NREL
Transforming ENERGY

Charging Infrastructure: What, Where, and How Many?

NREL Perspective

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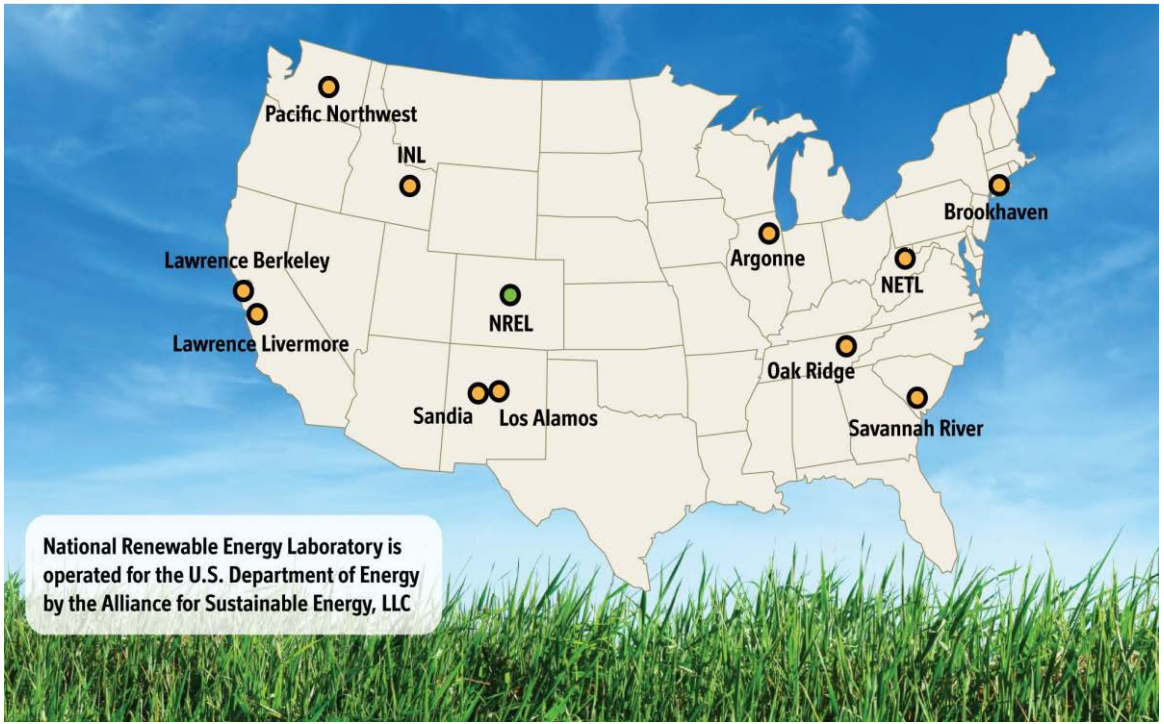
National Renewable Energy Laboratory (NREL)

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

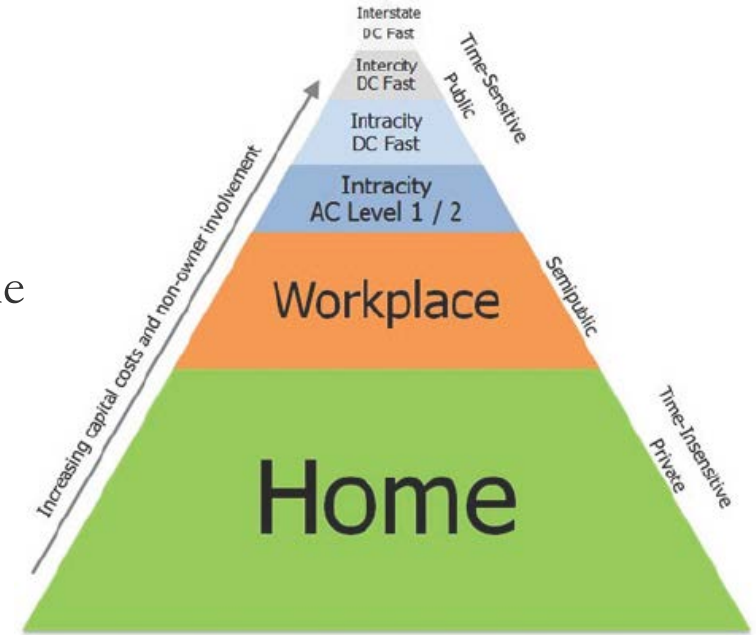


EV Charging Requirements

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)

