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April 23, 2024

VIA ELECTRONIC FILING

Ms. Shonta Dunston
Chief Clerk
North Carolina Utilities Commission
430 North Salisbury Street
Raleigh, North Carolina 27603

RE: Demand-Side Management and Energy Efficiency Cost Recovery Mechanism Review (Docket Nos. E-2, Sub 931 and E-7, Sub 1032)
Efficiency Advocates' Presentation Materials for the Mechanism Review Technical Conference

Dear Ms. Dunston:

The Southern Alliance for Clean Energy (SACE), Natural Resources Defense Council (NRDC), South Carolina Coastal Conservation League (CCL), Sierra Club, North Carolina Justice Center (NC Justice Center), and North Carolina Housing Coalition (NCHC), jointly with the North Carolina Sustainable Energy Association (NCSEA) (collectively, Efficiency Advocates) attached for filing in the above-reference dockets the presentation materials referenced at their presentation at the April 22, 2024 Mechanism Review Technical Conference.

We are forwarding a copy of the same to all parties of record by electronic delivery.

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Enclosure
Cc: Parties of Record (with enclosure)

Real Reliability
The Value of Virtual Power

PREPARED BY

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VOLUME I: SUMMARY REPORT

MAY 2023

Brattle

Notice

PLEASE NOTE

This report was prepared by The Brattle Group for Google. It is intended to be read and used as a whole and not in parts. The report reflects the analyses and opinions of the authors and does not necessarily reflect those of The Brattle Group's clients or other consultants.

We would like to thank Keven Brough and Rizwan Naveed of Google for the invaluable project management, insights, and data that they provided throughout the development of this report. We also are grateful for the modeling contributions of our Brattle colleague, Adam Bigelow.

Contents

Summary

Overview

Maintaining power system resource adequacy is a major investment.

Over the past decade, the U.S. added over 100 GW of new capacity intended largely to maintain resource adequacy. This amounted to over $120 billion of capital investment, primarily in gas-fired generators and lithium-ion batteries.

Virtual Power Plants (VPPs) are an emerging alternative to conventional resource adequacy options.

A VPP is a portfolio of actively controlled distributed energy resources (DERs). Operation of the DERs is optimized to provide benefits to the power system, consumers, and the environment. Within a decade, analysts forecast an inflection point in the trajectory of DER ownership. VPPs already are beginning to be deployed across the U.S. and internationally.

We explore the ability of VPPs to reliably reduce resource adequacy costs in the coming decade.

We model the economics of a residential VPP for a representative U.S. utility system in 2030. The utility system is 50% renewables, with both summer and winter resource adequacy needs. The VPP in our study is composed of commercially available residential load flexibility technologies. VPP operations are based on actual observed performance of DERs, accounting for operational and behavioral constraints. The net cost of providing resource adequacy from the VPP is compared to that of a gas peaker and utility-scale battery. Net cost accounts for additional value from energy, ancillary services T&D deferral, resilience, and greenhouse gas (GHG) emissions.

Key Findings

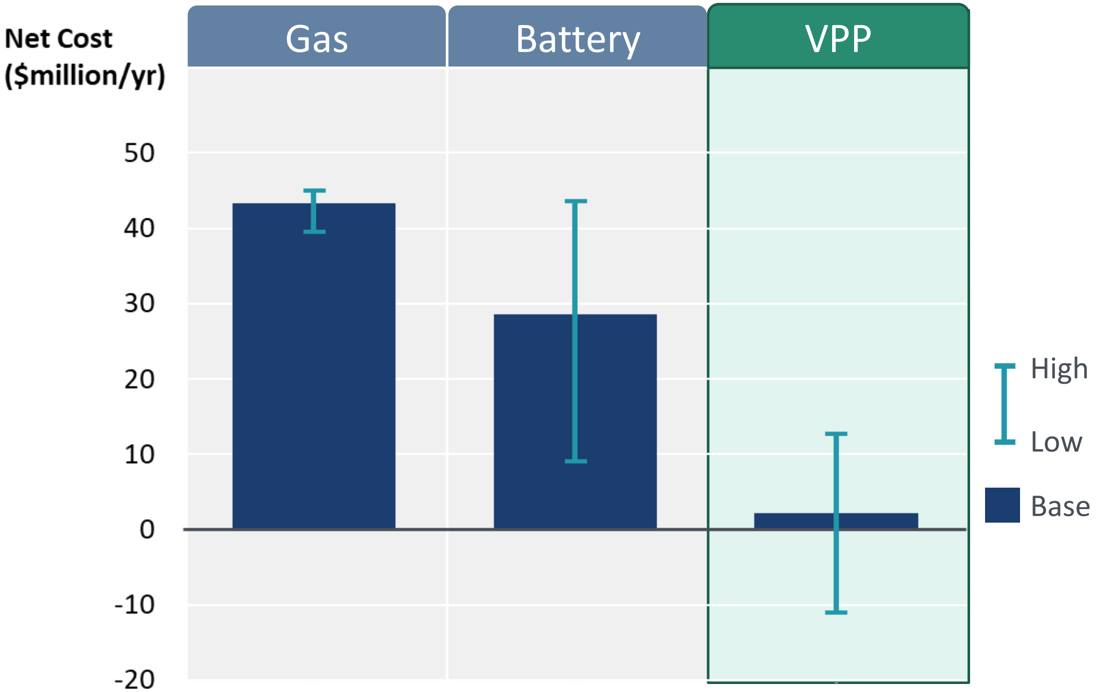
Real reliability: A VPP that leverages residential load flexibility could perform as reliably as conventional resources and contribute to resource adequacy at a similar scale.

Cost savings: Excluding societal benefits (i.e., emissions and resilience), the net cost to the utility of providing resource adequacy from the VPP is only roughly 40% to 60% of the cost of the alternative options. Extrapolating from this observation, a 60 GW VPP deployment could meet future resource adequacy needs at a net cost that is $15 billion to $35 billion lower than the cost of the alternative options over the ensuing decade (undiscounted 2022 dollars).

Additional benefits: When accounting for additional societal benefits, the VPP is the only resource with the potential to provide resource adequacy at negative net cost. 60 GW of VPP could provide over $20 billion in additional societal benefits over a 10-year period.

More work is needed: Key barriers must be addressed to fully unlock this value for consumers and ensure that virtual power plants become more than just virtual reality.

Net Cost of Providing 400 MW of Resource Adequacy
(Range observed across all sensitivity cases)



Note: Costs shown in 2022 dollars. Costs are net of societal benefits (i.e., GHG emissions avoidance and resilience value) and power system benefits (energy, ancillary services, and T&D deferral value).

An Introduction to VPPs

Introduction

Over 100 GW of capacity was built primarily to provide resource adequacy in the U.S. in the past decade, requiring over $120 billion of investment. More will be needed.

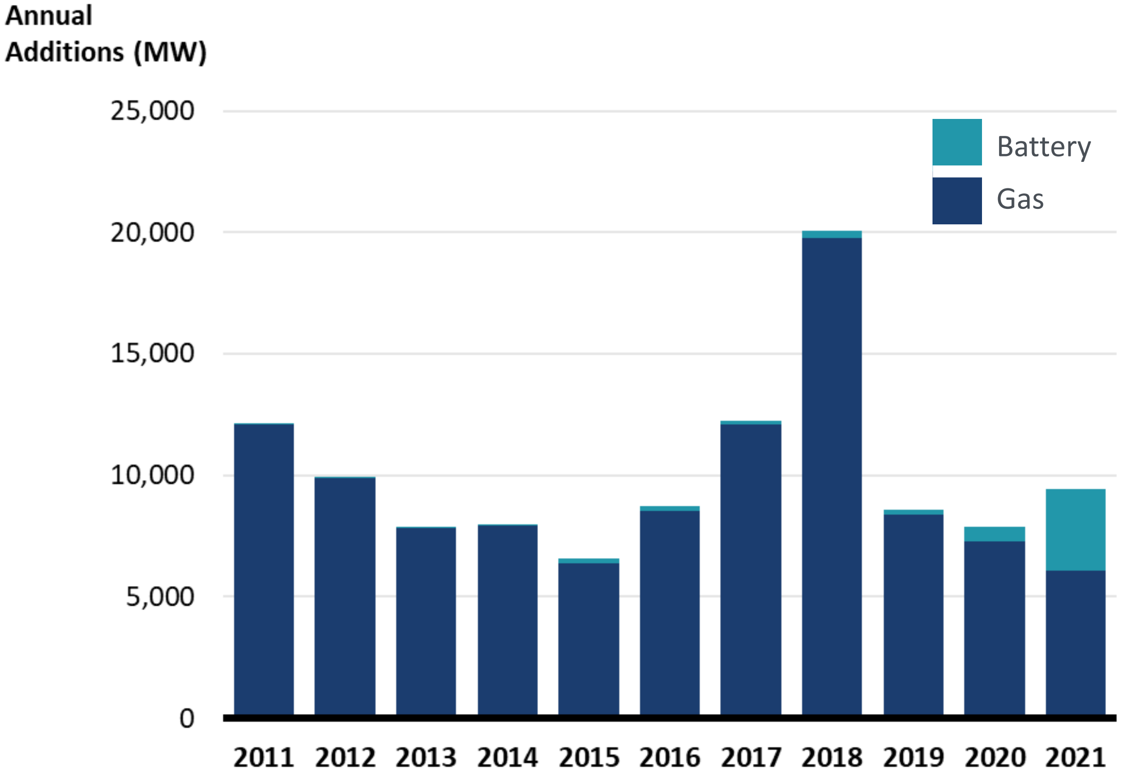
Providing affordable system reliability is the primary objective of utilities and regulators as they make generation resource investment decisions.

Electrification, coal retirements, and dependence on resources with limited capacity value (wind, solar) will continue to result in a persistent need to maintain sufficient system "resource adequacy" by adding new dispatchable capacity.

Historically, natural gas-fired combustion turbines and combined cycles have served this need. Increasingly, utility-scale battery storage is being deployed for the same reason.

Alternatively, in this study we explore the cost of serving resource adequacy needs from an emerging resource: a virtual power plant (VPP).

Historical U.S. Capacity Additions for Resource Adequacy
~110 GW, 2012-2021



Sources: EIA, Velocity Suite ABB Inc, and NREL.
Note: $120 billion estimate assumes 110 GW at an average installed cost of approximately $1,100/kW in 2022 dollars. "Gas" includes combustion turbines and combined cycles that have been built for a combination of resource adequacy and energy value.

What Is a VPP?

A VPP is portfolio of distributed energy resources (DERs) that are actively controlled to provide benefits to the power system, consumers, and the environment.

Virtual Power Plant
Examples of potential elements

- Smart thermostats
- Rooftop solar PV
- Electric vehicles (EVs)
- Distributed batteries
- Smart water heaters
- Commercial building automation systems

Note: VPPs can be composed of many distributed technologies. As described later, the VPP modeled in this study is composed of a subset of the options shown here.

1 Customers allow their DERs to be directly managed – subject to operational constraints – by an aggregator or electric utility.

Aggregator or utility with distributed energy resource management system (DERMS)

2 Utilities and aggregators manage the DERs in an orchestrated way to provide grid benefits (e.g., reducing demand during peak load hours to avoid investment in conventional generation capacity).

Power system (distribution grid, transmission grid, power generation)

3 The power system is expanded and operated at a lower total cost, reliability is maintained, and emissions are reduced.

4 The cost savings provided by the VPP are shared between the individual participants, the aggregator, the utility, and society broadly.

An Inflection Point for VPP Deployment

DER ownership is expected to grow by several multiples within the next decade in the United States.

Several forces currently are driving VPP deployment to an inflection point:

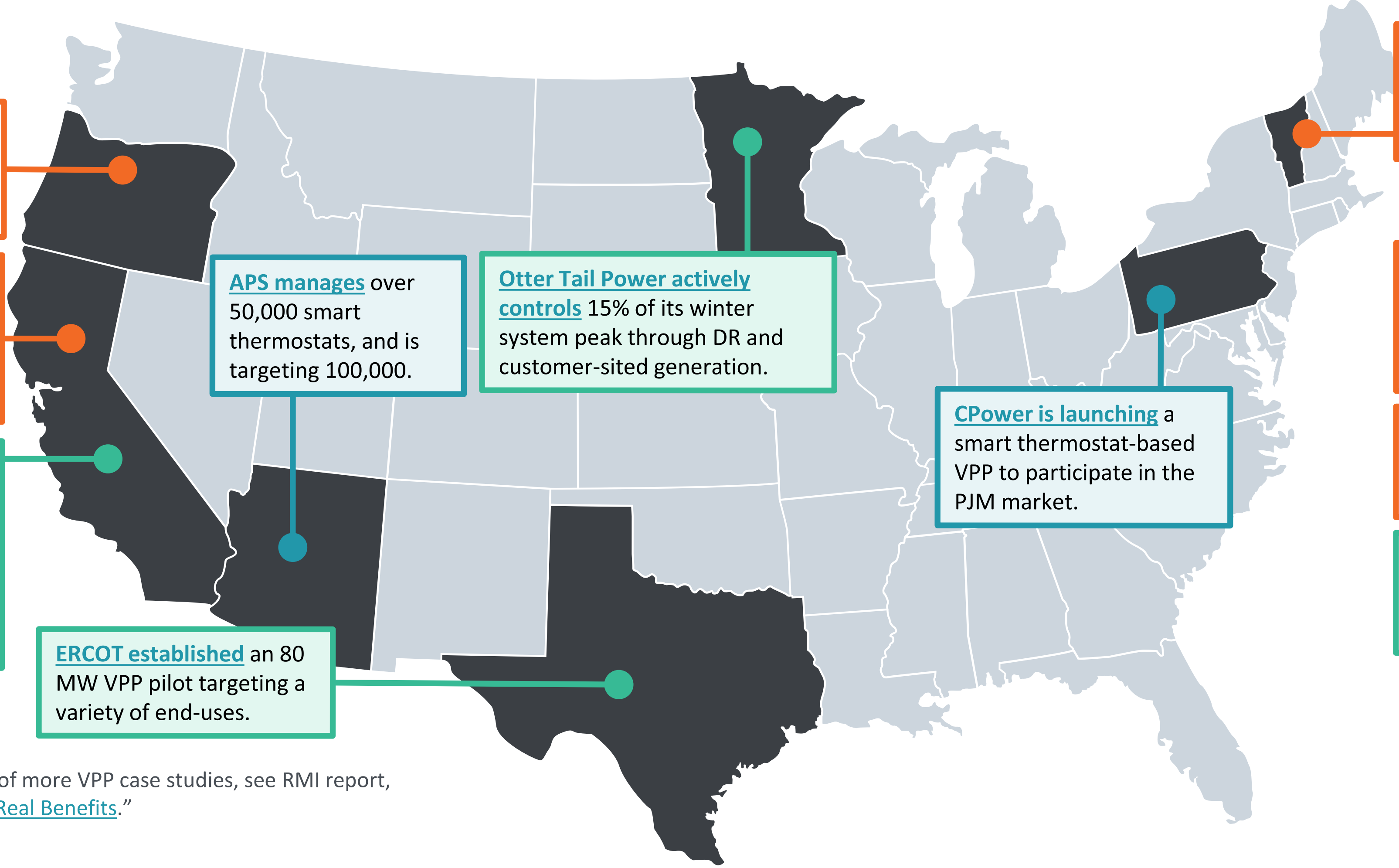
- **Declining DER costs**, particularly EVs and batteries
- **Technological advancement** in algorithms for managing and optimizing the value of DERs
- **Inflation Reduction Act (IRA) incentives** to promote electrification and efficiency
- **FERC Order 2222** and accompanying initiatives to open wholesale markets to VPP participation
- **Growing model availability** of EVs, thermostats, smart panels, and others
- **The decarbonization imperative**, a focus of policymakers, utilities, and consumers

	PRESENT	2030
Homes with Smart Thermostats	10%	34%
Homes with Electric Water Heating	49%	50%
Residential Rooftop Solar	27 GW	83 GW
Behind-the-Meter (BTM) Batteries	2 GW	27 GW
Light-Duty Electric Vehicles	3 mil.	26 mil.

