2025 Vehicle-Grid-integration Forum

April 16, 2025

Introduction & Safety Message

Emily Clayton

Transportation Electrification Analyst | CPUC Energy Division

VGI Definition

D.20-12-029 defines vehicle-grid integration as:

- Any **method of altering the time, charging level, or location** at which grid-connected light-duty electric vehicles, medium-duty electric vehicles, heavy-duty electric vehicles, off-road electric vehicles, or off-road electric equipment **charge or discharge in a manner that optimizes** plug-in electric vehicle or equipment **interaction with the electric grid**

Provides **net benefits to ratepayers** by doing any of the following:

a) Increasing electrical grid asset utilization and operational flexibility.
b) Avoiding otherwise necessary distribution infrastructure upgrades and supporting resiliency.
c) Integrating renewable energy resources.
d) Reducing the cost of electricity supply.
e) Offering reliability services consistent with the resource adequacy requirements established by Section 380 or the Independent System Operator tariff.

D.22-11-040 Established 3 VGI Strategic Focus Areas

Rates and Demand Flexibility

Objectives:

- Ensure rates for charging and discharging are revenue neutral.
- Develop rates and price signals to ensure EVs can benefit the grid and encourage third-party innovation.
- Ensure vehicles are a flexible load that can provide grid benefits and services.

Technology Enablement

Objectives:

- To further VGI, enable technology adoption and reduce/eliminate barriers to deployment.
- Role of the IOUs and CPUC is to reduce and eliminate barriers and provide opportunities for the market to deploy novel VGI-focused technology.

VGI & Planning

Objectives:

- Develop common VGI inputs and assumptions for use across planning processes to ensure we do not over or under build grid infrastructure.

VGI Forum Objectives from D.22-11-040

- Provide a venue to comprehensively discuss VGI topics that cut across multiple proceedings.
- Explore the adopted VGI strategic focus areas.
- Create an opportunity for strategic communication, information sharing, and discussion of relevant VGI issues with stakeholders.
- Offer a venue for stakeholders to raise emerging or persistent issues related to VGI.
- To the extent feasible and relevant, incorporate learning from the VGI Forums into existing programs (e.g. Funding Cycles, LCFS) and/or other Commission venues.

April 16th VGI Forum Agenda + Objectives

Time	Session	Objective(s)
9:00-9:30 am	**Welcome and Introduction**	
9:30-10:15 am	**Part 1— VGI Activities in CA**	• Discuss current state of VGI activities in CA. • Identify enablement opportunities to scale VGI beyond current state.
10:30 am- 12:00 pm	**Part 2— How Do We Value VGI?**	• Identify the roles that rates, managed charging and V2X can play in realizing quantitative and qualitive value from VGI.
1-2:30 pm	**Part 3— Crossing the Chasm from Pilots to Programs**	• Discuss potential frameworks and considerations to understand VGI maturity and readiness to scale through ratepayer and non-ratepayer funding pathways. • Identify key barriers preventing the transition from limited-scale pilots and studies to scaled programs.
2:45-4:00 pm	**Part 4— V2X Standards & Technology**	• Explore current state of V2X offerings and the technical, market and regulatory barriers to realizing V2X at scale, including a deep dive on V2G AC progress, trends and barriers.
4:00-4:05 pm	**Closing Remarks**	

Webex + In-Person Participation Logistics

Questions will be addressed during Q&A periods.

Please share your name and organization before providing comments to assist with notetaking.

Virtual Participants

- All virtual attendees will be muted on entry by default.
- Please write your questions in the Q&A panel.
- Alternatively, comments or questions can be provided verbally using the “raise hand” function.
    - The host will unmute you to ask your question.
    - Please lower your hand after asking your question by clicking on “raise hand” again.

In person participants

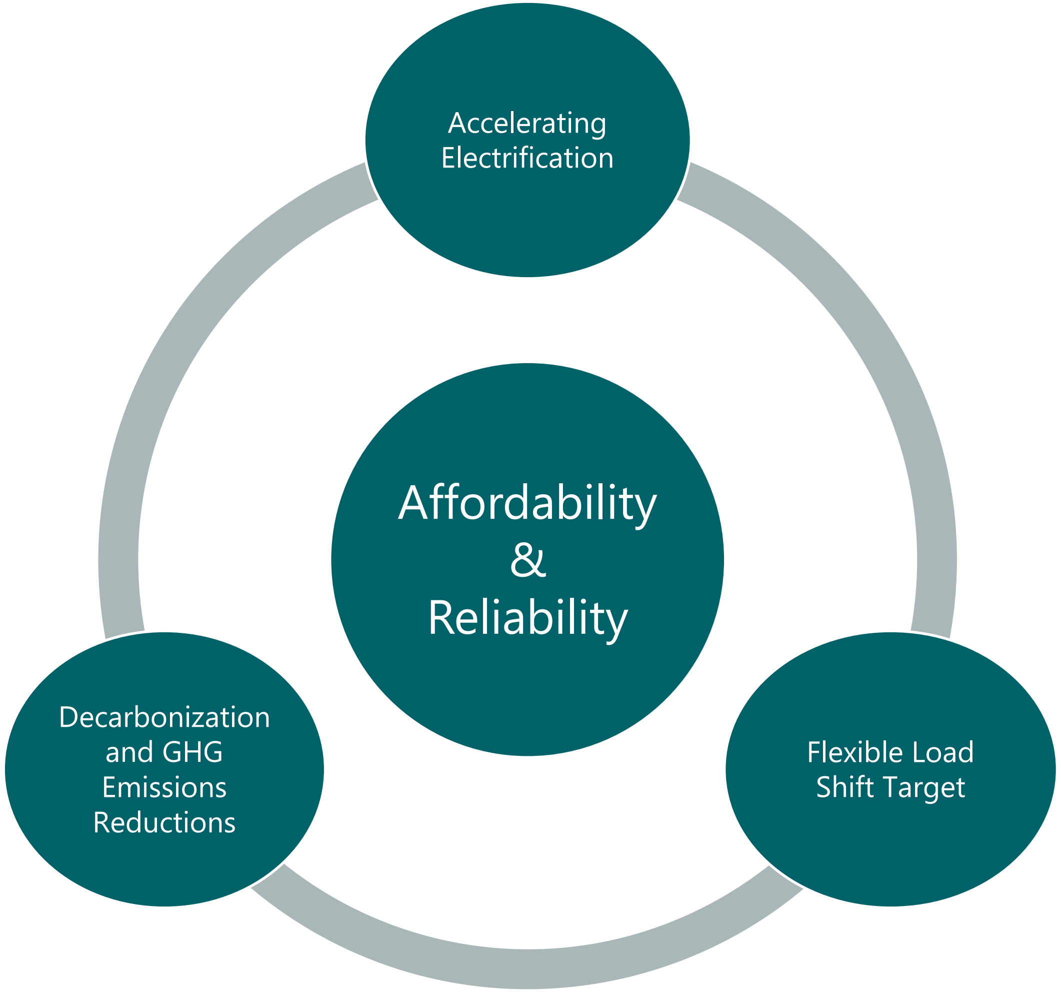
- Please come to the podium to ask questions.

VGI Activities in California

- BRIAN CHEN, PRINCIPAL ANALYST – PG&E
- NICK FIORE, CLEAN TRANSPORTATION INNOVATION MANAGER– SDG&E
- AARON R DYER, SR. MANAGER, PROGRAM DESIGN & DEVELOPMENT – SCE
- PETER CHEN, SUPERVISOR, ENERGY RESEARCH & DEVELOPMENT DIVISION – CEC

Why Do We Need VGI?

California has set ambitious electrification and greenhouse gas emissions reductions goals. VGI at scale will be a critical tool within the toolbox to ensuring we meet these goals while maintaining affordability and reliability.



Administered by other party

Available Now or Within 1 year

Sunsetting Within 1 year

No Longer Available

The IOU's VGI Activities

	PG&E	SCE	SDG&E
Rates	EV TOU Rates	EV TOU Rates	EV TOU Rates
	Hourly Flex Pricing	Expanded Dynamic Rate Pilot	Dynamic Export Comp Rate Pilot
Managed Charging (V1G)	EV Charge Manager (EPIC)	Flexibility Improvement Distributed Energy Resource (SIDER)	Emerging Technology Projects
	evPulse	Bidirectional Energy CEC Grant	REDWDS
		Smart Charge: Residential EV Deferred Distribution Upgrade Project	CCA Pilot
		BTM Optimization of Load Technology Study (BOLTS)	
V2X	V2X Pilots (Comm, Res, Microgrid)		Toyota V2X Pilot
	AC V2G VPP (EPIC)		V2X CRC Resilience Pilot (EPIC)
	Emergency Load Reduction Program (ELRP)	Emergency Load Reduction Program (ELRP)	Emergency Load Reduction Program (ELRP)
Other	Advisory Services (TEAS)	Advisory Services (TEAS)	Advisory Services (TEAS)
	Customer Insights Research		Community Outreach & Education

What It Takes To Scale

The current state of maturity across the VGI themes is disparate and nascent. Maturing our understanding in each of the themes creates the compelling value proposition to scale VGI.

Theme 1
Realizing VGI Value

- Executing on VGI services (e.g. rates, MC, V2X) that provide the greatest grid value.
- Qualitative & quantitative methods to determining value.
- Showing affordability benefits from VGI.

Theme 2
Technology Capability

- Which V2X offerings are accessible to customers and ready to scale.
- Streamlining of interconnection pathways for grid-tie EVs.
- Aligning trends in OEM product offerings, customer acceptance, and regulations.

Theme 3
Scaling Mechanism

- Composition of VGI services in the VGI portfolio.
- Framework of considerations & metrics to signal readiness to scale.
- Funding Pathways (ratepayer and non-ratepayer).

2025 CPUC/IOU Vehicle-Grid Integration Forum

CEC Efforts Enabling Vehicle-Grid Integration

April 2025 | Peter Chen

CEC's VGI Activities

Tech Funding | Analysis / Reports | Regs / Programs | Standards Support

Rates

Managed Charging (V1G)

V2X

Other

Responsive Easy Charging Products with Dynamic Signals (REDWDS)

Enabling EVs as DERs (EPIC)

Load Management Standards (LMS)

Grid-Supportive Transportation Electrification (EPIC)

Demand Side Grid Support Program (DSGS)

School Bus Bidi Charging

V2B for Resilient Backup Power (EPIC)

SB 59 Bidi Capable Vehicles

V2G Equipment List

Interoperability and Conformance Testing (ChargeYard)

Charger Block Grants and Solicitations (ex. EnergIIZE, CALeVIP Communities in Charge)

Integrated Energy Policy Report (IEPR)

AB 2127 Statewide Charging Infra Assessment

SB 49 Flexible Demand Appliance Standards

Demand Flexibility Potential Modeling

What does scaled VGI look like?

Theme 1
Realizing VGI Value

Theme 2
Technology Capability

Theme 3
Scaling Mechanism

- Access to appropriate value of VGI through rates and program-based options
- Broadly interoperable, reliable, and low-cost products and service offerings
- VGI both enables and benefits from cost-effective and timely grid connection
- VGI performance guides forecasting and planning
- Customers are willing to participate and aware of options

Break — we will resume at 10:30 am PT

How to Value VGI

Danielle Weizman
Clean Transportation Business Development Manager

Objectives

Presentations and panel discussion to explore the value of VGI.

What have we tried? What have we learned?

What is needed next? What are the gaps or barriers?

Are rates the only mechanism?

What is the role or need for ongoing programs?

How do the challenges and opportunities vary across customer classes?

What are the most promising value streams for VGI, and what are the barriers we need to overcome?

What market opportunities do you see for VGI in the next 5-10 years?

Panelists

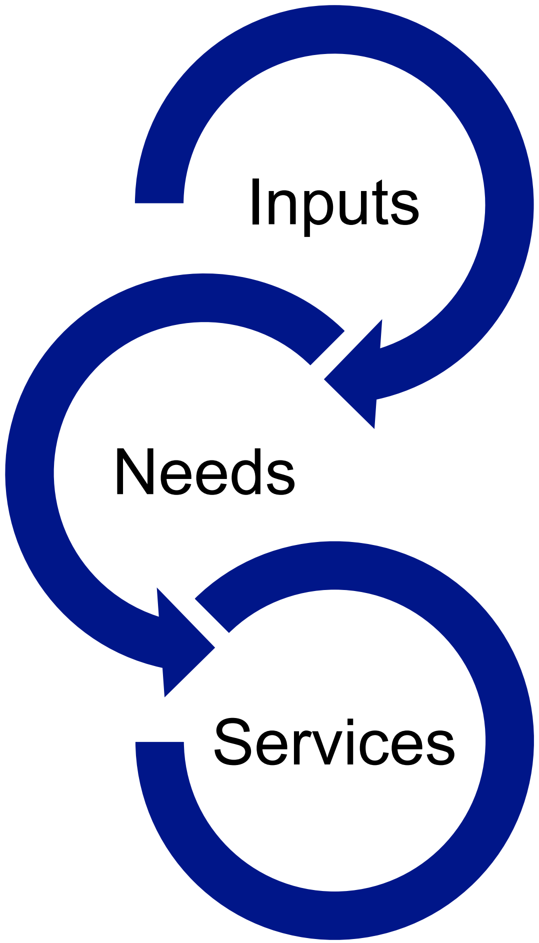
Achintya Madduri, Senior Retail Rates Analyst, CPUC
Phillip Kobernick, Associate Director of Energy Programs, Peninsula Clean Energy
Mathias Bell, Vice President of Policy and Regulatory Affairs, Weavegrid
Russell Vare, Vice President of Vehicle-Grid Integration, The Mobility House
Dan Fletcher, Head if Ecosystems ,dcbel
David Almeida, Senior Manager of Clean Energy Transportation Strategy, PG&E

Ongoing Planning and Market Integration

Value is based on cost-effectiveness and downward pressure on rates.

Wholesale Market

Retail Market



- IEPR forecast
- Known projects

- Transmission & distribution planning
- Supply side planning

- Rates
- Procurement

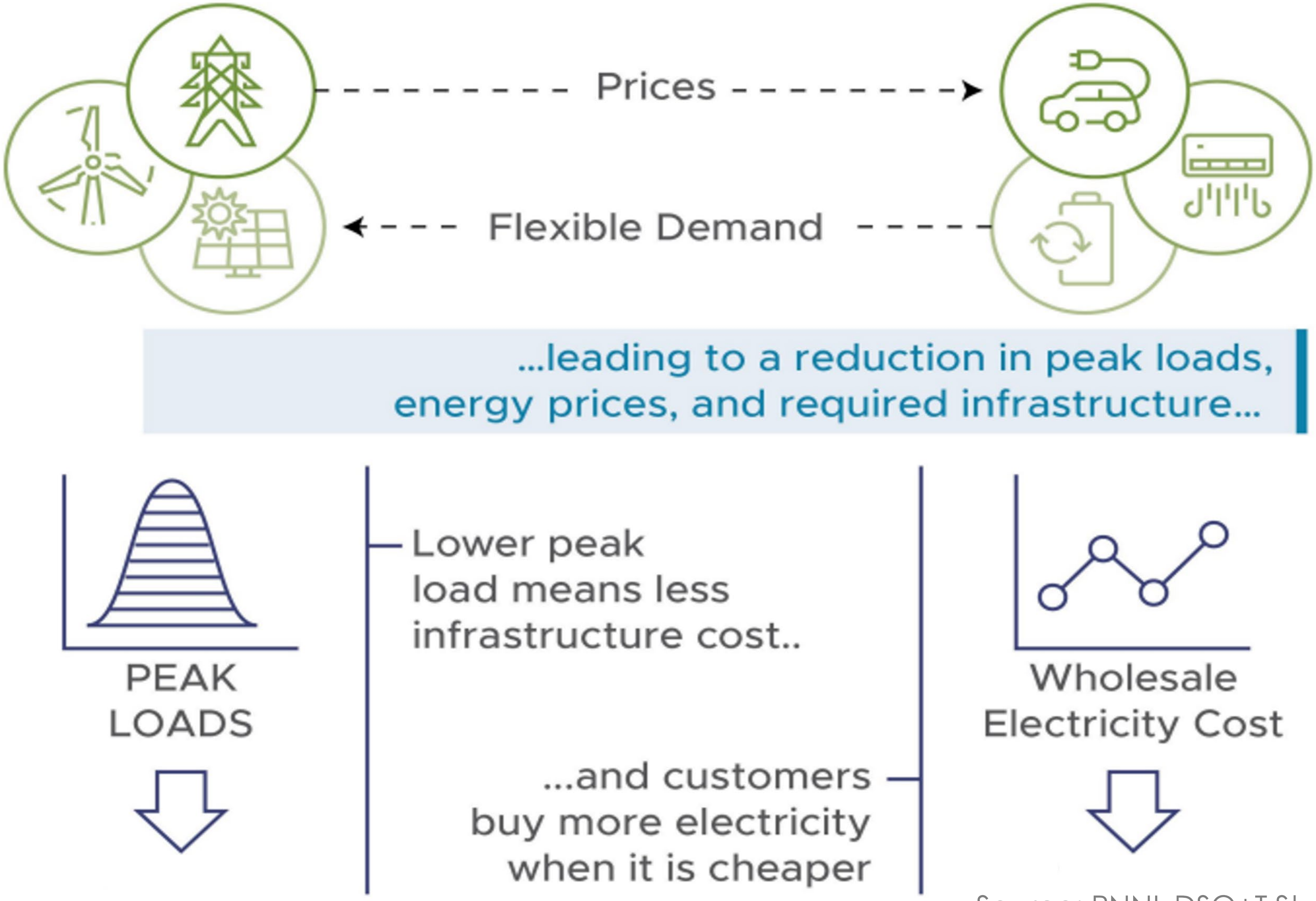
California Public Utilities Commission

Regulatory Roadmap for Dynamic Hourly Rates

Achintya Madduri, PhD

Senior Analyst | Retail Rates | Energy Division | California Public Utilities Commission

Potential of Widespread Demand Flexibility



Source: PNNL DSO+T Study January 2022

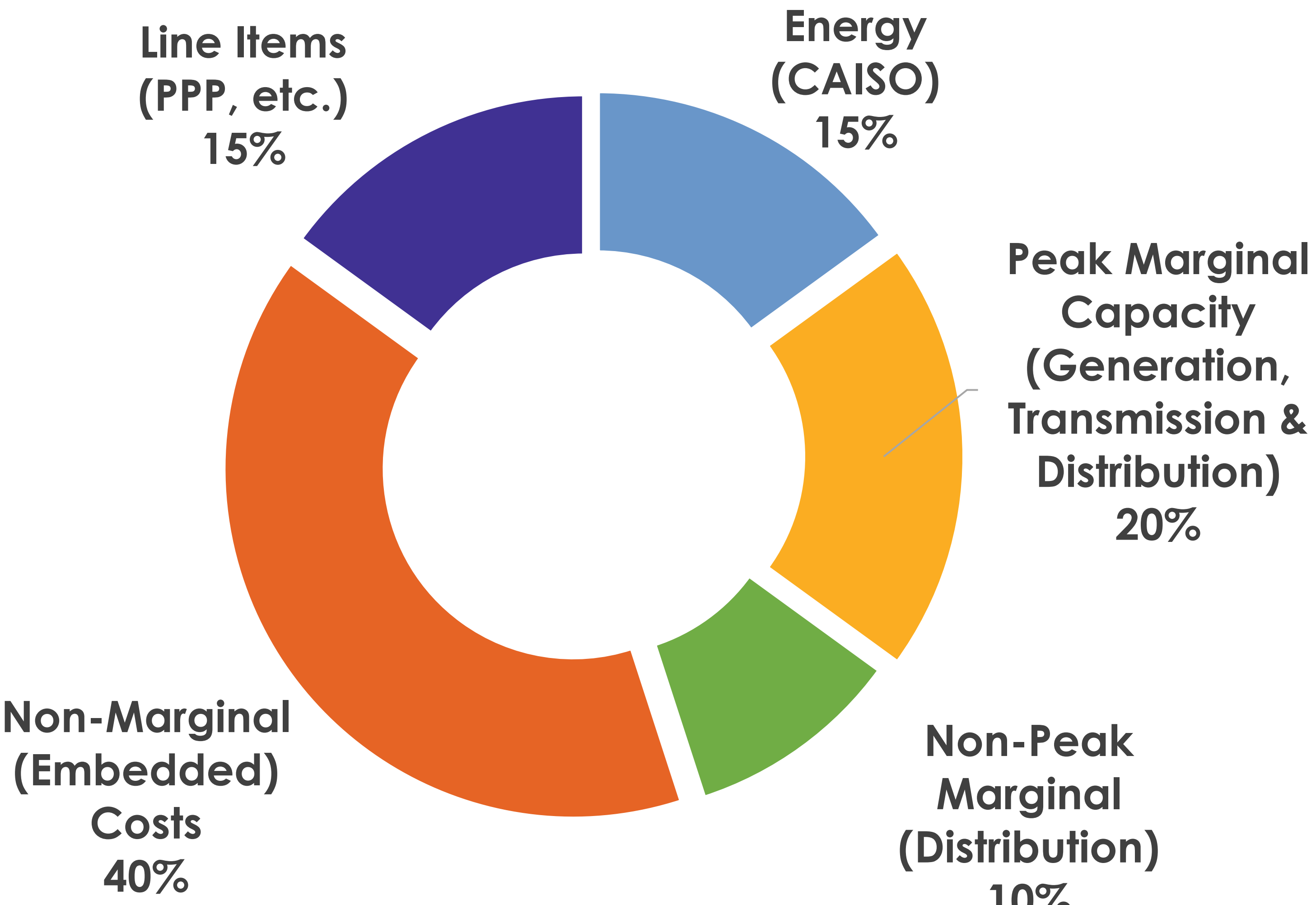
California Flexible Unified Signal for Energy – CalFUSE “Framework”

Three Pillars	Six Elements
Price Presentation	Element 1: Standardized price access
Rate Reform (Three-prong strategy)	Element 2: Real-time energy prices
	Element 3: Real-time capacity prices
	Element 4: Bi-directional prices
Customer Options for Energy Optimization	Element 5: Subscription option
	Element 6: Transactive option

Demand Flexibility OIR (R.22-07-005)

- Develop guidelines for dynamic rate applications that will be filed to comply with the CEC Load Management Standards
  - Hourly Marginal Cost Rates
- Ensure participation by both <u>bundled and unbundled customers</u>
- Ensure alignment with CPUC's Rate Design Principles and Demand Flexibility Principles
  - <u>Economically efficiency</u>: All Rate Incentives are **Cost-Based**

Which Revenues are Required to be included in Dynamic Rates per CEC Load Management Standards?



