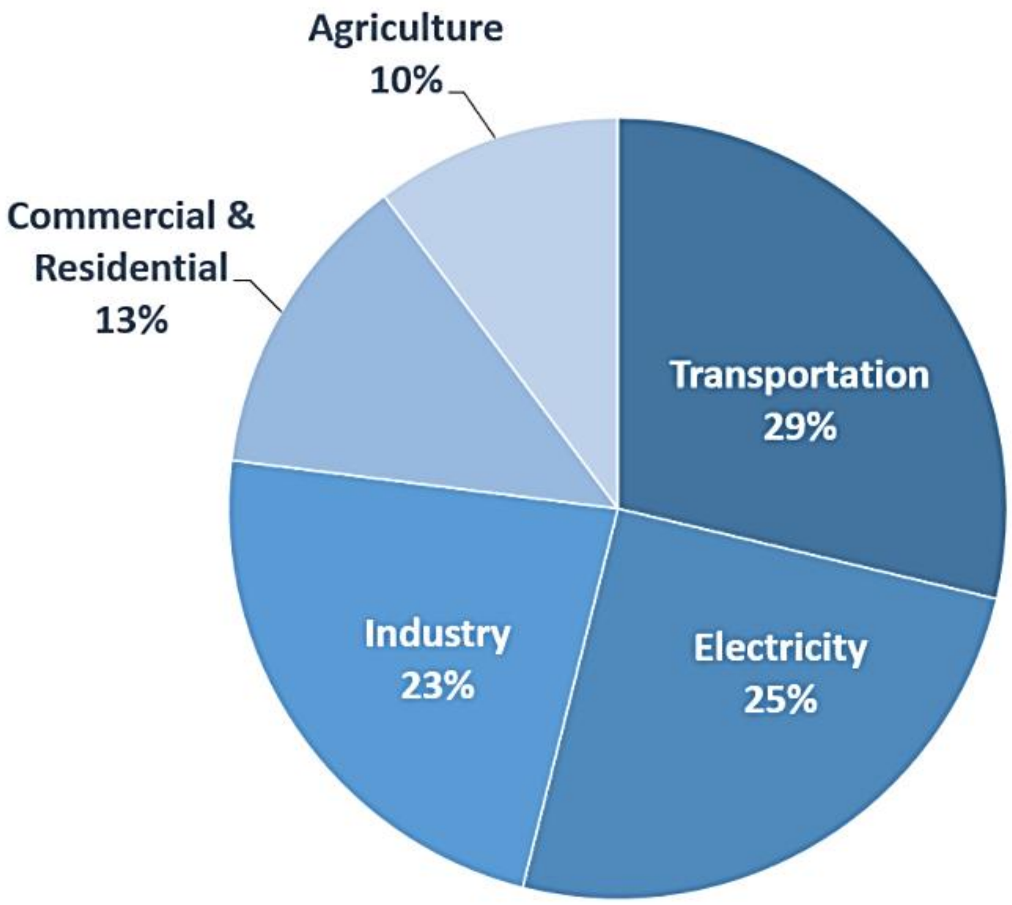
EV Charging Infrastructure Analysis

January 2022

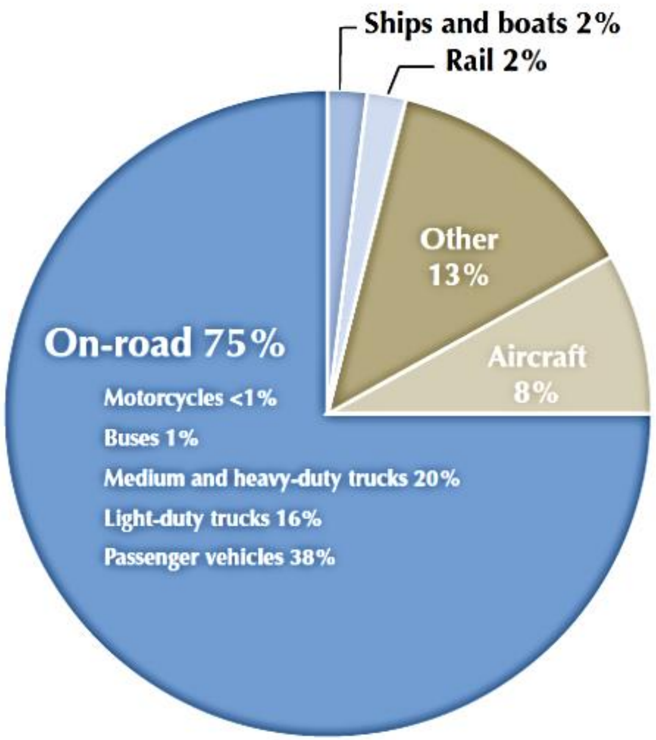
Outline

- What’s all the fuss about?
- Better than gasoline
- Show me the money!
- Measure twice, cut once
- 30 x 30
- Heavy-duty electrification
- Challenges and opportunities remain

The U.S. Transportation Sector



U.S. Environmental Protection Agency (2021). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019



The figure shows total U.S. transportation sector emissions in 2015. On-road transportation, comprised of passenger vehicles, truc buses, and motorcycles, accounted for 75 percent of the total. Emissions from pipelines, lubricants, and non-transportation mobile sources are shown collectively as 'Other.'

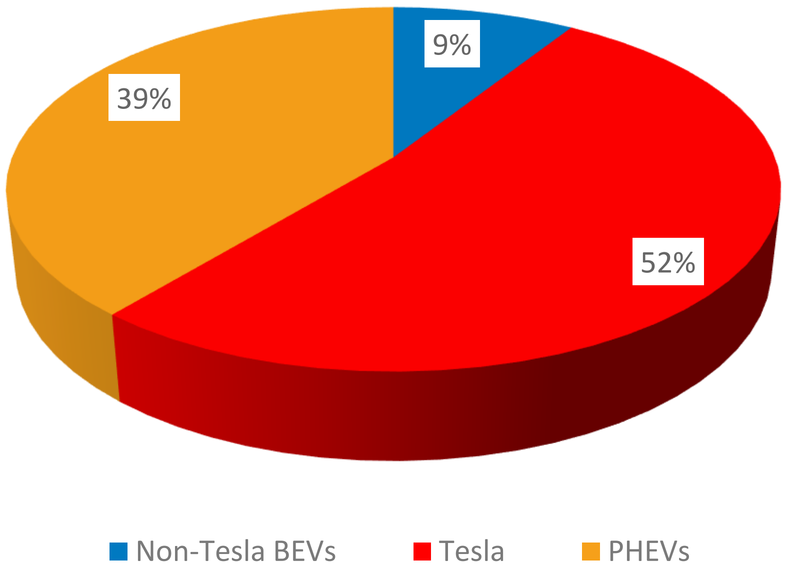
Source: U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2015 (Washington, DC: U.S. Environmental Protect Agency, 2017), https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2015.

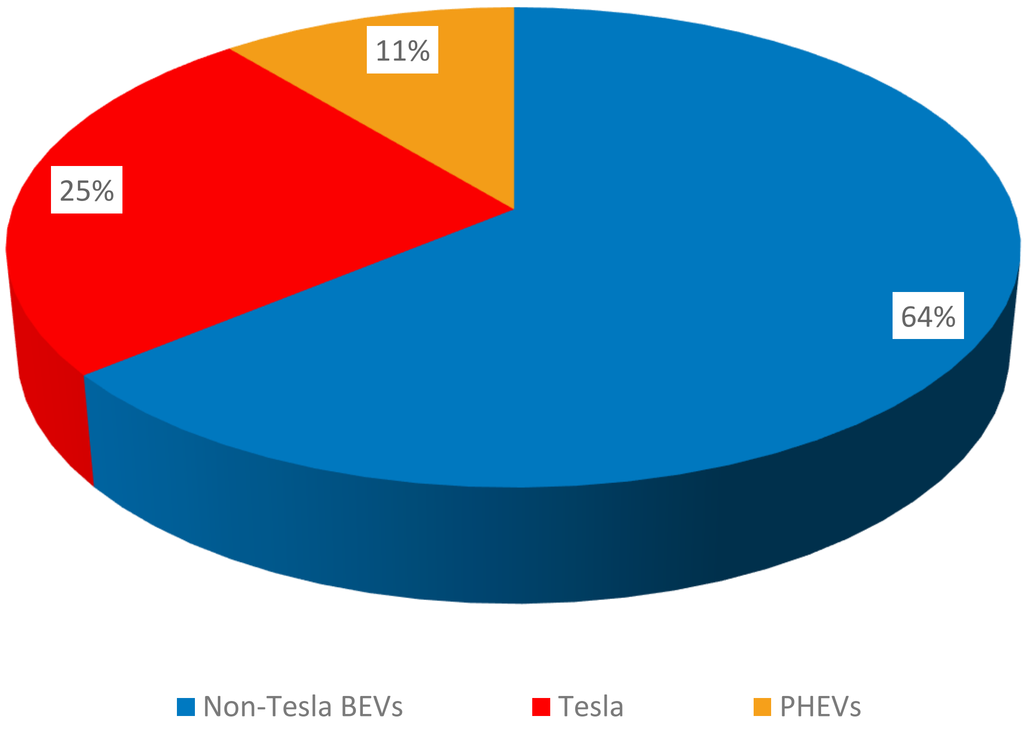
- **Light duty passenger vehicles cause 58% of sector emissions…**
- **While med/heavy duty trucks are 2nd highest at 20%**

Increasing Demand for EVs

2021: ~2m EVs in operation

2030: 30m EVs in operation*





Source: DOE ANL, Green Car Reports

Vehicle Technology

BEV Sedan

BEV CUV/SUV

BEV Pickup

BEV Van

PHEV Sedan

PHEV CUV/SUV

PHEV Pickup

PHEV Van

November 8, 2021- White House Announcement

Administrat

BRIEFING ROOM

FACT SHEET: The Bipartisan Infrastructure Deal Boosts Clean Energy Jobs, Strengthens Resilience, and Advances Environmental Justice

NOVEMBER 08, 2021 • STATEMENTS AND RELEASES

FACT SHEET: The Bipartisan Infrastructure Deal Boosts Clean Energy Jobs, Strengthens Resilience, and Advances Environmental Justice| The White House

IIJA White House Fact Sheet

- The Bipartisan Infrastructure Deal will invest **$7.5 billion** to build out the first-ever national network of EV chargers in the United States.
- A critical element in the Biden-Harris Administration's plan **to accelerate the adoption of EVs to address the climate crisis and support domestic manufacturing jobs**.
- Provide funding for deployment of EV chargers **along highway corridors to facilitate long-distance travel** and **within communities to provide convenient charging where people live, work, and shop**.
- Funding will have a particular focus on **rural, disadvantaged, and hard-to-reach communities**.

Infrastructure Investment & Jobs Act-
$7.5B Investment

- Sec. 11401 - Grants for Charging and Fueling Infrastructure for Corridors and Communities
  - **$2.5B** for **Alternative Fuels (EV, CNG, LNG, LPG, H2)**
- National Electric Vehicle Formula Program
  - **$5.0B** for **EV Corridors**
- Joint DOT/DOE Deployment Support Program to provide tools & technical assistance to funding recipients

Better than Gasoline

- Goals of a national charging network
  - Convenient, Affordable, Reliable, Equitable
- What should this network look like?
  - Lots of perspectives
    - Gas station scenario
    - EV happy hour
    - Home dominant

Key Stakeholders

Current and Future EV drivers
Understand and anticipate needs

Auto OEMs
Stimulate EV adoption

EVSPs
Support sustainable growth

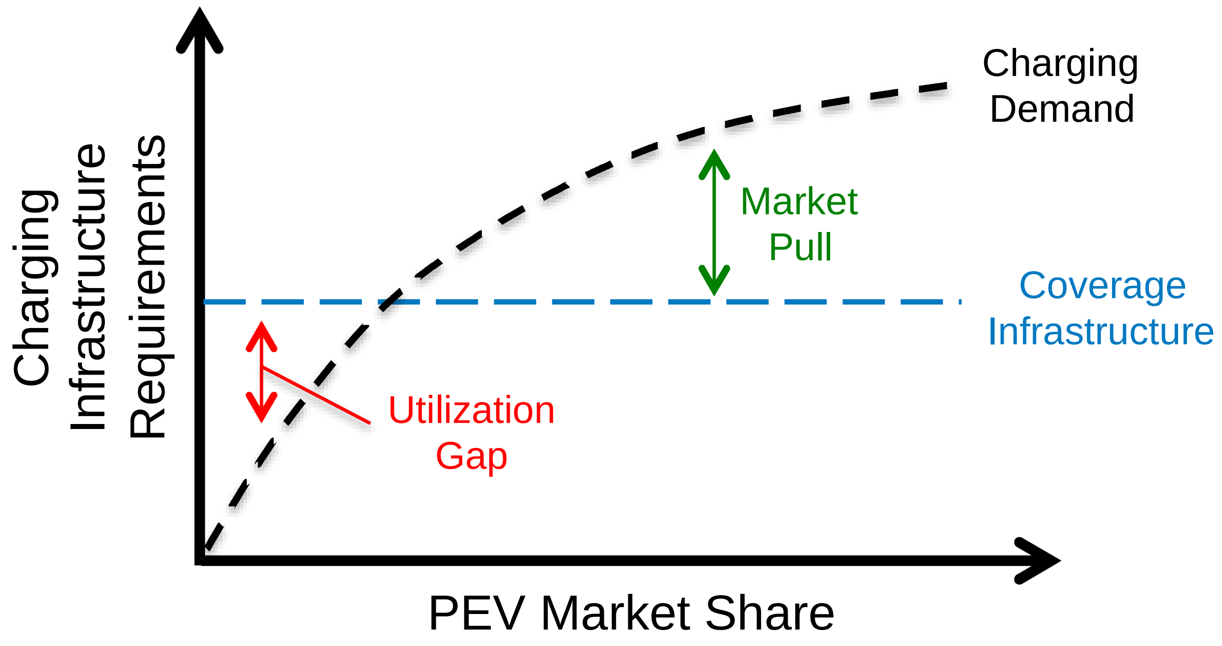
Site Hosts
Enable charging as an amenity

Electric Utilities
Well-integrated with the grid

Charging Networks:
Design Concepts

Coverage vs. Capacity

Establish coverage, then build capacity.



Terminology

Station = Charging Location
Port = Can Charge One EV at a Time
Connector = One or More per Port

Corridors vs. Communities

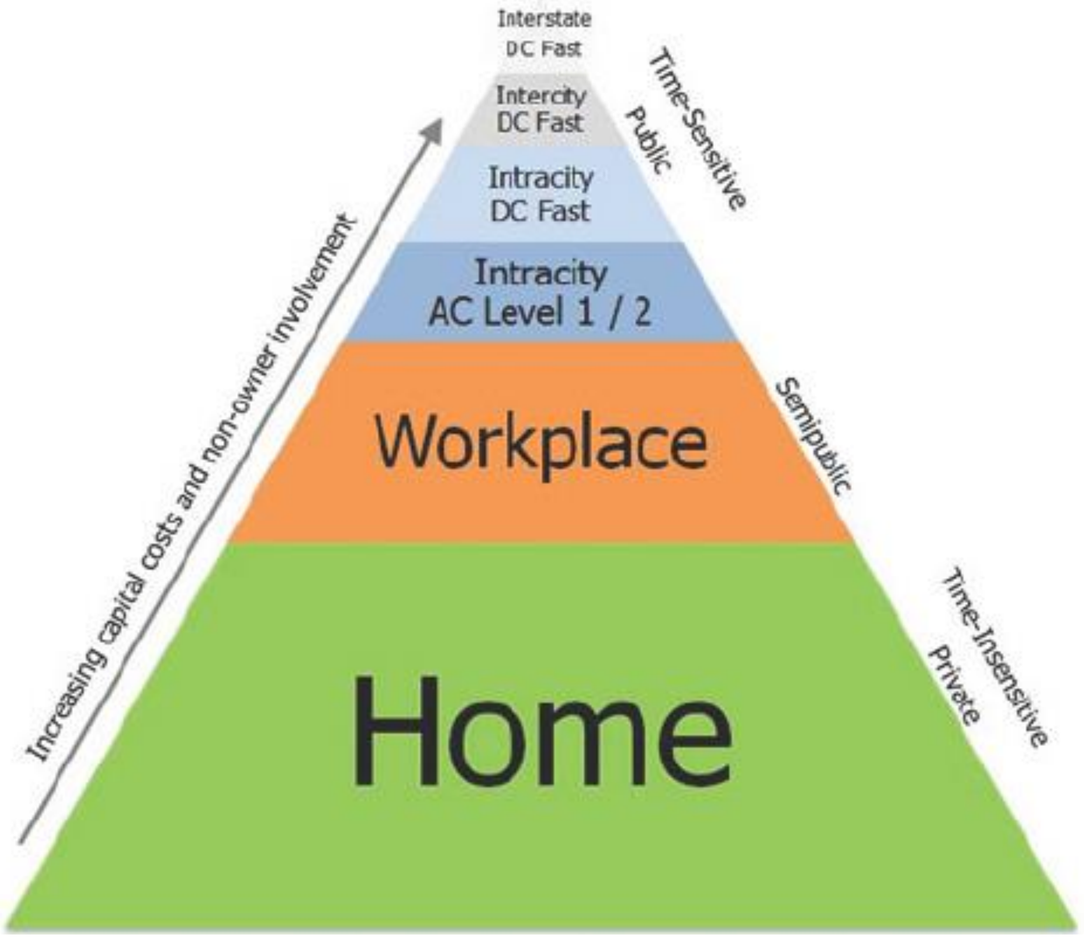
- Corridor needs are relatively small, but expensive and critical for adoption.