Notes: See technical appendix for details. Modest growth in electric water heating is due to significant existing market saturation and near-term focus of the adoption forecast. The Inflation Reduction Act may further accelerate these adoption forecasts.

Real-World VPPs

To a degree, VPPs have existed for decades as demand response programs. But VPPs are rapidly evolving to leverage the expanding mix of DER technologies.



PGE is launching a ~4 MW BTM battery VPP involving over 500 customers.

PG&E is developing a 30 MW solar-plus-storage VPP to address its summer net peak demand.

SCE has launched two VPP projects, one focused on 20 MWh of BTM storage and a second to procure 14 MW of DR.

APS manages over 50,000 smart thermostats, and is targeting 100,000.

Otter Tail Power actively controls 15% of its winter system peak through DR and customer-sited generation.

ERCOT established an 80 MW VPP pilot targeting a variety of end-uses.

CPower is launching a smart thermostat-based VPP to participate in the PJM market.

Green Mountain Power has enrolled more than 4,000 BTM batteries in its VPP and plans to expand the capacity of the program to 55 MW.

Hawaii: HECO will deploy an 80 MW VPP, composed primarily of solar-powered BTM batteries across 6,000 homes.

Australia: Tesla is developing a 250 MW / 650 MWh VPP involving up to 50,000 homes in South Australia.

Europe: Next Kraftwerke claims to have over 11 GW of resources managed through its VPP portfolio.

Smart thermostats

Solar/storage

Mix of DERs

Note: For descriptions of more VPP case studies, see RMI report, “Virtual Power Plants, Real Benefits.”

Modeling VPP Performance

The VPP Modeled in This Study

VPPs can be composed of a variety of technologies.

In this study, we focus on commercially-proven residential demand response applications.

The term “VPP” often is associated with aggregations of behind-the-meter (BTM) solar and storage. However, a VPP can be composed of a much broader range of technologies.

In fact, a VPP does not even need to generate power. Dispatchable demand response (DR), enabled by technologies such as smart thermostats and electric vehicles (EVs), can provide many of the same benefits as distributed generation resources by reducing or shifting load.

Composition of the VPP modeled in this study

Smart Thermostats
A/C and electric heating are controlled to reduce usage during peak times. Customer comfort is managed through pre-cooling/heating.

Smart Water Heating
Electric water heaters act as a grid-interactive thermal battery, providing daily load shifting and even real-time grid balancing.

Home EV Managed Charging
EV charging is a large, flexible source of load that can be shifted overnight.

BTM Battery Demand Response
Customer-sited batteries can be charged and discharged to provide services to the grid for a limited number of events, while providing resilience as backup generation during all other hours.

Analysis Approach Overview

We compare the net cost of providing 400 MW of resource adequacy from three resource types: a natural gas peaker, a transmission-connected utility-scale battery, and a VPP. Our methodology is illustrated below.

1 Define utility system

The prototypical U.S. utility is defined using publicly available data.

We conservatively assume operationally challenging conditions for a VPP.

2 Establish system resource adequacy need

Each resource must provide 400 MW of resource adequacy. This is approximately 7% of the gross system peak for the illustrative utility.

3 Determine MW of each resource type needed

Each resource must be available with sufficient generation or load reduction capability during the top system net load hours of the year.

4 Estimate total cost of each resource type

The all-in cost of each resource type includes CapEx, fuel, and ongoing program costs, and is sourced from publicly available data.

5 Simulate market value of each resource type

We use Brattle's LoadFlex and bSTORE models to simulate the additional (i.e., non-resource adequacy) value that could be provided by each resource.

6 Calculate net cost of each resource type

The value of each resource is subtracted from its all-in cost to arrive an estimate of the net cost of providing 400 MW of resource adequacy from each resource type.

Note: See technical appendix for a complete description of modeling assumptions and data sources.

The Illustrative Utility System

We model an illustrative mid-size utility with 400 MW of new resource adequacy need (7% of gross system peak demand).

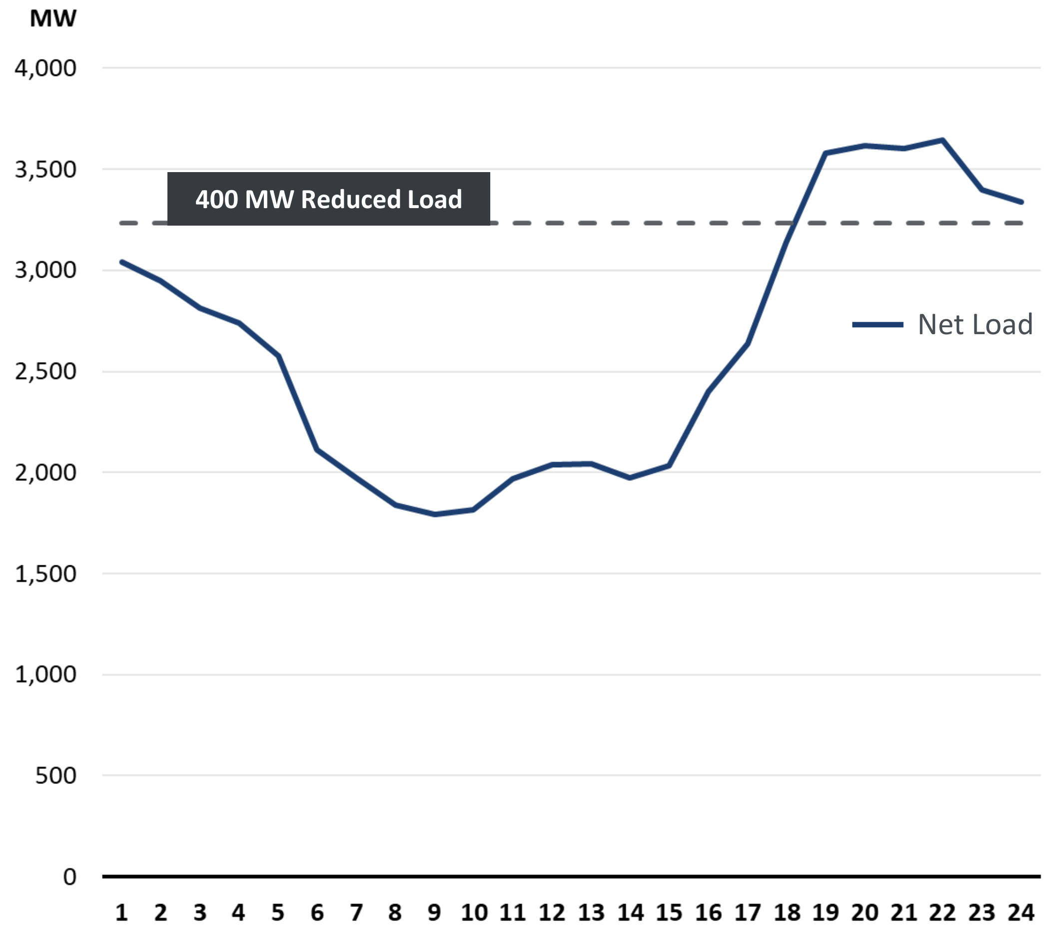
It includes a customer base of 1.7 million residential customers. Other factors in our illustrative utility include:

- 5,700 MW gross peak demand, 3,600 MW peak demand net of expected wind and solar generation
- Power generation is 50% renewable by 2030 (¼ solar, ¾ onshore wind), representing a growing trend toward decarbonized power supply

The illustrative utility is conservatively selected to represent challenging performance requirements for a VPP, such as a need for resource adequacy performance during many hours in both summer and winter

Data on marginal costs, hourly system load, renewable profiles, and customer characteristics are derived from sources such as NREL, EIA, and the U.S. Department of Energy.

Hourly System Net Load on Example Peak Day



Note: See technical appendix for a complete description of modeling assumptions and data sources.

Defining Resource Adequacy

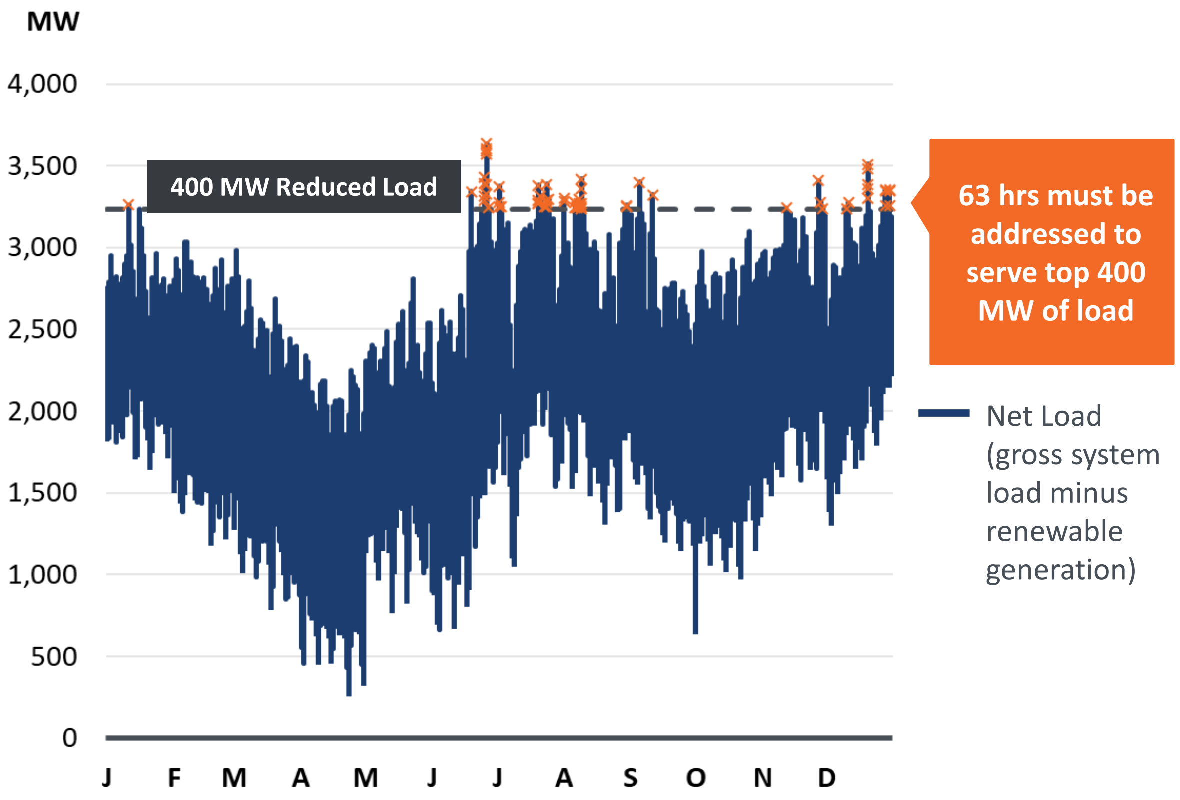
We conduct an hourly reliability assessment to ensure that all three modeled resource types are capable of fully providing 400 MW of resource adequacy to the utility system.

As a proxy for resource adequacy performance requirements, we require that the three resource options each be available to serve all load contributing to the utility's top 400 MW of net peak demand over an entire year (see figure at right).

This means that the resources must be available to perform at the required level for 63 hours of the year, spanning both summer and winter seasons.

One particular summer peak day in our analysis requires resource performance during seven consecutive hours.

Utility Hourly Net Load Profile



Note: See technical appendix for a complete description of modeling assumptions and data sources.

Calculating the Net Cost of Resource Adequacy

Our analysis estimates the cost of providing resource adequacy from each of the three resource types, net of any additional value those resources provide to the system and to society. The result is the "net cost" of providing resource adequacy.

Cost of installing and operating resource

CapEx

Fuel

Operations & Maintenance (O&M)

Program costs

−

System value of resource[1]

Energy value

T&D investment deferral

Ancillary services value

−

Societal value of resource[1,2]

GHG emissions reduction

Resilience value

=

Net cost of resource adequacy

Notes:
[1] Negative "value" indicates that the resource increases cost (e.g., a gas peaker increasing GHG emissions).
[2] Excluding societal value from the calculation results in an estimate of the net resource cost from the perspective of the utility or system operator.

Estimating Additional Market Value

The distributed nature of VPPs allows them to provide a broader range of system benefits than transmission-connected alternatives.

