Transportation Electrification: Overview and Emerging Opportunities

Allan Zhao
Engineer/Scientist II, Electric Transportation
+1 (408) 858-3673
azhao@epri.com
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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)
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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
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**OEM EV COMMITMENTS + INVESTMENTS**

- **2025**
  - $86b through 2025
  - $35.5b through 2025
  - 20% Kia EV sales by 2025, $7.4b in US by 2025
  - No ICE dev. after 2025
  - $35b through 2025
  - 50% BEV globalsales by 2025, $1.2b on EV plant

- **2026**
  - $50b through 2026
  - $17b through 2026
  - 1st EV launching in 2026
  - no ICE investments after 2026

- **2030**
  - 100% EV sales by 2030, $47b globally through 2030
  - 50% EV sales by 2030
  - 50% EV sales in US & 70% in EU by 2030
  - 40% EV sales by 2030 in US
  - 50% EV sales by 2030, Cadillac 100% EV by 2030
  - 55% EV sales in US by 2030

- **2035**
  - 100% EV sales by 2035
  - EV sales 50% in US & 70% in EU by 2030
  - 40% EV sales by 2030, $40b through 2030

- **2036+**
  - 100% EV sales in EU by 2035
  - 100% EV sales in EU by 2035
  - 100% EV sales by 2039, $3.4b on EV dev.
  - 100% EV sales by 2035

- **2040**
  - No ICE investments after 2026
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
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INCREASING VEHICLE DIVERSITY + CAPABILITY

![Graph showing increasing vehicle diversity and capability over time.](image)
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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**

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

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

2022 HIGHLIGHTS / 2023 EARLY TAKEAWAYS
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%

Nationwide avg new EV market share: 7.3%
Number of counties exceeding avg: 204
Number of states with counties exceeding avg: 38
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**ELECTRIFICATION PRESENTS SIGNIFICANT UTILITY OPPORTUNITIES**

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

1. CHARGING AVAILABILITY
2. CHARGING RELIABILITY
3. 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

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

**Budget %**
- Make-ready/Rebate 56%
- Utility-owned 6%
- Hybrid 38%
# North American Utilities EV Infrastructure Investment

## Dashboard Overview

<table>
<thead>
<tr>
<th>Utility</th>
<th>Investment Amount</th>
</tr>
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<tbody>
<tr>
<td>Hawaiian Electric</td>
<td>$2.3M</td>
</tr>
<tr>
<td>Seattle City Light</td>
<td>$2.8M</td>
</tr>
<tr>
<td>Otter Tail</td>
<td>$2.1M</td>
</tr>
<tr>
<td>Atlantic City Electric</td>
<td>$42.1M</td>
</tr>
<tr>
<td>Hydro Québec</td>
<td>$10M</td>
</tr>
<tr>
<td>Ontario</td>
<td>$20M</td>
</tr>
<tr>
<td>BC Hydro</td>
<td>NA</td>
</tr>
<tr>
<td>Avista</td>
<td>$3.1M</td>
</tr>
<tr>
<td>Puget Sound Energy</td>
<td>$15.5M</td>
</tr>
<tr>
<td>Bear Valley</td>
<td>$0.7M</td>
</tr>
<tr>
<td>Central Maine Power</td>
<td>$0.2M</td>
</tr>
<tr>
<td>Eversource Energy</td>
<td>$12.5M</td>
</tr>
<tr>
<td>Narragansett</td>
<td>$11.5M</td>
</tr>
<tr>
<td>PGE</td>
<td>$24.8M</td>
</tr>
<tr>
<td>Pacific Power</td>
<td>$0.8M</td>
</tr>
<tr>
<td>National Grid</td>
<td>$166.1M</td>
</tr>
<tr>
<td>NYSEG</td>
<td>$141.7M</td>
</tr>
<tr>
<td>New York Power Authority</td>
<td>$250M</td>
</tr>
<tr>
<td>Pepco</td>
<td>$17.3M</td>
</tr>
<tr>
<td>APS</td>
<td>NA</td>
</tr>
<tr>
<td>DWP</td>
<td>$420M</td>
</tr>
<tr>
<td>RG&amp;E</td>
<td>$141.6M</td>
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<tr>
<td>Delmarva Power</td>
<td>$13M</td>
</tr>
<tr>
<td>Pepco</td>
<td>$17.3M</td>
</tr>
<tr>
<td>SDG&amp;E</td>
<td>$191.4M</td>
</tr>
<tr>
<td>NV Energy</td>
<td>$23M</td>
</tr>
<tr>
<td>Southern California Edison</td>
<td>$855.7M</td>
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<tr>
<td>Consumers Energy</td>
<td>$22.2M</td>
</tr>
<tr>
<td>DTE</td>
<td>$13.1M</td>
</tr>
<tr>
<td>Central Hudson</td>
<td>$127.1M</td>
</tr>
<tr>
<td>Ameren</td>
<td>$11M</td>
</tr>
<tr>
<td>Xcel Energy</td>
<td>$132.3M</td>
</tr>
<tr>
<td>Rocky Mountain Power</td>
<td>$12M</td>
</tr>
<tr>
<td>TEP</td>
<td>$2.2M</td>
</tr>
<tr>
<td>PPL</td>
<td>NA</td>
</tr>
<tr>
<td>Dominion Energy</td>
<td>$0.5M</td>
</tr>
<tr>
<td>LG&amp;E</td>
<td>$26.8M</td>
</tr>
<tr>
<td>DP&amp;L</td>
<td>$7.2M</td>
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<tr>
<td>PPL</td>
<td>NA</td>
</tr>
<tr>
<td>American Electric Power</td>
<td>$191.4M</td>
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<tr>
<td>Ipl</td>
<td>$12.8M</td>
</tr>
<tr>
<td>FPL</td>
<td>NA</td>
</tr>
<tr>
<td>DLC</td>
<td>$1.5M</td>
</tr>
<tr>
<td>eversy</td>
<td>$25.6M</td>
</tr>
<tr>
<td>Georgia Power</td>
<td>$35M</td>
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<tr>
<td>Liberty Utilities</td>
<td>$11.3M</td>
</tr>
<tr>
<td>MGE</td>
<td>NA</td>
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<tr>
<td>PolaronEdison</td>
<td>$12.5M</td>
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<tr>
<td>Duke Energy</td>
<td>$67.9M</td>
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<tr>
<td>ConEdison</td>
<td>$162.2M</td>
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<tr>
<td>AEP</td>
<td>$0.4M</td>
</tr>
<tr>
<td>Alabama Power</td>
<td>$1.5M</td>
</tr>
</tbody>
</table>

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 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

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
<table>
<thead>
<tr>
<th>Distinctions among V2X Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vehicle to Load</strong></td>
</tr>
<tr>
<td>• Vehicle carries the DC/AC inverter on-board; Grid-independent operation</td>
</tr>
<tr>
<td>• Standby power with on-board 120V/240V outlets,</td>
</tr>
<tr>
<td>• Primary purpose is worksite / camping / mobile applications, very similar to a portable generator</td>
</tr>
<tr>
<td>• Vehicle charges from AC or DC, discharges via AC ports</td>
</tr>
<tr>
<td>• Can also be offered on an ICE or an HEV</td>
</tr>
<tr>
<td><strong>Vehicle to Home</strong></td>
</tr>
<tr>
<td>• 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</td>
</tr>
<tr>
<td>• Possible with ICE, HEV or EVs, although the OEMs are focused on making this an EV-only feature</td>
</tr>
<tr>
<td>• Vehicle standby power source needs to be wired into the residential circuit by a licensed electrician to create a safe operating environment</td>
</tr>
<tr>
<td>• EV and the EV owner must govern how to utilize the on-board batteries for backup power vs. mobility</td>
</tr>
<tr>
<td>• Utility side switch or notification may be required, if operated as a standby generator</td>
</tr>
<tr>
<td><strong>Vehicle to Grid</strong></td>
</tr>
<tr>
<td>• Similar to Vehicle to Home, except that the system can send power back to the grid as well</td>
</tr>
<tr>
<td>• Requires interconnection screening and approvals</td>
</tr>
<tr>
<td>• Can participate in the energy services markets</td>
</tr>
<tr>
<td>• The inverter can be on- or off-board, and capable of grid-parallel or grid-forming operation</td>
</tr>
<tr>
<td>• V2G is on all OEMs’ roadmaps, but not likely for another five years</td>
</tr>
<tr>
<td>• 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</td>
</tr>
</tbody>
</table>
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)

Why the variations in V2X?

- **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

All EV OEMs, whether on this list, are working on V2G Capable Products.
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)

  - 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

- 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

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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.