Home Charging is Foundational

- Today, most EVs do most of their charging at home.
- In the long-term, we expect the share of EVs without home charging to increase.

Charging Behavior Assumptions

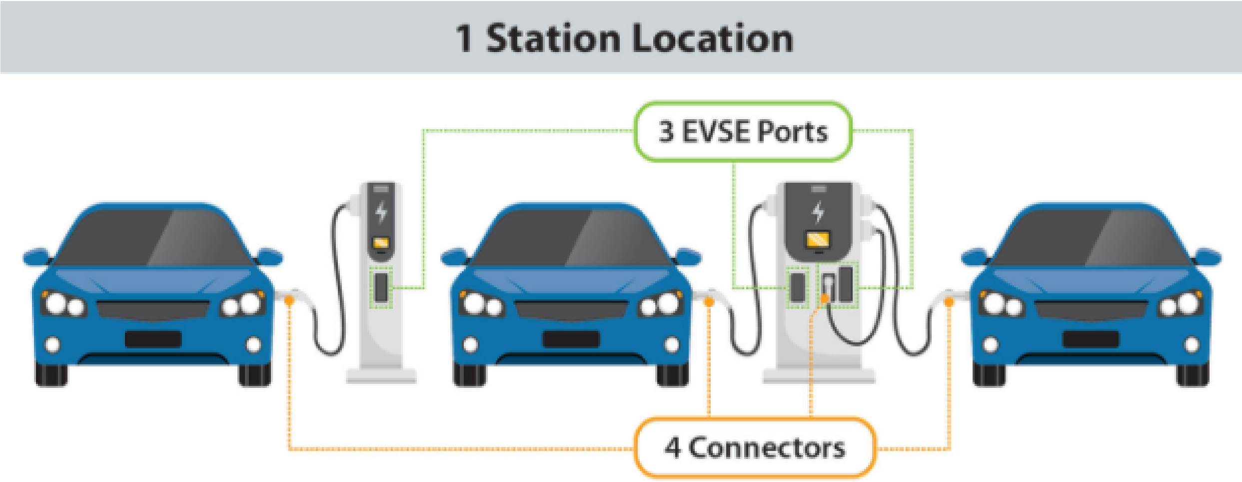
- Traditional approach assumes a pyramid structure to charging behavior
  - Maximize use of charging at home/work and complement with public charging as necessary
  - Take advantage of long dwell time opportunities for inexpensive slow charging
  - Rely on expensive fast charging as necessary (long trips, emergencies, etc.)



Source: National Research Council. *Overcoming barriers to deployment of plug-in electric vehicles.* National Academies Press, 2015.

EVSE Terminology

https://afdc.energy.gov/fuels/electricity_infrastructure.html



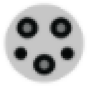
Charging Equipment

Charging equipment for PEVs is classified by the rate at which the batteries are charged. Charging times vary based on how depleted the battery is, how much energy it holds, the type of battery, and the type of charging equipment (e.g., charging level and power output). The charging time can range from less than 20 minutes to 20 hours or more, depending on these factors. Charging the growing number of PEVs in use requires a robust network of stations for both consumers and fleets.

For information on currently available charging infrastructure models, see the Electric Drive Transportation Association's GoElectricDrive website and Plug In America's Get Equipped resource, which include information on charging networks and service providers. When choosing equipment for a specific application, many factors, such as networking, payment capabilities, and operation and maintenance, should be considered.

Level 1 Charging

2 to 5 miles of range per 1 hour of charging

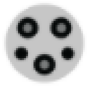


J1772 connector

Alternating Current (AC) Level 1 equipment (often referred to simply as Level 1) provides charging through a 120 volt (V) AC plug. Most, if not all, PEVs will come with a Level 1 cordset, so no additional charging equipment is required. On one end of the cord is a standard NEMA connector (for example,

Level 2 Charging

10 to 20 miles of range per 1 hour of charging



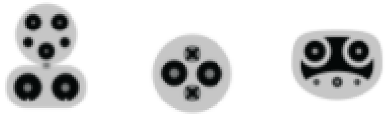
J1772 connector

AC Level 2 equipment (often referred to simply as Level 2) offers charging through 240 V (typical in residential applications) or 208 V (typical in commercial applications) electrical service. Most homes have 240 V service available, and because Level 2 equipment can charge a typical PEV

DC Fast Charging

60 to 80 miles of range per 20 minutes of charging

50kW



CCS connector | CHAdeMO connector | Tesla connector

Direct-current (DC) fast charging equipment (typically 208/480 V AC three-phase input) enables rapid charging along heavy traffic corridors at installed stations. As of 2020, over 15% of public EVSE ports in the United States were

Electric Vehicle Charging Standards

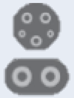
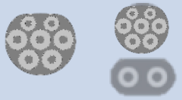
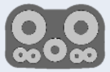
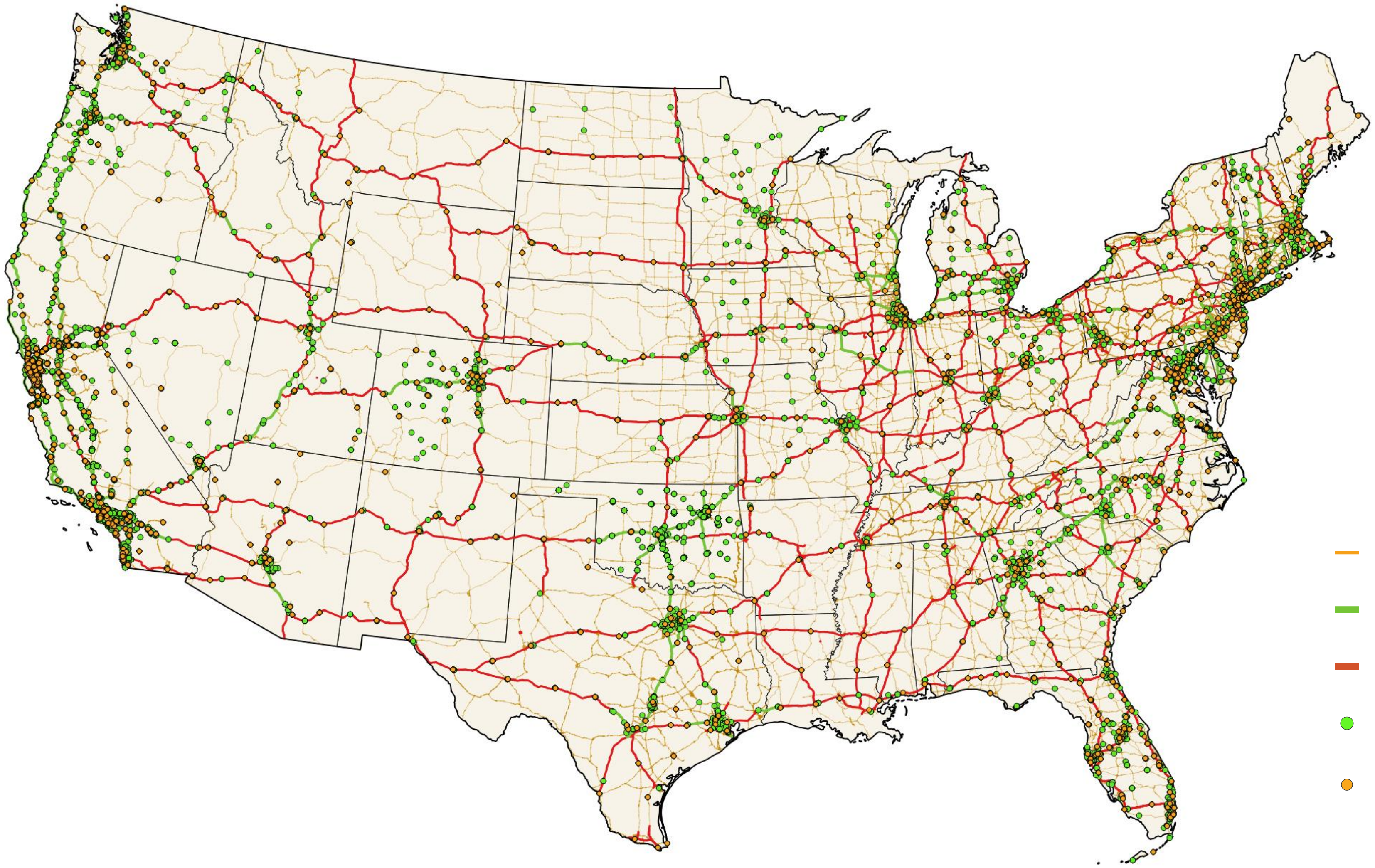
Diagram	Standard	Maximum Output Power	Application Notes
	SAE J1772	19.2 kW AC	Used for Level 1 and Level 2 charging in North America. Commonly found on home, workplace, and public chargers.
	CCS-1	450 kW DC	Used for DC fast charging most vehicle models in North America. Generally installed at public chargers.
	CHAdeMO	400 kW DC	Used for DC fast charging select vehicles models in North America. Generally installed at public chargers.
	Tesla	22 kW AC 250 kW DC	Used for both AC and DC fast charging for Tesla models only.
	J3068	166 kW AC 450 kW DC	Standard for both AC and DC charging utilizing the IEC 61851 ‘type 2’ connector for North America three-phase charging
	SAE J2954	22 kW light-duty 200 kW heavy duty	Wireless power transfer. Standard for MD/HD vehicles is under development.
	SAE J3105	>1 MW	Automated connection device to charge MD/HD vehicles. Variants include pantograph up or down and pin-and-socket.
	Chaoji	900 kW DC	Conductive charging for sub-MW charging of LD/MD/HD vehicles in Asia. Standard is under development.
	CharIN MCS	4 MW	Conductive MW-level charging for MD/HD vehicles. Standard is under development.

Table modified from “Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment (Staff Report), CEC 2021”

Existing US Deployment

EVSE Type	Stations	EVSE
Public DCFC	4,105	8,048
Tesla DCFC	1,068	10,554
Total DCFC	5,173	18,602
Public L2	34,267	70,828
Tesla L2	4,439	14,686
Total L2	38,706	85,514
Total Overall	**43,879**	**104,116**



- National Highway System
- FHWA Alt Fuel Corridor (EV Ready)
- Interstate System
- 4,105 Public DCFC Stations
- 1,068 Tesla Supercharger Stations*

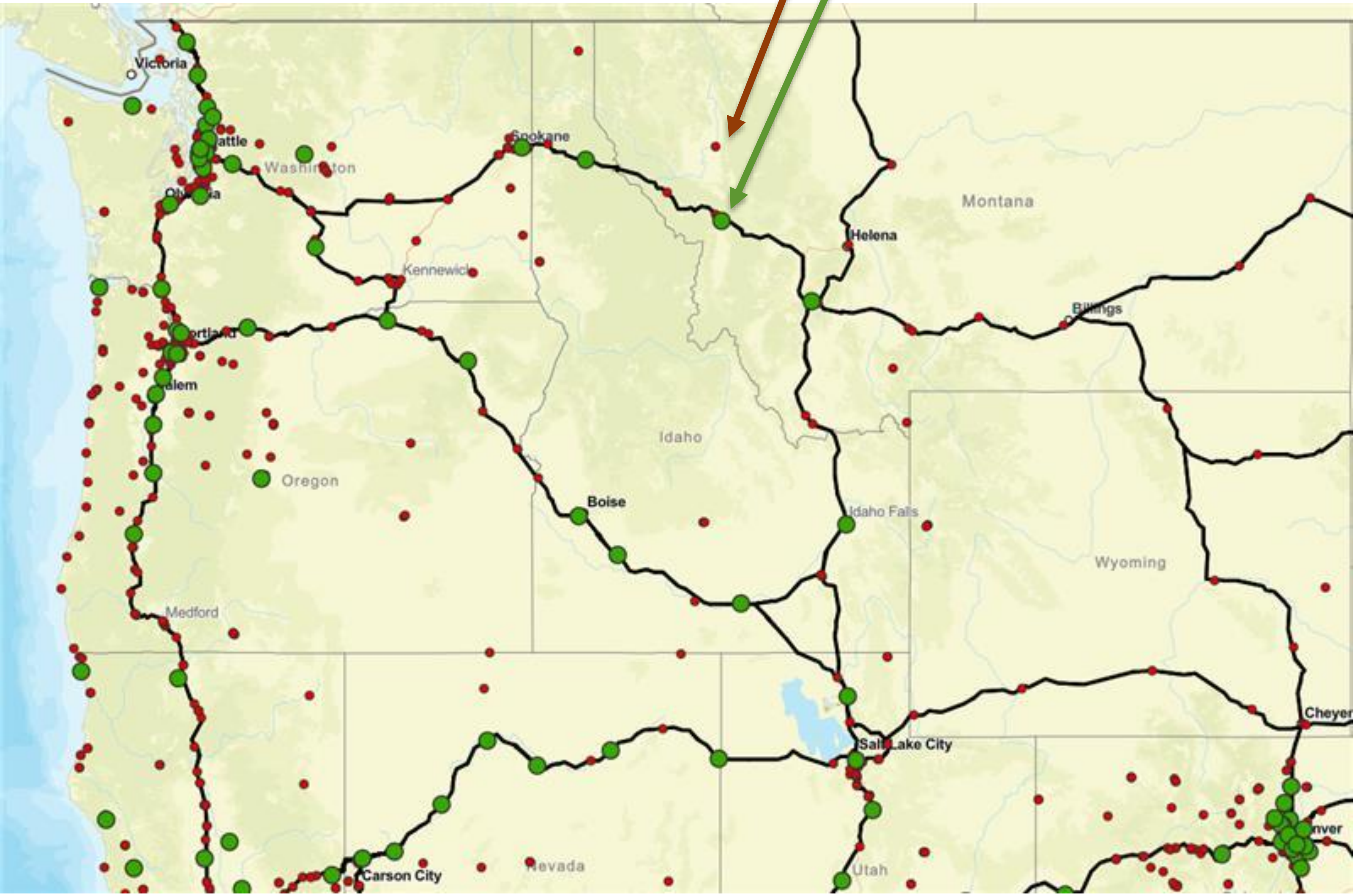
* Superchargers typically support 150-250kW per port

DOE AFDC Station Locator
(June 23, 2021)

Idaho: By the numbers

- ~2M LDVs
- ~1,000 gas stations

- ~6,000 PEVs
- ~100 public charging stations
- ~260 public charging ports



Source: DOE AFDC Station Locator (Jan 25, 2022)

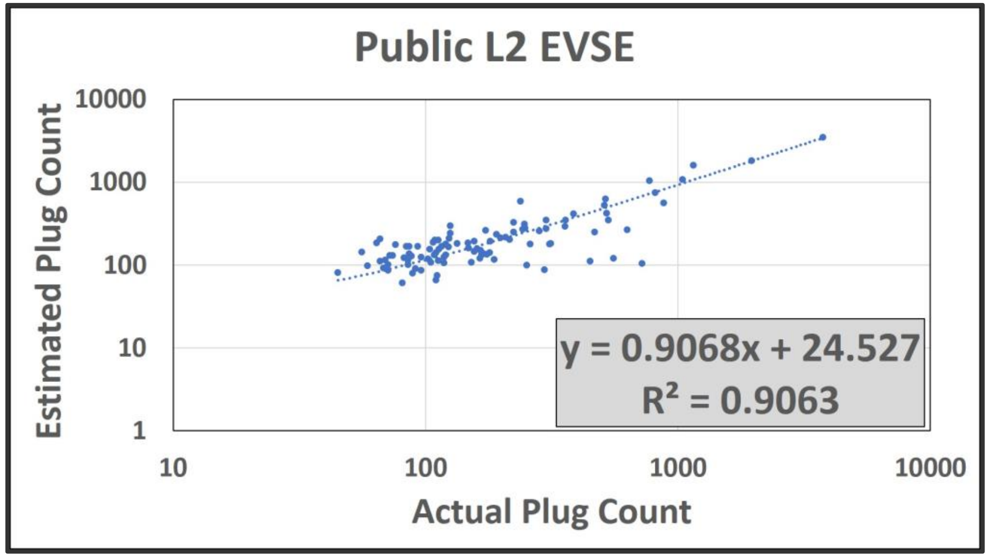
U.S. Trends in EV Charging Infrastructure: How many stations are being installed and where?