System Impact	Description	Gas Peaker	Utility-Scale Battery	VPP
Energy	Net change in system fuel and variable O&M costs due to the addition of the new resource.	+	+	+
Ancillary Services	Value associated with operating the resource to provide real-time balancing services to the grid.	+	+	+
Emissions	Net change in greenhouse gas (GHG) emissions due to the addition of the resource, valued at a social cost of carbon estimate of $100/metric ton.	–	–	+
T&D Investment Deferral	Deferred cost of investing in the transmission and distribution grid due to strategic siting of distributed resources.	N/A	N/A	+
Resilience	Avoided distribution outage associated with using DERs as backup generation.	N/A	N/A	+

+ = system benefit – = system cost

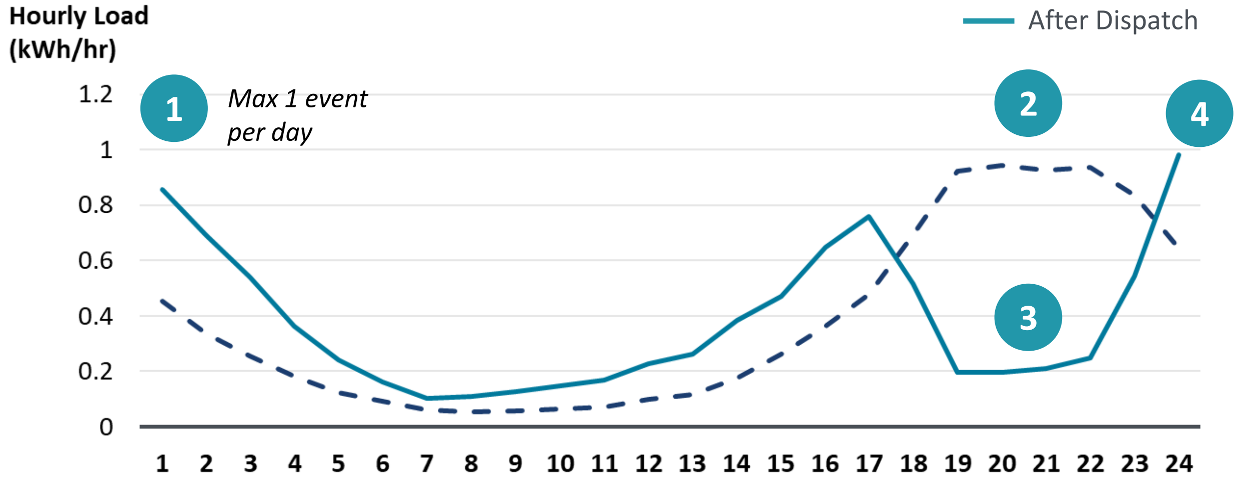
Notes:
Further discussion provided in next section.
Throughout the presentation, “utility-scale battery” refers to transmission-connected lithium-ion batteries.

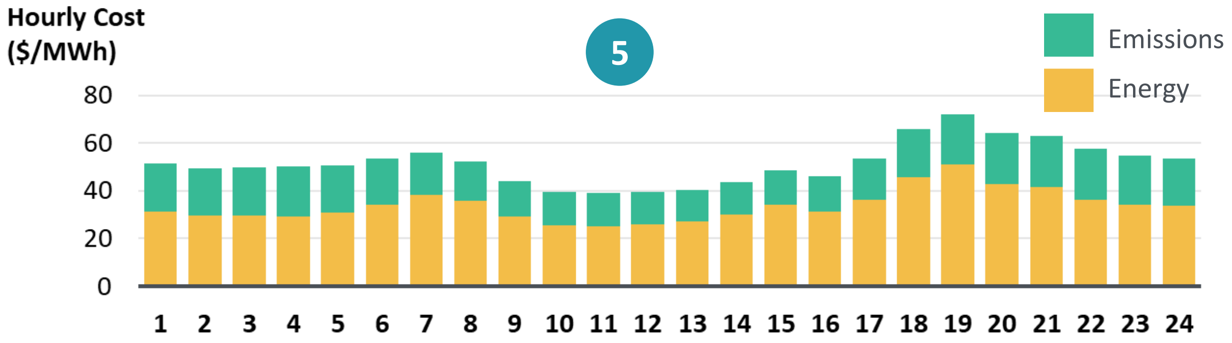
Modeling Realistic VPP Operations

We simulate VPP dispatch to account for real-world operational limitations, based on observed performance in actual deployments.

1. Limits on customer tolerance for number of interruptions
2. Load impacts limited to actual available load during system peak hours
3. Load impacts account for event opt-outs, remain within customer tolerance range
4. Pre- and post-event load building to ensure customer usage ability
5. Dispatch is simulated to maximize avoided power system costs, in addition to providing resource adequacy

EV Home Charging Load Profile Relative to Hourly System Costs
(Average across days and EV portfolio)





Note: Dispatch and costs are shown as averages across event days. See technical appendix for a compete description of modeling assumptions and data sources.

Defining the VPP

The VPP modeled for this study is composed of load flexibility from four home energy technologies.

This is just one of many potential configurations of VPPs. Eligibility reflects potential technology adoption within the next decade. We assume achievable levels of customer participation in each component of the VPP.

Modeled costs are those that would be incurred by the utility. Costs are based on market studies, review of actual deployments, and expert interviews.

	Smart Thermostat DR	Smart Water Heating	Home Managed EV Charging	BTM Battery DR
Eligibility (% of residential customer base)	67% summer; 35% winter	50%	15%	1%
Participation (% of eligible customers)	30%	30%	40%	20%
Total Controllable Demand at Peak (MW)	204 MW	114 MW	79 MW	26 MW
Participation Incentive ($ per participant per year)	$25 per season	$30	$100	$500
Other Implementation Costs, including marketing and DERMS ($ per participant per year)	$43	$55	$80	$140
VPP Operational Constraints	15 five-hour events per season, plus 100 hrs of minor setpoint adjustments per year	Daily load shifting of water heating load, ancillary services	Daily load shifting of vehicle charging load	15 demand response events per year

Note: Controllable demand sums to more than 400 MW across technologies to ensure sufficient capacity is available during all hours required for resource adequacy. Costs shown in 2022$. Smart water heating is the only option modeled as providing ancillary services (modeled as spinning reserves), as this is an existing commercial offering from grid-interactive electric resistance water heaters in PJM and other markets.

The Value of VPPs

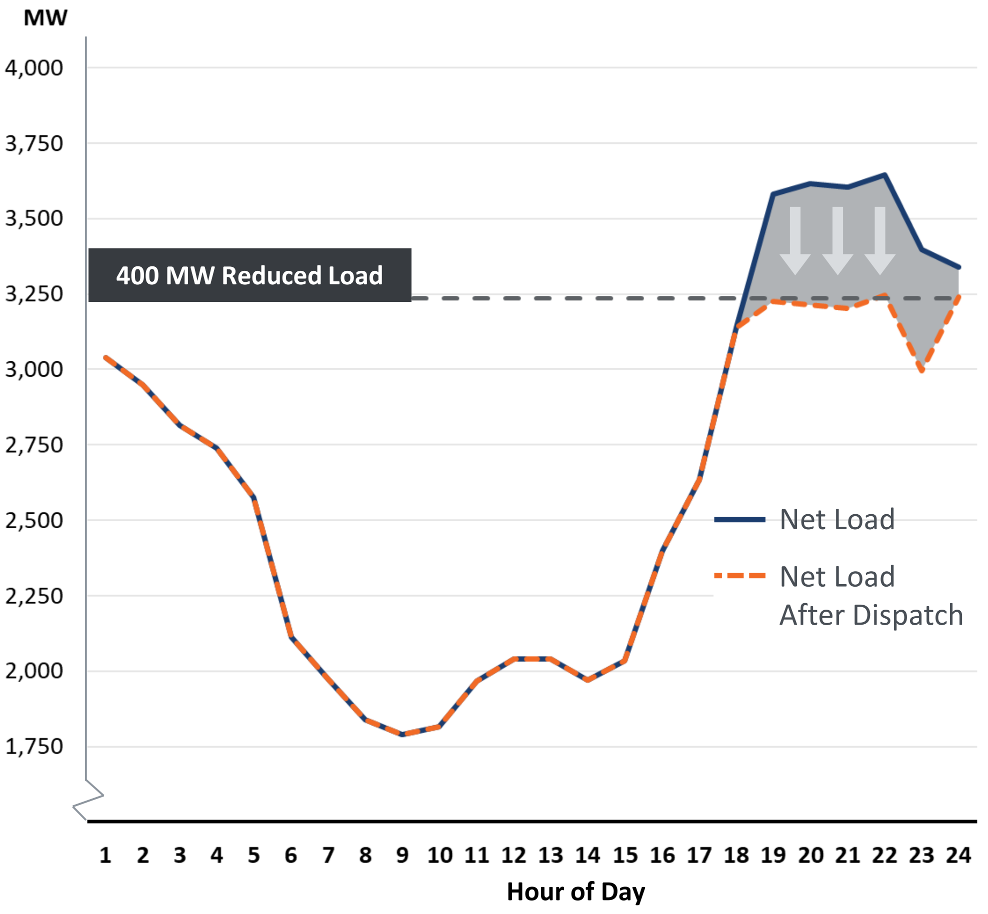
Gas Peaker Operations

The gas peaker provides resource adequacy by being available to generate when needed for system reliability reasons.

	System Impact	Discussion
Energy	+	The peaker runs in any hour when its variable cost is lower than that of the marginal resource (or the energy price in wholesale energy markets)
Ancillary Services	+	The peaker quickly ramps up and down in real-time to balance the grid
Emissions	–	When the peaker runs, it burns natural gas and emits GHGs but also displaces emissions from the marginal unit
T&D Investment Deferral	N/A	Not a distributed resource
Resilience	N/A	Not a distributed resource

+ = system benefit   – = system cost

Peak Net Load Day



Note: We assume that 440 MW of gas peaker capacity needs to be built in order to account for an expected forced outage rate of 10%.

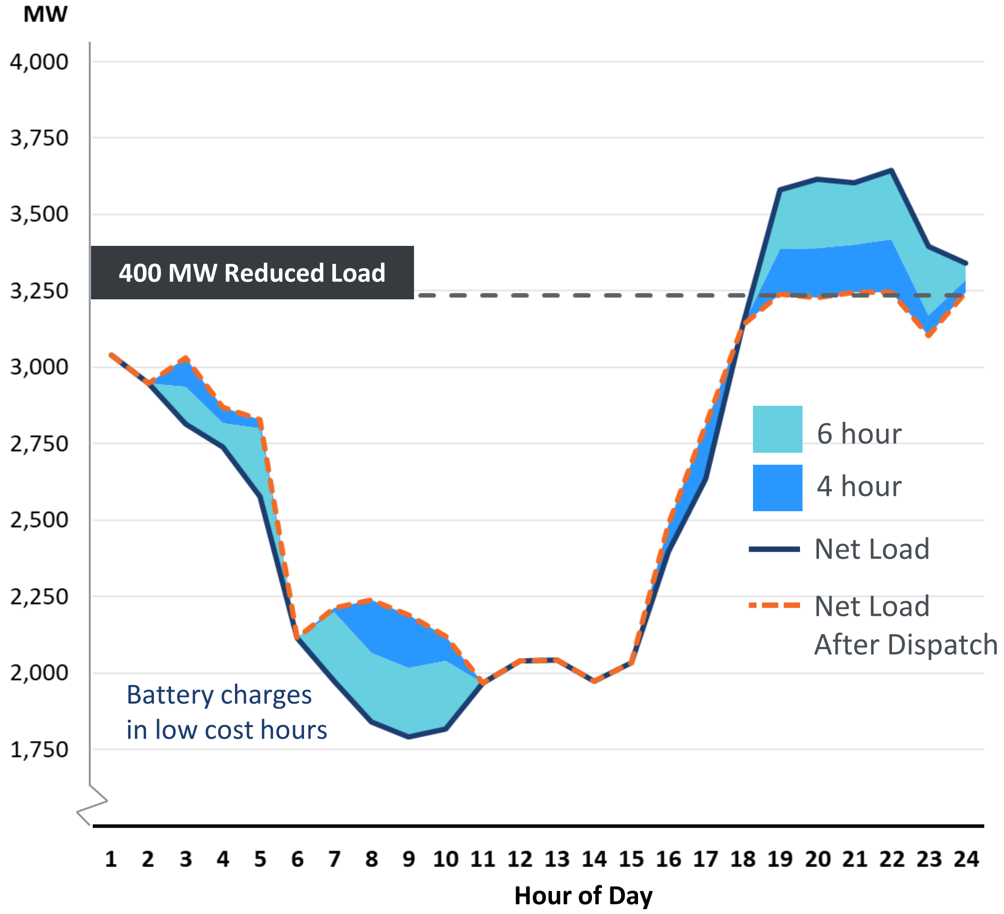
Utility-Scale Battery Operations

Batteries provide resource adequacy by charging during low cost hours and being available to discharge when needed for system reliability.

