



# Charging Infrastructure: What, Where, and How Many?

*NREL Perspective*

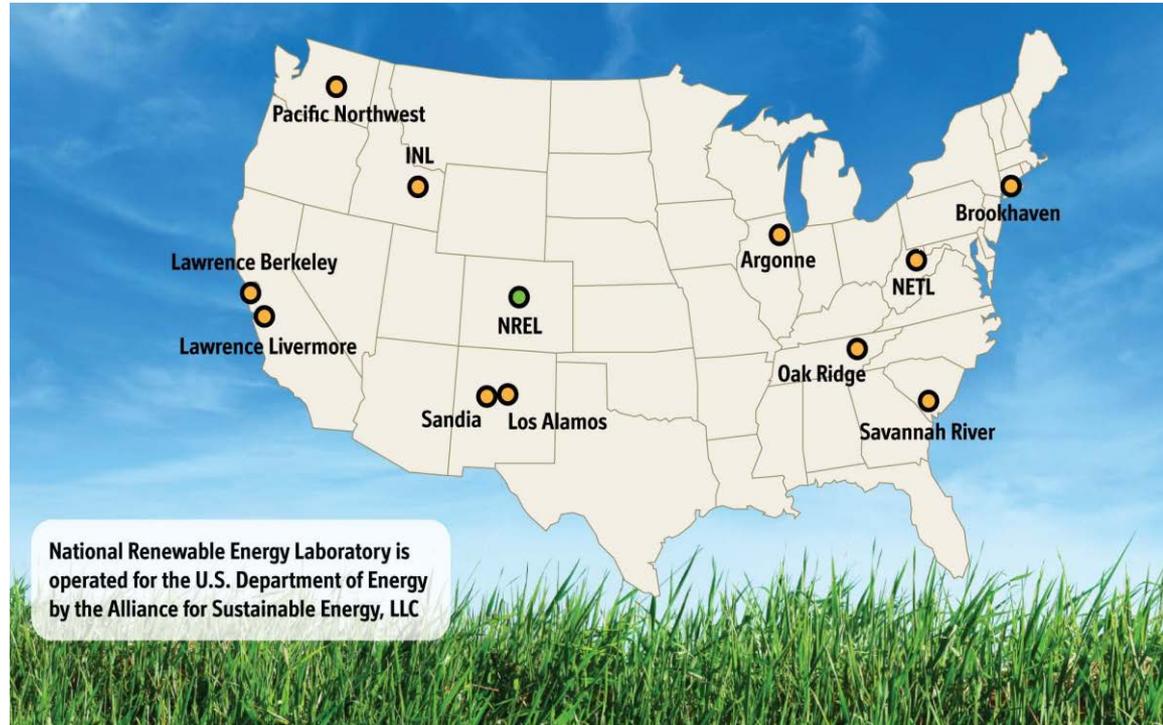
Matteo Muratori and Eric Wood

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Seattle, Washington  
April 4, 2019

# National Renewable Energy Laboratory (NREL)

Spearheads transportation research, development, and deployment to accelerate the widespread **adoption of high-performance, low-emission, energy-efficient passenger and freight vehicles.**

- ✓ **Infrastructure** to support vehicle electrification



# EV Charging Requirements

While the majority of plug-in electric vehicle (PEV) charging is expected to come from residential plugs, a network of **non-residential chargers** is required to:

- Support adopters that cannot charge at home
- Enable long-distance travel
- Cope with range anxiety (safety net)