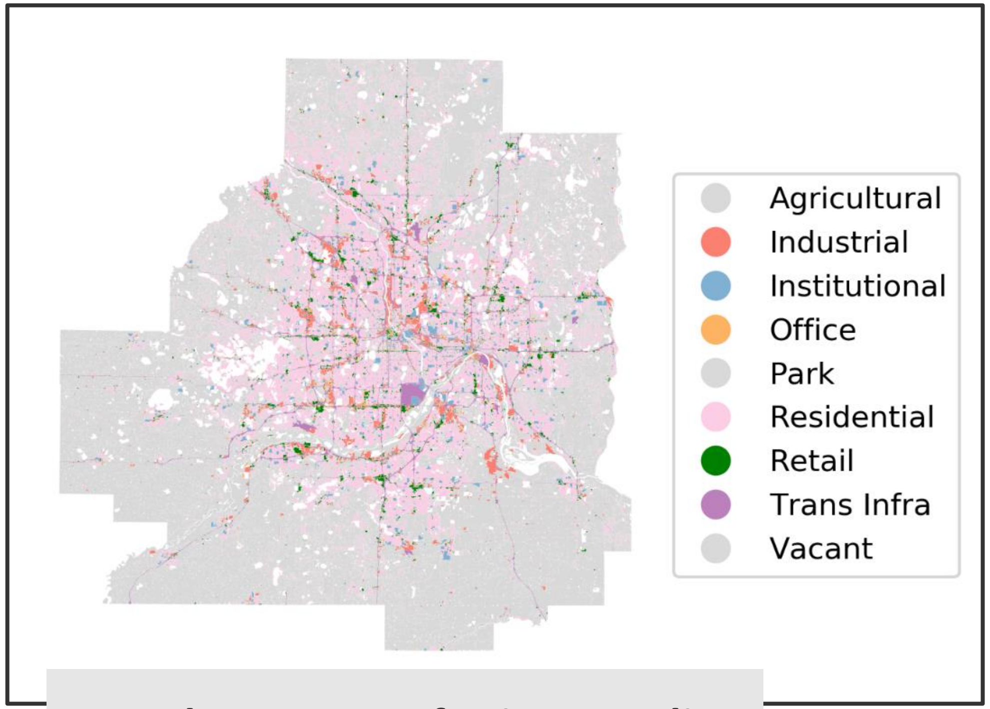
Regression analysis was used to quantify the existing volume of infrastructure with respect to vehicle registration data.

Results indicate that L2 public charging is being installed at a rate of **40 ports per 1000 PEVs** and public DCFC charging is being installed at a rate of **5 ports per 1000 BEVs.**

Retail locations are the most common for public charging with **20-40% of public L2** installations and **60-70% of public DCFC** installations occurring at retail facilities.

Supply of infrastructure tends to lead demand for public charging



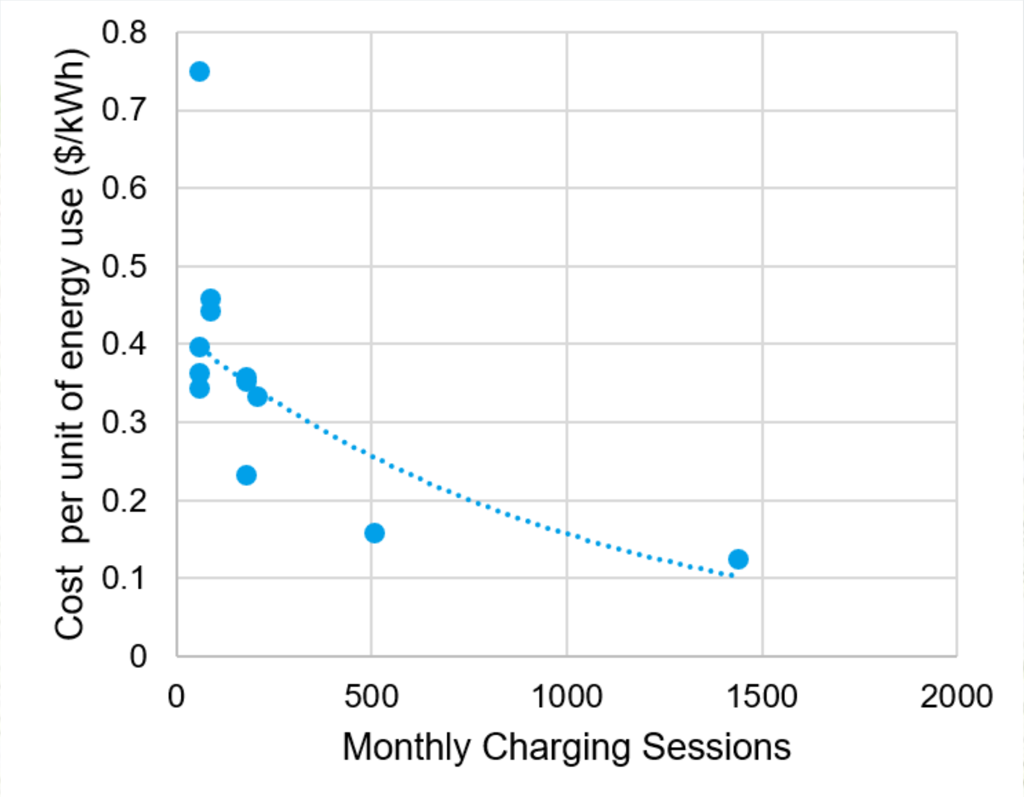


Land Use Map of Minneapolis

Demand-Based Network Design

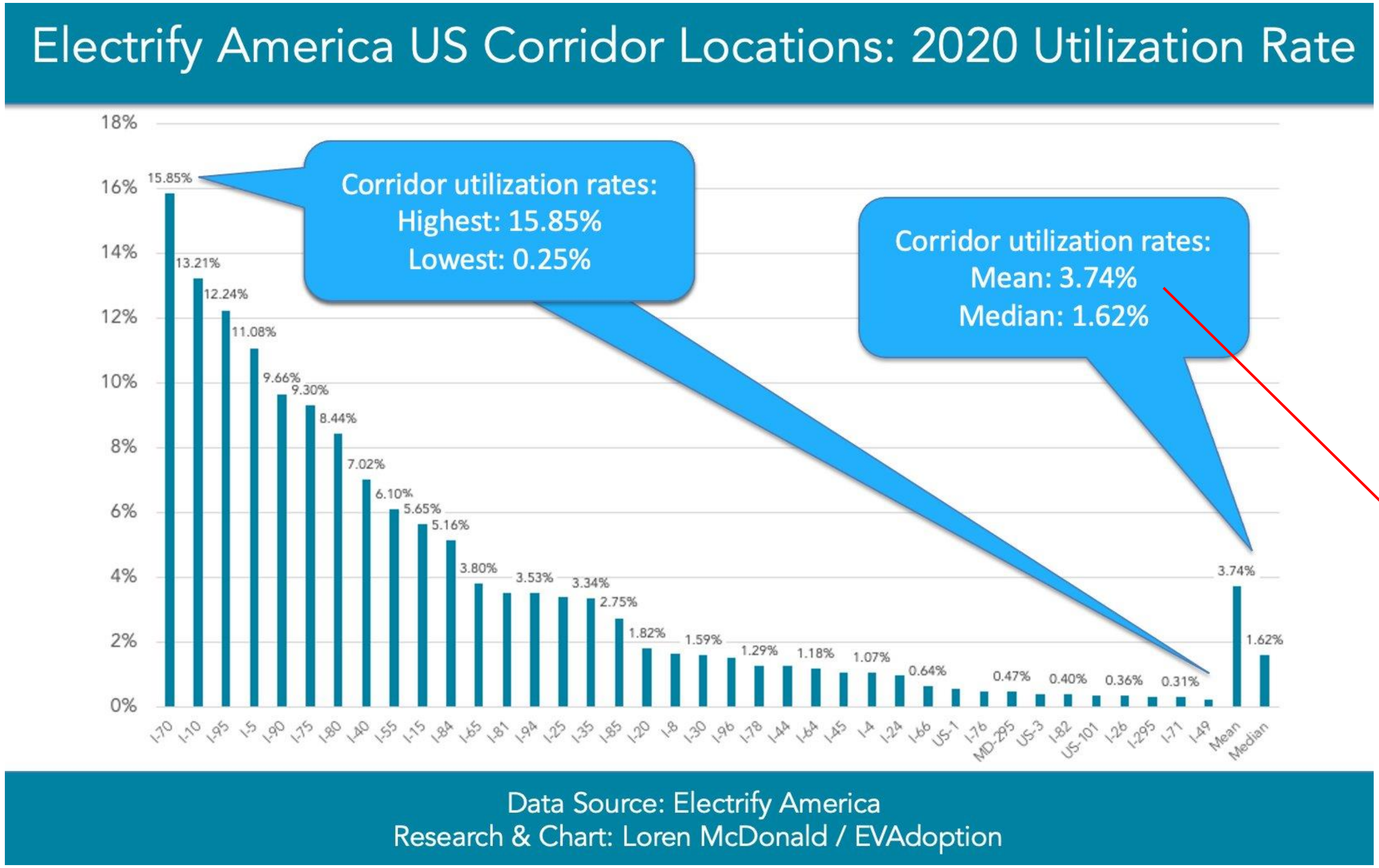
Low-cost installations are tempting in the short-term, but not financially viable in the long-term

- Simulation study in Columbus, OH using data from the local electric utility (AEP)
- Priority should be placed on siting fast charging at locations with high potential utilization
- Such sites are likely to include urban cores, transit hubs, and airports



Credit: ANL, INL, NREL

Utilization is key and it's currently too low for profitability



- Charger station utilization data generally not available (company confidentiality concerns)
- Many networks at most public stations achieve only single digit utilization
- **Electrify America average utilization on highways is less than 4%, or below 1 hour daily of EV charging!**
- RMI* cites a utilization level of 30% before costs can be sufficiently amortized to realize profitability
- And yet, queuing is predicted to begin ~20% utilization rate** (or nearly 5 hours a day of charging)

* RMI study, DCFC Rate Design, 2019

** PWC, Electric vehicles and the charging infrastructure: a new mindset? 2021

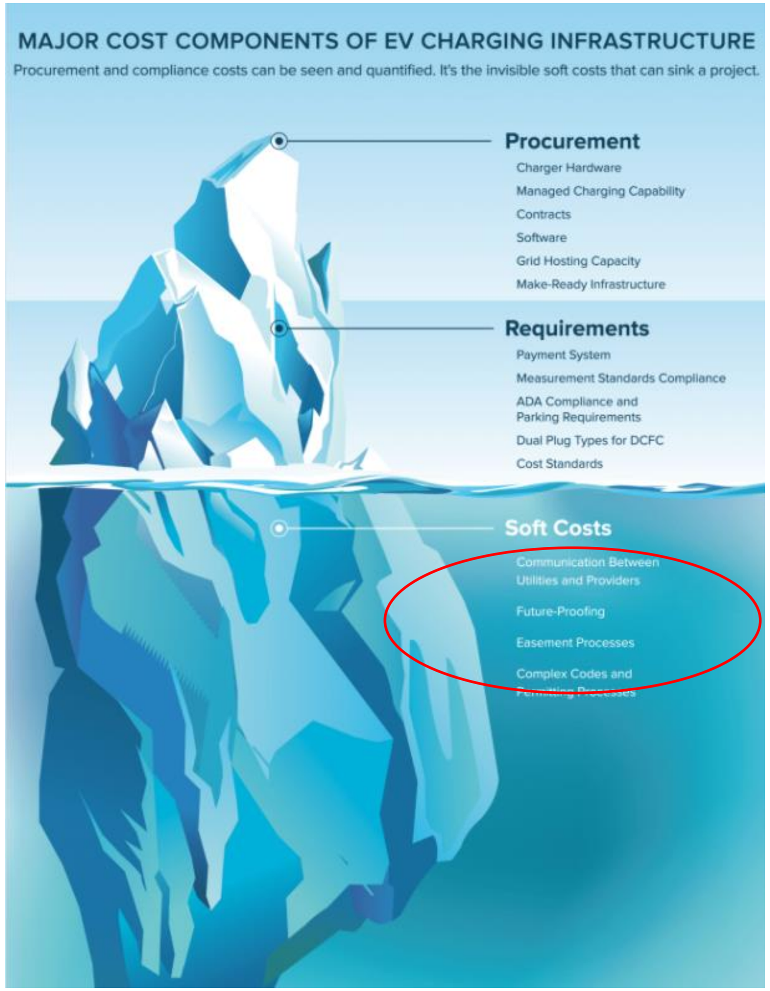
Modern Fast Charging Stations can exceed $1M CapEx

- Equipment costs relatively predictable, but installations are very site-specific
- Future trends
  - Manufacturing scale
  - Installation learning curve
  - Site scarcity

Charger Hardware	Unit cost per port	Installation cost per port
L2 commercial (7.2 kW)	low: $1,600 mid: $2,600 high: $4,100	low: $1,300 mid: $2,800 high: $4,800
DC 50 kW	low: $22,000 mid: $29,000 high: $36,400	low: $11,200 mid: $24,000 high: $39,800
DC 150 kW	low: $63,700 mid: $81,500 high: $100,000	low: $34,300 mid: $67,800 high: $131,100
DC 350 kW	low: $112,000 mid: $130,500 high: $142,000	low: $52,400 mid: $93,400 high: $135,500

Sources: NREL, RMI, BNEF, ICCT

Charging infrastructure "soft costs"



* 2019 RMI study – Reducing EV Infrastructure Costs, Chris Nelder & Emily Rogers

The costs of permitting delays, lengthy utility interconnections, compliance with a mosaic of regulations, and the reengineering of projects because they were based on incorrect information…were frequently cited as <u>more significant cost drivers than charging station hardware</u> . ***These irregular and unplanned circumstances can add significant costs due to design rework, construction delays****…*

Electrify America's Q2 2021 annual report to CARB cited:

- *CA permits should take 15 days by law but average 79 days*
- *Utility interconnect process takes 273 days whereas site construction only assumes 21 – 28 days!*

EV charging can benefit from installation streamlining, just as solar did a decade ago; soft costs comprised 64% of total deployment cost.

Charging deployment is often slowed by local permitting processes that vary widely

NESCAUM
www.nescaum.org

Northeast States for Coordinated Air Use Management
89 South Street, Suite 602 Boston, MA 02111
Phone 617-259-2000 Fax 617-742-9162
Paul J. Miller, Executive Director

MAY 2019

PREPARING OUR COMMUNITIES FOR ELECTRIC VEHICLES:
FACILITATING DEPLOYMENT OF DC FAST CHARGERS

According to EVSE providers, the permitting process for DCFC stations is lengthy and fraught with delays due to unfamiliarity with the technology, protracted zoning reviews, and undefined requirements for permitting DCFC…In some extreme instances, station developers have withdrawn permit applications and found new charging station sites in neighboring towns

DCFC charging permitting problems

- Lack of knowledge or standardized process
- Subject to zoning and design reviews, even hearings oftentimes, when charging should be an accessory to the primary use of site
- EV charging parking doesn't count in minimum needed by zoning
- Permit desk visit or mail in process required
- AHJs lack DCFC expertise, don't have FAQs

Electric Vehicle Charging Station Permit Streamlining Fact Sheet

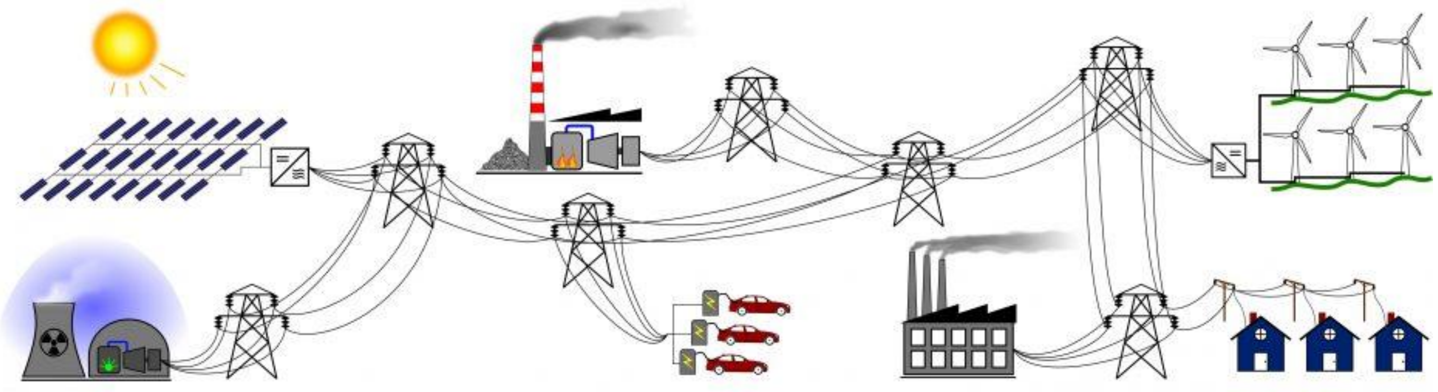
California Governor's Office of Business and Economic Development

AB 1236 (Chiu, 2015) Requirements for Cities and Counties

Even California, with more charging sites than any other state and AB1236 (which requires local jurisdictions to issue an EVSE permit within 15 days unless a health or safety violation is imminent) has had slow permitting approvals that can take 6 – 12 months or more.

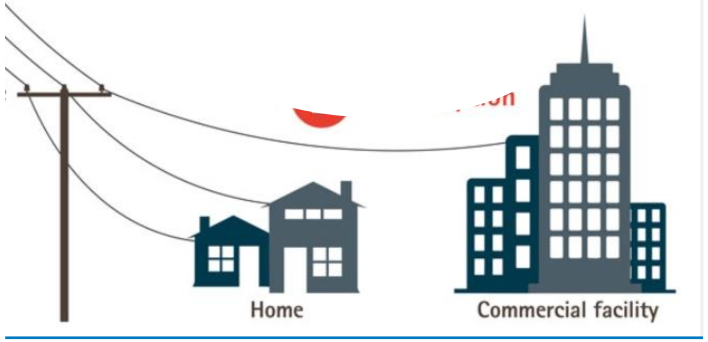
Source: NESCAUM study, 2019

Utility demand charges help balance grid supply, but load factor differences penalize DC fast charging



- Demand charges are a key tactic used by utilities to encourage consistent consumption and avoid peak power swings.
- Demand charges were initially developed for large and stable load consumers such as buildings and factories.

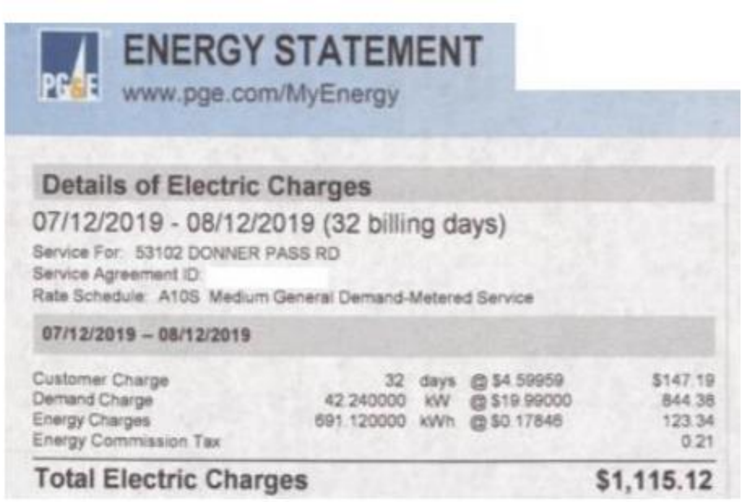
Consistent kw and kwh delivered with fewer spikes – demand charges more easily avoided



High kw and kwh delivered over shorter time period, intermittently – demand charges cannot be avoided!

Demand charges translate into staggering kwh costs and cannot be passed on to drivers

EVgo Utility Bill


ENERGY STATEMENT
www.pge.com/MyEnergy

Details of Electric Charges
07/12/2019 - 08/12/2019 (32 billing days)
Service For: 53102 DONNER PASS RD
Service Agreement ID:
Rate Schedule: A10S Medium General Demand-Metered Service

07/12/2019 – 08/12/2019

Customer Charge	32	days	@ $4.59959	$147.19
Demand Charge	42.240000	kW	@ $19.99000	844.38
Energy Charges	691.120000	kWh	@ $0.17846	123.34
Energy Commission Tax				0.21
Total Electric Charges				**$1,115.12**

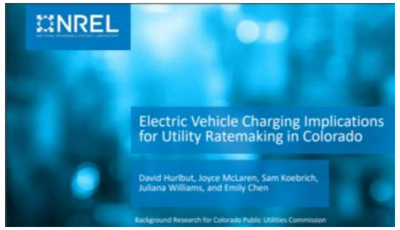
EVgo's monthly bill shows a kwh rate of 17.8 cents/kwh (compared with PG&E residential baseline rate of 11.9 cents) and a blended cost of $1.61/kwh!

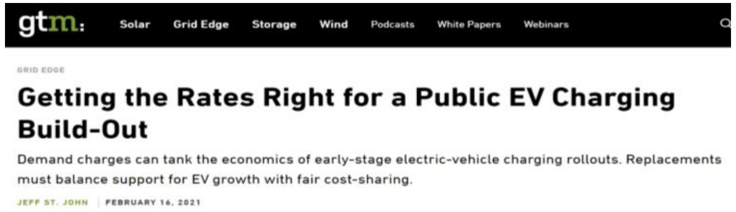
Source: Electrify America and EVgo

Electrify America blended kwh gasoline equivalent costs

Actual 2020 Bill Example	State	Cost per kWh, $*	Equivalent gas cost, $/gal**
Brigham City	UT	$8.55	$60.83
Kentucky Utilities	KY	3.36	23.91
Duck River	TN	2.85	20.29
PSEG	NJ	2.55	18.16
Oregon Trail Coop	OR	2.19	15.61
Toledo Edison	OH	2.04	14.50
Dominion	VA	2.02	14.35
Indianapolis P&L	IN	1.65	11.76

Several studies cite concerns with demand charges and recommend rate reform…




gtm: Solar Grid Edge Storage Wind Podcasts White Papers Webinars

GRID EDGE

Getting the Rates Right for a Public EV Charging Build-Out

Demand charges can tank the economics of early-stage electric-vehicle charging rollouts. Replacements must balance support for EV growth with fair cost-sharing.

JEFF ST. JOHN | FEBRUARY 14, 2021

As an alternative to demand charge elimination, utilities can consider incentivized storage on/offsite (charging site operator either funds storage to peak shave and to provide grid services on site or taps into larger utility scale storage – both at lower price premium than demand charges)*

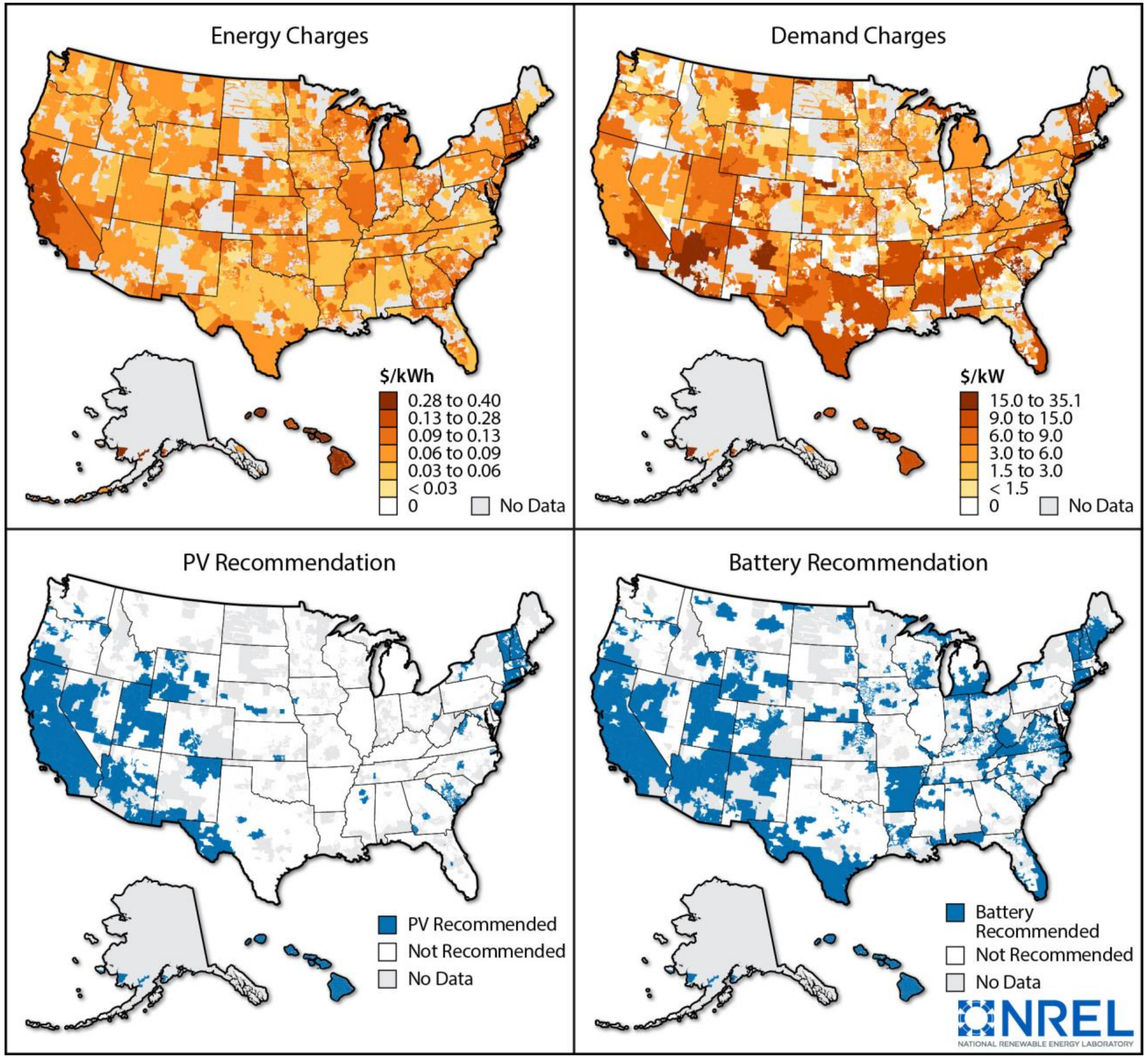
* SMUD reference

Technology Solutions

Energy and demand charges as well as the technology recommendation vary geographically.

Technology solutions can be leveraged to reduce cost of electricity for stations that experience higher electricity costs:

- Energy storage (battery) can mitigate high **demand charges**
- Photovoltaic (PV) energy can mitigate high **energy charges**, even in areas with lower solar irradiance (e.g., Vermont)



EVI-X: Tools for Forward-Looking Analysis

Network Planning Tools
How many ports?
What kind? Where?

Electric Vehicle Charging Infrastructure Analysis
NREL's EVI-X Modeling Suite

Light-duty vehicles
Medium- and heavy-duty vehicles

Site Design Tools
Station sizing, on-site storage, load profiles

Network Planning

EVI-Pro
Charging infrastructure projection based on typical daily travel

EVI-OnDemand
Charging infrastructure demand modeling for ride-hailing services

EVI-Pro Lite
Simplified version of EVI-Pro (free to use)

EVI-RoadTrip
Charging infrastructure analysis for long-distance travel

EVI-Equity
Charging infrastructure accessibility from environmental-justice perspective

EVI-Pro HD
Depot and corridor charging infrastructure projection for commercial vehicles

Site Design

EVI-Fleet
Operational and economic analysis for fleet electrification

EVI-InMotion
Dynamic and quasi-dynamic charging infrastructure design

EVI-EnSite
Charging infrastructure energy estimation and site optimization

HEVII
Multi-fidelity telematics-enabled vehicle and infrastructure design

EnStore
Techno-economic evaluation of behind-the-meter storage

Network & Station Economics
Levelized cost of charging

EVI-FAST
Charging infrastructure financial analysis (free to download)

can integrate with any of the above tools

Input Data Requirements
Future EV Fleet Size Scenarios
EV/EVSE Tech Attr & Cost
Driver Demographics & Land Use
Mobility Data or Scenarios (e.g., TEMPO)
Residential Access & Charging Behavior
Utility Rates & Local Hosting Capacity

NREL Charging Infrastructure Analysis Capabilities

... it's all about the PEOPLE!


Ahmed Mohamed


Nick Reinicke


Andrew Kotz


Catherine Ledna

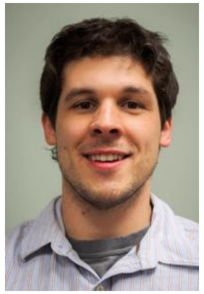

Alicia Birky


Brennan Borlaug


Matteo Muratori

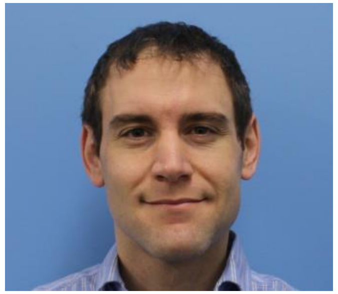

Partha Mishra


D-Y Lee


Eric Miller

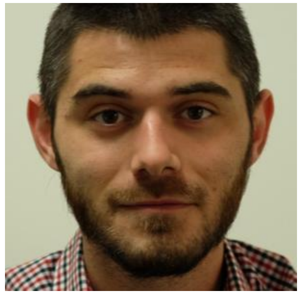

Eric Wood


Steve Lommele


Chris Neuman


Johanna Levene


Andrew Meintz


Matt Moniot

The EV Infrastructure Projection Tool

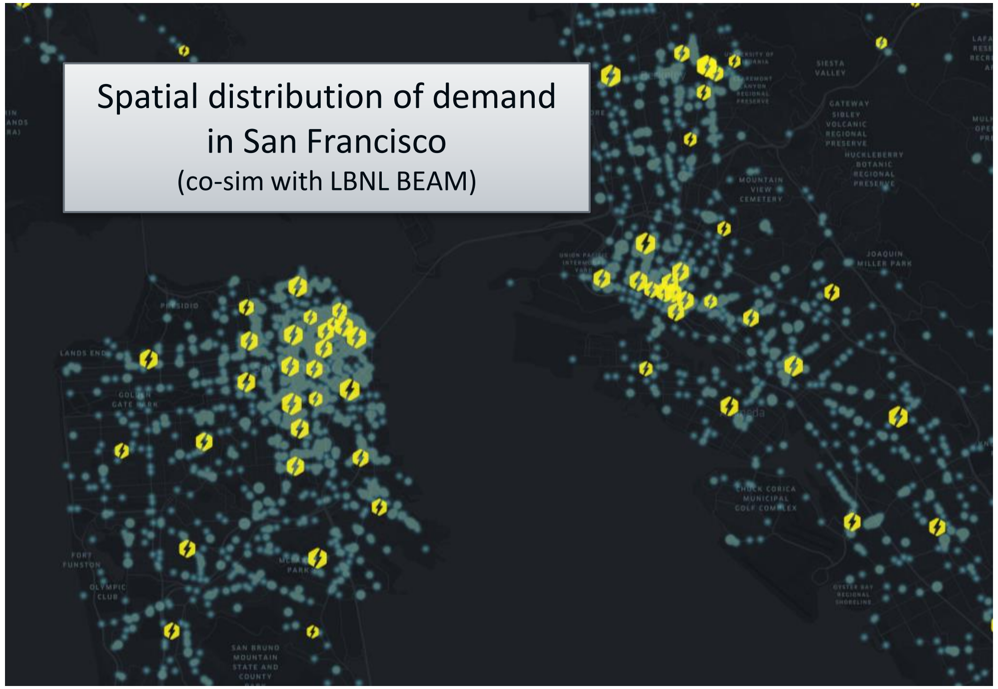
EVI-Pro

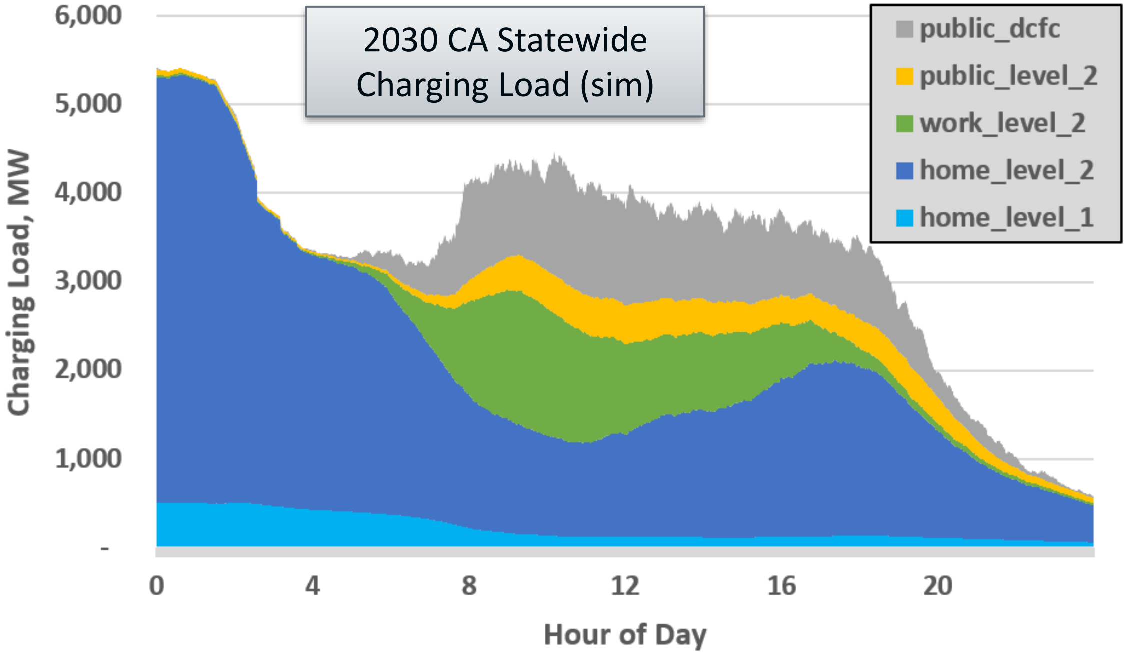
Simulation model to:

- Estimate charging **demand** from EVs
- Design **supply** of infrastructure

Informed by real-world data and integrated with models of vehicle adoption, mobility, station economics, and the grid

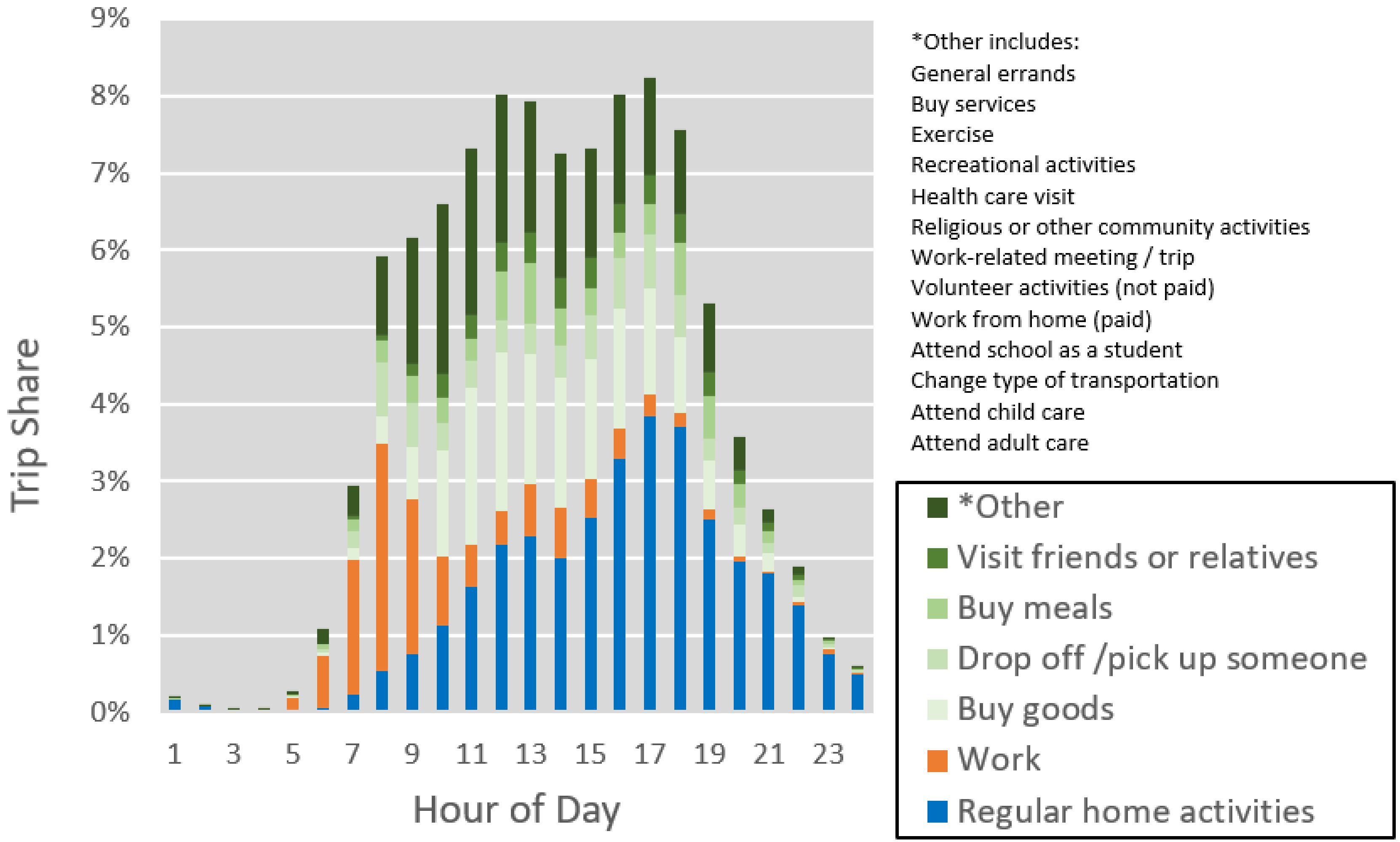
Originally developed through collaboration with the California Energy Commission and since applied at the city-, state-, and national-level





Travel Demand
Daily Driving

- Detailed driving data necessary to anticipate EV energy use and opportunities for charging
- Charging at home and work provide the most promising opportunities
  - Frequent visits for long durations
- Use of travel survey data assumes future PEV use conforms to historical precedent
  - Alternate vehicle use scenarios can be tested using sensitivity analysis



Driving / Charging Simulations

EVI-Pro

Departure	Arrival	Destination	Driver A	Driver B	Driver C
7:00 AM	7:45 AM	Public	None	None	Public DCFC
9:30 AM	10:30 AM	Public	None	Public L2	None
12:45 PM	3:00 PM	Public	None	None	None
4:00 PM	5:00 PM	Home	Home L2	Home L2	None

Travel Data (Departure, Arrival, Destination) — Simulated Charge Events (Driver A, Driver B, Driver C)

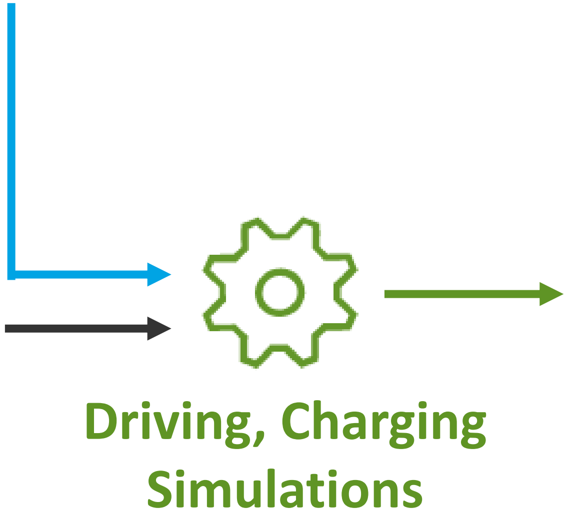
Charging demand to satisfy travel

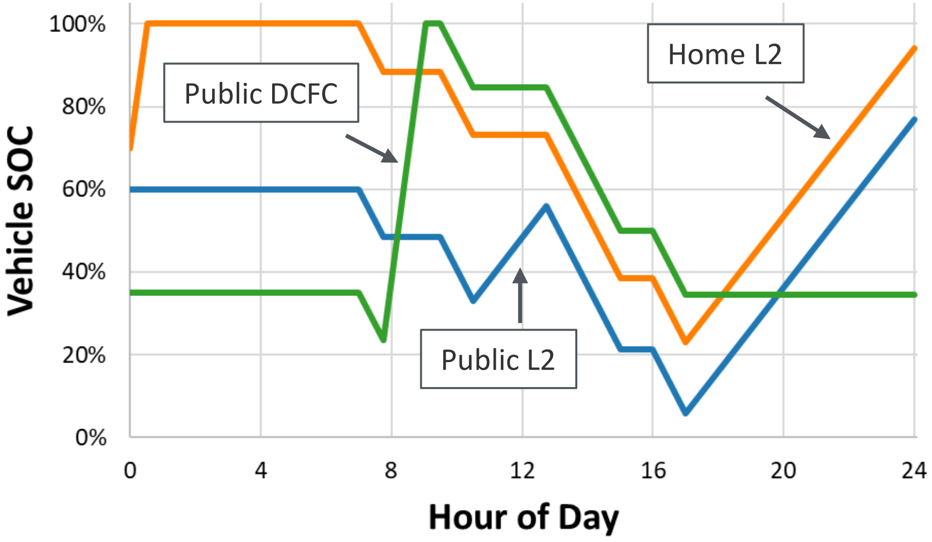
Sample Vehicle / Infra Assumptions:

- 250-mile BEV
- DCFC = 150kW
- L2 = 7.2kW

Sample Choice / Access Assumptions:

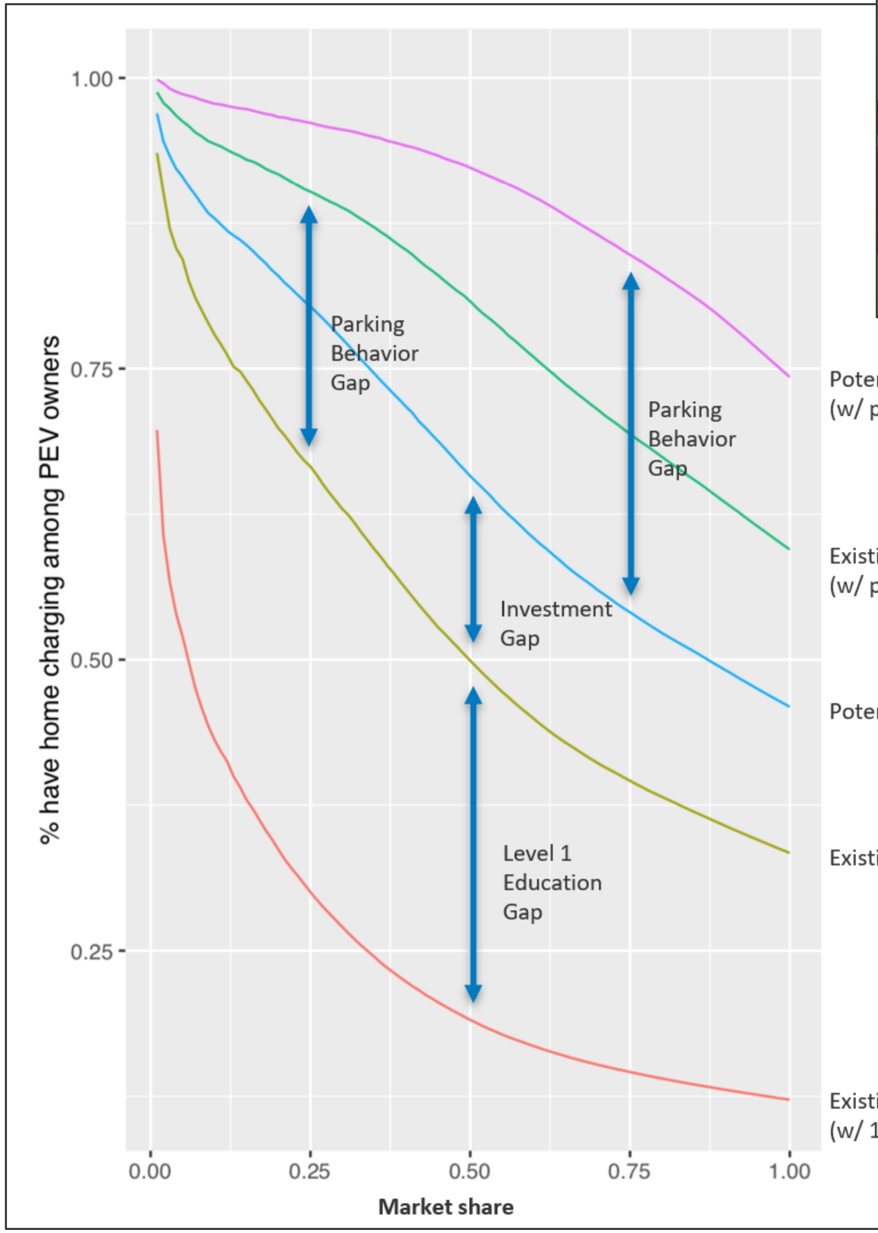
- Charge every night, home dominant
- Plug-in only if needed, even at home
- No home-charging, reliant on public infrastructure

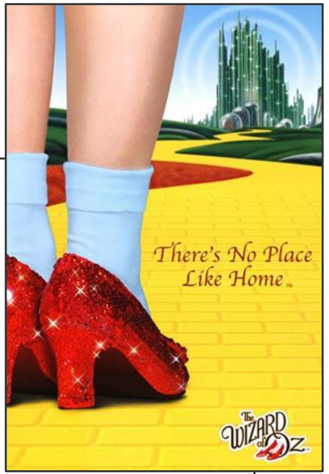




“There’s No Place Like Home”

- As electric vehicle adoption progresses, **residential charging access among electric vehicle owners is likely to decrease (as a %)** and become more uncertain.
- Residential access among **multi-family properties presents the greatest challenges**.
- Single family homes may dominate the light-duty vehicle stock, however residential access at these properties is not a given.
- Many opportunities exist for improving residential access across all property types.
- **Tradeoffs exist between residential and public infrastructure investments.**

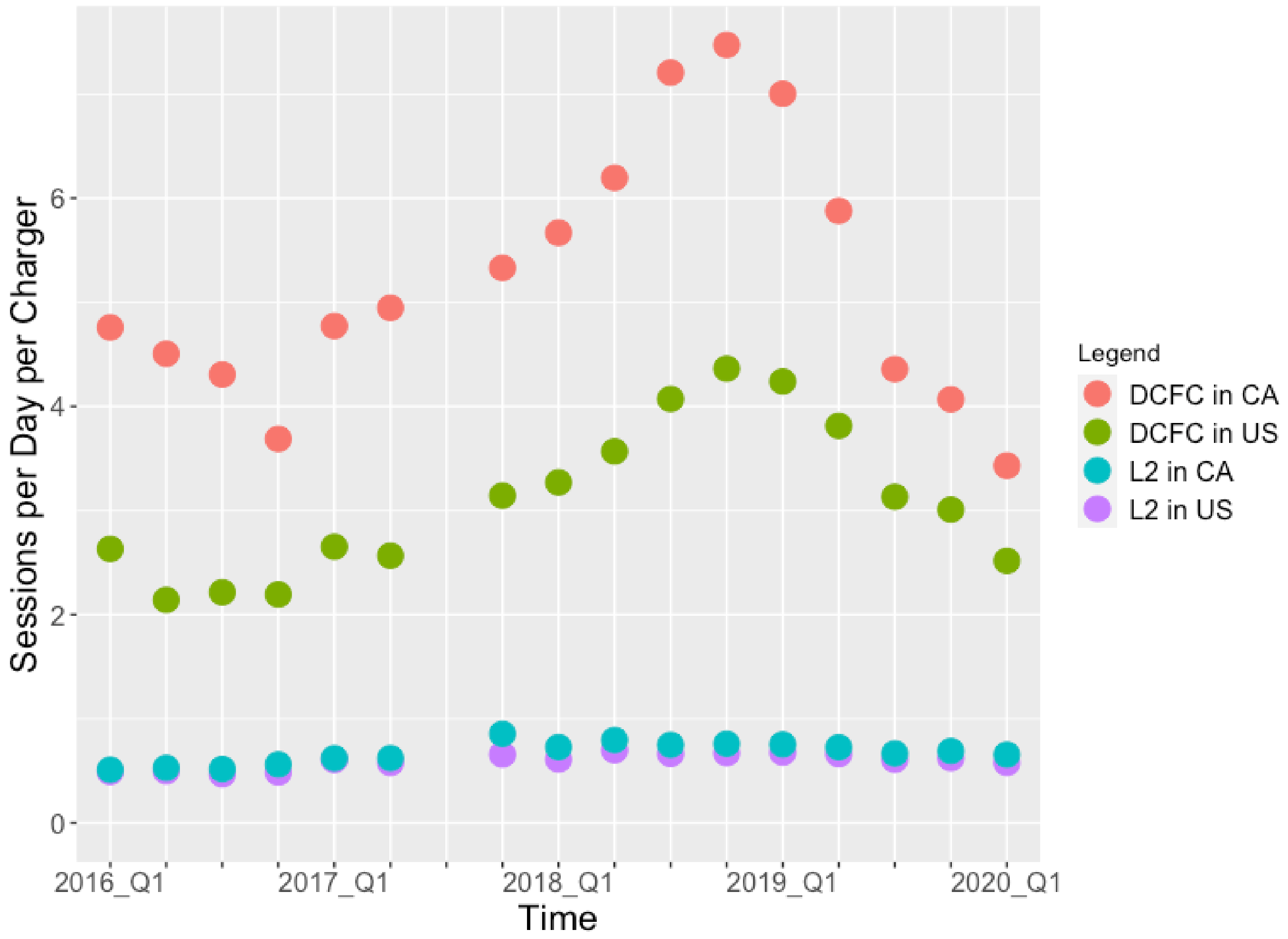




Recent EVSE Utilization
Jan 2016 to March 2020

- EVSPs have provided NREL with event-level data from networked L2 and DCFC units across the U.S.
- Highly utilized DC stations currently serving more than 10 daily charge events

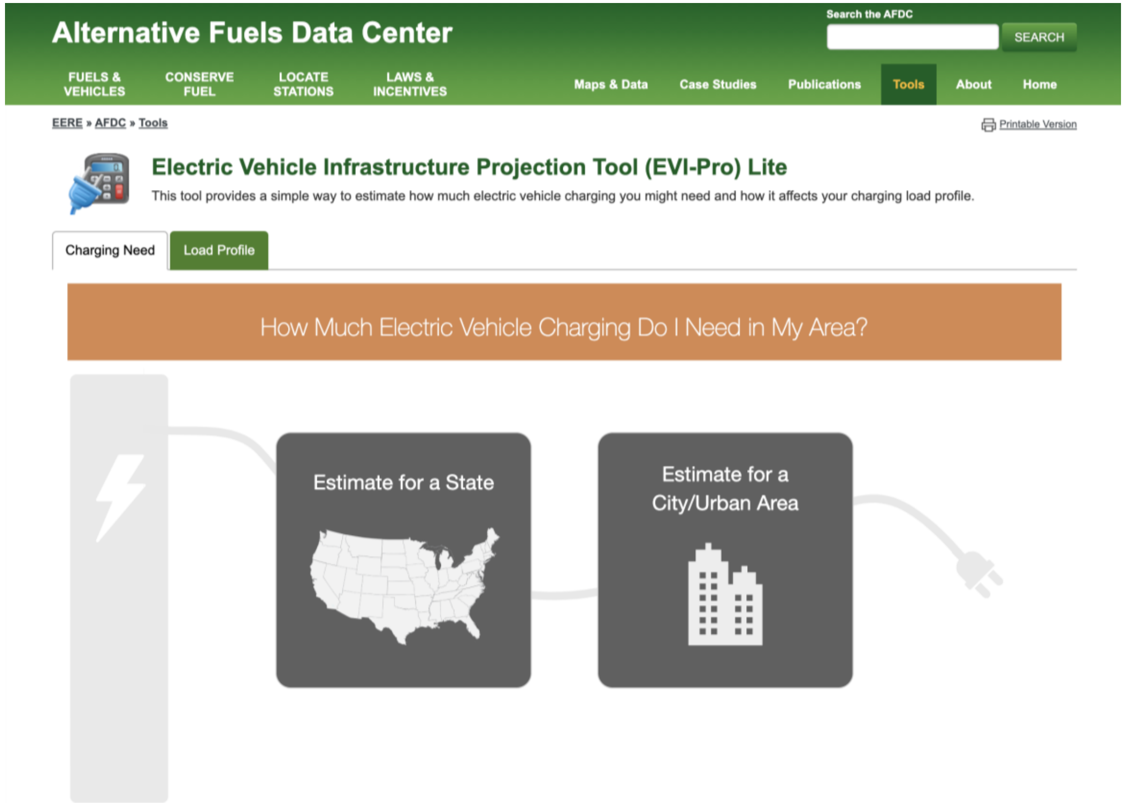
	U.S. (incl CA)	CA only
Station Count	3,036	1,151
Plug Count	6,372	3,524
Unique ZIP Codes	1,703	529
Individual Charge Events	~7.2M	~5.2M



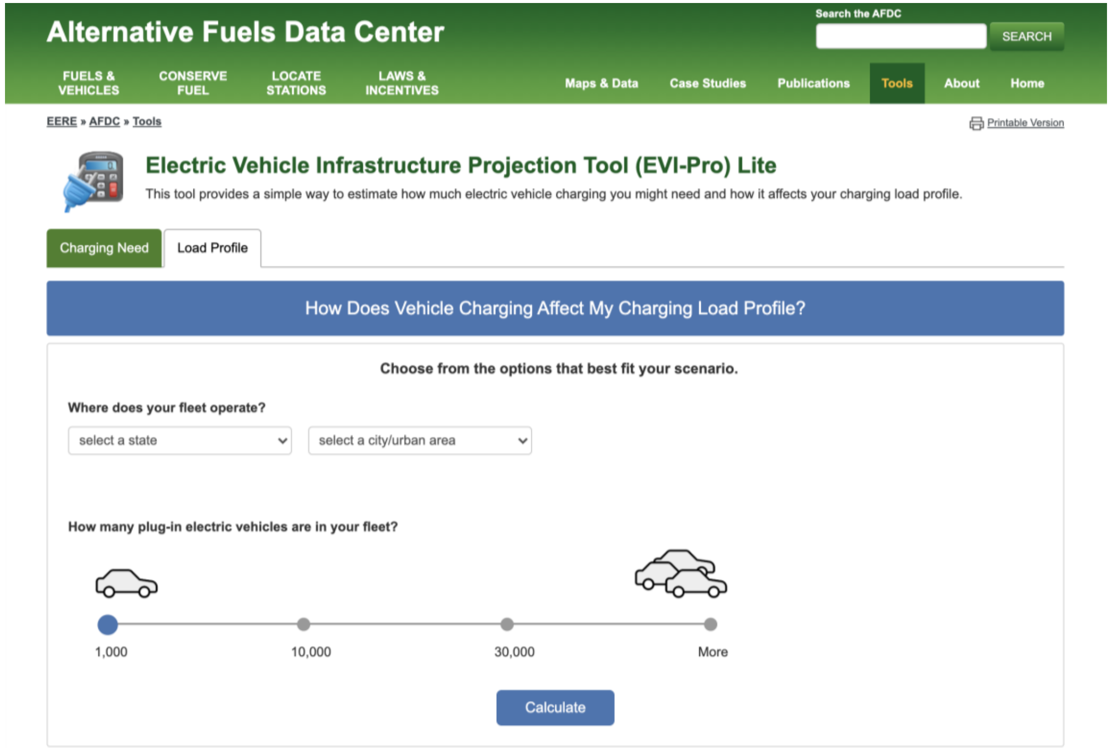
*2017 Q3 intentionally omitted (inconsistent reporting)

EVI-Pro Lite

Charging Need
Launched 2018



Load Profile
Launched 2020



afdc.energy.gov/evi-pro-lite

EVI-Pro Lite

Charging Need

Objective: Make analytic capabilities of EVI-Pro model accessible to broad group of stakeholders for EVSE investment decisions.

Approach: Develop a simplified, web-based interface for EVI-Pro that gives users access to a limited number of critical input variables.

Significance & Impact

- EVI-Pro "unlocks" an unlimited number of scenarios for planners to explore regarding EV charging infrastructure requirements.
- **Since its launch, 6,000 users have viewed 14,000 pages on the tool, spending almost 4 minutes per visit.**

afdc.energy.gov/evi-pro-lite

Waymo starts to open driverless ride-hailing service to the public

Kirsten Korosec @kirstenkorosec / 10:31 AM MDT • October 8, 2020 Comment

WAYMO

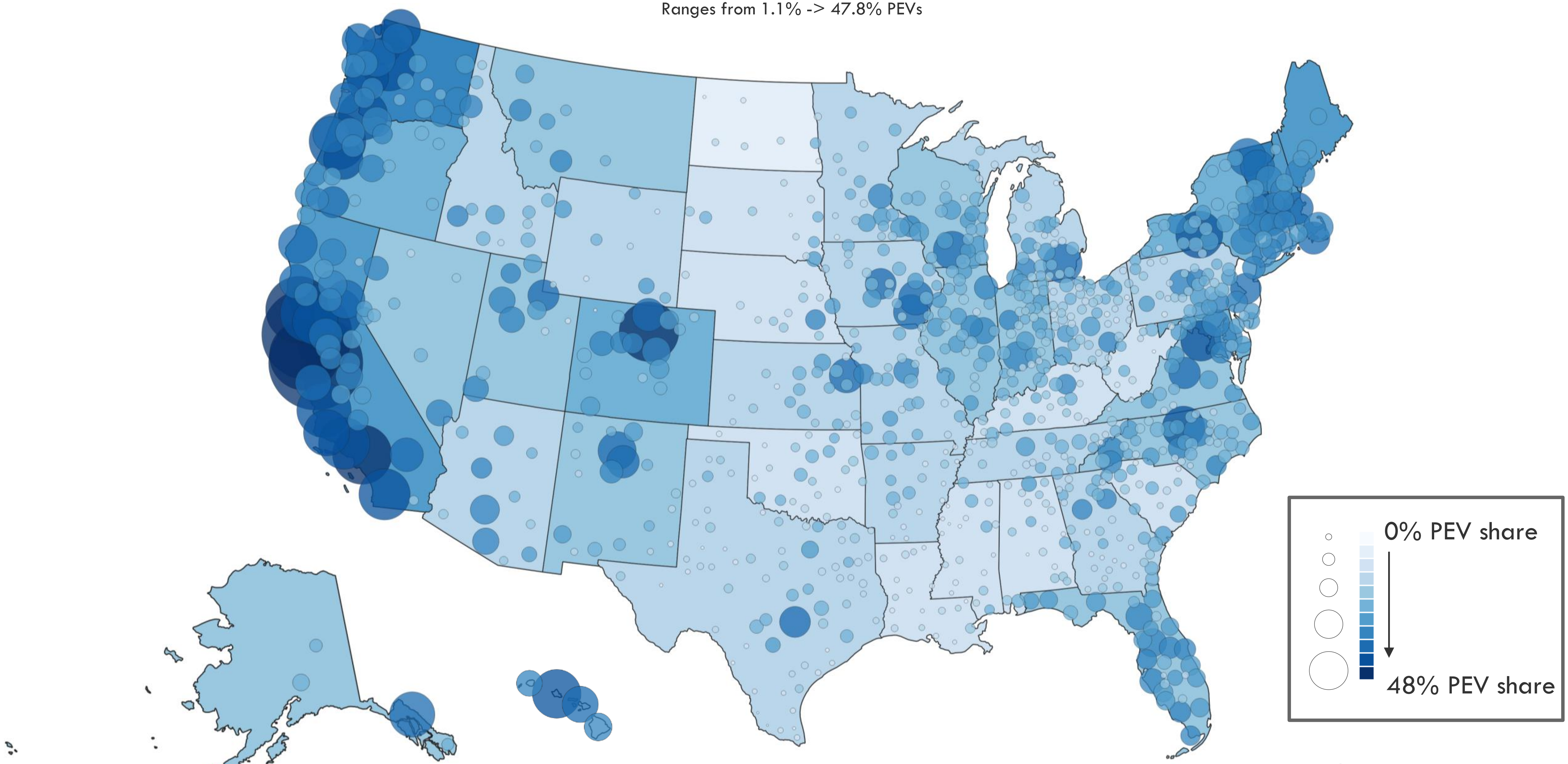
“30 by 30”

Charging Infrastructure Supporting 30M Electric Vehicles by 2030

Brennan Borlaug, Dong-Yeon (D-Y) Lee, Matt Moniot, Fan Yang, Yanbo Ge, and Eric Wood

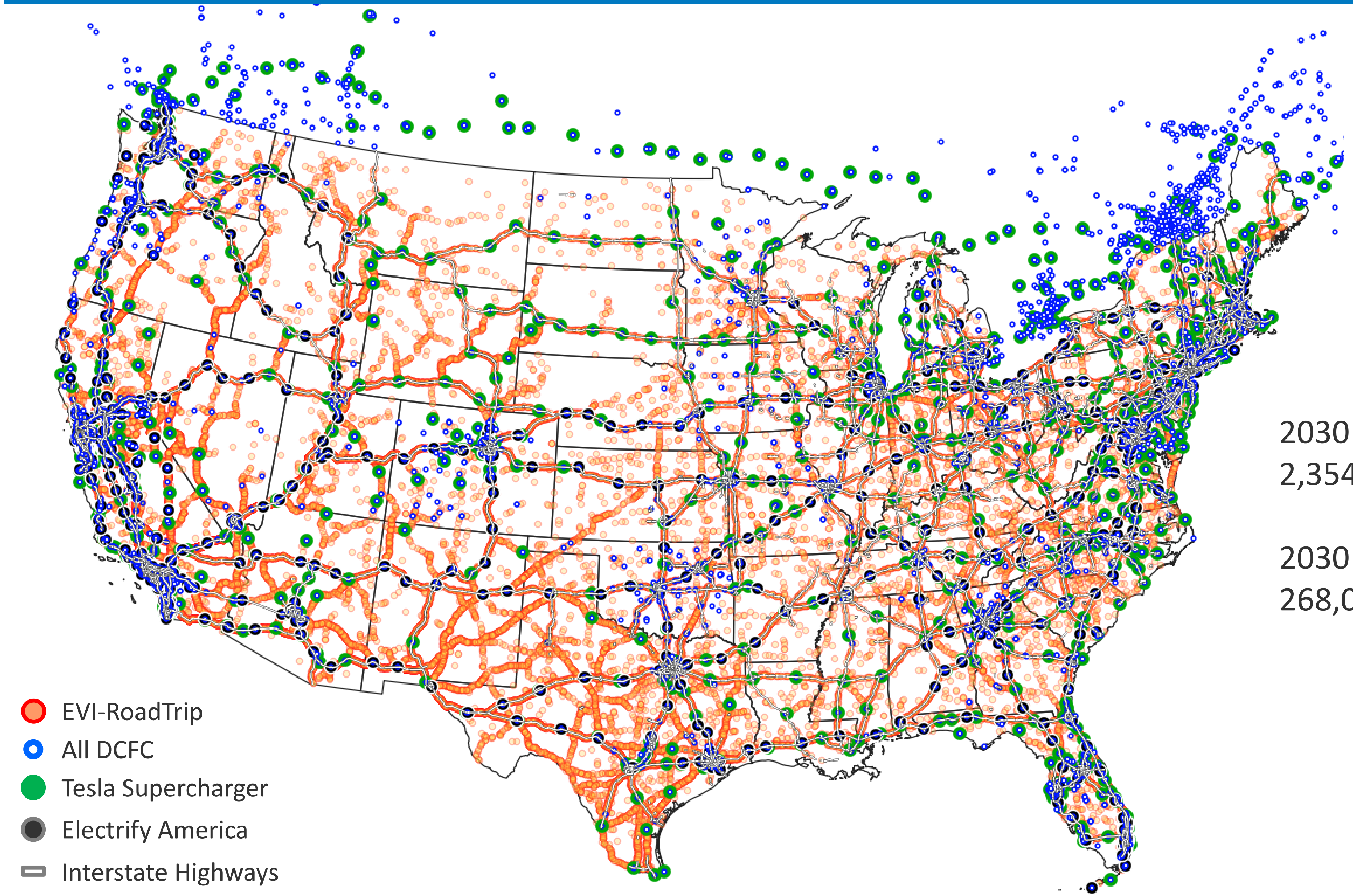
PEV Registration Shares – 2030 Scenario w/ 30M PEVs

Ranges from 1.1% -> 47.8% PEVs



Bubble size and color represent the PEV share of LDVs per core-based statistical area (CBSA); State color represents the PEV share of LDVs in state rural areas

EVI-RoadTrip Charging Demand Simulation



2030 Typical daily road trips: 2,354,000

2030 Typical daily BEV road trips: 268,000 (about 1% of the BEV fleet)

EVI-X Modeling for Idaho
(preliminary results)

2025

- **Total PEVs**: 20,231 (currently 5,980 in ID)
- **PHEV share of PEVs**: 37% (currently 41% in ID)
- **PEV share of veh regs**: 1.2% (currently 0.3% in ID; simulated 2025 U.S. share: 2.8%)
- **Share of PEV owners w/ access to home charging**: 98% (simulated 2025 U.S. avg.: 93%)

- **Total 2025 EVSE Ports (work L2; public L2; public DCFC)**: 1,123 (354; 282; 487)
- **Share of 2025 EVSE ports in Boise, ID**: 39% (54% of PEVs located here)

2030

- **Total PEVs**: 149,825
- **PHEV share of PEVs**: 12% (simulated 2030 U.S. share: 10%)
- **PEV share of veh regs**: 7.8% (simulated 2030 U.S. share: 11.5%)
- **Share of PEV owners w/ access to home charging**: 91% (simulated 2025 U.S. avg.: 83%)

- **Total 2030 EVSE Ports (work L2; public L2; public DCFC)**: 4,253 (2,398; 559; 1,296)
- **Share of 2030 EVSE ports in Boise, ID**: 48% (47% of PEVs located here)

Transit Bus Electrification

- Transit authorities have been early adopters of heavy-duty EVs
- High-VMT, fixed route operation tends to be ideal for electrification
- Allows fleets to take advantage of EV low operating costs
- Predictable schedule alleviate the need for fast charging

NREL-Hosted Event Supports Industry Development of Megawatt Charging System Connectors

Oct. 12, 2020

electrek Exclusives Autos Alt. Transport Autonomy Energy Tesla Shop

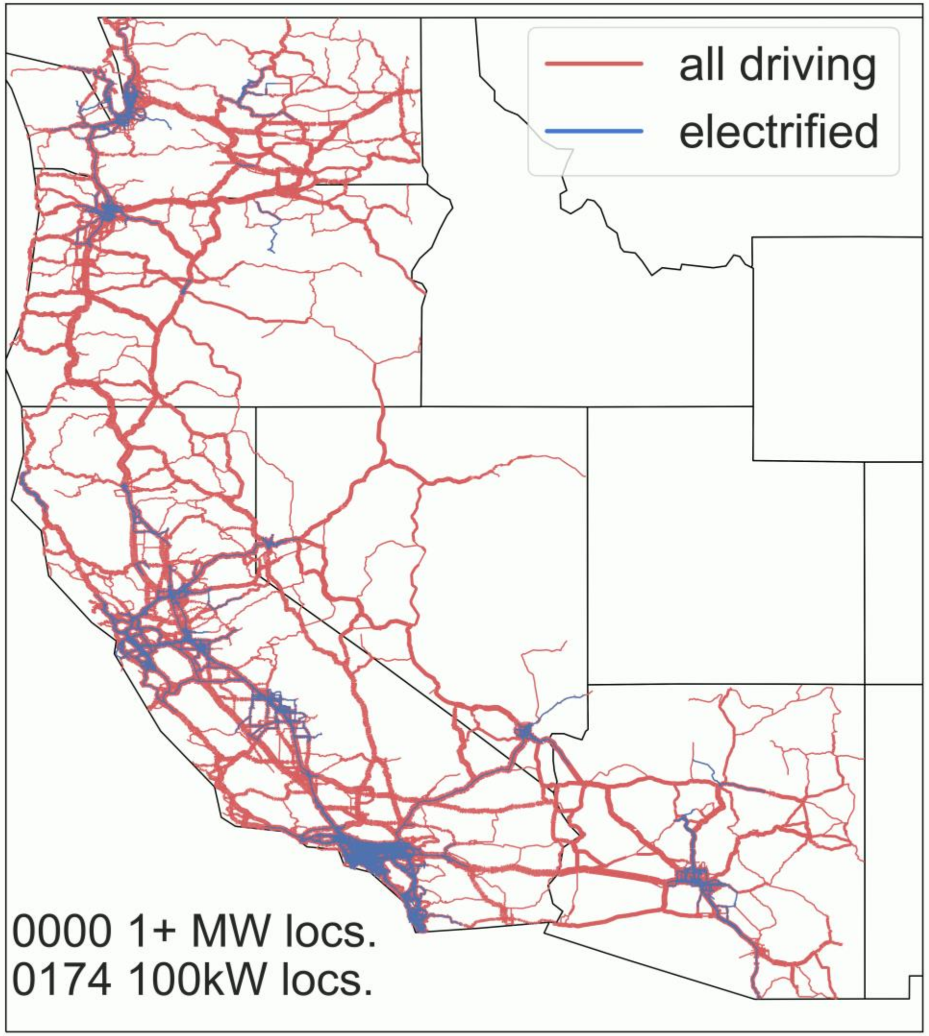
Tesla is deploying the first Megacharger to charge its Tesla Semi electric truck

Fred Lambert - Oct. 12th 2021 2:05 pm PT @FredericLambert

141 Comments Facebook Twitter Pinterest LinkedIn Reddit

US West Coast Scenario Analysis

- Simulations used to estimate future demand for heavy-duty charging
  - Includes mix of slow charging at overnight locations and fast charging along freight corridors
- Investment needed per port expected to far exceed that of light-duty vehicles
  - Potential for significant grid impacts at depots and travel centers



EVI-Pro HD

Reliability is Complicated and Must be Addressed

"This is about more than just up-time. Charging standards are such that compliant vehicles and infrastructure can still be inoperable. This is where Tesla has a real advantage. They control both sides of the handshake."

"Driver tolerance for inconvenience is very low. Even one negative experience waiting in line or finding a broken charger can sour the user experience."

"If someone struggles to charge and they can't - they blame us (auto OEM). Success rate of a customer plugging in at a public station today is abysmal. Auto OEMs cannot play this role long term."

Interoperability

- **Interoperability** refers to the ability to use a charging network membership at other networks' stations ("roaming"). Although every major charging network signaled interoperability intent before 2020, it is only enabled through two agreements which may become consolidated "soon".
- The benefit of interoperability is the reduced need for multiple plastic charging cards or charging apps (a frequent and longstanding complaint by EV drivers).
- Until such time interoperability becomes ubiquitous, other approaches such as credit card readers, like gas station, are likely needed.

Current Agreements → Coming Soon?

Current Agreements:

Greenlots
EV Connect
FLO
ChargePoint
EVgo

Notes: Largest networks in **bold**

- **Electrify America** absent
- Blink absent

Coming Soon?

Sema Connect
FLO
EV Connect
Greenlots
EVgo
ChargePoint

Even the top DC fast charging networks need big quality improvements

“If EVs are to replace fossil-fuel vehicles, they need to be able to make long highway trips, which means that DC fast charging needs to be reliable, convenient, affordable and ubiquitous…[but] the user experience often leaves much to be desired…”

Category	Electrify America	EVgo	ChargePoint	EVconnect
App & Website				
Website	58	48	48	3
App Operation	110	105	95	105
App Functionality	97	83	98	78
Price & Payment	79	89	97	77
Sub–Total	344	325	338	263
Charging Location				
Environment	107	70	52	80
Charging Station	126	116	113	118
Service	62	61	65	47
Access & Payment	52	38	36	58
Sub–Total	347	285	266	303
Total Score (Out of 1000)	691	610	604	566

Source: Charged EV Magazine, Dec 2020

Best 20 in 20 Test – Charging Infrastructure

CHARGED ELECTRIC VEHICLES MAGAZINE

umlaut

Although Electrify America won this 202 test with 691 points/1000 (C-score?), key customer issues include:

- Relatively high prices
- Starting problems and interruptions
- No QR code scanning for station ID
- Short cables make it difficult to reach EV charging ports
- Site designs don’t accommodate large vehicles

Site Design Best Practices

- Location, location, location
- Consider need for “future proofing”
- Anticipate technology evolution
- Use on-site storage/generation to mitigate operating costs
- Provide multiple, interoperable payment options
- Incentivize data sharing to help grow the network
- Emphasize importance of reliability

Neighborhood-Level Analysis: Refueling Infrastructure

Greater Chicago Area

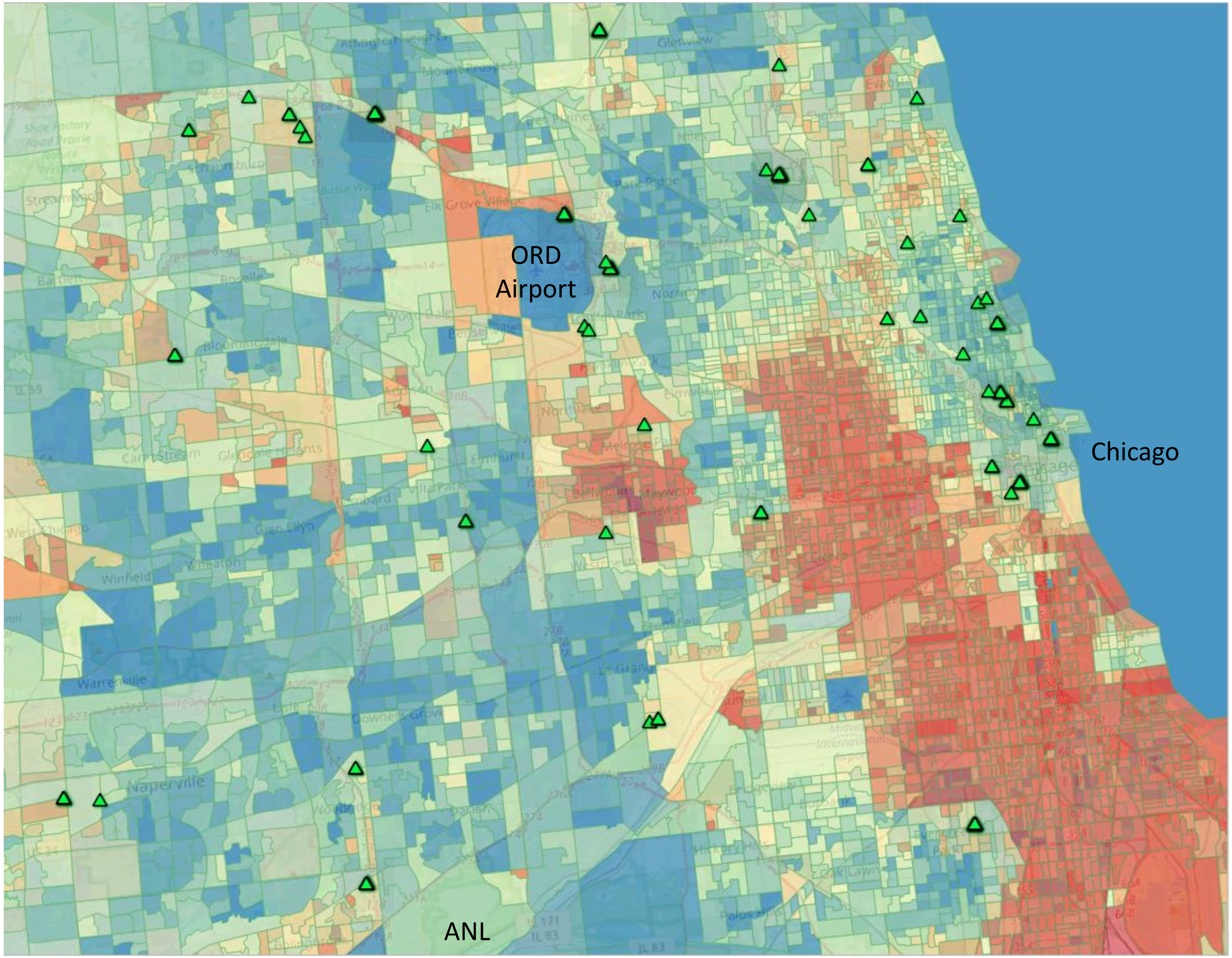
Broader context: IL is one of the top 10 states that have the worst equity of refueling infrastructure and PEV adoption in terms of income and race.

HH Income: High — Low

People of Color: Low — High

Income and race maps are overlayed.
If you see red areas, they are the ones with low-income and/or (higher share of) people of color.