	System Impact	Discussion
Energy	+	The battery charges during the lowest cost hours of the day, and discharges during the highest cost hours of the day, displacing higher cost units
Ancillary Services	+	Batteries have the flexibility to quickly ramp up and down in real-time to balance the grid
Emissions	−	In our simulations batteries slightly increase GHG emissions, primarily because they consume more energy than they discharge (i.e., due to roundtrip losses)
T&D investment deferral	N/A	Not a distributed resource
Resilience	N/A	Not a distributed resource

+ = system benefit − = system cost

Peak Net Load Day



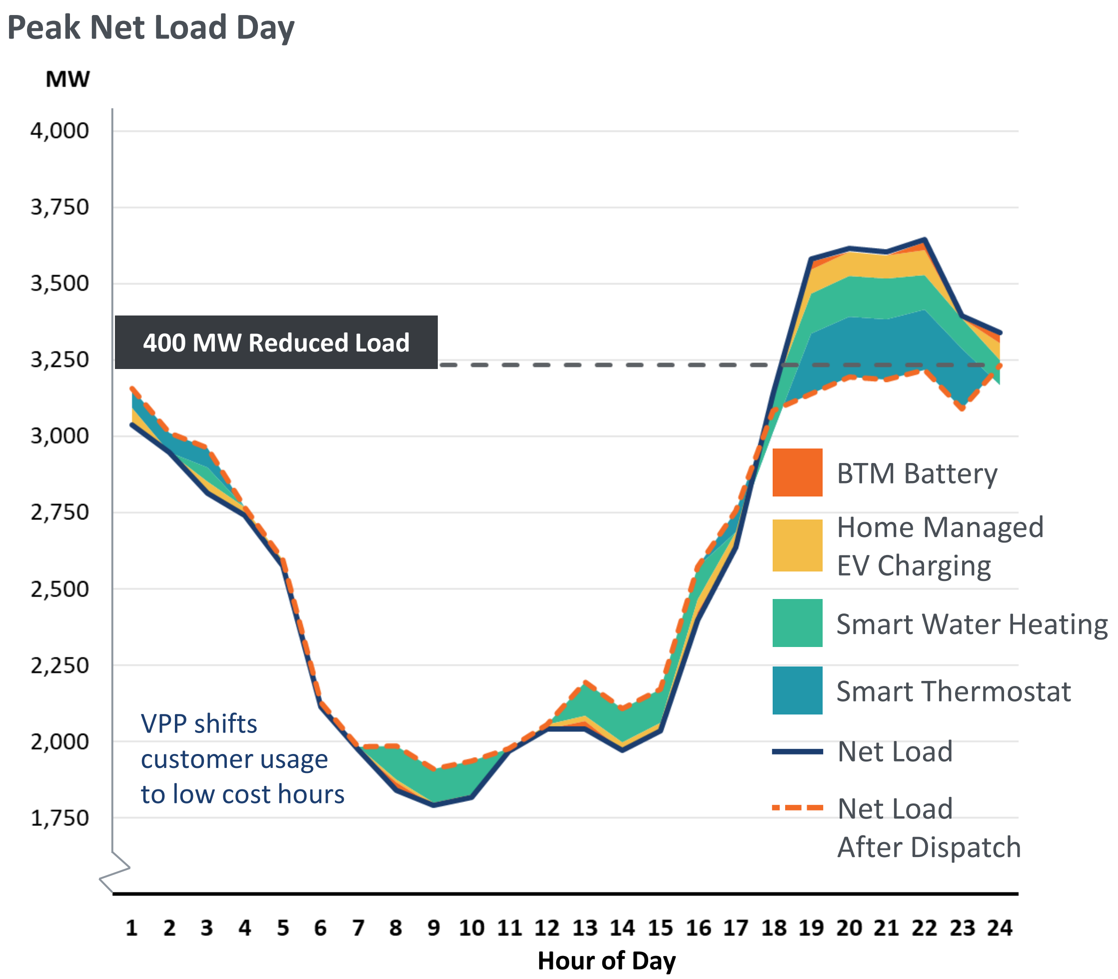
Note: We model a portfolio of 4-hour and 6-hour batteries; there are days when more than 4 hours of energy discharge is needed to provide full resource adequacy.

VPP Operations

The modeled VPP can fully provide 400 MW of resource adequacy, curtailing load across multiple hours of the day during summer and winter.

	System Impact	Discussion
Energy	+	The VPP curtails load during the highest cost hours of the day, and shifts load to lower hours
Ancillary Services	+	The heating element of smart electric water heaters can be managed to provide ancillary services
Emissions	+	The VPP reduces GHG emissions through an overall reduction in electricity consumption due primarily to the energy efficiency benefits of the smart thermostat
T&D Investment Deferral	+	Reductions in demand will delay the need for peak-related capacity upgrades to the T&D system
Resilience	+	Behind-the-meter batteries provide backup generation during distribution outages

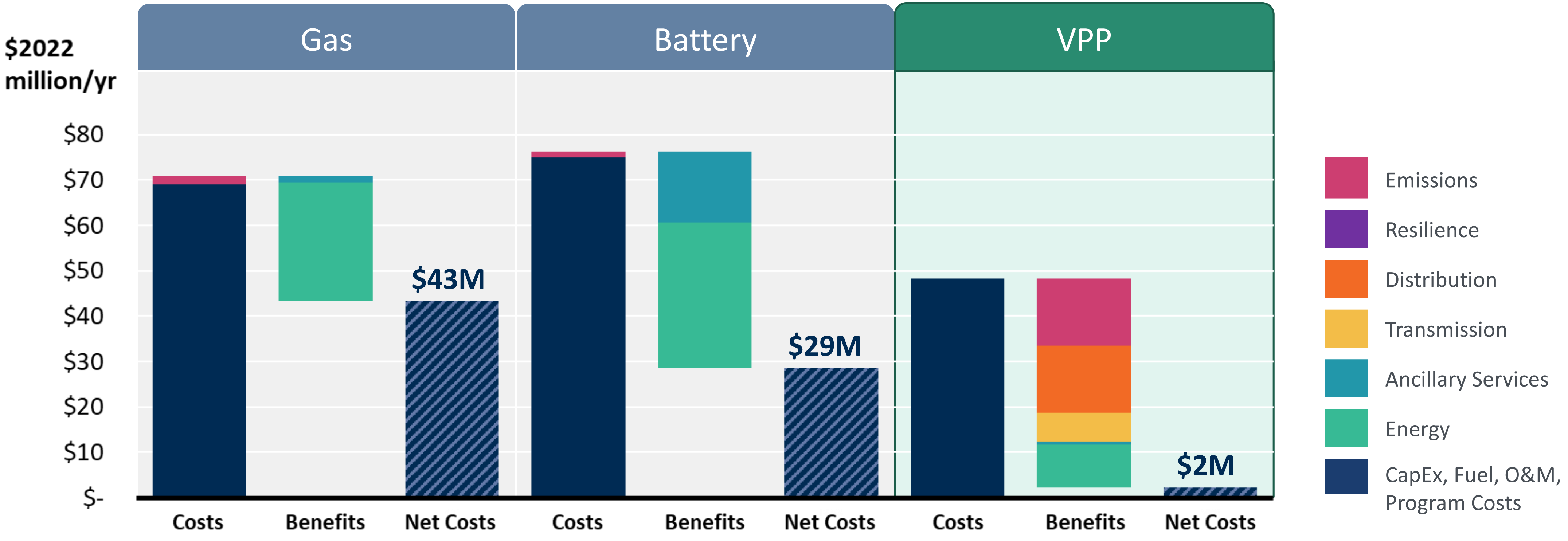
+ = system benefit   – = system cost



Resource Adequacy… For Cheap

The VPP could provide the same resource adequacy at a significant cost discount relative to the alternatives.

Annualized Net Cost of Providing 400 MW of Resource Adequacy



The Cost of 60 GW of U.S. Resource Adequacy

VPPs could save U.S. utilities $15 to $35 billion in capacity investment over 10 years.

Focusing only on utility system costs and benefits, and ignoring societal benefits (i.e., emissions, resilience), the VPP could provide resource adequacy at a net utility system cost that is only roughly 40% of the net cost of a gas peaker, and 60% of the net cost of a battery.

According to RMI, 60 GW of VPPs could be deployed in the U.S. by 2030. Extrapolating from the findings for our illustrative utility, a 60 GW VPP deployment could meet future resource adequacy needs at a net cost that is $15 billion to $35 billion lower than the cost of the alternative options over the ensuing decade.

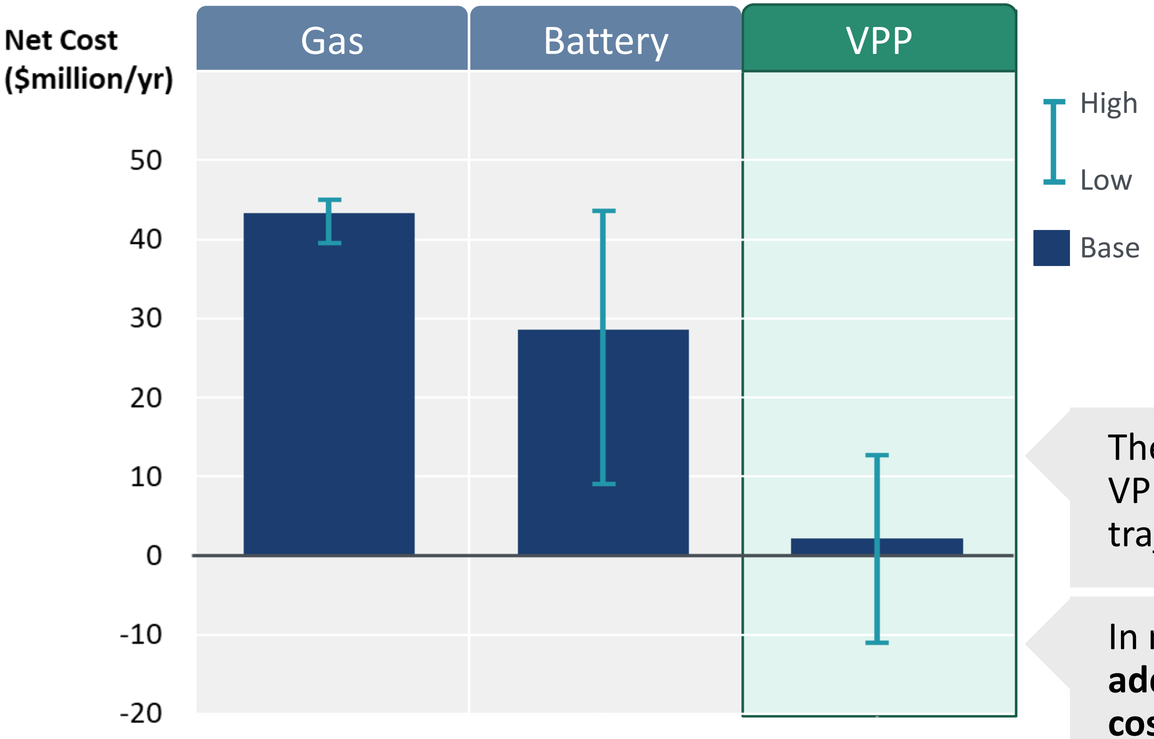
Decarbonization and resilience benefits are incremental to those resource cost savings. Consumers would experience an additional $20 billion in societal benefits over that 10-year period.

Notes: Assumes 60 GW of resource adequacy is procured for 10 years from each resource type at an annualized per-kW net cost that is based on the base case findings from this study. The VPP provides incremental societal value of approximately $37/kW-yr. Values are presented as an undiscounted sum over a 10-year period in real 2022 dollars.

Sensitivity Analysis

The VPP is the only resource with the potential to provide resource adequacy at a negative net cost to society.

Net Cost of Providing 400 MW of Resource Adequacy
(Range observed across all sensitivity cases)



Note: See technical appendix for a complete description of modeling assumptions and data sources. Costs shown in 2022$.

Sensitivity cases modeled:

- Higher carbon price
- Lower carbon price
- Higher T&D cost
- Lower T&D cost
- 2030 technology cost trends
- Business-as-usual renewables deployment
- Alternative battery configuration
- Energy only (no ancillary services benefit)

The economic competitiveness of battery storage and VPPs **will vary from one market to the next,** and also will depend on the trajectory of future cost declines.

In markets with higher T&D costs or higher GHG emissions costs, **the additional (i.e., non-resource adequacy) value of a VPP can outweigh its costs,** thus providing resource adequacy at a negative net cost to society.

Additional Unquantified Benefits of VPPs

VPPs can provide several additional major benefits not modeled in this study.

INCREASED RENEWABLES DEPLOYMENT

By shifting load to hours when excess solar and wind generation otherwise would be curtailed, VPPs can increase the capacity factor of wind and solar generation. In turn, the cost-effectiveness and economic deployment of those resources could increase.

BETTER POWER SYSTEM INTEGRATION OF ELECTRIFICATION

VPPs can facilitate cost-effective deployment of electrification measures by reducing load impacts and associated infrastructure investment needs.

FASTER GRID CONNECTION

The highly distributed nature of VPPs means they are not limited by the same interconnection delays currently facing many large-scale resources.

FLEXIBLE SCALING

A gas peaker is a multi-decade commitment with risks of becoming a stranded asset. Alternatively, the capacity of VPPs can be increased or decreased flexibly over time to align with the needs of a rapidly changing power system.

ENHANCED CUSTOMER SATISFACTION

The opportunity to participate in a VPP unlocks a new feature of customer-owned DERs, improving the overall consumer value proposition of the technologies.

IMPROVED BEHIND-THE-METER GRID INTELLIGENCE

Improved visibility into a portfolio of energy technologies that are connected to the distribution grid can enhance the operator's ability to detect and respond to local changes in system conditions.

Moving Forward with VPPs

The Ideal Conditions for VPP Deployment

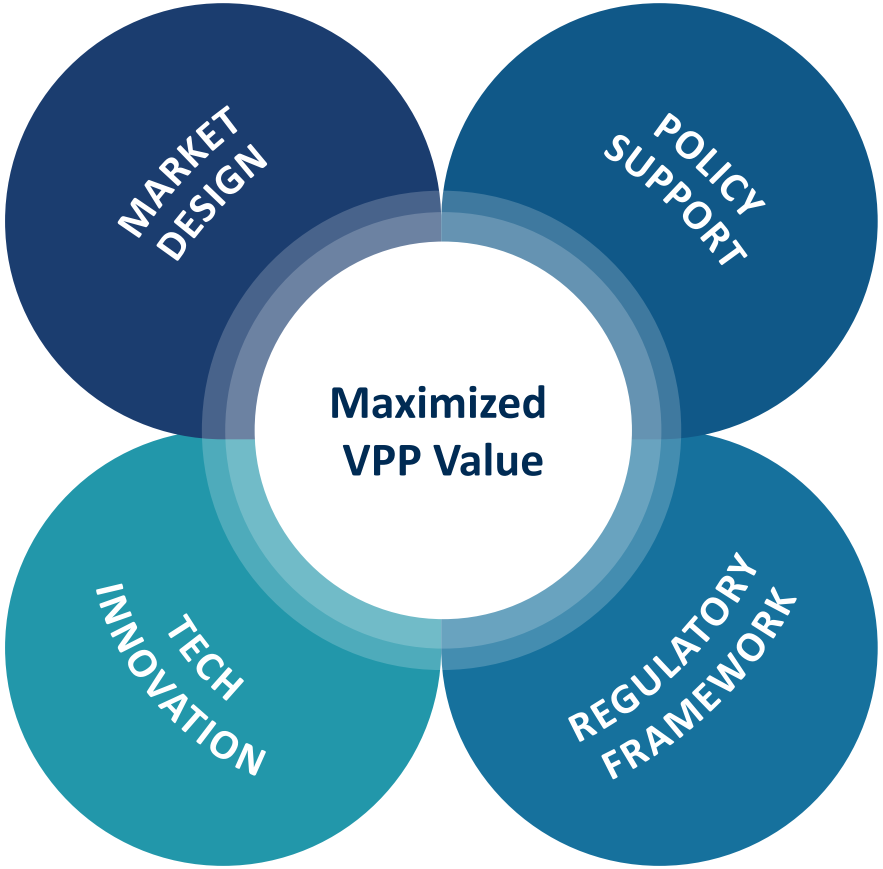
Innovation in technology, markets, policy, and regulation can enable VPP deployment.

