their demand response service provider's proprietary grid communication software in an automated fashion. Targeted building loads include HVAC setpoint reset, duct static pressure reset, smart ventilation, and control of chillers. Occupant comfort is a priority in addition to continuous demand management so IAQ sensors will be deployed across campus to measure temperature, humidity, CO_2, and particulate matter within buildings. Additional existing DERs that will be included in the demonstration are 40 kW of rooftop PV, 29 existing EVs totaling 300 kW, and 50 MW of wind energy procured via a power purchase agreement (PPA).

The grid services this project will demonstrate include PJM's **synchronized reserve** demand response program, plus **energy and capacity markets participation**.

Team PacifiCorp is also engaging with campus level DER deployment and control at both the University of Utah and the Utah State University (USU) campuses. An existing microgrid located at USU Advancing Sustainability through Powered Infrastructure for Roadway Electrification (ASPIRE) Research Center, will allow PacifiCorp to develop and test load flexibility controls with various DERs, including battery systems. As part of the project, the UDERMS iCommunity team will be engaged in the design and specifications of the new ASPIRE Electric Vehicle Roadway (EVR) laboratory and office facility and leverage the various new and existing DERs that will be available at the ASPIRE center. The ASPIRE EVR research facility and test track is a 22,000 sq ft systems integration facility with a quarter mile test track. The EVR is an ideal facility for testing the technologies being deployed in this project. By 2025, the EVR will be home to a MW stationary wireless charger, 1 MWh BESS, 1.2 MW DC supply capability, nine level-2 chargers, a 350 kW fast charging system for fleets, and multiple dynamic charging installations from commercial partners.

Team Edo also recruited campus buildings at Eastern Washington University, and a battery microgrid from Washington State University to join their demonstration in Spokane, WA.

[10] https://www.eia.gov/consumption/commercial/reports/

5. Trends Between Building Type, DER Technologies, and Grid Services

Table 7. Teams Deploying Multiple DER Technologies

	Solar PV	Battery Energy Storage	EV Charging	Smart Electrical Panel	Weatherization Upgrades	Centralized HVAC controls	Smart Thermostats	Heat Pumps (HP)	HP Water Heaters
OME	✔	✔	✔			✔	✔		
EPRI	✔		✔		✔	✔		✔	✔
PacifiCorp	✔	✔	✔				✔	✔	✔
Edo	✔	✔	✔		✔	✔	✔		
UC Irvine	✔	✔	✔	✔			✔	✔	✔
IBACOS, Inc		✔	✔	✔	✔		✔	✔	✔
Post Road		✔	✔				✔	✔	
Slipstream	✔	✔	✔			✔			
OSU	✔		✔			✔			
PGE	✔	✔	✔		✔		✔	✔	✔

Table 7 summarizes the technologies being considered or selected by each pilot team for their respective demonstrations. Building type is one driver for the technology packages that these teams are opting to deploy. Residential buildings are prioritizing energy efficiency and customer cost-saving technologies such as weatherization upgrades and smart thermostats. Commercial spaces emphasize reliability and consistent operational schedules, such as battery storage and optimizing central HVAC controls for flexibility. In the multifamily space (Team OME, Team EPRI), projects are emphasizing energy efficiency and cost savings through deploying technologies like solar PV and BESS to reduce whole building and/or shared common area energy use. Additionally, smart thermostats and HPs are providing efficient heating and cooling within residential units while providing localized demand response and bill reduction. Single family homes (Team UCI, Team IBACOS, Team Post Road) have greater autonomy over their energy use, so these projects are leveraging technologies like solar PV, smart electric panels and EV charging to empower self-generation and load management. These teams will help homeowners manage utility costs with efficient HVAC measures and through tariff optimization and enrolling smart thermostats in VPP-type demand response programs. Large commercial building demonstrations (Team OSU, Team Slipstream) are utilizing technologies to optimize energy use, which have greater potential to participate in energy market programs. They are more likely to have centralized HVAC strategies and use energy management systems for demand side strategies.

Residential building types are also prioritizing customer-centric services like bill management and demand response. These teams are also more focused on distribution-level services to address localized grid needs. Projects with commercial buildings are demonstrating wholesale energy market participation, leveraging their predictable energy profiles and high demand for grid reliability.

Section 3, Table 4 showcases the types of grid service provisions that each pilot team is evaluating as part of their demonstrations. Grid services are often influenced by the technologies being deployed. Teams deploying a BESS (Team UCI, Team PacifiCorp) are exploring bulk services like frequency regulation and response, reflecting the role of batteries in responding to real time imbalances. Teams deploying smart electrical panels (UC Irvine, Team IBACOS) are providing customer bill management services like tariff optimization, showcasing how smart panels can enable dynamic load adjustments. Teams with centralized building energy management systems (Team Slipstream, Team OSU) are using their platform's capabilities for aggregated load control for peak load management, such as through HVAC controls measures. Energy management systems can also be used to facilitate the integration and optimization of multiple DERs for grid reliability and efficiency.

5.1 Technology Downselection

As part of the process to select and finalize DER technology packages for their demonstration sites, some teams made changes or exclusions that are worth mentioning for future DF project planners. The reasons for technology downselection ranged from a refinement of the technical performance requirements, to a range of implementation issues spanning technological issues and barriers, to non-technical constraints.

