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EVI-X Updates and National Charging Assessment Report

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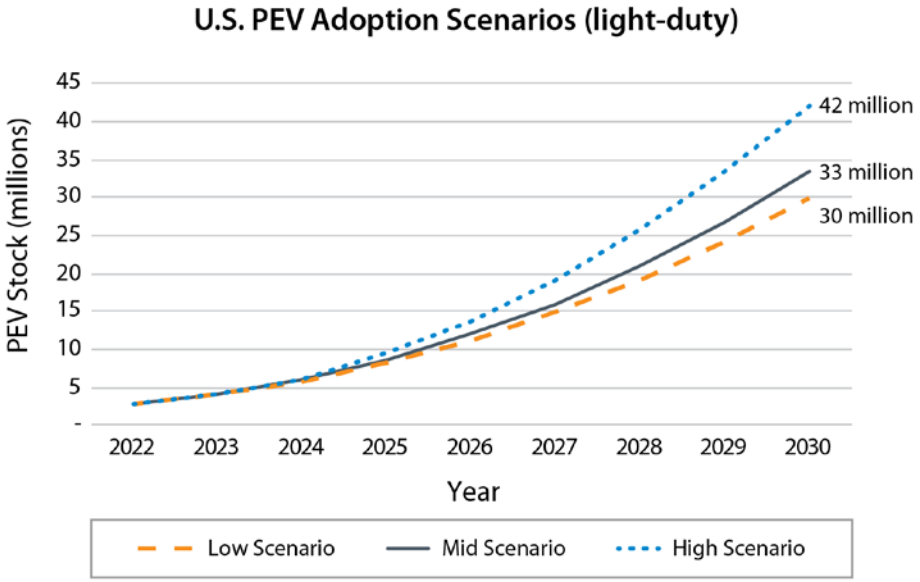
National Renewable Energy Laboratory

2023 Vehicle Technologies Office Annual Merit Review

June 15, 2023

Project ID # JOET001

The Road to 2030



Scenarios derived from NREL's TEMPO model.

PEV = plug-in electric vehicle
LDV = light-duty vehicle
Y/Y = year over year
ZEV = zero emission vehicle
ARB = Air Resources Board
BIL = Bipartisan Infrastructure Law
IRA = Inflation Reduction Act

U.S. climate goals necessitate rapid decarbonization and PEVs are well-positioned in the light-duty segment

PEV adoption is accelerating (2022 LDV Sales Share and Y/Y Growth)

- U.S. = 8% +55%
- California = 19% +38%
- China = 29% +80%
- Europe = 21% +15%
- Global = 14% +55%

U.S. Executive Order, 2021 = 50% (U.S. LDV ZEV Sales by 2030)
California ARB, 2022 = 100% (CA LDV ZEV Sales by 2035)

BIL & IRA provide significant incentives

Auto industry 100% ZEV ambitions

- Tesla, 2003
- Audi, Fiat, Volvo, Mercedes-Benz, 2030
- General Motors = 2035
- Honda = 2040

The National Charging Network

- Goals of the National Charging Network
  - Convenient, Affordable, Reliable, Equitable
  - Charging today rarely meets all these criteria… much work to do
- What should this network look like?
  - Many different perspectives
  - We're modeling with **EVI-X**
  - We're reviewing other national studies
  - We're talking to stakeholders

Key Stakeholders

Current/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

Multiple Tasks Contribute to a Common Vision

National Assessment

"What is the national need for charging infrastructure?"

EVI-Equity

"How do household demographics shape charging needs?"

EVI-X Online

"Can analysis capabilities be deployed at scale?"

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

EVI-EDGES
Techno-economic evaluation of behind-the-meter storage

Financial Analysis

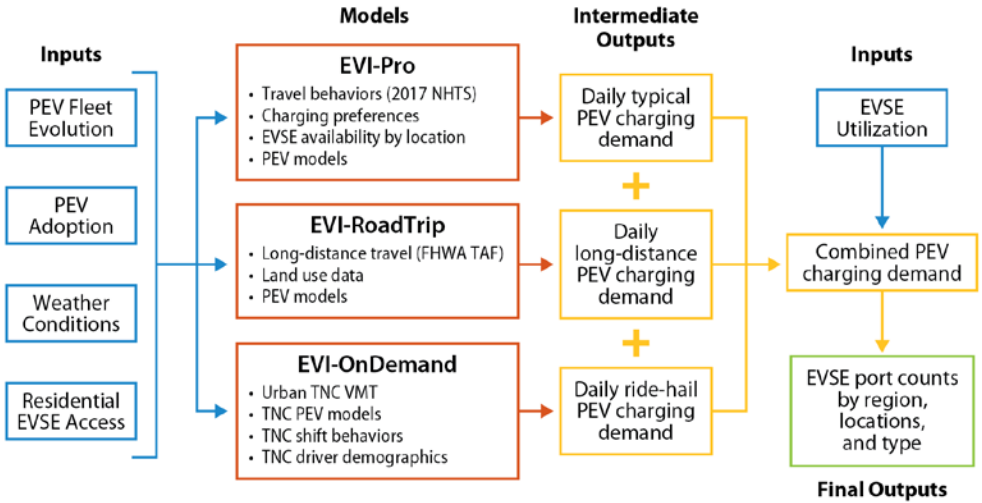
EVI-FAST
Charging infrastructure financial analysis (free to download)