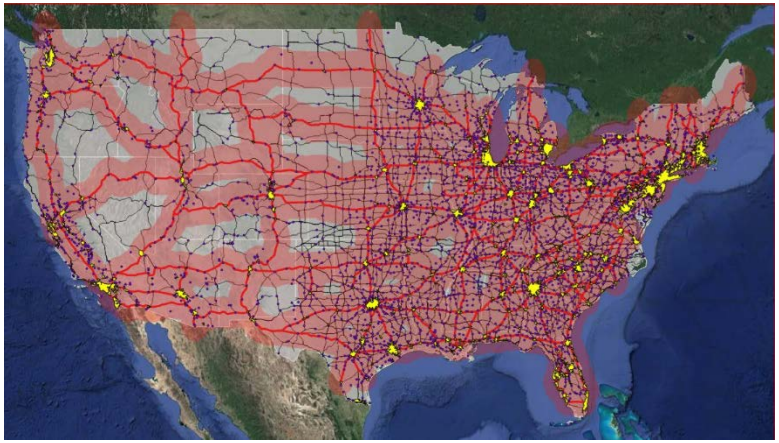
Infrastructure plays a big role in enabling and supporting EV adoption

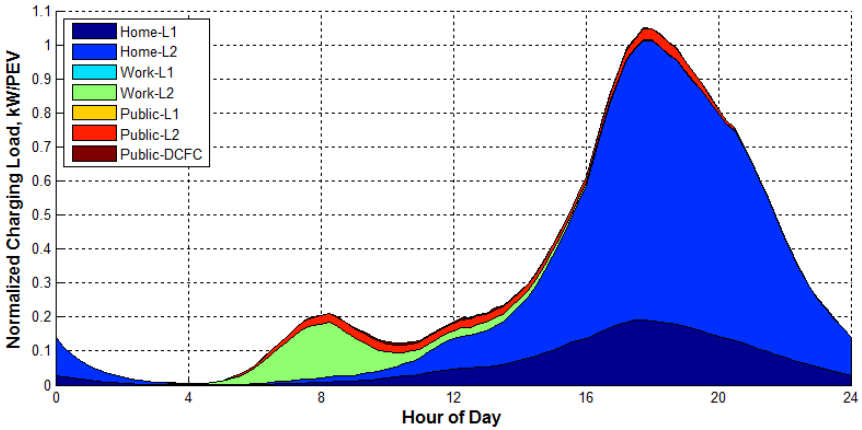


Source: National Research Council. *Overcoming barriers to deployment of plug-in electric vehicles*. National Academies Press, 2015.

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.