**Infrastructure plays a big role in enabling and supporting EV adoption**

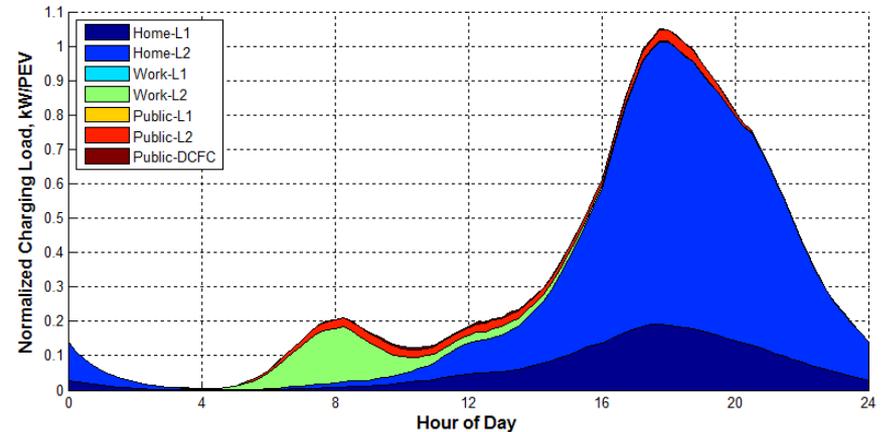
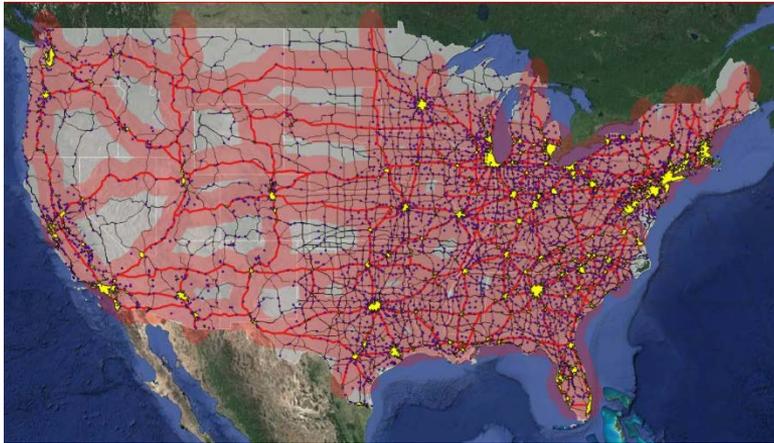


Source: National Research Council. *Overcoming barriers to deployment of plug-in electric vehicles*. National Academies Press, 2015.

# NREL's EVI-Pro



NREL, in collaboration with California Energy Commission, developed the **Electric Vehicle Infrastructure Projection (EVI-Pro)** tool to simulate charging behavior and estimates charging load profiles and charging requirements to support PEV adoption, including interstate corridors.



# EVI-Pro Lite

A free simplified online version of EVI-Pro to assist state and local governments and make insights from recent studies accessible to public and private organizations investing in PEV charging infrastructure.



How Much Electric Vehicle Charging Do I Need in My Area?

State Vehicles Results

Start Over

## Your Results

In Colorado, to support 250,000 plug-in electric vehicles you would need:

**5,590** Workplace Level 2 Charging Plugs

**3,693** Public Level 2 Charging Plugs

*There are currently 1,557 plugs with an average of 2.4 plugs per charging station per the Department of Energy's Alternative Fuels Data Center Station Locator.*

**550** Public DC Fast Charging Plugs

*There are currently 214 plugs with an average of 3.3 plugs per charging station per the Department of Energy's Alternative Fuels Data Center Station Locator.*

## Where Do I Start?

Planners may want to prioritize installation of fast charging infrastructure above Level 2 charging.

**Build DC Fast First:** Establishing fast charging networks that enable long-distance travel, serve as charging safety nets, and provide charging for drivers without home charging is critical to support all-electric vehicles that have no other alternative for quickly extending their driving range.

**Build Level 2 Second:** EVI-Pro typically simulates the majority of Level 2 charging demand coming from plug-in hybrid electric vehicles, which have the ability to use gasoline as necessary for quickly extending driving range.

## Change Assumptions

Plug-in Electric Vehicles (as of 2016): 8,600

Light Duty Vehicles (as of 2016): 4,974,900

Number of vehicles to support

Vehicle Mix	
Plug-in Hybrids 20-mile electric range	<input type="text" value="15"/> %
Plug-in Hybrids 50-mile electric range	<input type="text" value="35"/> %
All-Electric Vehicles 100-mile electric range	<input type="text" value="15"/> %
All-Electric Vehicles 250-mile electric range	<input type="text" value="35"/> %
<b>Total</b>	<b>100%</b>

How much support do you want to provide for plug-in hybrid electric vehicles (PHEVs)?

- Full Support**  
*Most PHEV drivers wouldn't need to use gasoline on a typical day.*
- Partial Support**  
*Calculate using half of full support assumption.*
- Do not count PHEVs in charging demand estimates.**

Percent of drivers with access to home charging  %

Recalculate

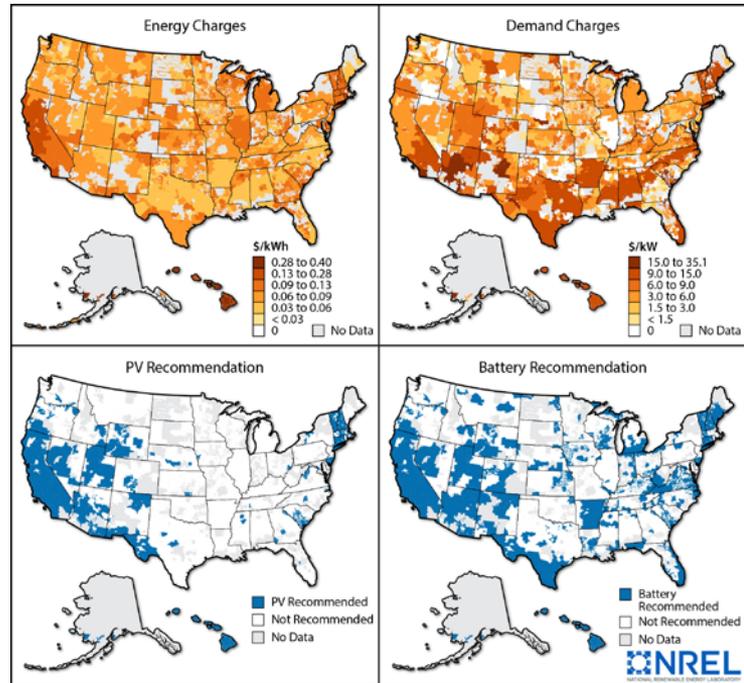
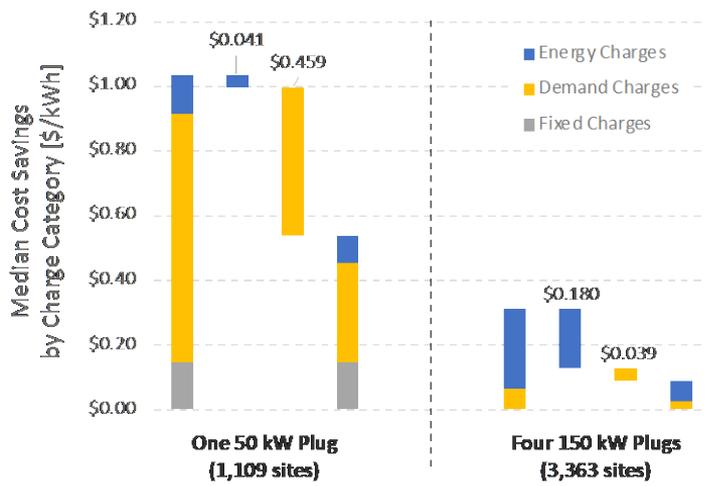
[See all assumptions.](#)

# Mitigate DC Fast Charging Cost



Cost of fast charging can be high, due to **low utilization & demand charges**

**Technology solutions** can be used to reduce cost, including batteries and PV



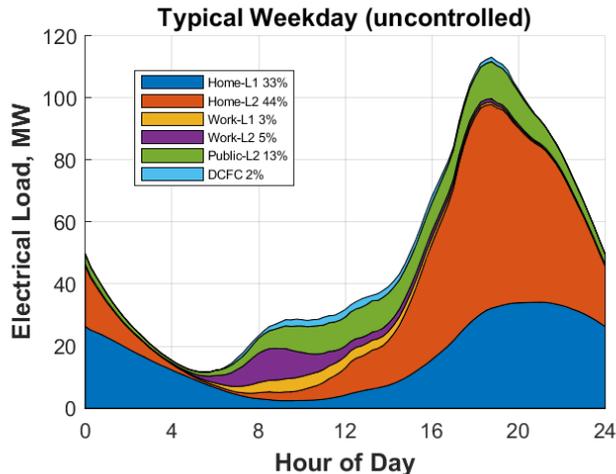
Source: Muratori M. et al. "[Technology solutions to mitigate electricity cost for electric vehicle DC fast charging.](#)" Applied Energy 242 (2019).