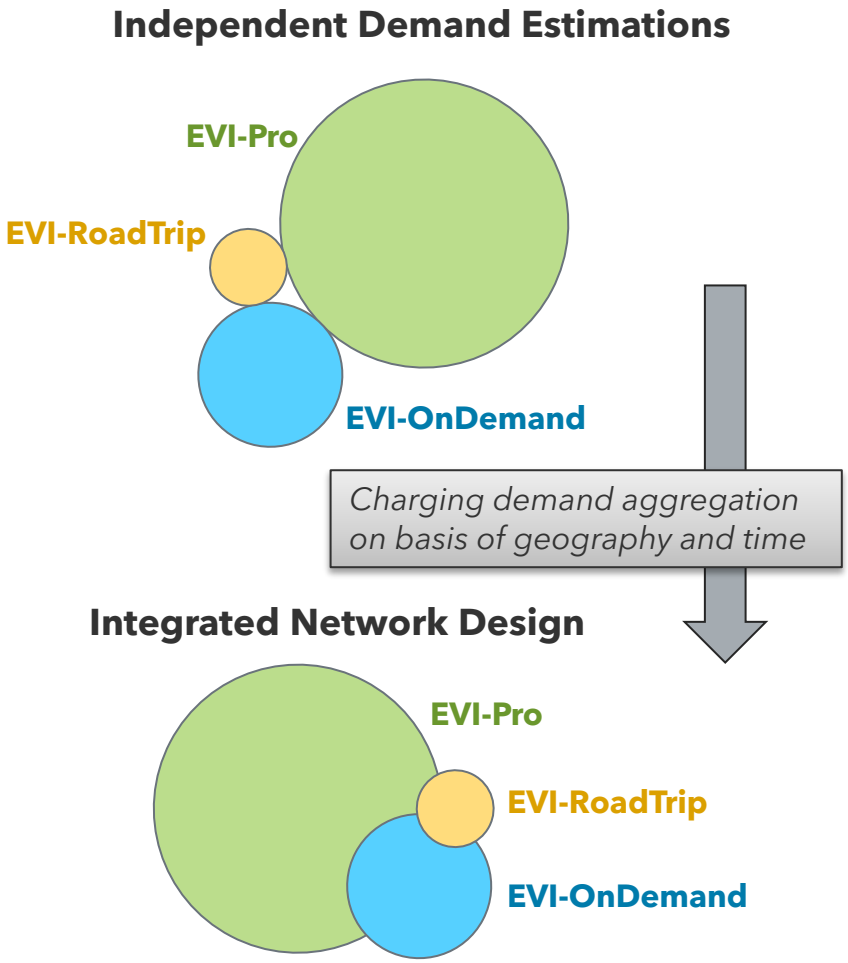
can integrate with any of the above tools

Network & Station Economics
Levelized cost of charging

Model Integration

This project leverages the EVI-X national light-duty infrastructure framework (below) to estimate charging needs of those without residential access, long-distance travel, and ride-hailing electrification





Modeling Assumptions

Real-world Telematics Data (INRIX)

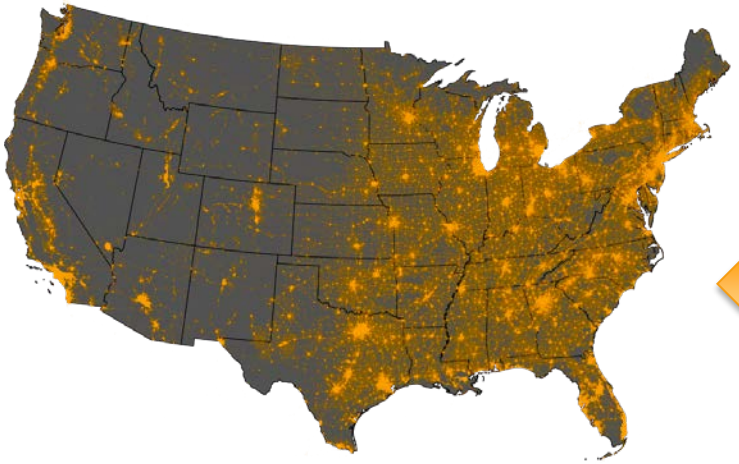
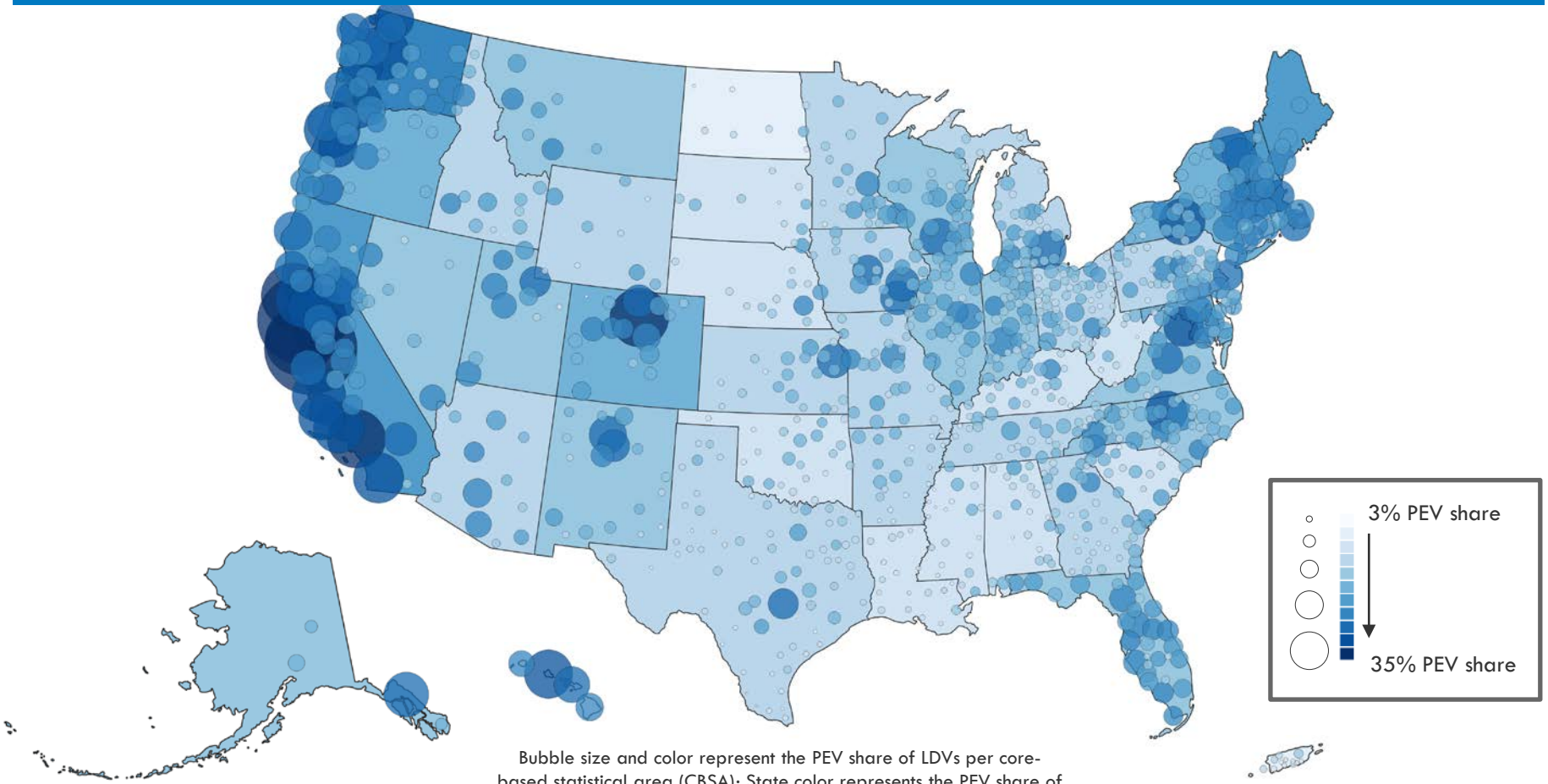


Table 2. Demand-Side Assumptions Used in the Mid Adoption Scenario

Modeling Parameter	2030 Nominal Assumption
PEV fleet size (LDV only)	33 million (2.7 million registered as of 2022)
PEV powertrain shares	BEV = 90% (2022: 72%) PHEV = 10% (2022: 28%)
PEV body type distribution	Sedan = 24% (2022: 58%) C/SUV = 56% (2022: 40%) Pickup = 17% (2022: 0%) Van = 3% (2022: 2%)
Average PEV electric range (model year 2030)	BEV = 280 miles PHEV = 45 miles
BEV minimum DC charge time (model year 2030; 20%–80% state of charge [SOC])	20 minutes [a]
Maximum DC power rating (per port)	350+ kW
Geographical distribution	Scaled proportional to existing PEV and gasoline-hybrid registrations with a ceiling of 35% of LDVs on the road in 2030 as PEVs in high adoption areas and a floor of 3% in low adoption areas
PEVs with reliable access to residential charging	90%
Weather conditions	Typical ambient conditions are used for each simulated region, impacting electric range accordingly
Driving behavior	EVI-Pro: Consistent with Federal Highway Administration (FHWA) 2017 National Household Travel Survey (NHTS) EVI-RoadTrip: Directly applies FHWA Traveler Analysis Framework (TAF) EVI-On Demand: Consistent with Balding et al. (2019)
Charging behavior	All models attempt to maximize use of home charging (when available) and utilize charging away from home only as necessary. When fast charging is necessary, BEVs prefer the fastest option compatible with their vehicle, up to 350+ kW.

33M PEVs by 2030 – Adoption Assumptions



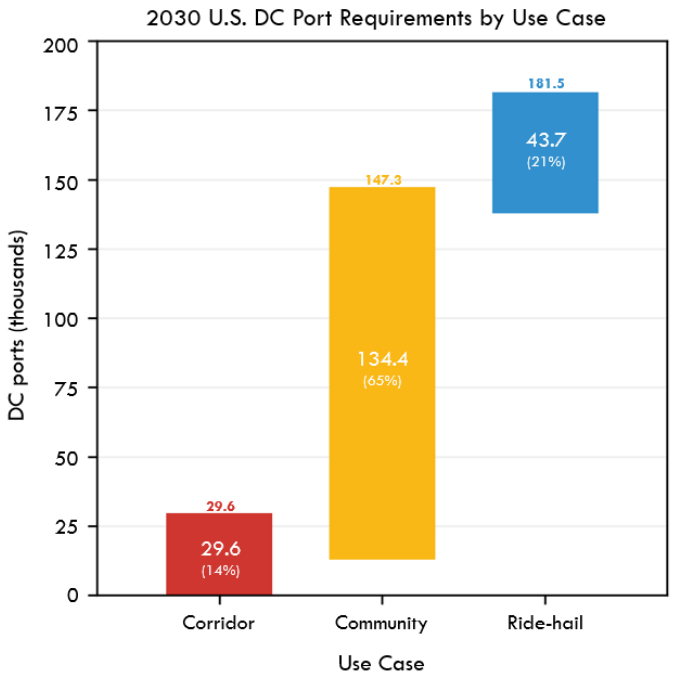
Bubble size and color represent the PEV share of LDVs per core-based statistical area (CBSA); State color represents the PEV share of LDVs in state rural areas

National Results (33M LD PEVs by 2030)

Ports (thousands)

Public	1,248			
	Level 2	1,067		
			Neighborhood	305
			Office	206
			Retail	178
			Healthcare	100
			Recreational	84
			Transport Hub	75
			School	62
			Com. Center	56
	DC Fast	182		
			DC150	63
			DC250	55
			DC350+	64
Private	26,762			
	Level 1	7,024		
			Single Family	7,024
	Level 2	19,738		
			Single Family	18,686
			Multi Family	568
			Workplace	485

*Network size estimates for national fleet of 33M PEVs under baseline assumptions.



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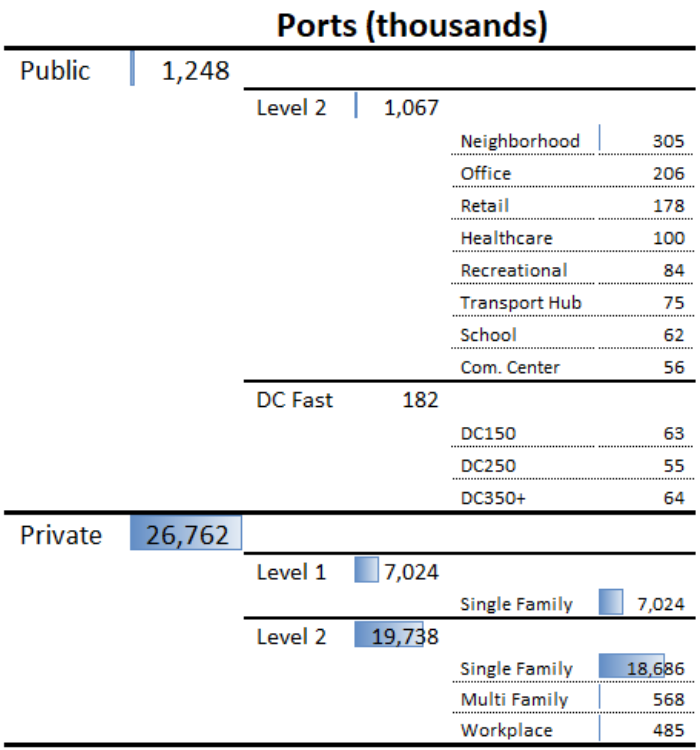

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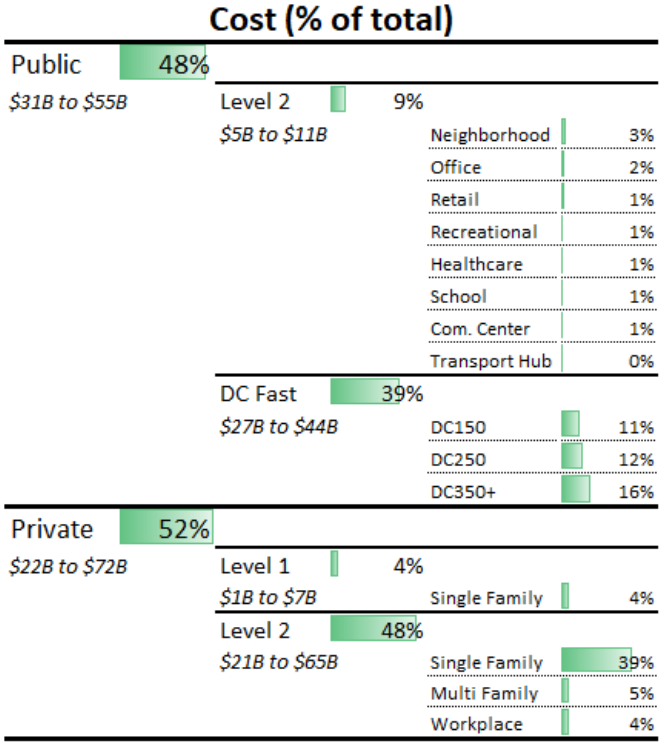


**Installation cost estimates derived from historical data (e.g., BNEF 2020, Borlaug et al 2020, Borlaug et al 2021).

Similar Studies

Organization	LD PEV Stock	Public Ports (incl DC)	DC Ports
ICCT (2021)[1]	26,000,000	2,400,000	180,000
Atlas (2021)[2]	48,000,000	600,000	300,000
McKinsey (2022)[3]	44,000,000	1,200,000	600,000
S&P Global (2023)[4]	28,000,000	2,300,000	172,000
NREL (2023)	33,000,000	1,250,000	182,000

1- Bauer, Gordon, Chih-Wei Hsu, Mike Nicholas, and Nic Lutsey. 2021. "Charging Up America: Assessing the Growing Need for U.S. Charging Infrastructure Through 2030." ICCT. https://theicct.org/publication/charging-up-america-assessing-the-growing-need-for-u-s-charging-infrastructure-through-2030/

2- McKenzie, Lucy, and Nick Nigro. 2021. U.S. Passenger Vehicle Electrification Infrastructure Assessment. Washington, D.C.: Atlas Public Policy. https://atlaspolicy.com/u-s-passenger-vehicle-electrification-infrastructure-assessment/

3- Kampshoff, Philipp, Adi Kumar, Shannon Peloquin, and Shivika Sahdev. 2022. "Building the electric-vehicle charging infrastructure America needs." McKinsey & Company, April 18, 2022. https://www.mckinsey.com/industries/public-and-social-sector/our-insights/building-the-electric-vehicle-charging-infrastructure-america-needs#/

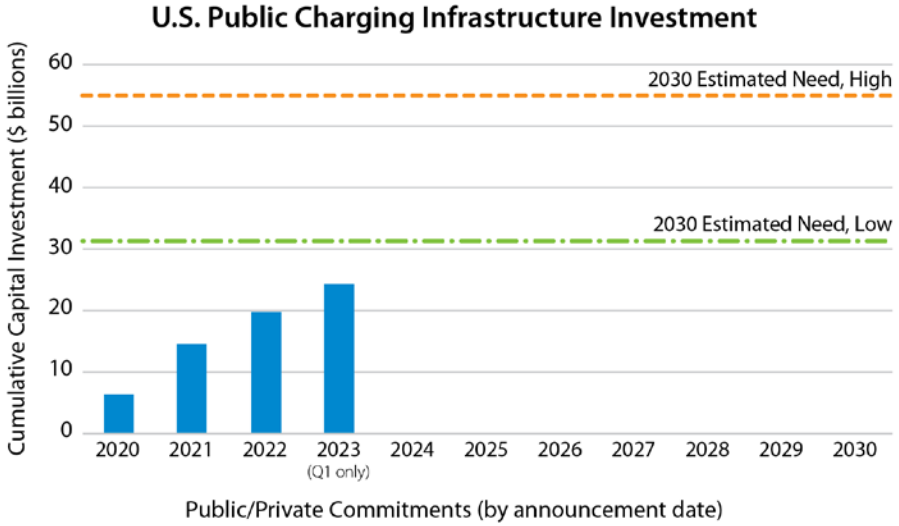
4- S&P Global Mobility. 2023. EV Chargers: How many do we need? https://press.spglobal.com/2023-01-09-EV-Chargers-How-many-do-we-need

What makes NREL's work unique?

1- Distinct EV use cases
2- Sensitivity analysis
3- Geographic resolution

Existing announcements put the United States on a path to achieving 2030 goals

- An estimated $900B has been invested in transportation electrification globally
  - $220B in the U.S.
- Domestic investment in public charging infrastructure exceeds $24B (and counting)
  - $7.5B from Bipartisan Infrastructure Law
  - $3.0B in additional public funding
  - $11.2B in private investment
  - $2.7B in approved utility filings
- Capital raised by charging network companies and incentives from Inflation Reduction Act and Low Carbon Fuel Standards are expected to stimulate additional investment



*Estimates derived from tracking provided by Atlas Public Policy

National Charging Network Supporting 33 Million Light-Duty PEVs by 2030

The Branches:
Public Destination Charging
right speeding* for neighborhood, office, retail

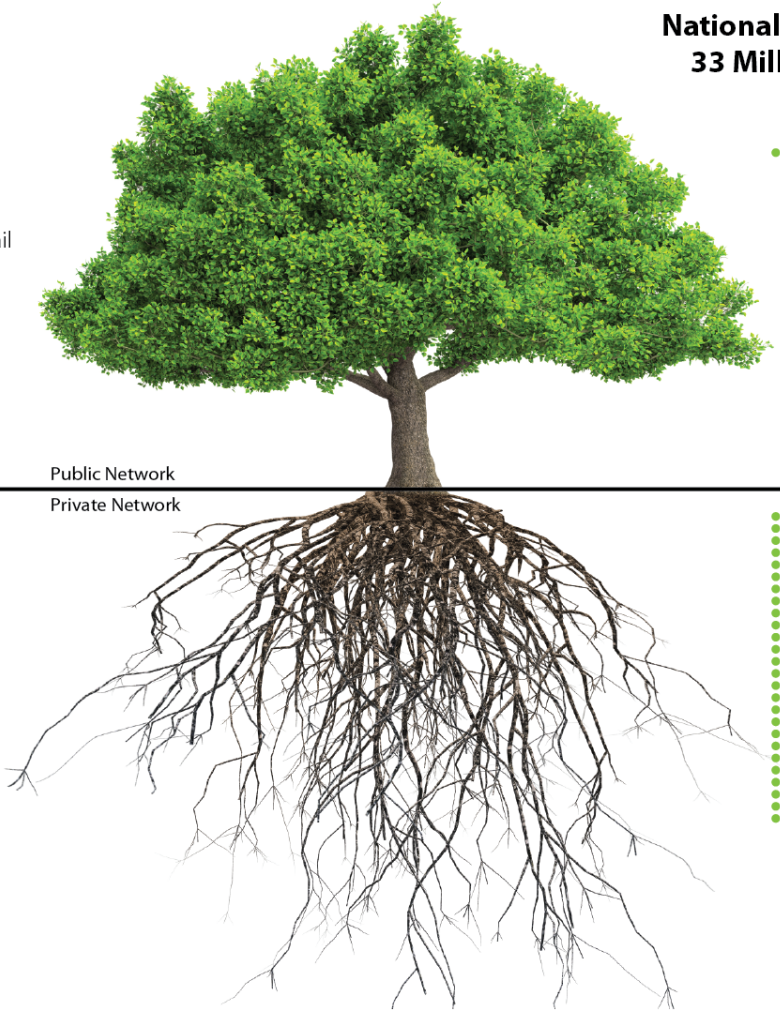
1,067,000 ports

9% of the national investment

The Trunk:
Public Fast Charging
corridor and community

182,000 ports

39% of the national investment



The Roots:
Private Charging
single family, multifamily, workplace

26,762,000 ports

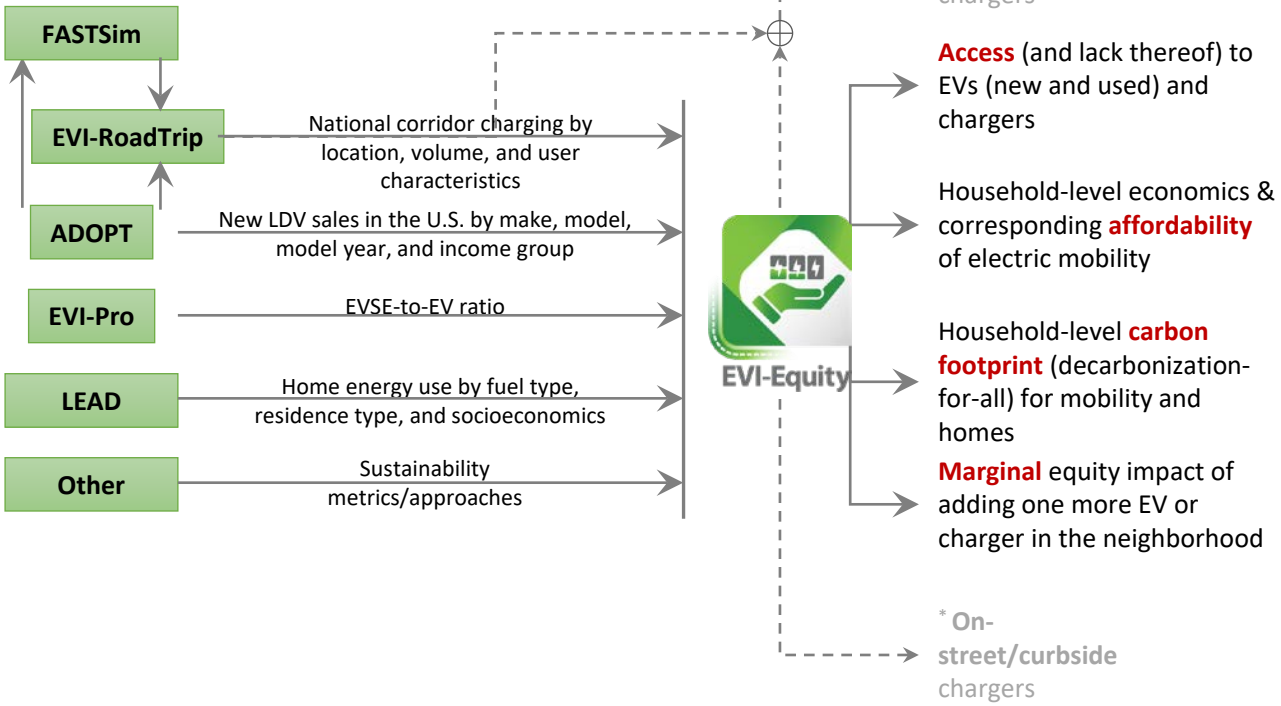
52% of the national investment

**Right speeding refers to matching the charging power provided at a particular location with the typical duration of the activity.*

Each ● represents 50,000 charging ports.

