Real Reliability
The Value of Virtual Power

PRESENTED BY

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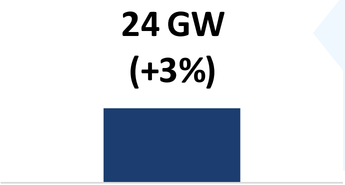
U.S. Generation Capacity: Supply and Demand

	2016 to 2023 (Historical)	2023 to 2030 (Forecast)

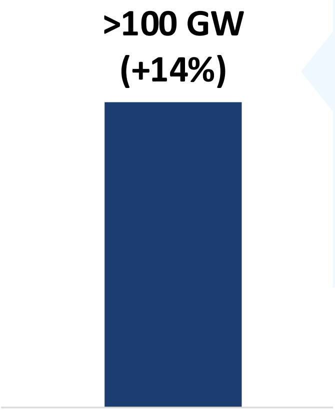
Demand:
Peak Load Growth

2016 to 2023 (Historical)



Limited growth
- Overhang from 2009 recession
- Efficiency improvements
- Decoupling of GDP and electricity demand

2023 to 2030 (Forecast)



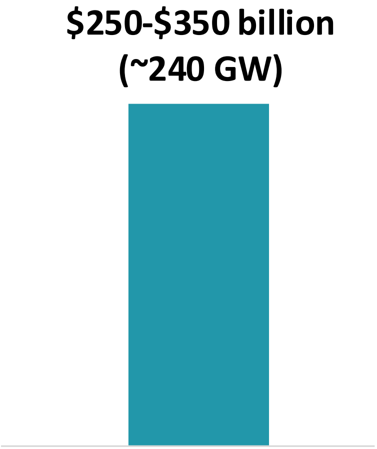
Massive growth
- Data centers
- Building electrification
- Electric vehicles
- Advanced manufacturing

Supply:
Investment in Capacity for Resource Adequacy

2016 to 2023 (Historical)

Persistent investment despite limited demand growth
- Coal replacement
- Renewables integration
- Increasingly volatile weather

2023 to 2030 (Forecast)

