NREL
Transforming ENERGY

# Integrating EVs in the Electricity System

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**"Smart Mobility for Smart Cities"**

# U.S. DOE's National Lab System

# NREL Advanced Vehicles and Fueling Infrastructure

The 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.

NREL is assessing the potential for **energy diversification** in transportation (CNG, biofuels, hydrogen and electrification) and related **infrastructure requirements** and providing technical support to national, state, and local entities to:

- ✓ Assess long-term **electrification opportunities** across different transportation segments & evaluate policy/technology scenarios for **alternative fuel vehicle adoption**
- ✓ Estimate **infrastructure requirements** to support vehicle electrification
- ✓ Understand **EV charging costs** (affordability) and optimize DCFC station design
- ✓ Explore opportunities for **EV integration with buildings and the electric grid**

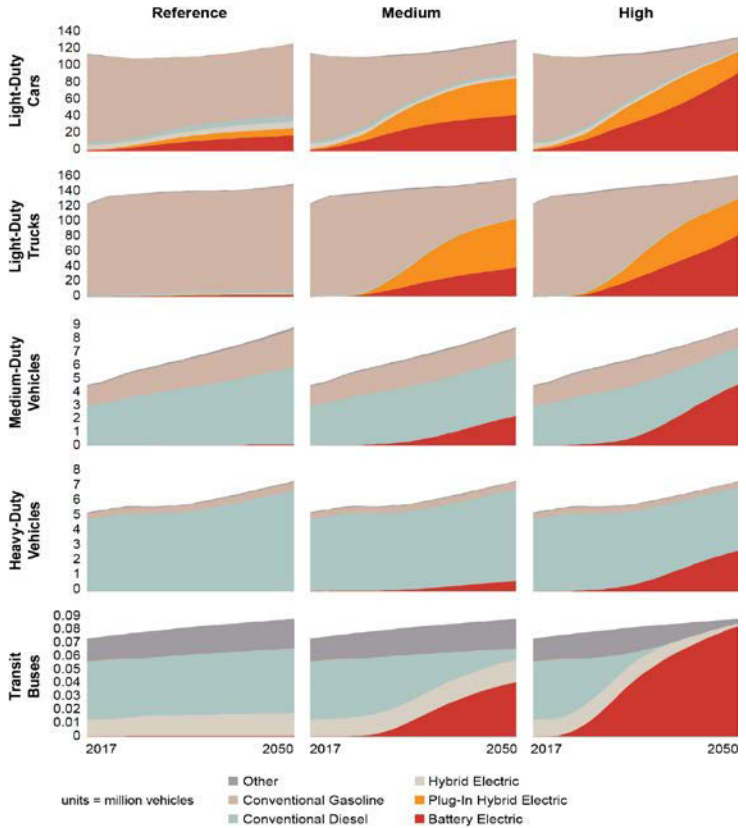
# Electrification Opportunities

**Vehicle electrification** has the potential to disrupt the U.S. transportation energy landscape.

Different opportunities for electrification across **different segments and applications** in real-world technology adoption.

- **Today**: Complete reliance on petroleum, 90+%
- **Possible future**: in the EFS High scenario 76% of on-road miles traveled from electricity in 2050
  - ~85% for light-duty vehicles
  - ~95% for buses
  - ~40% for heavy trucks

  Transportation accounts **for 23% of U.S. electricity consumption in 2050**, up from 0.2% today.



# EV Infrastructure Requirements

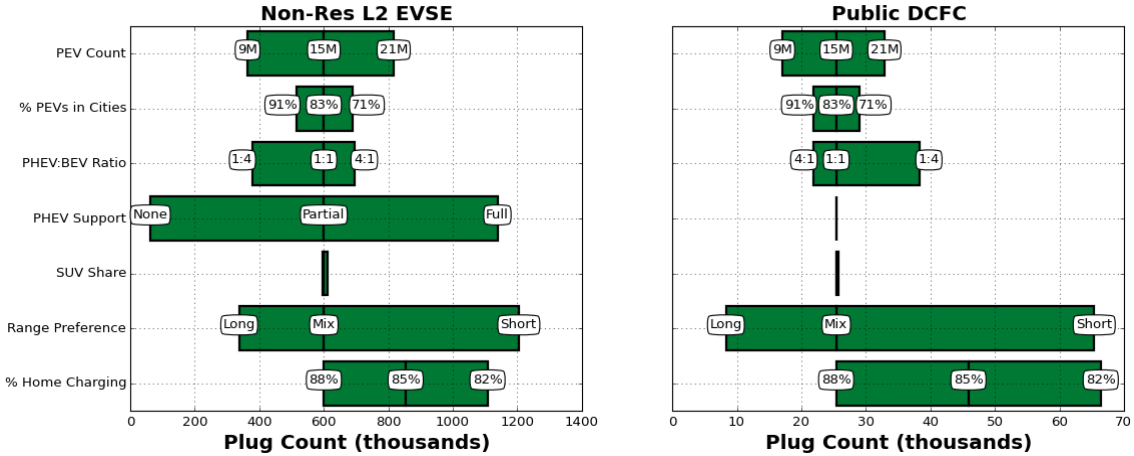
EVI-Pro

NREL developed EVI-Pro to analyze **charging behavior and translate those in public charging infrastructure requirements** to support PEV adoption, including interstate corridors and support for "garage orphans".

**Sensitivity Analysis**

Estimated requirements for EV charging infrastructure are heavily dependent on:

- Home charging availability
- Evolution of the EV market,
- Consumer preferences,
- Technology development

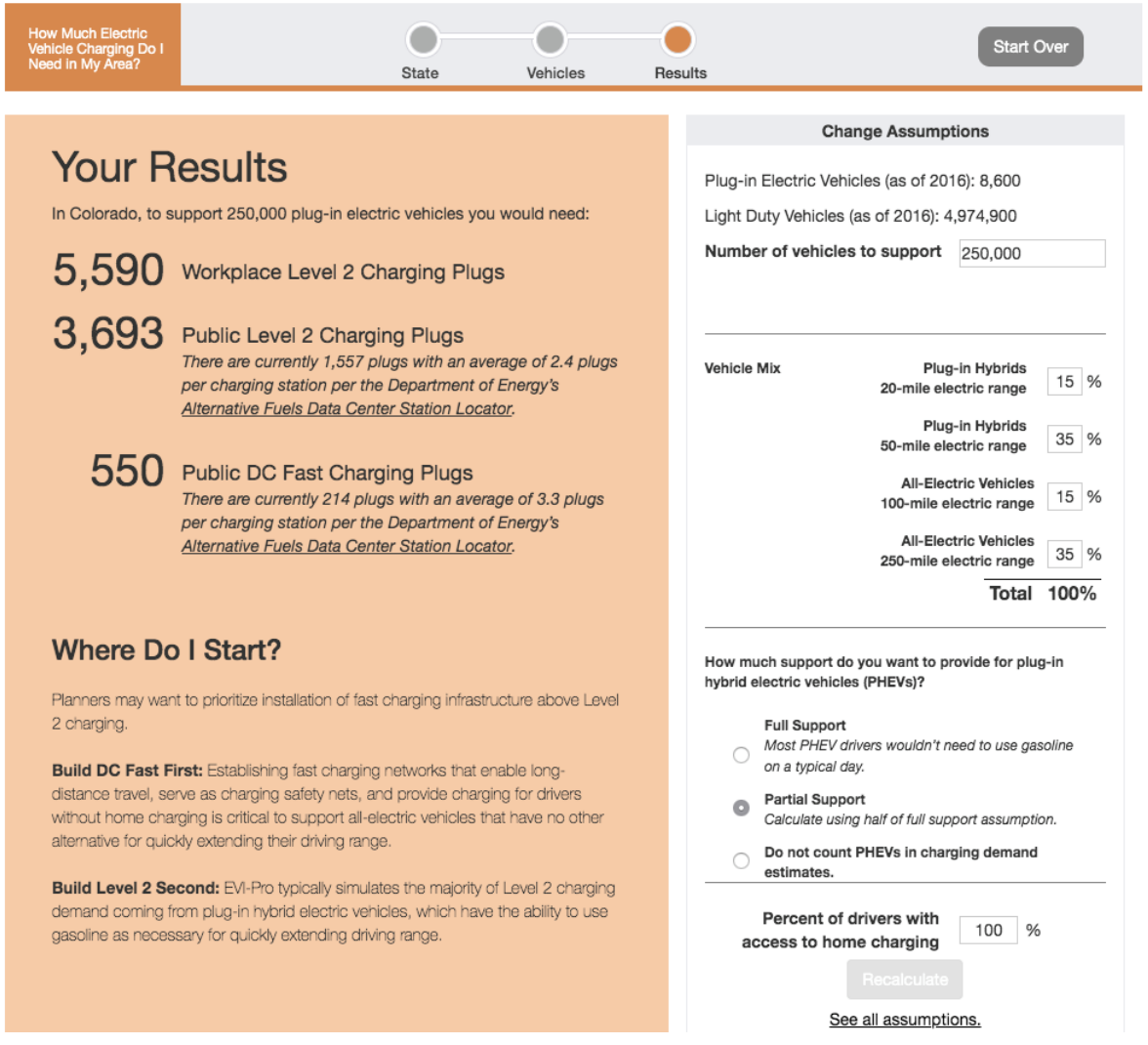



Source: Wood et al. 2017. Model: NREL's EVI-Pro

# EVI-Pro Lite

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

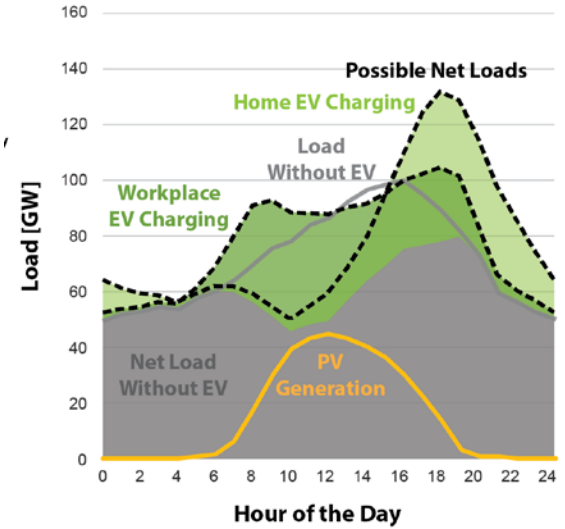
EVI-Pro



# EV-Grid Impact

**EVs are an additional load** that increases total electricity demand and changes its shape. Integrating EVs creates **load growth opportunities** for electric utilities but also poses **new challenges** in a system of growing complexity.

- Impact on the **overall energy consumption increase is limited** (e.g., 10% PEV market share → demand increase of 5%)
- Impact on system-level **peak electricity demand** can be more significant.
- At the local level, **clustering effects** in EV adoption and high power charging exacerbate the **impact on distribution systems**

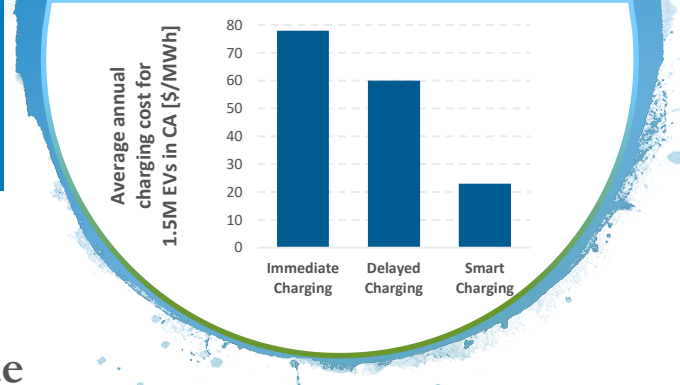


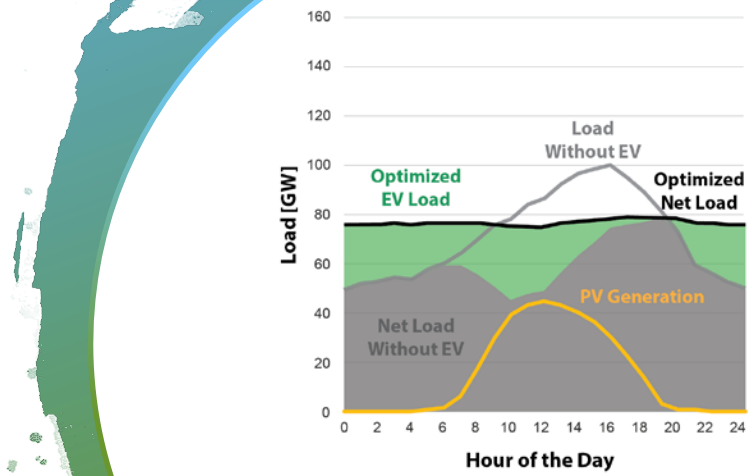
# Flexible EV Charging

The grid is evolving into a more integrated supply/demand system in which **demand-side distributed resources respond to supply-side requirements.**

**Flexible PEV charging** can satisfy mobility needs while also supporting the grid (cheaper electricity) by optimizing the **design and operation of the electric power systems** and facilitate the **integration of renewables**:

- Peak shaving /valley filling
- Ramping mitigation
- Support operations (e.g., curtailment)
- Distributed services (e.g., reserve, contingency)



# Conclusions

*Emerging topic:*

- **Vehicle electrification** is rapidly changing the transportation demand landscape and requires advanced modeling tools to explore future scenarios.

*System-level changes:*

- **Integrated demand/supply models** are required to inform this transformation, including the key role of recharging infrastructure and EV-grid integration.

*Integration challenges/opportunities:*

- Electric vehicles introduce load that the grid was not designed to accommodate and can **impact the electricity system**, especially the distribution networks.
- Electric vehicles offers great opportunities to **optimize the design and operation of future integrated transportation/energy systems.**

# References & Acknowledgement

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# Thanks! Questions?

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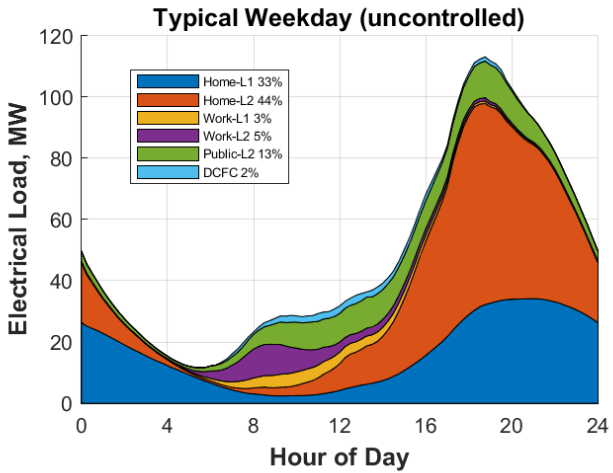
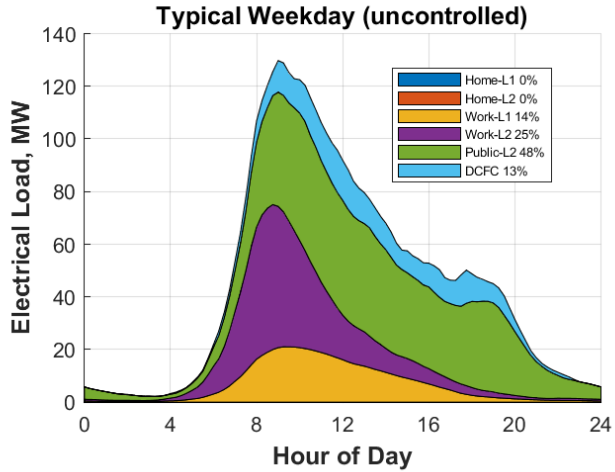
# EV Charging Profiles (Location)

EV charging profiles can look significantly different (and would require different levels of charging infrastructure) if **vehicles are charged at different locations** (while respecting mobility needs)

## Home-Dominant Charging



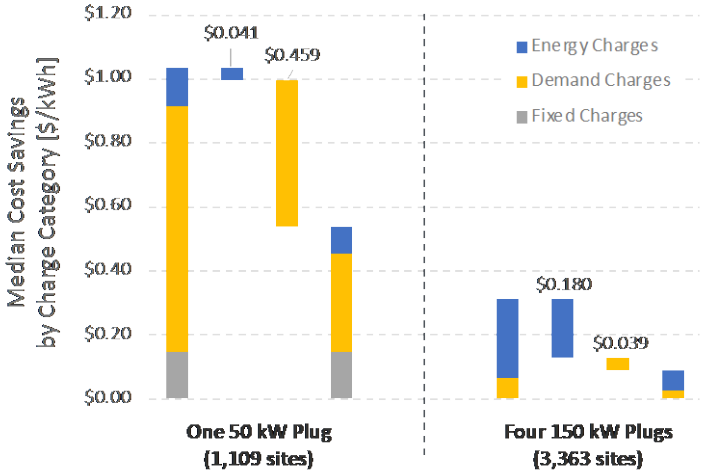

## No Home Charging

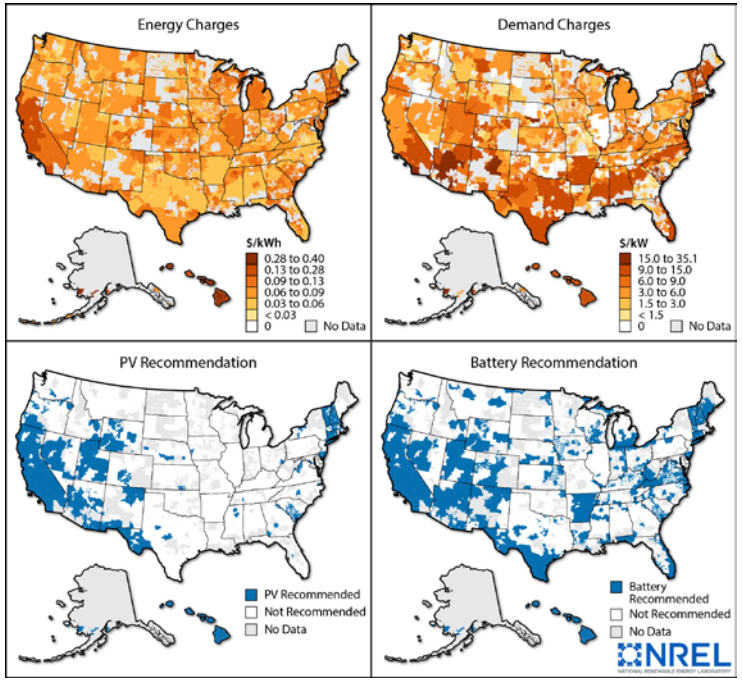


# Mitigate DC Fast Charging Cost

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).