Category	%	Avg Rate (cents/ kWh)
CAISO + Peak Marginal Costs (In Dynamic Price)	35%	14
Non-Peak Marginal Distribution	10%	4
Remaining "Non-Marginal" Costs	40%	16
Line Items (NBCs)	15%	6
Total	100%	40

Regulatory Timeline for Dynamic Retail Rates in CA

Date	Milestone
March 2024	**Expanded Pilots authorized in SCE and PG&E (D.24-01-032)** • Pilots include eligibility for VGI (including submetering) • Enrollment target of 150 MW by 2027
Oct 2024	**PG&E V2X Pilot (SB 676) Phase 2 launched** • EV pilot that provides export compensation for bidirectional EV charging on a CalFUSE rate for residential and commercial fleets
Jan 2025	**SDG&E Dynamic Export Rate Pilot Program** • Generation-only Hourly Export Rate Rider Program that includes CAISO Day Ahead price and Generation Capacity Price Adder
2025	**Large IOUs and CCAs to submit applications for opt-in dynamic hourly rates in response to CEC LMS**
2027	**CEC Load Management Standards require that large IOUs and CCA offer dynamic hourly rates for all customer classes**
2030	**CEC's adopted CA load shift goal – 7,000 MW**

PENINSULA CLEAN ENERGY

EV Managed Charging

VGI Forum

Phillip Kobernick,
Associate Director of Energy Programs

A Community Led Agency

How Community Choice Energy Works

PCE

Buys & generates clean electricity for its communities

PG&E

Delivers electricity & customer bills

CUSTOMERS

Benefit from cleaner, cheaper energy

PCE Residential EV Managed Charging Pilot

PCE EV Managed Charging Pilot Summary

1. Used telematics-based managed charging, ~year long test

2. Focus on residential customers (charging during evening ramp up)

3. Tested multiple incentive types and amounts (up to $40/mo)

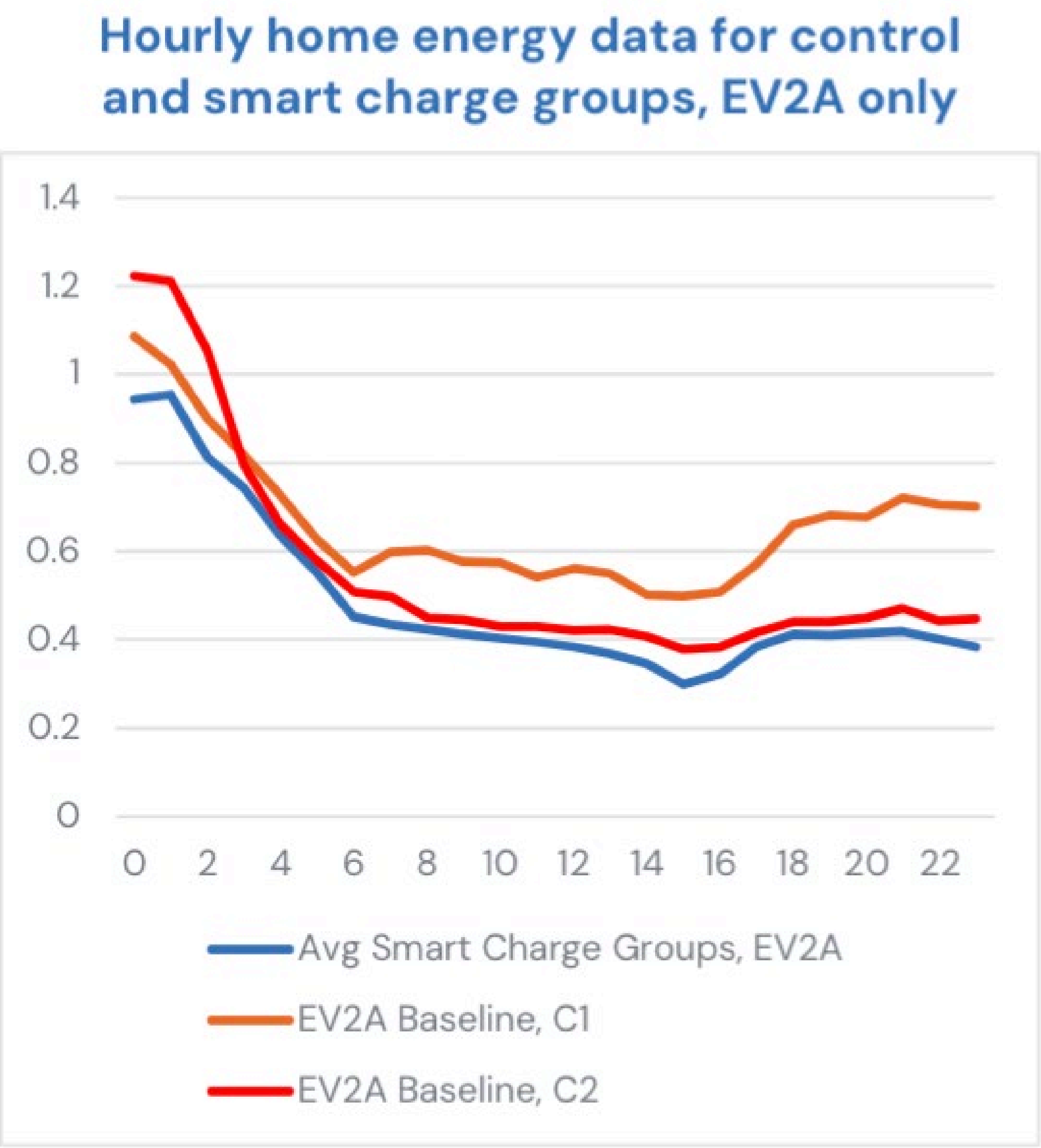
PCE EV Managed Charging Pilot Major Takeaways

1. Challenging recruitment
   - 700 enrolled (out of about 16K targeted)
   - 4% enrollment

2. Self-selection bias
   - EV2A customers oversampled
   - Very little on peak charging

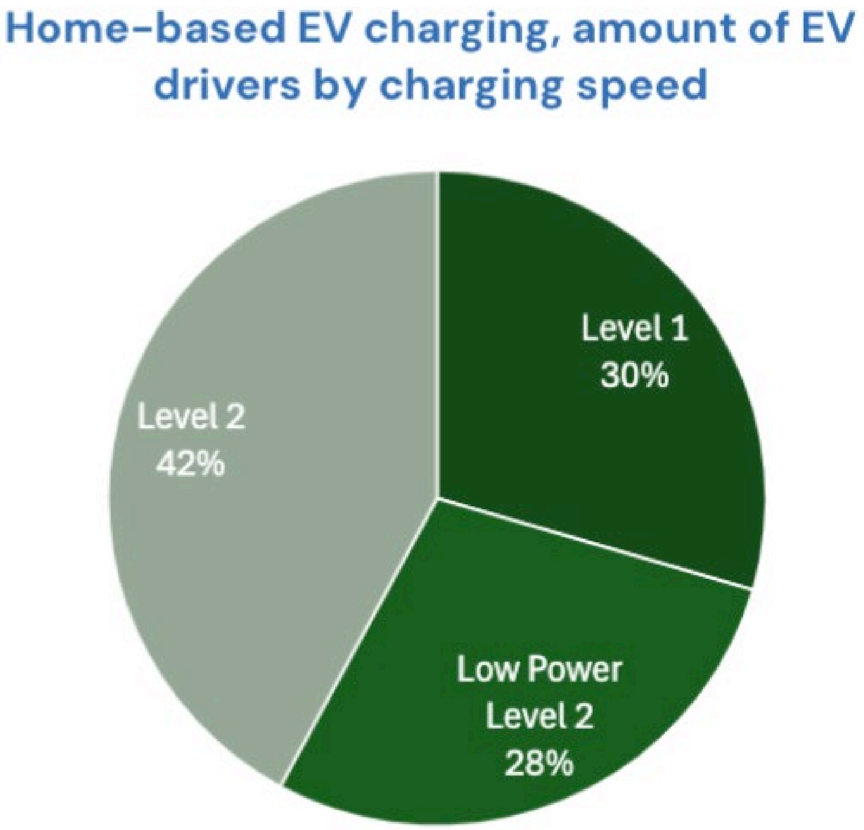
3. Time peak reduction potential, but no (<.1 kW) actual load shift during peak hours

PCE EV Managed Charging Pilot Major Takeaways



Home charging speeds verified

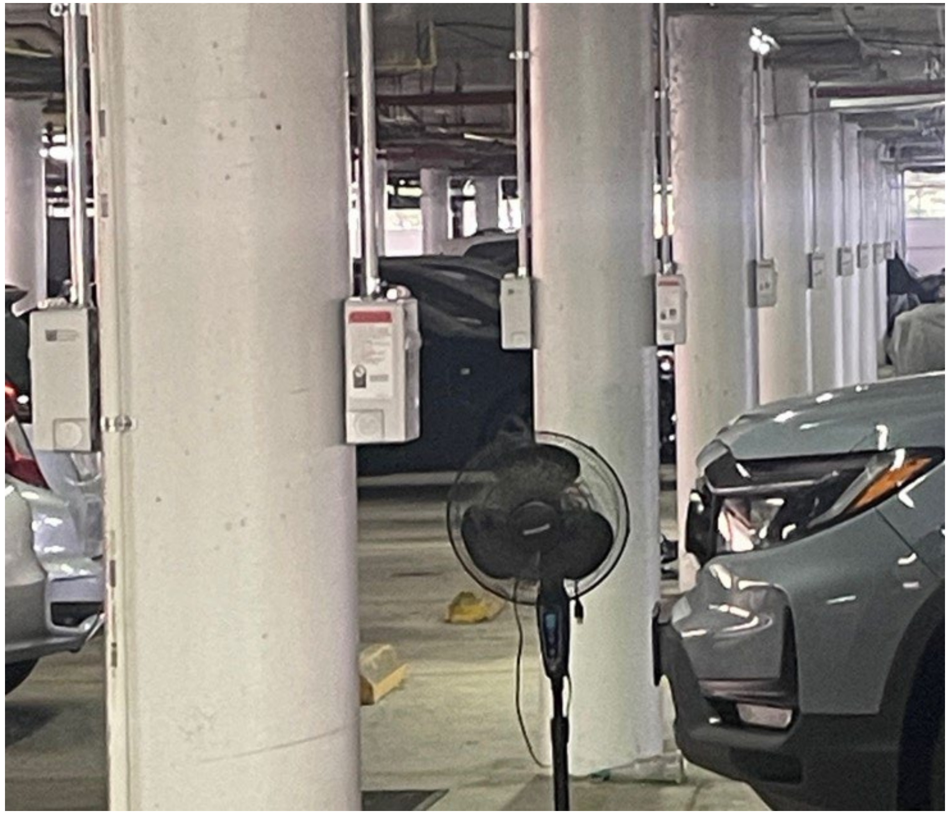
Level 2 charging isn't the norm



What’s another way for EVs to provide grid benefits?

Right-sized EV charging = Level 1 residential charging.

Installed Level 1 charging at apartments/condos in PCE EV Ready Program



L1 charging is affordable ($2,500/ea, 1/5 the cost of an L2 charger) and better for the grid.

Some of the largest multi-family EV charging projects in the nation happening in PCE's EV Ready Program:

- 92 outlets in East Palo Alto condos
- 140 outlets in Daly City apartments
- 144 outlets at Millbrae condos
- 200+ outlets at South San Francisco apartments

Phillip Kobernick
Associate Director of Energy Programs, Peninsula Clean Energy
pkobernick@PenCleanEnergy.com

Report available at
https://www.peninsulacleanenergy.com/wp-content/uploads/2025/03/PCE-EV-Mgd-Charging-Final-Report.pdf

THE MOBILITY HOUSE

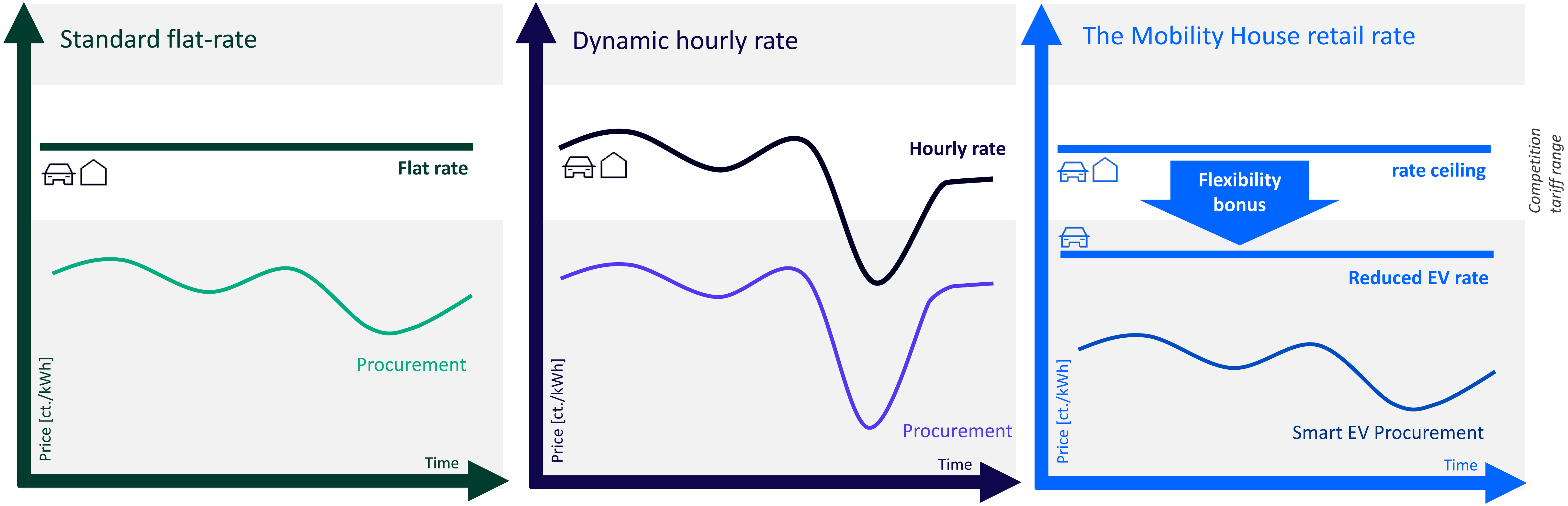
VGI Value Streams

Value for the end-customer

Russell Vare | VGI Forum | April 16, 2025

Examples of Rate Design to enable EV Flexibility

Schematic comparison of rate types including offer from The Mobility House



Standard tariff with fixed kWh price for entire energy consumption

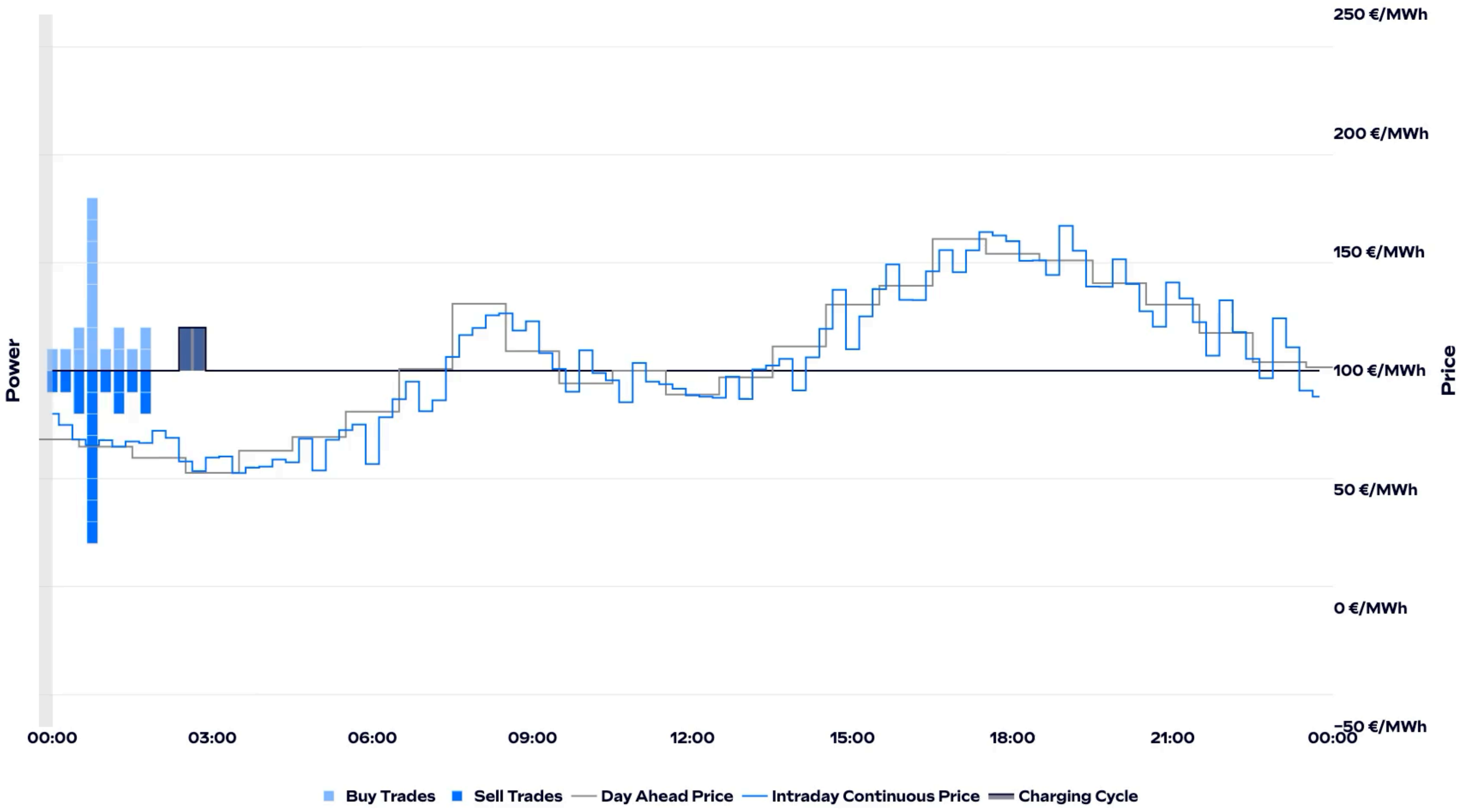
No tariff cap, customer bears price risk of dynamic spot market

Attractive, risk-free tariff; flexibility bonus reduces electricity cost significantly

Source: The Mobility House

V1G EV-Portfolio Wholesale Trading

Visualization from trading with V1G assets in German wholesale market on 08.01.2025



Monetization

- The Mobility House is registered to participate in various energy markets in Europe.
- The Mobility House is an aggregator of EVs.
- Load flexbility from EV charging is bid into markets to generate revenue.
- Revenue is shared with end-customer via their retail rate.

Linking Wholesale Market Value to the End Customer

The Mobility House launched a V2G offer with Renault in 2024

Renault 5 E–TECH
with integrated bidirectional AC charging

Mobilize verso
AC bidirectional charging station

MyRenault
- Customer app for individual control
- Customers earning €50/month

Source: The Mobility House/Renault/Mobilize

Customer Fleet Needs and VGI Value Streams

Reduce CapEx	**ALM** **FIX**	• Automated Load Management (ALM) to lower site upgrades • Flexible Interconnection (FIX) to lower utility-side investment • Integrate customer-side DER to lower investment

Reduce OpEx	**V1G**	• Bill Management
		  • TOU rate optimization
		  • Dynamic rate
		  • Demand charge management (DCM)
		  • Onsite solar integration

Additional Value	**V2G**	• Islanded backup power • Grid Services (e.g. Demand response) • Bill Management (TOU, DCM)

Source: The Mobility House

WeaveGrid

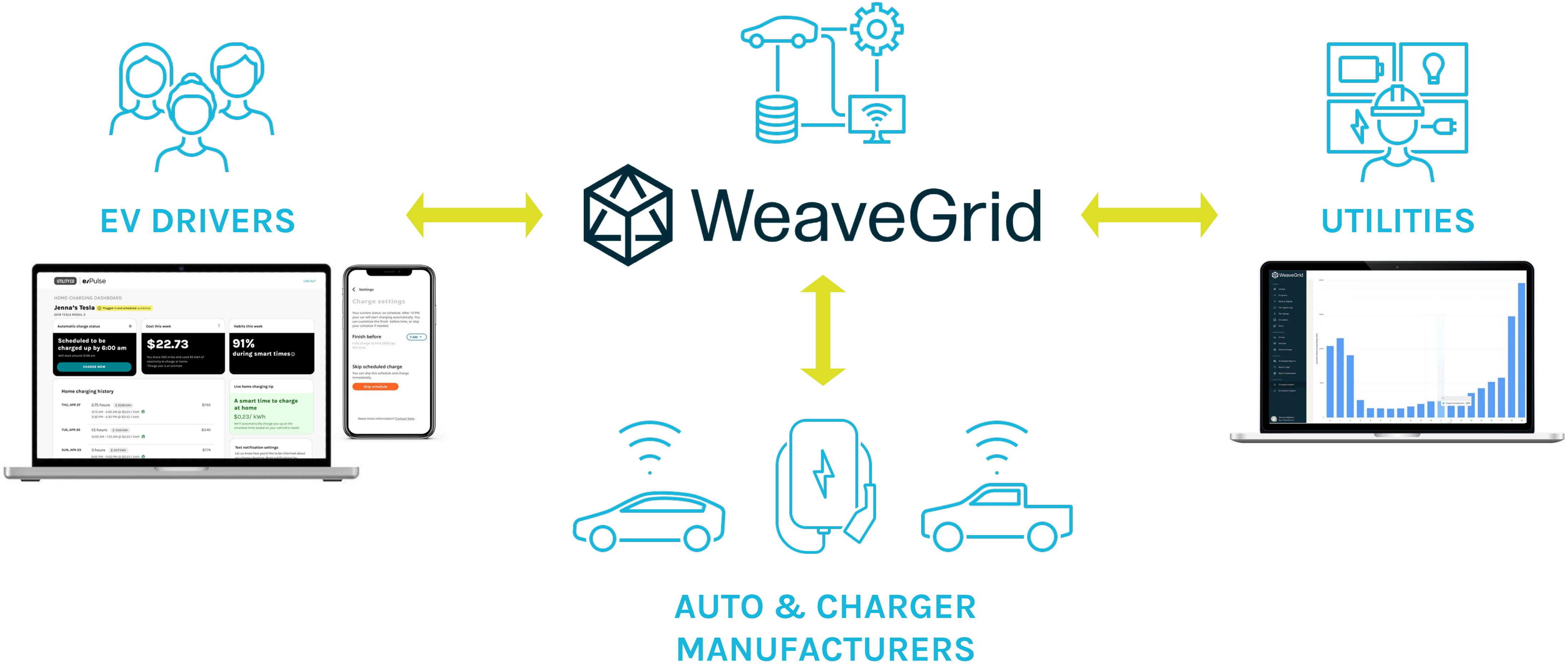
How do we value VGI?

Mathias Bell

April 16, 2025

WeaveGrid

WeaveGrid helps utilities integrate EVs by transforming them into dynamic grid resources with software



THE PROBLEM

The grid's growing bottoms ups distribution challenge

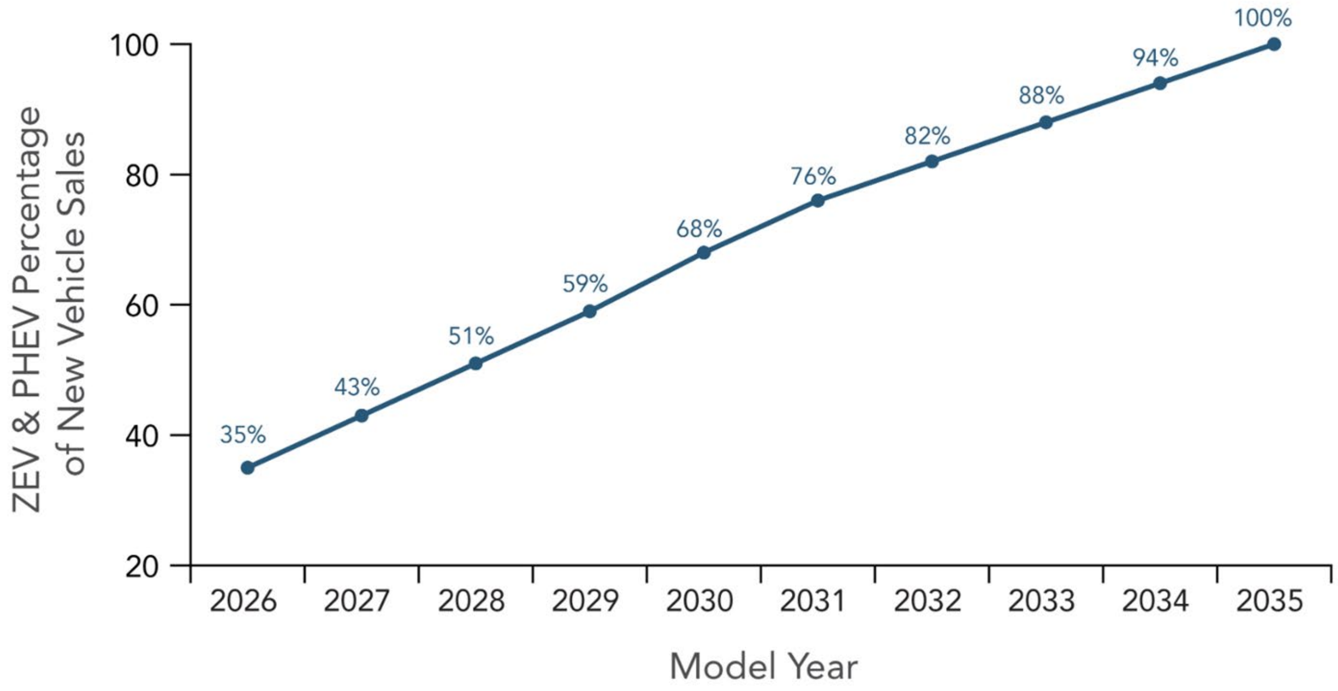
80% of charging happens at home

Level 2 charger doubles average home electricity demand

EV adoption is very clustered

Rapid increases in distribution asset failure and upgrade needs

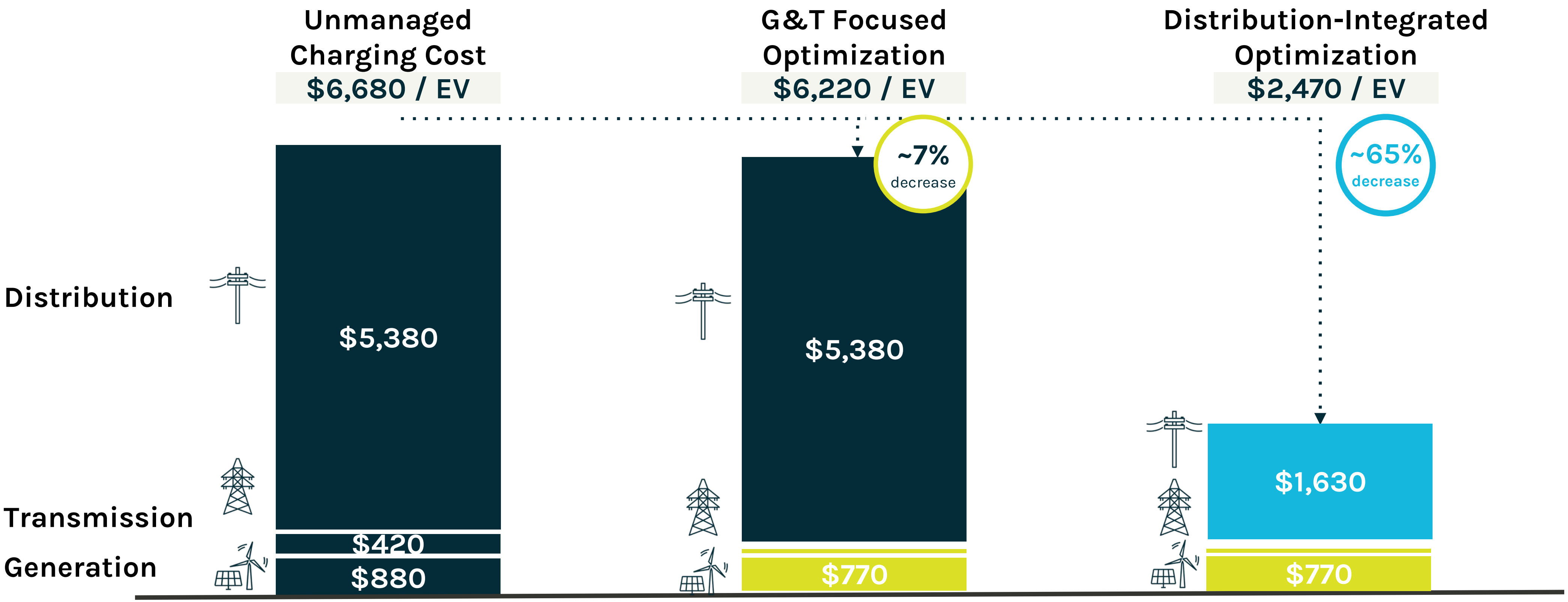
California EV Adoption Projection



WeaveGrid

POTENTIAL COSTS

Distribution optimization is critical to meaningfully reduce costs of integrating EVs with the grid



