ELECTRIC TRANSPORTATION

Transportation Electrification: Overview and Emerging Opportunities

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AGENDA

Transportation Electrification | Market Overview

- EV Adoption Dashboard
  - Global
  - Domestic
- Projection Trends

Utility Investment and Immediate Barriers to Scale

V2X Discussion | What is It? Why is it Important?

Challenges and Opportunities with EVs on the Grid

V2X Value to the Grid

Communications and Interconnection Standards

TRANSPORTATION ELECTRIFICATION MARKET OVERVIEW

WHY DOES A UTILITY CARE?

Transportation Electrification

QUICK FACTS

60+ EV models today in the U.S., ~150 by 2026 including SUVs, crossovers, and pickups

~3.37M+ EVs on the road in the U.S. (though December 2022)

$1.2T+ being invested globally by automotive industry

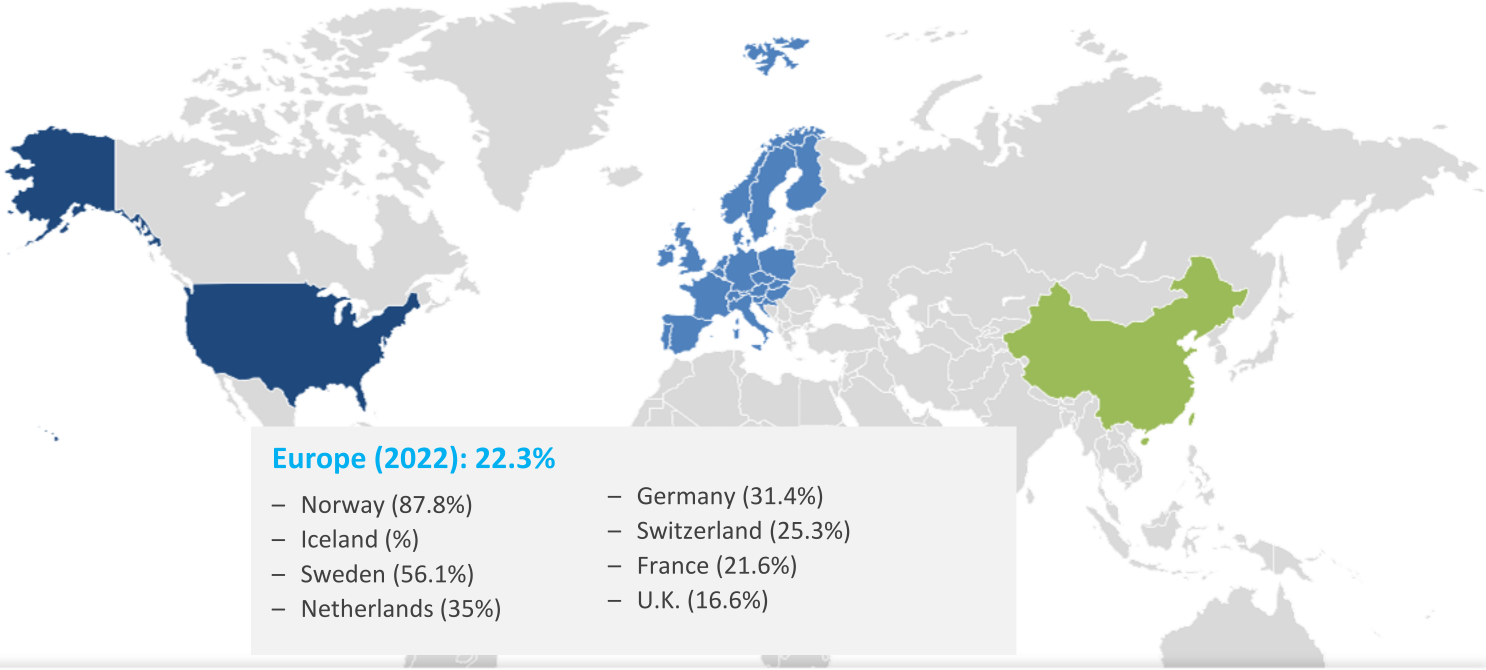
Each EV is ~3,500 kWh each year in new, largely movable load

Sources: BloombergNEF; Bloomberg Intelligence; ACEA; CATARC; OFV; New Zealand Ministry of Transport (BEV trends shown)

Transportation Electrification

KEY GLOBAL MARKETS

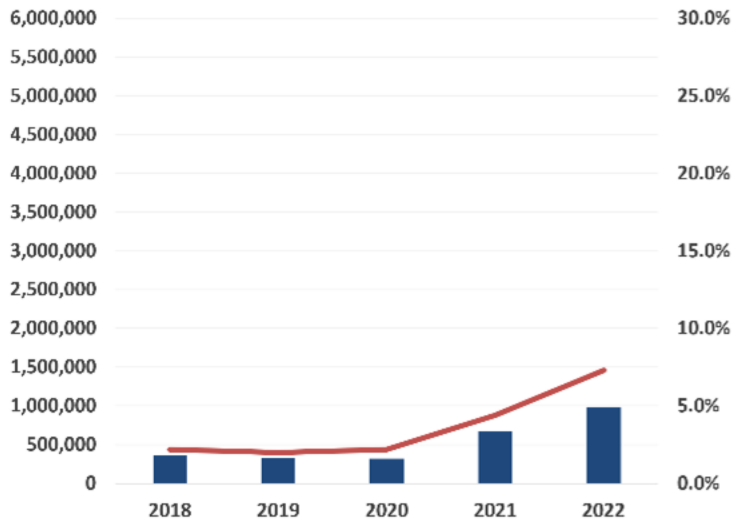
- 2022 global EV sales exceeded 10.5M (+55%, 15.9% of market)
- Strong growth in regions supported by policy and EV supply



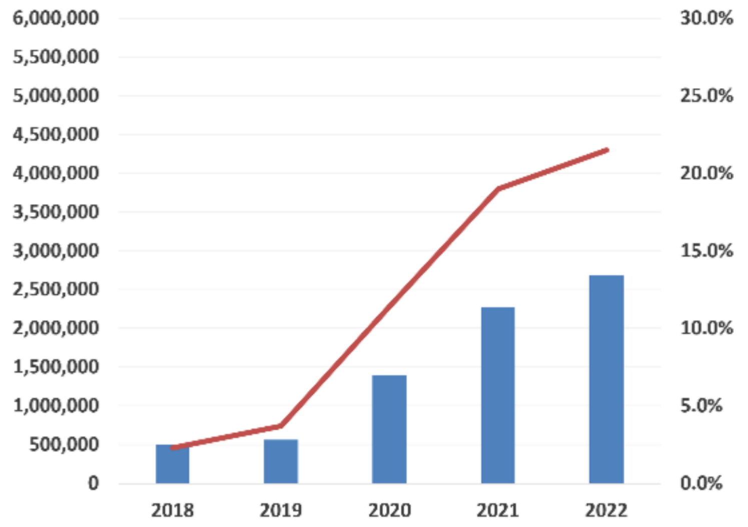
Europe (2022): 22.3%

- Norway (87.8%)
- Iceland (%)
- Sweden (56.1%)
- Netherlands (35%)
- Germany (31.4%)
- Switzerland (25.3%)
- France (21.6%)
- U.K. (16.6%)

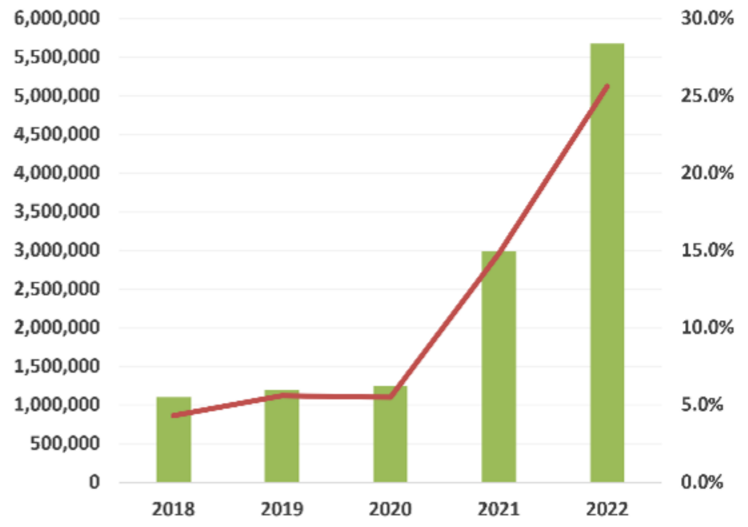
US EV Sales 2018–2022



Europe EV Sales 2018–2022



China EV Sales 2018–2022



OEM EV COMMITMENTS + INVESTMENTS

2025

- $86b through 2025
- STELLANTIS — $35.5b through 2025
- HYUNDAI MOTOR GROUP — 20% Kia EV sales by 2025, $7.4b in US by 2025
- No ICE dev. after 2025
- gm — $35b through 2025
- VOLVO — 50% BEV globalsales by 2025, $1.2b on EV plant

2026

- Ford — $50b through 2026
- NISSAN — $17b through 2026
- BENTLEY — 1st EV launching in 2026
- no ICE investments after 2026

2030

- 100% EV sales by 2030, $47b globally through 2030
- TOYOTA — $35b through 2030
- VOLVO — 100% BEV by 2030
- ASTON MARTIN — 100% PHEV/BEV sales by 2030
- Ford — 50% EV sales by 2030
- mazda — 25% EV sales by 2030
- NISSAN — 40% EV sales by 2030 in US
- HONDA — 40% EV (incl. FCEV) sales by 2030, $40b through 2030
- STELLANTIS — EV sales 50% in US & 70% in EU by 2030
- BENTLEY — 100% BEV sales by 2030, $3.4b through 2030
- gm — 50% EV sales by 2030, Cadillac 100% EV by 2030
- BMW — 50% EV sales by 2030
- 55% EV sales in US by 2030

2035

- Ford — 100% EV sales in EU by 2035
- TOYOTA — 100% EV sales by 2035 in EU
- HYUNDAI MOTOR GROUP — ICE models end by 2035
- gm — 100% EV sales by 2035

2036+

- HONDA — 100% EV sales by 2040
- JAGUAR — 100% EV sales by 2039, $3.4b on EV dev.

DOMESTIC FORECASTS

Biden EO 14037 Goal of 50% of new sales be ZEVs by 2030

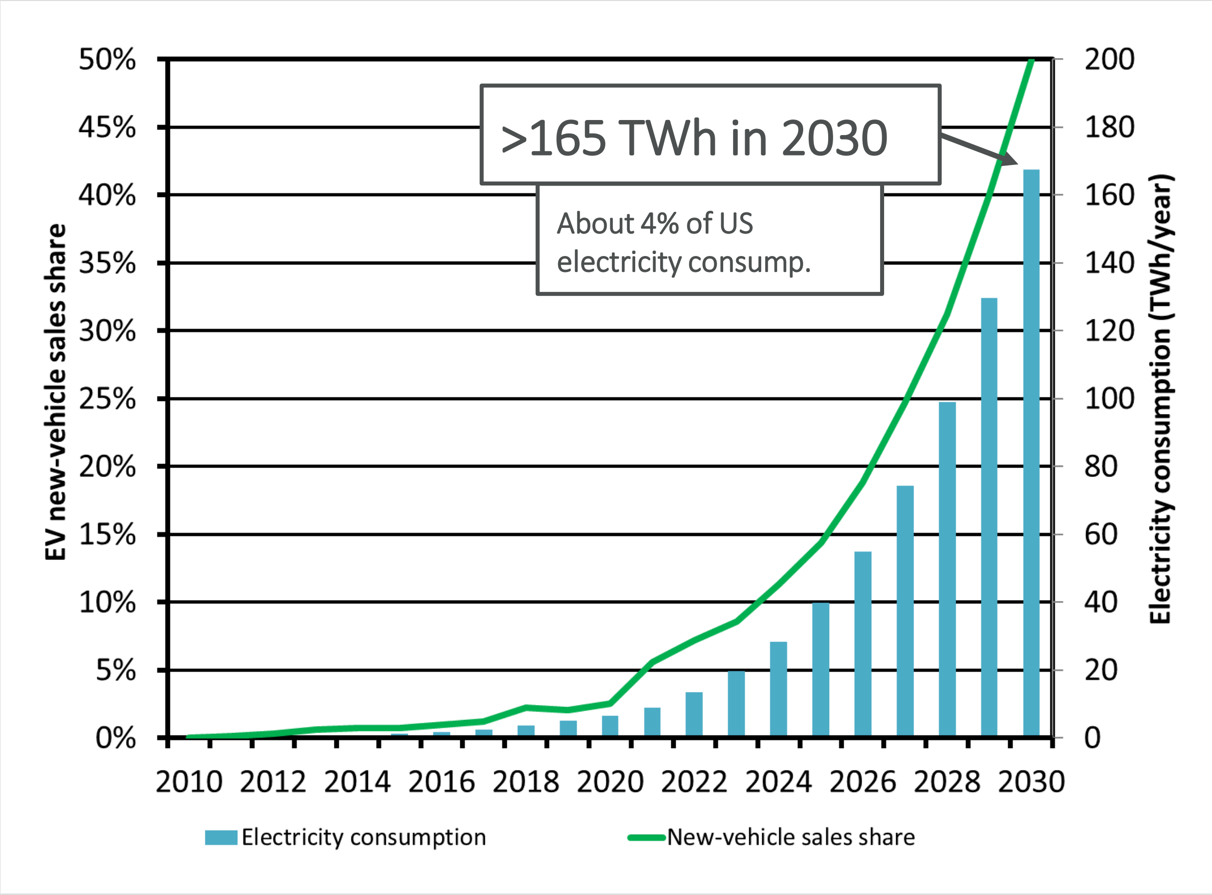
- ZEV includes BEV, PHEV, and fuel-cell EVs
- Goal applies to **passenger vehicles**
- New MD/HD fuel economy rules for MY2027+

