CESA Webinar

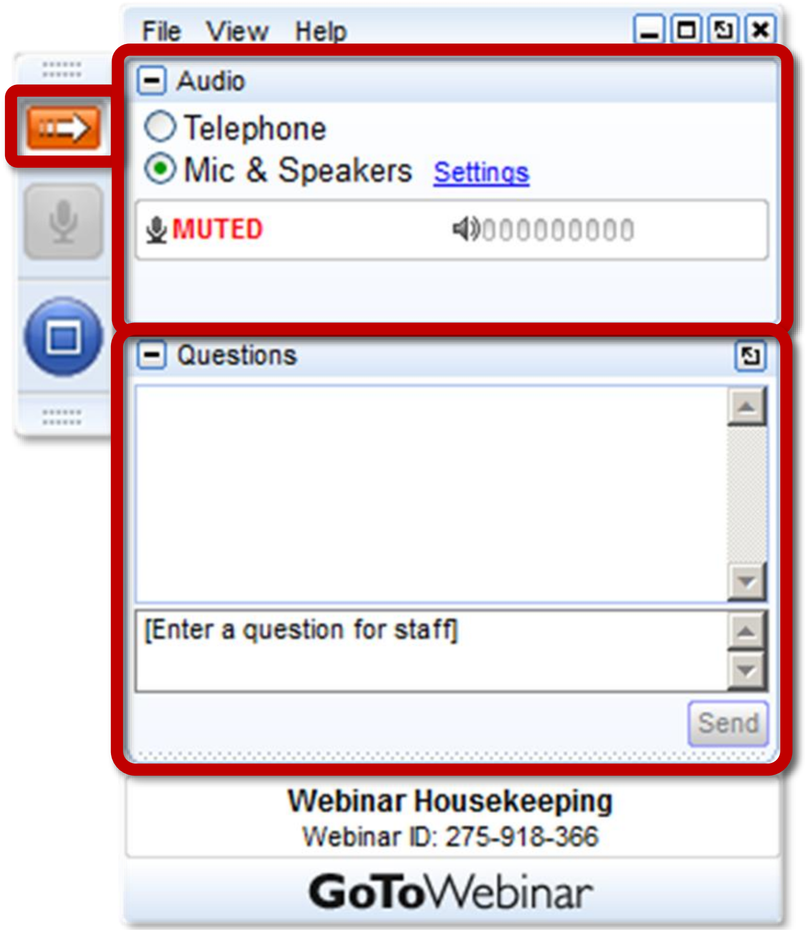
EVs and the Electricity System

Hosted by
Warren Leon, Executive Director, CESA

July 2, 2019

Clean Energy States Alliance

Housekeeping



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CleanEnergy States Alliance

Clean Energy States Alliance

ALASKA ENERGY AUTHORITY

State of California Energy Commission

Department of Energy & Environment

Energy Trust of Oregon

IOWA economic development

Massachusetts Clean Energy Center

IPA Illinois Power Agency

New Mexico emnrd Energy, Minerals and Natural Resources Department

OEI Wisconsin Office of Energy Innovation

New York State of Opportunity. NYSERDA

BPU New Jersey Board of Public Utilities

New Jersey's cleanenergy program™ njcleanenergy.com

Connecticut Green Bank

New Hampshire Public Utilities Commission

Maryland Energy Administration

State of Washington Department of Commerce Innovation is in our nature.

MI Energy Michigan Agency for Energy Michigan Energy Office

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Smart Electric Power Alliance

NREL National Renewable Energy Laboratory

ACEP Alaska Center for Energy and Power

www.cesa.org

Webinar Speakers

Matteo Muratori
Engineer, Integrated Transportation and Energy Systems, NREL

Chris Nelder
Manager, EV Grid Integration, Rocky Mountain Institute

Warren Leon
Executive Director, Clean Energy States Alliance (moderator)

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

ROCKY MOUNTAIN INSTITUTE

CleanEnergy States Alliance

EVs and the Electricity System

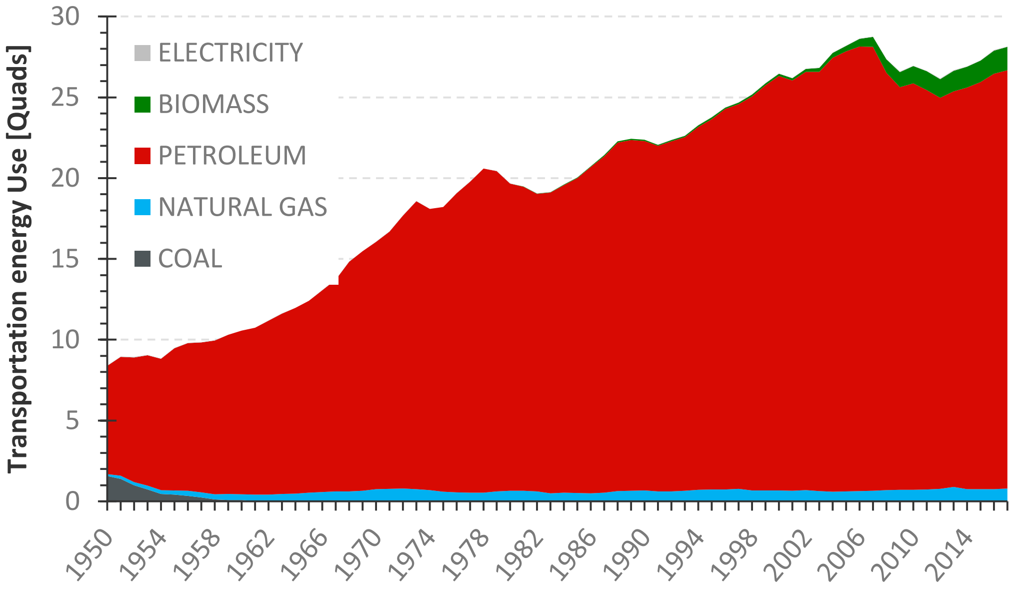
Matteo Muratori

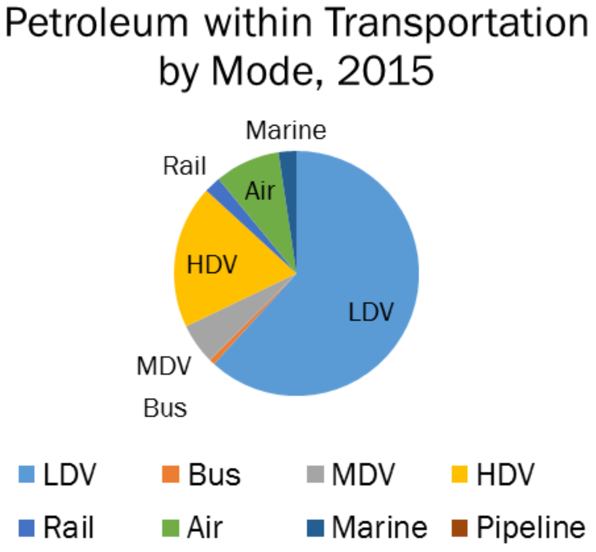
For the Advanced Vehicle and Fueling Infrastructure group

July 2019 – Clean Energy State Alliance

Historical Transportation Energy Use

For **over a century** the transportation sector has relied on petroleum, and today transportation accounts for **~75% of total U.S. petroleum use.**





Rapidly Changing Landscape

Ford plans **$11 billion investment**, 40 electrified vehicles by 2022
– Reuters Business News

Tesla's electric semi truck: Musk unveils his new freight vehicle
– Tesla

Toyota aims to get half of its global sales from EVs by 2025, five years ahead of schedule, and will tap Chinese battery makers to meet the accelerated global shift to electricity-powered cars.
– Reuters

In 2018, the global electric car fleet exceeded 5.1 million, up 2 million from the previous year and almost doubling the number of new electric car sales.
– International Energy Agency