MARKET DESIGN

- Wholesale markets provide a level playing field for demand-side resources
- Retail rates and programs incentivize participation in innovative, customer-centric ways

TECHNOLOGY INNOVATION

- DERs are widely available and affordable. DERs can communicate with each other and the system operator
- Algorithms effectively optimize DER use while maintaining customer comfort and convenience



POLICY SUPPORT

- Codes and standards promote deployment of flexible end-uses
- R&D funding supports removal of key technical barriers

REGULATORY FRAMEWORK

- Utility business model incentivizes deployment of VPPs wherever cost-effective
- Utility resource planning and evaluation accounts for the full value of VPPs

Overcoming Barriers to VPP Deployment

Barriers are preventing VPP potential from being realized. With work, they can be overcome.

	Key VPP Barriers	Possible Solutions	Examples
Technology	Lack of communications standards (between devices, with grid)	Initiatives to create coordination and standardization among product developers	The Connected Home over IP (CHIP) working group, Matter, the VP3 initiative
	Uncertain consumer DER adoption trajectory	R&D / implementation funding to improve products and reduce costs	Inflation Reduction Act tax credits for DERs and smart buildings
Markets	Prohibitive/complex wholesale market participation rules	Market products that explicitly recognize VPP characteristics	ERCOT's 80 MW Aggregated DER (ADER) Pilot Program
	Retail rates and program design that do not incentivize DER management	Subscription pricing coupled with load flexibility offerings; time-varying rates	Duke Energy pilot coupling subscription pricing with thermostat management
Regulation	Utility regulatory model that does not financially incentivize VPPs	Performance incentive mechanisms, shared savings models	At least 12 states with utility financial incentives for demand reduction
	Full value of VPPs not considered in policy/planning decisions	Regulatory targets for VPP development	Minnesota PUC 400 MW demand response expansion requirement

Note: For further discussion of barriers and solutions, see the U.S. DOE's A National Roadmap for Grid-Interactive Efficient Buildings.

Quick Wins

Among many options for enabling VPP deployment, here are three low-risk actions utilities and regulators can take in the near-term.

Conduct a jurisdiction-specific VPP market potential study. Then establish VPP procurement targets.

This is a common approach to promoting the deployment of renewables, energy efficiency, and storage.

Potential studies should account for achievable adoption rates and cost-effective deployment levels.

Establish a VPP pilot. Test innovative utility financial incentive mechanisms.

An inflection point in DER adoption is rapidly approaching; pilots will provide critical experience before it's too late.

Technology demonstration is not enough; regulatory models that allow utilities to share in the benefits also must be tested.

Review and update existing policies to comprehensively account for VPP value.

Methods for evaluating VPP cost-effectiveness often consider only a portion of the value they can create.

Evaluation of VPP proposals will need to account for benefits created by the full range of services VPPs provide, including energy savings, load shifting, peak clipping, real-time flexibility, and exports to the grid.

Conclusion

As decarbonization initiatives ramp up across the U.S., **affordability and reliability** are in the spotlight as the top priorities of policymakers, regulators, and utilities.

This study demonstrated that VPPs have the potential to provide the same reliability as conventional alternatives, with **significantly greater** affordability and decarbonization benefits.

While VPPs are beginning to be deployed across the U.S. and internationally, achieving the scale of impacts described in this study will require a **collective industry effort** to place VPPs on a level playing field with other resources.

A renewed focus on innovation in technology development, wholesale and retail market design, utility regulation, system planning, and customer engagement will be **key to ensuring that virtual power plants become more than just virtual reality.**

UNIQUE FEATURES OF THIS STUDY

Hourly reliability assessment, to ensure VPPs are evaluated on a level playing field with alternatives

Realistic representation of VPP performance characteristics and achievable levels of adoption

Analysis of net benefits, with comprehensive accounting for VPP costs

Focus on commercially-proven residential demand flexibility

Additional Reading

Brehm, Kevin, Avery McEvoy, Connor Usry, and Mark Dyson, "Virtual Power Plants, Real Benefits," RMI report, January 2023.

Hledik, Ryan, Ahmad Faruqui and Tony Lee, "The National Potential for Load Flexibility," Brattle report, June 2019.

Hledik, Ryan, Sanem Sergici, Michael Hagerty, and Julia Olszewski, "An Assessment of Electrification Impacts on the Pepco DC System," Brattle report prepared for Pepco, August 2021.

Kuiper, Gabrielle, "What is the State of Virtual Power Plants in Australia?" Institute for Energy Economics and Financial Analysis report, March 2022.

Langevin, Jared Aven Satre-Meloy, Andrew Satchwell, Ryan Hledik, Julia Olszewski, Kate Peters, and Handi Chandra Putra, "The Role of Buildings in U.S. Energy System Decarbonization by Mid-Century," pre-print, October 2022.

Satchwell, Andrew and Ryan Hledik, "Making Grid-interactive Efficient Buildings a "Win" for Both Customers and Utilities," prepared for 2022 ACEEE Summer Study on Energy Efficiency in Buildings, August 2022.

Sergici, Sanem, Ryan Hledik, Michael Hagerty, Ahmad Faruqui, and Kate Peters, "The Customer Action Pathway to National Decarbonization," Brattle report for Oracle, September 2021.

Shah, Jigar, "VPPieces: Bite-sized Blogs about Virtual Power Plants," US DOE Loan Programs Office blog series.

U.S. Department of Energy, "A National Roadmap for Grid-Interactive Efficient Buildings," May 17, 2021.

Zhou, Ella and Trieu Mai, Electrification Futures Study: Operational Analysis of U.S. Power Systems with Increased Electrification and Demand-Side Flexibility," NREL report, May 2021.

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Clarity in the face of complexity

Brattle

VP3 | RMI

Virtual Power Plants, Real Benefits

How aggregating distributed energy resources can benefit communities, society, and the grid

Report / January 2023

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Kevin Brehm, Avery McEvoy, Connor Usry, and Mark Dyson, *Virtual Power Plants, Real Benefits,* RMI, 2023, **https://rmi.org/insight/virtual-power-plants-real-benefits/**.

About VP3

Virtual Power Plant Partnership, or VP3, is a coalition of nonprofit and industry voices that seeks to shift the necessary policies, regulations, and market rules to unlock the market for virtual power plants (VPPs). Our members span hardware and software technology solution providers, distributed energy resources (DER) aggregators, nonprofits, and others.

A robust VPP market expands the possibilities for all DERs — empowering households, businesses, and communities to play a role in the energy transition alongside technology solution providers. Learn more at vp3.io.

About RMI

RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

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Executive Summary

Virtual power plants (VPPs) — grid-integrated aggregations of distributed energy resources — are providing benefits to households, businesses, and society today. Moreover, they are on the cusp of significant market growth due to recent federal legislation and the ongoing technology- and market-driven transformation of the electricity grid.

- By 2030, VPPs could reduce peak demand in the United States by 60 gigawatts (GW). That number could grow to more than 200 GW by 2050. By avoiding generation build-out, decreasing wholesale energy costs, and avoiding or deferring transmission and distribution investments, VPPs can help reduce annual power sector expenditure by $17 billion in 2030.

- VPPs are also a key resource to meet climate goals — VPPs can reduce greenhouse gas emissions by decreasing reliance on the most polluting fossil fuel–fired power plants, incentivizing build-out of clean generation, and enabling economy-wide electrification.

- To access the full benefits of VPPs, there remains a need to understand and communicate VPP benefits, advance best practices, and shift policy and regulation to put VPPs on a level playing field with traditional grid investments.

- The next few years are a critical window for VPP market development. Coordinated and collective action over this time can set the VPP market on a path to delivering long-term benefits.

RMI's new coalition

To accelerate the growth of the VPP market and deliver the reliability, affordability, and climate benefits of VPPs at scale, RMI is launching the Virtual Power Plant Partnership (VP3): a coalition of nonprofit and industry voices dedicated to growing a vibrant VPP market. VP3 will publish technical resources, provide direct support in key venues, convene across stakeholders, and communicate to targeted and mass-market audiences to raise awareness of the VPP opportunity. For more information, please contact **vp3@rmi.org**.

Virtual Power Plants: An Overlooked Resource

The coming decade will be a period of rapid change for the US electric grid. Policy, climate change, geopolitics, and consumer preferences will push the grid to evolve at unprecedented speeds. Grid planners, regulators, and operators have the challenge of managing these changes while simultaneously advancing power system performance across seven objectives:

1. **Reliability:** increasing system reliability and resilience even as extreme weather and cybersecurity threats increase
2. **Affordability:** driving down household energy burden in the face of rising inflation and global energy supply chain disruption
3. **Decarbonization:** reducing greenhouse gas emissions to meet national, state, and corporate climate targets
4. **Electrification:** enabling rapid electrification of homes, transportation, and industry to reduce economy-wide emissions and avoid the worst impacts of climate change
5. **Health:** reducing or eliminating early deaths and other health damages resulting from power plant pollution
6. **Equity:** addressing inequitable health and community impacts embedded in the current energy system
7. **Consumer empowerment:** providing energy consumers choice and a voice in shaping the power system in which they participate

Virtual power plants (VPPs) — grid-integrated aggregations of distributed energy resources — are a resource to help advance performance across each of these objectives in the coming years.

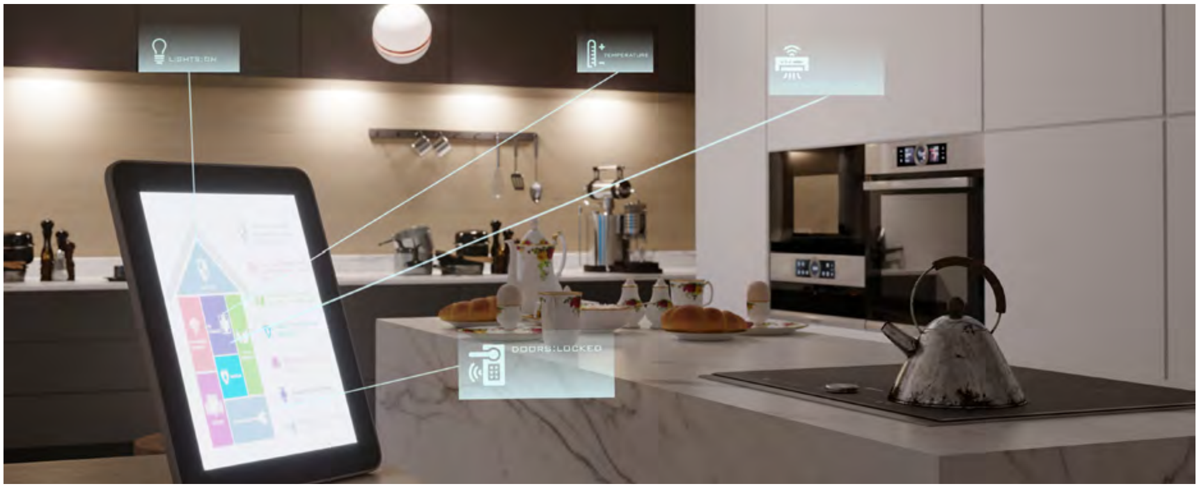
Unfortunately, VPPs are often overlooked by policymakers, utilities, and consumers. This brief defines VPPs in the context of emerging challenges and opportunities, discusses their benefits, and provides a set of recommendations for growing the VPP market in ways that help communities and society.

VPPs are not new. This paper draws on data from a decade of successful VPP pilots and programs to demonstrate how VPPs help the grid meet pressing challenges. This paper also summarizes power system modeling to show VPPs can grow in scale and impact — with the potential to offset or provide 14% of US peak electric power demand in 2050.[1]

Although VPPs are not new, they are at an inflection point. Consumer adoption of flexible devices such as heat pumps, electric vehicles (EVs), and battery storage is accelerating just as the Infrastructure Investment and Jobs Act and Inflation Reduction Act will pump billions of dollars into the electric grid. At the same time, regulators and utilities are looking for short- and long-term solutions to reliability and affordability challenges.

Over the next decade, VPPs could play a central role in meeting grid and societal needs. However, barriers related to wholesale market value, retail offerings, and consumer awareness must be addressed to unlock the full potential of VPPs.

Over the next decade, VPPs could play a central role in meeting grid and societal needs. However, barriers related to wholesale market value, retail offerings, and consumer awareness must be addressed to unlock the full potential of VPPs. Planning and policy choices over the coming years will set the path for VPP market development over the coming decade.



Understanding VPPs

What Is a Virtual Power Plant?

