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Driving Our Future: The Impact of Electric Vehicles

Jane Lin, PhD
Professor of Transportation Engineering
Department of Civil, Materials, and Environmental Engineering
University of Illinois at Chicago

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Electric Vehicle (EV)

- Hybrid EV (HEV)
  - HEVs are powered by an internal combustion engine and an electric motor that uses energy stored in a battery. The vehicle is fueled with gasoline to operate the internal combustion engine, and the battery is charged through regenerative braking, not by plugging in.
    - e.g., Toyota Prius
- Plug-in EV (PEV)
  - Plug-in hybrid EV (PHEV)
    - PHEVs are powered by an internal combustion engine and an electric motor that uses energy stored in a battery. PHEVs can operate in all-electric (or charge-depleting) mode (20-40 miles) or solely on gasoline, similar to a conventional hybrid.
  - All-EV (also referred to as Battery EV or BEV)
    - BEV has a battery that is charged by plugging the vehicle in to charging equipment. EVs always operate in all-electric mode and have typical driving ranges from 150 to 300 miles.
      - E.g., Tesla Model 3

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EV is not a new idea

- In the U.S., the first successful electric car made its debut around 1890 thanks to William Morrison, a chemist who lived in Des Moines, Iowa.
  - a six-passenger vehicle capable of a top speed of 14 miles per hour
- By 1900, electric cars were at their heyday, accounting for around a third of all vehicles on the road. During the next 10 years, they continued to show strong sales.
- Henry Ford's mass-produced Model T that dealt a blow to the electric car.
  - Introduced in 1908, the Model T made gasoline-powered cars widely available and affordable. By 1912, the gasoline car cost only $650, while an electric roadster sold for $1,750.
- Gas shortages spark interest in electric vehicles in 1970s
- Environmental concern drives electric vehicles forward – 1990 Clean Air Act Amendment
- The first turning point many have suggested was the introduction of the Toyota Prius. Released in Japan in 1997, the Prius became the world's first mass-produced hybrid electric vehicle.
- Tesla's announcement and subsequent success spurred many big automakers to accelerate work on their own electric vehicles.
- The future of EVs – one of the few positive things that came out of the COP26 is the wide adoption of electrification of transportation by many nations.

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Memorandum

U.S.Department of Transportation
Federal Highway Administration

Subject: **INFORMATION: The National Electric Vehicle Infrastructure (NEVI) Formula Program Guidance**

Date: February 10, 2022

From: Andrew C. Rogers
Chief Counsel

In Reply Refer To:
HCC and HEP

Gloria M. Shepherd
Associate Administrator for Planning, Environment, and Realty

To: Division Administrators

On November 15, 2021, the President signed into law the Bipartisan Infrastructure Law (BIL), enacted as the Infrastructure Investment and Jobs Act (IIJA), (Pub. L. 117-58). The purpose of this memorandum is to highlight the new National Electric Vehicle Infrastructure (NEVI) Formula Program authorized under Paragraph (2) under the Highway Infrastructure Program heading in title VIII of division J of the BIL.

This memorandum provides background, funding eligibilities, and program guidance for implementation of these historic investments in electric vehicle (EV) charging infrastructure that will put the United States on a path to a nationwide network of 500,000 EV chargers by 2030 and ensure a convenient, reliable, affordable, and equitable charging experience for all users.

POLITICOPRO

Biden lays out program for $5 billion in EV charging infrastructure

By Alex Guillén

02/10/2022 05:01 AM EST

The Biden administration on Thursday launched the process to distribute $5 billion to states to expand the nation's network of charging stations for electric vehicles and speed the adoption of the technology that plays a major role in the White House's efforts to fight climate change.

The funds — along with another $2.5 billion coming later this year for discretionary charger grants — are a designed to help achieve Biden's target for electric vehicle to make up half of all new vehicle purchases by the end of the decade. EV sales in the U.S. have lagged the levels seen in other industrialized countries, and the new effort forms a core part of President Joe Biden's climate strategy, particularly with additional measures in Democrats' Build Back Better bill apparently dead in the water.

The money is a “significant down payment” on Biden’s prior promise to install 500,000 charging stations by 2030, a senior administration official told reporters on a call Wednesday evening.

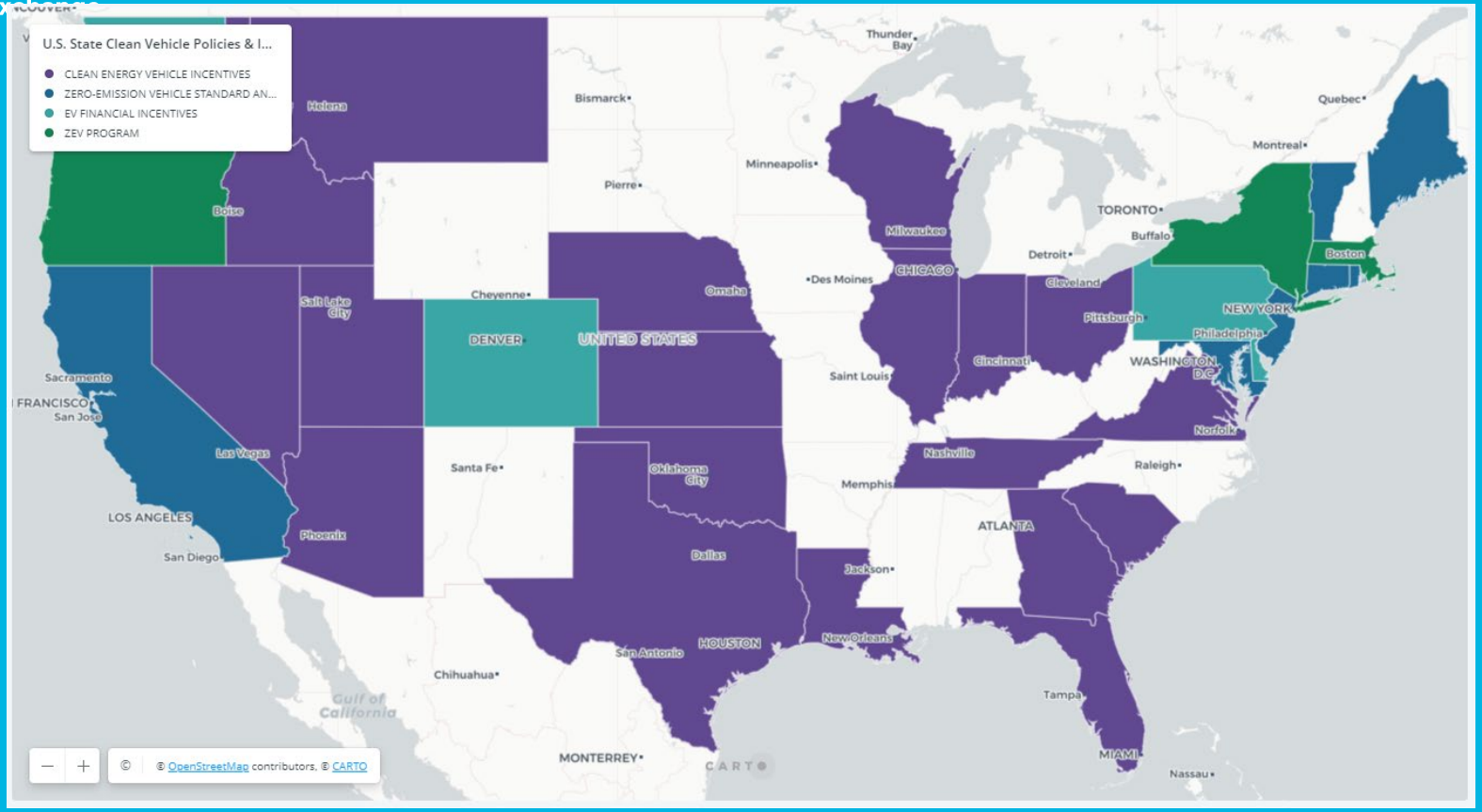
Details: A 31-page guidance document released by the Transportation Department details the National Electric Vehicle Infrastructure, or NEVI, formula program that requires states to lay out their plans for the money before it dispersed.

The guidance calls on states to prioritize placing charging infrastructure along interstate highways that are part of DOT’s " alternative fuel corridors." If those are fully built out with charging stations roughly every 50 miles, states can instead fund infrastructure on other public roads or in accessible areas such as public parking facilities, schools and parks.

“We need a network that connects the country and gives people the ability to access chargers the same way they would expect to have gas stations, not a patchwork of disconnected different systems that vary by region,” the official said.

Money: Funds will be sent to states over the next five years. For 2022, a total of $615 million will be disbursed, with Texas leading the pack at over $60 million and California close behind at almost $57 million. No state gets less than $2.5 million,

Electrification Programs



https://www.c2es.org/document/us-state-clean-vehicle-policies-and-incentives/

State	LEV emisson standards	ZEV emission standards	ZEV program	EV financial incentives	Electrification of commercial vehicles/trucks/HDV (via purchase/conversion/replacement)	Charging facility incentives
California	v	v	v	v	LDV and HDV, buses	EVSE
Maine	v		v	v	HDV	?
Vermont	v		v	v	?	EVSE, charging stations
Connecticut	v		v	v	LDV and HDV	EVSE
New Jersey	v		v	v	?	EVSE
Maryland	v		v	v	?	Public chargers
Oregon	v		v		?	?
New York	v		v	ZEV rebates	?	EVSE, dual-port chargers
Washington	v			v	?	EVSE
Colorado	v			v	L/M/HDEV purchase	EVSE
Pennsylvania	v			v	L/M/HDV conversion	EVSE

Zero-emission Vehicle Actions

- ZEV emission standards, ZEV programs, and EV financial incentives:
  - CA is the leader
  - Maine, Vermont, Connecticut, New Jersey, and Maryland have adopted CA's LEV standards and ZEV programs, as well as EV incentives.
- ZEV program only:
  - Oregon and New York have adopted CA's LEV standards and ZEV programs.
- EV financial incentives only:
  - State of Washington, Colorado, Pennsylvania

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Current Status of EV sales and Infrastructure

- Currently more than 3 percent of new vehicle sales are electric
- The latest report by Bloomberg New Energy Finance shows that by 2040, 58% of global passenger vehicle sales will come from electric vehicles.
- At the same time, they will make up less than 33% of all the cars on the road

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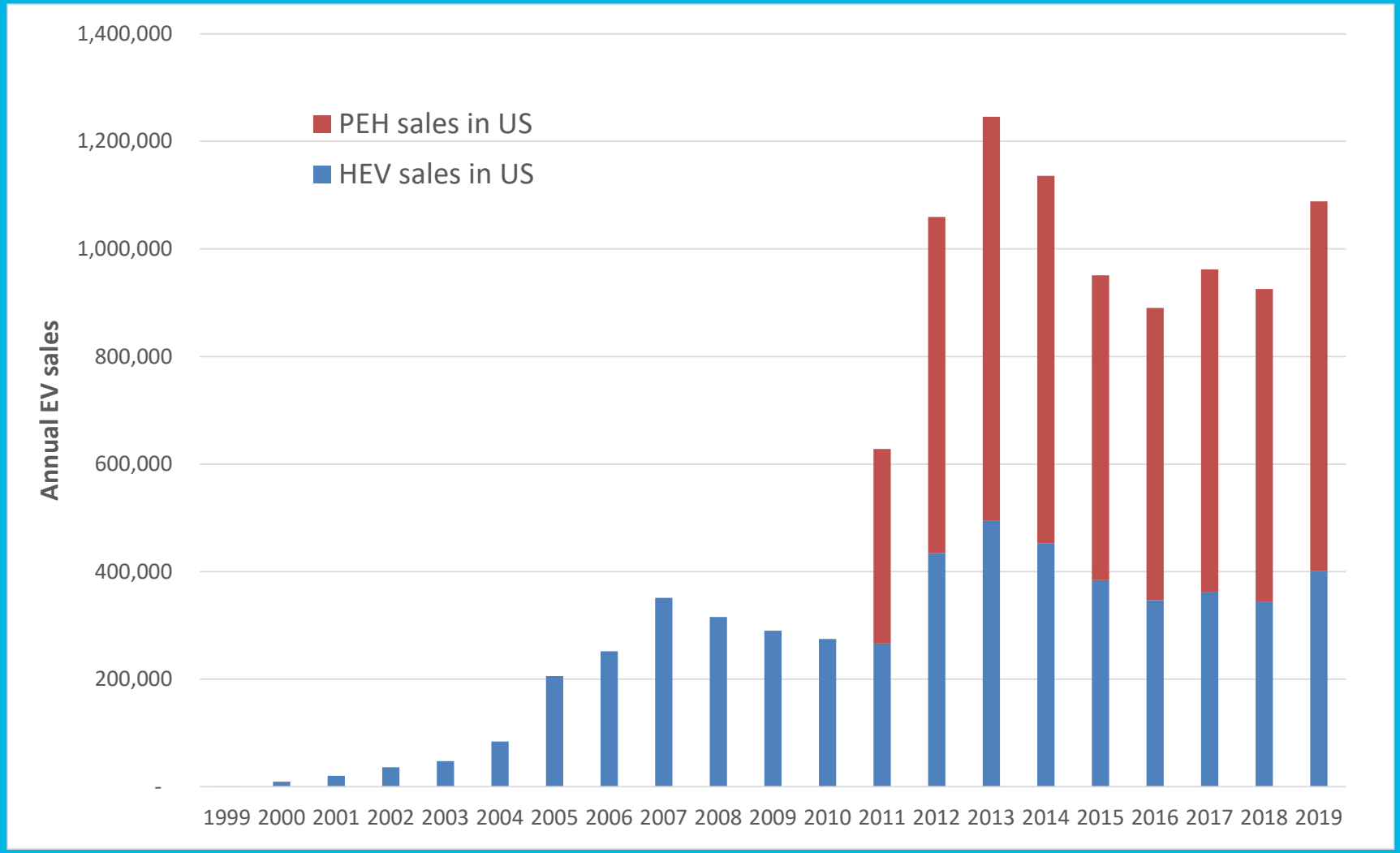
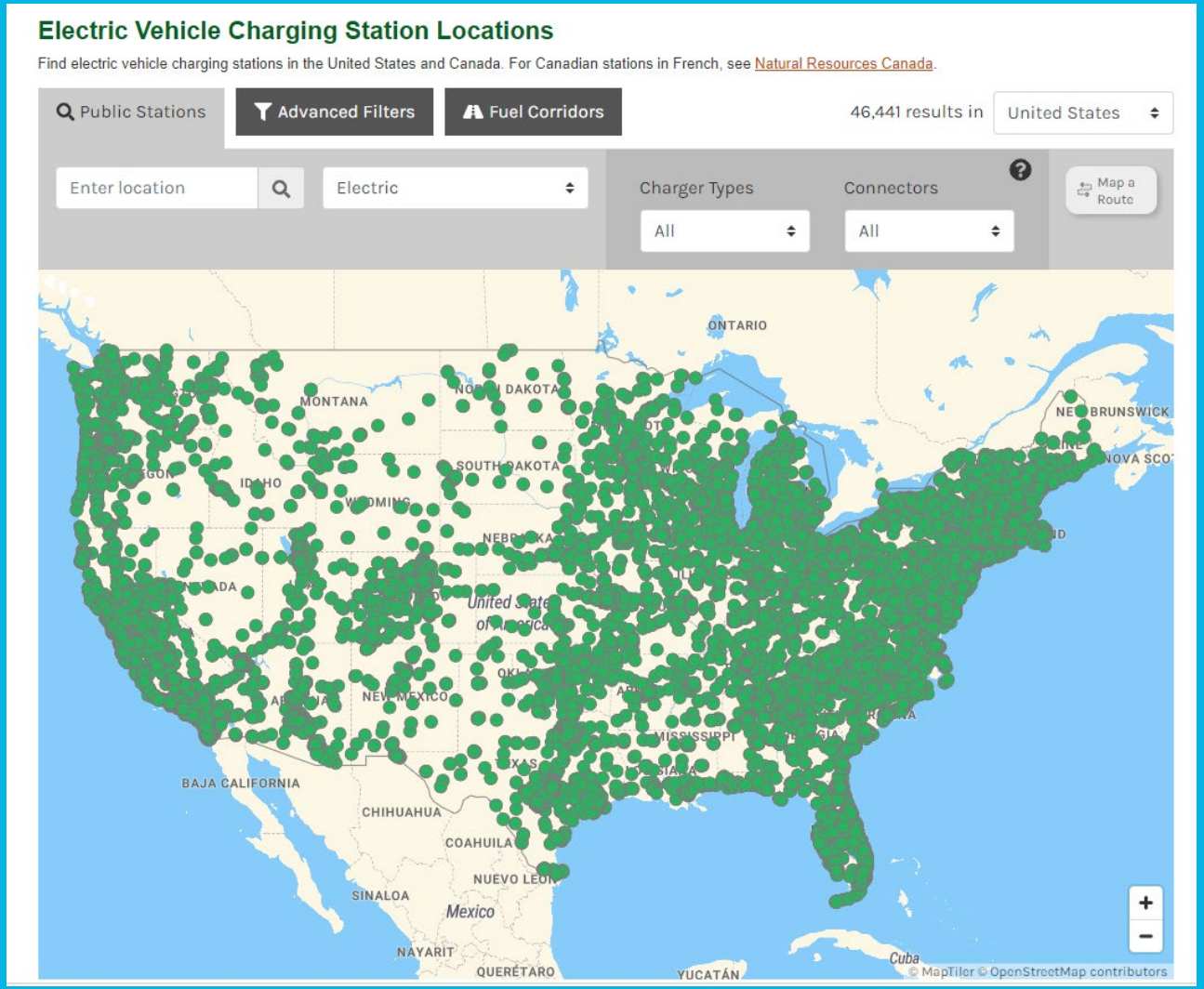

1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
-
Annual EV sales
PEH sales in US
HEV sales in US
1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019

Top Five EV Makes and Models in Sales

Vehicle	Type	Total
Tesla Model 3	EV	296,392
Tesla Model S	EV	162,285
Chevy Volt	PHEV	156,733
Nissan Leaf	EV	141,888
Prius PHEV	PHEV	116,927

Vehicle	Type	Total
Toyota Prius	HEV	2,242,397
Toyota Camry	HEV	431,233
Ford Fusion & Milan	HEV	356,898
Toyota RAV4	HEV	237,770
Honda Civic	HEV	235,437

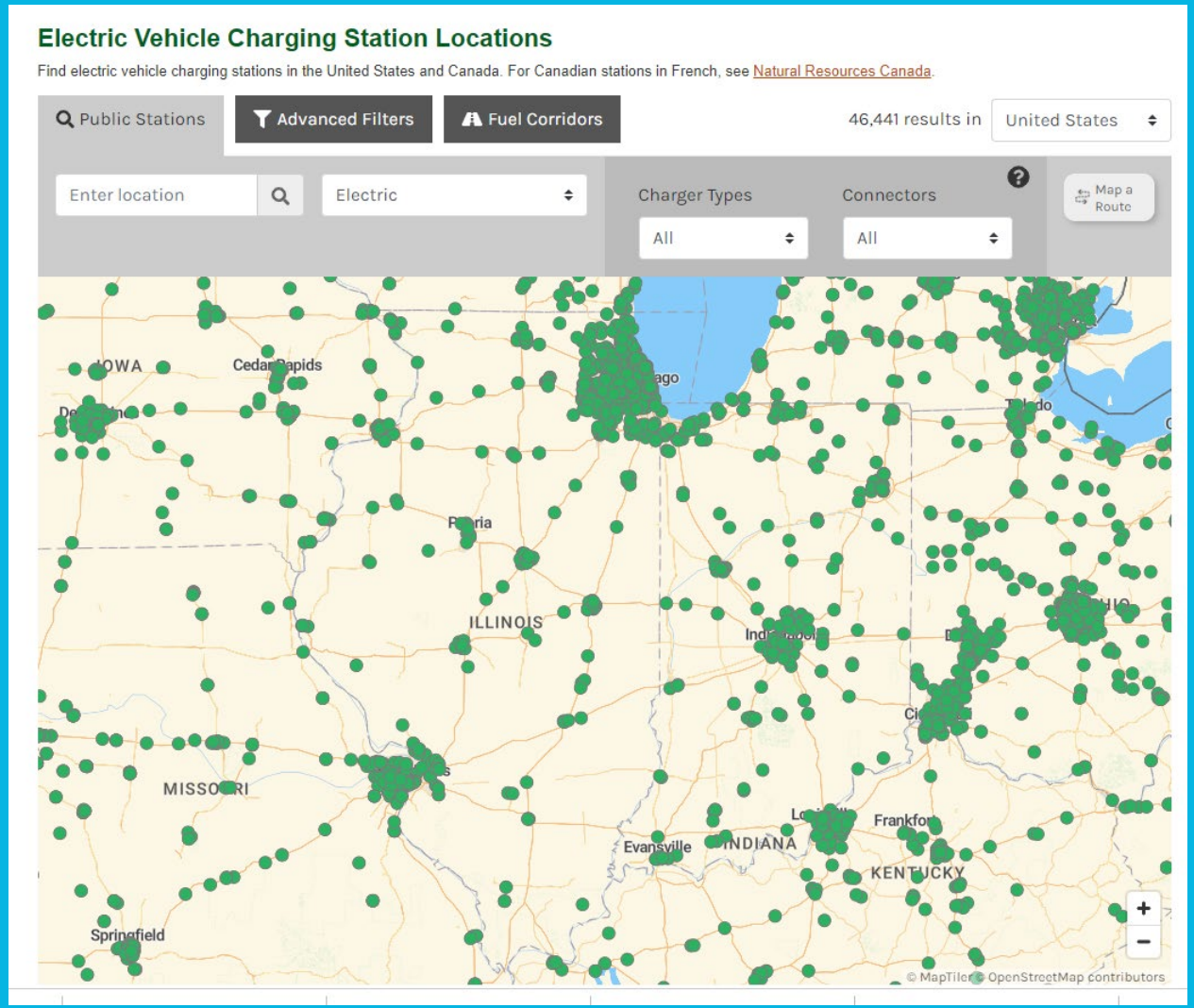
Data source: Transportation Research Center at Argonne National Laboratory, anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates



46,441 Stations:
Leve 1: 2 to 5 miles of range per 1 hour of charging (<5% of public EVSE ports).

Level 2: 10 to 20 miles of range per 1 hour of charging (>80% of public EVSE ports).

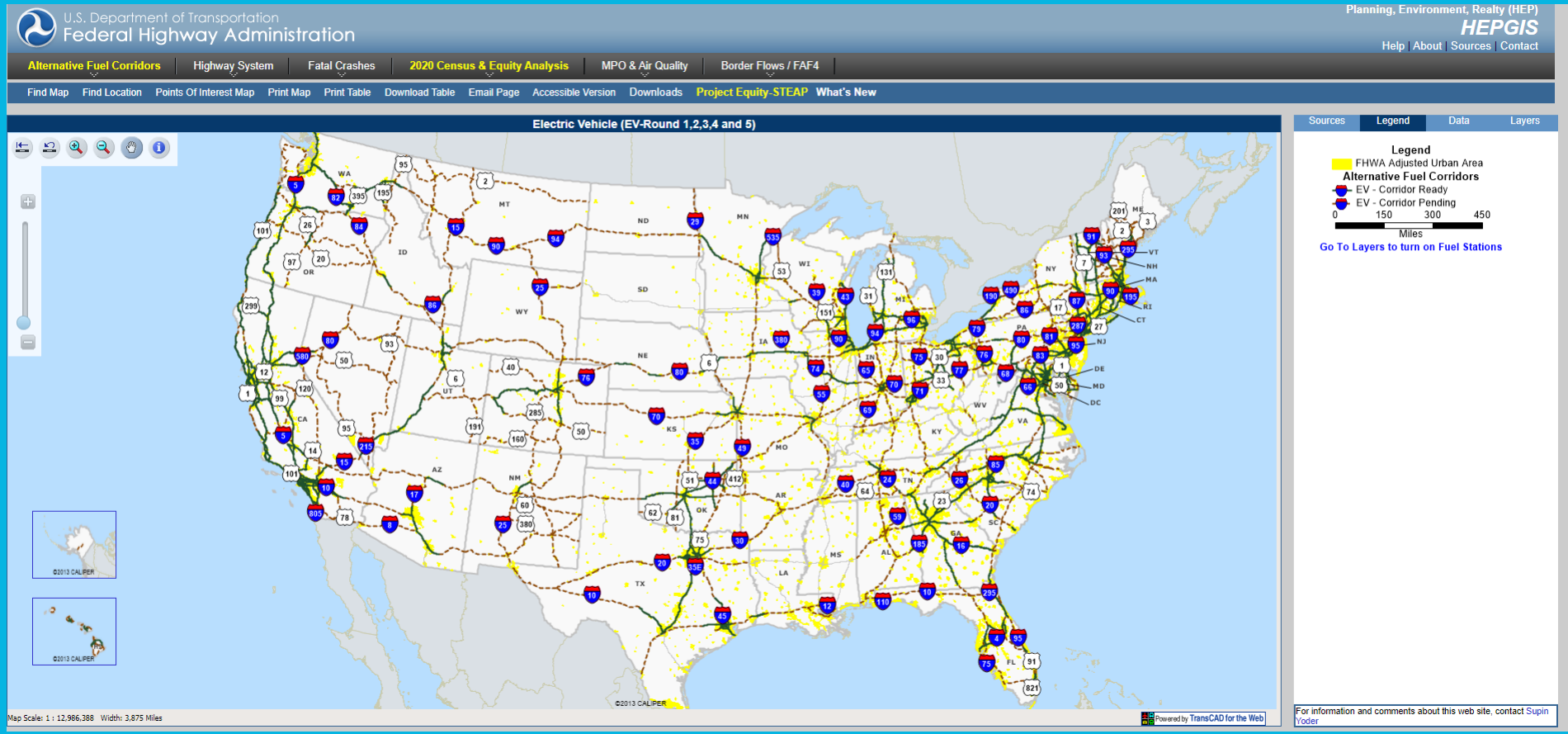
DC fast charging: 60 to 80 miles of range per 20 minutes of charging (>15% of public EVSE ports).



In Illinois, there are 927 public EV charging stations with 2,339 EVSE ports.

https://afdc.energy.gov/fuels/electricity_locations.html#/find/nearest?fuel=ELEC&ev_levels=all&country=US

Federal Highway Administration EV Corridor Map



https://hepgis.fhwa.dot.gov/fhwagis/ViewMap.aspx?map=Highway+Information%7CElectric+Vehicle+(EV-Round+1,2,3,4+and+5)#

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Challenges and Opportunities in Electrification

- Battery technology
- Charging technology
- Costs and benefits
- Power grid and electrified transportation

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Battery Technology

- Active research area for new and cheap battery technologies in materials science and engineering, chemistry, and chemical engineering, mechanical engineering
  - Currently the average cost to replace an EV battery is around $5,500.
- Types of battery:
  - Lithium-Ion batteries (most widely used in PHEVs and BEVs)
  - Nickel-Metal Hydride batteries (widely used in HEVs)
  - Lead-Acid batteries (for ancilliary loads)
  - Ultracapacitors (for additional power during acceleration and hill climbing and help recover braking energy)
- Battery recycling: relatively new and challenging research area
  - Stumbling block: separating the different kinds of battery materials efficiently at low cost

Charging Technologies

- Leve 1: 2 to 5 miles of range per 1 hour of charging (<5% of public EVSE ports).
- Level 2: 10 to 20 miles of range per 1 hour of charging (>80% of public EVSE ports).
- DC fast charging: 60 to 80 miles of range per 20 minutes of charging (>15% of public EVSE ports).

- To put this in perspective, for an E-Force One (by COOP Switzerland) 18 ton electric truck with a battery capacity of 300 kWh, its energy consumption is 130 kWh per 100 km.

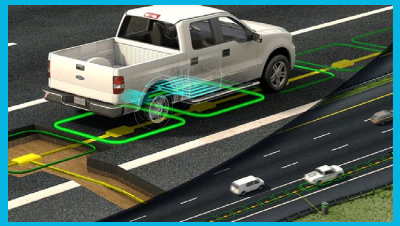
➢ That means it will take over 35 to 50 minutes to charge the truck even with the DC fast charging technology, or 7 to 14 hours with level 2 charging technology.

Innovations in Electrification of Freight Vehicles

- There are eHighway pilot projects in Germany, Sweden, and Southern California by Siemens.

- Tesla's Semi all-electric freight truck.

- Wireless energy transfer technology



EV Costs and Benefits

- Transitioning to a light-duty fleet of HEVs and PEVs could reduce U.S. foreign oil dependence by 30-60% and greenhouse gas emissions by 30-45%, depending on the exact mix of technologies.

- Costs are primiarily
  - EV ownership cost
  - Charging infrastructure cost

EV Costs and Benefits (cont'd)

- EV ownership cost
  - Upfront cost is high for EV
  - Life time ownership cost (including fuel cost, maintenance cost, and insurance cost) is slightly less than a gasoline minivan or a pickup truck
    - Some estimate of $9,000 annual cost for owning an EV.

- Cost for a single electric vehicle supply equipment (EVSE) port:
  - Level 1: $300 - $1,500
  - Level 2: $400 - $6,500
  - DC Fast: $10,000 - $40,000
- Installation cost:
  - Level 1: $0 - $3,000
  - Level 2: $600 - $12,700
  - DC Fast: $4,000 - $51,000

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EV Costs and Benefits (cont'd)

- For electic trucks, according to a California Air Resources Board (CARB) study,

Table 1. Annual requirements in the proposed rule

	Zero emission performance thresholds		
Model year	Class 2b-3	Class 4-8	Class 7-8 tractors
2024	5%	9%	5%
2025	7%	11%	7%
2026	10%	13%	10%
2027	15%	20%	15%
2028	20%	30%	20%
2029	25%	40%	25%
2030	30%	50%	30%
2031	35%	55%	35%
2032	40%	60%	40%
2033	45%	65%	45%
2034	50%	70%	50%
2035	55%	75%	55%

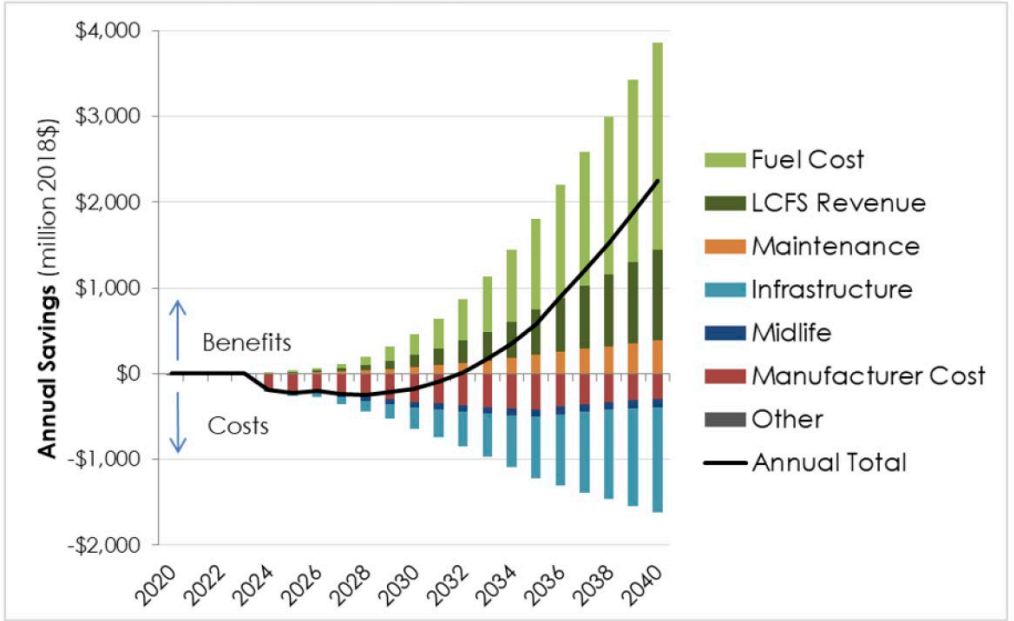
Source: CARB (2020a)

Table 3. Air quality and climate benefits from the proposed ACT rule

	CARB's assessment
NOx (oxides of nitrogen) emission reductions through 2040	58,000 tons
CO_2e (carbon dioxide equivalent) emission reductions through 2040	17.3 MMT of CO_2e

Source: California EPS and CARB (2020B)

Figure 4. Total savings (CARB battery costs)



Source: California EPS

https://energyinnovation.org/wp-content/uploads/2020/06/Clean-Trucks-Big-Bucks_June_17_2020.pdf

Integration of Power Grid and Electrified Transportation

- For an existing EV model in the market, the Tesla model 3, the standard battery capacity is 50 kWh, which can last 4.4 hours when the vehicle is running at the 50 miles per hour.
  - Considering a person drives to work from the suburbs to the downtown Chicago in the morning and reverses back in the afternoon, his/her average daily commute time is about 2.5 hours.
  - The resulting daily electricity consumption for an AV is about 28.5 kWh, which is nearly half of a month electricity usage of a family in United States.
- A recent statistical report showed that 82% of Illinois residents and 58.25% of Chicago residents commute via vehicles .
- This will result in massive electricity demand with the large-scale penetration of AEVs.

Integration of Power Grid and Electrified Transportation

- Smart pricing mechanisms
  - Dynamic demand pricing
    - to regulate electricity charging demand and shift it to off-peak hours
  - Electricity trading
    - to allow unused electricity on EVs to be sold back to the grid during peak hours.
  - Auxillary floating electricity supply
    - to deploy EVs to supply electricity to where power grid is down or cannot reach

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In summary, there are plenty of hard challenges and exciting opportunities ahead for electrification of transportation!

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Questions?