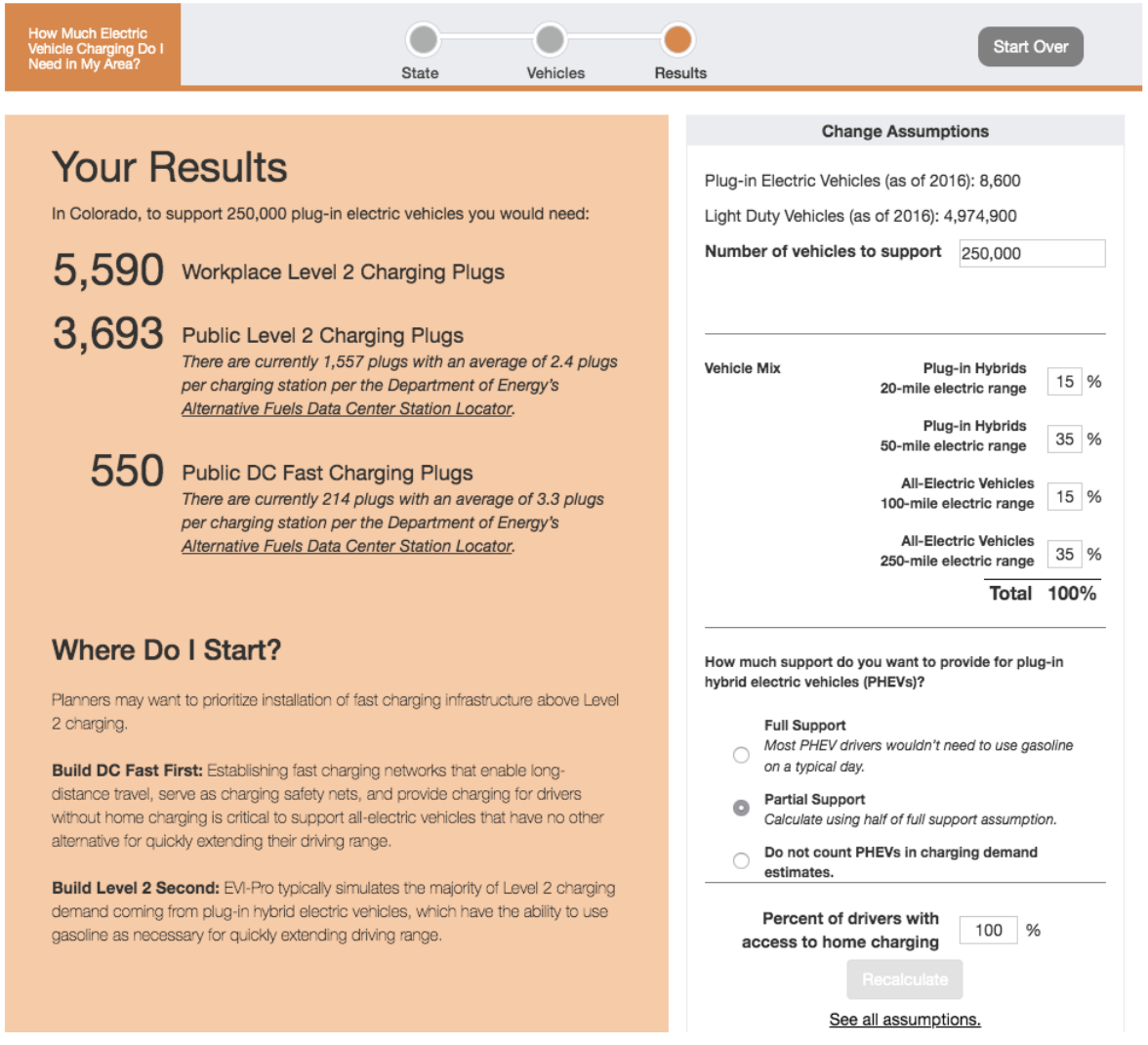


Source: Wood E. et al. "*National Plug-In Electric Vehicle Infrastructure Analysis*." U.S. DOE Report (2017)

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.