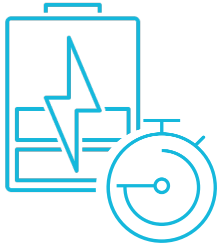
Sources: BCG, WG Analysis

Most managed charging solutions focus solely on peak coincident impacts but fail to address distribution needs

DISTRIBUTION → BULK SYSTEM

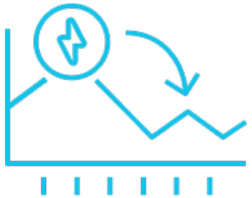
TIME-OF-USE

- ✓ Static bulk peak
- ✗ Dynamic bulk conditions
- ✗ Increased feeder



DEMAND RESPONSE

- ✓ Discrete bulk events
- ✗ Dynamic bulk conditions



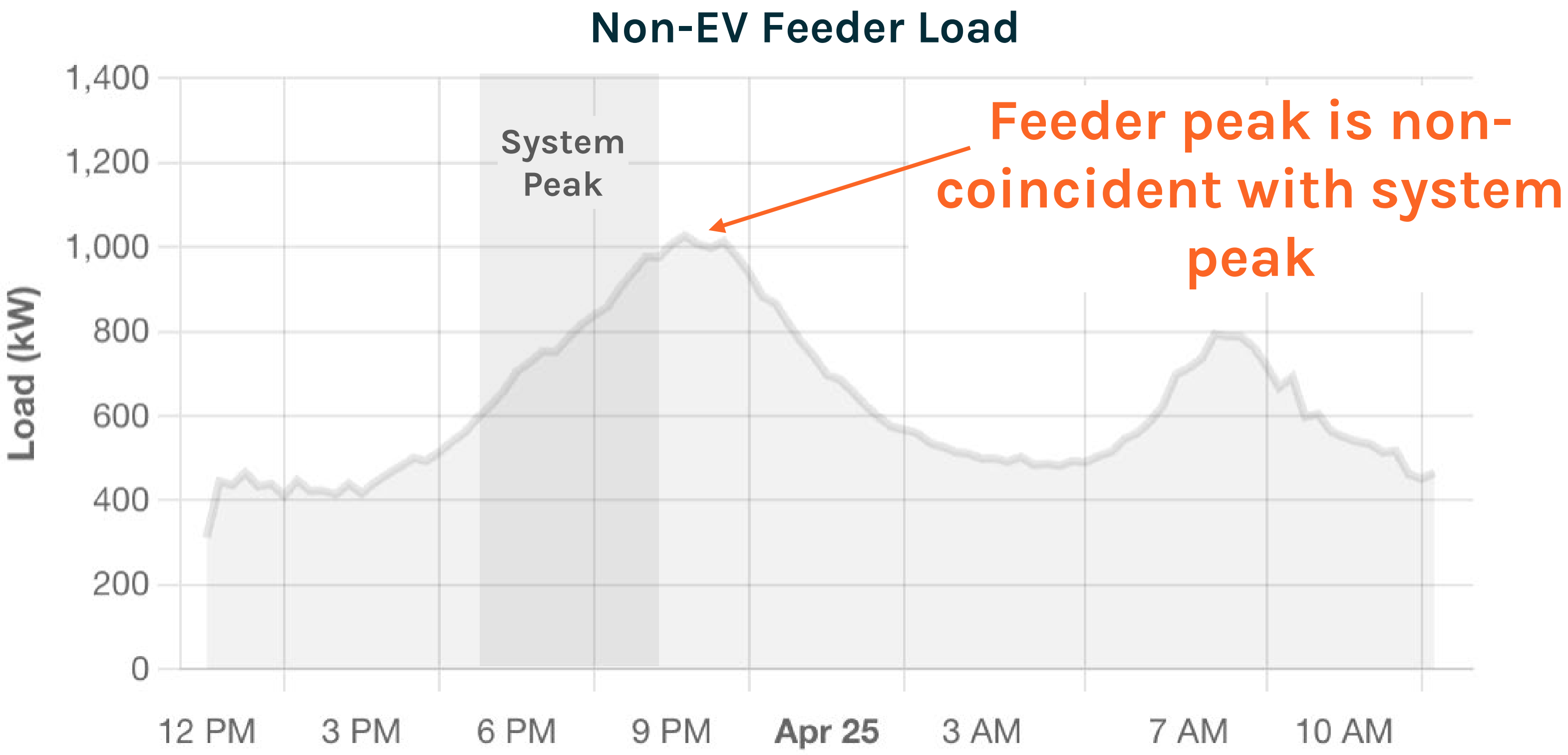
DYNAMIC RATES

- ✓ Dynamic bulk conditions
- ✗ Customer understanding and utility

Regional distribution variability, feeder overload, or localized grid constraints

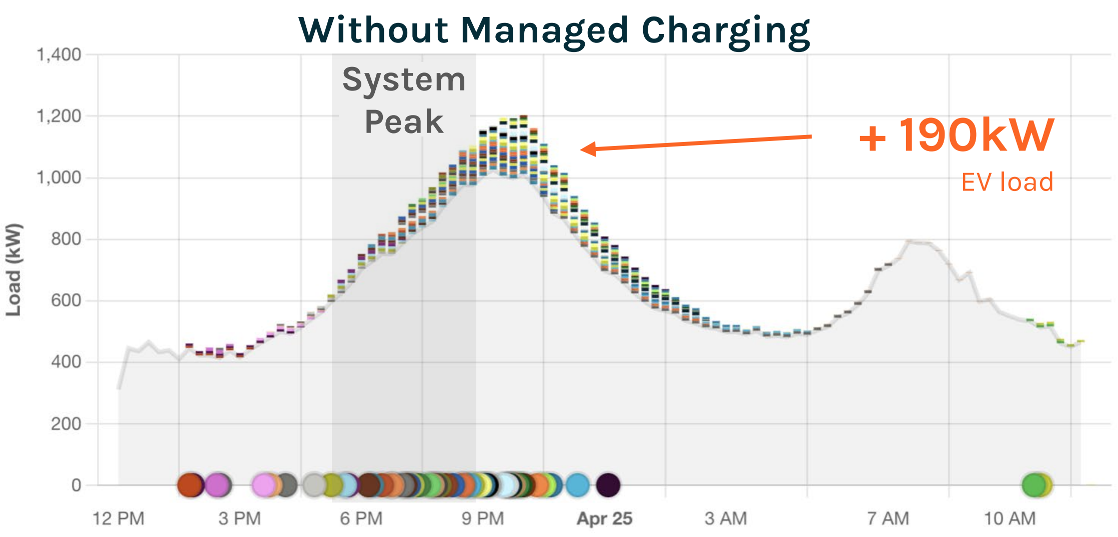
WeaveGrid

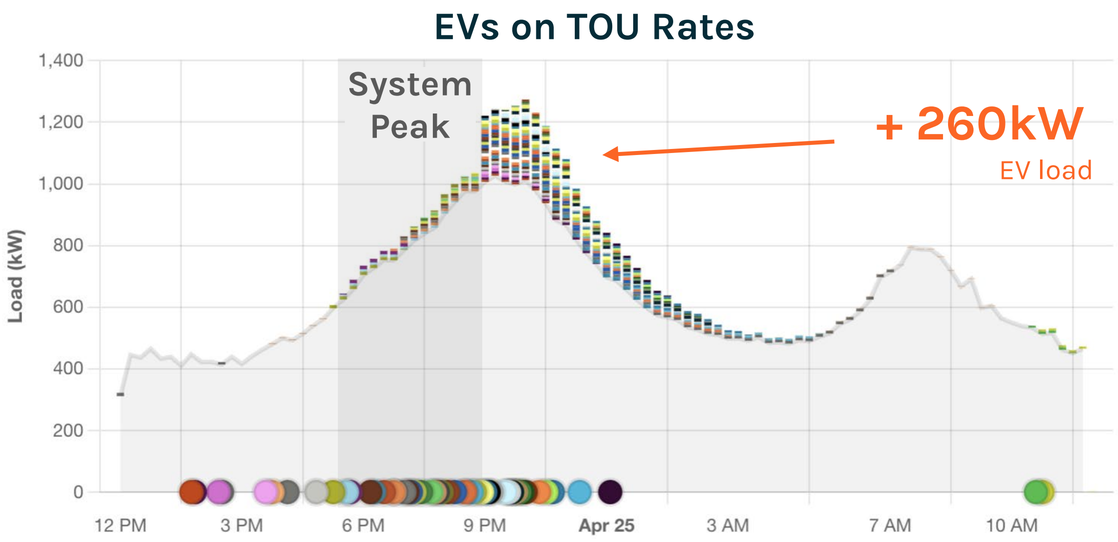
EV load is not the only stressor distribution systems face - how do these solutions look layered on non-EV load?



WeaveGrid

TOU timer peak coincides with feeder peak, increasing strain

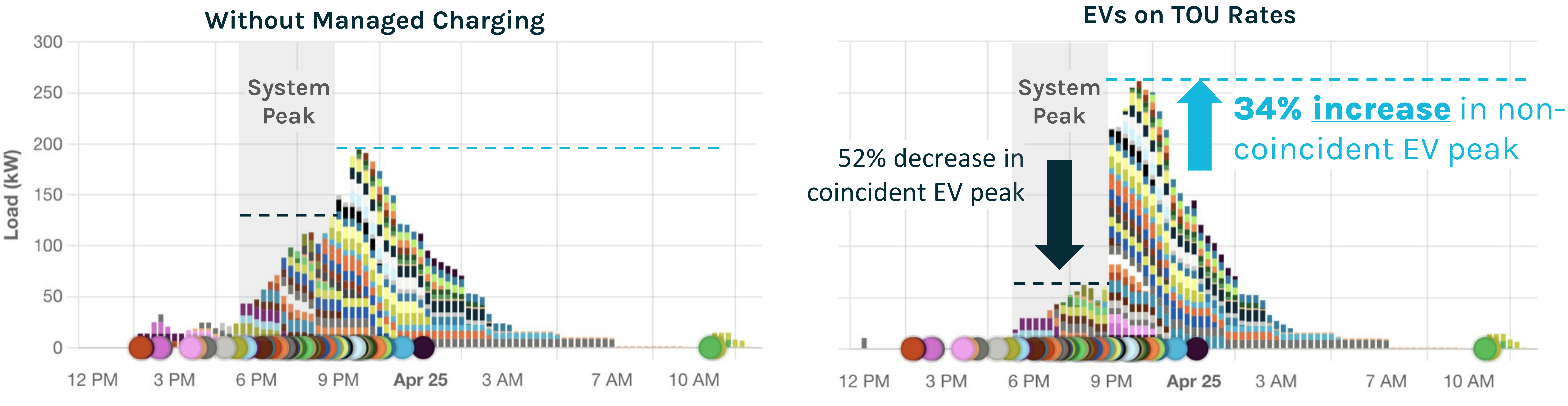




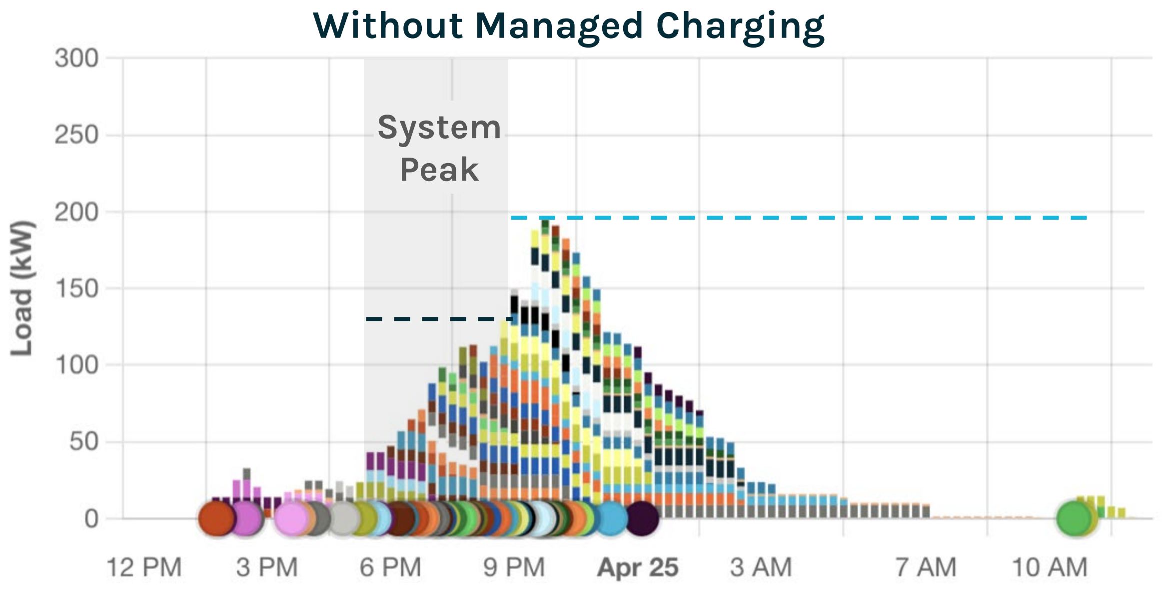
increase *in feeder peak charging load*

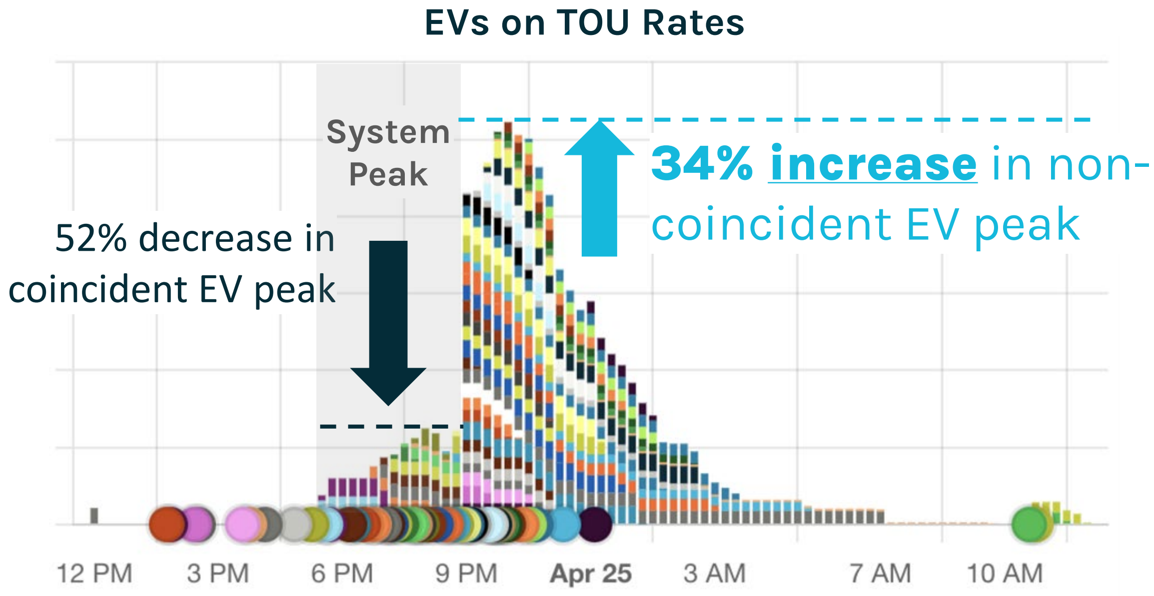
with TOU optimization

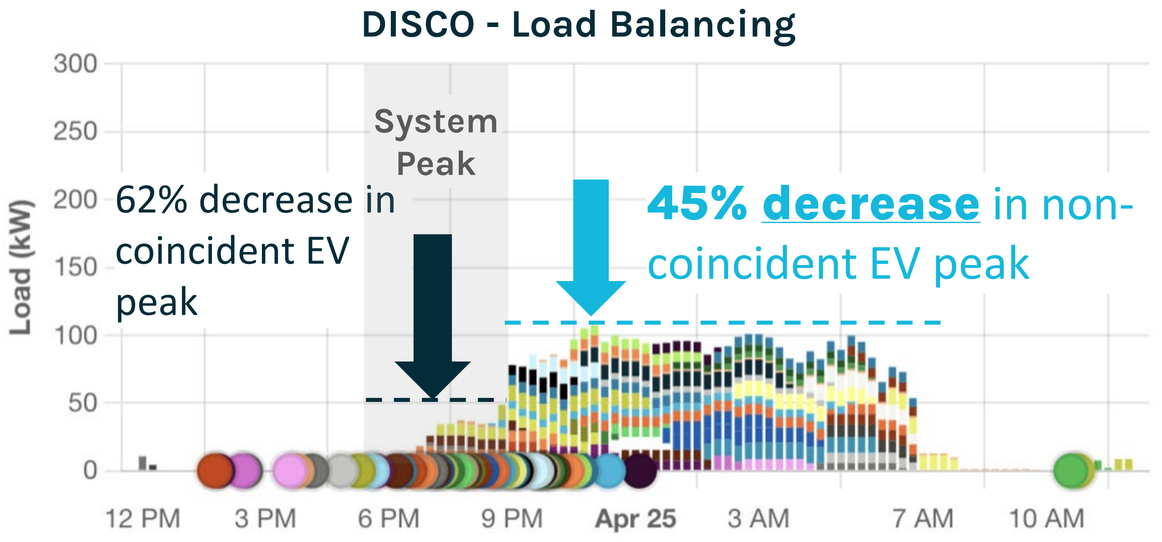
How to complement time-of-use rates?



How to complement time-of-use rates?





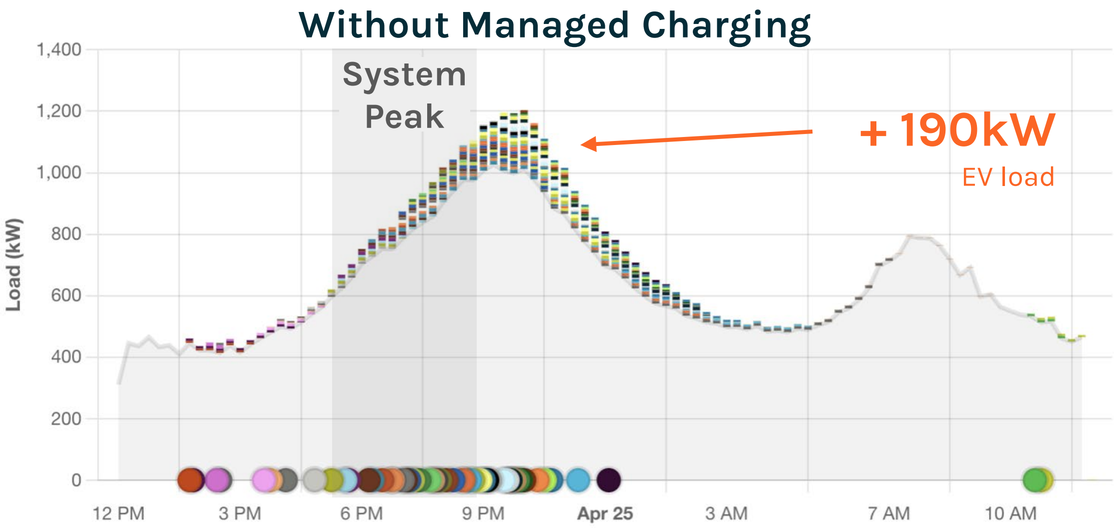


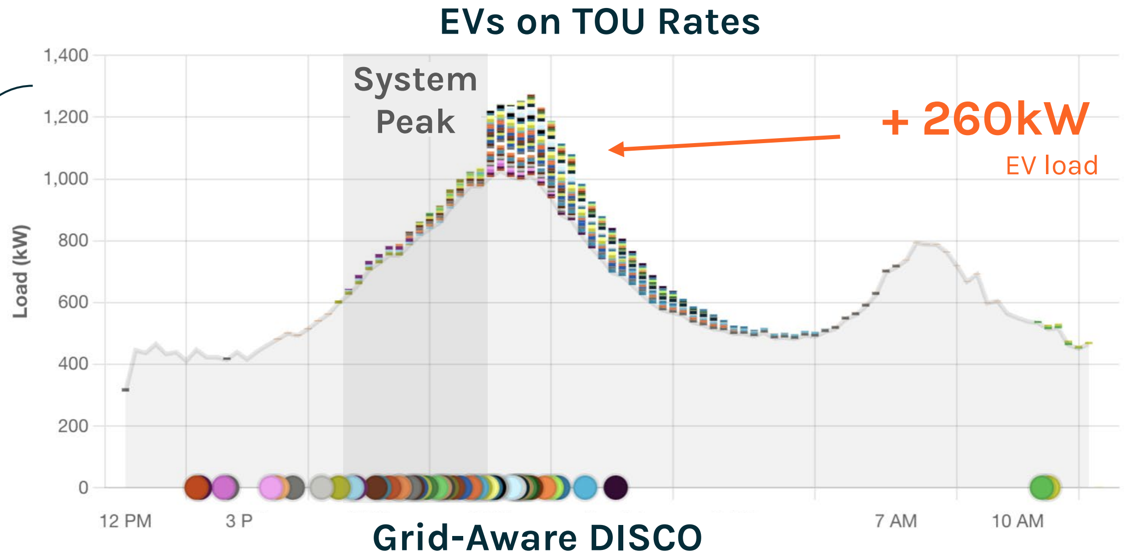
Load Balancing **flattens EV load** in off-peak to **resolve timer and non-coincident peaks**

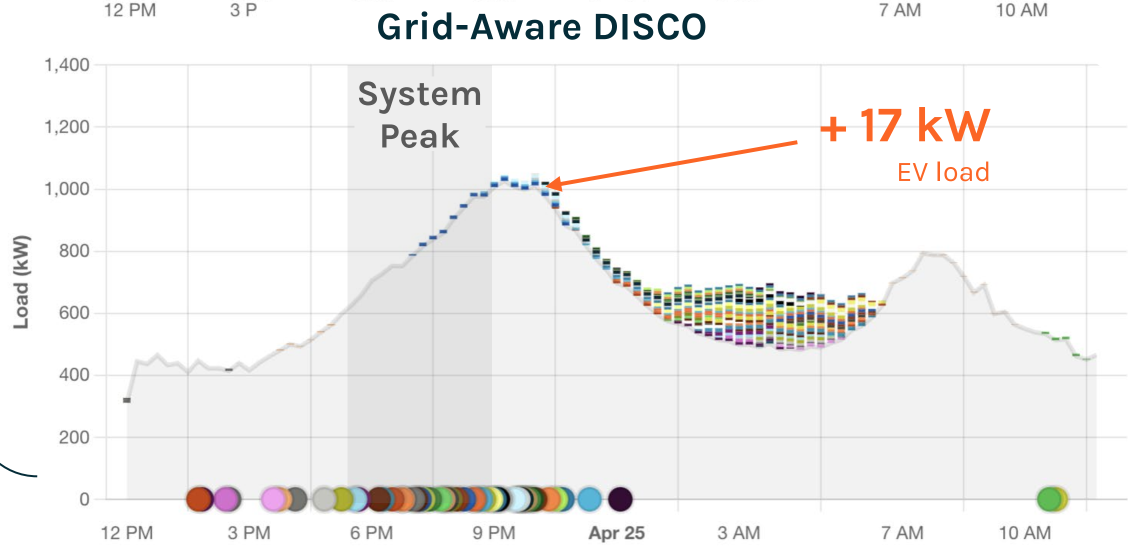
WeaveGrid

MAXIMIZING DISTRIBUTION VALUE

Minimized feeder peaks by optimizing for EV and non-EV load







decrease *in asset peak coincident charging load* **with Grid-Aware DISCO**

WeaveGrid

Thank You!