First, a careful review of grid issues and technical functionalities informed some downselection. Team Slipstream's technology package for demonstration within City of Madison municipal buildings will largely stay intact as Madison Gas & Electric (MGE) develops its utility pilot. The main difference will be exclusion of smart inverter functionality, as there are minimal voltage violations on MGE's distribution network, resulting in low need for the grid services capabilities of these products.

In another case, Team IBACOS and their new construction home builder partners originally planned to include HEMs in their package design, but later determined it made more economic sense to install smart panels instead, as the latter have broader use cases for load management and control compared to the former with the current state of the technology. One of their builders, Mattamy Homes, is actively pursuing solar and batteries as a standard home design offering. Team IBACOS helped them determine pricing and installation practices at scale for installing smart panels, which were more economical than the incremental labor and material costs of adding an HEM to a standard panel.

Team EPRI originally recommended the use of 120V HPs to replace gas wall furnaces at one of their multifamily communities. One of the requirements for the use of 120V heat pumps is the need for sufficient clearances around the point of installation. This was found to be lacking in the interior spaces of the smaller resident units in the building. Instead, the engineering design found that the use of mini-splits with small-form-factor indoor units may be more feasible than the originally specified 120V HPs.

In some cases, the reasons for technology downselection related to non-technical barriers. For example, Team OSU hoped to include optimization of their central plant for inclusion in their demonstrated grid services, however, barriers related to third party performance-contracted operation of the plant may prevent its inclusion.

Overall, insights about technologies considered but ultimately not deployed show that demand flexibility projects can encounter cost effectiveness, physical infrastructure limitations and stakeholder barriers. Technology selection should also consider the minimum set of functionalities needed to provide the grid services involved, to support overall cost effective approaches.

6. Conclusion

This cohort of DF demonstrations offer valuable lessons for utilities or other stakeholders looking to design customer programs centered on demand flexibility. A key takeaway is that DER package selection is most effective when tailored to specific building types, customer profiles, and system constraints. Packages in multifamily buildings typically include efficiency upgrades in HVAC systems to help reduce customer bills. The current cohort of multifamily projects include master-metered buildings or buildings with owner-paid utilities, where value streams from aggregating flexible loads are easier to monetize. Programs targeting this building sector will benefit from directly engaging building owners or operators as the primary customer. Single family homes offer more flexibility in DER integration and are a strong fit for aggregation in VPPs, so these projects are focused on individualized packages such as smart thermostats, solar PV, EV charging paired with behavioral change tools like HEMs. Commercial and campus projects emphasize operational reliability and load optimization, leveraging centralized EMIS platforms, battery storage and wholesale market participation. Multiple internal decision markers and navigating cybersecurity requirements can be a programmatic challenge here. New construction projects allow for a clean slate approach to deploying integrated DER-ready homes that embed demand flexibility at lower marginal costs, especially if utility customer programs can coordinate with developers early on. For retrofits, project teams prioritize technologies with minimal tenant disruptions, making staged deployment and strong customer engagement strategies important.

From a utility planning perspective, embedding DERMS capabilities early and aligning packages with tariff design—such as TOU or performance-based incentives—can streamline grid integration and improve participation. Utility-involved teams were also more likely to leverage granular AMI data and incorporate grid modeling to target specific constraints and inform DER package selection. The trends from the pilots also suggest that customer program offerings may benefit from a modular approach where customers or developers can select DER packages that make sense for their context, whether it be streamlined incentive structures, retrofit solutions with financing support, or technical assistance.

6.1 Areas for Further Evaluation

Further evaluation is needed regarding the long-term performance, effectiveness and replicability of scaling DF from aggregated DERs. As of this report's authorship, all of the demonstrations are in their implementation phases. The pilots can benefit from evaluation in areas such as energy and grid service performance; customer experience; costs and benefits, and business models from the perspective of each of the customer, aggregator and utility; resilience and reliability benefits and more.

For DF program developers, it's important to recognize the ongoing questions these demonstrations can help answer. Cost-effectiveness of the pilots across stakeholder groups is a top interest, as well as their abilities to improve energy affordability for power customers. Customer survey data collected at various stages of implementation can help reveal customer behavior under different DER control strategies (e.g. price signals, performance incentives, or behavioral nudges). Evaluating how each aggregated control architecture performs in real-world conditions, particularly under seasonal peaks and local congestion, can help inform whether program developers should prioritize centralized control, customer-directed flexibility, or hybrid approaches.

Other useful evaluation topics include assessing operational challenges, occupant comfort tradeoffs, cybersecurity concerns in campus and public settings, and real-world persistence of load shifting or shedding behaviors over time. These insights are informative for scaling flexible DER deployments beyond pilot stages.

Learnings from pilots can also shed light on which combinations of technologies and incentives drive the greatest load impact per dollar and how to structure programs for replicability and reliability. When more data is available for measuring grid service delivery from aggregated DERs, further clarity is needed on the market value of these services versus their deployment and integration costs. The effectiveness of each DER pre-retrofit analysis and selection process can also be explored, in relation to the successful outcomes in the demonstrations.

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