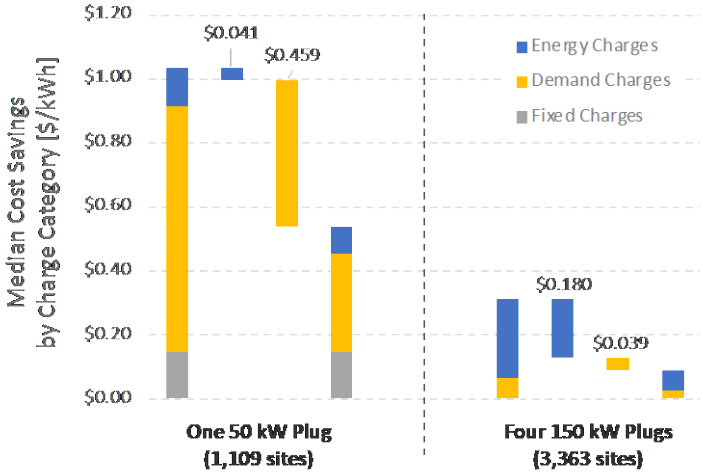
EVI-Pro

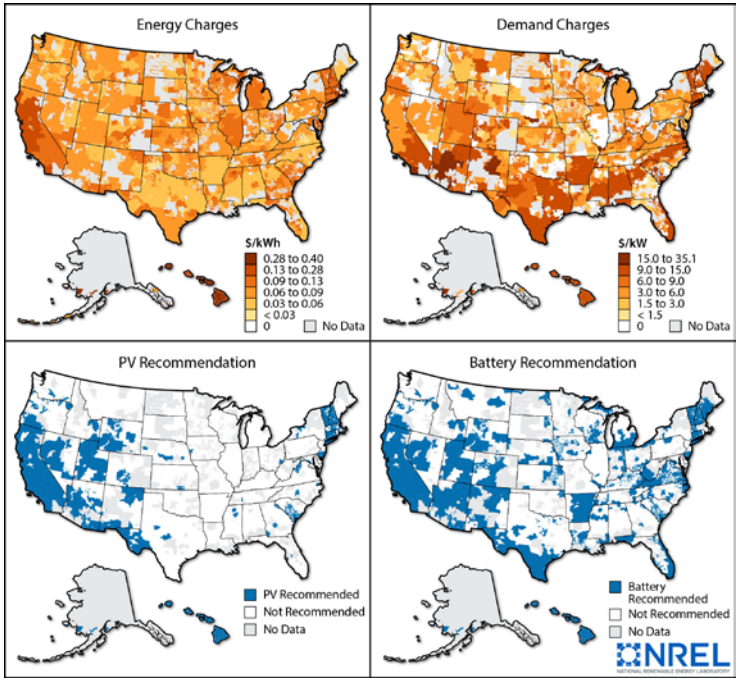


Mitigate DC Fast Charging Cost

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





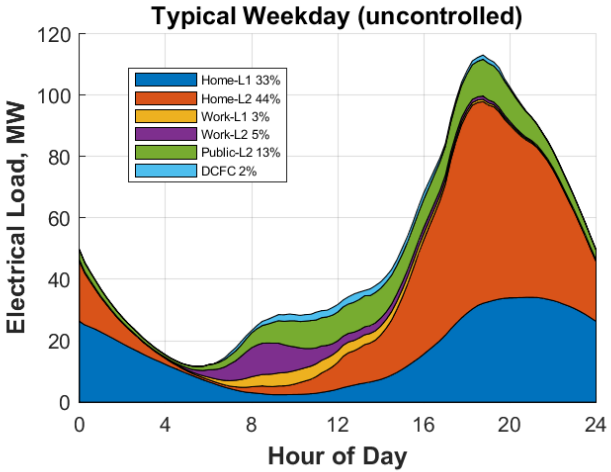
Source: Muratori M. et al. "Technology solutions to mitigate electricity cost for electric vehicle DC fast charging." Applied Energy 242 (2019).

Impact on Power Systems

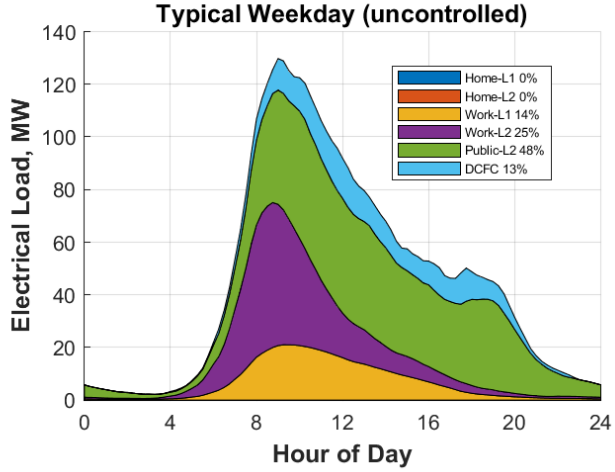
PEV charging can have significant impact on **power systems** and provide opportunities for optimizing integrated systems (e.g., "smart" charging)