We define virtual power plants (VPPs) as grid-integrated aggregations of distributed energy resources. There are three key parts to that definition:

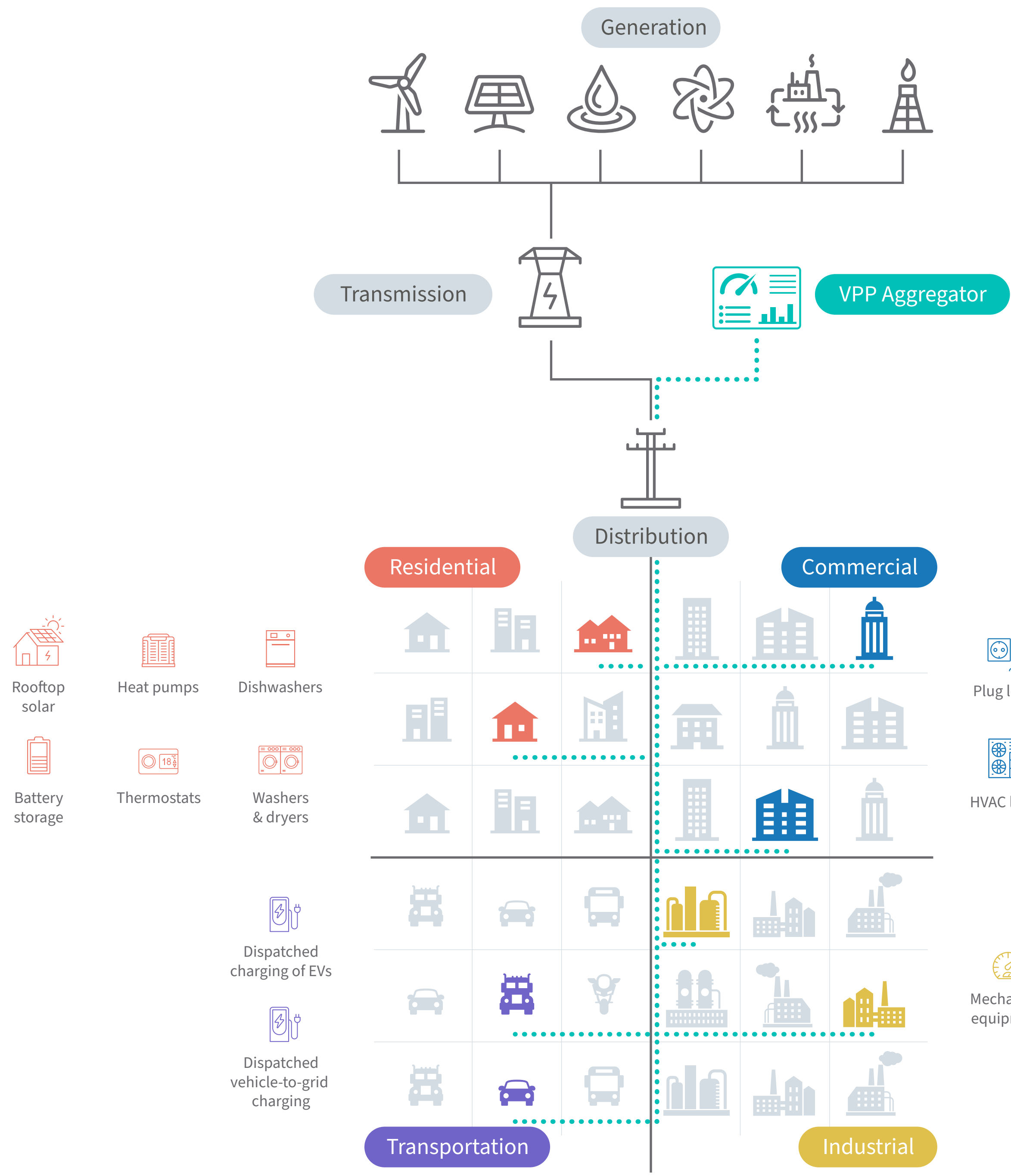
- **Distributed energy resources (DERs):** At its core, a VPP is comprised of hundreds or thousands of devices located at or near homes and businesses. Some of these assets (e.g., behind-the-meter batteries) are readily dispatchable. Other assets (e.g., solar photovoltaic [PV], or passive energy efficiency investments) are less likely to be flexibly dispatched but still can be aggregated and provide value to the grid.

- **Aggregation:** A VPP brings these DER assets together into aggregations. In some instances, these aggregations can be collectively and directly controlled by a grid operator. At other times, the aggregation is much looser, with less direct control by a grid operator.

- **Grid-integrated:** Finally, VPPs provide value to the grid, and they are compensated for the value they provide. Properly integrated into long-term grid planning and real-time operations processes and/or markets, VPPs can add value alongside other, traditional grid assets like large-scale generating facilities.

Exhibit 1 (next page) shows possible components of a VPP. VPPs can include EVs and chargers; heat pumps; home appliances; heating, ventilating, and air conditioning (HVAC) equipment; batteries; plug loads; solar PV; or industrial mechanical equipment. Single-family homes, multifamily homes, offices, stores, factories, cars, trucks, and buses can all participate in a VPP.

Exhibit 1 **VPPs Aggregate Distributed, Grid-Interactive Electric Devices**



How Do VPPs Work?

There is no standard design for a VPP. Broadly, however, there are two channels through which VPPs can provide value and be compensated:

1. **Market-participant VPPs** provide services to and are compensated by wholesale electricity markets.
2. **Retail VPPs** provide services to and are compensated by utilities.

Market-participant VPP

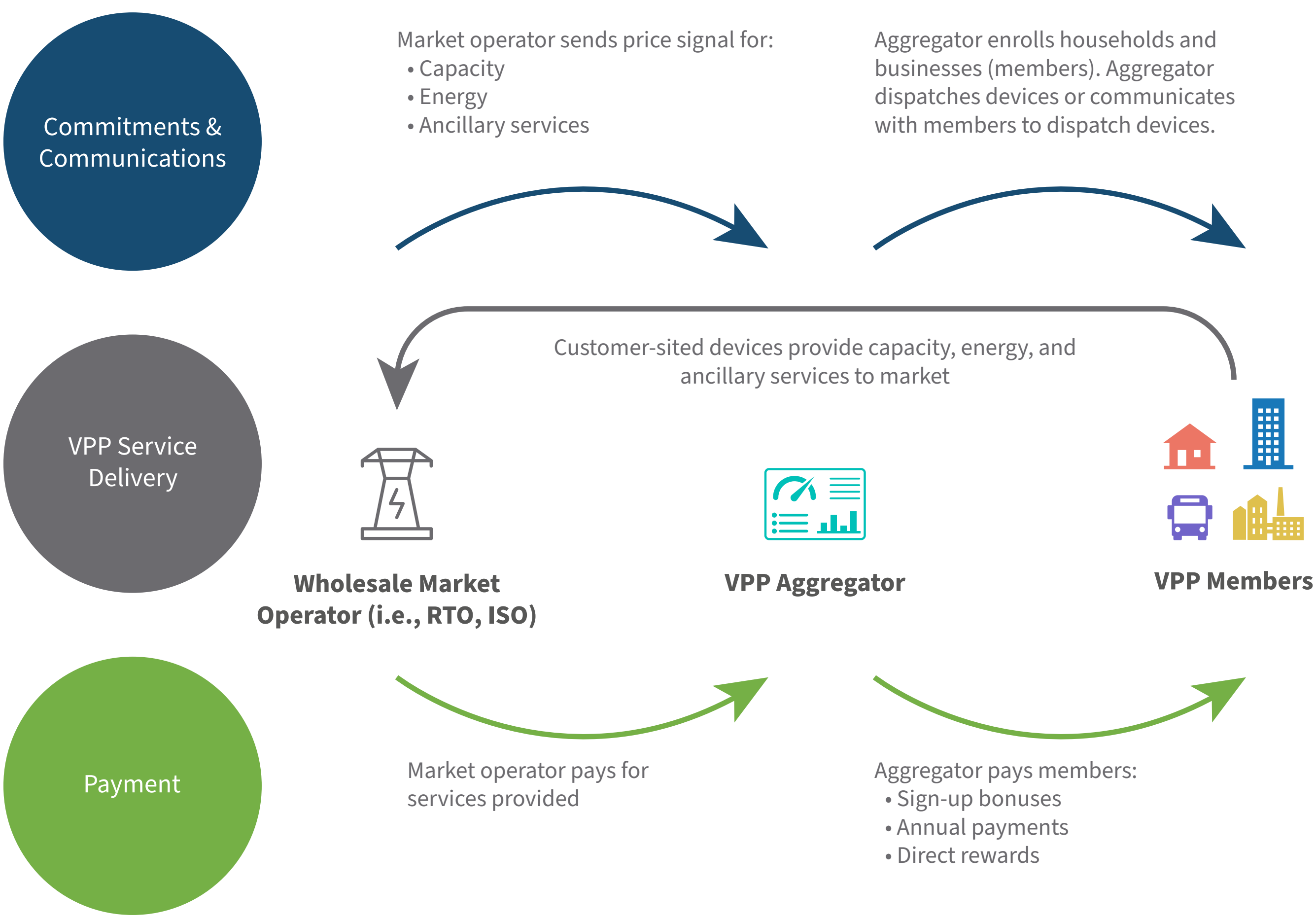
OhmConnect operates a market-participant VPP in California's wholesale electricity market. OhmConnect's VPP is comprised of more than 200,000 members with 250,000 dispatchable smart devices.[2]

During an extreme heat wave that lasted from August 31 to September 8, 2022, California's wholesale market operator, California Independent System Operator (CAISO), called on all available resources to match supply and demand. These resources included VPPs managed by OhmConnect, Tesla, Sunrun, Leap Voltus, AutoGrid, and others.[3]

Over the nine-day heat wave, OhmConnect's VPP automatically dispatched member devices 1.3 million times in response to real-time signals from CAISO. CAISO paid OhmConnect for services delivered. OhmConnect in turn paid $2.7 million in rewards to its members.[4]

Exhibit 2 illustrates how a market-participant VPP works.

Exhibit 2 **A Market-Participant VPP Calls on Customer-Sited Devices to Provide Services to Wholesale Electricity Markets**



Retail VPP

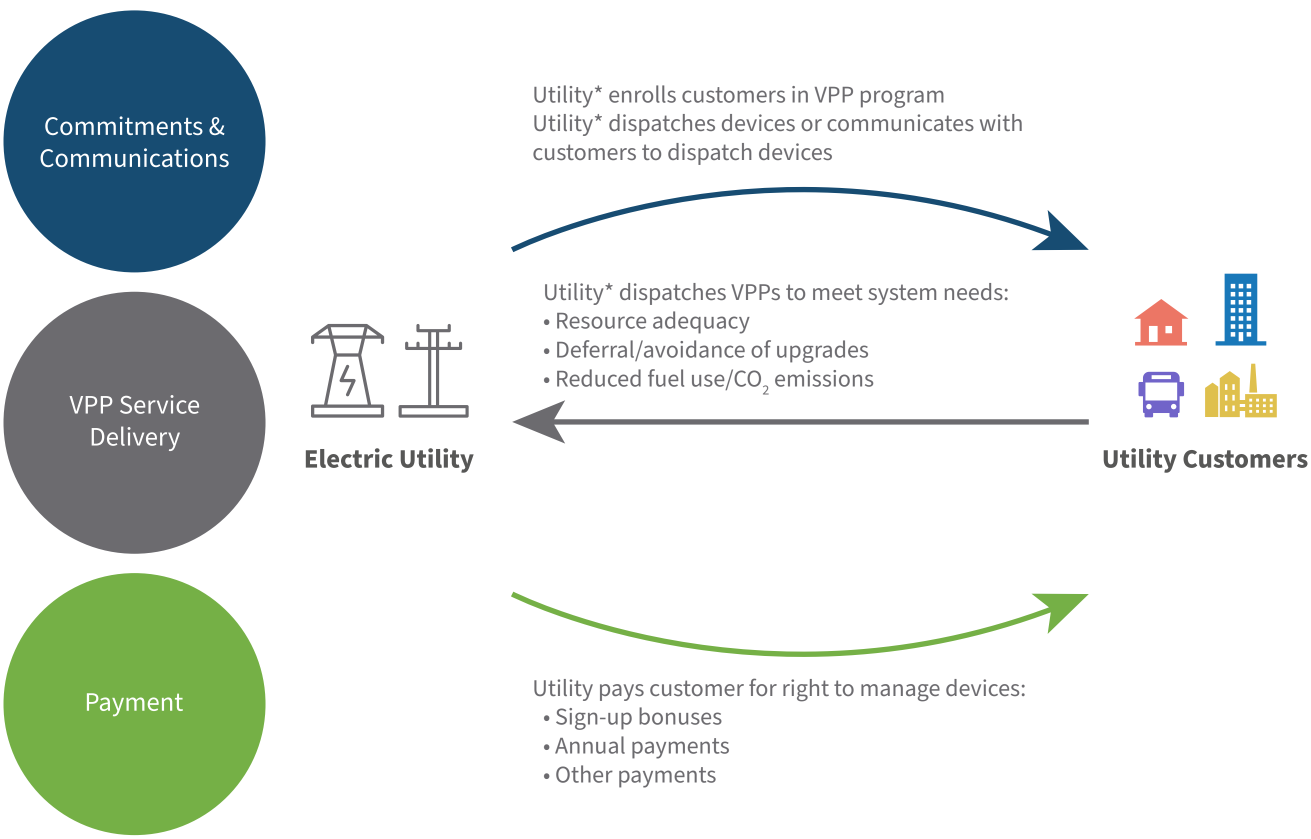
National Grid's ConnectedSolutions is an example of a retail VPP.

In the ConnectedSolutions program, National Grid — an electric utility serving customers in New York and Massachusetts — pays customers both upfront and annual incentives to enroll their smart thermostats, home batteries, and EVs in the VPP program. National Grid dispatches these devices to balance summer peak demand.

In 2020, the VPP helped reduce summer peak demand by 0.9%.[5] This helps National Grid avoid costs it would otherwise need to spend on wholesale power costs, transmission and distribution infrastructure upgrades, fuel, and other expenditures.

Exhibit 3 illustrates a retail VPP.