# Impact on Power Systems

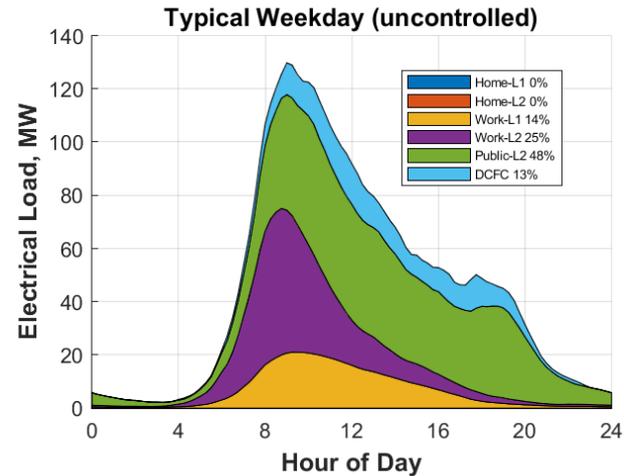
PEV charging can have significant impact on **power systems** and provide opportunities for optimizing integrated systems (e.g., “smart” charging)

**Charging infrastructure determines charging options** and impacts PEV loads

## Home-Dominant Charging



## No Home Charging



# References and Acknowledgments

- Transportation Research Board and National Research Council. 2015. *Overcoming Barriers to Deployment of Plug-In Electric Vehicles*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/21725>.
- Wood, E., C. Rames, M. Muratori, S. Raghavan, and M. Melaina. 2017. *National Plug-In Electric Vehicle Infrastructure Analysis*. DOE/GO-102017-5040. Washington, DC: U.S. Department of Energy. <https://www.nrel.gov/docs/fy17osti/69031.pdf>.
- Muratori, M., E. Elgqvist, D. Cutler, J. Eichman, S. Salisbury, Z. Fuller, and J. Smart. 2019. “Technology solutions to mitigate electricity cost for electric vehicle DC fast charging.” *Applied Energy* 242: 415–423. <https://doi.org/10.1016/j.apenergy.2019.03.061>.

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# Thanks!