Automakers pledge increasing share of ZEV sales through 2030

- Share of annual new U.S. sales
- U.S. autos GM, Ford, Stellantis pledged 50%
- Several other OEMs targeting 25% to 100% EV

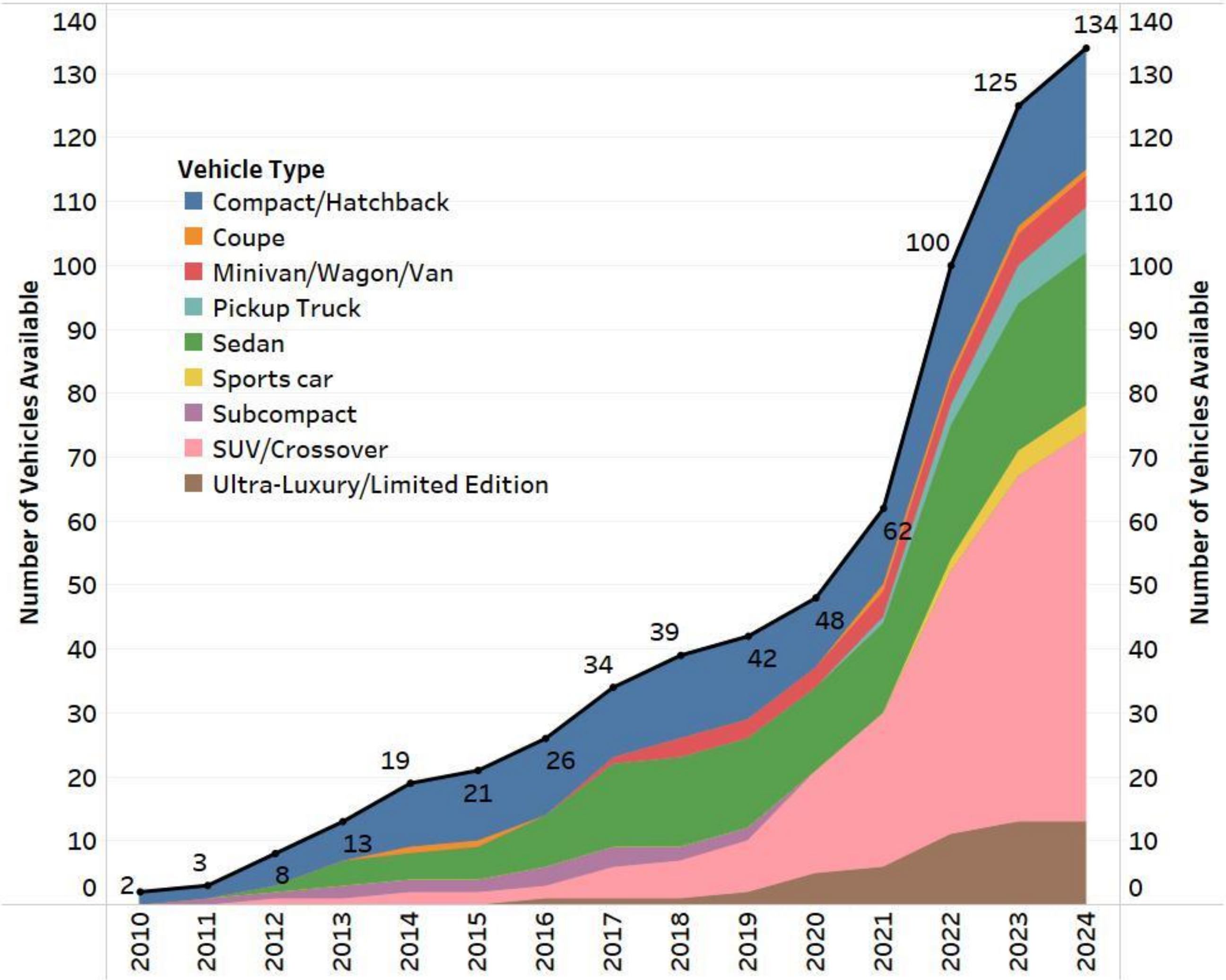
LDV EV charging >165 TWh by 2030

- About 4% of US consumption*
- 36M EVs in operation in 2030
- About 1 in 7 (14%) LDV in operation are EV



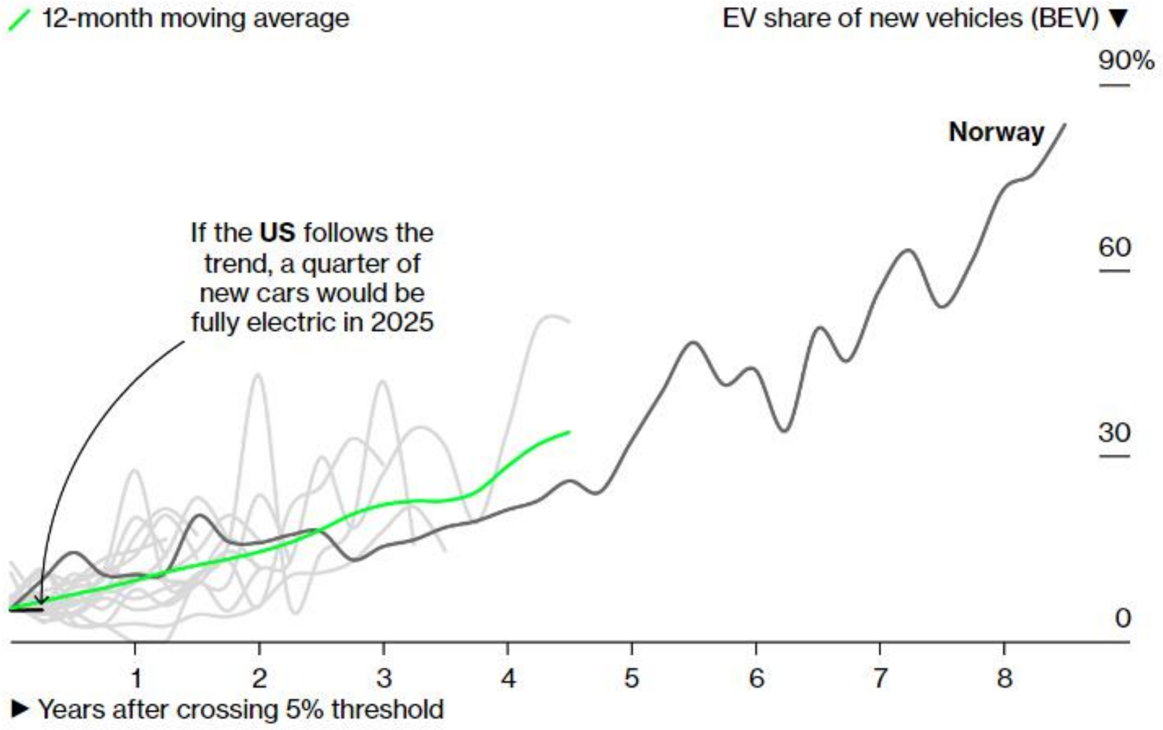
* Total U.S. electricity consumption in 2030 is estimated to be 4,210 TWh
Annual Energy Outlook 2022, Reference Case, Table 8. https://www.eia.gov/outlooks/aeo/tables_ref.php

INCREASING VEHICLE DIVERSITY + CAPABILITY



CROSSING THE TIPPING POINT

- US has passed 5% EV sales as a portion of total LDV sales for the past six months
- 18-country trend analysis suggests US will pass **25% EV sales by the end of 2025**



Country	EV sales in Q1 2022	EV share of new cars	First quarter to cross 5%
Austria	7,772	14.8%	2018 Q3
Belgium	10,898	11.0	2020 Q4
China	924,530	16.7	2018 Q4
Denmark	5,945	17.4	2020 Q3
Finland	3,025	13.9	2020 Q4
France	44,774	12.3	2020 Q1
Germany	84,749	13.5	2020 Q3
Iceland	1,630	51.7	2017 Q3
Ireland	6,483	13.0	2019 Q4
Italy	14,263	4.2	2021 Q3
Netherlands	12,501	15.9	2018 Q4
New Zealand	2,896	6.2	2021 Q3
Norway	27,023	83.5	2013 Q3
Portugal	4,025	11.6	2020 Q1
South Korea	29,306	6.5	2021 Q2
Sweden	20,024	28.7	2020 Q1
Switzerland	8,898	16.4	2020 Q1
United Kingdom	68,954	16.5	2020 Q2
United States	172,748	5.3	2021 Q4

Sources: BloombergNEF; Bloomberg Intelligence; ACEA; CATARC; OFV; New Zealand Ministry of Transport (BEV trends shown)

2022 HIGHLIGHTS / 2023 EARLY TAKEAWAYS

EVs2Scale2030

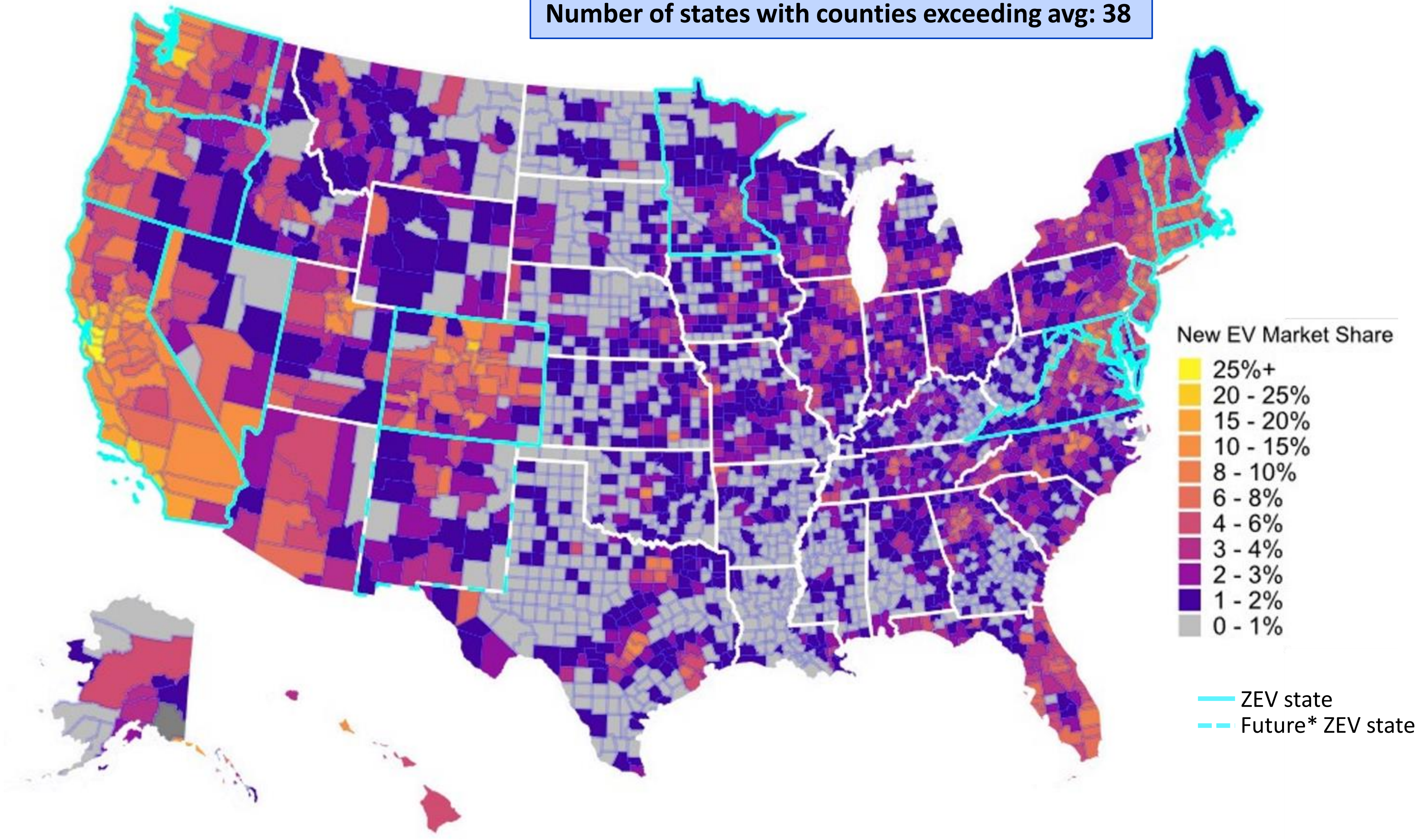
- **Overall**
  - ~3.37M EVs in the U.S.; supply-limited
  - Electric SUVs, pickups, and crossovers launched
  - 2022 EV deliveries ~980K+ (up from 668K in 2021)
- **Plug-in hybrids re-emerging**
- **Charging power increasing**
  - AC ~10 kW - 12 kW; multi-EV households
  - DC 150+ kW
- **Commercial & Industrial EVs**
- **Key challenges**
  - Public charging infrastructure reliability, interoperability, usability, transparency, performance, customer experience
  - Early fleet experience has been mixed at best
  - Managed charging / V2X

EPRI

NATIONWIDE NEW EV MARKET SHARE BY COUNTY (2022)