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**Figure 5.4** Available capacity for controlled charging (V1G) or vehicle-to-grid (V2G) relative to global on-board EV battery capacity in the Sustainable Development Scenario, 2030

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
V2X VALUE TO THE GRID
<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resiliency</td>
<td>Savings of $15,000 - $20,000 by <em>not</em> using a stationary battery for power backup</td>
</tr>
<tr>
<td>Distribution System Peak</td>
<td>~$1100/year/vehicle, at $11/kW</td>
</tr>
<tr>
<td>Resource Adequacy</td>
<td>$1200/year/vehicle, at $10/kW/month</td>
</tr>
<tr>
<td>Renewable Curtailment</td>
<td>$454/year/vehicle</td>
</tr>
</tbody>
</table>

*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**

<table>
<thead>
<tr>
<th>Season</th>
<th>Summer</th>
<th>Winter</th>
<th>Summer &amp; Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On Peak</td>
<td>Mid Peak</td>
<td>Off Peak</td>
</tr>
<tr>
<td></td>
<td>$0.47/kWh</td>
<td>$0.277/kWh</td>
<td>$0.182/kWh</td>
</tr>
</tbody>
</table>

**Time of Use Definition**

<table>
<thead>
<tr>
<th>Season</th>
<th>Period</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>On Peak</td>
<td>16:00 – 21:00 (Weekdays)</td>
</tr>
<tr>
<td></td>
<td>Mid Peak</td>
<td>16:00 – 21:00 (Weekends)</td>
</tr>
<tr>
<td></td>
<td>Off Peak</td>
<td>0:00 – 16:00 &amp; 21:00 – 00:00 (Weekdays &amp; Weekends)</td>
</tr>
<tr>
<td>Winter</td>
<td>Mid Peak</td>
<td>16:00 – 21:00 (Weekdays &amp; Weekends)</td>
</tr>
<tr>
<td></td>
<td>Off Peak</td>
<td>0:00 – 8:00 &amp; 21:00 – 00:00 (Weekdays &amp; Weekends)</td>
</tr>
<tr>
<td></td>
<td>Super Off Peak</td>
<td>8:00 – 16:00 (Weekdays &amp; Weekends)</td>
</tr>
</tbody>
</table>

**Results – Demand Charge Mitigation @ $11/kW**

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

<table>
<thead>
<tr>
<th>Scenario</th>
<th>EV Availability</th>
<th>Average Net Peak Load Reduction</th>
<th>Total Bill Savings</th>
<th>Incentive per EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>100 EVs</td>
<td>6.29%</td>
<td>$241,672</td>
<td>$1,208</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>150 EVs</td>
<td>9.18%</td>
<td>$346,148</td>
<td>$1,154</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>200 EVs</td>
<td>10.77%</td>
<td>$430,786</td>
<td>$1,077</td>
</tr>
</tbody>
</table>

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)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of RA Events</td>
<td>10 per year</td>
</tr>
<tr>
<td>RA Event Duration</td>
<td>4 hrs</td>
</tr>
<tr>
<td>Contracted Capacity</td>
<td>10 kW, 20 kWh</td>
</tr>
<tr>
<td>RA Monthly Payment</td>
<td>$10/kW-month</td>
</tr>
</tbody>
</table>

*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

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Renewable Curtailment Mitigation: $454/year

Inputs and Control Strategy

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

24-hour Battery SOC Variability

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

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

- 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 May
COMMUNICATIONS AND INTERCONNECTION STANDARDS
DERMS to EV/EVSE Integration Still Has Gaps

More Mature

PV

Energy Storage

PV + ES

EVs/EVSEs

Less Mature

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

Different EV/EVSE configurations have different comms protocols

- **EV**
  - SAE J1772 (AC), SAE J3072 (AC), DIN 70121 (DC)

- **EVSE**
  - SAE J1772 (AC), SAE J3072 (AC), DIN 70121 (DC)

- **Local Controller**
  - OCPP 1.6

- **Charging Network Operator**
  - OCPP 1.6, Other

- **DERMS/ADERMS**
  - IEEE 2030.5, OpenADR, Modbus, DNP3, Web API
  - OVGIP (Open Vehicle Grid Interface Platform)
  - IEEE 61850 or IEEE 2030.5

There are several communication protocol options between the DERMS and EV’s/CNO’s, too

- **Proprietary OEM Protocol**
- **Automotive OEM Server**
WHAT NEXT?
Follow the 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?

<table>
<thead>
<tr>
<th>Standards and Interoperability – When?</th>
<th>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</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customers – Ready?</td>
<td>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</td>
</tr>
<tr>
<td>Markets – Which, and how?</td>
<td>Which potential market mechanisms can V2G capable EVs participate in? What is the anticipated benefit to the grid (and to the consumer)?</td>
</tr>
<tr>
<td>Vehicles – When?</td>
<td>Technology readiness on-vehicle and off-vehicle: When can the at-scale deployable hardware cost-effectively show up?</td>
</tr>
</tbody>
</table>
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?

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!