EVI-Equity: Input and Output

EVI-Equity is a simulation model dedicated to evaluating equity implications, such as access, affordability, and decarbonization, of electric mobility. The model is being refined and updated for a web-based deployment.

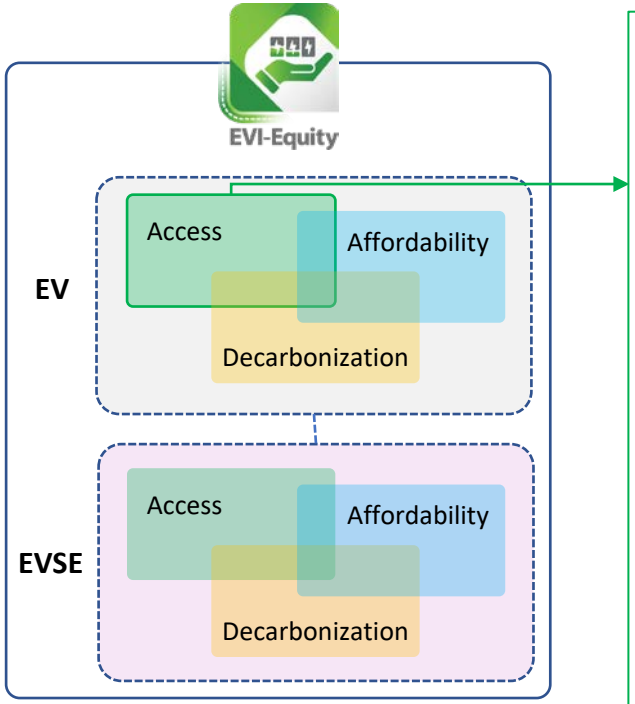


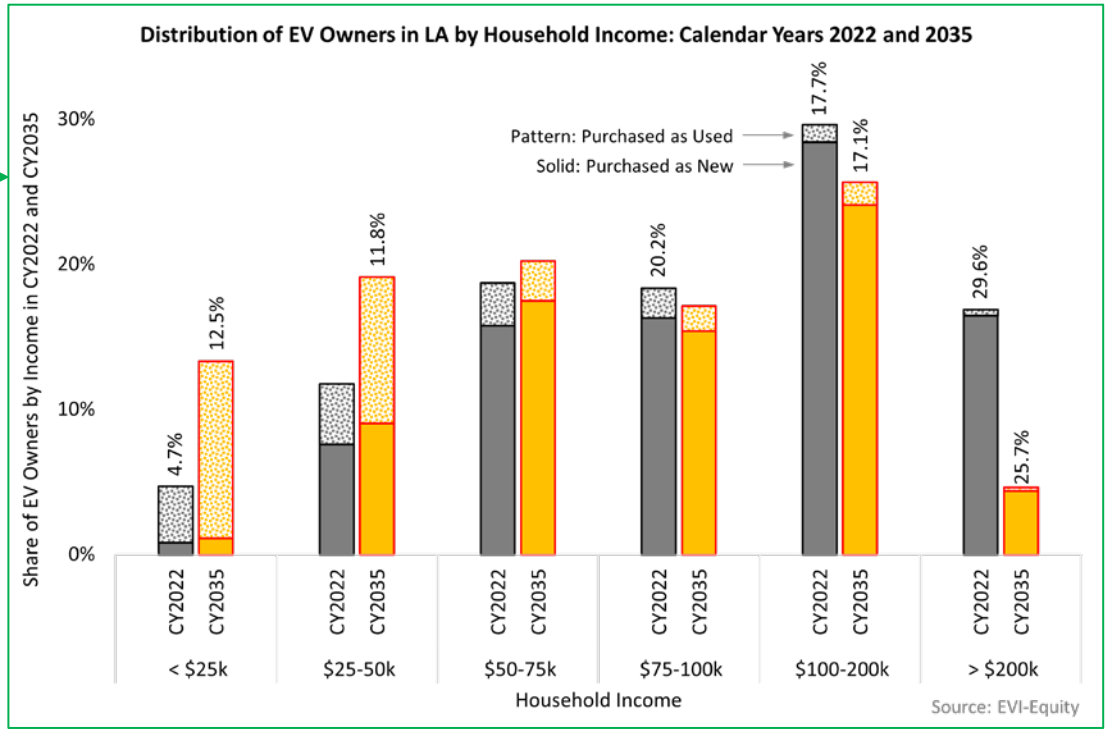
"Household" in EVI-Equity

Socio-demographics and economics	Household income, expenditures, race, ethnicity, household size, occupation, education, age, etc.
Transportation	Vehicle ownership, refueling behavior, travel distance, destination type, etc.
Building	Housing type (e.g., single family detached, apartments), parking options (e.g., personal garage, on-street), utilities (e.g., electricity, natural gas), etc.
Environmental	Air quality, proximity to hazardous facilities/sites, crime rate, etc.

* Small-scale case study (subject to budget/time)

EVI-Equity: LA Case Study





A **two-pronged approach f**or more equitable access to EVs:
(1) Affordable EVs in the new vehicle market
(2) Support the deployment of used EVs

Source: Lee et al. (2023). **LA100 – Equity Strategies: Equitable Transportation Electrification – EVs, Charging, and Multimodal.**

Develop and refine “lite” versions of EVI-X models

https://afdc.energy.gov/evi-pro-lite

EVI-Pro Lite (above) will be updated to include ride hail information

Goal: Build on success and demand for user friendly web tools such as EVI-Pro Lite by refining and developing “lite” online versions of EVI-X models: EVI-RoadTrip, EVI-Equity, and EVI-OnDemand

Impact: Simplifying and exposing aspects of EVI-X models will allow non-researchers to access NREL’s world class research and modeling without the expertise, research-grade software, and training required to understand the full models

Progress: The back- and frontend teams have worked together to define inputs/outputs and data needs for the new tool. Targeted feedback from the May 2nd outreach session has been aggregated and is being considered as database and tool design are finalized.