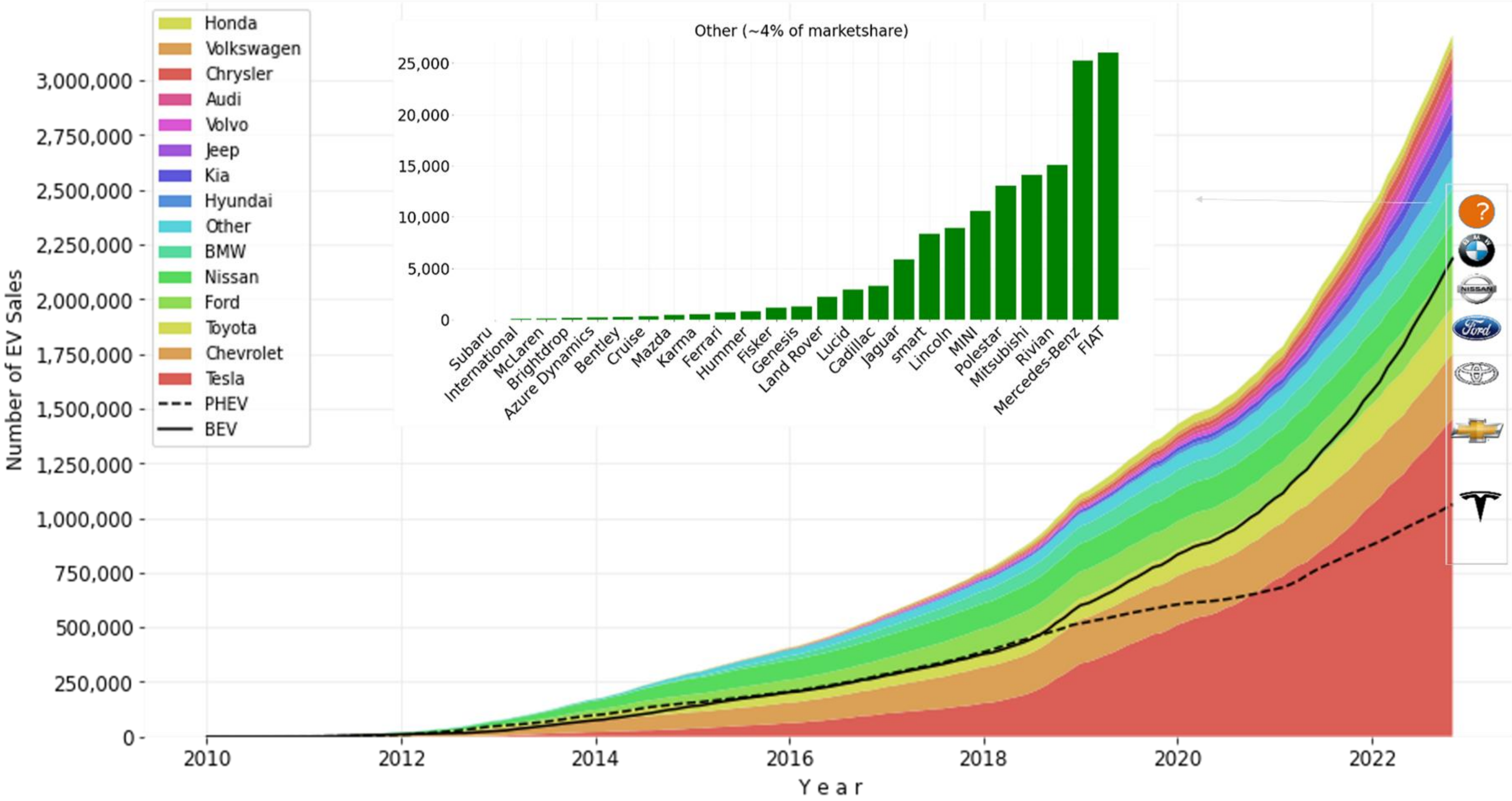
Nationwide avg new EV market share: 7.3%
Number of counties exceeding avg: 204
Number of states with counties exceeding avg: 38

Top 5 counties in CA and Top 15 counties outside CA	
Santa Clara, CA	35.4%
Marin, CA	33.3%
Alameda, CA	32.1%
San Mateo, CA	31.4%
San Francisco, CA	28.3%
San Juan, WA	21.9%
Boulder, CO	21.6%
King, WA	20.1%
Yakutat, AK	20.0%
Loudoun, VA	19.2%
Jefferson, WA	17.3%
Multnomah, OR	16.6%
Summit, UT	16.1%
Falls Church city, VA	16.1%
Howard, MD	15.6%
Arlington, VA	15.3%
Essex, NJ	14.9%
Snohomish, WA	14.9%
Clackamas, OR	14.5%
Charlottesville city, VA	14.3%



ELECTRIFICATION PRESENTS SIGNIFICANT UTILITY OPPORTUNITIES

3.4M EV sales through 12/31/2022 = ~11.8 TWh to the grid



Infrastructure Investment is Needed to Drive Scale

Nationwide [in the US], **900,000 public charging ports will be needed by 2030** to meet the EV market growth predicted by the Edison Electric Institute and the Institute for Electric Innovation. This represents a 16-fold increase over the 56,000 public charging ports recorded at the end of 2019.

UNPRECEDENTED INDUSTRY CHALLENGES + IMMEDIATE BARRIERS

Unprecedented Industry Challenge…

- Government, industry, and fleets are increasingly aligning on aggressive 2030 vehicle electrification goals
- The pace of needed year-over-year action and investment to prepare charging sites and the grid is not clear
- Consumers and fleet operators must have confidence in charging availability, reliability, and affordability
- Consumers and fleets operators are increasingly looking to the utility industry to scale up efforts to support charging solutions, ensure the grid is capable of meeting vehicle loads

THIS TRANSITION IS UNPRECEDENTED AND COMPLEX. IT REQUIRES:

- **Extraordinary collaboration and partnering** across all the major EV stakeholder groups
- **Redesigned processes, useful tools, and increased standardization** to simplify the planning and complex interactions between major stakeholder groups
- **An evaluation of regulatory/board oversight** that may not be conducive to driving actions on the pace and scale required to meet 2030 targets

Barriers to Scale

TOP BARRIERS TO SCALE THAT MUST BE ADDRESSED:

- CHARGING AVAILABILITY
- CHARGING RELIABILITY
- GRID INTERCONNECTIONS & GRID READINESS

3 ENABLING ACTIONS:

1. **Ensure utilities (and regulators) are in lock-step** with vehicle OEMs, fleets, and consumers
2. **Optimize systems and processes** that support the pace of activity/investment required
3. **Develop needed tools and technologies** that enable EV scale and capture EV grid benefits

UTILITY INVESTMENT + ENGAGEMENT IS CRITICAL TO ACHIEVING SCALE

Utility Investment + Engagement is Needed to Drive Scale

- From the utility perspective, the two most important trends in EV adoption are **EV growth rate** and **number of charging stations** installed.
- It is projected that 20 million EVs will add **60–95 TWh of annual demand** and **10–20 GW of peak load** to the system, require 12–18 GW of renewable capacity, and 1–2 million public chargers to serve EV demand.*
- Future investments will be necessary across the supply chain, including $30–$50 billion for generation and storage, $15–$25 billion for T&D upgrades, and $30–$50 billion for EV chargers & customer-side infrastructure.*

**The Brattle Group*

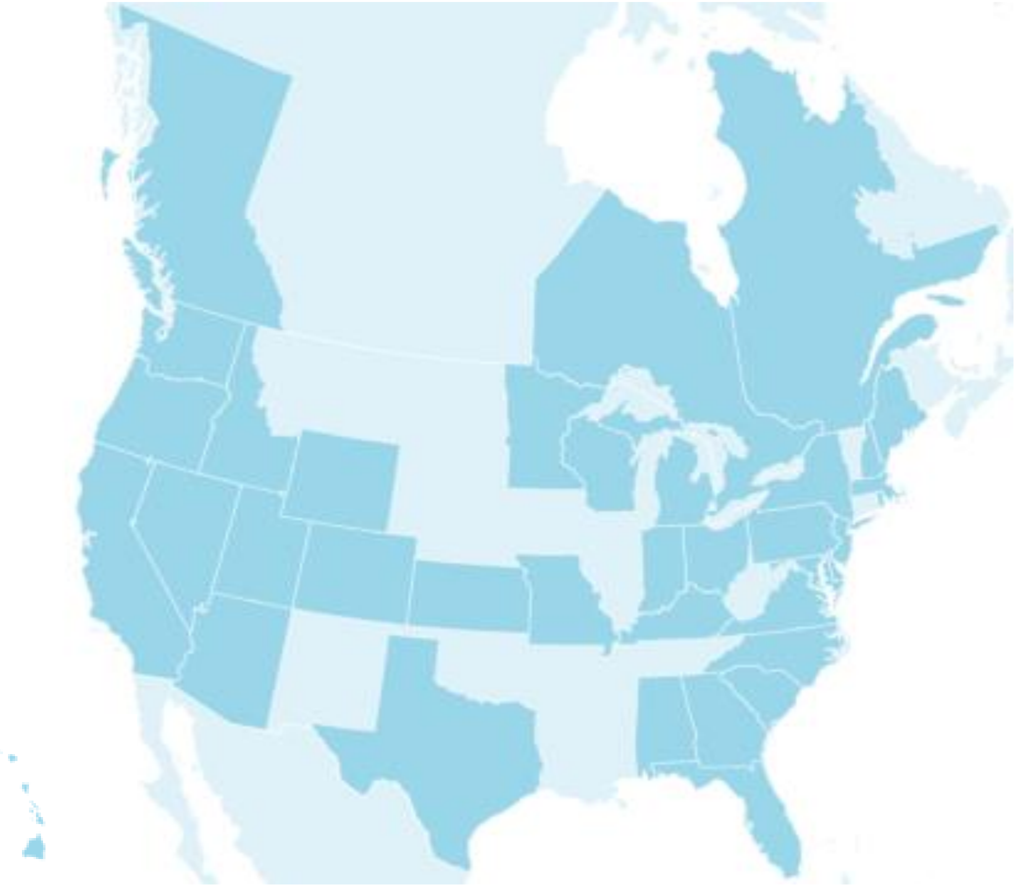
The Opportunity…

- Boston Consulting Group estimates that the rise of EVs could create **$3 billion to $10 billion of new value** for the average utility.
- Assuming that the market share for battery EVs ramps up from 1% to 15% from 2019 to 2030, Boston Consulting Group projects that **the required transmission and distribution upgrades will range from $1,700 to $5,800 for each electric vehicle** that comes online, depending on when and where people charge.
- According to Brattle, $75–125 billion of investment is needed across the electric power sector to serve 20 million EVs by 2030s.

Electric Transportation Impacts the Entire Utility Ecosystem

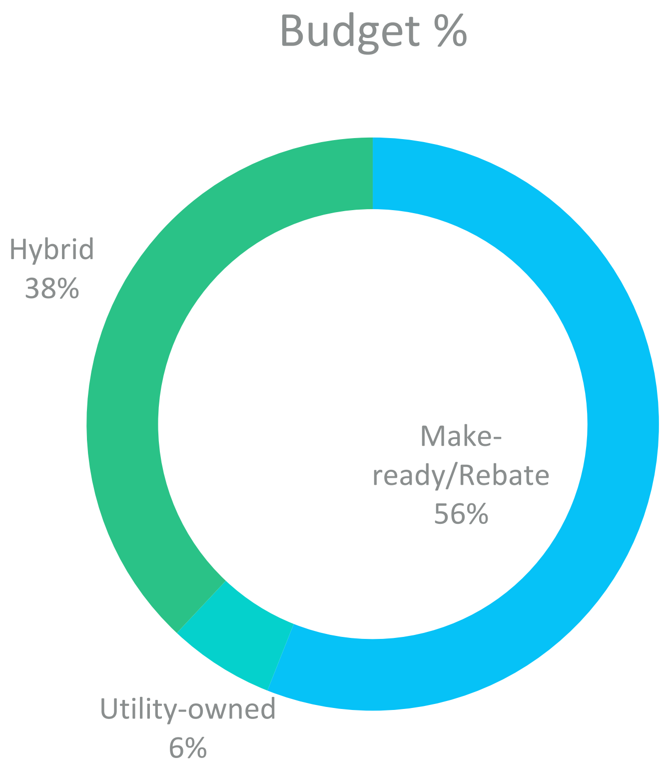
UTILITY STAKEHOLDER	SAMPLE KEY QUESTIONS
Executives	When is this change coming? How can I lead my utility to maximize potential while supporting all customers and short- and long-term growth?
Regulatory	How can we meet or exceed all the myriad of EV policies? How can we structure successful rate cases to support EV charging?
Workforce	Do we have the workforce needed to meet the demands of electrification scale?
Rates	What rates should exist that support EV market growth without cross-subsidies?
Customer	What subject-matter expertise do I need and how do I grow it ahead of the EV market growth? How do I effectively communicate with various customer segments about EVs and EV charging? How do I support various customer segments who are switching to EVs?
Finance	How can we support the increased load growth with maximum investment and minimal cost? What does that mean for our financials?
Procurement	How much additional energy and when we will need to support EV load growth?
Distribution, substation, and transmission planning	How should our planning timeframes and specs change to support EV charging load growth? How does concentration of high-power charging differ?
Service planning	How do we support an increasing amount of EV-related service planning requests? How does fleet electrification differ?
Government relations	What key facts and trends in the fast-moving EV market do I need to know to effectively communicate with key stakeholders?
Metering	How is EV charging metered? How does it integrate with current systems?
Environment	How do EVs and EV charging impact the environment?
Fleet	What EVs and EV charging solutions are options for my fleet? What do I need to do to plan and prepare?