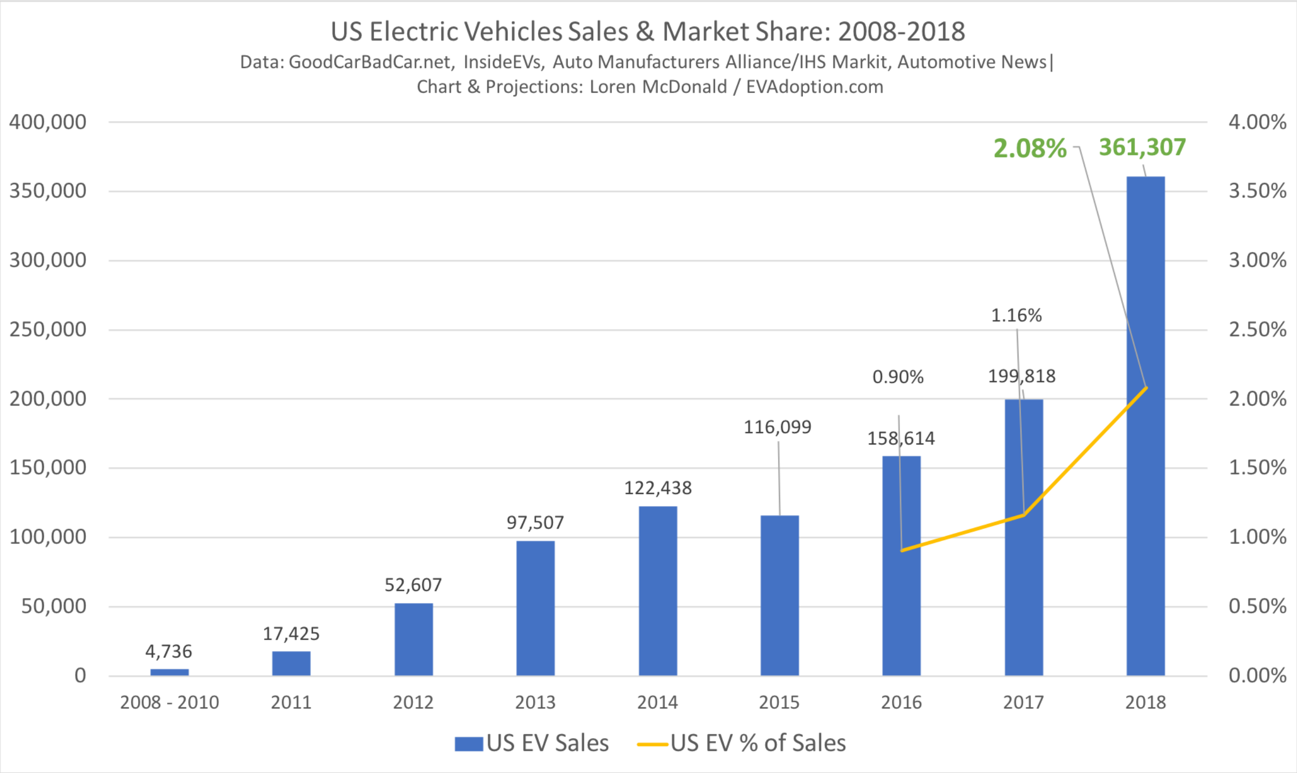
BMW is anticipating that sales of electric cars will increase by 30 percent per year through 2025, and it now plans 25 electrified models by 2023.
–Greencar Reports

General Motors believes the **future is all-electric** and announced 20 fully electric models by 2023
– Wired

Volvo Cars announces new target of **1 million electrified cars sold by 2025**
– Volvo Car Group

U.S. EV Sales

More than 1 Million EVs sold in the U.S.



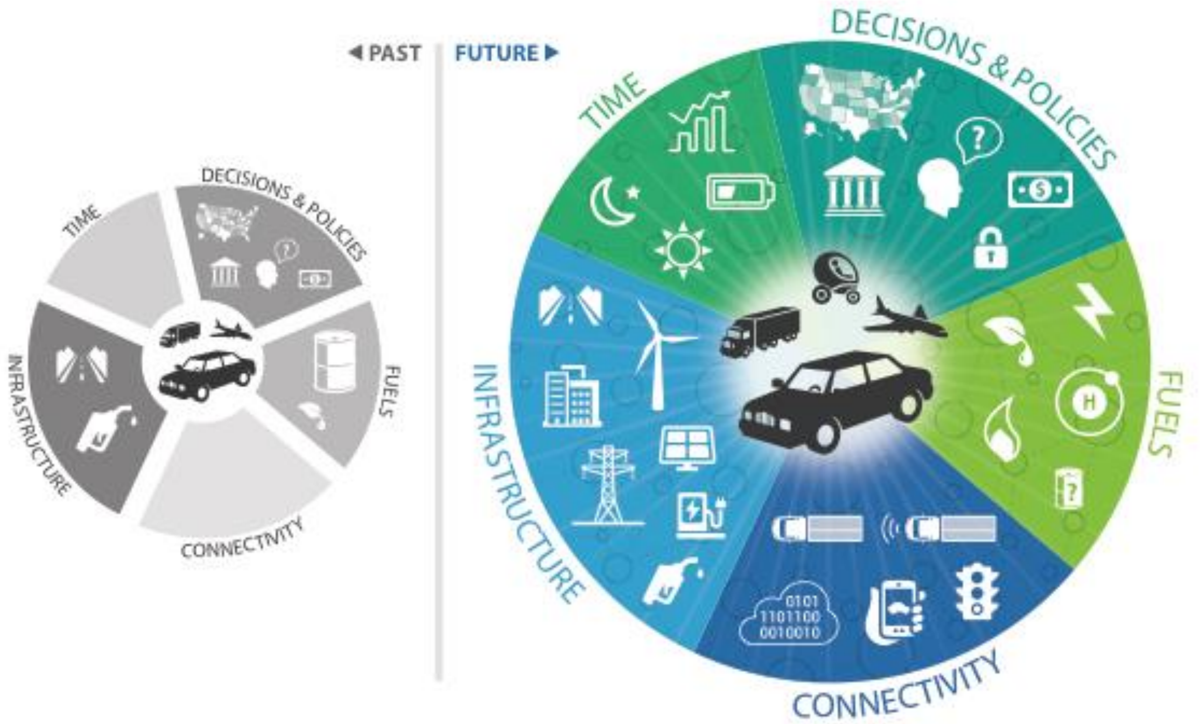
Source: Cleantechnica

Transforming Electricity Grid

This revolution is happening at a time in which the **electric power system is also undergoing profound changes**.

The traditional system based on the predicament that generation is dispatched to match demand is evolving into a more integrated supply/demand system in which **demand-side distributed resources** (generation, energy storage, and demand response) **respond to supply-side requirements**, mainly driven by variable renewable generation.

We envision a future transportation system that will be optimally **integrated** with smart buildings, the electric grid, renewables, and other infrastructure to maximize energy productivity and to achieve an economically competitive, secure, and sustainable future.



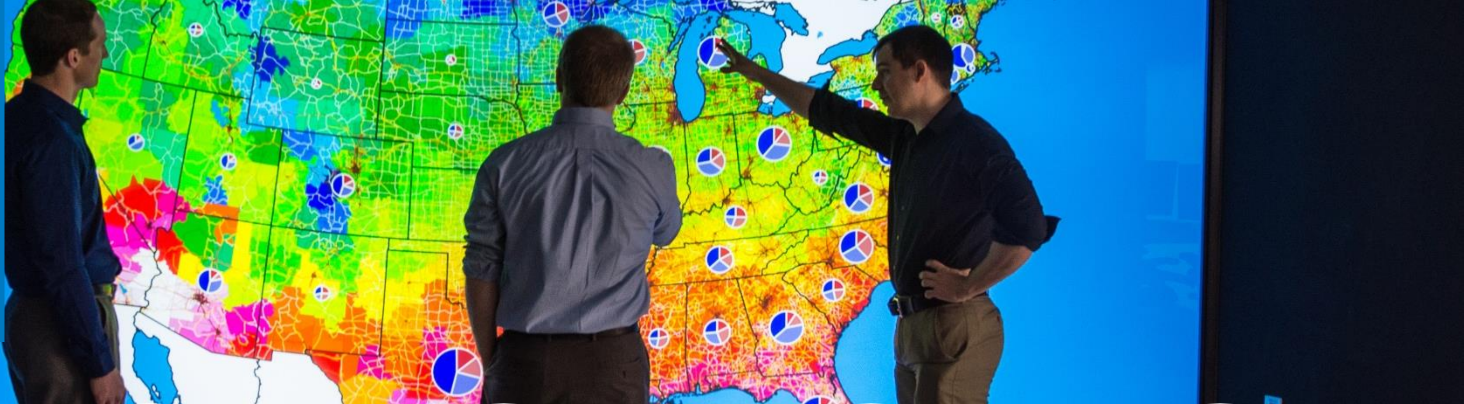
NREL Advanced Vehicles and Fueling Infrastructure

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.

Among other things, NREL is currently providing technical support to national, state, and local entities to:

- ✓ Assess **electrification opportunities** across different transportation segments, including light-duty as well as medium/heavy-duty
- ✓ Evaluate policy/technology scenarios for **alternative fuel vehicle adoption**
- ✓ Estimate **infrastructure requirements** to support vehicle electrification
- ✓ Understand EV charging costs and optimize **DCFC station design**
- ✓ Explore opportunities for **EV integration with buildings and the electric grid**

Key Capabilities and Tools



Data

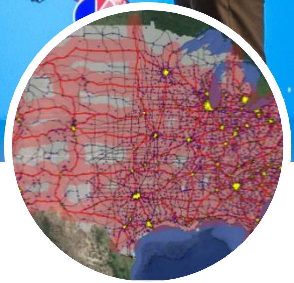
Transportation Secure Data Center & Alternative Fuels Data Center

ADOPT

Vehicle Adoption Modeling

FASTSim

Vehicle Powertrain Modeling



EVI-PRO

Plug-in Electric Vehicle Charging Infrastructure

TEMPO

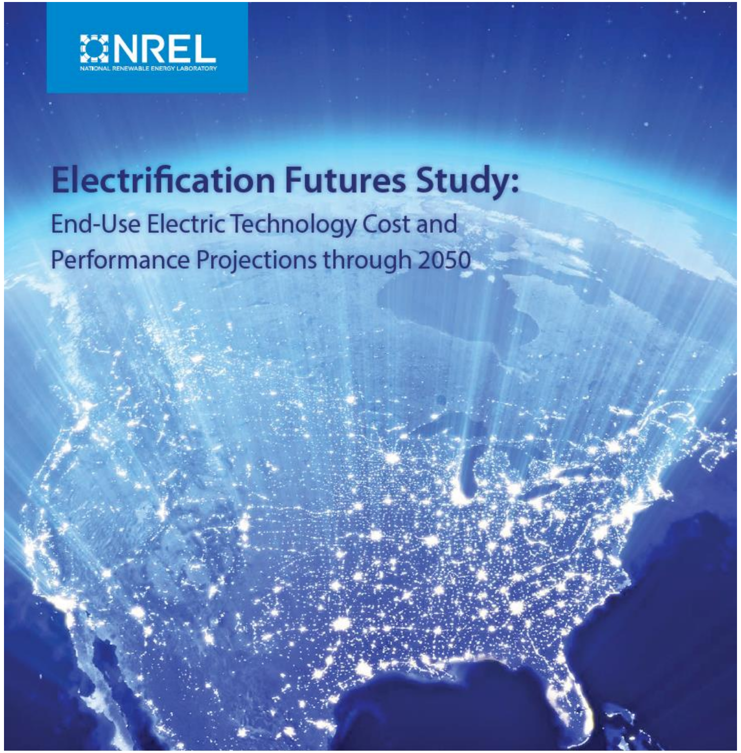
Transportation Energy and Mobility Pathway Options

NREL’s Electrification Futures Study

Through the **Electrification Futures Study**, NREL is exploring scenarios with and impacts of **widespread electrification** in the United States:

- How might widespread electrification impact **national and regional electricity demand?**
- How would the U.S. **electricity system need to transform**?

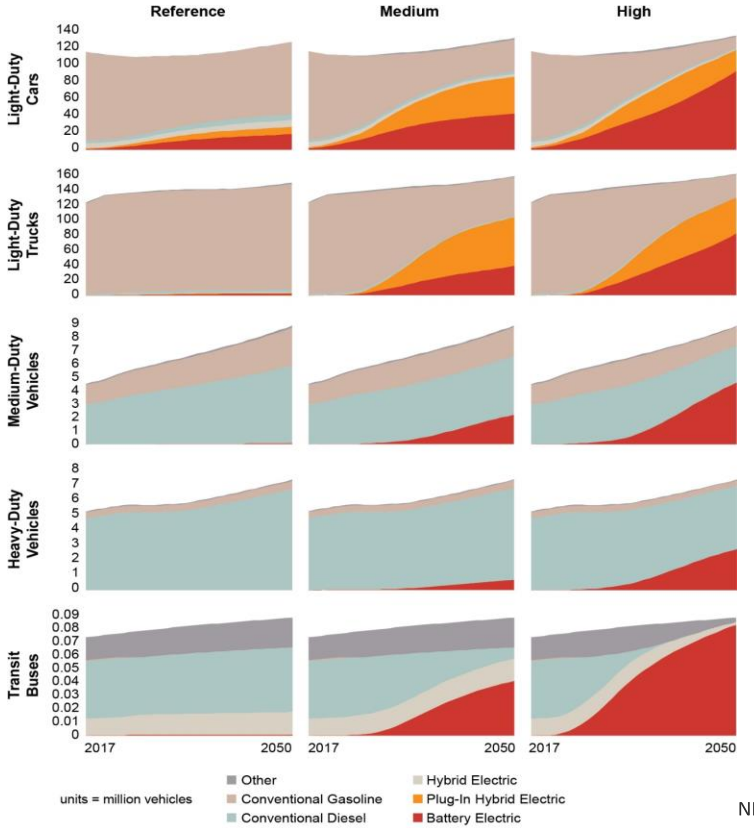
It is important to assess opportunities for electrification across **different segments and applications** and model real-world technology adoption.



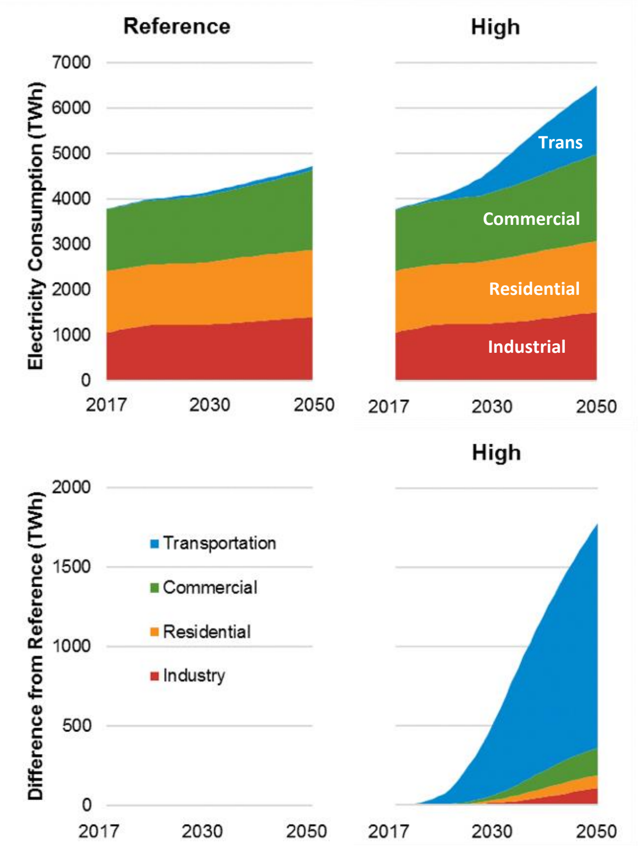
https://www.nrel.gov/analysis/electrification-futures.html

EFS Vehicle Electrification

- 2050 U.S. transportation fleet (EFS High scenario):
  - **240 million** light-duty plug-in electric vehicles
  - **7 million** medium- and heavy-duty plug-in electric trucks
  - **80 thousand** battery electric transit buses
- Together these deliver up to **76%** of miles traveled from electricity in 2050
- 138,000 DCFC stations (447,000 plugs) and 10 million non-residential L2 plugs for light-duty vehicles



U.S. Scenarios of Electrification



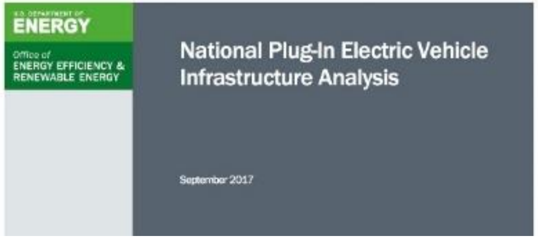
EFS scenarios project **great degree of future electrification, especially for transportation**, in line with other recent energy system transformation scenarios

- In the EFS High scenario, **transportation accounts for 23% of electricity consumption in 2050**, a 1,424 TWh increase in transportation-related electricity consumption relative to the 2050 Reference scenario.
- 138,000 DCFC stations (447,000 plugs) and 10 million non-residential L2 plugs for light-duty vehicles

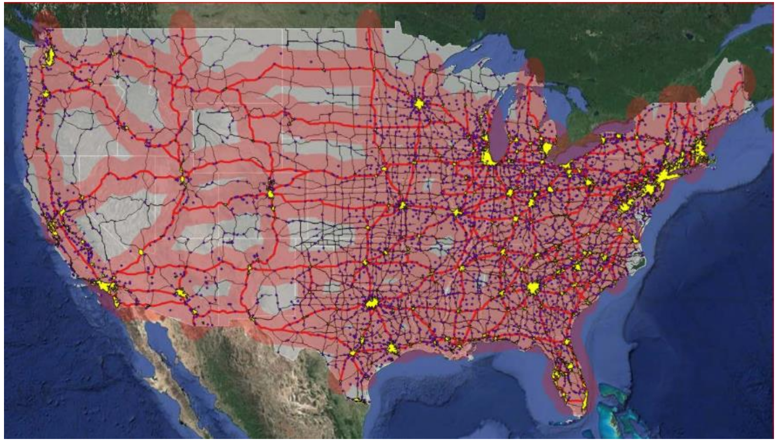
Source: *https://www.nrel.gov/analysis/electrification-futures.html*

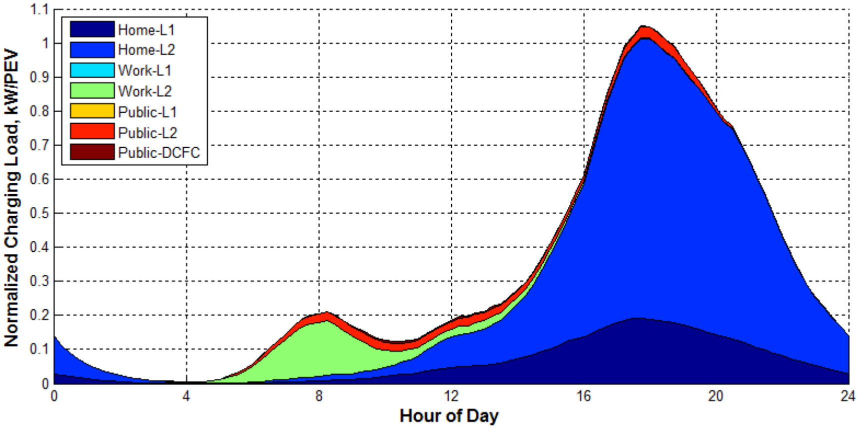
National Infrastructure Analysis

EVI-Pro



NREL analyzed National **charging behavior and infrastructure requirements** to support PEV adoption, including interstate corridors





Source: [Wood et al. 2017](). Model: NREL's EVI-Pro

Results – Central Scenario & Sensitivity Analysis

EVI-Pro

		Cities	Towns	Rural Areas	Interstate Corridors
PEVs		12,411,000	1,848,000	642,000	---
DCFC	Stations (to provide coverage)	4,900	3,200	---	400
	Plugs (to meet demand)	19,000	4,000	2,000	2,500
	Plugs per station	3.9	1.3	---	6.3
	Plugs per 1,000 PEVs	1.5	2.2	3.1	---
Non-Res L2	Plugs (to meet demand)	451,000	99,000	51,000	---
	Plugs per 1,000 PEVs	36	54	79	---

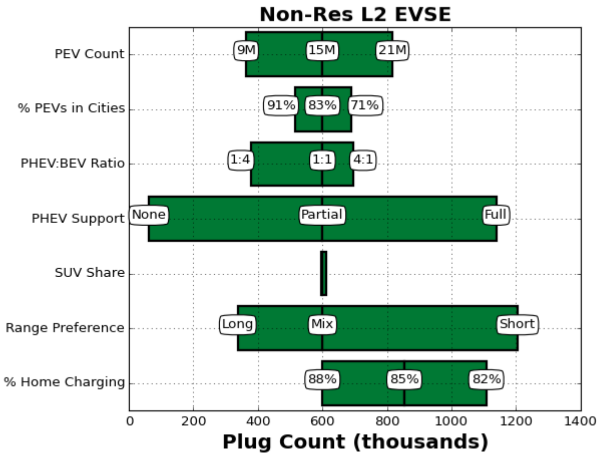
Central Scenario

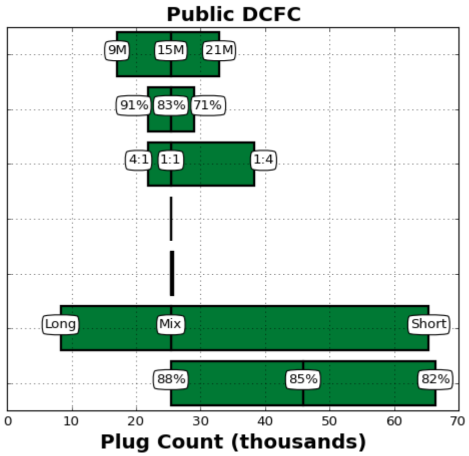
Source: [Wood et al. 2017](). Model: NREL's EVI-Pro

Sensitivity Analysis

Estimated requirements for PEV charging infrastructure are heavily dependent on:

1) Evolution of the PEV market,
2) Consumer preferences,
3) Technology development

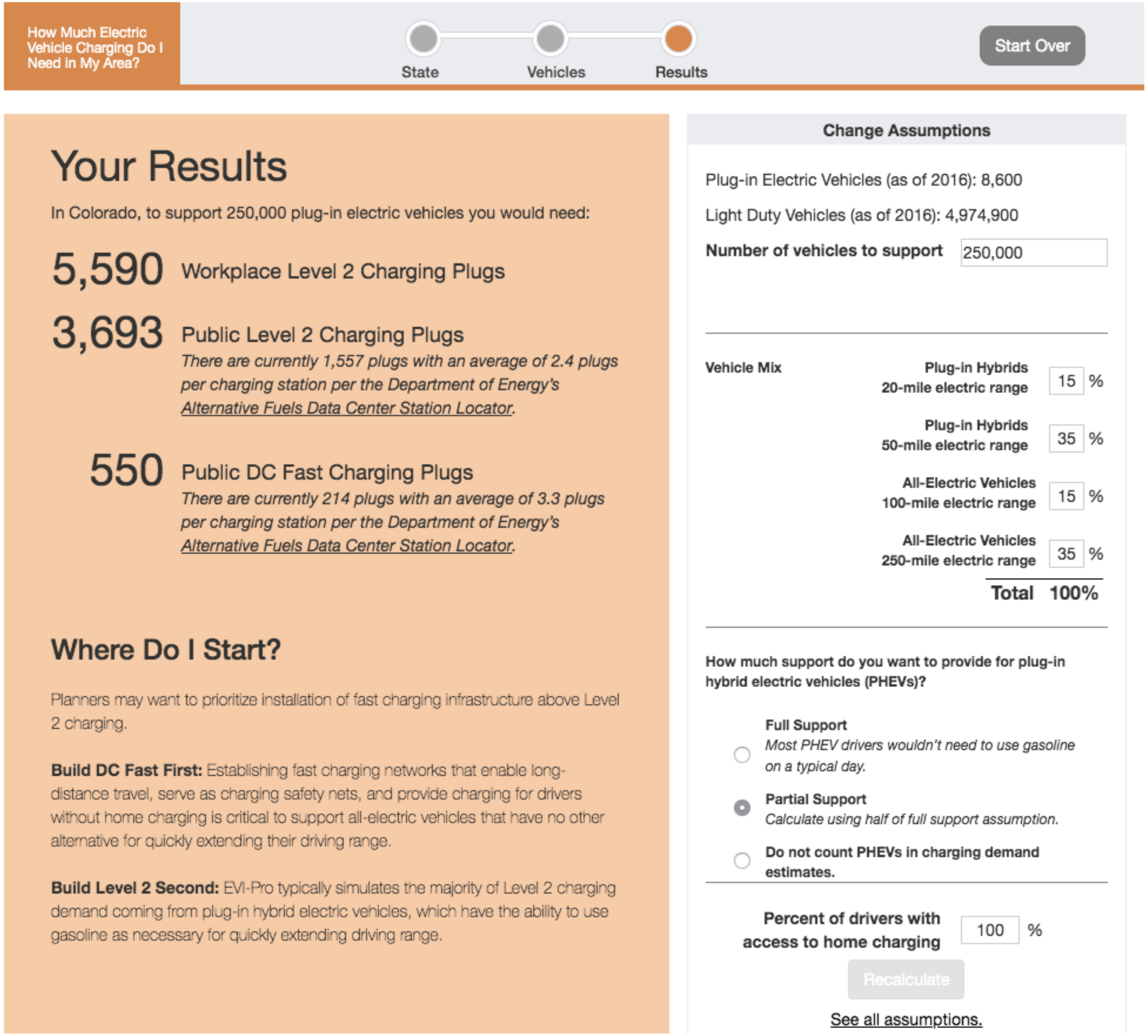




EVI-Pro Lite

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


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 250,000

Vehicle Mix

Plug-in Hybrids 20-mile electric range	15	%
Plug-in Hybrids 50-mile electric range	35	%
All-Electric Vehicles 100-mile electric range	15	%
All-Electric Vehicles 250-mile electric range	35	%
Total	**100%**	

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 100 %

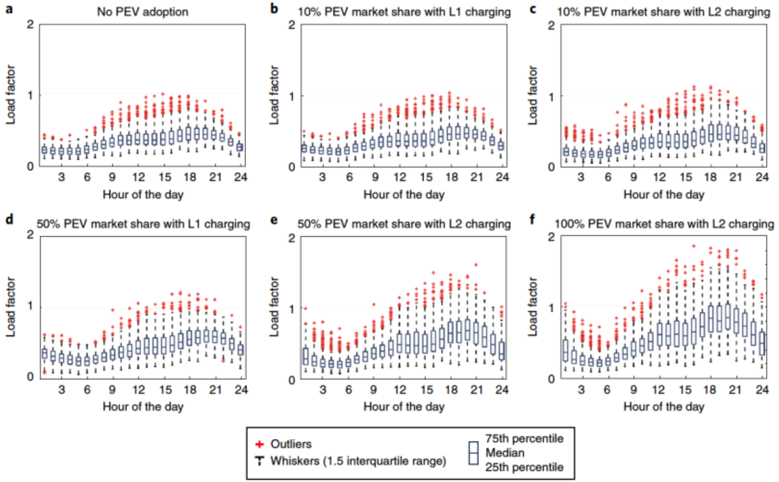
Recalculate

See all assumptions.

EV-Grid Impact

PEVs are an additional load that increases total electricity demand and changes its shape. Integrating PEVs 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%)
- At the local level, **clustering effects** in PEV adoption exacerbate the impact
- **Level 2** charging significantly aggravates the impact of PEVs on the residential distribution infrastructure

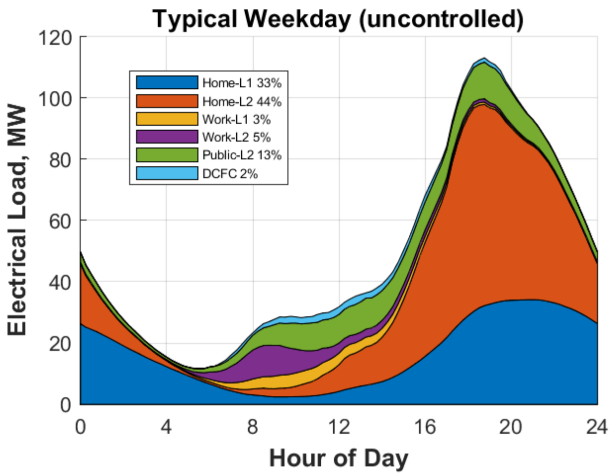


$$Load\ factor = \frac{hourly\ power\ consumption}{transformer\ nominal\ power}$$

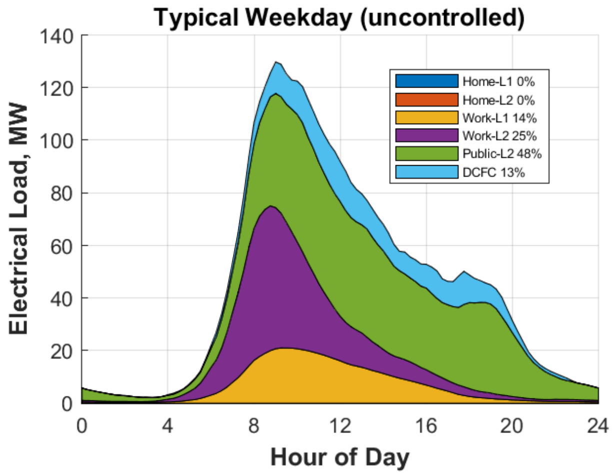
EV Charging Profiles (Location)

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

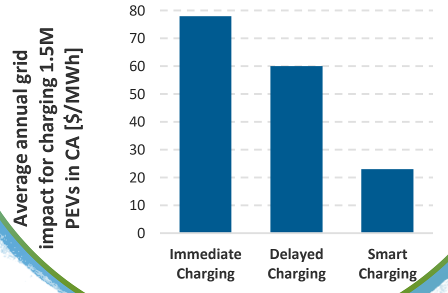


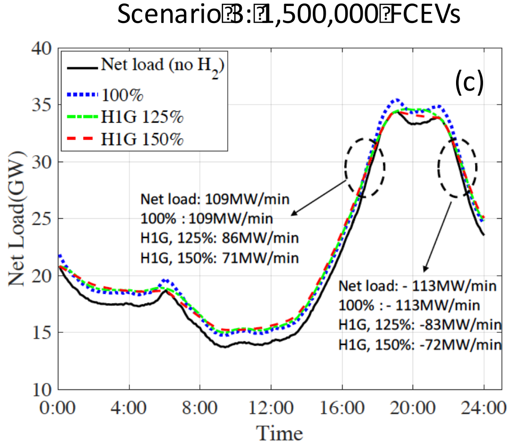
No Home Charging



Flexible EV Charging

- **Flexible PEV charging** can provide cheaper electricity while optimizing the **design and operation of the electric power systems** and facilitate the **integration of renewable** energy sources:
  - Peak shaving/valley filling
  - Ramping mitigation
  - Distributed services
- Availability and charging power limits for PEV charging must be **constrained to respect mobility needs,** but personally-owned LDV offer great flexibility.





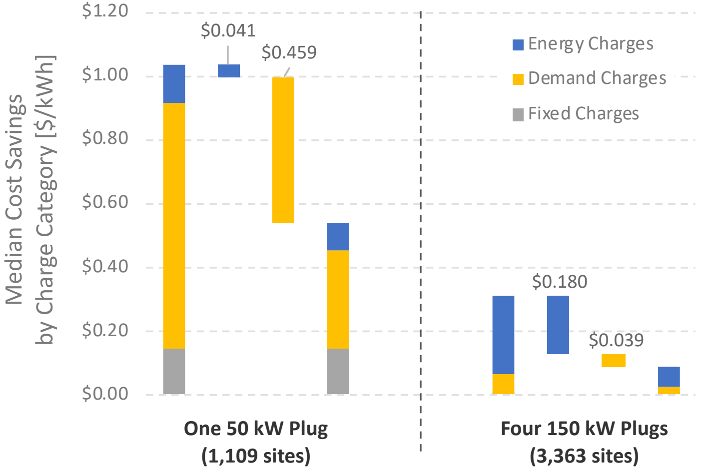
Mitigate DC Fast Charging Cost

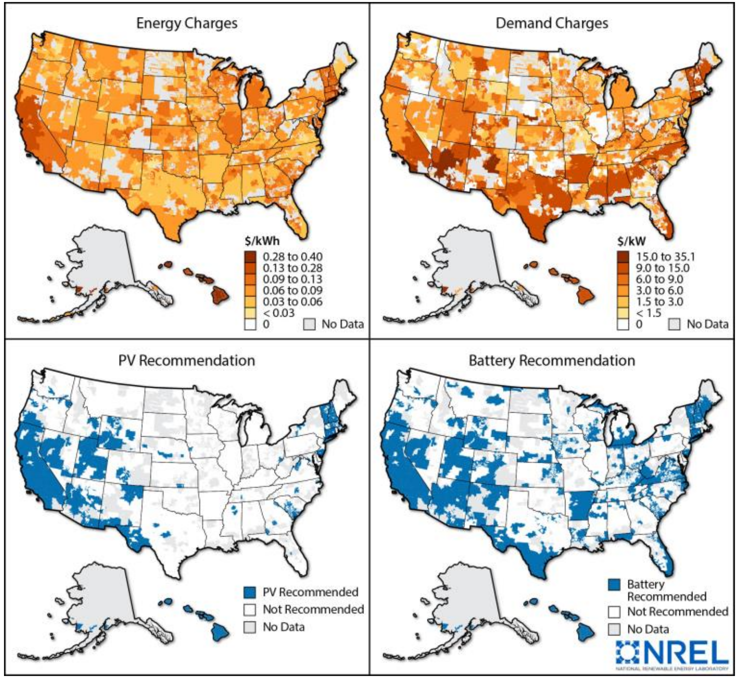
REopt

Utility Rate DATABASE

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).

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.

Integration challenges/opportunities:

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

References & Acknowledgement

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The views and opinions expressed in this presentation are those of the author alone and do not reflect the positions of NREL or of the US government.

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- Muratori, M., Elgqvist, E., Cutler, D., Eichman, J., Salisbury, S., Fuller, Z. and Smart, J. "Technology solutions to mitigate electricity cost for electric vehicle DC fast charging." Applied Energy 242 (2019).

Thanks! Questions?

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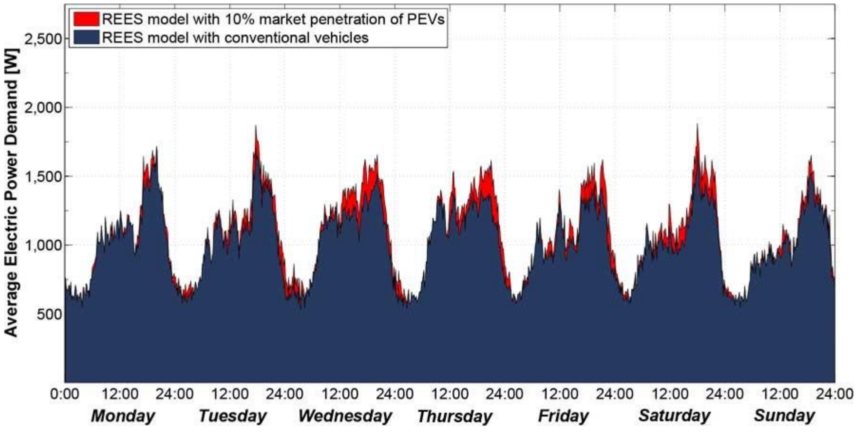
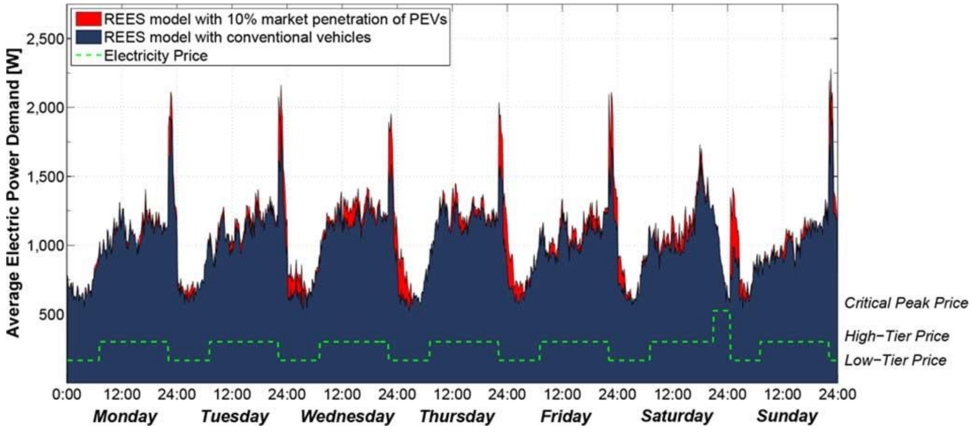
Rebound peaks

Widespread participation (automated energy management systems) in demand response programs using time-varying electricity pricing (e.g., TOU) might create pronounced rebound peaks.





M. Muratori and G. Rizzoni. 2016. "Residential demand response: dynamic energy management and time-varying electricity pricing". IEEE Trans. on Power Systems, Vol. 31 (2). [10.1109/TPWRS.2015.2414880](https://doi.org/10.1109/TPWRS.2015.2414880)

EVs AND THE ELECTRICITY SYSTEM

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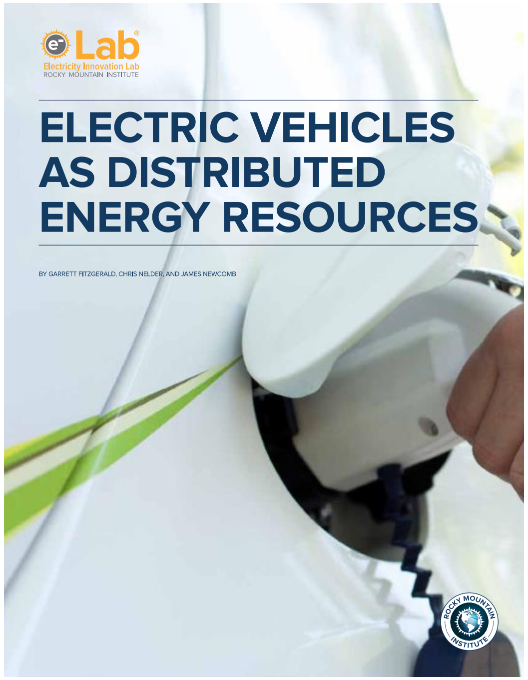
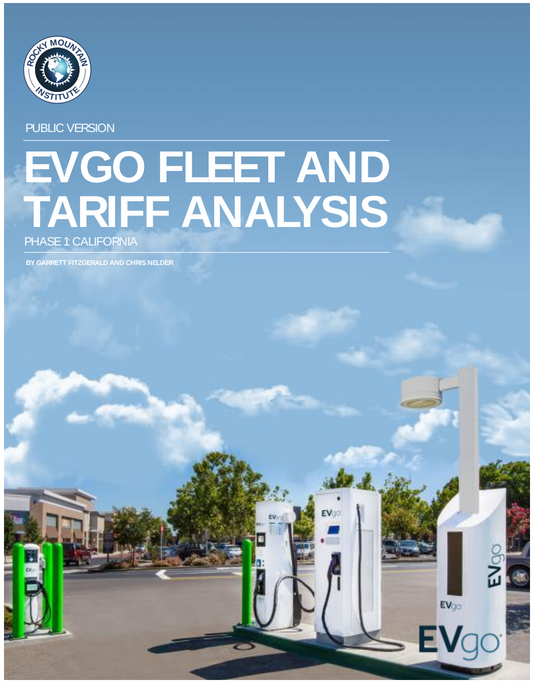
Rocky Mountain Institute

Clean Energy States Alliance (CESA) Webinar: "EVs and the Electricity System" - July 2, 2019

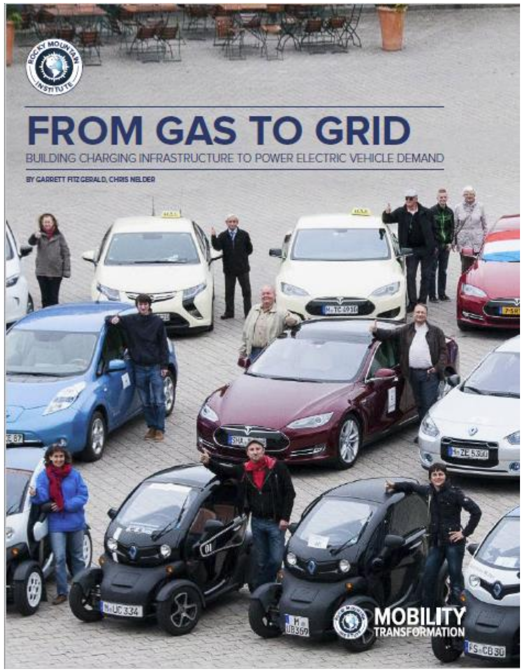
RMI EV-GRID REPORTS



Electric Vehicles as Distributed Energy Resources **(June 2016)**



EVgo Fleet and Tariff Analysis **(March 2017)**



From Gas to Grid **(October 2017)**

RMI EV-GRID ADVISING

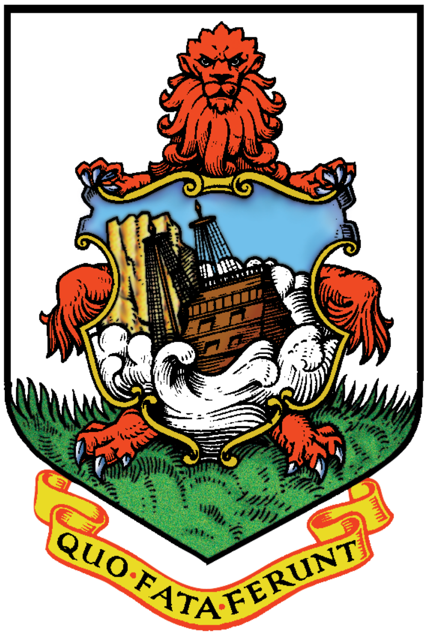
New York Power Authority

- Helped develop Transportation Electrification Strategy
- Supported NYPA in planning "EVolve NY" - A network of 400 150-kW DCFC across the state
- Advising on rate design (demand charge relief) and utility make-ready investments
- Developing a charging-as-a-service strategy for NY transit bus fleets

Seattle City Light

- Helped develop Transportation Electrification Strategy
- Gap analysis of charging infrastructure and identifying where City Light could address un-met needs
- Forecast loads for medium- and heavy-duty EVs (buses, delivery trucks, Class 8 trucking) and evaluate against system hosting capacity

RMI EV-GRID ADVISING



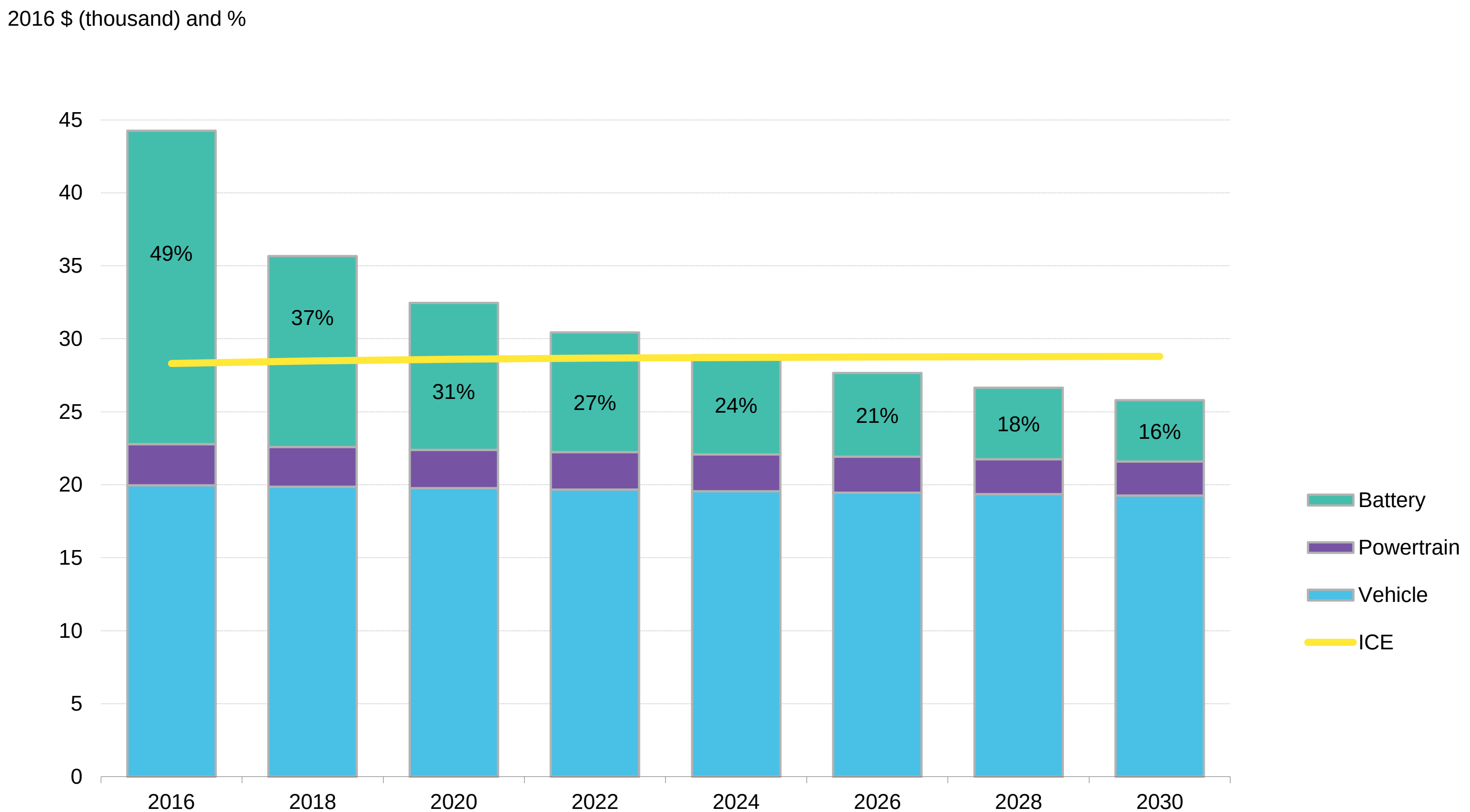
GOVERNMENT OF BERMUDA

- Developing plan to transition old fleet of diesel buses to new fleet of electric buses
- Working with local utility to provide power using local renewables
- Advising on rate design

VARIOUS OTHER ENTITIES

- Transportation Electrification Strategy
- Fleet transitioning guidance
- Rate design analysis & advice
- Standards and protocols
- Best practices for system design (REV West)
- Cost analysis & mitigation
- Regulatory advice
- Load forecasting

EVS CHEAPER THAN ICE IN US BY 2023

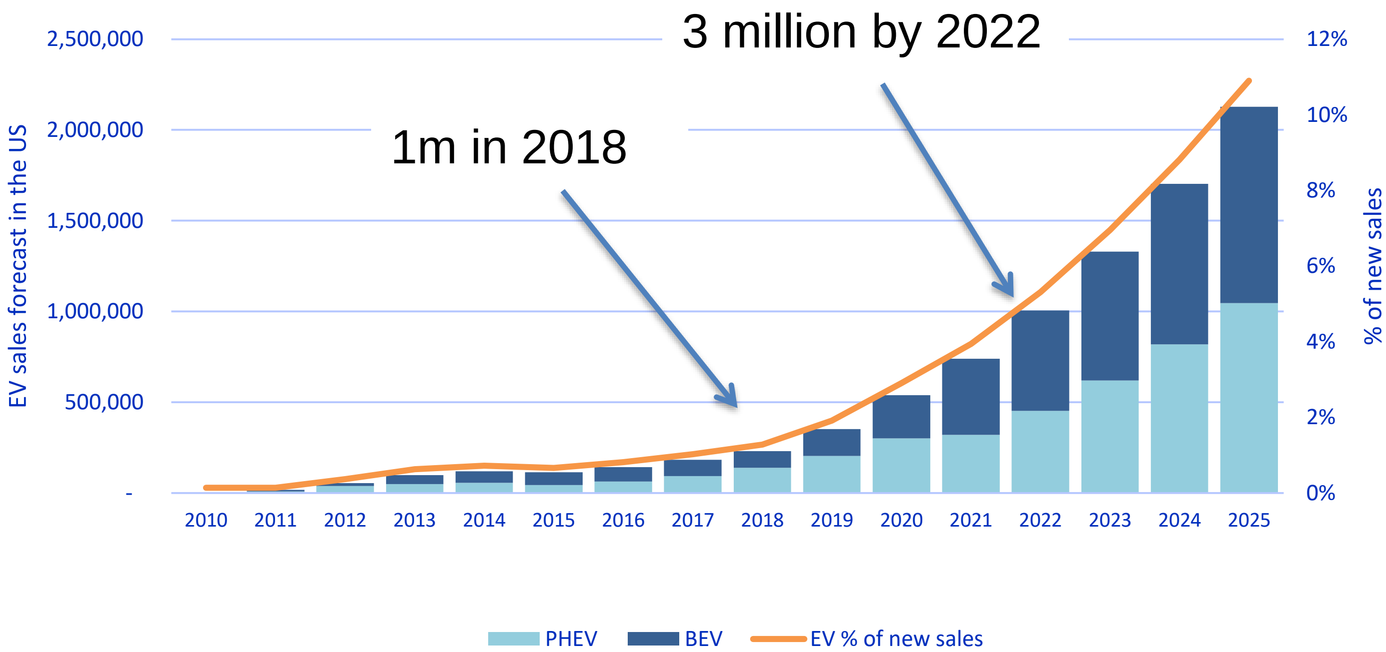


Pre-tax cost. Source: Bloomberg NEF EVO2018

ARE YOU READY FOR THIS?

By 2022…

- there could be **3 million EVs** in the U.S.
- bringing over **11,000 GWh** of load, or
- about **$1.5 billion** in annual electricity sales



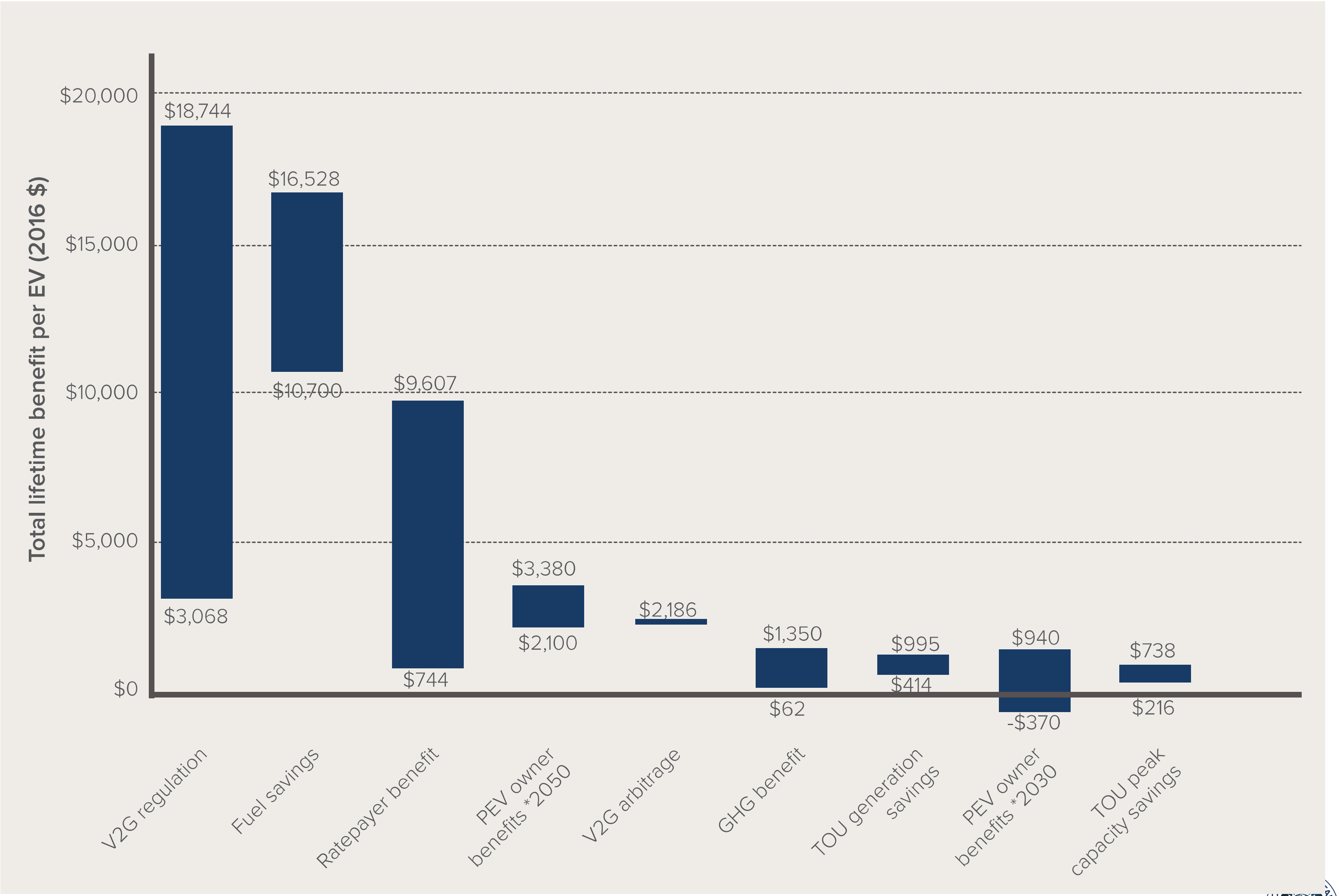
MOST COMMUNITIES AREN'T…

Bloomberg New Energy Finance warns the U.S. will hit an **"infrastructure cap"** in the mid-2030s due to a lack of charging stations.

The questions we should be grappling with now are:

- **what kind** of EV chargers we need
- **where** to build EV chargers
- **who** should own them
- **whether** utilities should be able to recover costs via the rate base
- **how** to make fast charging a profitable (sustainable) business – role of utility vs. private sector operators
- **should** the cost of infrastructure be broadly (i.e. federally) socialized?

THE BENEFITS ARE CLEAR

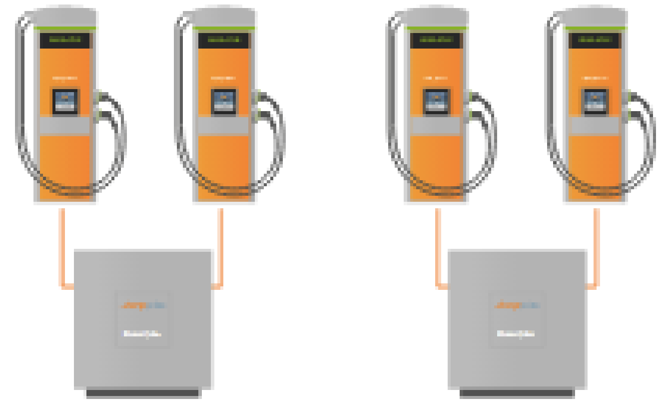


CHARGER TYPE

Level 2 chargers (4-22 kW) are **inexpensive** ($500-1500) and **can provide grid services** with **managed charging**.

Level 2 is appropriate anywhere vehicles can stay a few hours:

- bus barns
- fleet yards
- charging depots
- residences
- workplaces
- shopping areas



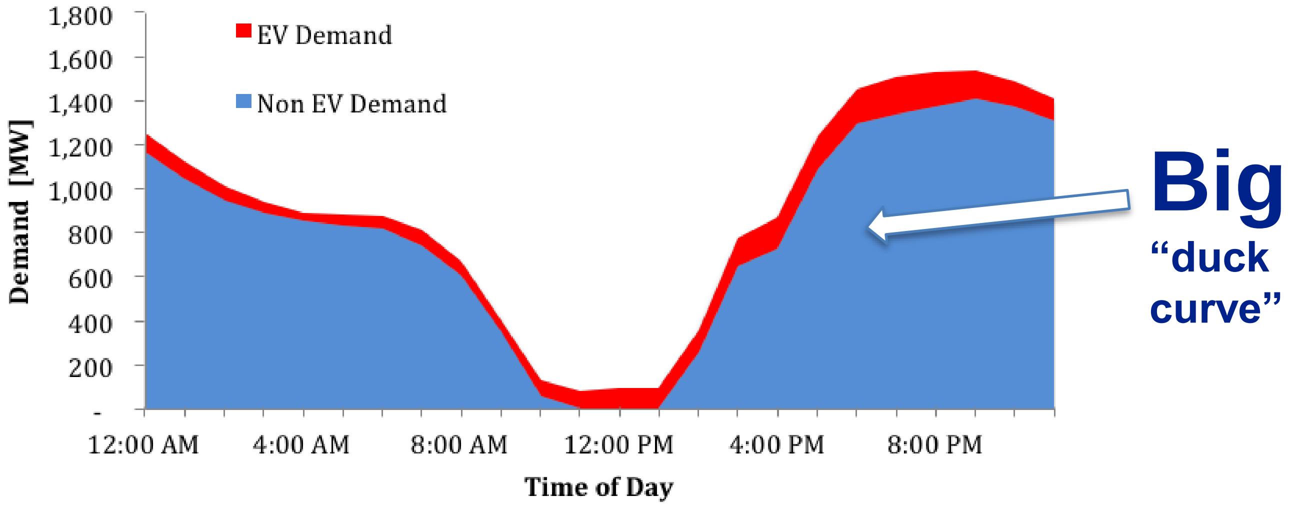
DCFC (50-350+ kW) are **very expensive** ($125,000+) and **can't easily provide grid services** with managed charging.

DCFC is appropriate for:

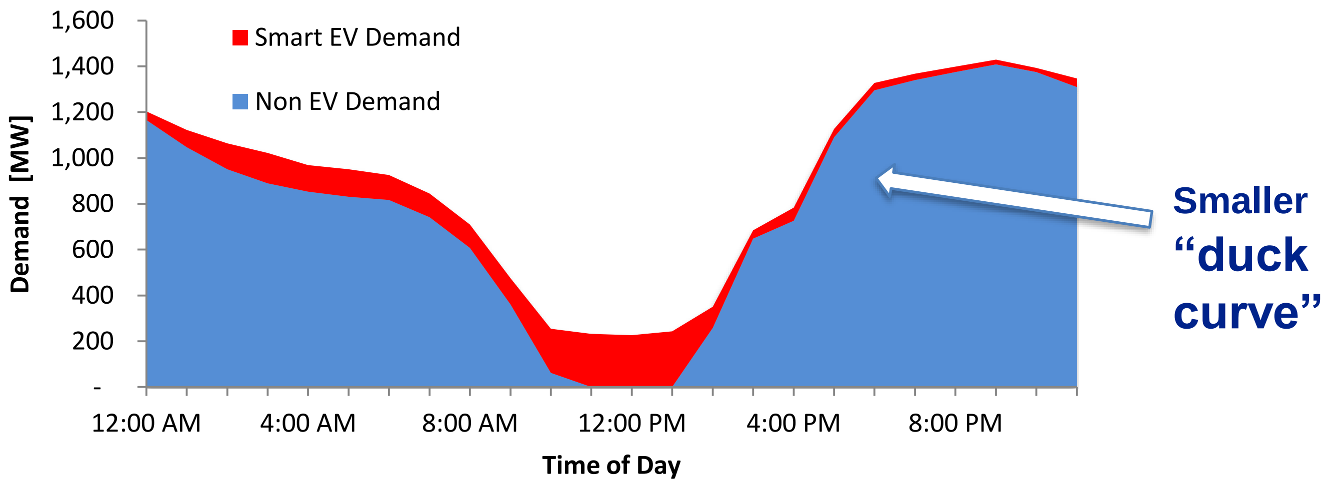
- on-route charging depots
- mass transit
- high-traffic urban centers
- commuting corridors
- stops on interstate highways

MANAGED CHARGING: PRESSED DUCK

Projected HECO demand with 23% EV penetration with **uncontrolled** EV charging



Projected HECO demand with 23% EV penetration with **managed** EV charging



MANAGED CHARGING

Managed charging (G2V not V2G) can deliver many benefits…

- Optimize existing grid assets and extend their useful life
- Avoid new investment in grid infrastructure
- Supply ancillary services, such as frequency regulation and power factor correction.
- Absorb excess wind and solar generation to allow greater share of renewables on the grid
- Reduce emissions
- Reduce electricity and transportation costs
- Reduce petroleum consumption

MANAGED CHARGING

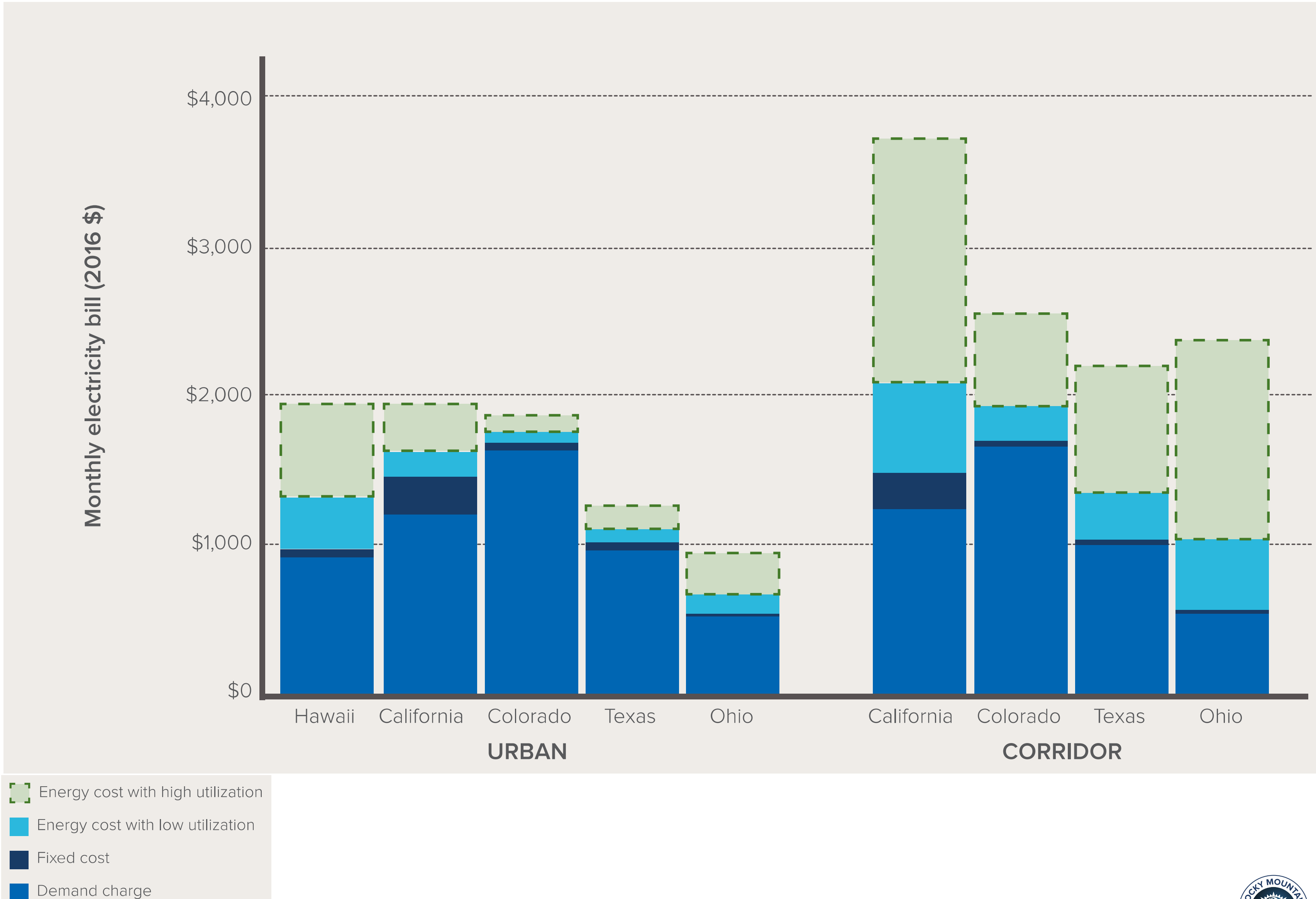
On Level 2 chargers, where there are hours of “dwell time” per charging session, managed charging can be implemented in a number of ways:

- The operator programs the vehicle or charger to charge at certain times, hopefully to take advantage of a TOU rate.
- An aggregator (like eMotorWerks) controls many chargers (within limits set by the operator) to respond to price signals in a *wholesale* market.
- A utility directly controls chargers in accordance with grid conditions.

Most methods also allow chargers to react to demand response signals from the utility.

However: Managed charging is difficult on DCFC!

DEMAND CHARGES: PROBLEMATIC AT LOW UTILIZATION



RATE DESIGN GOALS

- Charging should be **profitable** so that it is sustainable. But **demand charges make this impossible** when utilization rates are low.
- Charging should always be **cheaper than gasoline** (typically $0.29/kWh, or ~$0.09/mile, or less).
- Level 2 charging should be considerably **cheaper than DC fast charging.**
- EV chargers should be on **dedicated tariffs** and on **separate meters**, preferably the meter built into the charging station.
- Tariffs should offer an opportunity to **earn credit for providing grid services** through managed charging.
- Ideally, utilities could leverage distributed energy resource management systems (DERMS) to **promote a more efficient use** of existing grid infrastructure by offering varying rates, or interconnection costs, or levels of cost sharing for make-ready by location.

Vehicle-Grid Integration

Good integration

- Reduce electricity and transportation costs
- Reduce oil consumption and emissions
- Optimize existing grid assets and extend their useful life
- Minimize new investment in grid infrastructure
- Supply ancillary services to the grid, such as frequency regulation and power factor correction
- Enable greater integration of wind and solar
- Provide multiplier benefits from increased money circulating in the community
- Improve energy security

Bad integration

- Increase electricity and transportation costs
- Require greater investment in gas-fired peak and flexible capacity
- Increase grid power emissions
- Shorten the life of grid infrastructure components
- Make the grid less efficient
- Make the grid less stable and reliable
- Inhibit the integration of variable renewables
- Increase demand on foreign oil and reduce energy security

Thank you for attending our webinar

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