- Public DCFC
- Public L2
- Gas station



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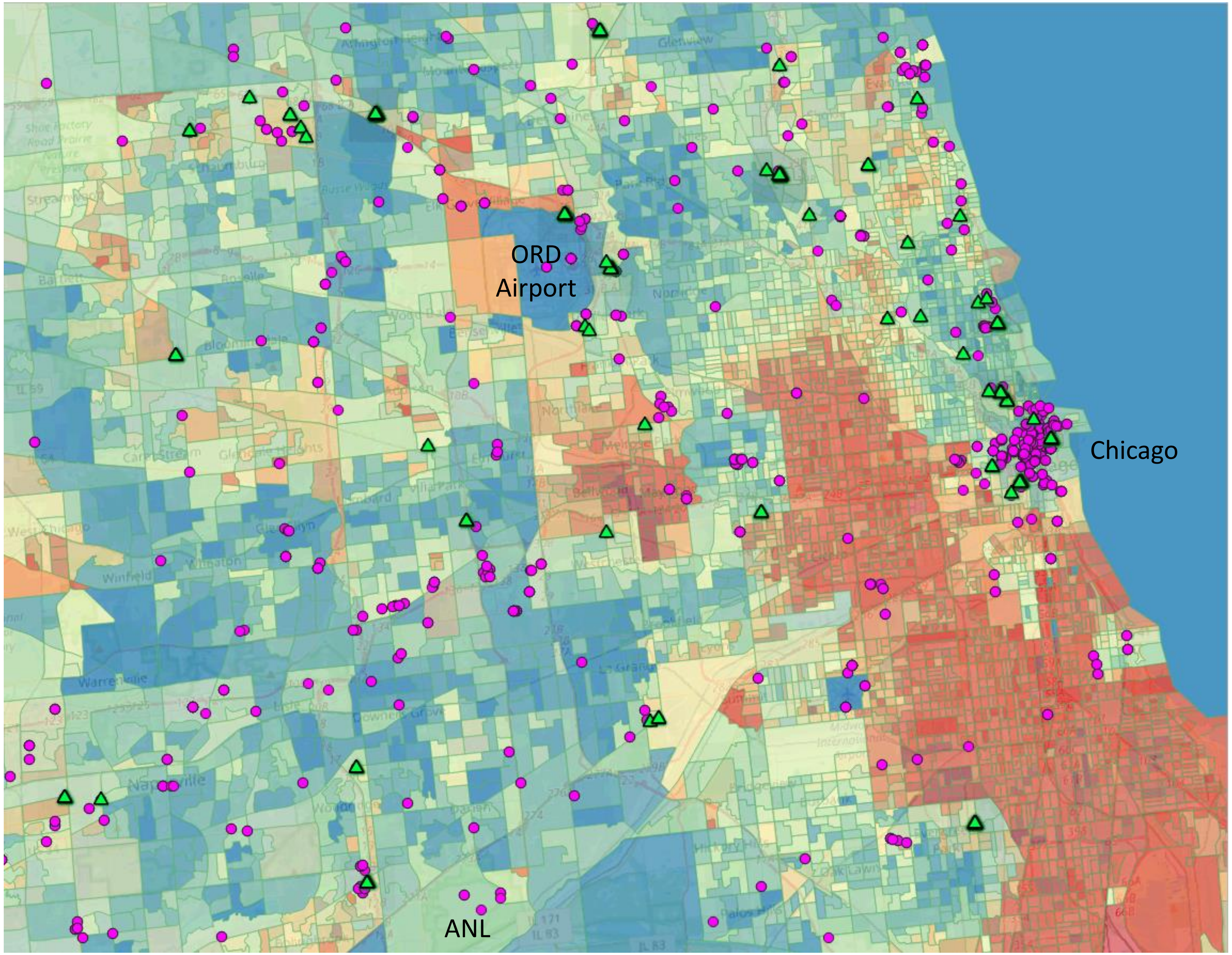

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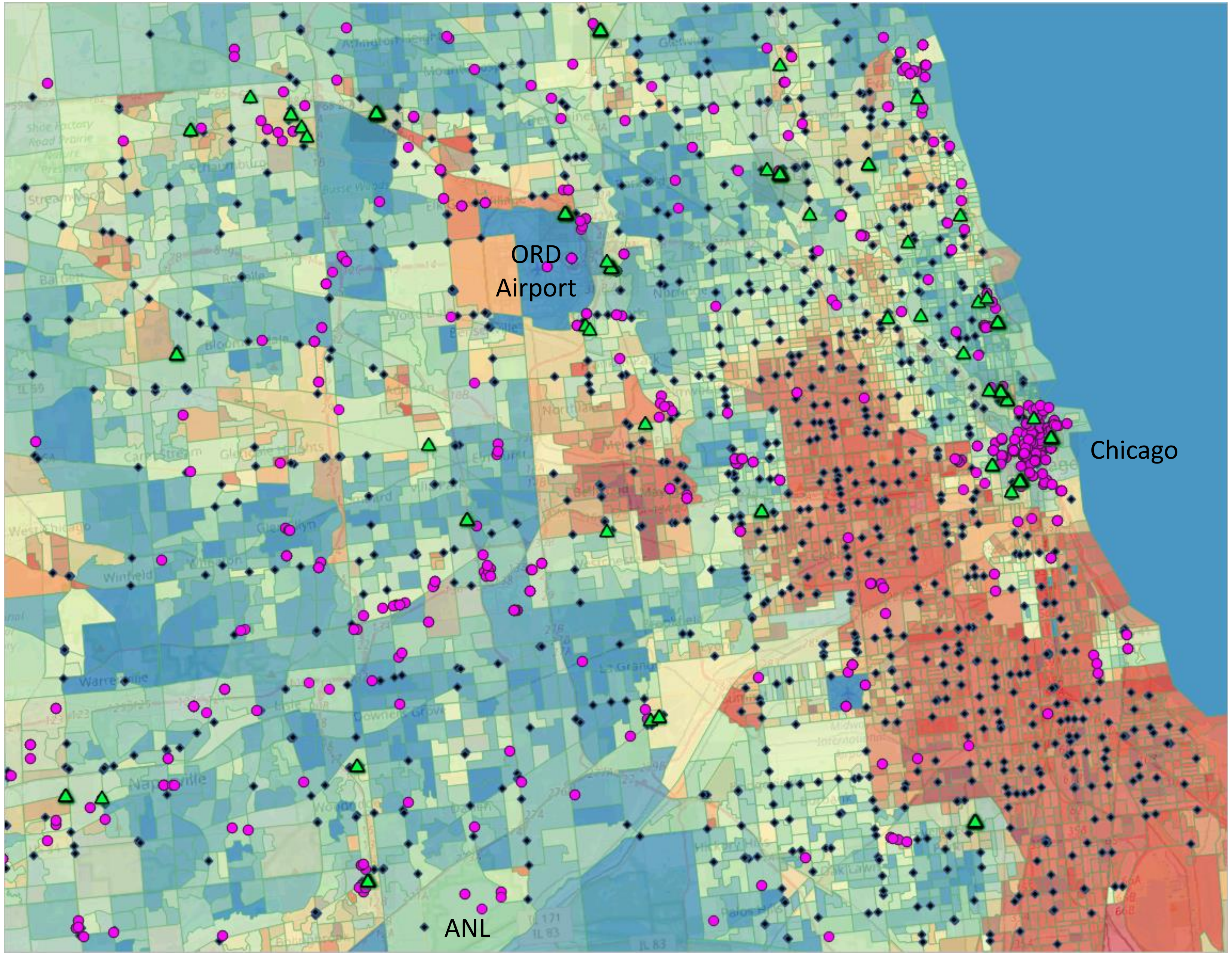
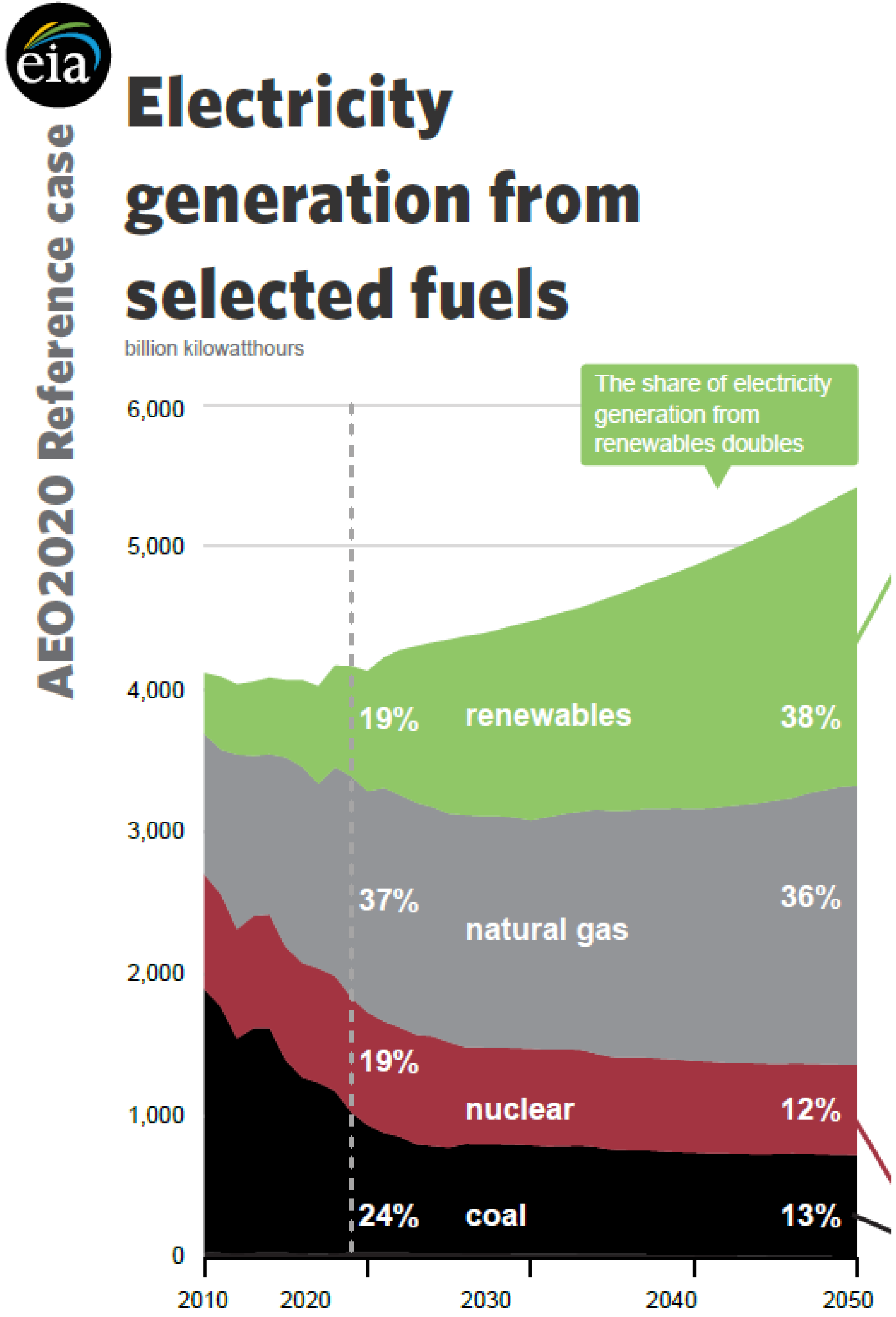


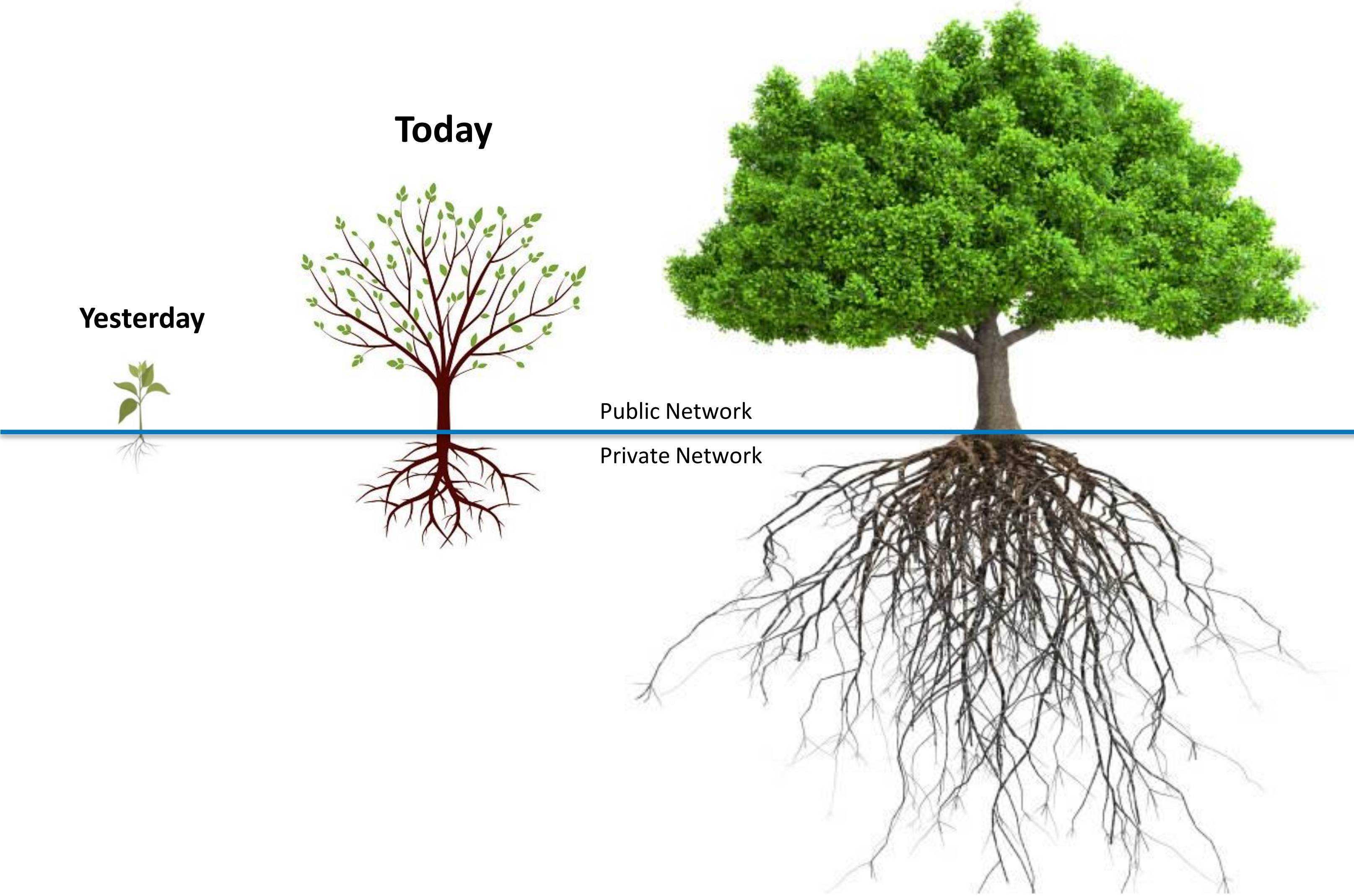
Decarbonization of the power sector means EVs keep getting greener as they age

Managed charging is an enabling technology to help the grid operate efficiently and lower the carbon intensity of EV charging



Growing a Charging Network from the Ground Up

Charging Network of the Future



The Branches: Destination Charging
(right speeding at offices, recreation, dining, etc.)

The Trunk: Fast Charging
(corridors and retail)

The Roots: Home Charging
(single family, apartments, curbside)

EV Analysis Takeaways

1. Data, Data, Data
2. Understand Coverage Needs
3. Bridge the “Valley of Death”
4. Evaluate the Potential for Residential Charging
5. Value of “Lite” Tools
6. Emerging Mobility Options (short term)
7. Role of Automation (long term)

Thanks! Questions?

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