North American Utilities Investing ~$3.6B in EV infrastructure



KEY STATS

- $3.630B
- 38 states
- 3 provinces
- 62 utilities
- 94 programs
- 11 programs without budget detailed



North American Utilities EV Infrastructure Investment
Dashboard Overview

Hawaiian Electric $2.3M	Seattle City Light $2.8M	Otter Tail Power Company $2.1M	atlantic city electric $42.1M	Hydro Québec $10M	Ontario $20M	BC Hydro NA
Avista $3.1M	PSE Puget Sound Energy $15.5M	Bear Valley Electric Service, Inc. $0.7M	Central Maine Power $0.2M	bge An Exelon Company $12.5M	Eversource Energy $45M	atlantic city electric $42.1M
PGE $24.8M	Pacific Power $0.8M	nationalgrid $166.1M	NYSEG $141.7M	New York Power Authority $250M	Narragansett $11.5M	PSEG We make things work for you. NA
PG&E $414.4M	aps NA	LA DWP Los Angeles Department of Water & Power $420M	RG&E $141.6M	Orange & Rockland $123.8M	delmarva power $13M	pepco $17.3M
SDG&E A Sempra Energy utility $191.4M	NV Energy $23M	Southern California Edison $855.7M	Consumers Energy Count on Us $22.2M	DTE $13.1M	Central Hudson $127.1M	Ameren $11M
Xcel Energy $132.3M	Rocky Mountain Power $12M	TEP $2.2M	Idaho Power An IDACORP Company NA	Dominion Energy $0.5M	LG&E KU PPL companies $26.8M	DP&L $7.2M
Tri-State Generation and Transmission Association, Inc. $2M	Austin Energy $3.2M	American Electric Power Boundless Energy $12.8M	ipl an AES company $3.7M	FPL NA	DLC Duquesne Light Co. $1.5M	evergy $25.6M
						Georgia Power $35M
Liberty Utilities $11.3M	MGE Madison Gas and Electric NA	Potomac Edison A FirstEnergy Company $12.5M	Duke Energy $67.9M	conEdison $162.2M	Gulf Power $0.4M	Alabama Power $1.5M

Updated: 8/18/2022, Source: North American Utility Electric Transportation Charging Infrastructure: Program Overview, EPRI, March 2021; individual utility interviews

Utility Preparedness Needed for Rapid Transportation Electrification

EVALUATE ROLE
in supporting or providing charging infrastructure (ETIPS)

STAFF UP ET teams

REVIEW COST ALLOCATION POLICIES
for grid upgrades for ET residential customers as well as fleets

REVIEW PROCESSES your service planning, interconnection, and distribution planning processes for residential and fleet customers

REVIEW RATE OPTIONS for large ET customers

CONNECT WITH STATE AND LOCAL AGENCIES to coordinate EV incentives and public education programs

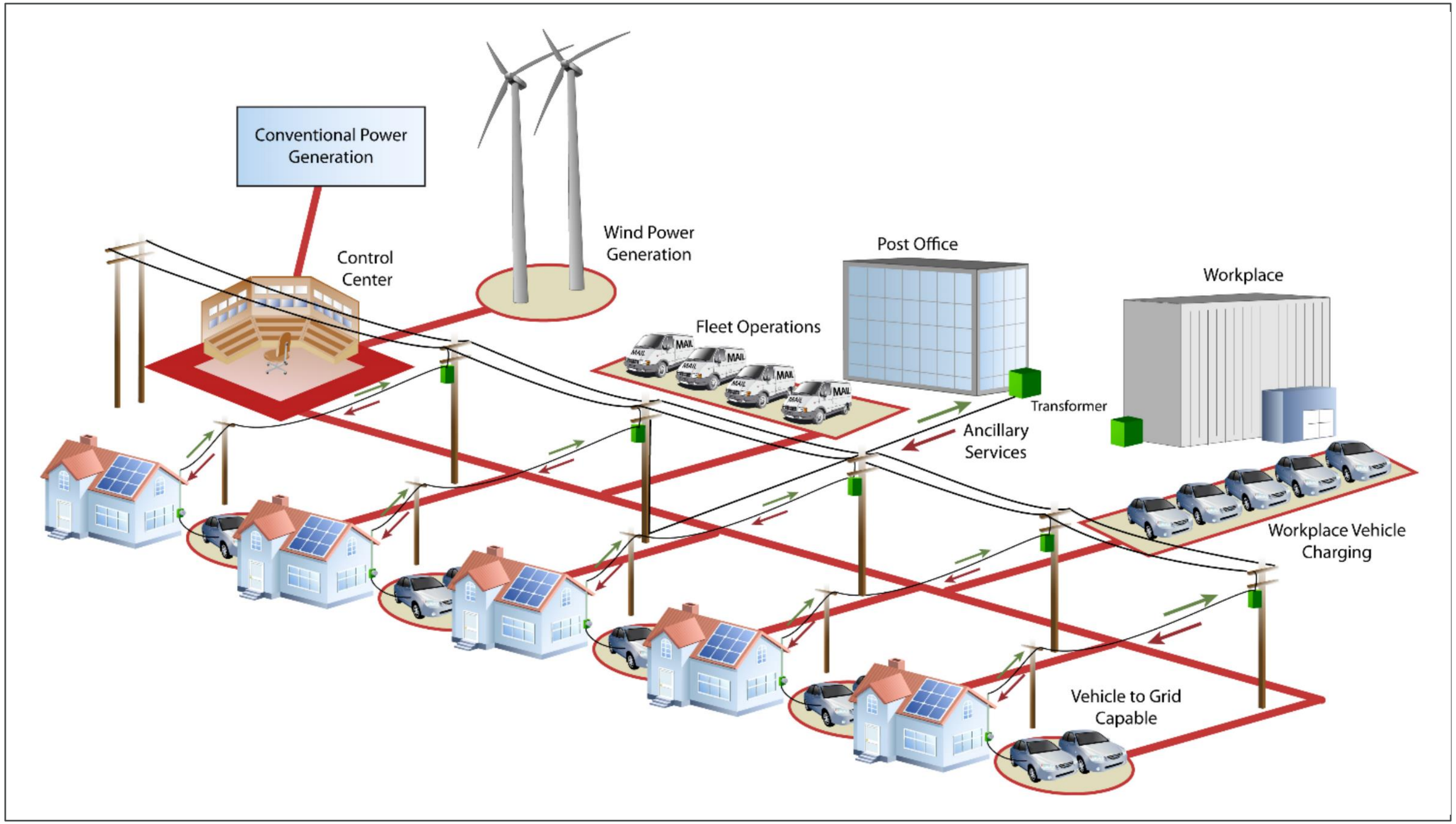
CONNECT WITH STATE AND LOCAL AGENCIES to coordinate EV incentives and public education programs

REVIEW SUPPLY CHAIN AND LABOR
Figure out how to ensure that parallel bottlenecks are also resolved

OPEN DIALOGUE
with neighboring utilities to explore or coordinate regional EV charging networks for passenger EVs (highway)

V2X DISCUSSION

What is Vehicle to X (V2X)?



Vehicle to Load (V2L), Vehicle to Building (V2B), and Vehicle to Grid (V2G) are separate concepts, collectively referred to as Vehicle to X (V2X).
V2X = V2G + V2L + V2B

Vehicle to X is the use of electrical components in plug-in vehicles to support power system functions.

Vehicle types:

- Battery Electric Vehicles
- Plug-in Hybrid Vehicles

Ownership types:

- Personal Vehicles
- Commercial Vehicles
- Industrial Vehicles

Services:

- Time-shifting energy
- Capacity (G, T, and/or D)
- Power Factor Correction
- Voltage Support
- Ancillary Services
- Anything a battery can do

Distinctions among V2X Systems

EVs2Scale2030

Vehicle to Load -

- Vehicle carries the DC/AC inverter on-board; Grid-independent operation
- Standby power with on-board 120V/240V outlets,
- Primary purpose is worksite / camping / mobile applications, very similar to a portable generator
- Vehicle charges from AC or DC, discharges via AC ports
- Can also be offered on an ICE or an HEV

Vehicle to Home

- Similar to V2L, but primarily tied to the residential circuit through a dedicated emergency load panel, or through a smart panel. The system only sends reverse power when isolated from the grid
- Possible with ICE, HEV or EVs, although the OEMs are focused on making this an EV-only feature
- Vehicle standby power source needs to be wired into the residential circuit by a licensed electrician to create a safe operating environment
- EV and the EV owner must govern how to utilize the on-board batteries for backup power vs. mobility
- Utility side switch or notification may be required, if operated as a standby generator

Vehicle to Grid

- Similar to Vehicle to Home, except that the system can send power back to the grid as well
- Requires interconnection screening and approvals
- Can participate in the energy services markets
- The inverter can be on- or off-board, and capable of grid-parallel or grid-forming operation
- V2G is on all OEMs' roadmaps, but not likely for another five years
- Given the designs the OEMs are pursuing, V2H to V2H will be an over-the-air software upgrade, once the on and off-board equipment and systems are interconnection-capable

Benefits of Managed Charging and V2G

Reduce customer's costs (ToU rates, demand charge, etc.)

Local energy management based on circuit capacity constraints

Distribution service (DR, managed DER program, etc.)

Peak Shaving, regulation services

Renewable balancing at local, distribution, and market-level

Local resiliency (V2H or V2B

(Reference) Technology Overview: Smart Charging. EPRI, Palo Alto, CA: 2021. 3002022458

Why the variations in V2X?

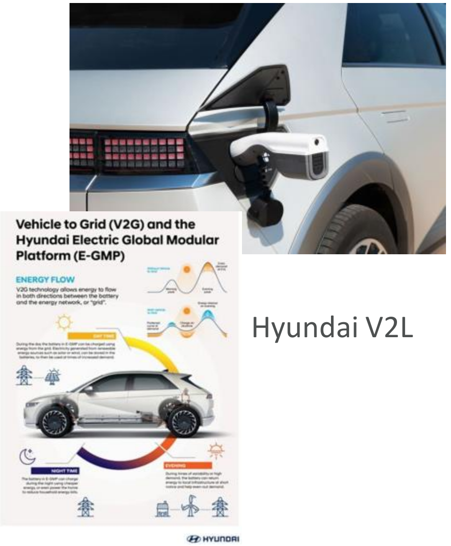
EVs2Scale2030

- Mid-2000s: Kempton et al set a very high expectation from EVs participating in regulation services market
  - EVs were not available, then not ready, then the batteries were an unknown for grid services applications
  - Most grid services focused on frequency / voltage regulation: continuous charge/discharge, 4 second signals – e.g., Nuvve
  - Interconnection was identified as a challenge, yet the technology did not deliver the value, and the OEM interest waned
    - Nissan CHAdeMO introduced in this timeframe
    - Big DoD pilot around the country – Early technology validation with mixed results
- OEMs then turned to V2L – Japanese OEMs spurred by Fukushima – every EV/HEV was required to have AC outlets for emergency power
  - GMT 800 Parallel Hybrid Truck had AC mains outlets for tailgaters
  - Simple, inexpensive, quick value to customers
  - Outlets delivered power to wifi, small appliances, mobile campers, etc
  - This trend continues – you can find products today with 120V outlets – no connection to the grid
- Standards mature for V2G, OEMs gain more confidence in battery capabilities, on-board batteries become substantial – approaching 100kWh or higher in some cases, and in California and in renewable-heavy jurisdictions, reliability/resiliency became an enabler
- OEMs are now looking at V2L as mainstream, V2H (backup power only) to be the near-term feature, with the wallbox connected to the breaker panel, supplying power to the house for several hours, likely integrated with local solar
- V2G is a stretch goal, subject to value and market participation ability, and subject to streamlining of the interconnection standards nationwide

OEMs Active in V2X Space

Nissan, With Fermata FE-15

Ford F150 System



Hyundai V2L

Rivian V2Fun

EPRI On-Vehicle (AC) V2G
Pilot with Stellantis, Honda, c:2019

Stellantis V2G pilots in EU

Flex Power SPIN DC V2G + Solar + Storage,
tested with Chevy Bolt, August 2021

Porsche Taycan EV V2G Pilot in the EU

EPRI has been at the Forefront of V2G Work

- 2008-2014 – Standards – based on IEEE2030.5
  - SAE J2847/3 – Smart Inverter Functions for V2X Systems
  - SAE J2847/2 – DC Charging Communications (harmonized with DIN70121)
  - SAE J3072 – Bidirectional Power Transfer
- 2011-present – Demonstrations
  - GM ARRA Project - V2X use cases
  - On-Vehicle (AC) V2G
    - Phase 1 (2016-2019) – CEC EPC 14-086 Development and demonstration with Stellantis and Honda, at UCSD Microgrid
    - Phase 2 (2022-present) – SCE, Stellantis, Eaton, Kitu, EPRI – Formalizing production requirements including Rule 21 interconnection
  - Off-Vehicle (DC) V2G – Smart Power Integrated Node (SPIN)
    - Phase 1: Concept /requirements development – EPRI TI
    - Phase 2: Proof of concept, production-intent design and integrated demonstration with Stellantis and (GM) – DoE VTO, DoE SETO, and CEC projects
  - V2G Battery impacts testing with NREL – 4.3 years of data
  - School Bus V2G pilot with Dominion Energy (Ben Y, Mark K)
- 2011-2015 – V2G Equipment Testing (Halliwell)
  - Two systems, tested in EPRI Knoxville lab
- Current work
  - Ford F150 Lightning grid interconnection requirements for V2H and V2G
  - V2G-DERMS integration requirements
  - AC and DC V2X backup power system integration/control systems into smart home systems
  - Just put in large-scale School Bus V2G deployment proposal (DoE GRIP)
  - V2G Cybersecurity – project just beginning within the SCE V2G Forum

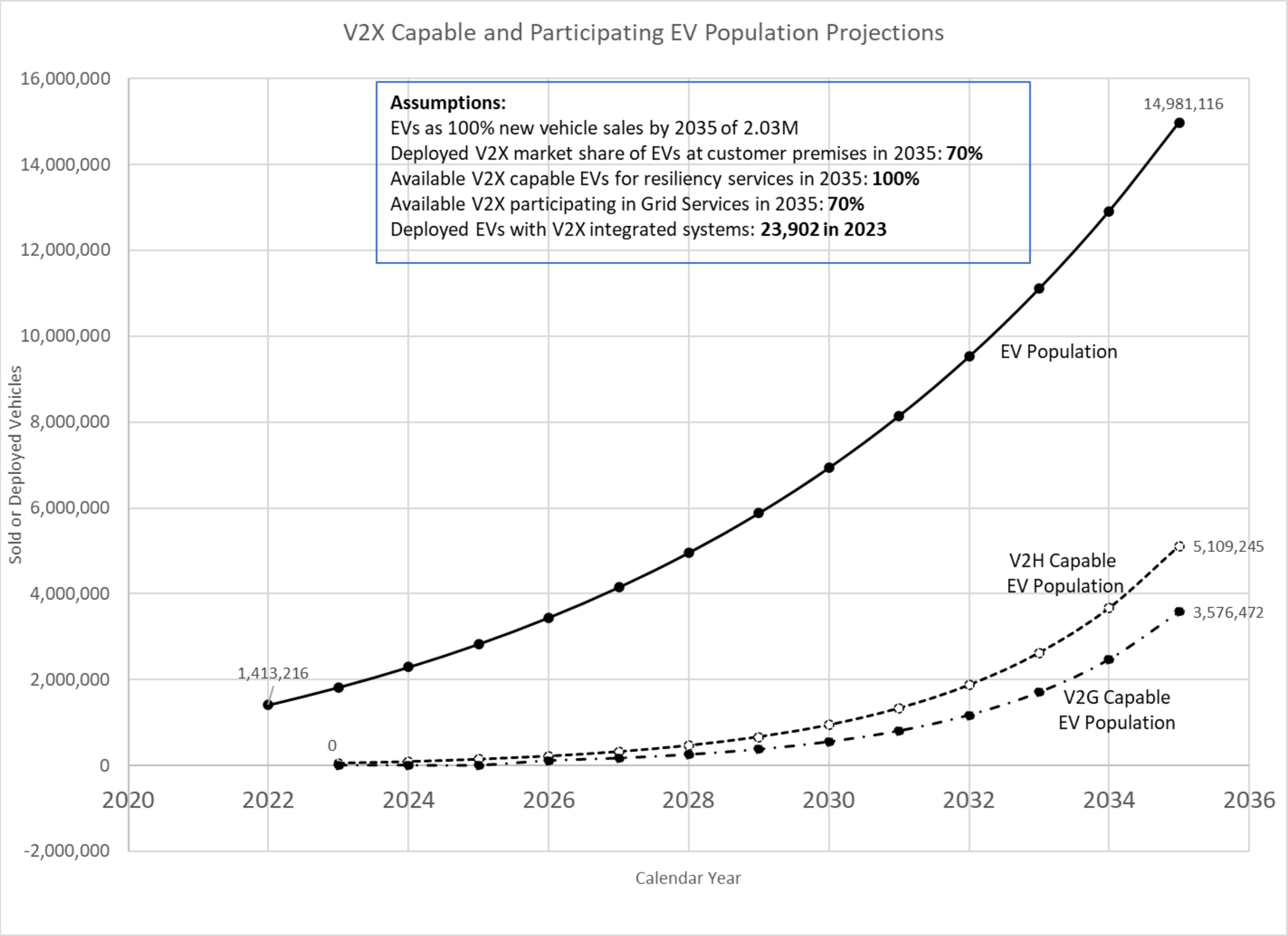
Some Thoughts (i.e., ‘Connecting the Dots’)

- In the US, light-duty product focus is on backup power operation for outage resilience – the auto industry ‘ask’ is how to qualify their equipment for a backup generator-only mode of operation
- Grid-interactive operation can be enabled for DC V2G systems – the interconnection requirements well-known (Rule 21, IEEE1547, IEEE2030.5, UL1741, UL9741 etc)
  - Subject to value being available to the EV owner through market mechanisms
  - Subject to tight control over battery operation from the OEMs and EV owners to ensure no warranty violations
- EPRI has the broadest reach within the global automotive industry to enable and demonstrate industry-wide uniform requirements for grid integration

CHALLENGES AND OPPORTUNITIES WITH EVs ON THE GRID

Gazing the Crystal ball – Forecasted* EV Sales in CA with V2X Capabilities

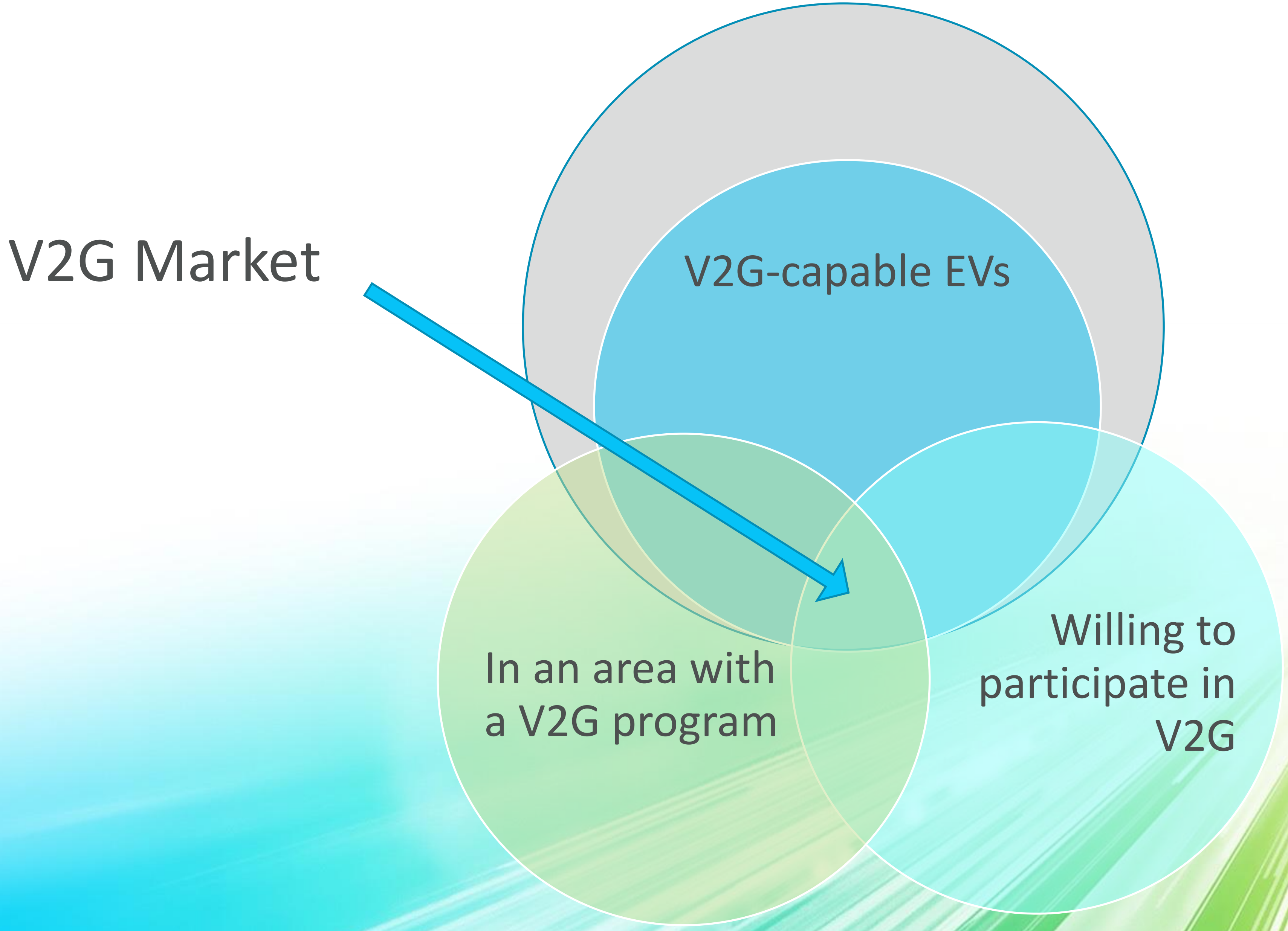
EVs2Scale2030



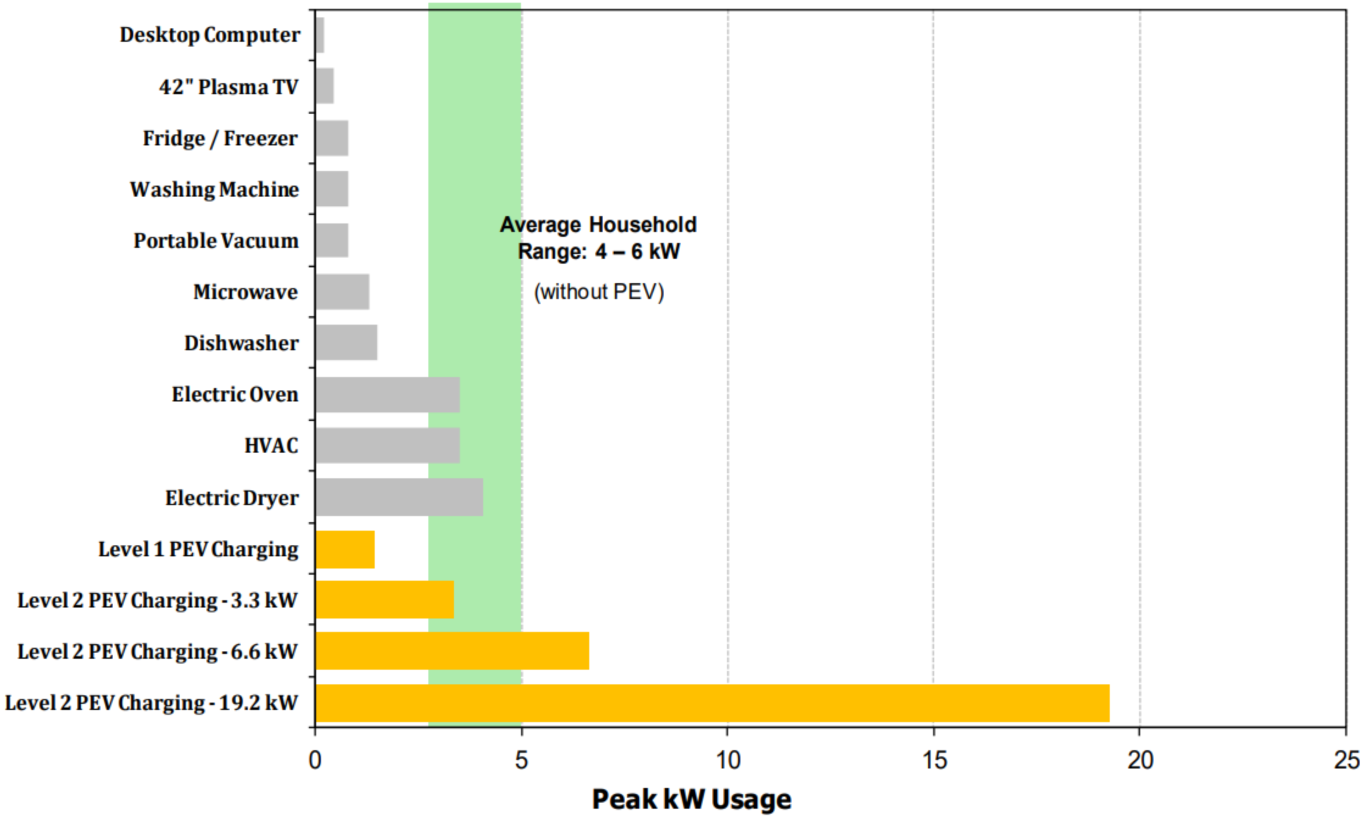
- Our calculations include 250,000 V2X capable EVs available for resiliency / grid services by 2030 (250,000 EVs = 2.5GW capacity @ 10kW/EV)

- There is sufficient evidence of value to the customer and the value to the grid to justify investing in promoting this technology through policy enablers

**Source: EPRI high level analysis, meant to make the central point*


V2G Market
V2G-capable EVs
In an area with a V2G program
Willing to participate in V2G

V2G can be 3-5x Residential Average Load



V2G export capacity can be limited by the capacity of the onboard charger for power export, or the capacity of a separate device.

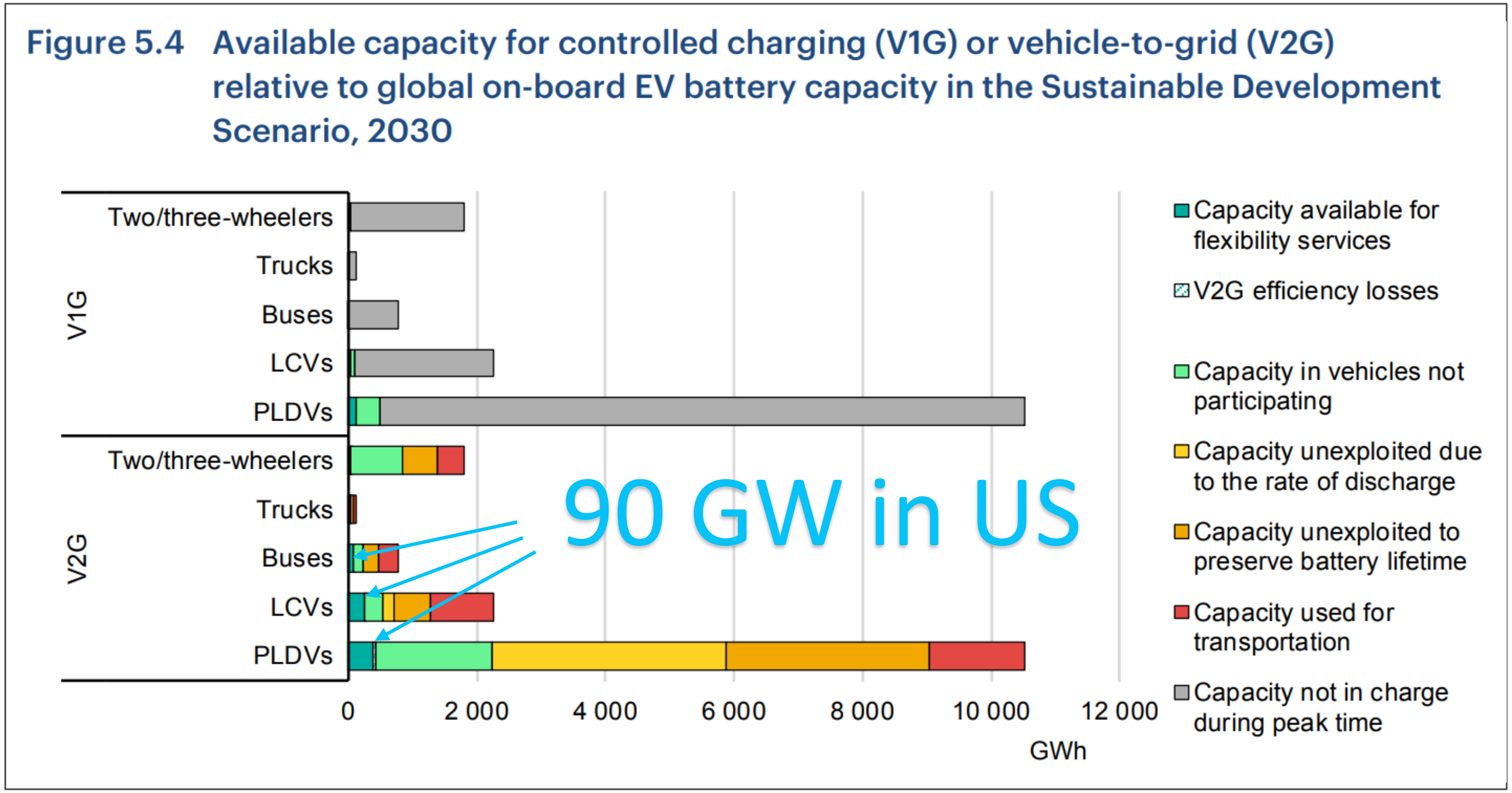
Higher capacities may be preferred, depending on compensation structures.

V2G can be dispatched by the utility, an aggregator, a third party, or the vehicle user.

19.2kW onboard chargers have been available for several years, they are increasingly common standard equipment on trucks and SUVs.

Open Standards-Based Vehicle-to-Grid: Value Assessment (epri.com) EPRI Product ID 3002014771

IEA International Perspective



The same EVs may provide 10x or more capacity under different assumptions.

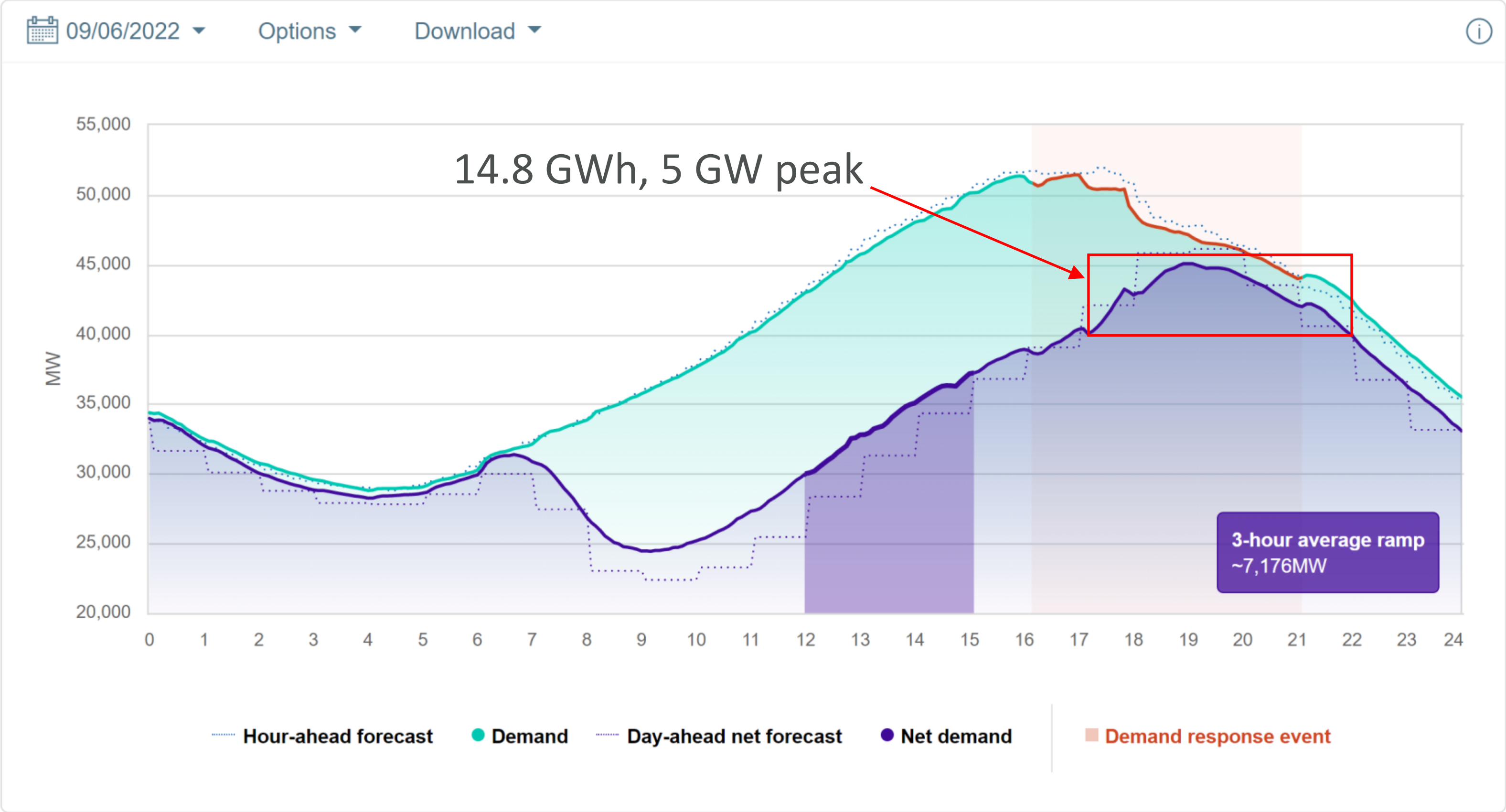
Capacity in Vehicles Not Participating may become available through changes to compensation schemes.

Capacity Unexploited Due to the Rate of Discharge may become available with higher capacity V2G interfaces. Limited to 10kW in this analysis.

Capacity Unexploited to Preserve Battery Lifetime may become available with battery chemistry changes, compensation, or improvements in lifecycle asset knowledge.

From IEA Global EV Outlook 2020 https://www.iea.org/reports/global-ev-outlook-2020

So what? Who Cares?



Record heat in California resulted in grid stress. What if V2G was operational?

Days with <40 GW peak use little or no demand response, indicating minimal grid stress. Estimate V2G need to reduce Net Demand to 40 GW.

25 kWh of V2G from 590k EVs would prevent the Net Demand from exceeding 40 GW. Each EV would contribute at 8.5 kW peak.

Getting 590k EVs to contribute requires:

- 1.5M EVs with 39% participation
- 36M EVs with 1.6% participation

1.5M EVs in CA today
36M total registered vehicles in California

https://www.caiso.com/TodaysOutlook/Pages/default.aspx#section-net-demand-trend

https://www.dmv.ca.gov/portal/uploads/2020/06/2019-Estimated-Vehicles-Registered-by-County-1.pdf

V2X VALUE TO THE GRID

Value per EV from Near-Term Applications

Resiliency	Savings of $15,000 - $20,000 by *not* using a stationary battery for power backup
Distribution System Peak Savings	~$1100/year/vehicle, at $11/kW
Resource Adequacy	$1200/year/vehicle, at $10/kW/month
Renewable Curtailment	$454/year/vehicle

**Source: EPRI Distributed Energy Resource Value Estimation Tool (DER-VET)*

Distribution Circuit Peak Shaving (Avoided Capacity Costs)
Value per EV: $1100-$1200/year

Assumptions

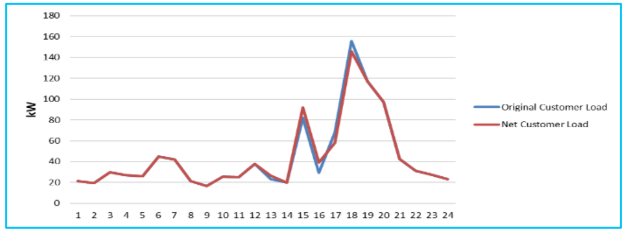
Tariffs

Summer			Winter			Summer & Winter
On Peak	Mid Peak	Off Peak	Mid Peak	Off Peak	Super Off Peak	All Hours
$0.47/kWh	$0.277/kWh	$0.182/kWh	0.297/kWh	$0.173/kWh	$0.14/kWh	$10.77/kW

Time of Use Definition

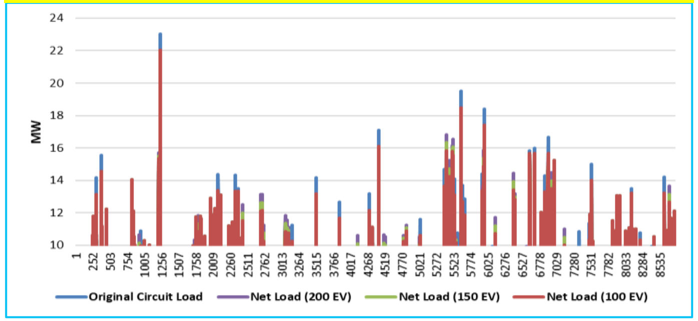
Season	Period	Hours
Summer	On Peak	16:00 – 21:00 (Weekdays)
	Mid Peak	16:00 – 21:00 (Weekends)
	Off Peak	0:00 – 16:00 & 21:00 – 00:00 (Weekdays & Weekends)
Winter	Mid Peak	16:00 – 21:00 (Weekdays & Weekends)
	Off Peak	0:00 – 8:00 & 21:00 – 00:00 (Weekdays & Weekends)
	Super Off Peak	8:00 – 16:00 (Weekdays & Weekends)

Original vs. Net Load Comparison – Per Customer



Results – Demand Charge Mitigation @ $11/kW

Original vs. Net Load Comparison – Per Feeder Circuit, with 100, 150 and 200EVs per Feeder



Distribution Demand Charge Savings/EV

Scenario	EV Availability	Average Net Peak Load Reduction	Total Bill Savings	Incentive per EV
Scenario 1	100 EVs	6.29%	$241,672	$1,208
Scenario 2	150 EVs	9.18%	$346,148	$1,154
Scenario 3	200 EVs	10.77%	$430,786	$1,077

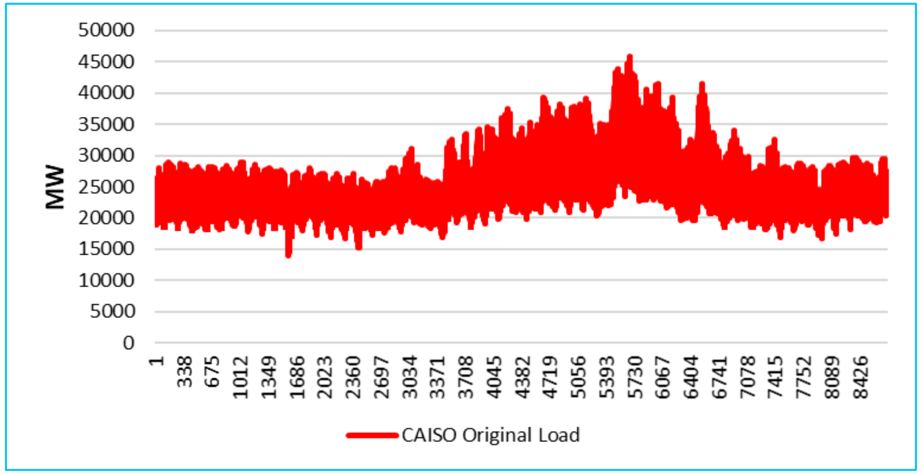
Note: For all analyses except resiliency, 10kW/20kWh EV capacity is assumed to be available on a more frequent basis

**Source: EPRI Analysis with DER-VET*

Resource Adequacy - $10/kW/month, $1200/year

Inputs

CAISO Load Profile (2020)