Charging infrastructure determines charging options and impacts PEV loads

Home-Dominant Charging



No Home Charging



References and Acknowledgments

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- 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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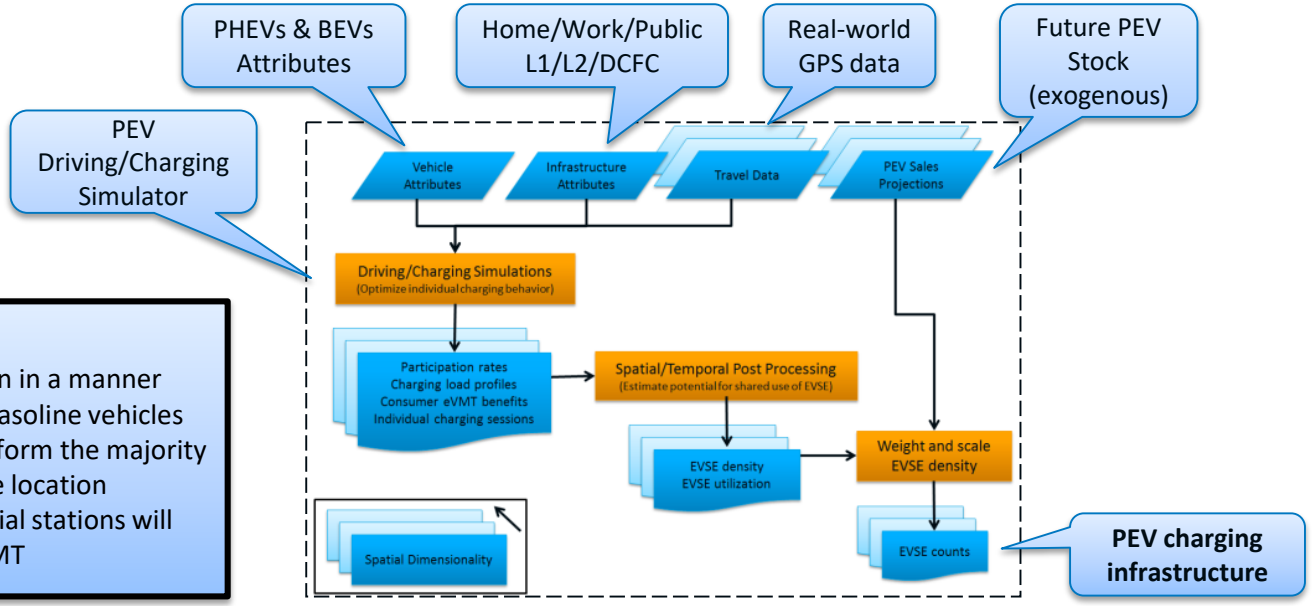
NREL's EVI-Pro

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



Foundational Assumptions

- Future PEVs will be driven in a manner consistent with today's gasoline vehicles
- Consumers prefer to perform the majority of charging at their home location
- Charging at non-residential stations will be used to maximize eVMT

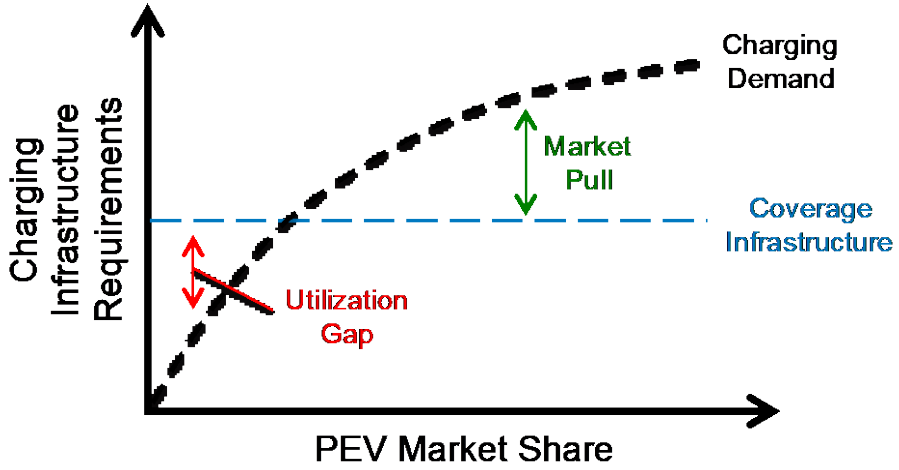
EVI-Pro: Conceptual

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: