

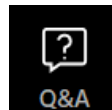
An Introduction to Virtual Power Plants (VPPs)

September 29, 2026

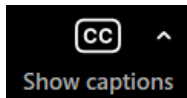
Webinar Logistics

All attendees are in **“listen only” mode** – your webcam and microphone are disabled. The Chat function is also disabled for attendees.

Submit questions and comments via the Q&A panel



Automated **captions** are available



Speakers' bios will be made available in the chat

This webinar is being recorded. We will email you a webinar recording within 48 hours. This webinar will be posted on CESA's website at www.cesa.org/webinars



The Clean Energy States Alliance (CESA) is a national, nonprofit coalition of public agencies and organizations working together to advance clean energy.

CESA members—mostly state agencies—include many of the most innovative, successful, and influential public funders of clean energy initiatives in the country.

CleanEnergy States Alliance

www.cesa.org



Wisconsin Office of Energy Innovation



VPP Acceleration Initiative

Helps states, local governments, communities, and financial institutions deploy and scale virtual power plants (VPPs)—advancing affordability, strengthening grid reliability, and supporting decarbonization.

Our goal: Enable gigawatt-scale VPP deployment nationwide by 2028.



WORLD
RESOURCES
INSTITUTE



www.cesa.org/projects/vpp

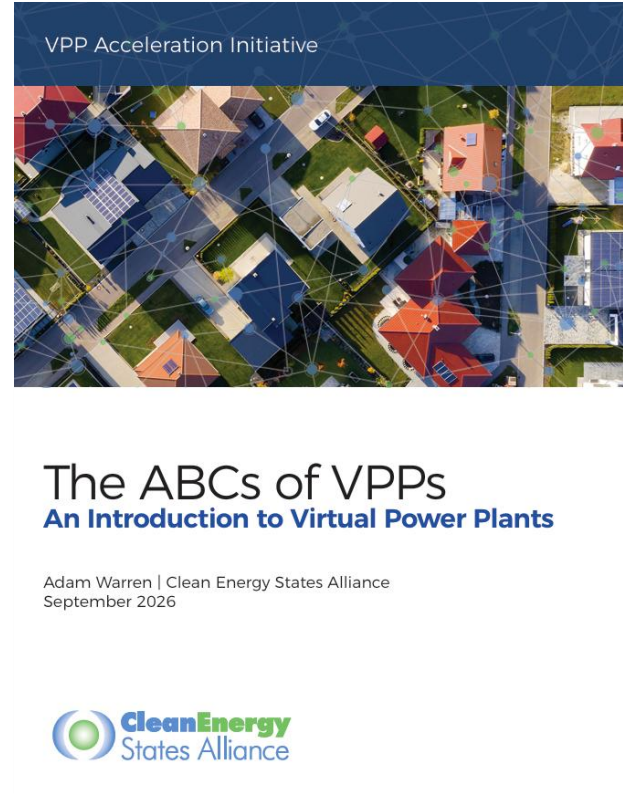


Clean Energy
States Alliance

The ABCs of VPPs: An Introduction to Virtual Power Plants

September 2026

Adam Warren | Clean Energy States Alliance



AN INTRODUCTION TO VIRTUAL POWER PLANTS (VPPS)

Webinar Speakers



Adam Warren

Senior Advisor
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Todd Olinsky-Paul

Senior Project Director
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Thank You

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Upcoming Webinar

DSGS: California's Award-Winning
Virtual Power Plant (VPP) Program
(October 28)

Read more and register at
www.cesa.org/webinars

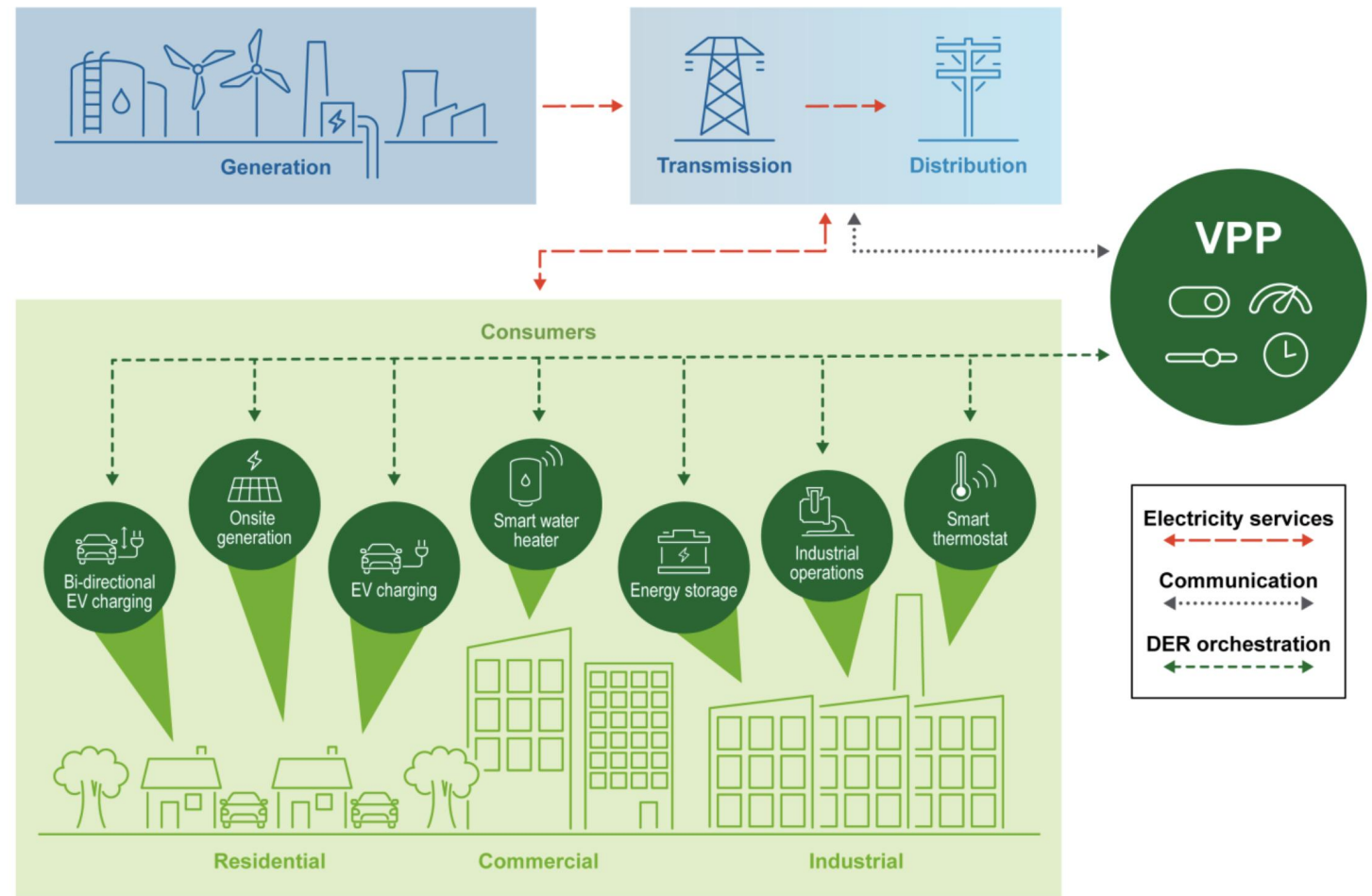
ABCs of VPPs

An Introduction to VPPs

Adam Warren

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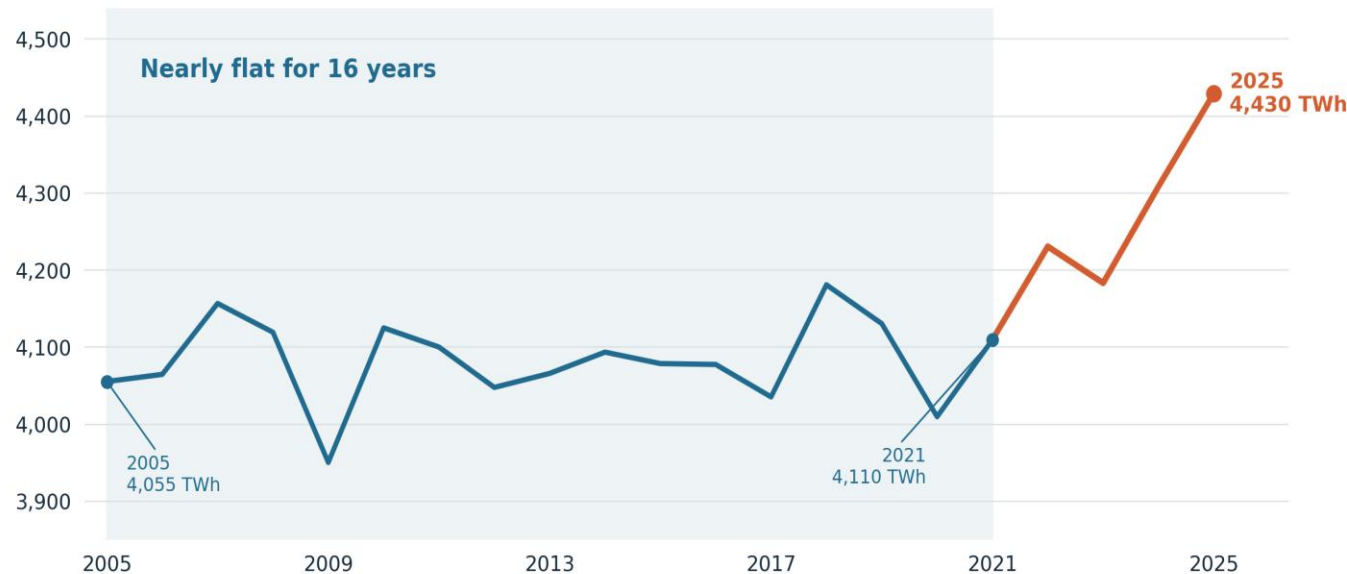
Clean Energy State Alliance (CESA)



Today's Grid

U.S. electricity generation, 2005-2025

Annual net generation • terawatthours (TWh)



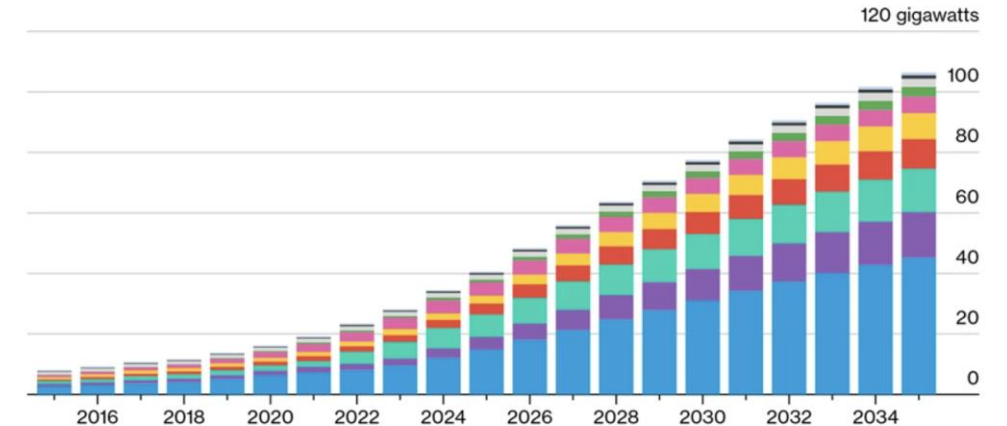
Source: U.S. Energy Information Administration, Monthly Energy Review, Table 7.2a (annual total, all sectors).
Net generation is closely related to electricity demand; it is not the same measure as retail electricity sales.

<https://www.eia.gov/totalenergy/data/browser/index.php?tbl=T07.02A>

ref: [EIA, 2025](#)

US Data Center Demand to Triple in a Decade

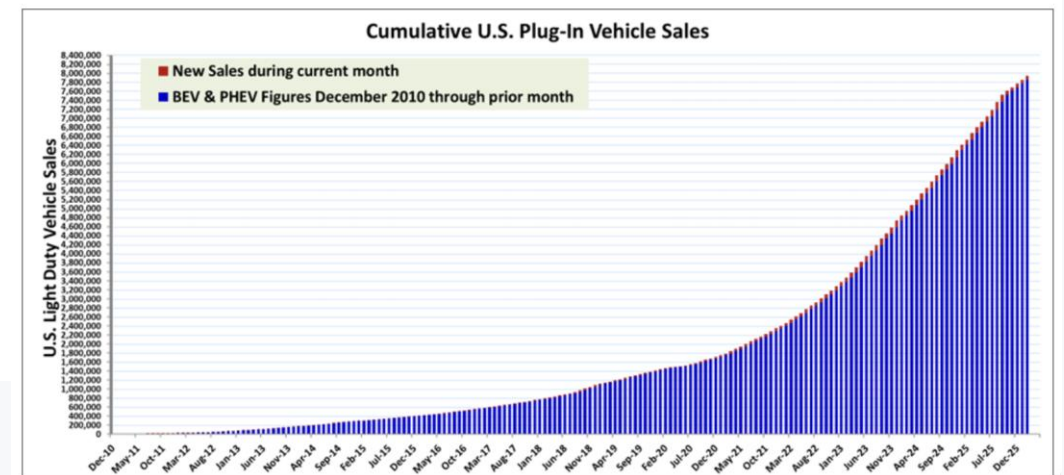
■ PJM ■ Southeast ■ Ercot ■ Southwest ■ MISO ■ Northwest ■ SPP ■ California
■ New York ■ New England ■ Florida



Source: BloombergNEF, DC Byte.

Note: "Power demand" refers to the total electricity used by the entire data center facility.
Ercot is Electric Reliability Council of Texas. MISO is Midcontinent Independent System Operator. SPP is Southwest Power Pool.

ref: [BNEF](#)



February 2026 Cumulative U.S. Plug-In Vehicle Sales

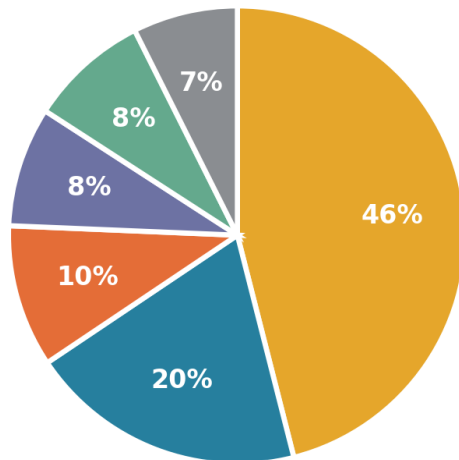
ref: [ANL](#)

Today's Grid

Global investment in new electricity generation

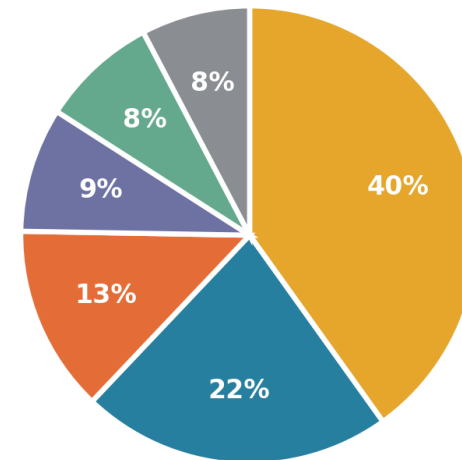
Selected technologies • approximate USD billions, 2025 dollars

2025 estimate



≈ \$945B across these six sources

2026 forecast



≈ \$910B across these six sources

■ Solar PV • USD 435B → 365B

■ Natural gas • USD 95B → 120B

■ Hydropower • USD 80B → 75B

■ Wind • USD 185B → 200B

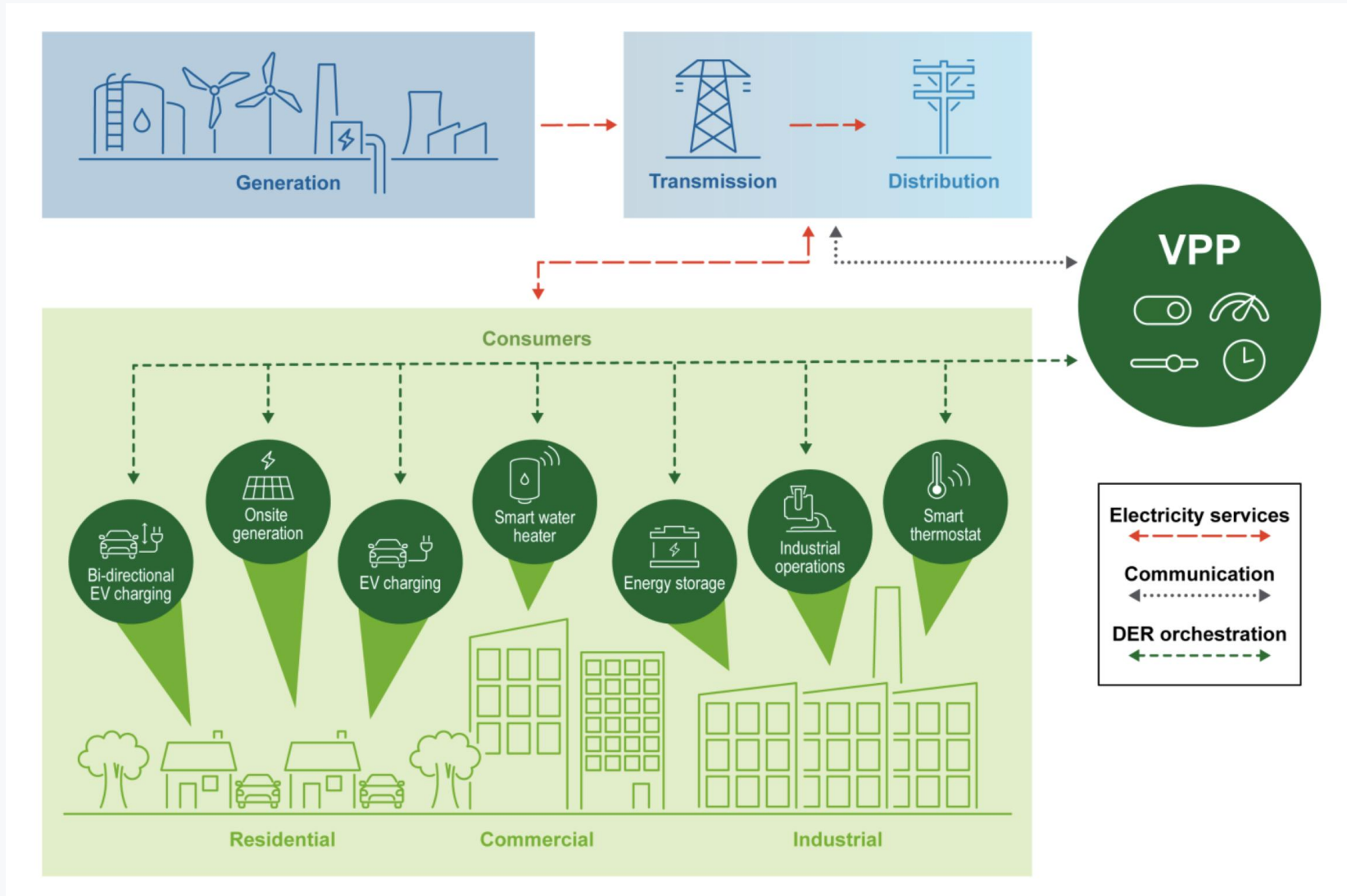
■ Nuclear • USD 80B → 80B

■ Coal • USD 70B → 70B

Source: IEA, World Energy Investment 2026, p. 72. Values read from chart and rounded to nearest \$5B.
Totals cover the six sources shown; they exclude other generation technologies, grids and battery storage.
<https://www.iea.org/reports/world-energy-investment-2026>

ref: [IEA](#)

Virtual Power Plants (VPP) *are* playing a role during this time of growth

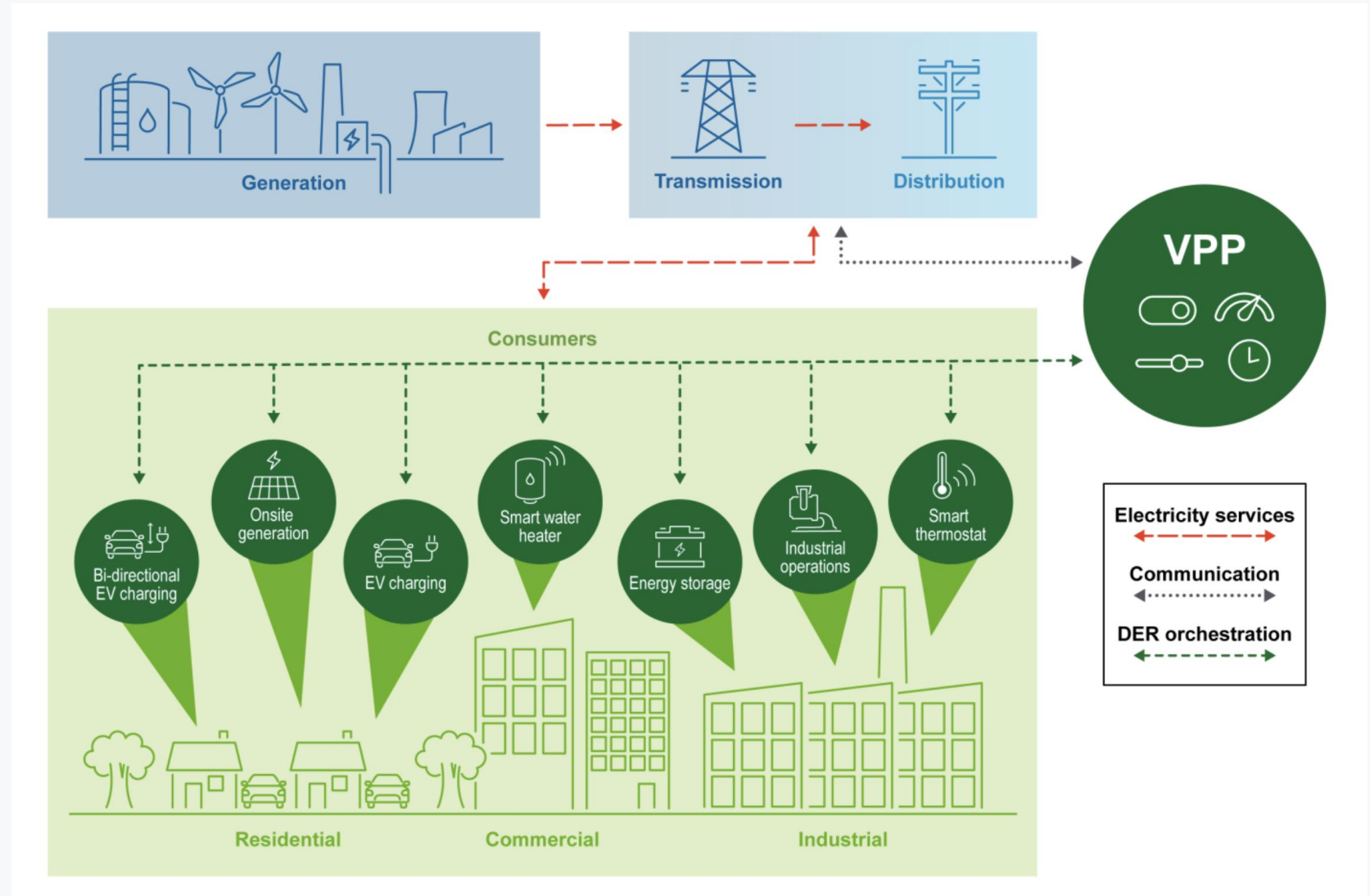


ref: [DOE – LPO](#), [VPP Liftoff Report](#), [Pathways to Commercial Liftoff](#).

Virtual Power Plants (VPP) *are* playing a role during this time of growth

But at what scale...?

And why isn't the market growing more quickly?



ref: [DOE – LPO](#), [VPP Liftoff Report](#), [Pathways to Commercial Liftoff](#).

What happens during a VPP event?

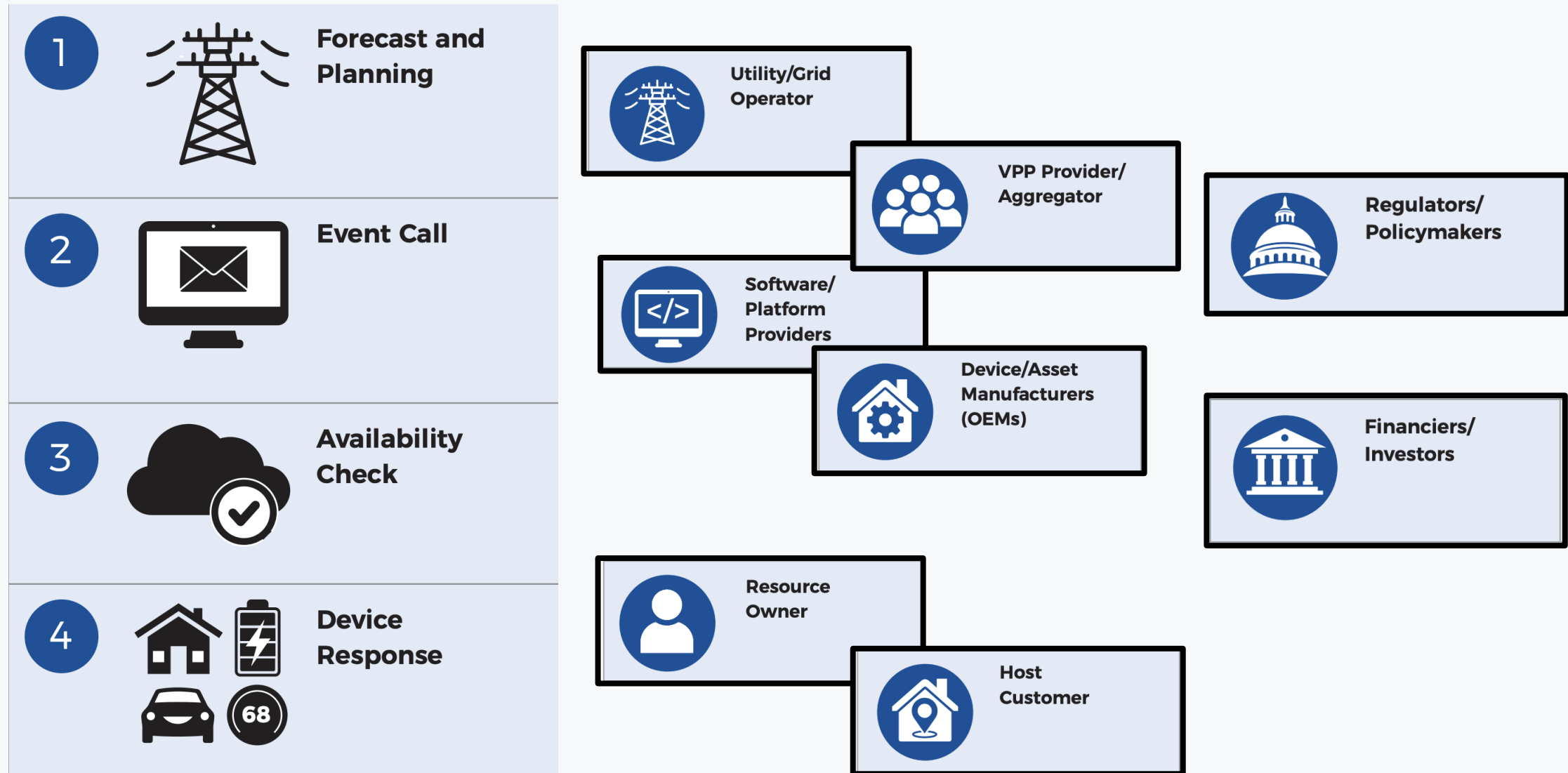


What happens during a VPP event?



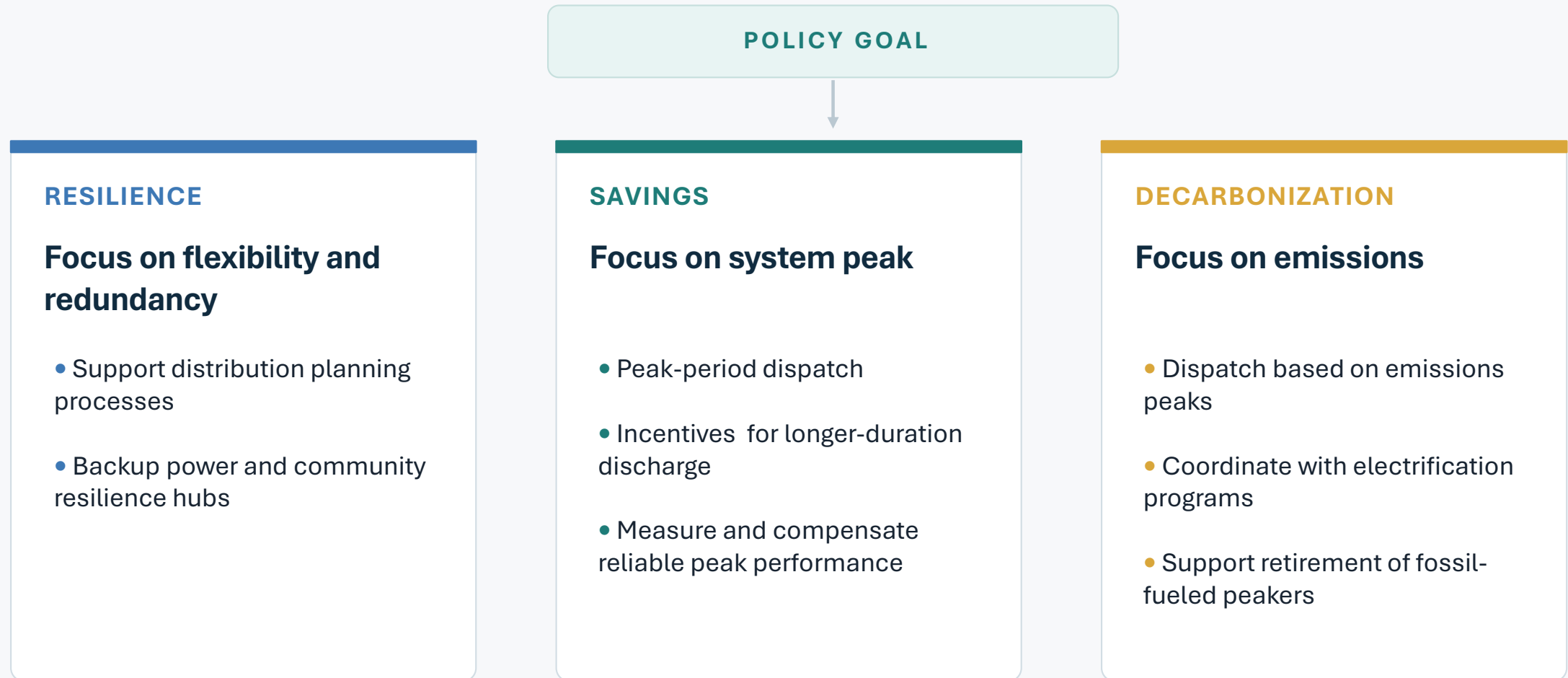
Standard/Framework	Where It Applies
 IEEE 1547	Grid interconnection point
 IEEE 2030.5	DER communications
 OpenADR	Demand response communications
 IEC 61850-7-420	Utility operational systems
 OCPP	EV charger network communications
 ISO/IEC 15118	EV-to-charger communications

What happens during a VPP event?



Start with the policy goal — the program design follows.

The same distributed technologies can support very different state objectives, depending on how dispatch, incentives, and program rules are designed.



Ref: The ABCs of VPPs

Where to learn more about VPPs

ORGANIZATION	RESOURCE	INFORMATION
Clean Energy States Alliance	<u>VPP Acceleration Initiative</u> www.cesa.org/projects/vpp	Best state-focused starting point: program design, case studies, webinars, and a national VPP resource directory.
Department of Energy	<u>Pathways to Commercial Liftoff: VPPs — 2025 Update</u> www.energy.gov/sites/default/files/2025-07/LIFTOFF_DOE_Virtual-Power-Plants%202025_0.pdf	National market outlook: scale, economics, barriers, and the actions needed for commercial growth.
LBNL / National Labs	<u>Virtual Power Plants: Insights, Profiles and Inventory</u> emp.lbl.gov/publications/virtual-power-plants-insights	Independent research: definitions, VPP archetypes, program profiles, and a detailed U.S. inventory.
RMI / VP3	<u>VPP Flipbook + Policy Principles</u> rmi.org/resources/virtual-power-plant-flipbook	Implementation examples: utility case studies, program comparisons, and policy principles for scaling.
SEPA + NC Clean Energy Technology Center	<u>50 States of VPPs & Supporting DERs</u> sepapower.org/resource/50-states-of-virtual-power-plants-and-supporting-distributed-energy-resources	State policy tracker: legislative, regulatory, and utility actions across the country.
EnergyHub	<u>Building Trustworthy VPPs: The VPP Maturity Model</u> www.energyhub.com/resource/building-trustworthy-power-plants-vpp-maturity-model	Utility-operational lens: maturity levels, the Huels Test, and what makes VPPs dependable in the control room.

ALSO USEFUL

- Market sizing: [Wood Mackenzie](#)
- Standards + interoperability: [EPRI / Mercury Consortium](#) + [IEEE Standards Association](#)
- Wholesale market rules: [FERC Order 2222](#)

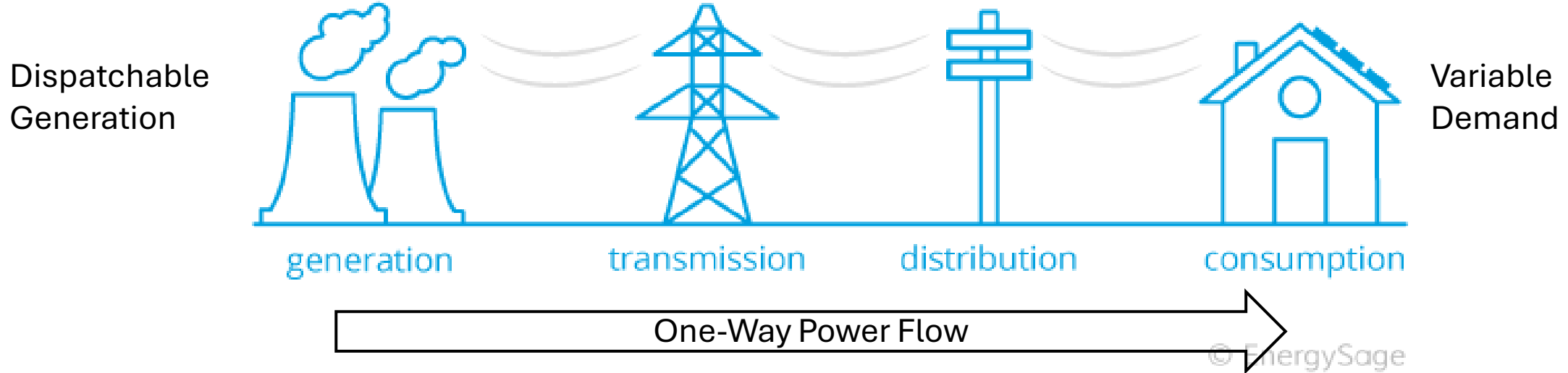
Excellent examples of VPP programs

- Vermont's Energy Storage Access Program ([ESAP](#))
- California Self-Generation Incentive Program ([SGIP](#))
- Connecticut Energy Storage Solutions ([ESS](#))
- Puerto Rico's Customer Battery Energy Sharing ([CBES](#))
- Hawai'i Bring Your Own Device ([BYOD](#)) Plus / Battery Bonus programs

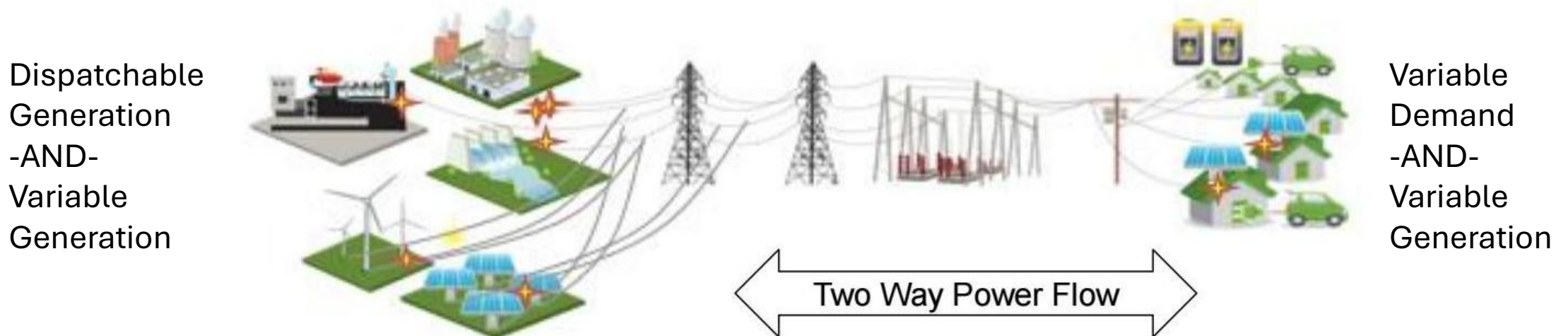
Learn more

- [1] U.S. Department of Energy, “Pathways to Commercial Liftoff: Virtual Power Plants - 2025 Update,” 2025. [Link](#)
- [2] Federal Energy Regulatory Commission, “Order No. 2222: Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators,” 2020. [Link](#)
- [3] U.S. Department of Energy, “Standard Distribution Services Contract,” 2023. [Link](#)
- [4] U.S. Department of Energy, “Cybersecurity Considerations for Distributed Energy Resources on the U.S. Electric Grid,” 2022. [Link](#)
- [5] North American Electric Reliability Corporation, “Cyber Security for Distributed Energy Resources and DER Aggregators,” 2023. [Link](#)
- [6] Lawrence Berkeley National Laboratory, “Virtual Power Plant Profiles and Inventory,” 2025. [Link](#)
- [7] T. Olinsky-Paul, “Program Design for Battery-Based Virtual Power Plants,” Clean Energy States Alliance, 2026. [Link](#)
- [8] T. Olinsky-Paul and O. Tym, “Energy Storage Program Design for Peak Demand Reduction,” Clean Energy States Alliance, 2024. [Link](#)
- [9] H. Jones, “Lessons Learned from Puerto Rico’s First Virtual Power Plant,” Clean Energy States Alliance, 2026. [Link](#)
- [10] EnergyHub, “Building Trustworthy Virtual Power Plants: The VPP Maturity Model,” 2026. [Link](#)
- [11] IEEE, “IEEE Std 1547-2018: Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces,” 2018. [Link](#)
- [12] California Public Utilities Commission, “Electric Rule 21: Generating Facility Interconnections.” [Link](#)
- [13] OpenADR Alliance, “OpenADR Specification Resources.” [Link](#)
- [14] International Electrotechnical Commission, “IEC 61850-7-420:2021.” [Link](#)
- [15] Open Charge Alliance, “OCPP 2.0.1.” [Link](#)
- [16] CharIN, “ISO/IEC 15118 Communication Standard.” [Link](#)
- [17] Electric Power Research Institute, “Mercury Consortium.” [Link](#)
- [18] North American Energy Standards Board, “Distribution Grid Services Base Contract,” press release, Jan. 2025. [Link](#)
- [19] Consumer Technology Association, “CTA-2045 / EcoPort,” 2024. [Link](#)
- [20] ERPI’s Mercury Consortium [Link](#)
- [21] CESA’s VPP Accelerator Initiative! [Link](#)

Old Power Grid (world's biggest just-in-time delivery system)

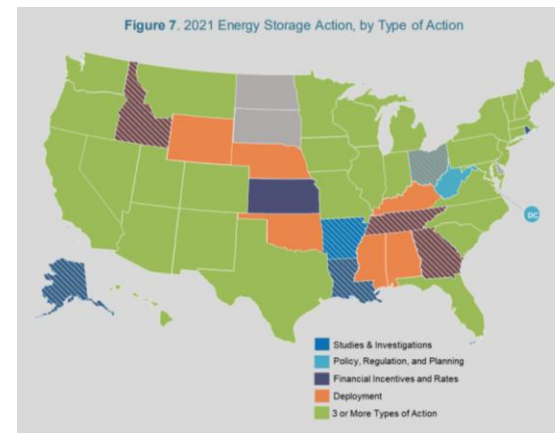


Modern Power Grid (decentralized, flexible, resilient, highly variable)



State policy TOOLS for VPPs

1. Studies and planning, commissions, reports
2. Pilots and demonstration projects
3. Longer-term policy and programs
 - a. Utility mandates/ targets
 - b. Customer incentives
 - c. Financing through clean energy financial institutions (green banks)
 - d. Market rules reform
 - e. Removal of barriers/reduction of soft costs
 - f. Technical assistance and resources
 - g. Regulatory initiatives/reform
 - e. Utility ownership of DERs
 - f. Inclusion in utility IRPs
 - g. Distribution system planning
 - h. Changes to existing utility tariffs/retail rates
 - i. Changes to legacy interconnection standards
 - j. Benefit/cost analysis (accommodation of VPPs in state cost effectiveness tests such as TRC, PCT, SCT, RIM, UCT etc.)
 - k. Pilot programs and demonstrations



NOTE: State policy TOOLS should support state policy GOALS!

State policy GOALS for VPPs

- Improved grid resilience/reduced power outages
- Improved customer resilience/critical infrastructure support
- Reduced peak demand/capacity savings
- Fossil fuel peaker plant retirement
- Grid modernization/Distribution System Planning
- Non-wires alternatives to accommodate new DERs
- Non-wires alternatives to accommodate new large loads (Data center BYOC)
- Reduced emissions (global or local)
- Improved integration of renewables/increased capacity value for renewables
- Ancillary services provision (frequency regulation etc.)
- ETC ETC ETC

PROGRAM DESIGN FUNDAMENTALS

Program design should generally follow from state policy goals, taking into account the market and regulatory landscape.

EXAMPLES

Policy goal: reducing greenhouse gas (GHG) emissions in the electricity sector

Program design: performance based incentives to reward storage owners for charging from solar (or from the grid when there is a surplus of solar generation) and discharging at times when high-emitting fossil generators are on the margin (for load reduction, power export, or both); energy storage included in utility RPS or clean peak standard.

Policy goal: advancing building electrification

Program design: rebates to incentivize installation of home solar+storage+heat pump systems to replace existing gas and oil heating systems, in tandem with other electrification and efficiency measures; solar+storage and electrification added into utility-administered state efficiency program.

VPP Program Examples

There are active battery VPP programs in at least 30 states plus the District of Columbia, Puerto Rico and the Virgin Islands

Many states have multiple programs

Most launched post-2019



Example: California Self Generation Incentive Program (SGIP)

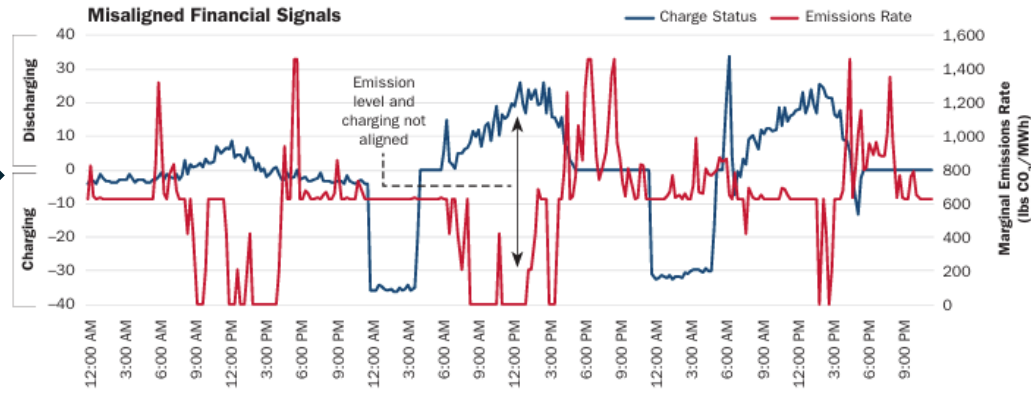
- Goals: Peak demand reduction, GHG reduction, resilience
 - Strong GHG emissions reduction focus
- Began as 100% rebate program
- Incentive changed to 50% rebate, 50% performance incentive, with dispatch linked to ISO GHG emissions signals, to improve emissions outcomes
- Budget carve-outs and incentive adders for equity and outage-prone customers
 - “Equity resilience” rebate (\$1,000/kWh) covers close to 100% of the cost of an average energy storage system for qualifying customers (directed mainly toward low-income customers in wildfire outage areas)

California SGIP Program Results – Before and After Emissions-Aligned Dispatch

Incentives
Not Aligned
with
Emissions



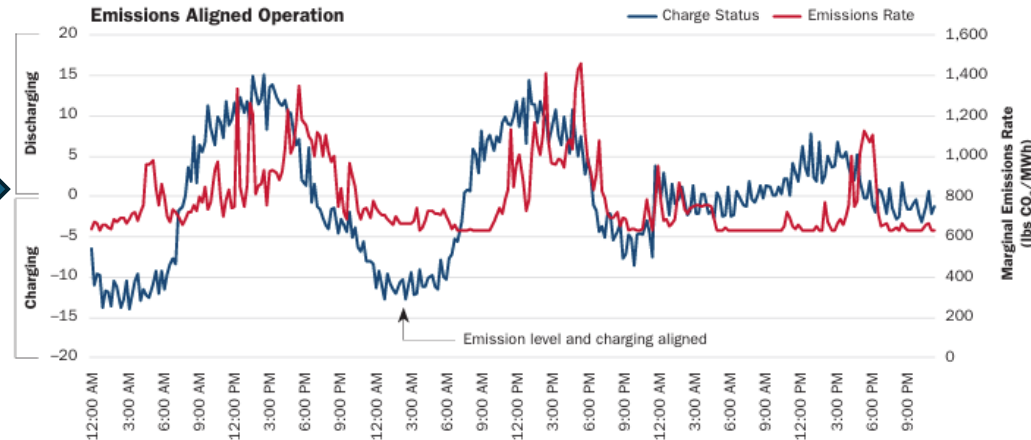
Figure 1a
SGIP Emissions Alignment Before and After Incentives were Aligned with Goals



The California SGIP program initially suffered from financial signals that were not aligned with state emissions data. As a result, battery owners frequently discharged their batteries during low emissions periods, rather than charging when emissions were low and discharging when they were high.

Source: WattTime

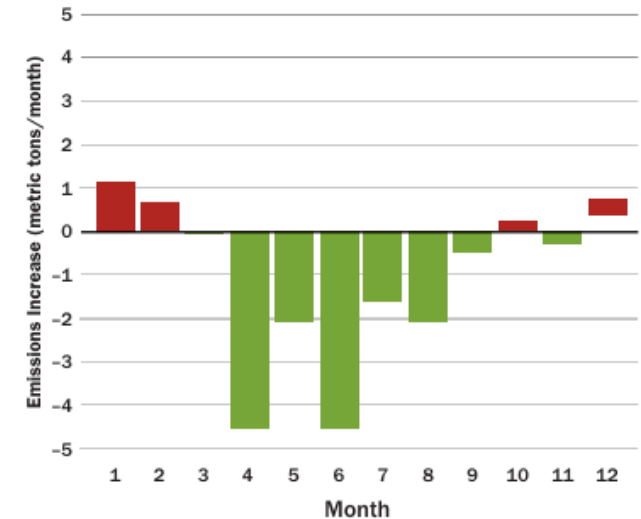
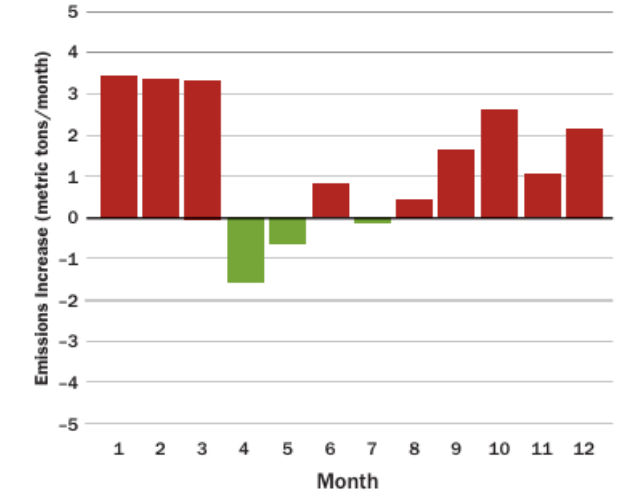
Incentives
Aligned with
Emissions



After program incentives were revised to encourage battery discharge during periods of high emissions, customer battery use became much better aligned with state emissions reduction goals.

Source: WattTime

Outcomes



Example: Connecticut Energy Storage Solutions program



- Goals: Peak demand reduction, demand response, grid reliability
 - Strong equity commitment
- Co-administered by utilities and CT Green Bank
 - Customers receive up-front rebate from CT Green Bank, and performance payment from utility
 - Residential customers from low-income and underserved communities receive 2x rebate adder
 - For purposes of ESS program, multi-family affordable housing facilities are considered “residential” and thus qualify for the LMI rebate adder
 - UPDATE: In April, the CT ESS was updated. Nearly all incentives are now performance-based to reduce clawbacks.

Example: Duke Energy Power Pair (North Carolina)



- Goals: Peak demand reduction, Grid support, increased solar adoption, GHG reduction
- Up-front rebate plus monthly performance payments
- Residential solar+storage customers contract with Duke Energy
- Incentives comprise a one-time, \$0.36/watt-AC payment for solar panel installation up to 10 kW-AC, plus a one-time \$400/kWh payment for battery storage installations up to 13.5 kWh (up to \$5,400)
- Qualifying PowerPair installations that also enroll in Power Manager® Battery Control (allowing Duke to remotely control and discharge batteries) get an additional monthly bill credit based on battery capacity, up to a maximum of 20 kW per home

Example: Green Mountain Power Powerwall Program (Vermont)



- Goals: Peak demand reduction, frequency regulation, customer resilience
- GMP owns batteries; residential customers host batteries, make lease payments (“resilience subscription” model)
 - 10-year lease at \$55/month or one payment of \$5,500 (about 1/3 installed cost for a single battery)
 - Low-income customers can qualify for free batteries
- “Whole home” program (two batteries per home to provide long term resilience)
- GMP discharges batteries for peak demand reduction and frequency regulation (cost savings)
- GMP removes and recycles batteries at end of life
- GMP has more than 10,000 batteries behind residential meters; program had a 2-year waiting list until the regulator lifted the enrollment cap

Best Practices (according to me)

- Incorporate equity provisions (carve-outs, incentive adders and low/no-cost financing). This makes programs accessible to more customers.
- Employ both up-front rebates and performance payments
 - Up-front payments help defray capital costs
 - Performance payments ensure desired grid/social benefits
- Contracts should be 7-10 years with locked payment rates; if shorter, offer a renewal option. This makes systems more financeable.
- Allow a variety of ownership options (utility owns, customer owns, customer leases) wherever possible, to fit more customers' needs
- Incorporate third-party aggregators: they bring expertise in development, marketing, operations and maintenance, and financing
- Allow a wide variety of eligible equipment options including existing BTM resources (controllable loads, EVs/managed charging, etc.): this expands the value of the VPP

Resources

CESA/CEG VPP Acceleration Initiative:

<https://www.cesa.org/projects/vpp/>

The ABCs of VPPs:

<https://www.cesa.org/resource-library/resource/the-abcs-of-vpps/>

CESA VPP Summary Table: <https://www.cesa.org/projects/energy-storage-policy-for-states/virtual-power-plant-programs-summary-table/>

Thank You

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