RA Analysis Inputs

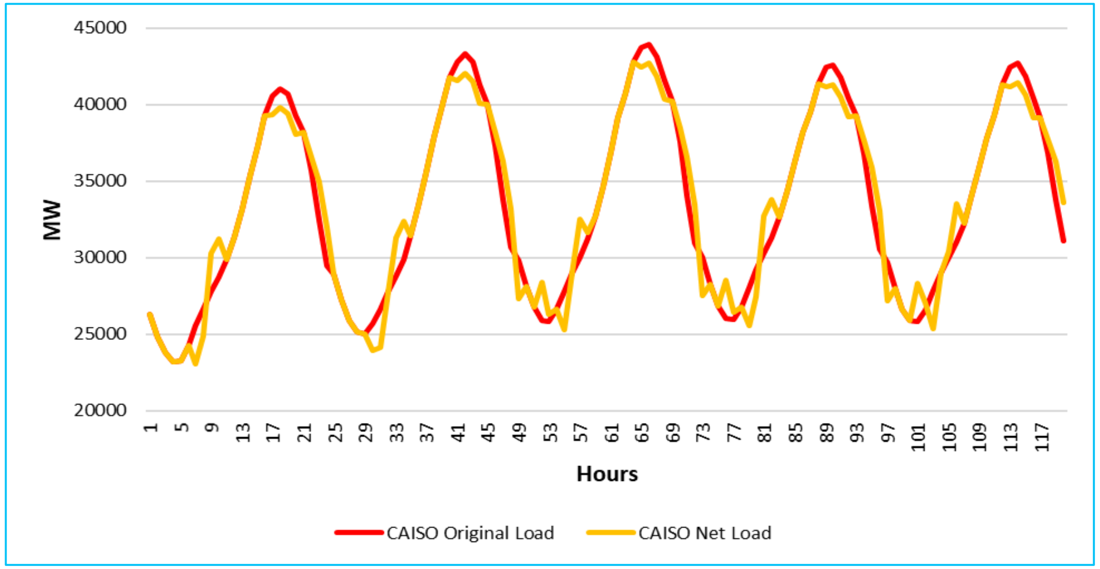
Parameter	Value
No. of RA Events	10 per year
RA Event Duration	4 hrs
Contracted Capacity	10 kW, 20 kWh
RA Monthly Payment	$10/kW-month

Source: EPRI Analysis with DER-VET

Results

- Assuming 250,000 EVs effectively capable of DC V2G, at 10kW/20kWh, with $10/kW-month compensation, **Per-EV compensation can be $1200/year**

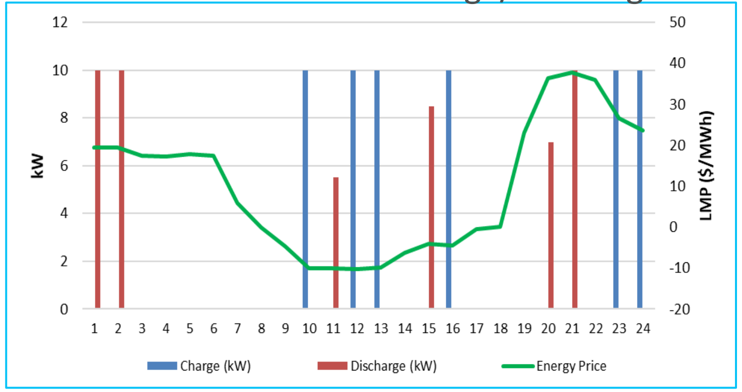
CAISO Load Profile (08/17-08/21/2020) with Hypothetical EVs w/ V2G



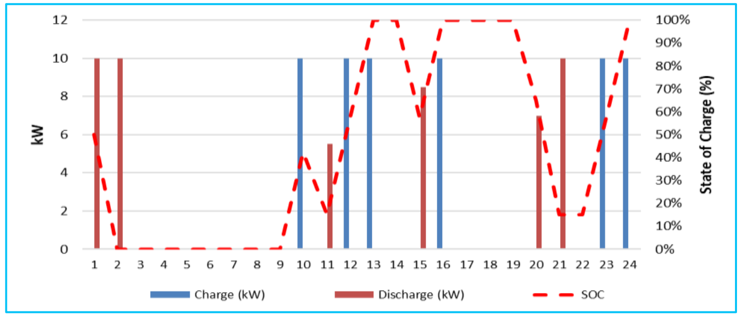
Renewable Curtailment Mitigation: $454/year

Inputs and Control Strategy

24-hour Load Profile with Charge/Discharge vs. LMP



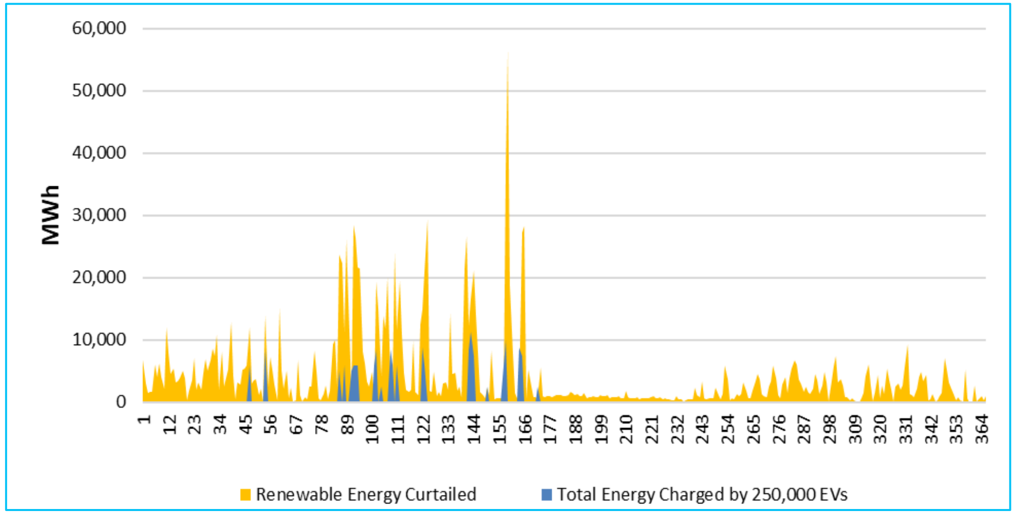
24-hour Battery SOC Variability



Assume 250,000 EVs effectively V2G Capable, at 10kW/20kWh Participating in the Market

Outputs and Net Impact

365-day Renewable Energy Reduced Curtailment



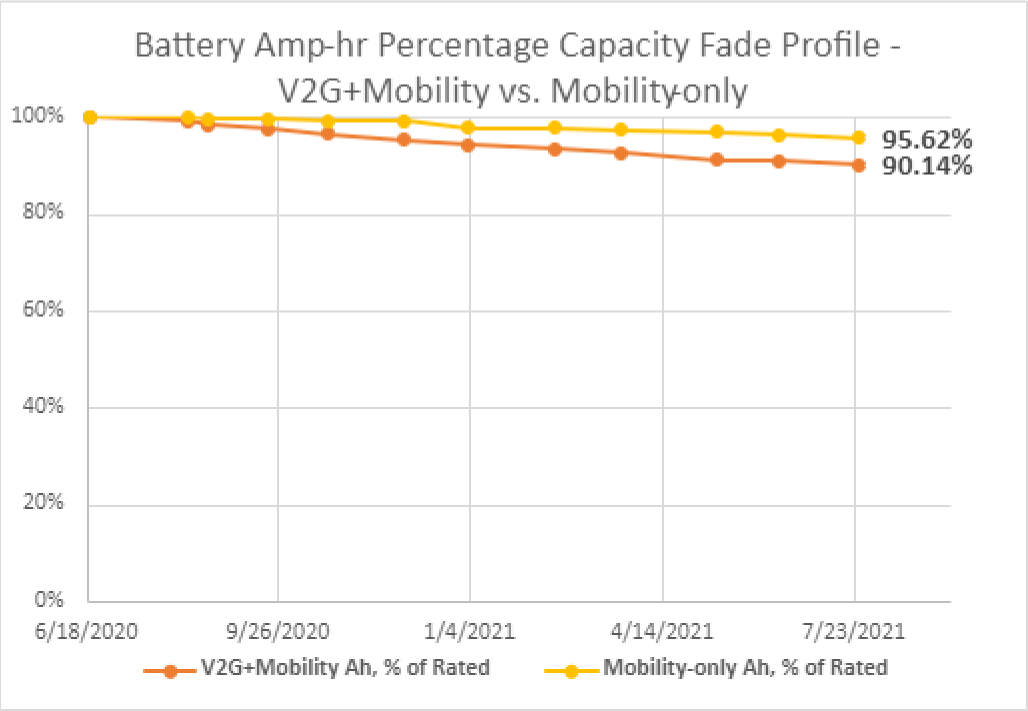
- Per-EV Impact on Grid GHG Reduction: 125 lb/year
- Per-EV Incentive earned: **$454/year** thru participation in the wholesale market

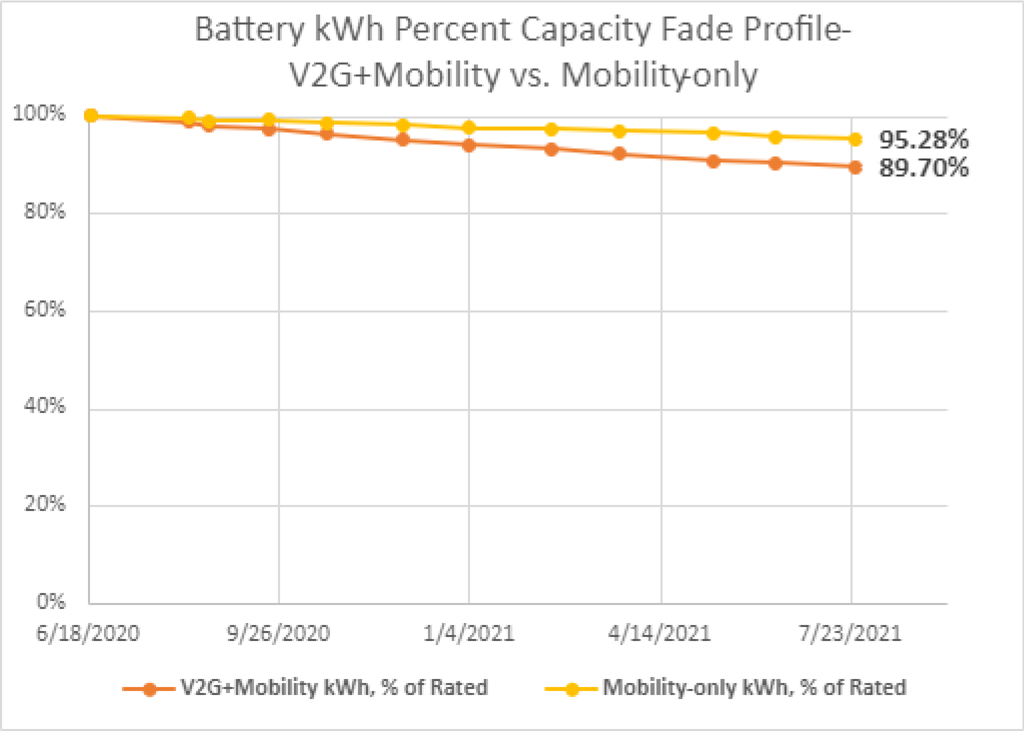
**Source: EPRI Analysis with DER-VET*

WHAT ABOUT THE BATTERY DEGRADATION? WON'T I LOSE MY WARRANTY?

The OEM and customer can *manage* capacity degradation by allowing the batteries to participate only in the highest-value use cases

EVs2Scale2030

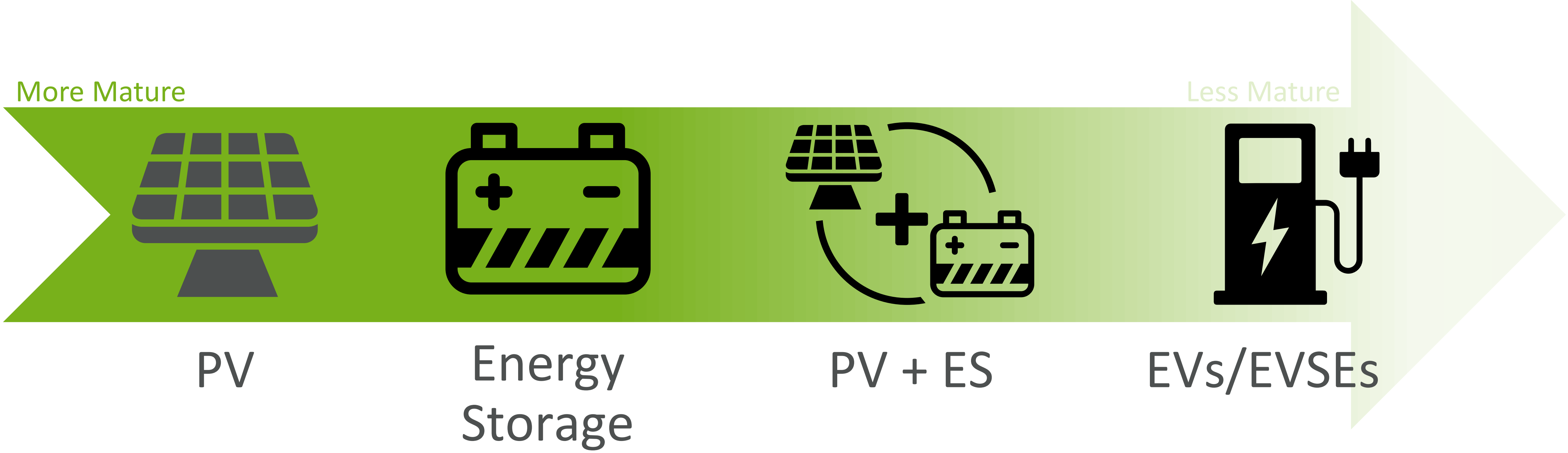




- EPRI-NREL joint data, with real-world test schedule, real-world batteries, very aggressive discharge each day 35% SOC
- This resulted in an incremental 1.5% battery capacity loss per year due to V2G
- 10 years: Mobility-only: 15%, Mobility + V2G: 30%
- Needs to be validated at scale, but it's not doom and gloom, and no two vehicles are driven alike, so YMMV (Your Mileage Ma

COMMUNICATIONS AND INTERCONNECTION STANDARDS

DERMS to EV/EVSE Integration Still Has Gaps

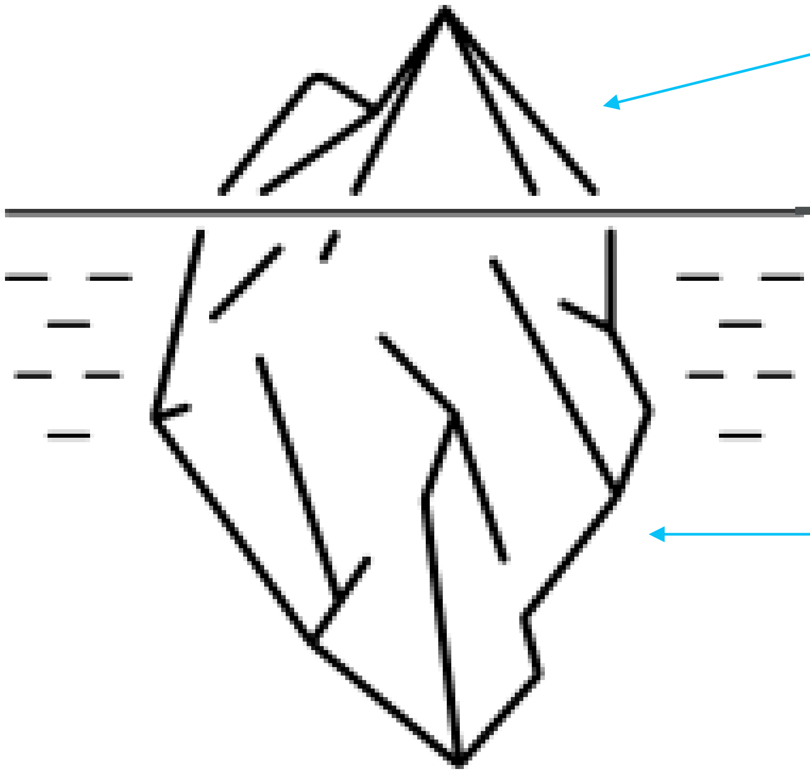


EVs are not just “ES systems on wheels” – small differences can matter

However, can leverage existing systems and intel

Source: EPRI Research, Program 18 (Electric Transportation) and Program 174 (Distributed Renewables)

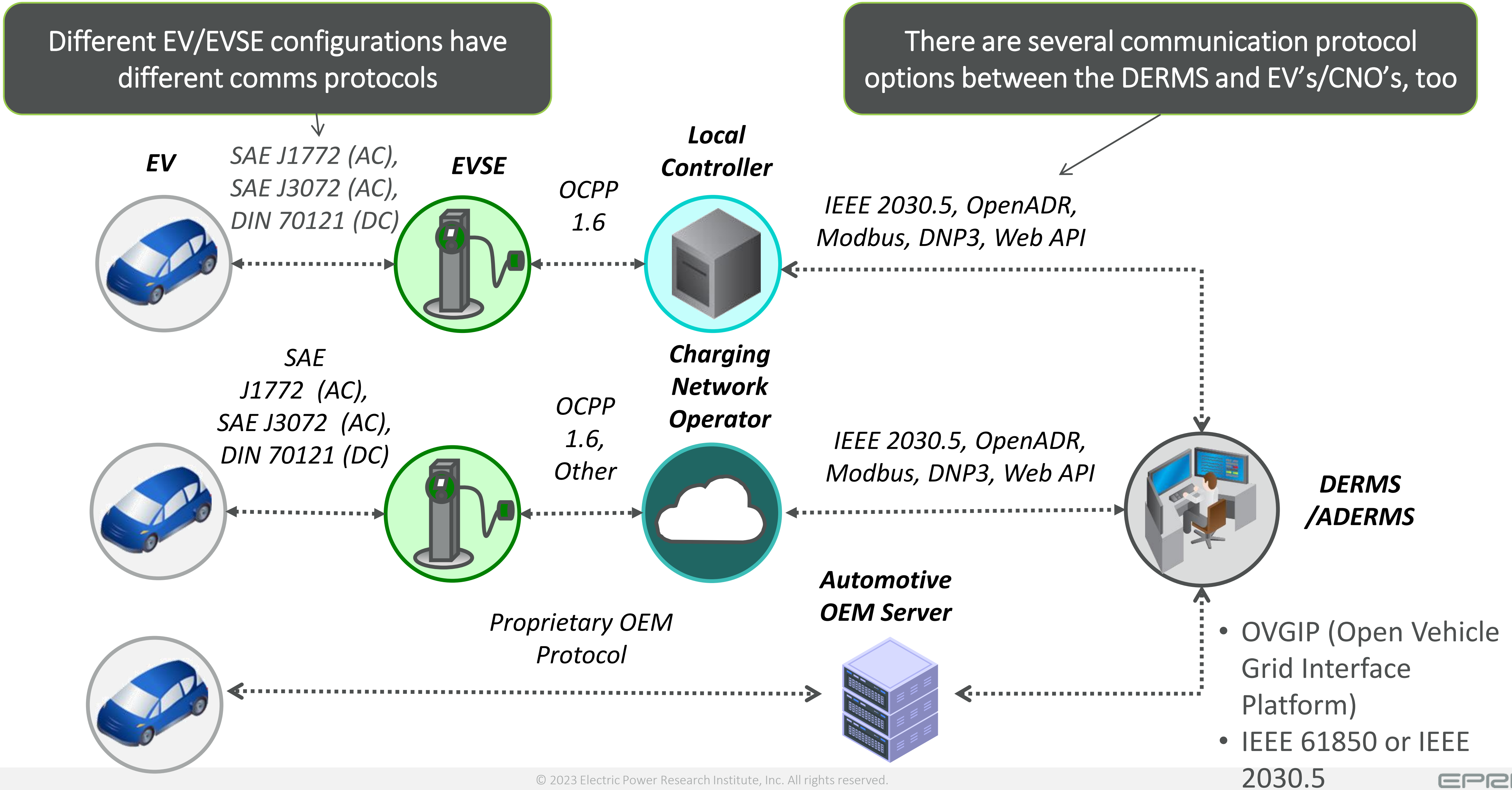
The Hidden Difficulties of V2X Coordination



V2X Services Work Seamlessly for the Consumer

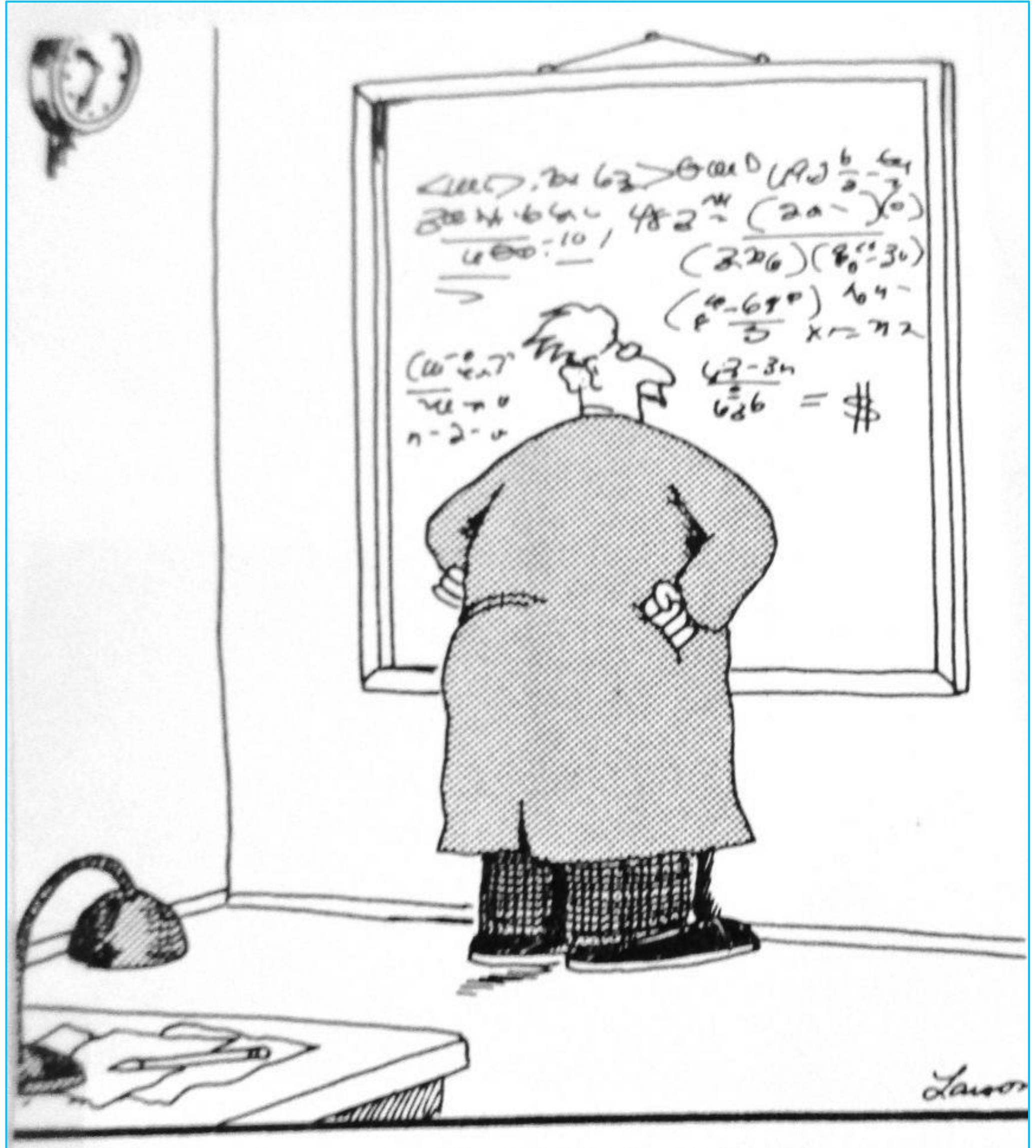
Aligning Communications Protocols
Standards Harmonization
Interoperability
Coordination Between EVSE/OEMs

Communications Protocol Interaction



WHAT NEXT?

Follow the Money



Einstein discovers that time is actually money.

- Multiple business cases must be simultaneously satisfied
  - **Customer**: must see the value, net of cost, with no downside
  - **OEMs** and equipment providers: Must see a positive return on investment
  - **Utilities**: Must be able to realize the grid benefits
  - **Market**: must be able to accommodate this new resource class

How do we get V2X at Scale?

EVs2Scale2030

Standards and Interoperability – When?	Timeline for interoperable systems – a realistic assessment as to when J1772-equivalent IEC/ISO-compliant V2X systems could make a significant entry into the marketplace
Customers – Ready?	How will the customers see this technology to be willing to pay for the wall boxes (or on-vehicle systems) for significantly long-term backup power provision
Markets – Which, and how?	Which potential market mechanisms can V2G capable EVs participate in? What is the anticipated benefit to the grid (and to the consumer)?
Vehicles – When?	Technology readiness on-vehicle and off-vehicle: When can the at-scale deployable hardware cost-effectively show up?

Customers – When are they ready?

Once reverse power flow functionality is available (e.g., F150 Lightning), customers see the benefits of EV batteries for back-up power (without dedicated stationary storage), and NEM3 benefit enhancers

- Biggest benefit is to replace dedicated storage, a $25k-30k value for 20kWh or 40kWh batteries

Market participation subject to proven interconnection capabilities and sufficient remuneration

- Incentives expected by consumers to 'bite' >> grid benefits (e.g., PG&E pilot)
- EPRI working with Ford and other utilities to formalize the interconnection requirements (contact me if interested)

OEMs need to design the stationary storage support functionality and customer preferences ability into the vehicles and support systems

Standardization of the home wiring and grid disconnect/reconnect (Grid parallel/independent) transition algorithms necessary and approved

Entire systems need to be proven to be safe, durable, and value-providing

V2G Services Markets – which and how?

Value elements

- Distribution upgrade deferral (market?),
- Resource adequacy
- Demand charges
- Ancillary services
- Renewable curtailment mitigation

Signaling, procurement, M&V and remuneration mechanisms must be defined – good news – they exist for stationary storage

Value could be as high as $100/month cumulatively – if markets can be available

Vehicles – When?

EVs2Scale 2030

All vehicles have DC CCS – make it bidirectional and they are here!

Equipment needs to follow

Causality: utilities and markets are ready → Vale prop is proven → technology is settled → Vehicles available → All hypothesis proven → Customers buying in large numbers →More V2X capable EVs and equipment appear

This is a causal chain. If you break a link, it breaks down. So,V2X Vehicles will appear when the business case is clear and the customers want them

What can the Utilities do to help?

1. Jointly define grid integration requirements – EPRI is the best forum to collaborate with the OEMs, Standards bodies, and equipment manufacturers in an actionable way
    - Communications Protocols
    - Interconnection Standards
    - Orderly Integration with local DERs, premise, and distribution grid
2. Engage the customers through small and medium-scale pilots to assess real-world value, customer interest, and grid integration challenges
3. Enable deployment of V2X technology at scale through customer programs designed to bring value to the grid

Thank You!