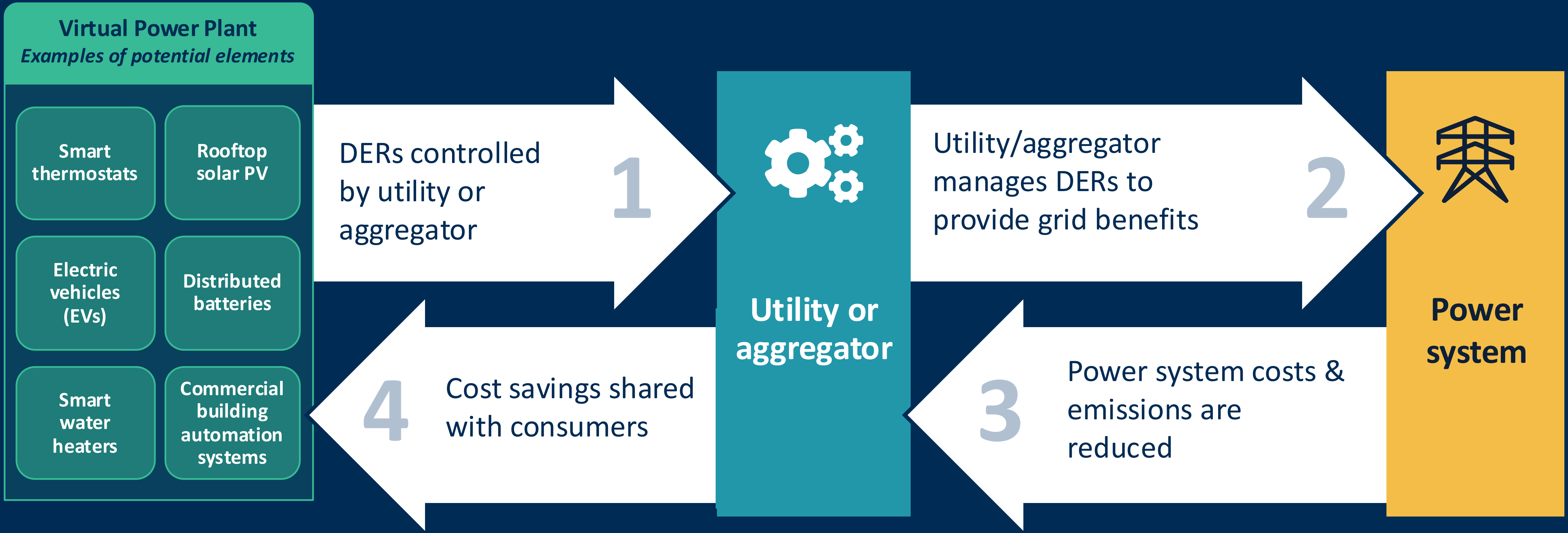


Likely infeasible with traditional generation resources
- Equipment shortages
- Interconnection delays
- Affordability concerns
- Decarbonization constraints

Innovative solutions are needed to address supply/demand gap

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.



Innovative example of a VPP

GREEN MOUNTAIN POWER

The Program

- Customer leases battery from utility at a discount
- Under limited conditions, utility operates battery to manage power system
- 1% participation currently; targeting 4-8% by 2030

Customer benefits

- Discounted battery
- No up-front payment
- No outages
- Bill savings
- Additional discounts for low-income customers

Utility benefits

- Sharing cost of battery with customer
- Ownership of grid asset
- Improved customer satisfaction
- Reduced distribution system costs
- Avoided transmission payments

VPPs are at a deployment inflection point

Drivers

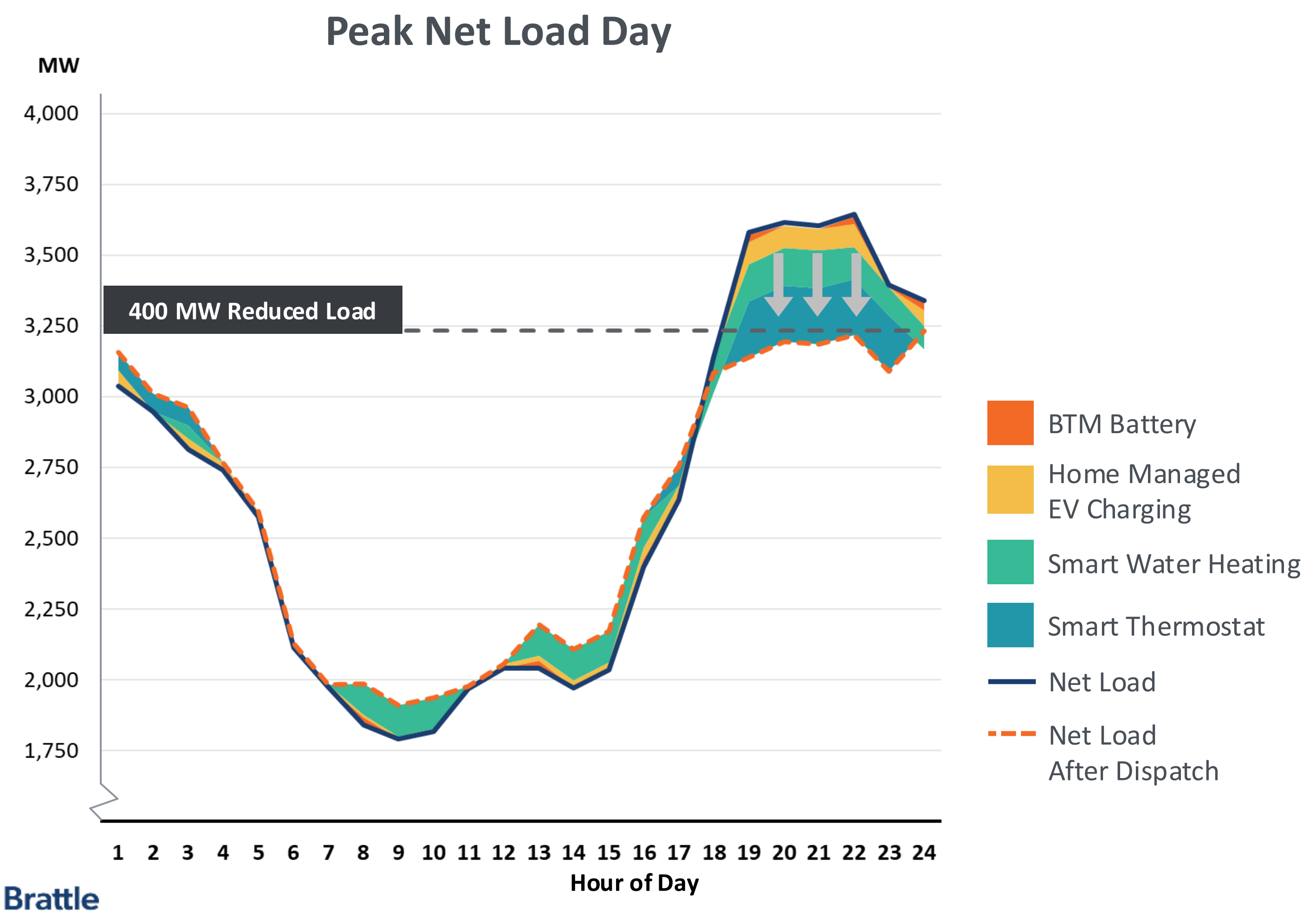
- Declining DER costs
- Technological advancement
- Policy incentives
- Wholesale market reform
- Growing model availability
- The decarbonization imperative

	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.
Data Center On-Site Generation	N/A	50 GW?

Note: Estimates are for US, based on review of various industry analyst projections.

We conducted hourly reliability analysis for a residential VPP

The modeled VPP could fully provide 400 MW of resource adequacy for a mid-sized utility (1.7 million customers) with 50% renewable generation



The VPP reduces load in:

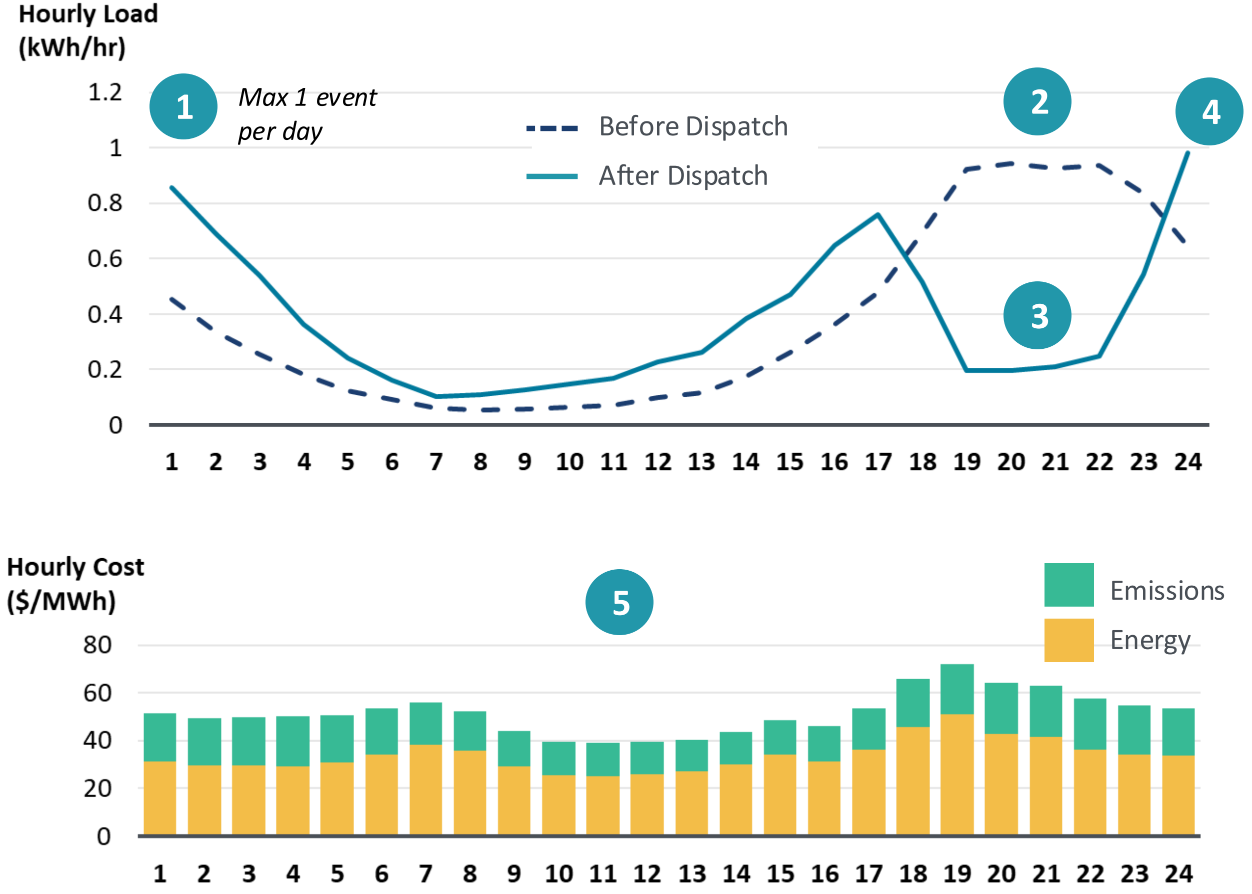
- Summer and winter
- 7 months
- 63 hours of the year
- 7 consecutive hours

VPP dispatch simulations are based on observed performance

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

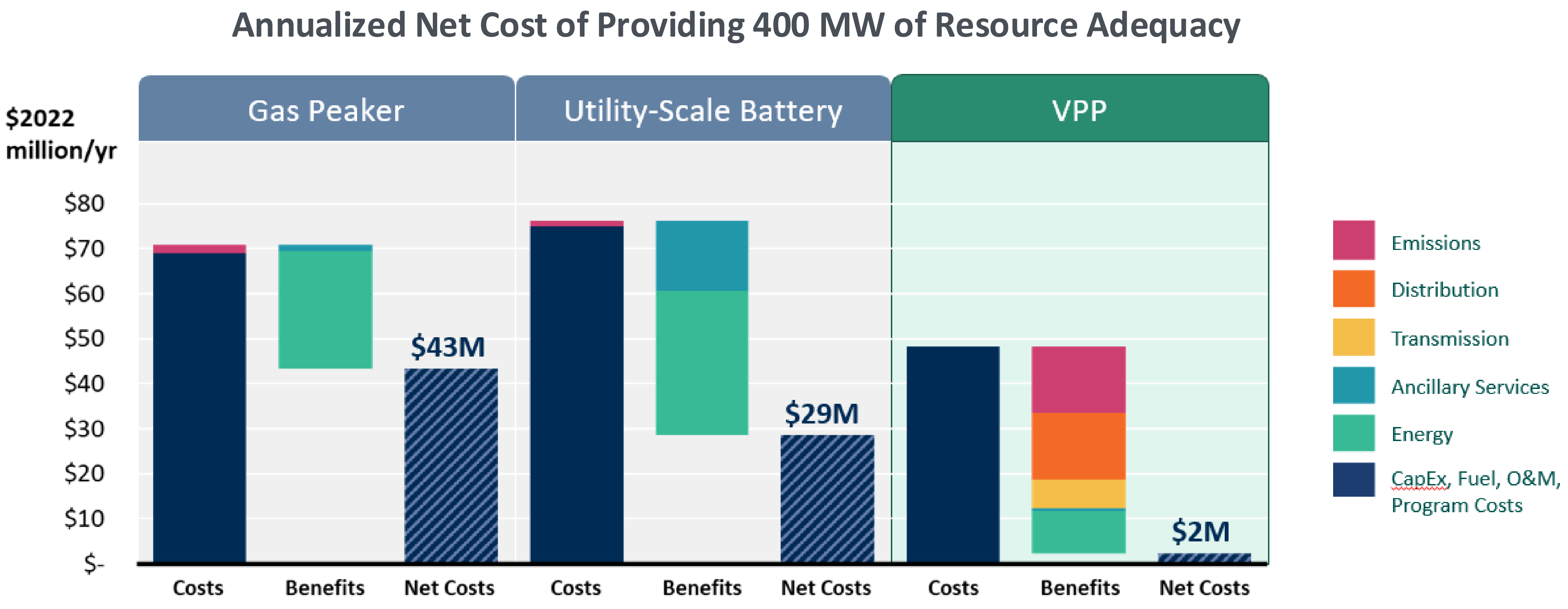
EV Home Charging Load Profile Relative to Hourly System Costs

(Average across days and EV portfolio)

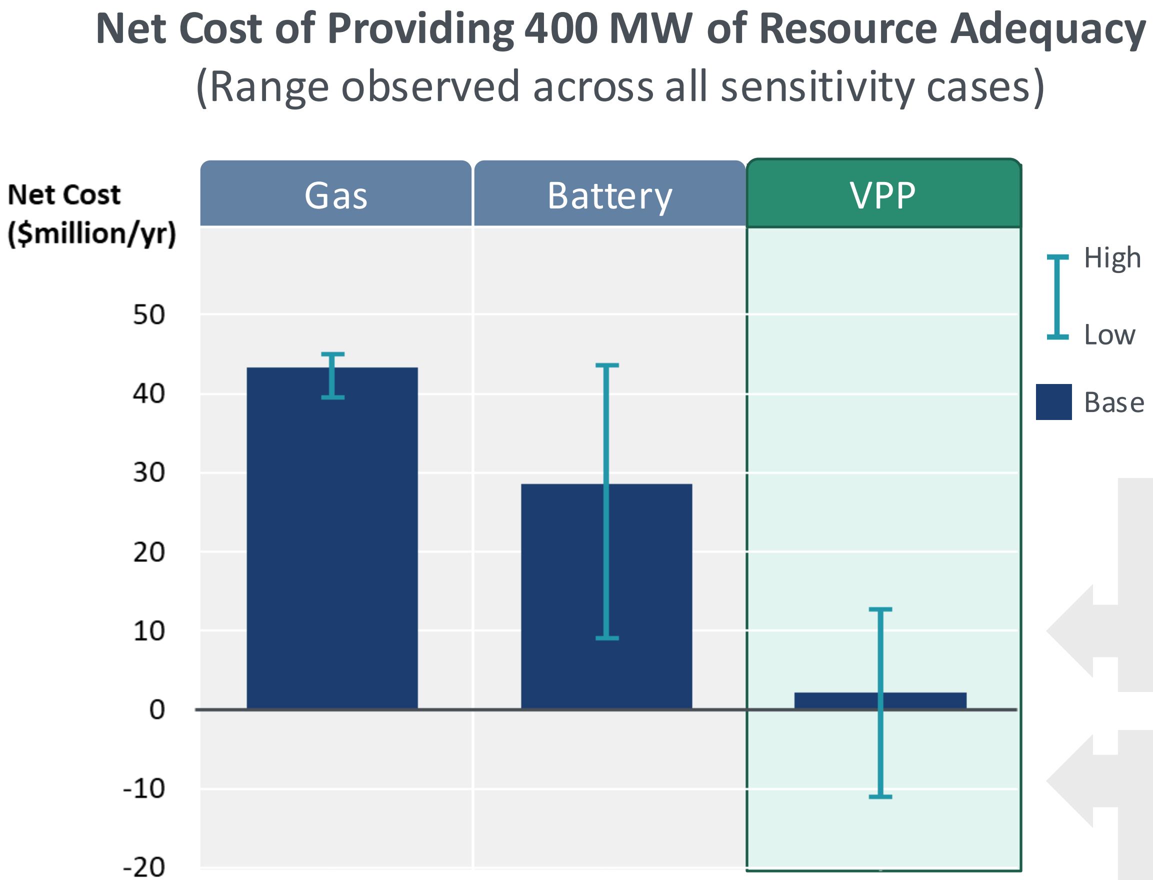


Resource adequacy… for cheap

VPP capacity is only 40-60% of the cost of alternatives, plus societal benefits



Resource adequacy at a *negative* net cost to society?



Economic competitiveness of battery storage and VPPs varies across markets, depends 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

VPPs can provide additional critical benefits

	Supply-centric approach	VPP approach
Resource development timeline	Transmission-connected resources constrained by 4-8 year interconnection approval process	Can be “built” as quickly as customers enroll
Resource development flexibility	Investments in traditional capacity are a 20-40 year commitment once steel is in the ground	Can scale as demand grows, and downsize if needed
Resilience	Large, centralized resources are vulnerable to attacks and consequential outages	Provides resource diversity and on-site backup during outages

The economic value of resilience

Photo credit: Travis Kavulla

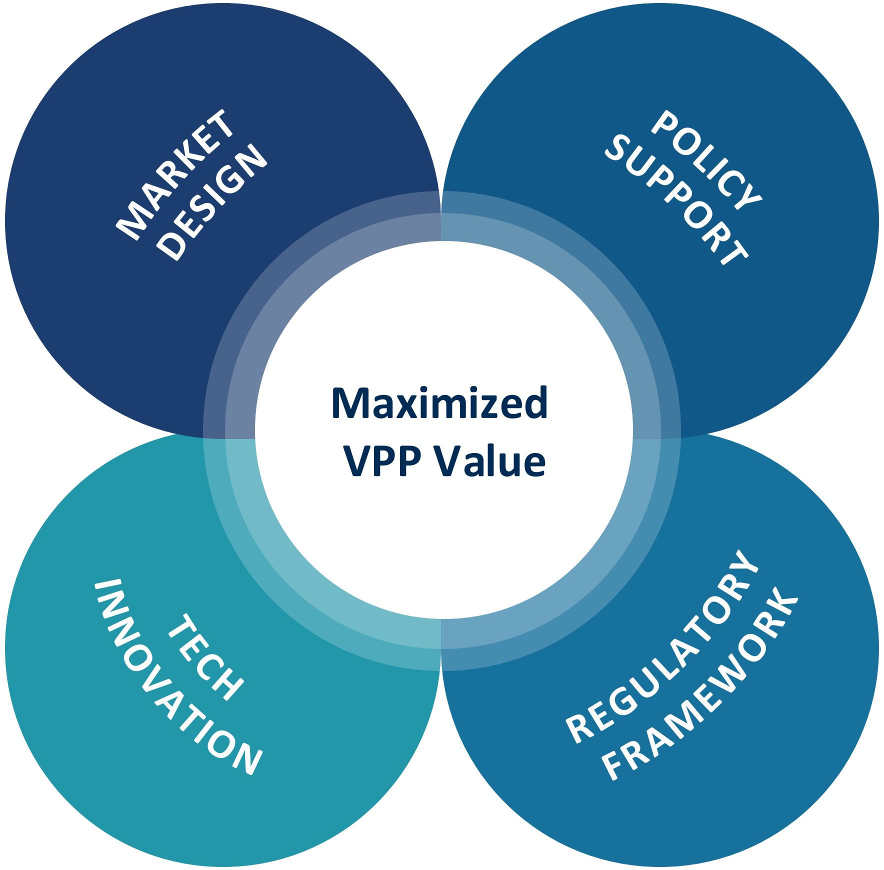
The ideal conditions for VPP deployment

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.

Three low-risk actions utilities and regulators can take now

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

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

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

For more information:

https://www.brattle.com/real-reliability/

Appendix

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

Increased renewables deployment

Flexible scaling

Better power system integration of electrification

Enhanced customer satisfaction

Faster grid connection

Improved behind-the-meter grid intelligence

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	+

Note:
Throughout the presentation, "utility-scale battery" refers to transmission-connected lithium-ion batteries.

+ = system benefit − = system cost

We modeled a VPP composed of four commercially available residential load flexibility technologies

	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
VPP Operational Constraints	15 five-hour events per season, plus 100 hrs of minor setpoint adjustments per year and energy savings	Daily load shifting of water heating load, ancillary services	Daily load shifting of vehicle charging load	15 demand response events per year

We model all utility-incurred costs (incentives, implementation including marketing and per-unit DERMS costs)

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

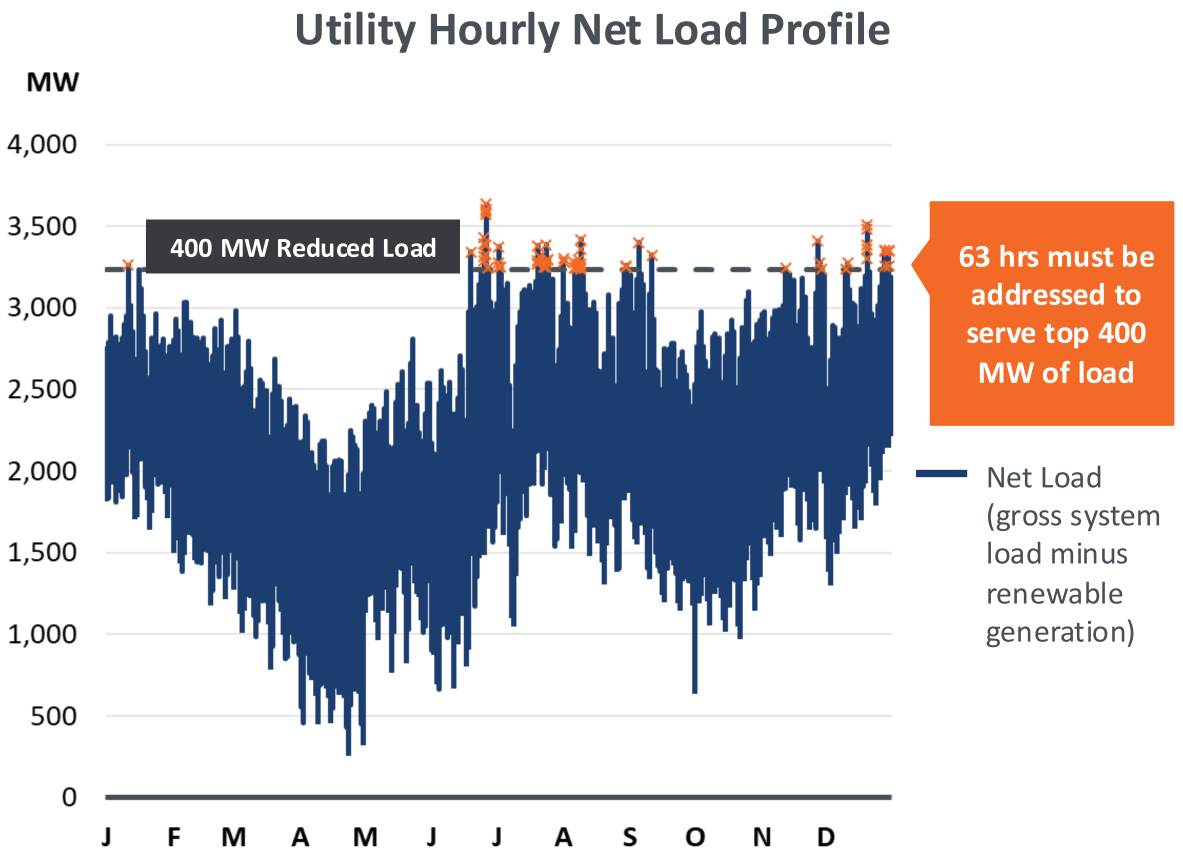
Note: For further discussion of barriers and solutions, see the U.S. DOE's A National Roadmap for Grid-Interactive Efficient Buildings.

We conducted hourly reliability analysis for a VPP, a gas peaker, and a utility-scale battery

The illustrative utility

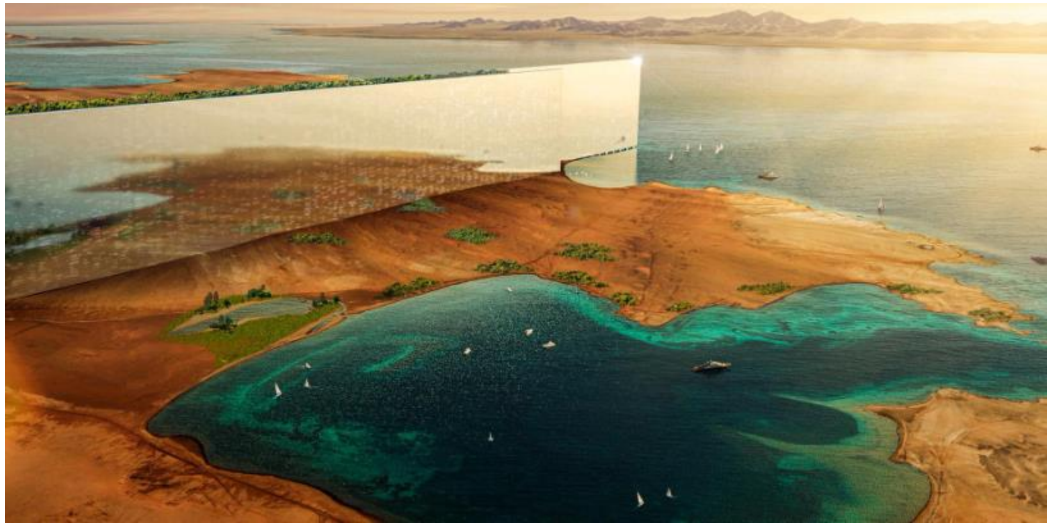
- Mid-sized (1.7 million customers)
- 50% renewables by 2030
- Winter and summer resource adequacy needs

To provide resource adequacy, the VPP must be able to serve all load contributing to top 400 MW of net peak demand over the year

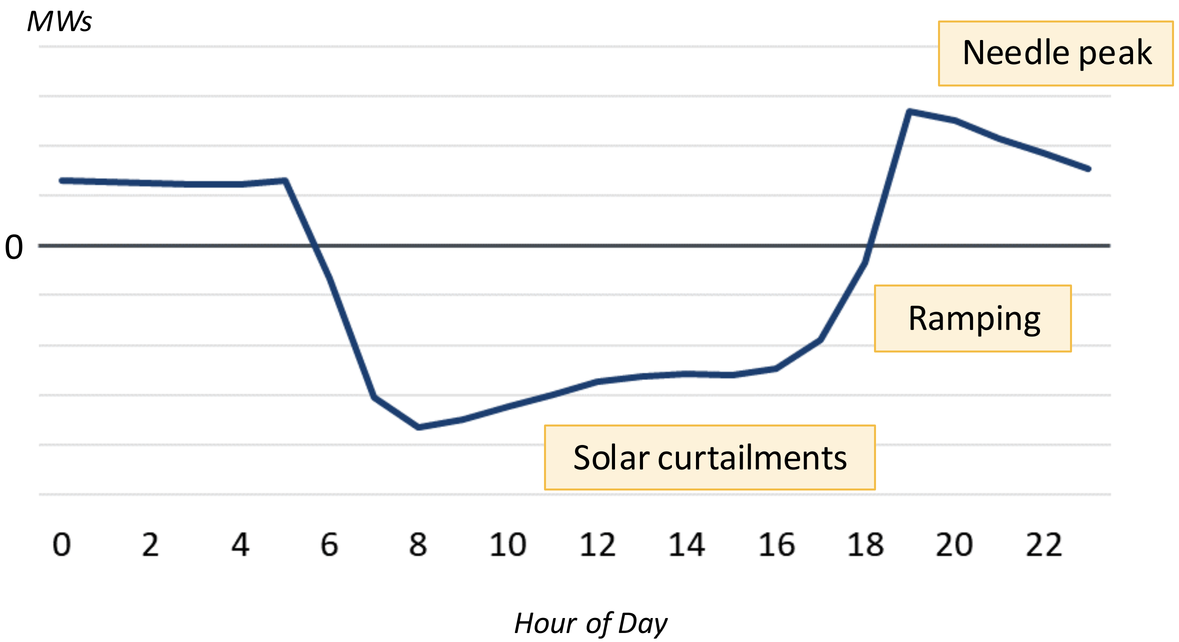


The future of VPPs?

"THE LINE"



Net load shape (not a line)



Clarity in the face of complexity

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