Mathias Bell
mathias.bell@weavegrid.com

WeaveGrid

dcbel

How to Value VGI

Dan Fletcher
Head of Ecosystems

Distributed Operational Intelligence

Value of Residential VGI

Your energy trader at home
Enabling VGI routines

dcbel

Ara

Powering your home with your EV
V2H Blackout Power

Home power supply during peak hours
V2H Peak Shaving

Generating new revenue streams
V2G VPP

Smart charging, Power Boost
DC Charging

Dual Charging /2nd car at once
AC Charging

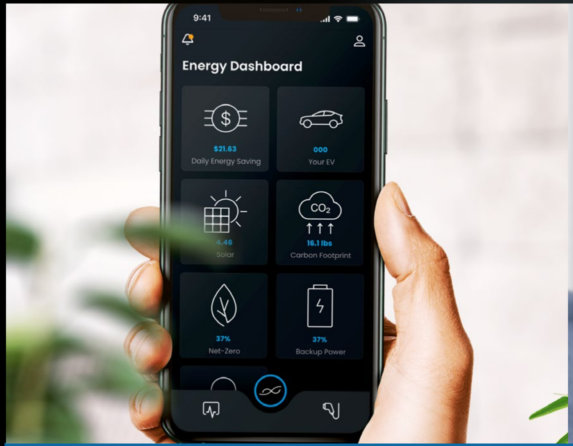
25kW

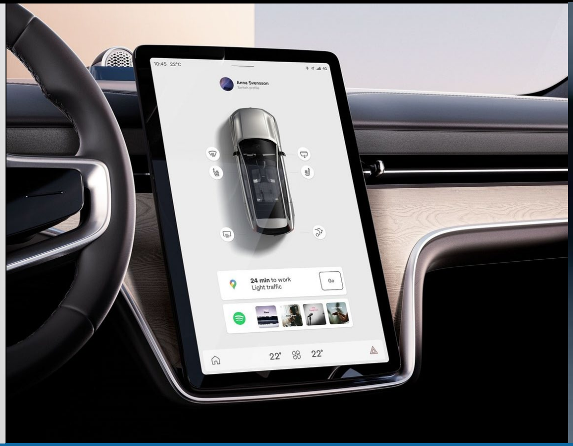
Universal bidirectional EV charging
works with enabled EVs

dcbel

PORTALS

Remote access from anywhere





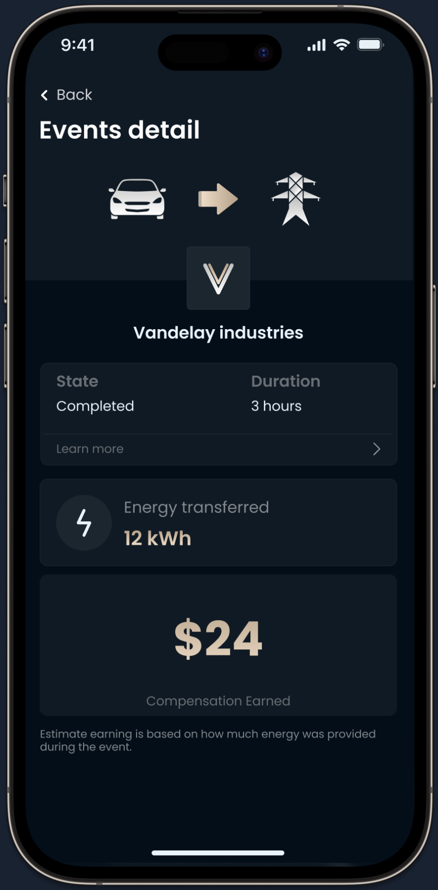
	Mobile Portal	Ara	EV	EV App
Location	Anywhere	Driveway, garage	Away from home	Anywhere
Time	Anytime	While using	In transit	Anytime
Home Energy	All Featured / For Full Control	Subset Features / For Practical Tasks	Selective Features / For Information	Key Features / For Convenience

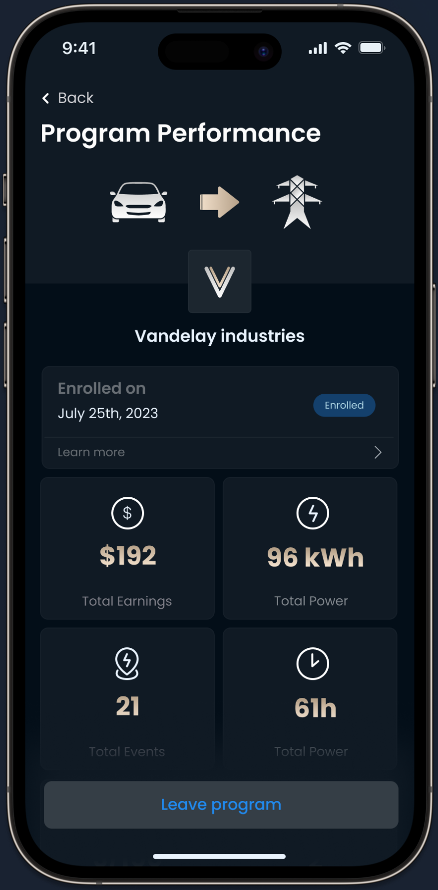
dcbel Energy Program Enablement

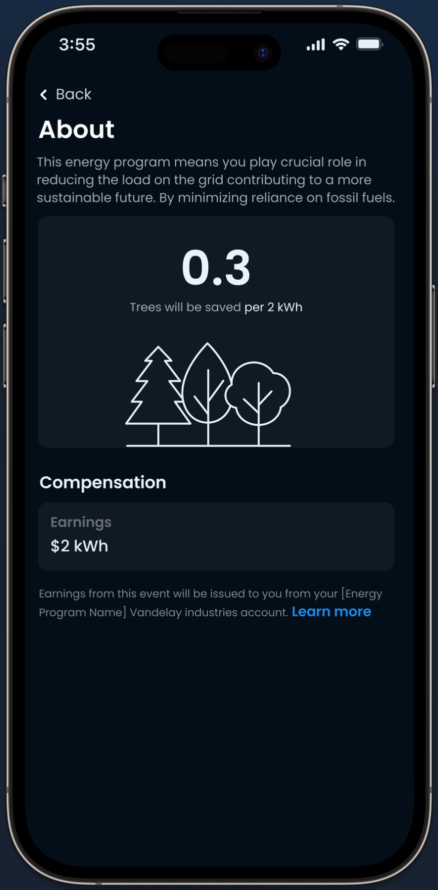
- Local program & incentives
- Personalized prosumer experience
- Decentralized grid-edge computing
- Local or cloud-based apps
- Flexible integration
- User-consented data
- Personalized home energy management

dcbel

Enrolled Energy Program







VPP Ready

Load Forecasts **Evolution**

dcbel

Increasing Deployment of DER & VGI

Unpredictable Net Load Profile | Meter Load ≠ Behind-the-meter demand

- Need for Grid Flexibility Services to be provided by distributed Assets

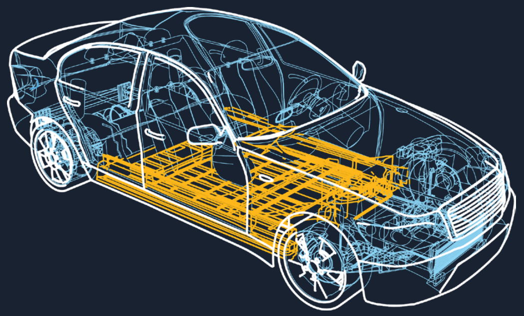
Ensure mutually beneficial goals & rewards

Behind the meter DER aggregation

Valuable double-digit flexibility

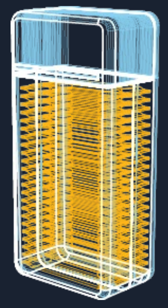
Bidirectional EV
Charging / Discharging

15 kW 12 hrs ⬇⬆



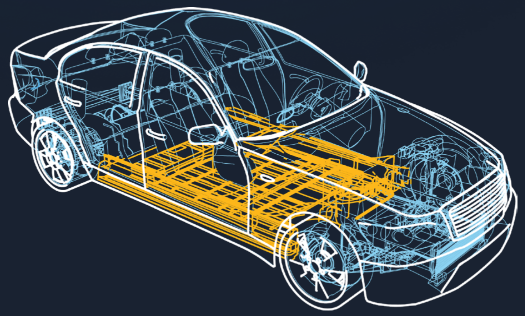
Home Battery
Charging / Discharging

10-15 kW 24 hrs ⬇⬆



Unidirectional EV
Charging / Discharging

10 kW 12 hrs ⬇



Heat Pump ⬇
4-5 kW 15 min

Water Heater ⬇
4-5 kW 15 min

30 kW - up signal / 35 kW down signal

We deliver energy so you can live a **life without compromise**

Lunch — we will resume at 1:00 pm PT

Crossing the Chasm from Pilots to Programs

- BLAKE HEIDENREICH, STRATEGIC ADVISOR, CUSTOMER EXPERIENCE PROGRAM DESIGN & DEVELOPMENT – SCE
- DANIELLE WEIZMAN, BUSINESS DEVELOPMENT MANAGER, CLEAN TRANSPORTATION – SDG&E
- AMY COSTADONE, PRINCIPAL PRODUCT MANAGER – PG&E
- JACQUELINE PIERO, US HEAD OF POLICY – THE MOBILITY HOUSE
- CASEY DONAHUE, CEO AND FOUNDER – OPTIWATT

Scaling Pilots to Programs

Danielle Weizman
Clean Transportation Business Development Manager

Scaling VGI Pilots into Programs

Develop Priority Use Cases to Pilot

- Identify need or value
- Establish metrics
- Assess the market
- Understand technology

Design Good Pilots

- Define objectives
- Consider the customer
- Design replicable frameworks
- Use infrastructure that can be expanded

Implement Pilots for Scalability

- Continuous and iterative approach to improvement
- Standardization
- Flexibility
- Customer value and journey

Identifying Key Pathways

- Funding sources
- Roles and partnerships
- Market alignment
- Regulatory pathways

Current Frameworks

Current Pilots

Use Case	**Managed Charging (V1G)**	**Resiliency (V2X)**	**Dynamic Rates (V2G)**
Pilot Design	Piloting managed charging for residential customers on Kaluza platform	Piloting resiliency via vehicle-to-everything at community resource center	Pilot compensation for exports by commercial customers
Funding Mechanism	CEC REDWDS Grant	EPIC 4	PPP

Scalability Mechanisms

- LCFS Implementation Plan via Tier 2 Advice Letter
- Application for any ratepayer-funded programs leveraging Avoided Cost Calculator
- Rates

VGI - Scaling Pilots to Programs

April 16, 2025

Amy Costadone, Principal Product Manager
Vehicle Grid Integration

Together, Building
a Better California

Current State in PG&E's Service Territory

Service Area

70,000

SQUARE MILES

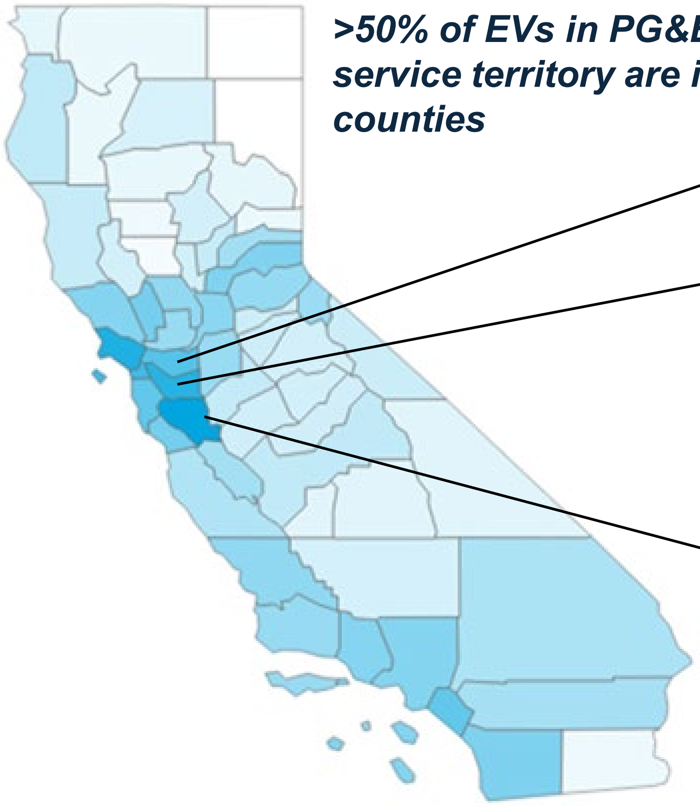
Service area population

16 million CALIFORNIANS

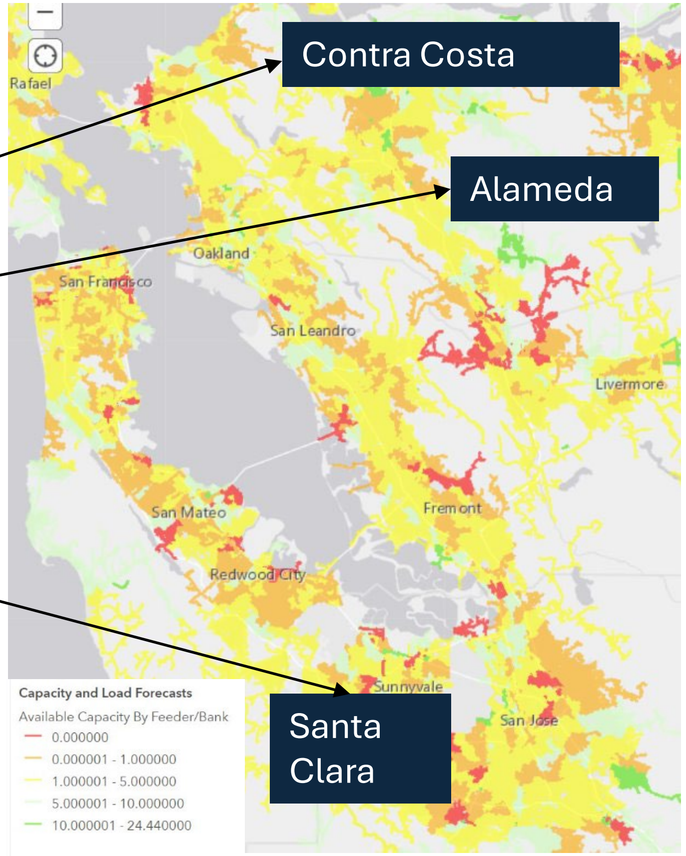
(That's 1 in 20 Americans!)

EVs Registered**

816,726



>50% of EVs in PG&E's service territory are in 3 counties



Source:
** Veloz **EPRI data*

Graphic shows Incremental EV Registrations (% of Sales Last 6 Years); EPRI data

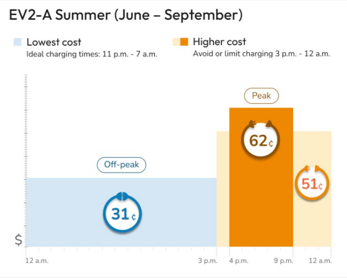
Geospatial tool forecast for December 2024 (Primary DX)

Current State - PG&E VGI Portfolio

Rates

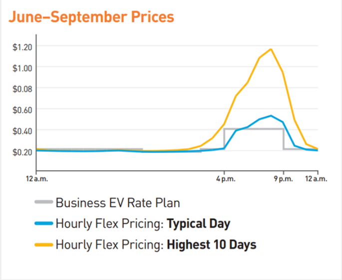
EV specific Time of Use Rates

EV2A, EV-B, and BEV rates use time of use pricing to drive charging to off-peak times for the system



Dynamic Pricing Pilot

- Testing day-ahead hourly dynamic pricing through the Hourly Flex Pricing shadow rate.
- Values energy based on system and distribution grid needs and compensates customer accordingly.

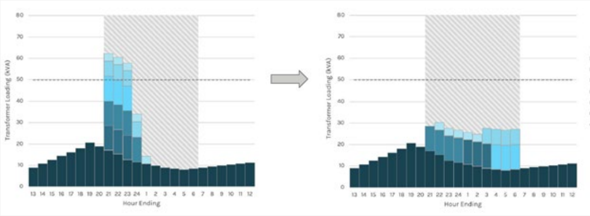


Managed Charging

EV Charge Manager Pilot

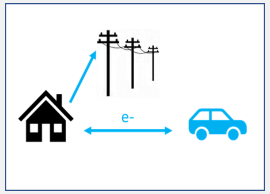
- Pilot offers a $75 participation incentive to customers to enroll and manage their EV charging in a way that optimizes their bill.
- Optimize EV charging on local distribution transformers via software and test ability to defer upgrades and extend the life of an asset.

Unmanaged load on a transformer *Managed load on a transformer*



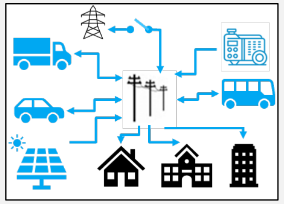
Export via V2X Technology

V2X Pilots – Residential & Commercial



- Provides incentives for V2X hardware to support adoption of technology
- Tests backup power and vehicle to grid export use cases

V2X Pilot - Microgrid



- Provides incentives for customers to incorporate V2X technology into single and multi-customer microgrids

AC V2G EPIC Pilot

- To be launched pilot to support development of interim interconnection pathway for AC V2G technology
- Phase 2 to enroll AC V2G customers in a VPP

VGI Scaling Framework

	Learnings	Opportunities
Quantifying Grid Value	• ~90% of EVs are on a TOU rate & ~90% of charging on TOU rates avoids peak hours • EV TOU rates have quantified system peak load avoidance • Managed charging has peak load avoidance impacts and local dx impacts	• VGI targets (where, when, how much) that are reflective of grid needs coupled with defined key metrics for net beneficial / cost effectiveness to determine optimized mix of VGI portfolio
Tech Maturity & Capabilities	• V1G managed charging works • V2G customer costs for equipment and installation is an order of magnitude higher than V1G	• Managed charging DERMS integration • Billing system updates • End to end frictionless registration process, including understanding panel needs and interconnection processes • Market alignment on scalable models
Customer Acceptance	• CSAT 4/5 for managed charging pilot • Significant home charging flexibility for managed charging pilot customers - plugged in 12-15 hours/day and charge 2-3 hours /day	• Customer findings from pilots • Customer research (qual and quant) • Measurement of customer response in pilots (efficacy of programs) to fully integrate VGI MWs into Operations and Grid Planning
Regulatory Enablement	• Current pilots are a combination of EPIC funding, memo accounts, CEC grants	• LCFS pathway provides flexibility in how to use these funding, however some constraints in how these funds can be spent • Standalone application

THE MOBILITY HOUSE

Crossing The Chasm From Pilots To Programs

Vehicle-grid Integration Forum

4/16/25

The Mobility House is the world's most trusted provider of Vehicle-Grid Integration (VGI) solutions

Founded 15 Years ago, backed by leading OEMs and utilities

300 people (San Francisco, Munich, Paris, Zurich, Singapore)

15 OEM partnerships for B2B & B2C charging / energy services

CEM solution ChargePilot trusted by **2000+ EV Fleets**

100+ MW stationary storage solutions using EV batteries

10 V2G pilots enabling 14 value-generating energy & grid services

Barriers to transition from pilots to programs

- **California's regulatory structure can be limiting**
  - The stakes of program choice and design is higher than in other places
- **Lack of integration with CAISO**
  - CAISO values must come via some proxy/translation via rates
- **Utility tipping points/needs for programmatic development are (understandably) unclear**
  - Pilot design to be onramps to commercial operation is therefore difficult
- **Retail resources and potential programs/value streams often contextualized/compared to solar**
- **Programs (and Pilot -> Program pathway may not be the only or best solution)**

MassCEC V2X Demonstration Project: A Path to V2G At Scale

*Goal: **increase access** to V2X technology as part of a model that can be replicated and scaled across Massachusetts to create a more **resilient energy grid**.*

Far-Reaching

Prioritizes members of Environmental Justice Communities

First program to award across 3 cohorts: Residential, Commercial, School Districts

Revenue-Generating

- Participation in EV programs like Connected Solutions, Clean Peak Energy Standard, Connected Homes, and more

Fast Paced

- Applications: Now – July
- EVSE Installations: 2H 2025
- EVSE Operation: Jan – Dec 2026
- V2X Guidebook Publication: Dec 2026

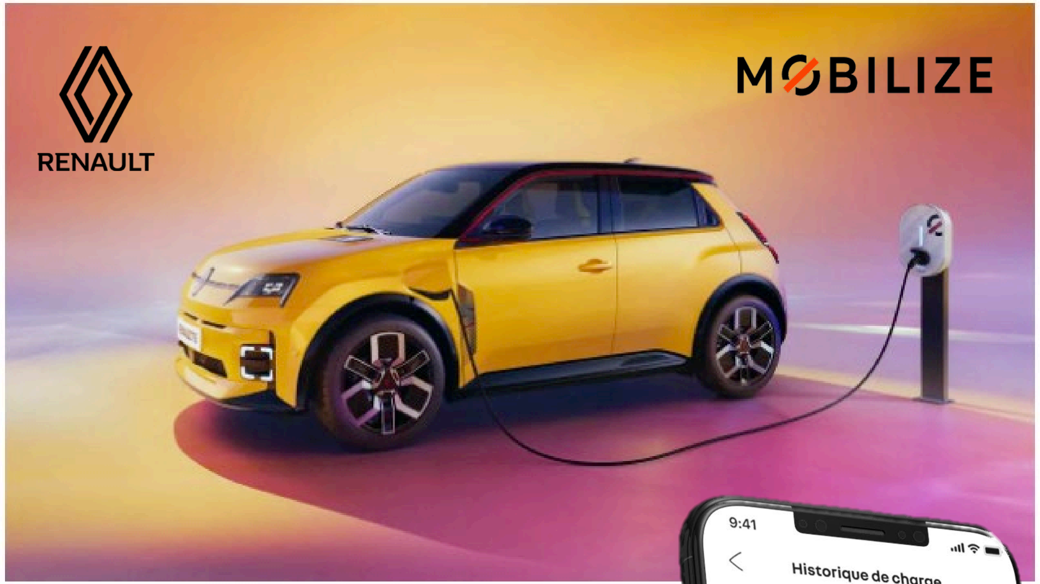
European V2G Experience

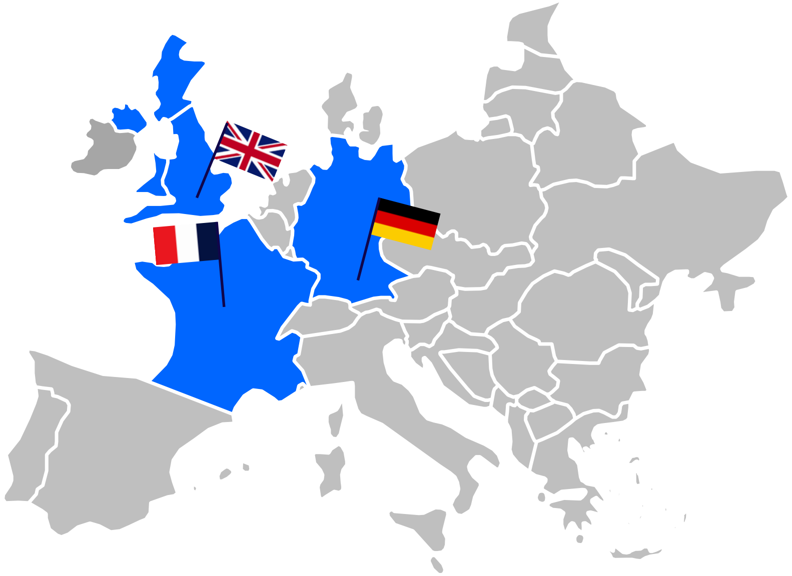
Renault V2G Offer

- Commercially-available residential V2G solution offered by Renault direct to customer
- The Mobility House as the technology provider
- **ZeroZero** offer:
  Energy for the EV is renewable electricity at zero cost
- V2G Bundle - customers buy EVSE and energy contract through the Renault dealer network

Technology

- Renault 5 EV (bidirectional onboard charger) with Mobilize Powerbox (bidirectional AC EVSE)
- Zero Cost for customer created through TMH optimization and trading in energy markets





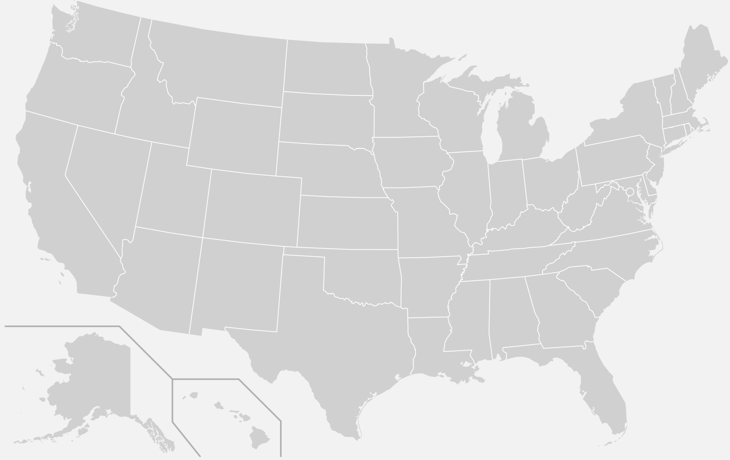
US vs. EU Energy Market Differences

Europe

- Retail energy markets with competitive tariffs for energy trading
- National laws
- DERs able to participate in energy markets
- Feed-in tariffs
- Low smart meter penetration

North America

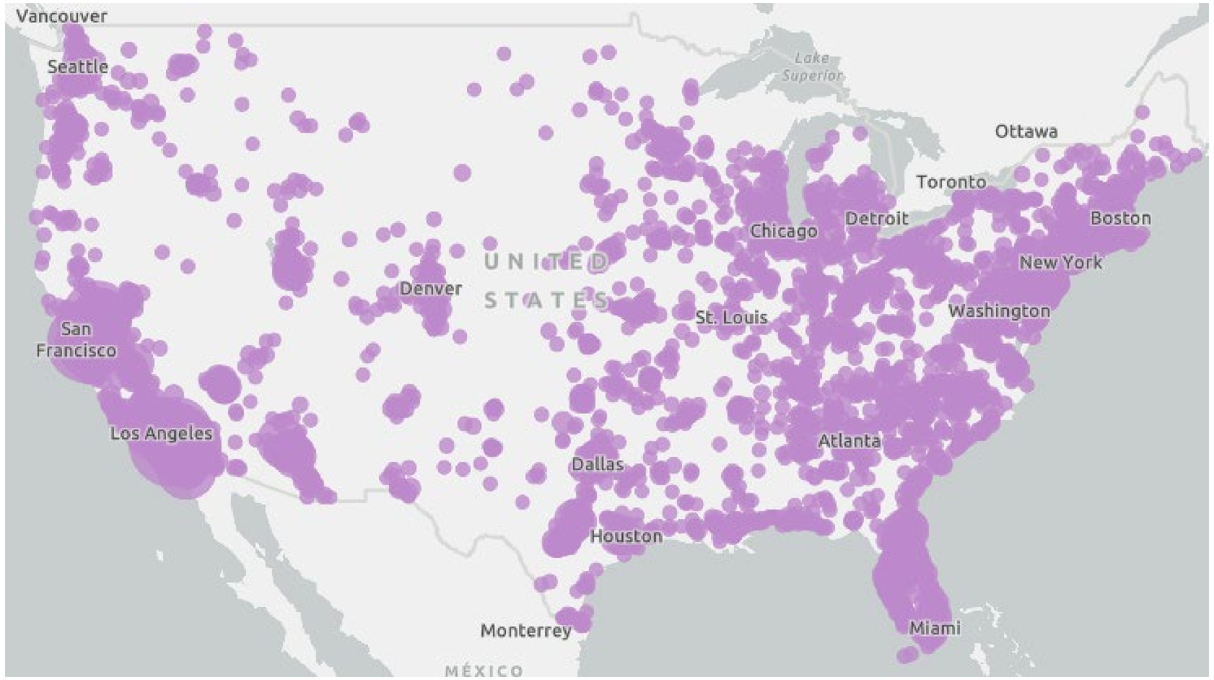
- Limited retail energy choice
- Rules by service territory
(not necessarily by federal or state level)
- DERs eligible for program participation, not market participation
- Net-energy metering / VDER
- High smart meter penetration

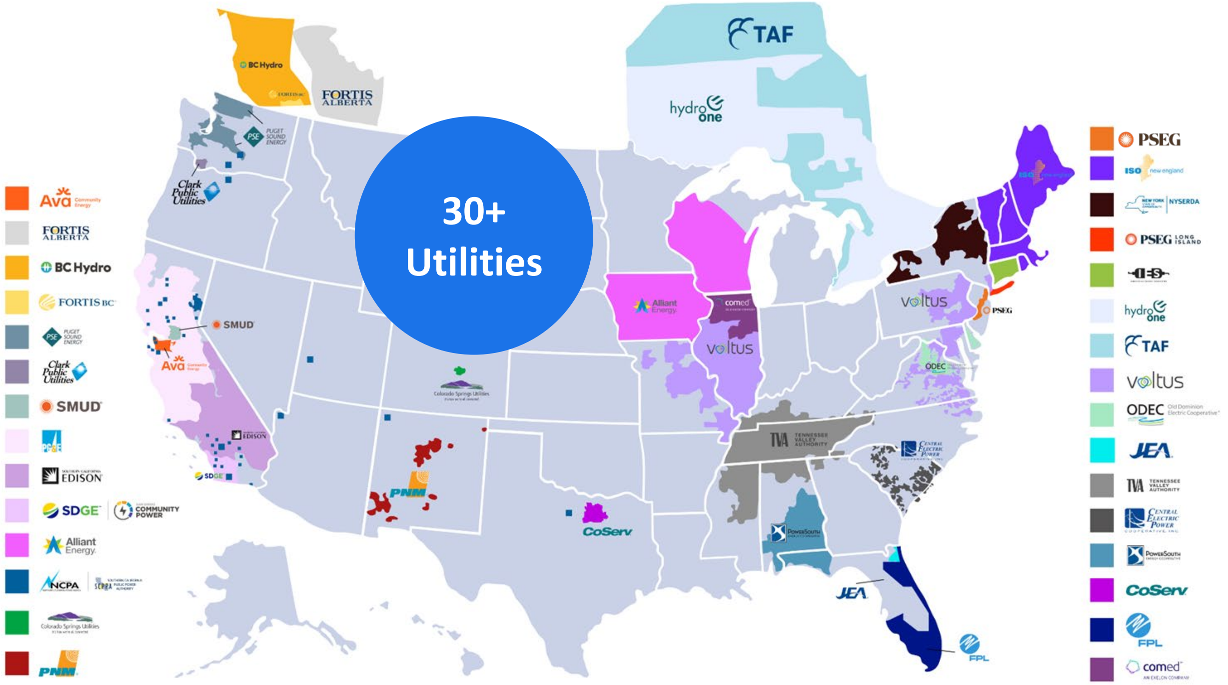


Optiwatt Overview

optiwatt

EV & Whole Home Energy Management Solution Provider for Customers and Utilities





Largest EV Managed Charging Provider in North America

- 80,000+ EVs actively connected
- 25,000+ Smart Thermostats
- Batteries Coming in 2025
- 4.8 Star Rating in app store

California Footprint

- **10+ VPP Programs + 27k Devices Managed**
- Scaled to 12k EVs in 9 mo. via REDWDS Grant
- 43% in Disadvantaged Communities
- 99% received no paid incentive, acquired with insights, savings, & ability to support the local grid

Cost effectiveness and value
is critical to move from pilot to program

optiwatt

Increasing managed charging grid value alone is not currently enough, **acquisition costs must be lowered**

1. **Scale programs with current economics** -> While distribution value is being proven out, it's critical to cost effectively drive customers into programs
   a. Efficient channels allow bulk system and customer value to be cost effective
   b. Leveraging grant dollars and stacking programs allow for quicker scale
2. **More EVs with managed charging means faster distribution value learnings and benefits**
   a. Distribution impact and opportunities are realized with multiple EVs overlapping on a single residential transformer
3. **Current barriers causing higher acquisition costs**
   a. Customers cannot dual enroll (i.e Ava vs PG&E program), even though the same vehicles could provide value at the system and distribution level
   b. Single vendor lock-in is preventing cost-effective channels from being used
   c. Incentives are not enough, customers want more functionality and more seamless enrollment

How to lower acquisition costs for scale

optiwatt

When moving from pilot to program, utilities need to maximize reach and customer value

1. **Open up all channels** → Third-party apps, OEM apps, Aggregators, Smart Home apps, Rewards Platforms
2. **Provide customer value beyond financial incentives (rebates)**
   a. EVs are part of a broader ecosystem, multi-device enrollment lowers $/kW acquired (we see 33% cost reduction, ⅓ Optiwatt customers add a smart thermostat)
   b. Offering cost insights, automated savings (TOU compliance), and rate tool recommendations make incentive dollars go further
3. **Allow multiple participation types**
   a. Newer EV models can participate through telematics
   b. Older EV models, more common in LMI districts, eligible through EVSE or behavioral control
4. **Streamline Enrollment and Validation Experience** → 40% lower conversion rates without account number validation requirements
5. **Make enrollment simple, don't lock anyone out, provide equal access and customer choice**

Break — we will resume at 2:57 pm PT

V2X Standards & Technology

- ZACH WOOGEN, EXECUTIVE DIRECTOR – VGIC
- JOSE ALIAGA-CARO, UTILITIES ENGINEER, ENERGY DIVISION – INTERCONNECTION AND DISTRIBUTION ENGINEERING – CPUC
- JOHN HOLMES, SUSTAINABILITY BUSINESS DEVELOPMENT, AMERICAN HONDA MOTOR COMPANY, INC. – HONDA
- ARI NAGGAR, MANAGER, RESIDENTIAL ENERGY PRODUCTS - TESLA
- SCOTT PICCO, PRINCIPAL ENGINEER, DISTRIBUTED ENERGY RESOURCES, EV POWER EXPORT, AND POWER CONTROL SYSTEMS – UL SOLUTIONS
- TIM ZGONENA, PRINCIPAL ENGINEER, ENERGY AND INDUSTRIAL AUTOMATION – UL SOLUTIONS

Vehicle-Grid Integration Forum: Interconnection and Distribution Engineering, Energy Division

Jose Aliaga-Caro

Utilities Engineer

April 16, 2024

Contact: Jose.Aliaga-Caro@cpuc.ca.gov

California Public Utilities Commission

V2G DC Interconnection (Ix): Where we are now

(1) <u>Unidirectional Mode</u> – Allowed

- Applicant must use an inverter/EVSE that meets certification requirements pursuant to Rule 21
- Switching to Bidirectional Mode: Upon request from the applicant, only the manufacturer or approved third-party installer may program or enable bidirectional operation.
- For details see: *Advice Letter 6500-E (Pacific Gas and Electric Company ID U 39 E), Advice Letter 3955-E (San Diego Gas & Electric Company ID U 902 E), Advice Letter 4718-E (Southern California Edison Company ID U 338 E)* dated February 11, 2022, submitted in response to Res. E-5165

(2) <u>Bidirectional Mode</u> – Allowed

- OP 39 of D.20-09-035 allows V2G DC bidirectional systems to use the existing Rule 21 interconnection process. (*See* Resolution E-5165, issued Nov. 4, 2021, disposing of SDG&E AL 3774-E, SCE AL 4510-E, and PG&E 6209-E and D.20-09-035 which states that Vehicle-to-grid (V2G) direct current (DC) EVSE may be interconnected under the existing Rule 21 tariff so long as it meets all Rule 21 requirements)
- An exemption for UL 1741 Supplement SA and SB certification exists for DC V2G Electric Vehicle Supply Equipment (EVSE) interconnecting for the purpose of participating in the Emergency Load Reduction Program

V2G AC IX: Where we are now

Only through the V2G AC Interconnection Pilot

- V2G AC Interconnection Pilot Allows:
  - Use of relays programmed with the applicable voltage and frequency settings, as required in Rule 21 Section H and other applicable settings, such as underpower and overcurrent, as may be specified in each Utility's Interconnection Handbook
  - Bilateral agreements between utilities and applicants
- See *Advice Letter 6500-E (Pacific Gas and Electric Company ID U 39 E), Advice Letter 3955-E (San Diego Gas & Electric Company ID U 902 E), Advice Letter 4718-E (Southern California Edison Company ID U 338 E)* dated February 11, 2022, submitted in response to Res. E-5165

V2G AC Interconnection: Going Forward

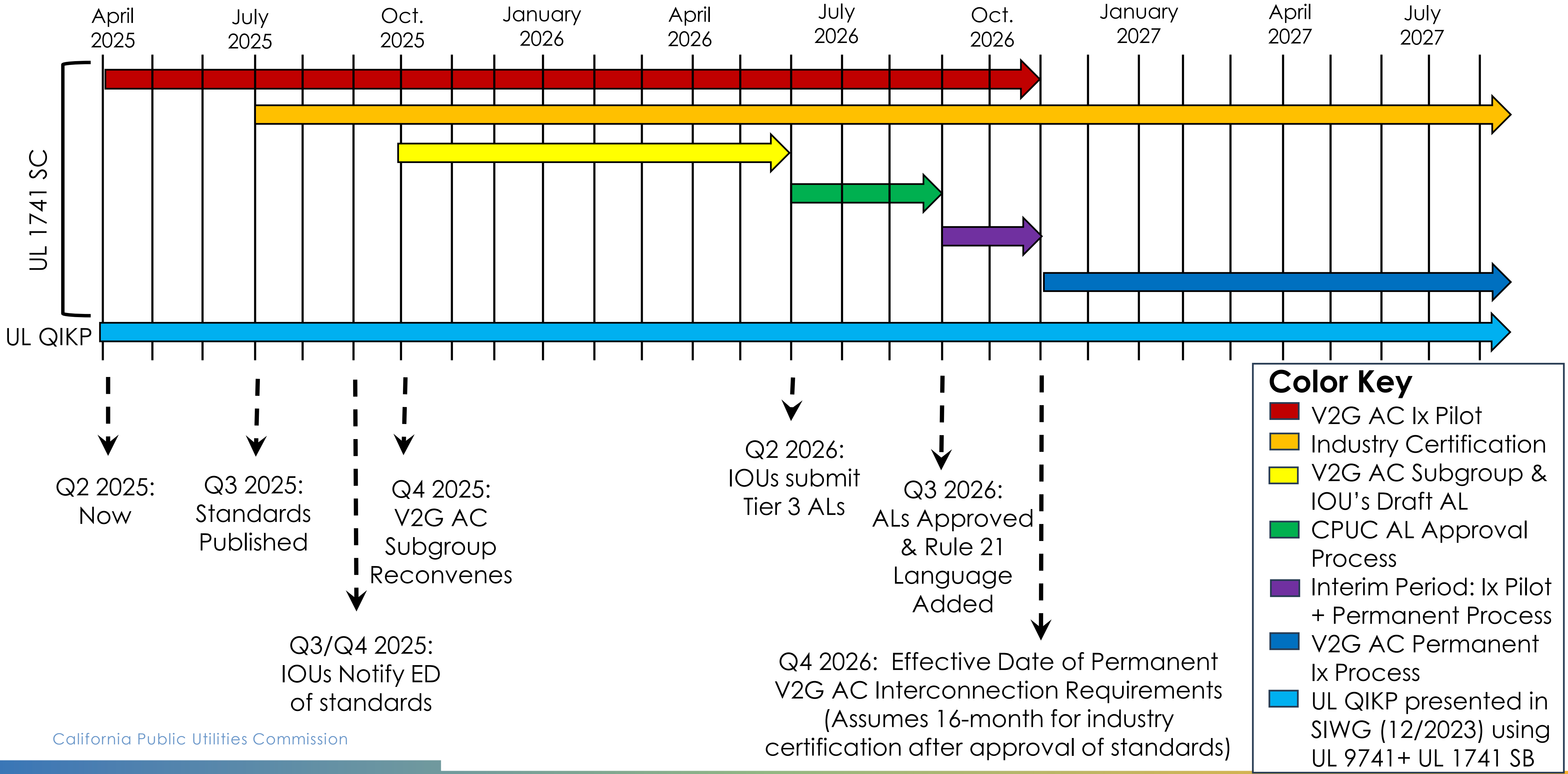
- **Resolution E-5315 (August 2024)**
  - (1) Reopens V2G AC Interconnection Pilot which ended December 2023 and extends it until tariff modifications or a permanent interconnection process for V2G AC systems are approved and added to, and become effective in, Rule 21. (2) Allows bilateral agreements for V2G AC systems interconnection
    - Avoids gaps in the interconnection process between the end of the V2G AC Interconnection Pilot and the time a permanent interconnection process for V2G AC systems is added to, and becomes effective in, Rule 21.
    - "become effective" -- allows time for V2G AC systems to be certified to industry standards in the event modifications to Rule 21 occur prior to industry being standards properly certified to those standards
- **D.20-09-035 (September 2020):** "When [industry] standards have been approved, Utilities shall inform the Director of the Energy Division, who is authorized to reconvene the Vehicle to Grid Alternating Current Subgroup no later than 90 days from the issuance of approved updated standards."
- **V2G AC Subgroup Objectives**
  - To review and assess the ability of approved industry standards to ensure safe interconnection of V2G AC systems,
  - (1) **If approved industry standards are sufficien**t for safe interconnection, to develop Rule 21 language to interconnect V2G AC systems outside of pilots. (2) **If approved industry standards are not sufficient**, identify the gaps to ensure a future pathway to safe interconnection and propose a method for interconnection on an interim basis until standards are sufficient for safe interconnection.
  - No later than sixty (60) days after completion of the discussions with the V2G AC Subgroup, and no later than eight months after the start of the subgroup the Large IOUs are directed to file Tier 3 ALs recommending: (1) Termination of the V2G AC Interconnection Pilot; and (2) Modifications to Rule 21 to incorporate language to allow V2G AC systems to interconnect if approved industry standards are sufficient for safe interconnection and if not sufficient, an a process for the interconnection of V2G AC systems on an interim basis until standards are sufficient for safe interconnection.

Industry Standards: PG&E, SCE and SDG&E Update on March 26, 2025

1. ***UL 1741 SC – Standard for Interconnection System Equipment (ISE)/EVSE***
    - The Working Group is planning to send the draft to the UL Technical Committee in April 2025, with an expected publication of early Q3 2025.
2. ***SunSpec J3072-2030.5 SunSpec profile standard and certification***
    - Per SunSpec profile leads, SunSpec will convene the J3072-2030.5 SunSpec profile standard work group in April 2025, coincident with the starting of the IEEE 2030.5/CSIP test procedures update. The expected publication date is Q3 2025.
3. ***SAE J3072- V2G-AC EV standard (equivalent to 1547-2018 and UL 1741 SB)***
    - A revised version of SAE J3072 was published June 10, 2024. As such, no further update will be provided.

V2G AC Interconnection: Path Forward

Timelines are approximate and conservative



EVSE Interconnection: Relevant Documents

- Working Group Three Final Report (June 14, 2019)
  - Discussed Issue 23: Should the Commission consider issues related to the interconnection of electric vehicles and related charging infrastructure and devices and, if so, how?
- Final Report of the Vehicle to Grid Alternating Current Interconnection Subgroup (Dec. 11, 2019)
- Decision 20-09-035: Decision Adopting Recommendations from Working Groups Two, Three, and Subgroup (Sept. 30, 2020): Adopted Issue 23 proposals that had consensus
  - Decision D2101027 - Order Correcting Errors in Decision 20-09-035
- **PG&E AL 6209-E, SCE AL 4510-E and SDG&E AL 3774-E (May 28, 2021)***
  - Presents (1) the implementation plan which allows V2G DC EVSE that has connected as load-only to switch to bidirectional mode upon receiving PTO from the utility, and (2) proposed temporary pathway for V2G AC EVSE interconnection (V2G AC Interconnection Pilot)
- Resolution E-5165 **(November 5, 2021):** Approval, with Modifications, of Vehicle-to-Grid Implementation Plans and Technical Requirements in Compliance with Decision 20-09-035
- PG&E AL 6500-E, SCE AL 4718-E and SDG&E AL 3955-E (Feb. 11, 2022)
  - Submitted to incorporate Resolution E-5165's modifications on the V2G AC Interconnection Pilot
- **PG&E AL 7125-E, SCE AL 5185-E and SDG&E AL 4350-E (January 5, 2024)***
  - Recommends (1) extending the V2G AC Interconnection Pilot with the same requirements for an additional two years, and (2) further study of V2G AC interconnection pathways
- Resolution E-5315 **(August 22, 2024):** Approves with modifications reopening and extension of the V2G AC Interconnection Pilot

*Advice Letters can be found on the utilities' websites

California Public Utilities Commission

For additional information on EVSE Interconnection contact:

Jose.Aliaga-Caro@cpuc.ca.gov

V2X Standards and Technology

April 16, 2025

VGIC MEMBERS / 2025

LEADERSHIP CIRCLE

Fermata Energy
Ford
gm
HONDA
NISSAN GROUP OF NORTH AMERICA

GENERAL MEMBERS

BIDIRECTIONAL ENERGY
BORGWARNER
ChargeScape
dcbel
EATON Powering Business Worldwide
emporia
EnergyHub
ev.energy
GridBeyond
GRAVITY
Gridwiz
HYUNDAI CRADLE
Innovation Core SEI
KALUZA
Landis Gyr+
LG Innotek
ORANGE
STELLANTIS
sunrun
TESLA
THE MOBILITY HOUSE
TOYOTA
WeaveGrid

ASSOCIATE MEMBERS

CPA CLEAN POWER ALLIANCE
HOLY CROSS ENERGY ESTABLISHED 1939
LA DWP Los Angeles Department of Water & Power
SMUD

Why bidirectional charging now?

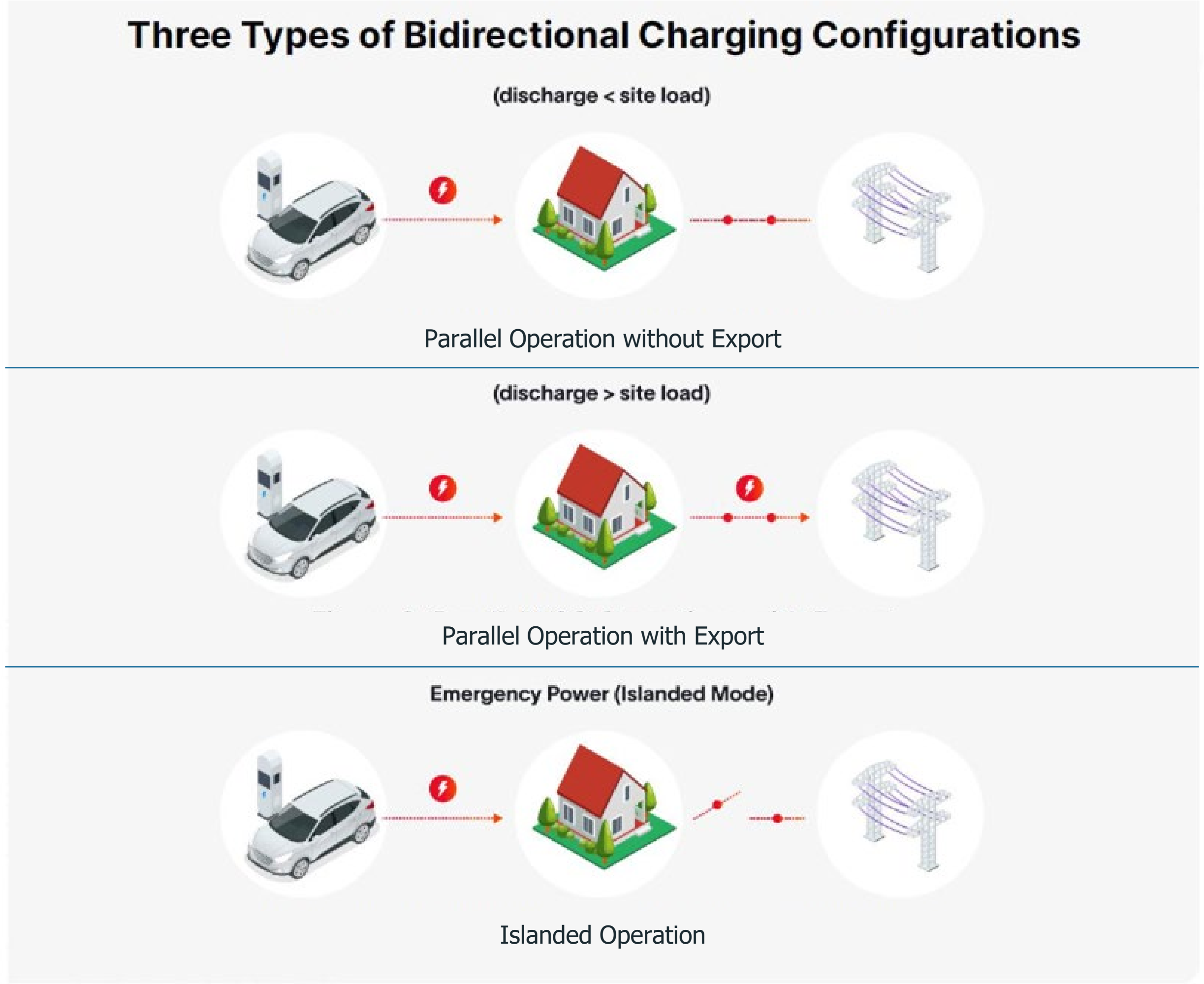
- Reduce net peak load
- Defer and avoid costly infrastructure upgrades
- Offset customer costs of state-mandated transportation electrification

Modeled 2030 Ratepayer Benefits

	Medium EV Forecast	High EV Forecast
Million EVs in 2030	3.3	5
percent V2G-enabled	50%	50%
$ million annual ratepayer benefit	$671	$1,018

Source: CEC-500-2019-027

Three types of bidirectional charging configurations



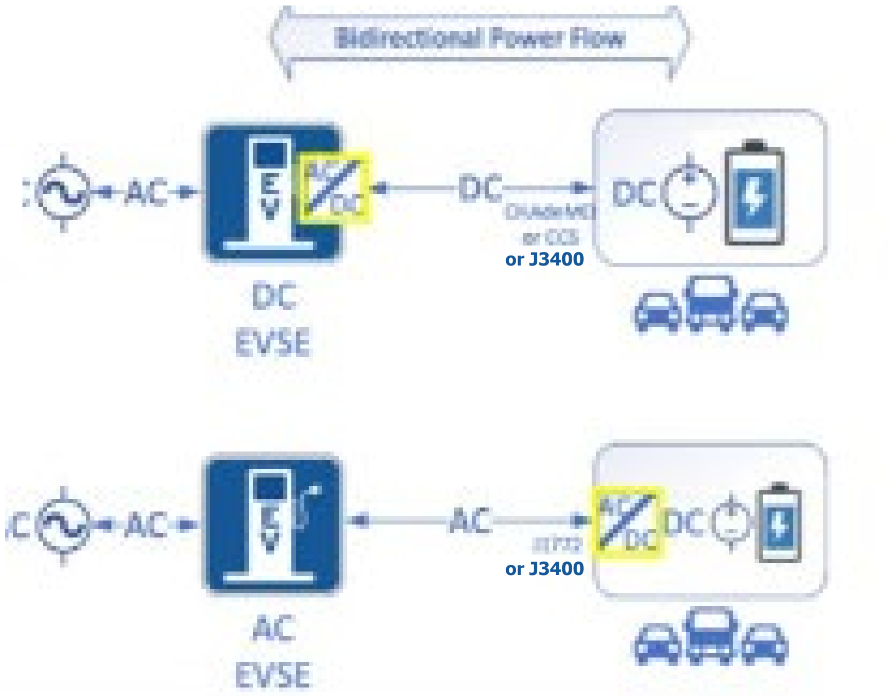
Adapted from Fermata Energy Presentation to Michigan Public Service Commission

Bidirectional charging systems 101

- Bidirectional charging systems are capable of discharging from the EV battery to serve a customer's onsite load or export to the grid
- There are two main types bidirectional power flow systems:

V2X DC:
(Stationary inverter offboard vehicle)

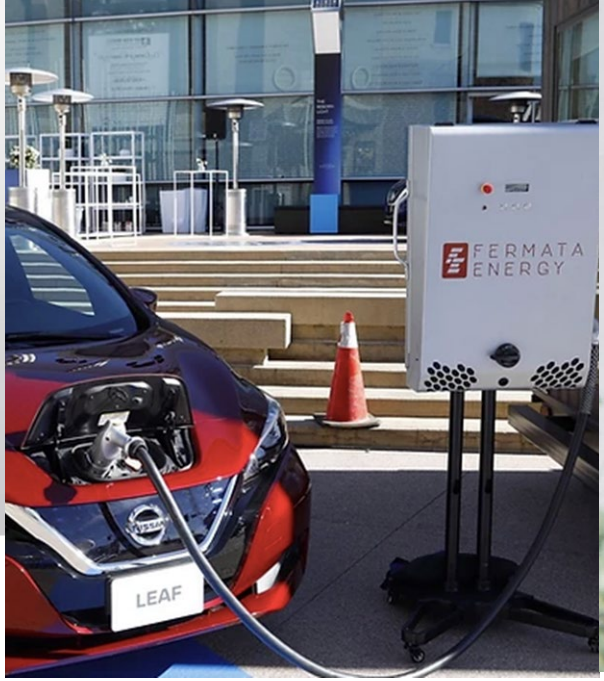
V2X AC:
(Inverter functions onboard vehicle)

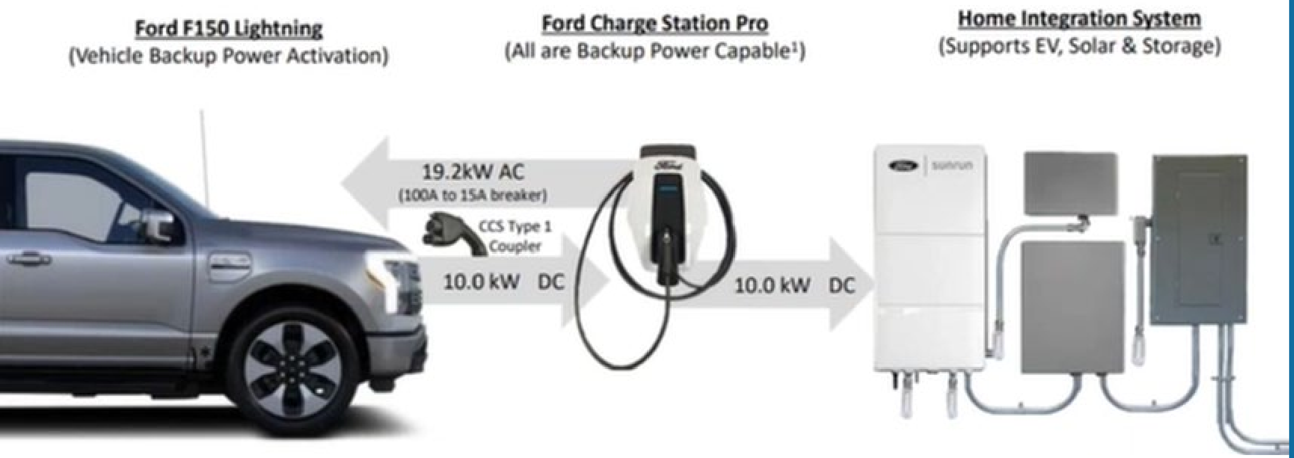


Adapted from Nuvve presentation to California Public Utilities Commission

The Essentials

GM Energy V2H Bundle





Most of today's light-duty and medium/heavy-duty equipment capable of bidirectional charging use the DC configuration (i.e., stationary inverter offboard vehicle)

Detailed Technology Availability: Existing Bidirectional LDV + EVSE

Vehicle	Charger	Charge/ Discharge	Key V2G EVSE Certifications	Rule 21 Interconnection	Price
Nissan LEAF	Fermata FE-20	20 kW / 20 kW	Integrated inverter – UL 1741 SA	**Permitted *if* participating in ELRP, SCE DRP 2.0, PG&E V2X Pilots, or PG&E Hourly Flex Pricing Pilot**	Unknown
Ford F-150 Lightning Electric	Ford Charge Station Pro	19.2 kW / 9.6 kW	Standalone inverter – UL 1741 SB	**Permitted**	EVSE: $1,310 V2X Kit: $3,895
Chevrolet Silverado EV	GM Energy PowerShift	19.2 kW / 9.6 kW	Standalone inverter – UL 1741 SB	**Permitted**	EVSE: $1,699 V2X Kit: $5,100
Chevrolet Blazer EV					
Chevrolet Equinox EV					
Cadillac Lyriq					
GMC Sierra EV					
Tesla Cybertruck	Tesla Universal Wall Connector	11.5 kW / 11.5 kW	None	**Eligible for Resolution E-5315 pilot pathway**	EVSE + V2X Kit Bundle: $2,500

Detailed Technology Availability: Anticipated Bidirectional LDV + EVSE

Vehicle	Charger	Charge/ Discharge	Key V2G EVSE Certifications	Rule 21 Interconnection	Price
Kia EV9	Wallbox Quasar 2	11.5 kW	Integrated inverter – UL 1741 SB	**Permitted**	Unknown
Volvo EX90	dcbel Ara	15.2 kW	Integrated inverter – UL 1741 SB	**Permitted**	Unknown
Cadillac Escalade	GM Energy PowerShift	19.2 kW / 9.6 kW	Standalone inverter – UL 1741 SB	**Permitted**	EVSE: $1,699 V2X Kit: $5,100
Cadillac Optiq					
Lucid Air	Lucid Connected Home Charging Station	20 kW / 10 kW	None	**Eligible for Resolution E-5315 pilot pathway**	EVSE: $1,200 V2X Kit: unknown

Additional product announcements: VW, Hyundai, Polestar, BMW, Mercedes-Benz, Stellantis, Rivian, Emporia, SolarEdge, Enphase, Autel, ChargePoint, and others

Detailed Technology Availability: Existing Bidirectional MHDV + EVSE

Electric School Bus Manufacturers	Battery Capacity
BlueBird	155 kWh or 196 kWh
Lion Electric	126 kWh, 140 kWh, 168 kWh, or 210 kWh
BYD	156 kWh, 230 kWh, or 288 kWh
Thomas Built	246 kWh
IC Bus	210 kWh or 315 kWh
Green Power Motors	118 kWh or 193 kWh
Phoenix Motorcars	100 kWh or 150 kWh

Electric school buses *must* be bidirectional-capable to receive CARB HVIP or ZESBI vouchers

Charger	Charge/ Discharge	Key V2G EVSE Certifications	Rule 21 Interconnection	Price
Tellus Power Green / ChargeTronix	20, 30, 40, or 60 kW	Integrated inverter – UL 1741 SA	Permitted if participating in ELRP, SCE DRP 2.0, PG&E V2X Pilots, or PG&E Hourly Flex Pricing	Unknown
InCharge	22, 44, 66 kW	Integrated inverter – UL 1741 SB	Permitted	Unknown
Heliox / Siemens	60 kW	Integrated inverter – UL 1741 SB	Permitted	Unknown

Key V2X Standards and Technology-Related Barriers

Key barriers, including those referenced in D.20-12-029 and R.23-12-008 Scoping Memo	Status	Detailed Outcomes
High upfront costs of bidirectional charging systems relative to unidirectional charging systems	Outstanding	Higher CEC incentives for bidirectional chargers at school bus sites through $125M zero-emission school bus and infrastructure program (ZESBI)
		CEC REDWDS supports several bidirectional charging projects
$800 interconnection application fee	Outstanding	Phase II Scoping Ruling in R.17-07-007 includes non-NEM application fee, but proceeding has since closed. New R21 proceeding has not yet opened.
Need to streamline interconnection for bidirectional charging systems	In progress	D.20-09-035 clarifies V2G DC EVSE is a type of energy storage system for purposes of Rule 21 interconnection
		Resolution E-5315 extends V2G AC pilot interconnection pathway and expands accepted interconnection options
Lack of utility reporting on V2G interconnection timelines	In progress	D.20-09-035 directs utilities to publish quarterly reporting on Rule 21 interconnection applications. Only PG&E's quarterly reports include a technology category for EVSE/EV.

Key V2X Market and Regulatory Barriers: Compensation

- "Open access" opportunities:
  - **Critical gap:** EV-specific utility rates and rate pilots
    - Static EV/whole-premise TOU rates – **non-export only**
    - SDG&E dynamic commercial EV export pilot – **only compensates for avoided gen energy and gen cap; charging/imports assessed under static TOU rate**
  - **At risk:** EV demand response / event-based VPP
    - DSGS Option 3 – **limited funding available**
    - ELRP A.3, A.5, B – **authorized through 2027**
- Contracted opportunities:
  - Rates:
    - Near-Term PG&E V2X/CalFUSE rate pilot – **limited volatility of dynamic rate; must be approved and contracted ASP**
  - Programs:
    - Utility EPIC-funded pilots
    - CEC EPIC- or CTP-funded pilots

Thank you!

Vehicle-Grid Integration Council (VGIC) is a national 501(c)(6) membership-based trade association committed to advancing the role of flexible electric vehicle charging and discharging through policy development, education, outreach, and research.

VGIC
VEHICLE GRID INTEGRATION COUNCIL
vgicouncil.org

UL 9741: EV Power Export (EVPE)

Overview of Bidirectional, EV Charging and EV Power Export Requirements

Safety. Science. Transformation.™

List of existing EV charging UL Standards

- **UL 2202**, the Standard for Electric Vehicle (EV) Charging System Equipment
- **UL 2594**, the Standard for Electric Vehicle Supply Equipment
- **UL 2251**, the Standard for Plugs, Receptacles, and Couplers for Electric Vehicles
- **UL 2231**, the Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits
- **UL 2750**, Outline of Investigation for Wireless Power Transfer Equipment for Electric Vehicles

UL 9741 Certification Scope

UL 9741

STANDARD FOR SAFETY

Electric Vehicle Power Export Equipment (EVPE)

- **UL 9741** – Offboard Bidirectional Electric Vehicle (EV) Charging System Equipment
- Usually utilized with DC EVPE applications but not restricted to DC
- One piece of equipment that performs both functions of a UL 1741 Grid Support Inverter and an EV charger.
- Includes power conversion equipment evaluated to 1741 SA or SB via UL 9741 references for grid interconnection / support.
- Addresses specific local grid codes so the EV's compliance with local grid codes is covered by the external, offboard UL 9741 certified device|
- UL 9741 bidirectional charger products can provide a compliance "gatekeeper" for EVs that have not been evaluated by a NRTL for current local grid codes.
- 9741 also covers all other EVPE products V2X, V2H, V2L, V2V, V2etc. (excluding UL 1741 SC)

UL 9741 – Past and Present

Past:

- March 18, 2014: UL 9741, Outline of Investigation for Electric Vehicle Power Export Equipment (EVPE) published
- New Outline of Investigation combined the applicable EV and DER standards
- UL 9741 OOI covered bi-directional (V2G) EV charging equipment to evaluate EVPE to the utility grid or other electric power systems
- UL 9741 OOI required UL 1741 testing / evaluation for grid interconnection compliance as rated by manufacturer (SA, SB, Special purpose, and/or IEEE 1547.1-2005)
- UL 9741, issue No. 2 of OOI published in 2021 to address all EV power export and V2X applications
- The UL 9741, issue No. 2 OOI is still being used to evaluate/certify these products up to the effective date of the new consensus-based standard (effective date of Mid 2027)

Present:

- UL 9741 reached consensus and was published on 9/28/2023 as a bi-national standard UL 9741/CSA 348 for publication in the U.S. and Canada
- Accommodates new technology, codes, and electric utility requirements
- Certifications are progressing via the new standard as we approach the effective date

Scope of UL 9741 includes many options

UL 9741 has variety of allowed configurations (A-L) within its scope. Below are allowed configurations that align with common implementations:

Overall description of allowed configurations	Equipment Supplied by	Equipment Provides Power to
(B) - Stand alone piece of equipment provided with optional voltage conditioning equipment	AC power from EV*	AC power to AC receptacles for connection of AC external loads
(E) - Inverter based device that is permanently connected to the premise (permanently installed)	DC power from EV	AC power interconnected with the premise wiring systems through a transfer switch
(G) - Inverter based equipment that is permanently connected to the premise wiring system. Device also is capable of import only mode (**no export**) via PCS control	DC power from the EV	AC power permanently connected to the premise wiring system; grid interconnected but **prevented** from export to the utility via Power Control System (PCS) control
(I) – Inverter based equipment capable of utility interaction **with export**. Permanently connected to the premise wiring system. **Not able** to provide off-grid (islanded) functionality when the grid is down.	DC power from EV	AC power permanently connected to the premise wiring system; grid interconnected but **not capable** of islanded operation
(K) – Inverter based equipment capable of utility interaction **with export**. Permanently connected to the premise wiring system. **Capable** of providing off-grid (islanded) functionality when the grid is down.	DC power from EV	AC power permanently connected to the premise wiring system; grid interconnected **and capable** of islanded operation

V2L application

V2G DC application with PCS enabled no export

V2G DC application

DC V2H – backup power only application

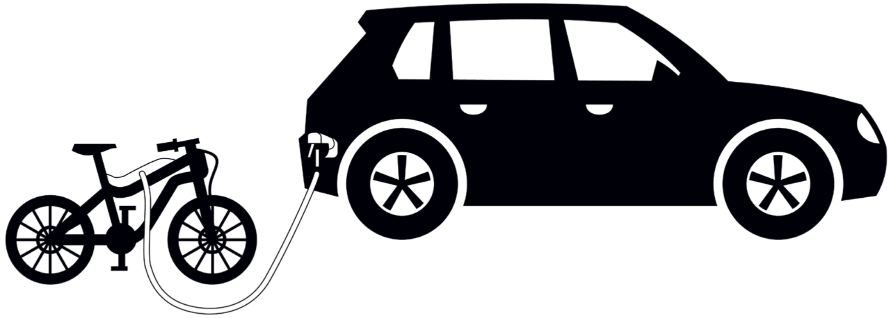
V2G & V2H DC with backup power option

UL Solutions

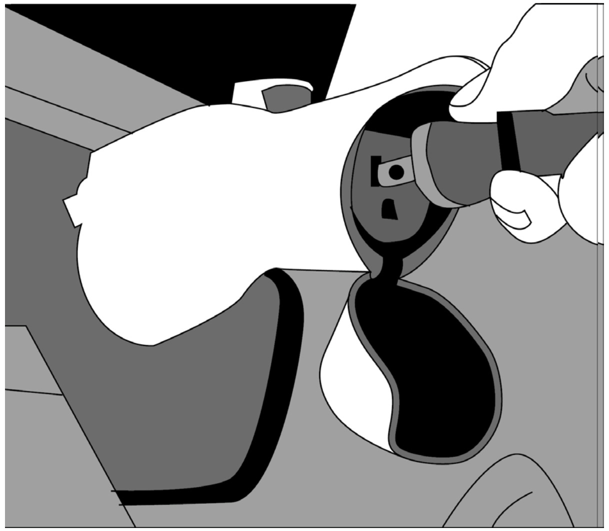
V2L examples and requirements

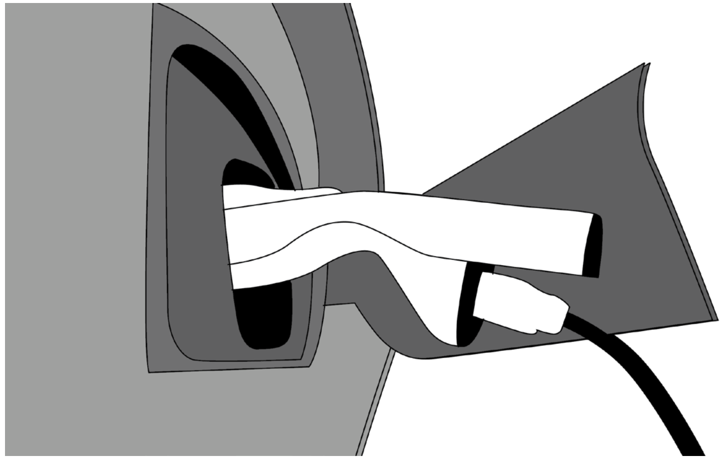
- Require ground fault protection for earthed loads/products. Class A, GFCI per UL 943.
- Require overcurrent protection to ensure an overload and/or fault condition in the connected loads can be safely mitigated
- Require harmonic distortion (V_{THD}) to be limited (<30%) to avoid damage/heating to connected loads

V2L adapter for EVPE: Power output for electric bike



V2L adapter for EVPE: generic power output for cord connected loads

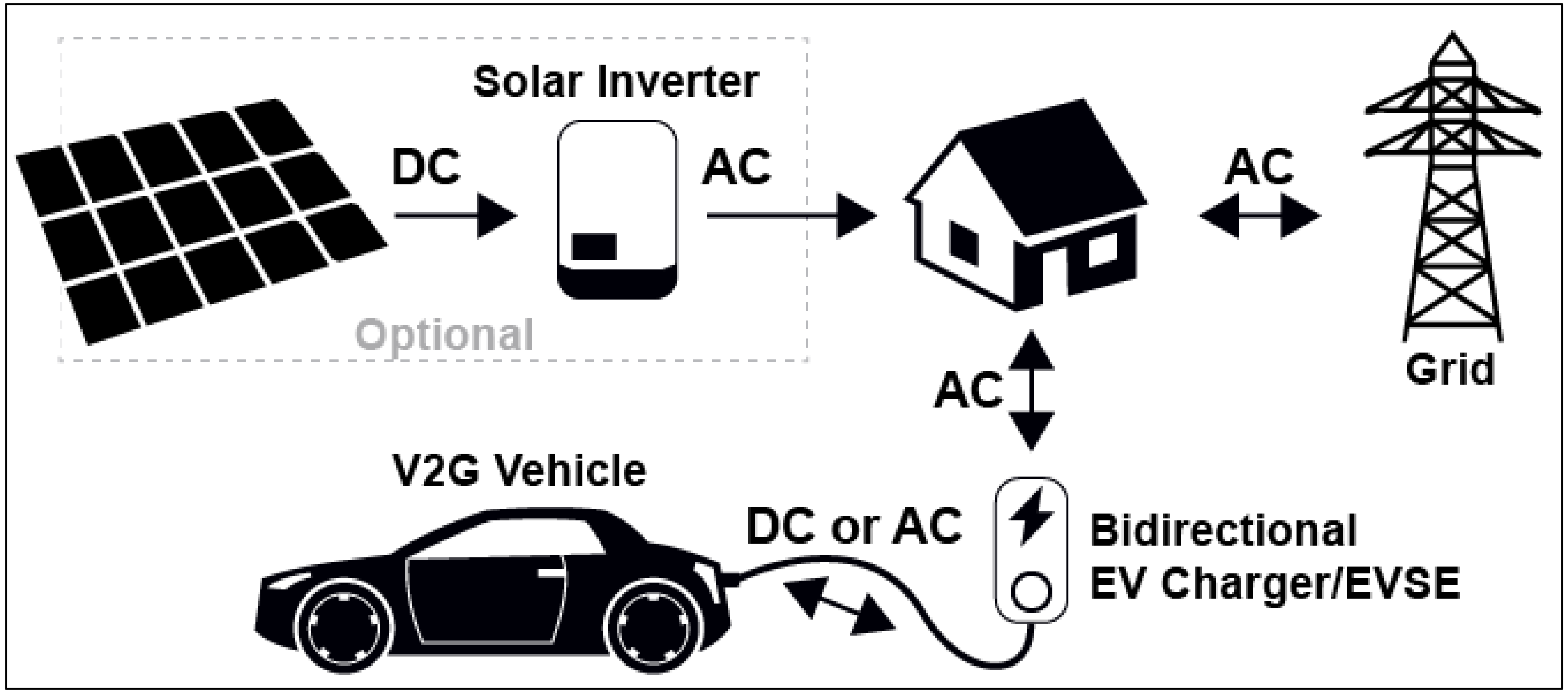




V2G functionality:
graphical overview

- V2G EVs act as an ESS in discharge mode or as a load in charging mode.
- V2G EVs may export via an onboard converter exporting AC power or bypass the onboard converter and export DC power.
- If the system is equipped only with V2G functionality, the system can only function when the grid is present.

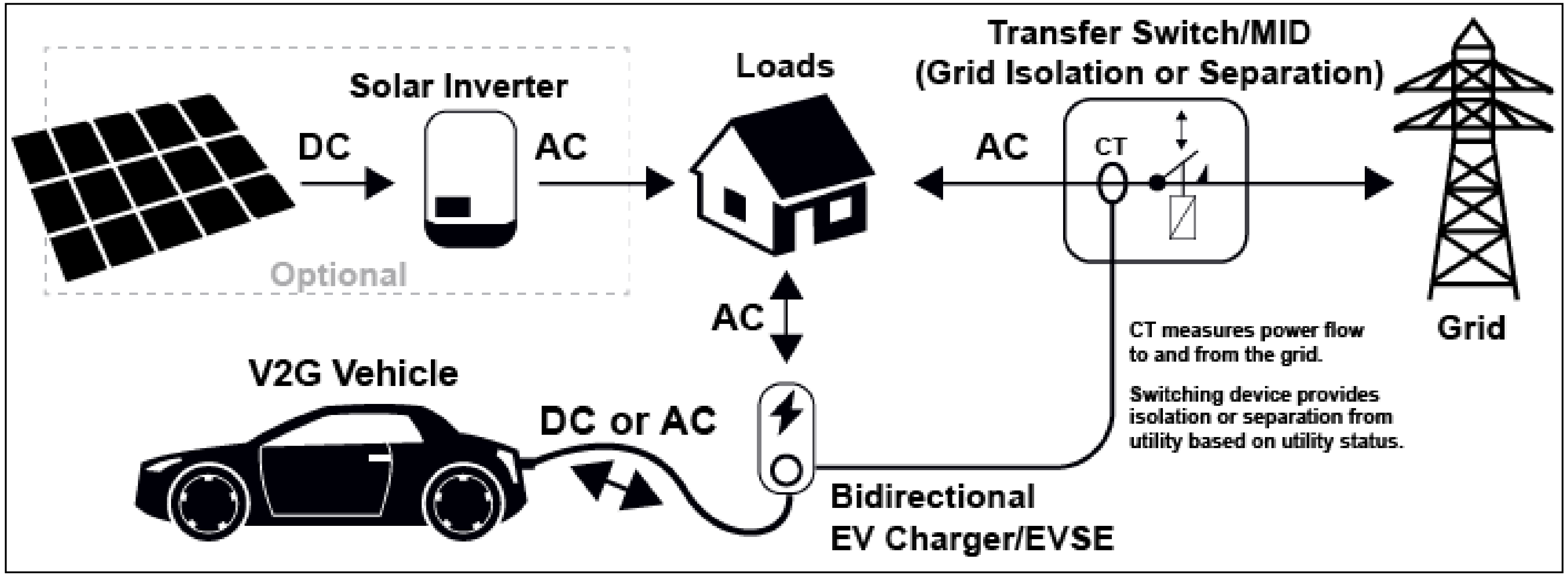
Vehicle to Grid (V2G) system



- EVSE may contain power conversion circuitry (e.g., an inverter with grid interconnection functions) receiving DC power from the V2G EV in discharge mode or the EVSE may have no power conversion circuitry and only act as a pass through/switching/communication device (usually in the case of AC power output from the V2G EV).
- V2G systems may or may not have other power sources (e.g., solar, stationary ESS, etc.) interconnected with the grid at the point of common coupling (PCC) as well as with one another.

V2H functionality: graphical overview

Vehicle to Home (V2H) system



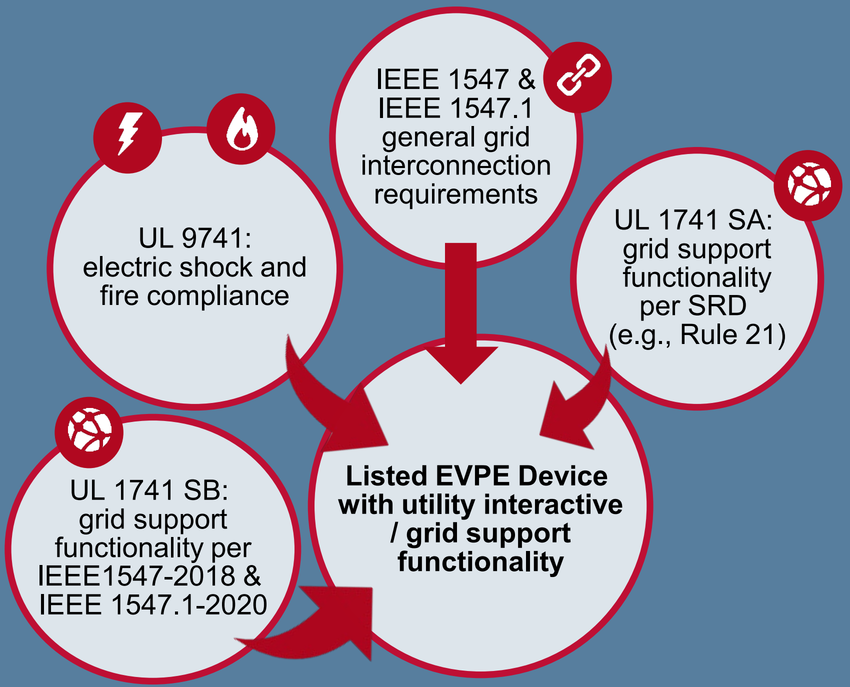
<u>V2H systems usually contain all the attributes of a V2G system with additional functionality and attributes noted below:</u>

- V2H systems can operate in parallel with the grid (V2G mode) or independent of the grid (V2H mode) via presence of a transfer switch/MID.
- Some V2H systems may only operate when the grid is down (backup power mode)
- When the system is paralleled with the grid, the transfer switch/MID is closed. The system follows the grid voltage and frequency (current source).
- When the system is independent of the grid (islanded), the transfer switch/MID is open. The sources (EV, solar, etc.) regulate/create the voltage and frequency of the system.

Need to Differentiate Utility Interactive Products

Applies to all UL 9741 Products capable of grid interconnection / support

- **UL Certification:** Grid Support, Utility Interactive Product via references within UL 9741
- **Scope:** Safety & Electric Shock Certification to UL1741 including UL 1741 SB or SA for grid support and general grid interconnection per IEEE 1547



Includes Testing to Verify:

1. UL 9741 electric shock/fire tests and:

   A. Unique tests of IEEE 1547 for general grid interconnection not covered by UL 1741 SA tests and UL 1741SA grid support tests and/or,

   B. UL 1741SB grid support per IEEE1547-2018 and IEEE 1547.1-2020

Deliverable: UL Certification as a Grid Support Interactive product via UL 9741 Certification of the EVPE Device / Product

DER safety standards and relationship to utility interconnection standards

A variety of DER safety standards refer to UL 1741 for utility-interactive requirements

EVPE
UL 9741
(offboard EVPE)

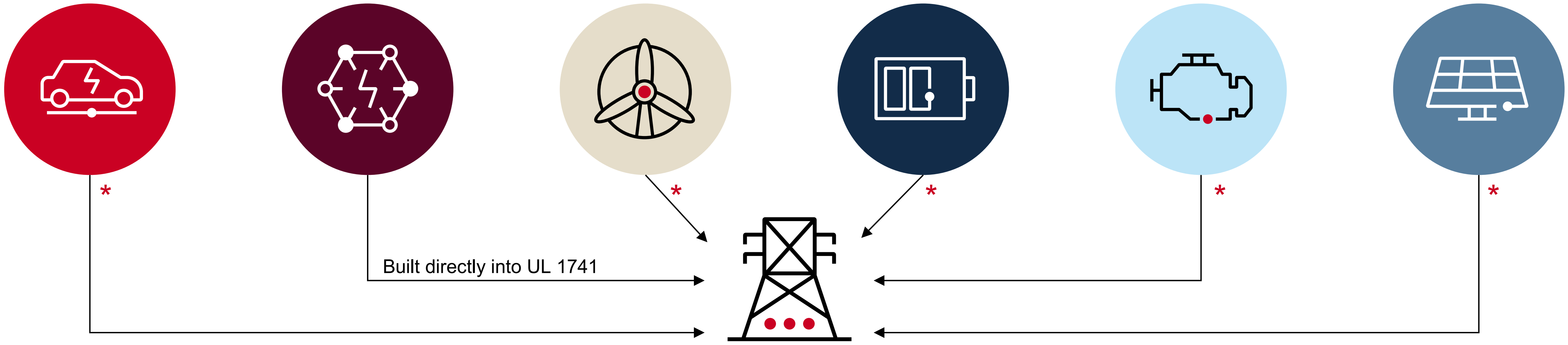
INVERTERS AND CONVERTERS FOR GRID INTERACTION AND SUPPORT
UL 1741

WIND CONVERTERS
UL 6142

ENERGY STORAGE SYSTEMS
UL 9540; UL 9540A
(battery fire safety)
UL 2262
(fuel cell modules)

ENGINE GENERATORS AND CONTROLS
UL 2200 (generators)
UL 6200 (controls)

MICROGRIDS AND SINGLE-SITE ENERGY SYSTEMS
UL 3001 (microgrids)
UL 3010 (single-site energy systems)



*QIKP for grid interconnection performance certification

Appendix: List of Standards

UTILITY INTERCONNECTION STANDARDS

UL 1741 SB – IEEE 1547 (2018), IEEE 1547.1 (2020)

UL 1741 SA – Configured with an SRD, e.g. Rule 21, 14H, etc.

UL 1741, Section 40 – IEEE 1547 and 1547.1 (earlier editions)

Note: QIKP for grid interconnection performance certification may or may not be linked to a base safety certification of a DER product type. QIKP certification will indicate linkage if applicable.

UL Solutions

UL 1741SC

V2G AC certification option for non-NRTL-certified EVs/OBC using NRTL-certified oversight devices (ISEs)

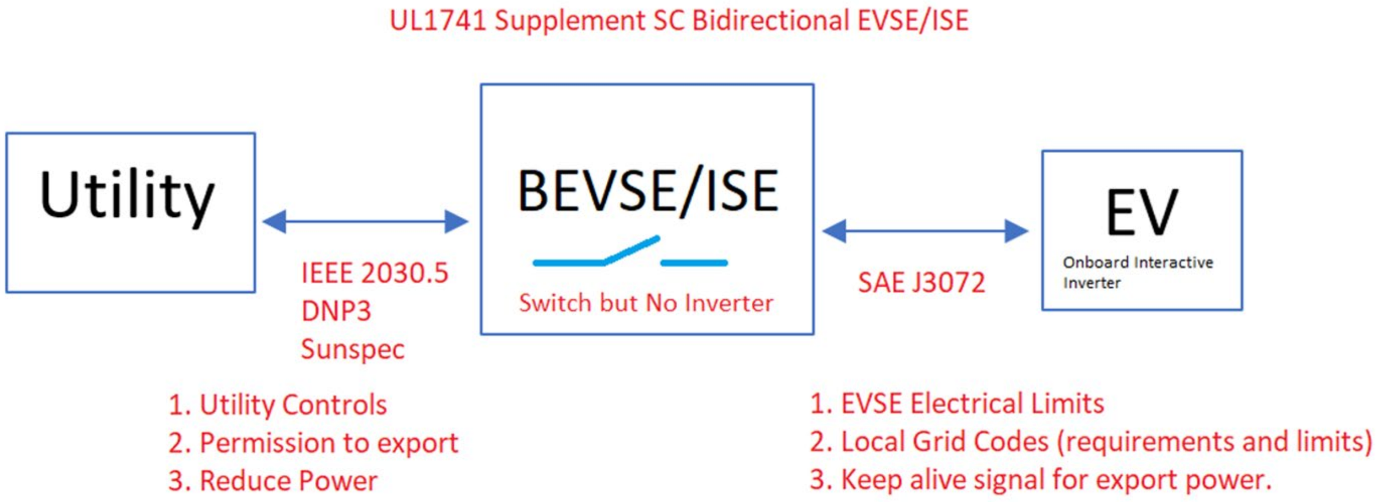
UL 1741 Supplement SC: BEVSE/ISE for EV AC V2G applications

Develop new UL 1741 Supplement SC for BEVSE/ISE to:

- Clearly define the requirements and compliance criteria for non-NRTL-certified EVs capable of V2G AC EVPE
- Interact/communicate with EVs via SAE J3072
- Monitor EV V2G grid interactions in accordance with local interconnection requirements via presence of UL 1741 SC-certified ISE device
- Cease EV grid export via ISE intervention if the EV:
  - Creates a hazardous overvoltage condition
  - Does not comply with electric utility requirements
  - **Note** – EV charging protective functions are required to be provided within the system.

The UL 1741 Task Group is developing the draft of Supplement SC.

Estimated publication: end Q3-Q4 2025

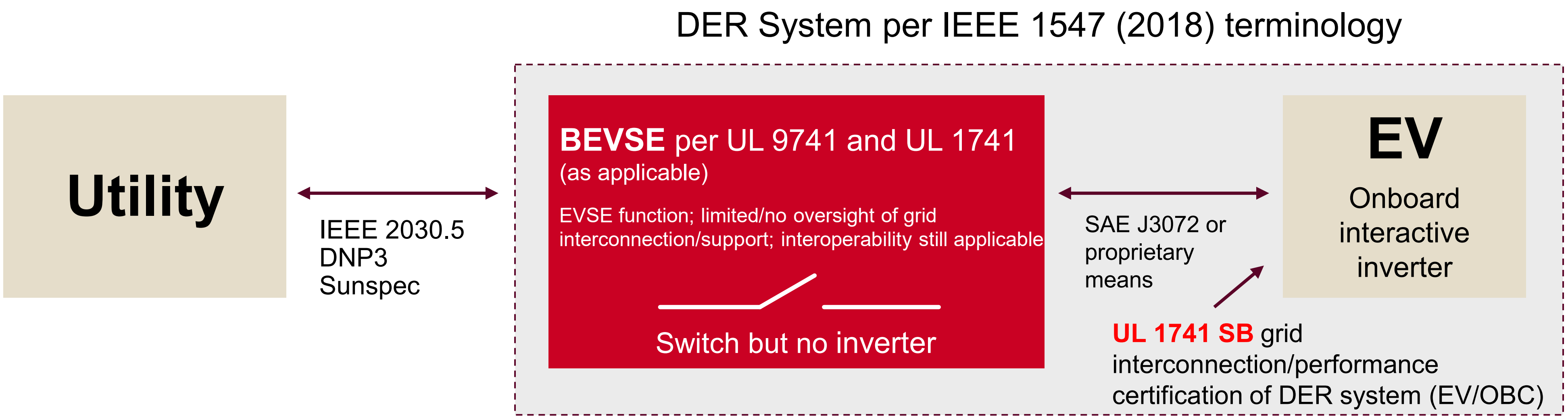


UL 1741 QIKP

V2G AC certification option for EVs/OBC certified for grid interconnection/support performance by UL Solutions

New alternative V2G AC option:

UL 1741 grid interconnection performance certification via UL 1741 SB



Nationally Recognized Testing Laboratory (NRTL)

Electric vehicle power export (EVPE)

Interconnection systems equipment (ISE)

Onboard charger (OBC)

Bidirectional electrical vehicle supply equipment (BEVSE)

- UL 1741 QIKP grid interconnection/performance certification of EV/OBC via UL 1741 SB requirements
- Fire/shock safety evaluation and testing of EV/OBC out of scope
- UL 9741 and UL 1741 (as applicable) safety certification of offboard equipment
- Consists of a performance certification addressing grid interconnection/support functionality of the DER system independent of the fire/shock safety aspects onboard the EV
- Software present in EV's OBC during testing documented and controlled under certification
- May be best suited for specific installation sites, with specific EVs and BEVSE
- Roaming EV application (with multiple BEVSE locations) likely out of scope
- UL drafting a certification requirement decision (CRD) to add clear definitions and requirements for how to test DER systems in accordance with UL 1741 SB

Solutions

UL Solutions

Thank you

Scott Picco: Principal Engineer - EV Power Export Equipment

UL.com/Solutions

Safety. Science. Transformation.™

HONDA
The Power of Dreams

VGI Forum
V2X Standards & Technology

California Public Utility Commission

San Francisco, CA

April 16, 2025

Honda's "Triple Zero" Environmental Goals

Honda introduced **Triple Zero Goals** to achieve zero environmental impact by **2050**.

Carbon Neutrality

Zero CO2 from our product lineup and from operations across the entire value chain.

Clean Energy

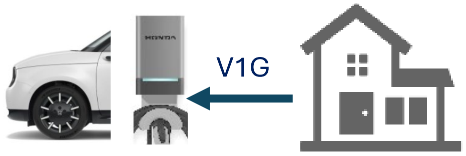
Zero CO2 from energy used for our products and operations across the entire value chain.

Resource Circulation

Zero use of mined resources by achieving resource circularity and using sustainably sourced materials for all products made and purchased across the entire value chain.

VGI: Vehicle-Grid Integration

V1G: Managed Charging

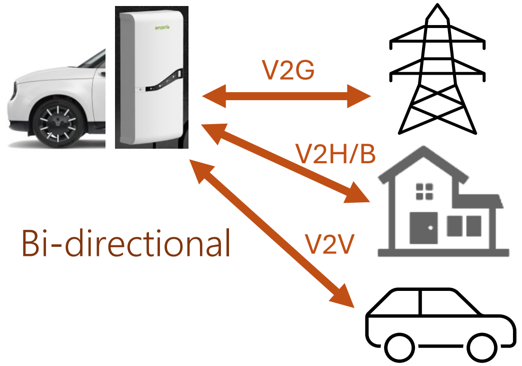


Uni-directional

Common Transactions

- ✓ Price Based Optimization
- ✓ Demand Response
- ✓ Load Flexibility
- ✓ Flow Reservation
- ✓ Demand/Export Limits

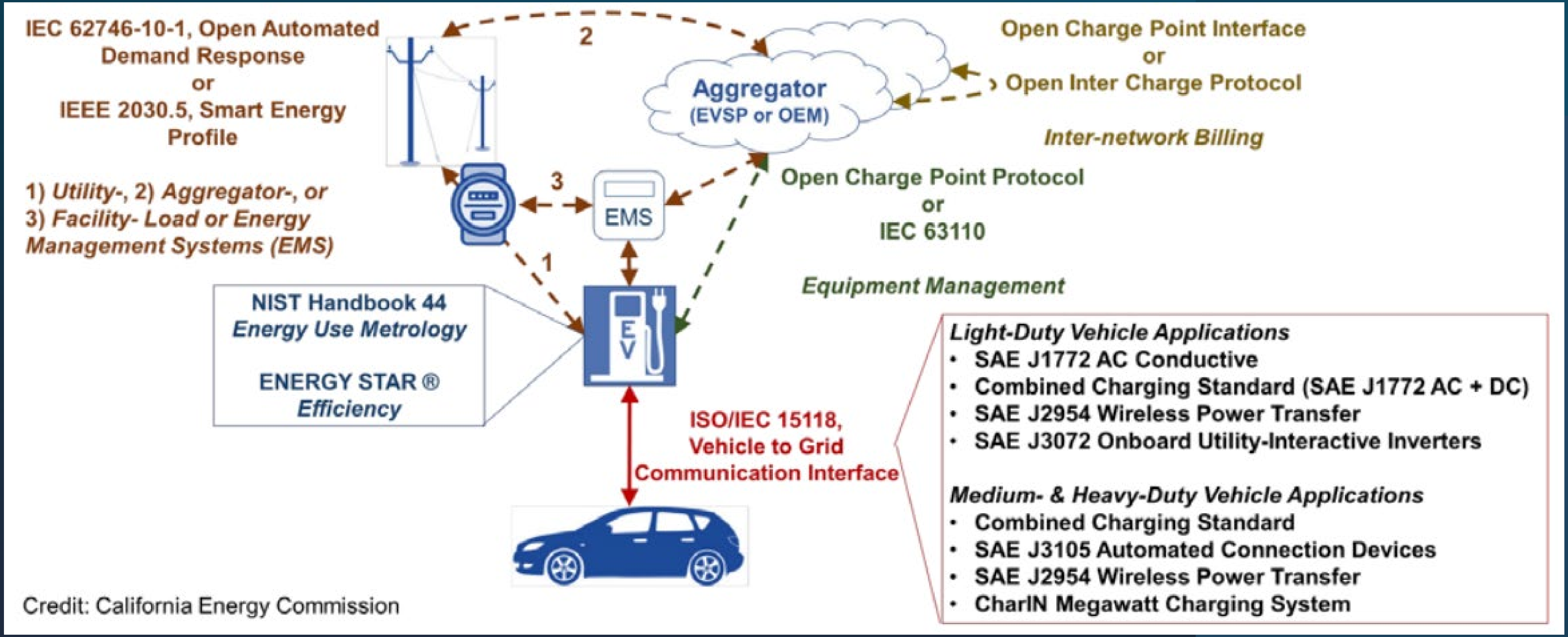
V2G: Managed (Dis)charging



Bi-directional

V1G	V2X Backup Power	V2X Grid-Parallel	Flexible Service Connection	DER-Paired Charging
Unidirectional managed charging or "smart charging"	Islanded bidirectional charging to power a load, home, building, or microgrid	Grid-parallel bidirectional charging to minimize customer bills and/or provide grid services	Minimizing time and costs for infrastructure deployment using charge management solutions or stationary energy storage	Co-located or integrated EV charging with customer generators and/or stationary energy storage

Example of a Grid-Integrated Charging Equipment Design Archetype



Source: DOE Vehicles-to-Grid Integration Assessment Report, January 2025

Overview of Grid Support Functions which EVs May Provide

IEEE 1547-2018 Mandatory Functions

- Low/High Voltage Ride-Through
- Low/High Frequency Ride-Through
- Dynamic Volt-Watt Function
- Frequency-Watt Function (Droop)
- Limit Active Power Function (Limit Generation Export)
- Volt-Watt Function
- Constant VArs Function
- Fixed Power Factor Function
- Volt-VAr Control Function
- Watt-VAr Function
- Dynamic Reactive Current Support
- Rate-of-Change-of-Frequency (ROCOF) Ride-through

Additional Storage and Market Functions

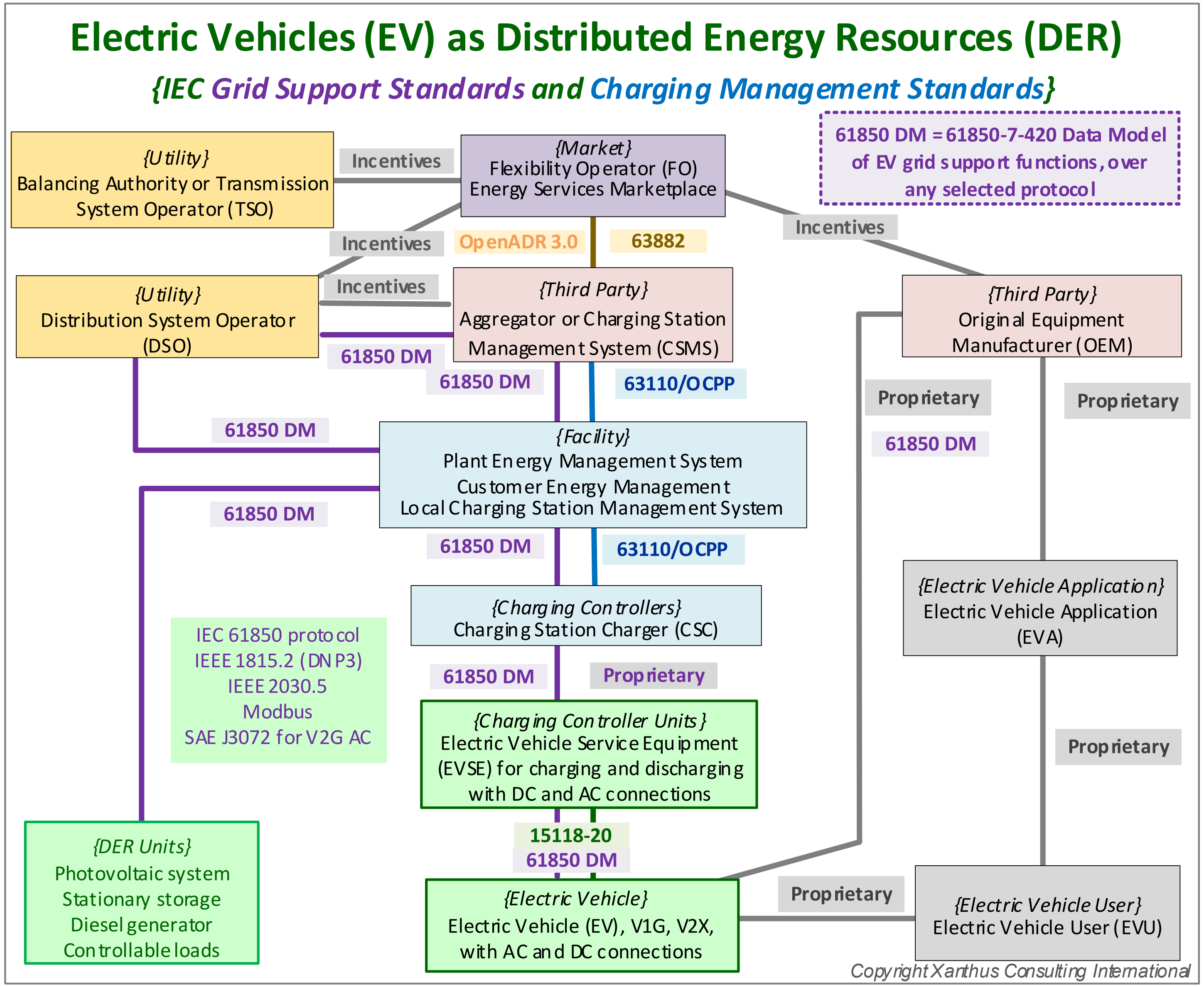
- Scheduling
- Charge/Discharge (Set Active Power)
- Coordinated Charge/Discharge (Charge EV only at specific times for specific amount)
- Peak Power Limiting (Limit Load Import)
- Generation Following
- Load Following
- Automatic Generation Control (AGC) (manage frequency based on Balancing Authority commands)
- Active Power Smoothing
- Artificial Inertia (pretend to have ramping constraints like turbines due to mechanics of physical devices rather than software like inverters in DER)
- Fast Frequency Response (FFR) (increase or decrease power rapidly during a frequency emergency) (TBD)
- Power Factor Correction
- Responses to Pricing Signals

Source: Frances Cleveland fcleve@xanthus-consulting.com

EV as DER: Protocols use Data Models

Data Model is IEC 61850-7-420

- Flexibility Operator interacts with 3rd Parties using IEC 63882: either Aggregators or Charging Station Management Systems (CSMS)
- Aggregators and/or CSMS interact with Facilities using IEC 63110: either the Customer Energy Management (CEM) or the Local Charging Station Management System (LCSMS)
- The CEM and/or LCSMS interact with local equipment using IEC 63110: the Resource Manager (RM) and the Charging Station Charger (CSC) (*now being updated to include IEC 61850-7-420 data objects for DER functions in both V1G charging and V2G charging/discharging*)
- One or more "Resource Management (RM)" Role may be located in many different places – not just in one place
- The RM and CSC interact with the charger using IEC 61850 models over some protocol: the Electric Vehicle Service Element (EVSE)
- The EVSE interacts with the Electric Vehicle using ISO/IEC 15118-20 (*now being updated to include IEC 61850-7-420 data objects for V2G AC charging/discharging, based on SAE J3072*)
- The IEC 61850-7-420 Data Model provides grid support electrical functions and technical characteristics. Although IEC 61850 has defined its own protocol, this Data Model is being mapped to other protocols as well: OCPP 2.0.1/2.1, ISO/IEC 15118-20, IEEE 1815.2, IEEE 2030.5, Modbus



Source: Frances Cleveland fcleve@xanthus-consulting.com

SAE maintains a dedicated focus on Transportation Electrification

Hybrid-EV Committee and 11 Task Forces

TEVHYB Hybrid - EV Committee
https://standardsworks.sae.org/standards-committees/hybrid-ev-committee

TEVVBC32 Vehicle Platform Power Management Committee
https://standardsworks.sae.org/standards-committees/vehicle-platform-power-management-committee

Hybrid and EV First and Second Responder Task Force
https://standardsworks.sae.org/standards-committees/hybrid-ev-first-second-responder-task-force

J3271 Megawatt Charging System for Electric Vehicles TF
https://standardsworks.sae.org/standards-committees/j3271-megawatt-charging-system-electric-vehicles-tf

98 SAE EV, Hybrid, Fuel Cell Vehicle Published Documents

Mobility, Advanced™

Fuel Cell Fueling: J2600, J2601, J2601/1. J2601/2, J2601/3,J2601/4, J2601/5, J2719, J2719/1, J2799, J1766, J2578, J2579

EV, Hybrid, Fuel Cell Vehicle Safety: J1766, J2344, J2910, J2990, J2990/1, J2578, 3108, J3235, J2950

EV, Hybrid, Fuel Cell Vehicle Economy, Range / Power: J2991, J1798, J2758, J2946, J2572, J2907, J2908, J1634, J1711, J2711

Fuel Cell Testing: J2615, J2616, J2617, J3219

EV, Hybrid, Fuel Cell Vehicle Crash Safety: J3040, J1766, J2990, J2990/2

Fuel Cell Systems: J2579, J2594, J3089

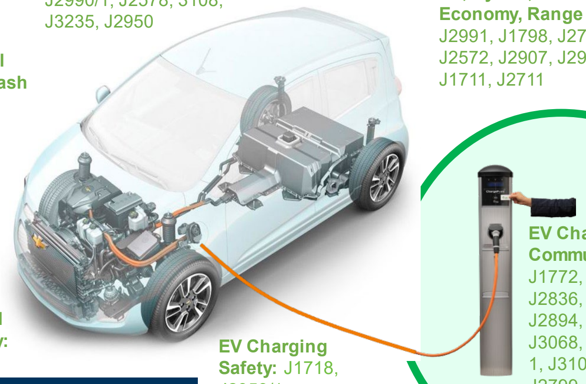
EV Battery Recycling/Secondary Use: J2984, J2974, J3071, J2997

Energy Transfer Systems: J2293, J2293/1, J3072

EV, Hybrid, Fuel Cell Vehicle Terminology: J1715, J2574, J2760

EV Charging Safety: J1718, J2953/1, J2953/3

EV Charging & Grid Communications: J1772, J1773, J2293, J2836, J2841, J2847, J2894, J2931, J2954, J3068, J3105, J3105-1, J3105-2, J3105-3, J2799, J3271, J3400



StandardsWorks™

All Committees

- Hybrid and EV First and Second Responder Task Force
- Medium and Heavy Duty Vehicle Conductive Charging Task Force
- J2908 Task Force
- J3271 Megawatt Charging System for Electric Vehicles TF
- Hybrid-EV J3400 NACS Electric Vehicle Coupler Task Force
- Hybrid J1772 Connector Task Force
- Hybrid Communication and Interoperability Task Force
- Hybrid J2894 Power Quality Task Force

Committees | Meetings | Help

Hybrid Communication and Interoperability Task Force

Overview | Work Area | Meetings

The scope of the Hybrid Communications and Interoperability Task Force (TEVHYB6) is to establish the use cases, signals and messages and communication protocol along with interoperability and security for Plug-in Electric Vehicles (PEV). This includes Smart Charging, DC (or Fast) Charging, using the PEV as a Distributed Energy Resource (DER) also known as Reverse Power Flow to a load or the grid or merely stabilizing voltage and frequency. Diagnostics, Customer to PEV communication and Wireless Charging are also included. The interoperability standards include the criteria for this added high level communication plus insures the EV Supply Equipment (EVSE), defined in J1772 and Grid Power Quality in the J2894 task forces are also included in this task forces' Interoperability standards to insure PEV to EVSE and Grid interoperability. Security is included for wired and wireless protocols defined in this task force.

Join Now

Committee Manager

DR Dante Rahdar
Staff Representative

Hybrid - EV Committee

Mobility, Advanced™

1,348	Committee Membership Individual Participants
192	Represented Employers (OEM's, Suppliers, Government, and Academia)
11	Reporting Task Forces
46	Published Documents

Vehicle Battery Standards Steering Committee

Mobility, Advanced™

715	Committee Membership Individual Participants
164	Represented Employers (OEM's, Suppliers, Government, and Academia)
28	Subcommittees
38	Published Documents

EPRI Guidebook to EV Standards

https://www.epri.com/research/products/000000003002029898

Questions:

EPRI Customer Assistance Center

800.313.3774 • askepri@epri.com

2 AN EXHAUSTIVE SUMMARY OF CODES, STANDARDS, AND RECOMMENDED PRACTICES FOR ELECTRIC TRANSPORTATION

The Standards Development Organizations Included in the Standards Catalog (Listed in Order of Appearance in Catalog)

- American National Standards Institute (ANSI): has official oversight of standards for the U.S.; includes standards development organization review and approval.
- California Air Resources Board: develops air quality requirements for California including for vehicle emissions.
- Canadian Standards Association (CSA): develops product safety standards for Canada.
- Code of Federal Regulations (CFR): U.S. National codes published by the federal government that include vehicle safety, behavior, and performance standards.
- Economic Commission for Europe of the United Nations (UNECE): develops standards for battery shipment safety and electromagnetic compatibility for the European Union.
- Environmental Protection Agency (EPA): has developed a program to encourage best in class efficiency for electric products including electric vehicle charging stations.
- European Telecommunications Standards Institute (ETSI): A European Standards Development Organization. Develops standards for telecommunications and communications supporting European regulations and legislation through the creation of Harmonized European Standards.
- German Institute for Standardization (DIN): national standards development body of Germany.
- Institute of Electrical and Electronic Engineers (IEEE): developer of standards for electrical and electronics systems related to vehicle interaction with the electric grid.
- International Electrotechnical Commission (IEC): developer of international standards for electrical product function and safety for vehicle charging.
- International Commission on Non-Ionizing Radiation Protection (ICNIRP): develops safety standards for human exposure to electromagnetic fields.
- International Standards Organization (ISO): developer of international standards related to vehicle communications and vehicle systems (including safety).
- International Telecommunications Union (ITU): sets standards for radio frequency emissions and compatibility.
- Japan Electric Vehicle Association (JEVA): develops vehicle and battery standards for electric vehicles.
- National Fire Protection Association (NFPA): developer of standards for fire safety—publisher of the National Electric Code in the US covering safe installation of charging infrastructure.
- National Institute of Standards and Technology (NIST): develops model code for sale of commodities such as electricity for electric vehicles.
- National Electrical Manufacturers Association (NEMA): develops standards for electrical hardware in North America.
- Normas Mexicanas (NMX): national standards development entity in Mexico.
- SAE International (SAE): developer of recommended practices and standards for vehicles and vehicle systems including vehicle charging and discharging.
- Svensk Elstandard (SEK): national electrical standards development body of Sweden
- Underwriters Solutions (UL): developer of product safety standards for electric vehicle charging infrastructure and offboard vehicle charging control.

Alliance Documents Included in the List (In Order of Appearance in Catalog)

There are several industry alliances that are active in the electric vehicle space, especially in the area of communications.

- OpenADR Alliance: alliance that supports development of the Open Automated Demand Response standard and compliance and test tools for that standard.
- Open Charge Alliance (OCA): alliance that support development of the Open Charge Point Protocol (OCPP) and compliance and test tools for that standard.

Table 2-1 provides an exhaustive list of codes, standards, and recommended practices along with a status, a web link if available and a brief description of the document for all relevant codes and standards related to electric transportation. Where possible abstracts have been taken directly from the document sources for accuracy. The list contains over 270 documents that related to transportation electrification.

The "Referenced By" column calls out the major charging interface related standards/recommended practices (primarily SAE documents) showing the external documents referenced by these documents.

ANSI EVSE Roadmap

NEMA participated in the ANSI EVSE Roadmap to identify standard gaps that needed to be addressed for further EV adoption. Power Export Permitting was identified in this analysis.

Gap

While permitting for EVSE installation is covered by codes, permitting for the actual delivery of power from the vehicle (i.e., power export) is not specified in codes.

SAE J3072

SAE J3072 specifies the need for a permit but does not describe how to comply. There are terms and conditions for interconnections related to power export. Addressing this gap requires coordination between utilities, AHJs, and code organizations.

Recommendation

Address power export in relevant codes in cases where the NEC does not apply (e.g., interconnection agreements). Identify and facilitate integration of energy services to vehicle power export capabilities.

NEMA EVSE 40011

Defines characteristics in key domains for permitting power export between Electric Vehicle Supply Equipment (EVSE) and Electric Power System (EPS).

EVSE Configurations

01

V2G-DC

The smart inverter and smart functions are both located in the EVSE, off-board the plug-in electric vehicle (PEV).

02

V2G-AC

The inverter and smart functions are located on-board the PEV. The EVSE can both consume and export power via either direct injection or through a grid-connected load.

03

V2G-AC Split

The smart inverter is on-board the PEV while the smart functions are housed in the EVSE, creating a hybrid system.

HONDA

The Power of Dreams

Thank you!

Vehicle Grid Integration Council (VGIC) is a national 501(c)(6) membership-based trade association committed to advancing the role of electric vehicles and vehicle-grid integration through policy development, education, outreach, and research.

VGIC
VEHICLE GRID INTEGRATION COUNCIL
vgicouncil.org

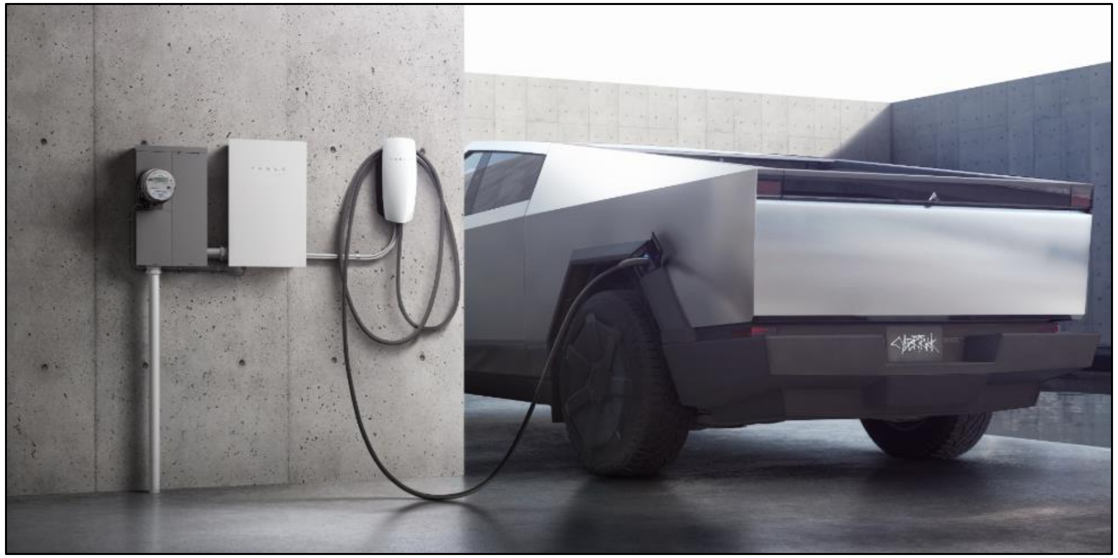
Zach Woogen, Executive Director, VGIC | zwoogen@vgicouncil.org
John Holmes, Senior Principal Energy Advisor, Honda | john_holmes@na.honda.com

Powershare

Introduction

Definitions

- **Vehicle to Home (V2H)** → vehicle can only discharge when **disconnected** from the grid
- **Vehicle to Grid (V2G)** → vehicle can discharge when **connected** to grid



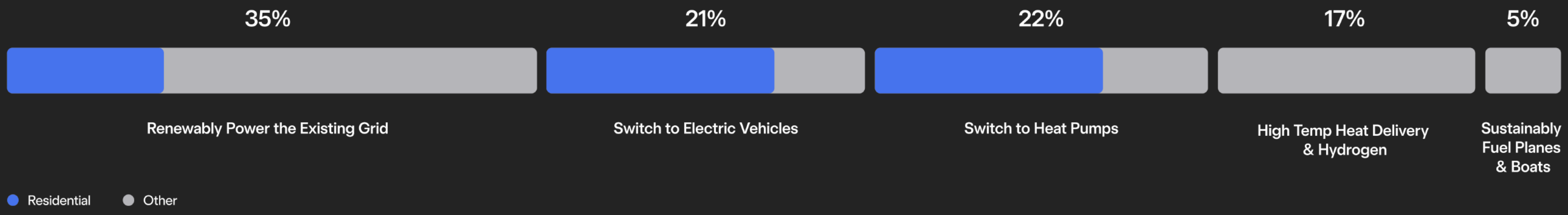
What is Powershare?

- Onboard vehicle technology that supports bi-directional AC power flow
- Enables the following functionality **today**
  - Charging electric appliances and loads (**Vehicle to Load**)
  - Charging other EVs (**Vehicle to Vehicle**)
  - Home backup (**Vehicle to Home)**

Goal to support Vehicle to Grid functionality in 2025

Home and EV Electricity Demand Will 5X

Drivers of Reduction in Fossil Fuel Use



Powershare is a critical part of the solution for meeting this new demand

Avoids transmission losses & network upgrades

VPPs support the grid locally and drive value for owners

Protects against outages and weak grids

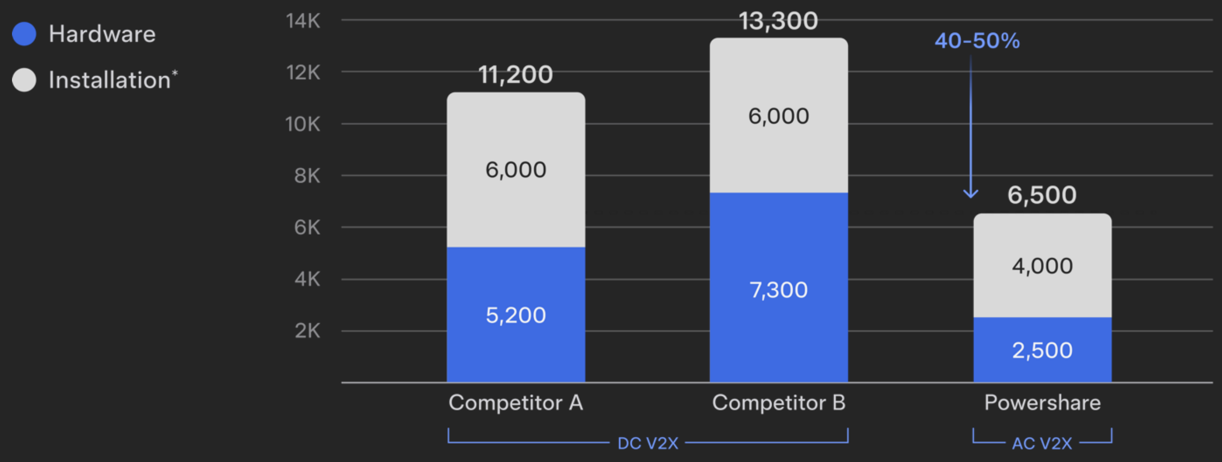
Maximizes the use of intermittent renewables

Lowest Cost, Most Affordable

- AC architecture reduces total cost of V2X by 40%-50% vs competitors
- Leverages existing onboard vehicle inverter
- Fewer boxes to install
- Accelerates speed of storage deployment, benefitting utilities

Tesla Powershare Install

Competitor Install



*All installation costs are estimated.

Powershare Products

Powershare Gateway (aka Gateway 3V)

Powershare Gateway controls connection to the grid, automatically detects outages and provides automatic transition to backup power.

Universal Wall Connector

Universal Wall Connector enables bi-directional charging, allowing Cybertruck to either charge or power the home during an outage when plugged in.

Cybertruck

Up to 11.5 kW of continuous power, ~98 kWh of energy (@ 80% SOE).

UL 1741 SB Evaluation of a DER System

Grid Performance

- UL 1741 SB (IEEE 1547-2018, IEEE 1547.1-2020)
- DER Communications per IEEE 1547-2018
  - SunSpec, IEEE 2030.5, DNP3
- EMC immunity testing per IEEE C62.41.2
- Evaluated at the point of interconnection (POI)

System Safety

- Powershare Gateway: UL 1741, UL 916, UL 67, UL 869A
- Universal Wall Connector: UL 9741, UL 2594, UL 2251, UL 2231-1/2

Similarities to Tesla Powerwall 2

- Stationary site controller located in the Gateway
- Local grid codes stored on the stationary site controller
- UL 1741 SB validated at the POI
- Proprietary communications between the DER and ISE
- IEEE 1547-2018 communications between ISE and grid
- Units can be added without impact to grid performance

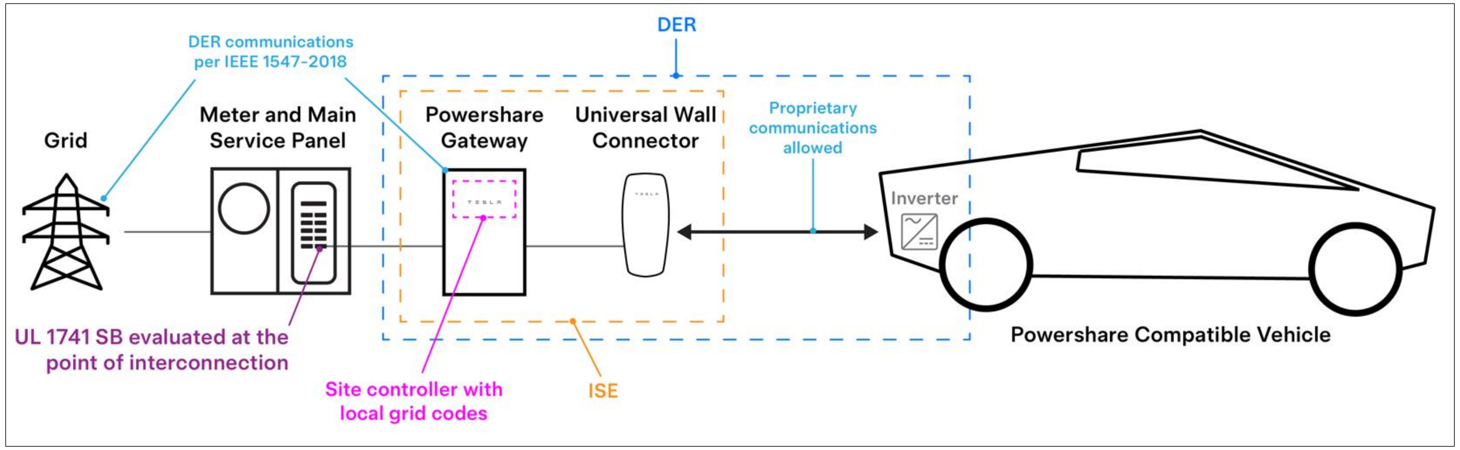


Figure 1: Tesla Powershare grid performance diagram

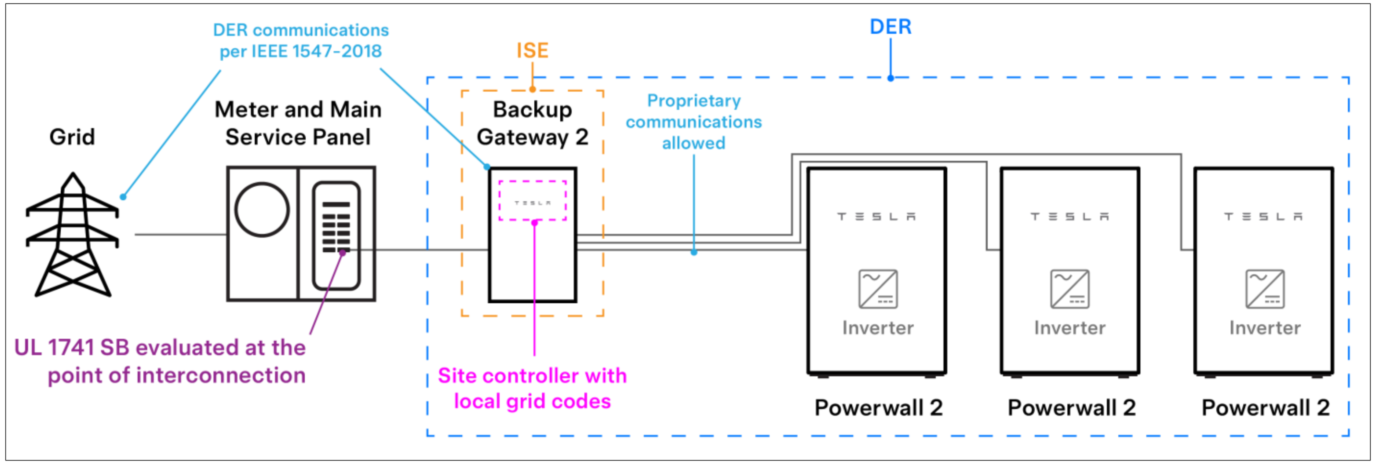


Figure 2: Tesla Powerwall 2 grid performance diagram

V2G Next Steps

- Utility **documented acceptance of AC V2G** and associated compliance, ahead 2025 interconnection applications
- **Simple vehicle participation** in existing DER programs
- Continue aggressively **lowering the cost of V2G** to customers

Closing Remarks