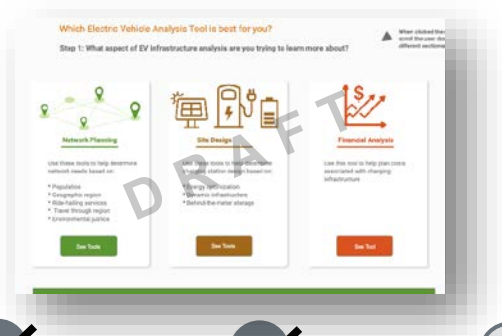
Next steps: Data load, API development, and site development

Unify EVI-X web presence

Goal: Build a central, robust web presence for EVI-X models and tools that makes it clear which tool is most appropriate for user needs

Impact: Reduces barriers to people finding information they need in order to make informed decisions about EVSE in their areas

Progress: Model and tool assessment/inventory completed along with May 2 listening session with relevant stakeholders. New page layouts have been designed.



Next steps: Implement updated page designs (content and structure), standardize model and tool logos, work with NREL communications to prepare news items to boost engagement

Stakeholder outreach

Templating and design

Page development

Content development

Updates go live

	NREL.gov Page	Web tool	API or Source Code
EVI-Pro			
EVI-Equity			
EVI-OnDemand			
EVI-RoadTrip			
EVI-Pro HD			
EVI-InMotion			
EVI-EnSite			
EVI-EDGES			
HEVII			
EVI-FAST			
EVI-Ratio			
EVI-Locate			
NEVI U-Finder			

Cells in green currently exist

Cells in yellow are in development

Collaboration and Coordination with Other Institutions

- This project has benefited from engagement with the following organizations:
  - California Energy Commission
  - Edison Electric Institute
  - Electric Power Research Institute
  - Environmental Resources Management
  - EVgo
  - General Motors
  - National Grid
  - New York State Department of Public Services
  - New York State Energy Research and Development Authority
  - Shell Recharge Solutions
  - Toyota Research Institute
  - Trillium
  - U.S. Department of Transportation
  - U.S. Environmental Protection Agency
  - U.S. Joint Office of Energy and Transportation

Summary

Relevance

- Significant investments are being made in U.S. EV charging infrastructure
  - >$5B private investment in 2023 Q1 alone
- Efficient deployment requires sophisticated planning

Approach

- Leverage EVI-X to estimate national needs
- Apply EVI-Equity to address household-level conditions
- Deploy capabilities through online tools

Technical Accomplishments

- Convenient and affordable charging at/near home is core to the ecosystem but must be complemented by reliable public fast charging
- Fast charging serves multiple use cases, and technology is evolving rapidly.
- Existing announcements put the United States on a path to achieving 2030 goals.

Collaboration

- Multiple stakeholder groups have contributed to the overall research scope

Proposed Future Research

(subject to future funding)

- Further enhance EVI-Equity
- Deploy more EVI-X resources online
- Continue to engage with industry stakeholders and adapt project plan accordingly

Thanks! Questions?

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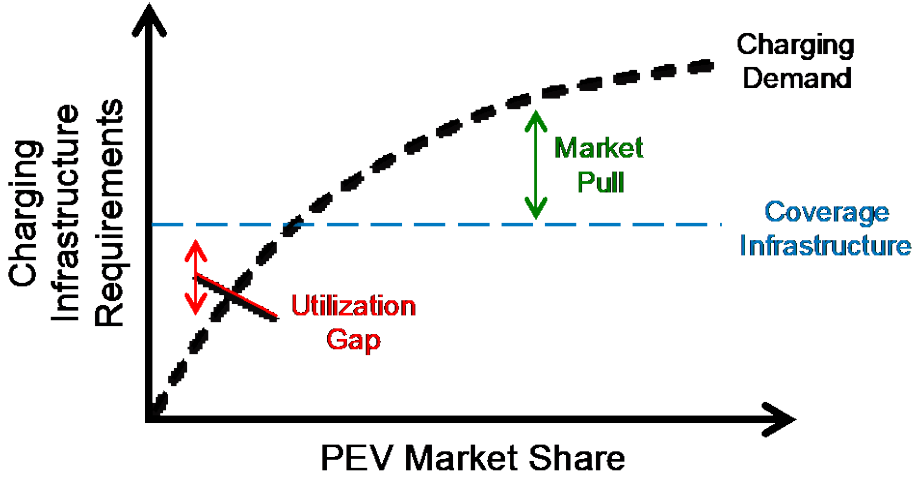
NREL/PR-5400-86417

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding was provided by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Vehicle Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

Charging Networks:
Design Concepts

Coverage vs. Capacity

Establish coverage, then build capacity.



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.

The EV Infrastructure Projection Tool

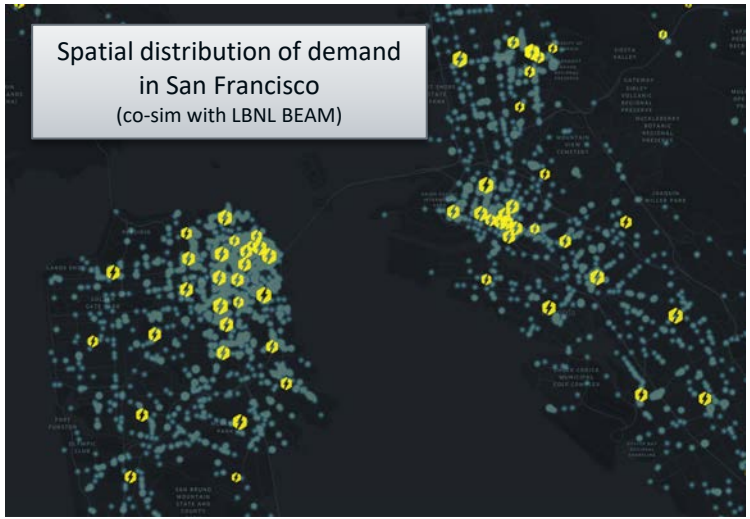
EVI-Pro

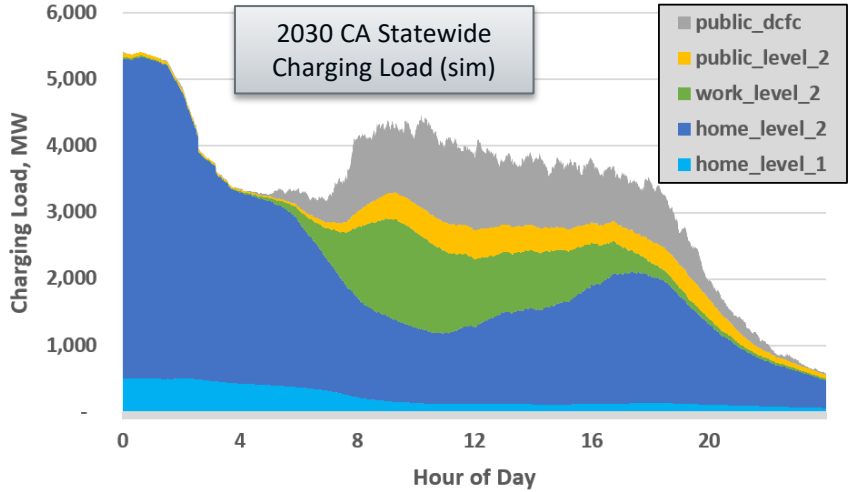
Simulation model to:

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

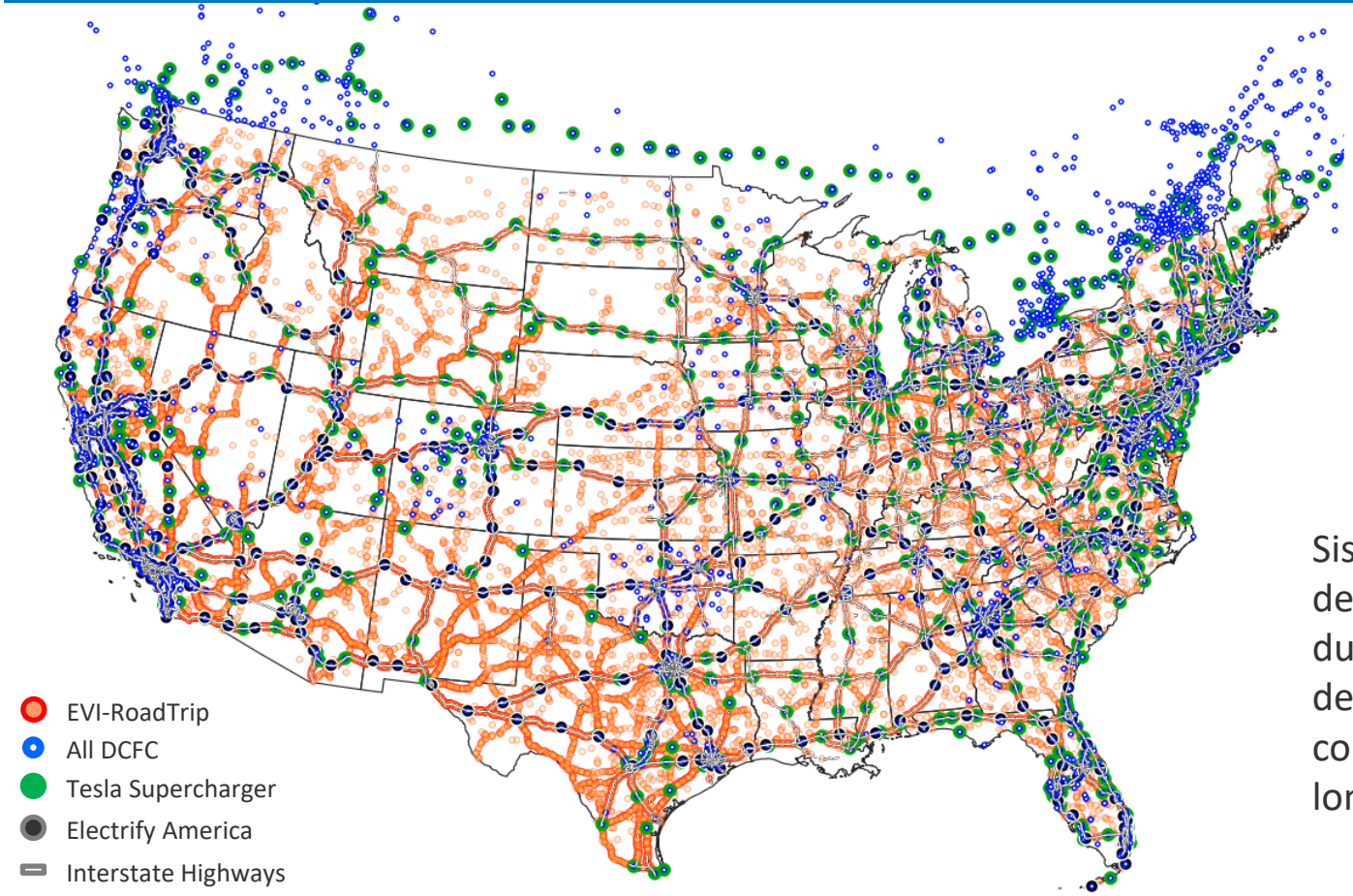
Informed by real-world data and integrated with models of vehicle adoption, mobility, station economics, and the grid

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





EVI-RoadTrip: Corridor-Based Fast Charging



EVI-RoadTrip

Sister tool to EVI-Pro designed to estimate light-duty vehicle charging demand along highway corridors for supporting long-distance travel

EVI-OnDemand
Electric Ride-Hailing

- Major ride-hailing fleets targeting full electrification by 2030, much faster than the broader light-duty fleet
- Drivers accrue high mileage, have limited access to overnight charging, and as a result exhibit high demand for fast charging
- EVI-OnDemand model created to estimate fast-charging infrastructure necessary to meet full electrification