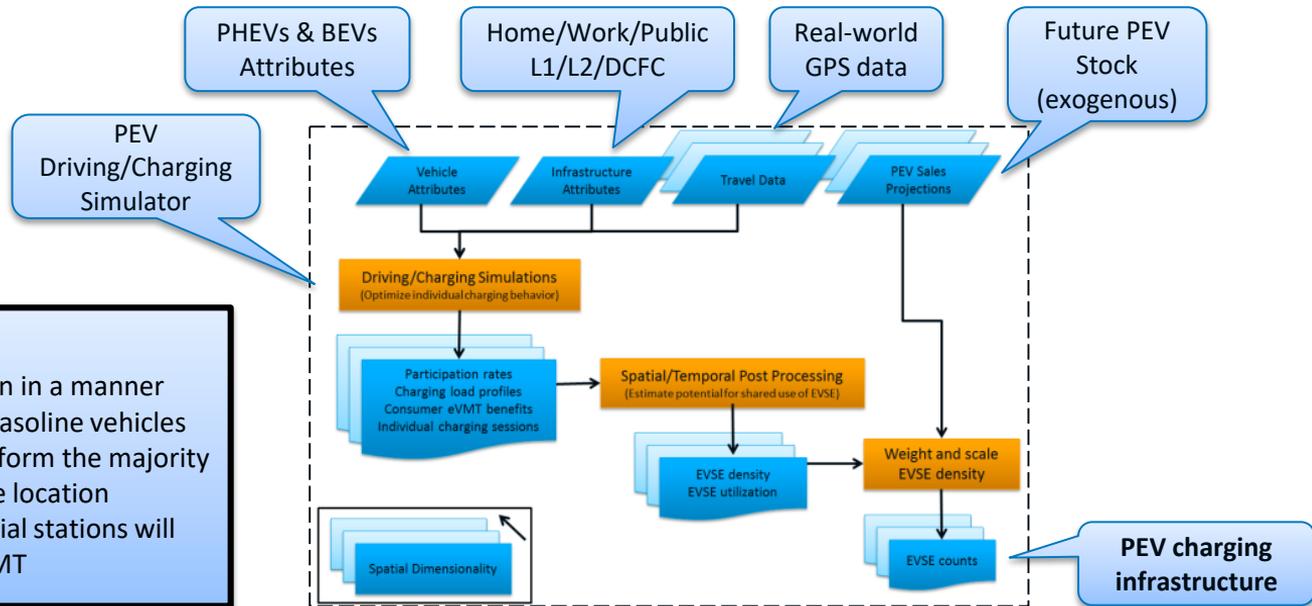
Looking forward to the panel discussion

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# NREL's EVI-Pro

The **Electric Vehicle Infrastructure Projection (EVI-Pro)** tool developed in collaboration with California energy commission estimates PEV charging requirements and charging load profiles



# EVI-Pro: Conceptual

Consumers demand for PEV charging is coverage-based:

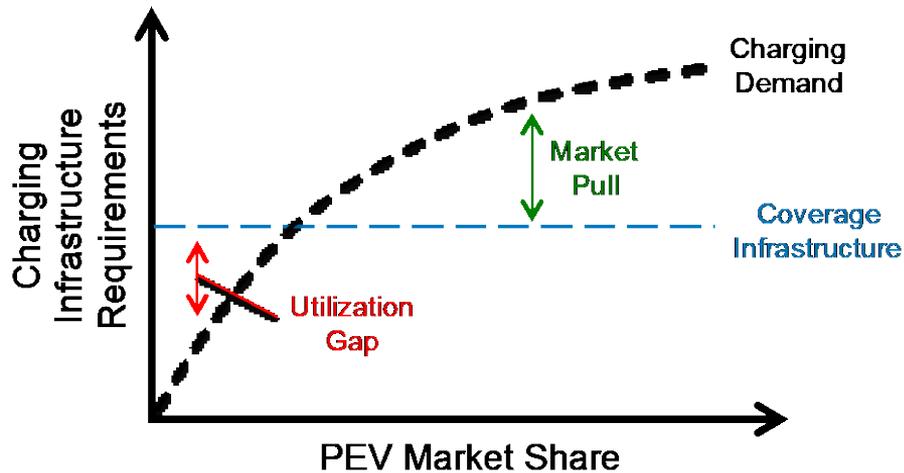
“Need access to charging anywhere their travels lead them”

Infrastructure providers make capacity-driven investments:

“Increase supply of stations proportional to utilization”

A “utilization gap” persists in a low vehicle density environment making it difficult to justify investment in new stations when existing stations are poorly utilized (aka: chicken & egg)

We **quantify non-residential PEV charging requirements** necessary to meet consumer coverage expectations (independent of PEV adoption level) and capacity necessary to meet consumer demand in high PEV adoption scenarios

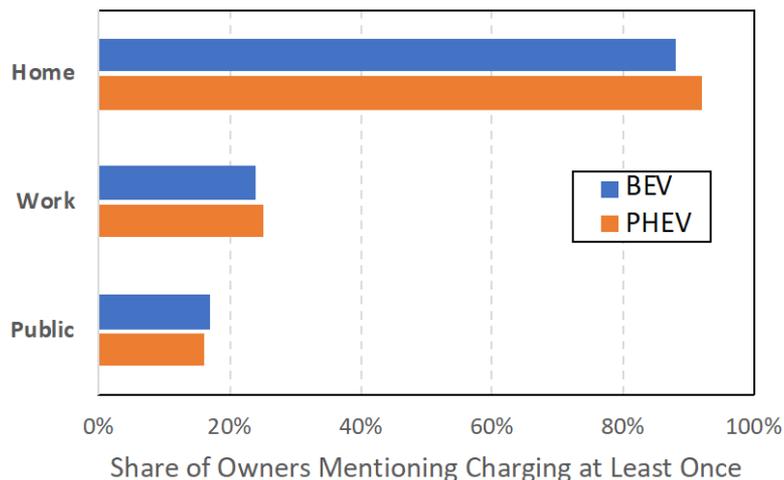


# L1 Vs. L2 Charging

With 12% of the population of the United States, California has 24% of the public PEV charging stations and 30% of the outlets for charging PEVs .

159 BEV owners and 156 PHEV owners responded to questions in the [2016 California Vehicle Survey](#) about where and when they charged their vehicles on a typical weekday:

Typical Weekday Charging



Home Charging