Exhibit 3 **A Retail VPP Can Help a Utility Meet Demand and Reduce Costs for Both the Utility and Its Ratepayers**



**Utility may partner with third-party service provider*

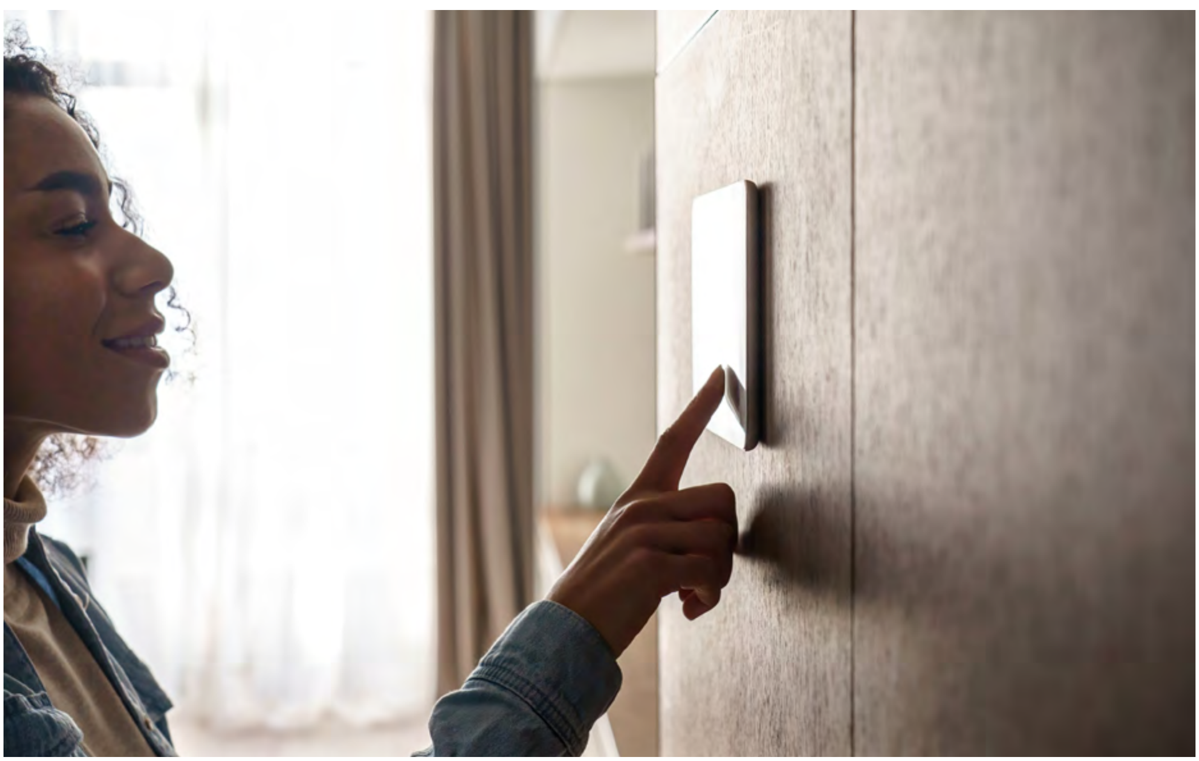
A specific, but important, category of retail VPP is a VPP in which aggregations of DERs respond, either actively or passively, to rate designs set by power providers — usually retail utilities or load-serving entities, but in some cases wholesale market operators. In the examples above, OhmConnect and National Grid actively aggregated households and businesses into VPPs and have technology to directly control devices' operations. In contrast, tariffs (rates) paid by electric customers can also induce DER build-out and demand flexibility. These include time-of-use pricing, real-time pricing, critical peak pricing, and participation incentives, which all can achieve some level of demand flexibility but differ in their level of responsiveness and ability to dynamically adjust incentives in real time.

How Are VPPs Different than Other Demand-Side Solutions?

Our definition of VPPs is intentionally broad. It encompasses a wide range of solutions that harness and compensate DERs to meet the needs of the grid. Demand response, demand flexibility, demand-side management, DER aggregations, bring-your-own-device programs, and grid-interactive efficient buildings are all examples of programs and technologies that can contribute to VPPs.

VPPs build on the success of decades of progress in demand-side management programs and participation models for DERs. Given the current landscape of rapidly shifting technology and emergent challenges to reliability, affordability, and other priorities, we use a broad definition of VPPs to characterize how, with renewed attention and targeted interventions, aggregated demand-side resources and programs can address these challenges at a scale rarely contemplated in previous decades.

Though our definition is broad, not all programs that shape customer behavior are VPPs. For example, calls for voluntary conservation in a time of crisis do not compensate customers for the benefits they provide to the grid and thus do not transact value in the same way as commercially viable VPPs.



How VPPs Can Address Key Grid Challenges

VPPs are a powerful tool to help regulators, utility planners or operators, and other grid stakeholders address key challenges facing the grid. This section looks backward to see how VPPs have already provided value, as well as forward to project how VPPs can further address grid challenges in the coming years and decades, if policies and markets are structured to enable this.

Reliability

VPPs are key solutions to enhance grid reliability and resilience

Grid planners and regulators want to know if they can count on VPPs to show up during the days, hours, and minutes when the grid needs them most. VPPs are showing they can be trusted to support grid reliability.

Each year there are more examples of how VPPs have contributed to grid reliability. A few are described below:

- **Sunrun's** VPP reduced more than 1.8 gigawatt hours (GWh) of energy demand over the summer in ISO New England.[6]
- **Arizona Public Service's** Cool Rewards Program has enrolled 60,000 thermostats and helped shed nearly 100 megawatts (MW) during the hot summer months in 2022.[7]
- **South Australia's** VPP stabilized the grid in October 2019 when a coal-fired power plant tripped offline and left a supply gap of 748 MW.[8] The VPP has also provided critical support during November 2019 and January 2020 grid disruptions between South Australia and Victoria.[9]
- **VPPs managed by AutoGrid's platform** collectively represented 5 GW of capacity and 37 GWh of energy across 15 countries as of summer 2021. These assets were dispatched 1,500 times to meet grid needs in summer 2021.[10]

These examples demonstrate how VPPs are ensuring reliable operation of the bulk power system by reducing demand or injecting power into the system during times of critical demand. VPPs also provide three reliability-related benefits that traditional power plants do not:

1. **Rapid and flexible deployment:** Whereas a fossil fuel–powered thermal energy plant (such as coal or gas) needs on average over four years to be developed and built,[11] some VPPs can be developed in as little as months. Furthermore, while traditional power plant investments tie utilities to a single asset for decades, VPPs can be more flexibly reconfigured or scaled back in response to changing grid needs.
2. **Sited near load:** VPPs can bypass transmission or distribution constraints or congestion by providing capacity close to load.
3. **Community energy resilience:** Solar, batteries, and EVs can participate in VPPs when the grid is up or provide resilient power supply to homes and critical facilities when the grid is down. For example, General Motors, Ford, and others are piloting bidirectional charging programs in which EVs become backup home power sources.[12]

Looking forward, VPPs can play a large role in supporting grid reliability in this decade and beyond. RMI analysis (detailed in the Appendix) estimates that VPPs could provide 62 GW of peak coincident dispatchable capacity by 2030. This is comprised of 17 GW flexible EV load, 10 GW behind-the-meter battery storage, 20 GW flexible residential demand, and 15 GW flexible commercial demand. Analysis from the National Renewable Energy Lab (NREL) found that by 2050, demand flexibility could reduce system-wide peak demand by roughly 200 GW.[13,i]

Exhibit 4 **Peak Coincident VPP Capacity — 2030**

Source: See Appendix

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i This is the impact of demand flexibility on a modeled peak load day. It corresponds to the high electrification scenario, in which load grows 81% by 2050 compared with 2019. The figure from NREL does not include behind-the-meter storage, distributed solar, or energy efficiency.

Affordability

VPPs are a cost-effective resource to improve electricity affordability

The average price of electricity is projected to increase 7.5% in 2022 compared with 2021.[14] This is an inconvenience for many but an acute hardship for the 30.6 million energy-burdened households in the United States — households paying more than 6% of their gross annual household income on energy bills.[15] VPPs can make electricity more affordable both for customers who participate in VPPs and for homes and businesses that do not.

VPPs directly compensate participating households and businesses through bill savings, cash payments, or rewards programs:

- **OhmConnect's California VPP,** which includes 40% of their consumers qualifying as low income, saves customers on average $250–$300 per year.[16]

- In **South Australia,** customers save $200 per year by participating in the state's VPP.[17]

VPPs also help drive down bills for nonparticipating customers by reducing the total cost to operate the electric grid. VPPs do this in a few ways:

1. **Avoid or defer generation capacity investments** by reducing peak demand.

2. **Avoid or defer distribution and transmission system investments** by reducing peak demand.

3. **Reduce wholesale energy and fuel costs** by shifting demand away from high-cost peaking resources and toward low- or no-marginal cost resources. This also provides decarbonization benefits.

Looking into the future, NREL's electrification futures study found that demand flexibility could avoid or defer $120 billion (net present value [NPV]) worth of generation capacity investments through 2050.[18,ii] Efficient operation could avoid $10 billion in annual bulk system fuel and maintenance costs in 2050.[19] Those studies do not include the potential impact of deferred or avoided distribution system upgrades, which further increase the economic value of VPPs.

According to Brattle Group analysis, by 2030, demand flexibility could avoid generation capacity worth $9.7 billion, wholesale energy costs worth $4.8 billion, ancillary service charges worth $0.3 billion, and transmission and distribution costs worth $1.9 billion.[20]

ii 2019–50 NPV of bulk system savings from enhanced flexibility as compared with current flexibility (Murphy et al. 2021).

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Decarbonization

VPPs accelerate power sector decarbonization

VPPs can help regulators, policymakers, businesses, and households reduce CO_2 pollution. VPPs do this in three ways:

1. **Decrease dispatch of highly polluting power plants:** VPPs can directly impact emissions by shifting demand away from times when the grid relies on the most highly polluting coal- and gas-fired power plants and toward times when carbon-free resources are available. This is the direct and near-term emissions impact of VPPs.

2. **Drive build-out of carbon-free power supply:** VPPs provide flexibility and capacity that will be critically important in a future carbon-free power system. By shifting demand, VPPs can reduce solar and wind curtailment. This enhances the value of solar and wind in a region and can indirectly lead to more solar and wind build-out in the future. VPPs also can help avoid the need to build new fossil fuel–fired power plants and help accelerate closure of some existing fossil fuel–fired plants.

3. **Enable economy-wide electrification:** VPPs can facilitate economy-wide electrification of other end uses, further reducing economy-wide emissions outside the power sector. This is discussed in the next section on electrification.

VPPs have already shown how they can help enable retirement of some fossil fuel peaker plants:

- **Green Mountain Power's VPP** attributed part of the retirement of two diesel generators with 4 MW of peaker capacity to the ability to call on its VPP participants' residential home battery systems while maintaining system-ramping capabilities and reliability.[21]

- **The City of Redondo Beach, California,** is working with OhmConnect to develop a community VPP that eliminates reliance on AES's 68-year-old gas peaker plant in Redondo Beach. Over 20,000 people live within 1 mile of the gas peaker plant, which emits harmful nitrogen oxides and particulate matter.[22]

The climate benefits of VPPs will increase over time as the United States deploys more electric devices, brings online more renewable energy, and retires coal generation.[iii] By 2050, VPPs could avoid 44 million–59 million tons of CO_2 in 2050.[23,iv] This could go a long way toward helping the United States close the gap between current policy and commitments made in the Paris Climate Agreement.

iii Multiple studies (including Zhou and Mai 2021) have shown that economic dispatch of demand flexibility could lead to increased utilization of coal generation. This is particularly the case if natural gas prices are high, in which case demand-side flexibility can lead to increased coal dispatch at the expense of natural gas–fired generation. This finding points to a potential need to co-optimize VPP dispatch for both economics and emissions.

iv Based on analysis in Zhou and Mai (2021). Fifty-nine million tons (Mt) is the annual emissions reduction from flexibility in the high-electrification scenario. Forty-four Mt of emissions are avoided through demand flexibility in the high-electrification, high-renewables scenario. As context, 2021 power sector emissions were 1,551 Mt, according to the Energy Information Administration.

Electrification

VPPs enable economy-wide electrification

Over the coming decades, homes and businesses will increasingly adopt heat pumps, EVs, and other electric devices. The electricity system will need to grow and adapt to accommodate sustained load growth. VPPs enable cost-effective electrification in two ways:

1. **Avoided bottlenecks:** By shifting demand, VPPs can avoid bottlenecks in transmission, distribution, or generation capacity, which could otherwise constrain electrification.

2. **Provide electrification revenue streams:** VPPs provide additional revenue streams for flexibility from electric devices, helping encourage consumers to adopt them over nonelectric alternatives.

Demand flexibility significantly eases the challenges associated with sustained load growth from EVs and heat pumps. For example, in a study of electrification strategies for a Colorado utility,[24] RMI found that simple managed charging for EVs could reduce peak load growth by 20% relative to unmanaged demand from newly electrified devices. In this way, VPPs can accelerate a transition to a future in which electrified devices can help the grid be more resilient without incurring unneeded costs of infrastructure required to deliver energy to inflexible electric loads.

Health, Equity, and Consumer Empowerment

The examples in the preceding sections show how VPPs can also help advance health, equity, and consumer empowerment objectives.

One way VPPs drive positive health outcomes is by decreasing reliance on natural gas-fired peaker plants. The examples in the decarbonization section show how the need for some peaker plants can be avoided through VPPs.

These health benefits will disproportionately flow to people of color and low-income communities. Black, low-income populations are 1.2 times more likely than the average person in the United States to die prematurely from exposure to particulate matter from fossil fuel plants.[25] Furthermore, as discussed in the affordability section, VPPs can advance equity outcomes by providing revenue- and cost-reduction opportunities for low-income households.

Finally, VPPs empower consumers — all consumers — to play a more active role in shaping the way energy is used and consumed in society and within their homes and businesses.

Unlocking the VPP Opportunity

Barriers to Scaling VPPs

For VPPs to grow in the long term, more customers need access to attractive VPP offerings. Three core barriers stand in the way of VPP long-term growth: wholesale market rules, retail utility offerings, and consumer and policymaker awareness.[26] Once these core barriers are addressed, more VPP businesses will have access to reliable revenue streams from utilities or wholesale markets, and customer-acquisition and grid-integration costs will fall. VPP businesses, in turn, will be able to provide highly compelling offerings to households and businesses.

Wholesale market rules

Federal Energy Regulatory Commission (FERC) Order 2222 (2020) requires regional transmission organizations (RTOs) and independent system operators (ISOs) to allow DERs to participate alongside traditional resources in the regional organized wholesale markets through aggregations. In theory, this decision allows the two-thirds of US businesses and households served by utilities and retail electricity providers within RTOs and ISOs to participate in VPPs.

DER integration into wholesale markets is complex, and FERC is relying on RTOs to make rules that efficiently integrate and fairly compensate DER aggregations. The rules RTOs make in at least six areas will impact whether VPPs are able to thrive in those markets:[27]

1. Order 2222 implementation timing
2. Limits on eligible aggregations
    - Minimum aggregation size
    - Technologies involved
    - Location of devices
3. Metering and telemetry requirements
4. Interconnection processes and aggregation reviews
5. Dispatch override by electric distribution companies
6. Customer data access

Retail utility offerings

In areas not served by wholesale electricity markets, retail programs and retail rates are the only option for customers who want to be compensated for the services their devices can provide. Additionally, in areas served by wholesale markets, retail programs and rates will remain an important channel for VPPs.

Unfortunately, in many areas retail programs are not available, or if they are available they are not yet compelling. Utilities may not yet provide compelling offerings for a few reasons:

- Operators at utilities do not yet trust VPPs to show up and provide services when critically needed.
- Necessary infrastructure (e.g., smart meters) and software systems are not yet in place.
- Utilities are required (by law or regulation) to provide multiple technology-specific programs such as smart thermostat programs, managed charging programs, and battery storage programs instead of integrated multi-technology programs.
- Through the cost-of-service regulatory model, most utilities are financially incentivized to make capital investments, not to promote demand-side solutions.
- Legacy planning and resource procurement models and processes fail to consider or adequately consider demand-side resources.[28]

Public utility commissions are responsible for regulating utilities' VPP-related efforts. Unfortunately, VPPs cut across several topic areas — energy efficiency, demand response, EVs, resource planning, procurement, and so on — that have traditionally been handled through separate processes within commissions, making it unclear how to regulate them within existing dockets and proceedings. Furthermore, VPPs touch on complex planning- and cost-recovery issues for which regulatory best practice is still evolving.

Consumer and policymaker awareness

Although VPPs are not new, awareness of them and their potential remains relatively low among customers and policymakers. As a result, VPP technology and service providers need to spend significant time and resources educating customers about VPP benefits, adding cost to the customer-acquisition process.

Similarly, solutions providers and industry organizations need to educate elected officials and energy offices on VPPs. Without high levels of awareness and understanding, these policymakers may not be developing policies that capture the full benefits of VPPs.

Interventions to Scale a Vibrant VPP Market

To enable a vibrant VPP market that can unlock projects at the hundreds of gigawatts scale in the next decade, and the benefits associated with them, there is a need to work on three priorities in the next two to three years:

1. **Catalog, research, and communicate VPP benefits.** This insight brief and the research referenced in this report attempt to describe and quantify the benefits of VPPs, but more work must be done to understand and communicate the full benefits of VPPs. For example, more work is needed to comprehensively characterize the current VPP market and the benefits VPPs are already providing. More research is needed to model mid-term (i.e., 2030) state-specific impacts of VPPs on reliability, affordability, decarbonization, and other key policy objectives. This research must be translated and communicated in ways that are useful to technical audiences (e.g., utility planners and regulators) as well as less technical audiences (e.g., elected officials, households, and businesses).

2. **Develop industry-wide best practices, standards, and roadmaps.** Once the potential benefits are better understood, industry stakeholders must work together to develop efficient and effective ways to unlock those benefits. As things stand, the VPP market is characterized by nonstandard regulatory approaches, wholesale market rules, retail program structures, technology interoperability protocols, and finance approaches.

   To remove friction from the VPP market, service providers, utilities, regulators, and technology providers need to develop and advance a set of best practices, standards, and roadmaps. This work is complex and will not necessarily result in a one-size-fits-all approach to VPPs, but it will help to unlock VPP benefits by showcasing proven approaches to effective market integration and delivery of customer value.

3. **Inform and shape policy development.** The two activities above are critical, but they will not be sufficient to drive market growth. Stakeholders who have an interest in the growth of the VPP market, including consumer advocates, large energy users, technology developers, and service providers, need to ensure that their voice is heard and listened to in federal, state, and RTO policy venues. Through collaboration across a wide variety of interested businesses and other groups, VPP advocates can marshal the resources and organizational force to effect change in policy and regulation that can put VPPs on a level playing field with traditional electricity system investments.

Appendix

Peak Coincident VPP Capacity Methodology

VPP Resource	RMI Capacity Assumption	Approach
Total	**61.9 GW**	**See below**
Electric Vehicles (Light-Duty Vehicles [LDVs])	**17.3 GW**	***17.3 GW = [26.4 million light-duty EVs] × [0.654 kWh/unit-hour]*** *[# vehicles] × [hourly energy use assumed per unit during system-wide peak day/hour of the year]* **Number of Vehicles** • Based on Edison Electric Institute analysis: 26.4 million light-duty EVs[29] **Energy Use per Vehicle** • Representative annual hourly demand for typical LDV based on modeling from RMI • Peak hourly demand for June 30 at 5 p.m. (**0.654 kWh/unit**)[30] **Notes/Conservatisms** • Based on light-duty EV load shape. Medium- and heavy-duty EV load shapes will be different. • Does not account for shift in load shape over time. • Peak demand and EV load profile will vary by region. As such, this is approximate only.
Behind-the-Meter (BTM) Battery Storage	**9.9 GW**	• Global projections for BTM storage in 2030: **57 GWh**[31] • The United States will have 40% of 2030 BTM storage: **22.8 GWh**[32] • Average system can reasonably assume ~2.3 watts per watt-hour of capacity. *"Typically, residential consumers' batteries can reach 5 kW/13.5 kWh, whereas a battery for a commercial or industrial system is typically 2 MW/4 MWh."*[33] • 22.8 GWh/2.3 hours = **9.9 GW**
Residential Demand Flexibility	**19.8 GW**	**Midpoint between:** • Mid-adoption: **14.2 GW**[34] • High adoption: **25.3 GW**[35] • Peak demand reductions are computed as the sum of impacts during each region's coincident peak hour[36]
Commercial Demand Flexibility	**14.9 GW**	**Midpoint between:** • Mid-adoption: **11.6 GW**[37] • High adoption: **18.2 GW**[38] • Peak demand reductions are computed as the sum of impacts during each region's coincident peak hour
Residential-, Commercial-, and Community-Scale Solar	**N/A**	Ignore "solar" contribution to the capacity and reliability value of VPPs.
Energy Efficiency	**N/A**	Ignore "energy efficiency" contribution to the capacity and reliability value of VPPs.

Endnotes

1 Ella Zhou and Trieu Mai, *Electrification Futures Study: Operational Analysis of US Power Systems with Increased Electrification and Demand-Side Flexibility,* National Renewable Energy Laboratory, 2021, **https://www.nrel.gov/docs/fy21osti/79094.pdf**.

2 OhmConnect Paid Members $2.7M and Saved 1.5 GWh of Energy During Recent California Heat Wave," *PR Newswire,* September 29, 2022, **https://www.prnewswire.com/news-releases/ohmconnect-paid-members-2-7m-and-saved-1-5-gwh-of-energy-during-recent-california-heat-wave-301636415.html**.

3 "Join the Tesla Virtual Power Plant: 2022 Performance," Tesla, accessed October 24, 2022, **https://www.tesla.com/support/energy/tesla-virtual-power-plant-pge-2022#2022-performance**; and "East Bay Customers Support California's Grid During Extreme Heat Wave Through Innovative Program," Sunrun, September 20, 2022, **https://investors.sunrun.com/news-events/press-releases/detail/271/east-bay-customers-support-californias-grid-during-extreme**; and "Leap Delivers Crucial Grid Support during California's Record-Breaking September Heat Wave," Leap, September 7, 2022, **https://www.leap.energy/blog/leap-delivers-crucial-grid-support-during-california-s-record-breaking-september-heat-wave**; and "Voltus Helps Prevent Blackouts During California's Record-Breaking September Heat Wave," Voltus, September 13, 2022, **https://www.voltus.co/press/voltus-helps-prevent-blackouts-during-californias-record-breaking-september-heat-wave**; "Oh California! California's Grid Flexes but Doesn't Break. Autogrid Flex Dispatches over 100 Events," AutoGrid, September 10, 2022, **https://blog.auto-grid.com/oh-california/**.

4 "OhmConnect Paid Members $2.7M and Saved 1.5 GWh of Energy During Recent California Heat Wave," 2022.

5 *ConnectedSolutions: A Program Assessment for Massachusetts,* Applied Economics Clinic on behalf of Clean Energy Group, 2021, **https://www.cleanegroup.org/wp-content/uploads/ConnectedSolutions-An-Assessment-for-Massachusetts.pdf**.

6 Miranda Willson, "Northeast Embraces a First-of-a-Kind Virtual Power Plant," *E&E News,* October 12, 2022, **https://www.eenews.net/articles/northeast-embraces-first-of-a-kind-virtual-power-plant/**.

7 "APS Virtual Power Plant Benefits Customers, Smart Grid & Environment," APS, last modified November 8, 2021, **https://www.aps.com/en/About/Our-Company/Newsroom/Articles/APS-Virtual-power-plant-benefits-customers-smart-grid-environment**.

8 Robert Walton, "Tesla's Australian Virtual Power Plant Propped Up during Grid Coal Outage," *Utility Dive,* December 11, 2019, **https://www.utilitydive.com/news/teslas-australian-virtual-power-plant-propped-up-grid-during-coal-outage/568812/**.

9 "South Australia's Virtual Power Plant," Government of South Australia, accessed August 2022, **https://www.energymining.sa.gov.au/consumers/solar-and-batteries/south-australias-virtual-power-plant**.

10 Amit Narayan, "AutoGrid Announces $85 Million Funding Round to Accelerate Energy Transition," AutoGrid, October 15, 2021, **https://blog.auto-grid.com/autogrid-announces-85-million-funding-round-to-accelerate-energy-transition/**.

11 "Average Power Generation Construction Time (Capacity Weighted), 2010–2018," International Energy Agency, last modified November 22, 2019, **https://www.iea.org/data-and-statistics/charts/average-power-generation-construction-time-capacity-weighted-2010-2018**.

12 Kavya Balaraman, "PG&E, GM Initiative Will Pilot Use of Electric Vehicles to Power Homes in Northern California," *Utility Dive,* March 8, 2022, **https://www.utilitydive.com/news/pge-gm-initiative-will-pilot-use-of-electric-vehicles-to-power-homes-in-n/619959/**.

13 Zhou and Mai, *Electrification Futures Study,* 2021.

14 "Short-Term Energy Outlook," Energy Information Administration, last modified October 12, 2022, **https://www.eia.gov/outlooks/steo/report/electricity.php**.

15 Ariel Drehbol, Lauren Ross, and Roxana Ayala, *How High Are Household Energy Burdens? An Assessment of National and Metropolitan Energy Burden across the United States,* American Council for an Energy-Efficient Economy, 2020, **https://www.aceee.org/sites/default/files/pdfs/u2006.pdf**.

16 Jeff St. John, "OhmConnect bets $100M That Free Smart Thermostats Can Prevent Summer Blackouts in California," *Canary Media,* June 15, 2021, **https://www.canarymedia.com/articles/grid-edge/ohmconnects-100m-bet-on-1-million-free-thermostats-to-save-california-from-summer-blackouts**.

17 Gabrielle Kuiper, *What Is the State of Virtual Power Plants in Australia? From Thin Margins to a Future of VPP-tailers,* Institute for Energy Economics and Financial Analysis, 2022, **https://ieefa.org/wp-content/uploads/2022/03/What-Is-the-State-of-Virtual-Power-Plants-in-Australia_March-2022_2.pdf**.

18 Caitlin Murphy et al., *Electrification Futures Study: Scenarios of Power System Evolution and Infrastructure Development for the United States,* National Renewable Energy Laboratory, 2021, **https://www.nrel.gov/docs/fy21osti/72330.pdf**.

19 Murphy et al., *Electrification Futures Study,* 2021.

20 Ryan Hledik et al., *The National Potential for Load Flexibility: Value and Market Potential through 2030,* The Brattle Group, 2019, **https://www.brattle.com/wp-content/uploads/2021/05/16639_national_potential_for_load_flexibility_-_final.pdf**.

21 Andrew Blok, "What's a Virtual Power Plant? Should You Join One?" *CNET,* March 18, 2022, **https://www.cnet.com/home/energy-and-utilities/whats-a-virtual-power-plant-should-you-join-one/**.

22 Sammy Roth, "How a Beachfront Gas Plant Explains California's Energy Problems," *Los Angeles Times,* April 1, 2021, **https://www.latimes.com/environment/newsletter/2021-04-01/how-a-beachfront-gas-plant-explains-californias-energy-problems-boiling-point**.

23 Zhou and Mai, *Electrification Futures Study,* 2021.

24 *Managing and Accelerating Electrification in Holy Cross Energy,* RMI, February 9, 2022, **https://www.holycross.com/wp-content/uploads/2022/04/2022.02.09-HCE-Electrification-Study-Clean_FINAL.pdf**.

25 Maninder P. S. Thind et al., *Fine Particulate Air Pollution from Electricity Generation in the US: Health Impacts by Race, Income, and Geography,* Environmental Science & Technology, 2019, **https://pubs.acs.org/doi/10.1021/acs.est.9b02527**.

26 Jigar Shah, "Real Barriers to Virtual Power Plants," *PV Magazine,* September 22, 2022, **https://pv-magazine-usa.com/2022/09/22/real-barriers-to-virtual-power-plants/**.

27 *FERC Order 222 Implementation: Preparing the Distribution System for DER Participation in Wholesale Markets,* Advanced Energy Economy and Grid Lab, 2022, **https://gridlab.org/wp-content/uploads/2022/01/AEE-GridLab-FERC-O.2222-Campaign-Final-Report.pdf**.

28 *Opportunities to Improve Analytical Capabilities towards Comprehensive Electricity System Planning,* NARUC-NASEO Task Force on Comprehensive Electricity Planning, 2021, **https://pubs.naruc.org/pub/18289C3B-155D-0A36-3110-2FAED4C94618**.

29 *Electric Vehicle Sales and the Charging Infrastructure Required Through 2030,* Edison Electric Institute, 2022, **https://www.eei.org/-/media/Project/EEI/Documents/Issues-and-Policy/Electric-Transportation/EV-Forecast--Infrastructure-Report.pdf**.

30 Zhou and Mai, *Electrification Futures Study,* 2021.

31 "Global Energy Storage Set to Triple in 2021," Wood Mackenzie, October 7, 2021, **https://www.woodmac.com/press-releases/global_energy_storage_report/**.

32 "The Growth and Growth of the Global Energy Storage Market," Wood Mackenzie, October 7, 2021, **https://www.woodmac.com/news/opinion/the-growth-and-growth-of-the-global-energy-storage-market/**.

33 *Behind-the-Meter Batteries: Innovation Landscape Brief,* International Renewable Energy Agency, 2019, **https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_BTM_Batteries_2019.pdf**.

34 *A National Roadmap for Grid-Interactive Efficient Buildings,* Lawrence Berkeley National Laboratory, 2021, **https://gebroadmap.lbl.gov/**.

35 Ibid.

36 Ibid.

37 Ibid.

38 Ibid.

Kevin Brehm, Avery McEvoy, Connor Usry, and Mark Dyson,
Virtual Power Plants, Real Benefits, RMI, 2023,
https://rmi.org/insight/virtual-power-plants-real-benefits/.

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