Zero-Emissions Technology for Freight: Heavy-Duty Trucks

Tools to Advocate for Zero-Emissions Technology

Jimmy O'Dea

October 2020

Moving Forward Network

MFN communities have been leading the charge to demand a shift to zero-emissions technology in goods movement. After many years of organizing, available zero-emissions technology and political will are aligning to create a viable pathway to move freight transportation off of dirty diesel. To keep up the necessary momentum, we keep up the pressure and grow our skills as advocates.

Zero-emissions technology was the most requested webinar topic when we polled MFN members for our *Building Power for a Stronger Network initiative*. This guide has been adapted from a three-part webinar created for the MFN by the Union of Concerned Scientists. We would like to thank Jimmy O'Dea and UCS for supporting our community-led organizing model with their technical expertise.

About Jimmy O'Dea, UCS

Jimmy O'Dea is a senior vehicles analyst in the Clean Transportation program at the Union of Concerned Scientists. He specializes in vehicle technology, policy, and emissions.

The Union of Concerned Scientists uses rigorous, independent science to solve our planet's most pressing problems. Joining with people across the country, we combine technical analysis and effective advocacy to create innovative, practical solutions for a healthy, safe, and sustainable future.

Question or comments?

Contact: Candice Kim, MPH & CHES
MFN, Project Director
Urban & Environmental Policy Institute
Occidental College
1600 Campus Road (M-1)
Los Angeles, CA
Email: ckim3@oxy.edu

For more information about MFN, to see an online PDF version of this report, or to find links to the webinar series, visit: www.movingforwardnetwork.com.

Cover Photo of the Port of Oakland by Jimmy O'Dea.

© 2020 Moving Forward Network
All Rights Reserved

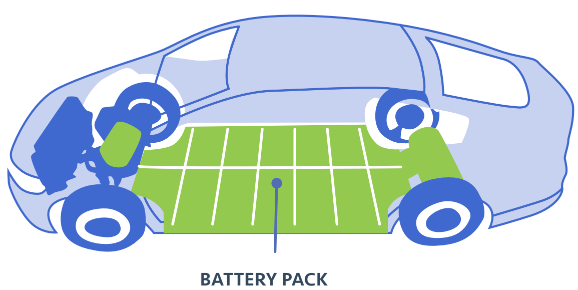
What Are Zero-Emissions Technologies?

In vehicle & freight transportation, there are 2 types of zero-emissions technologies: battery & fuel cell. Fuel cells and batteries both work by converting chemical energy into electrical energy. Both are electric.

Battery

Lithium-ion batteries function by charging to store electricity in, to discharge electricity out.

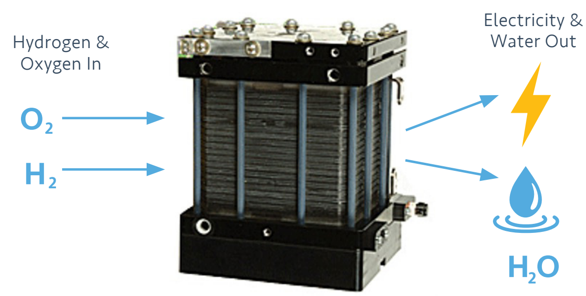
Batteries are charged by plugging into electricity and the chemicals are always already inside the battery pack.



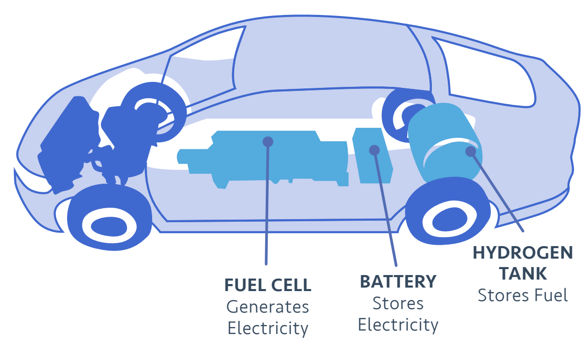
Safety Advantage: A battery pack provides stability to a car by lowering the center of gravity, more than combustion vehicles.

Fuel Cell

Fuel cells are fueled with hydrogen and oxygen gases. The fuel cell converts those gases into electricity and water, a by-product.



Fuel cells are fueled with hydrogen, by filling a tank with hydrogen gas and using oxygen from the air.



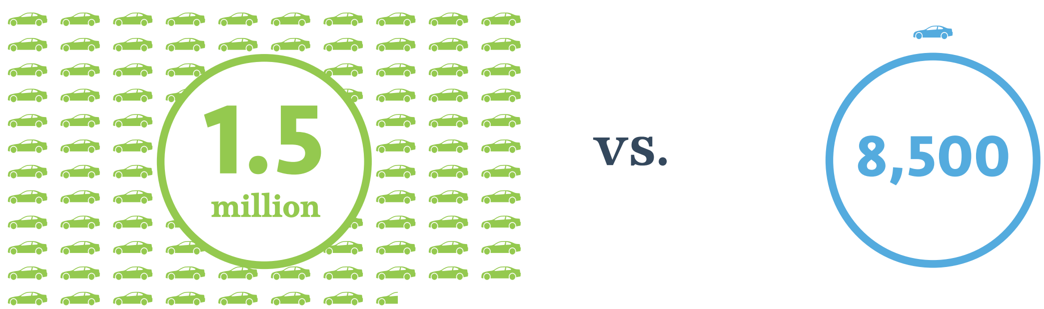
A fuel cell is about the same size as a 5 gallon water jug.

ZERO-EMISSIONS = ELECTRIC = BATTERY OR FUEL CELL

Electric Cars & the Auto Industry

Automakers are focusing on battery technologies right now. In the US today, there are less fuel cell vehicles: 8,500 fuel cell cars versus 1.5 million battery electric cars. There are roughly 117.6 battery electric cars for every 1 fuel cell electric car.

Battery Cars in the US **Fuel Cell Cars in the US**



Why Are There More Battery Electric Cars?

Cost. Fuel cells are more expensive than batteries and electricity, that's why we see more battery powered cars than fuel cell powered cars. Automakers have invested in fuel cell technologies, but most are focusing on batteries.

Fuel Cell Car Prototypes Developed by Automakers


Daimler "F-Cell" FCV


Ford Edge with HySeries


Volkswagen Touran HyMotion


General Motors HydroGen3


Hyundai FCEV


Honda Clarity


Nissan FCV


Toyota FCHV


Toyota Mirai

🚫 Prototype has not been commercialized by auto maker.

SOURCE: fuelcellpartnership.org

How Do We Get Hydrogen for Fuel Cells?

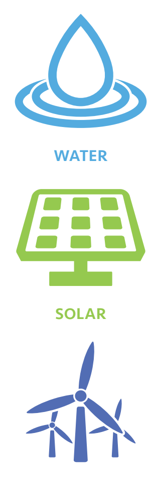
Most hydrogen currently comes from heating methane, a natural gas. You heat methane with water, and this produces hydrogen and carbon dioxide. This is not ideal because it uses a fossil fuel, and the by-product is carbon dioxide, a global warming emission. Even so, there are still lower global warming emissions compared to a gasoline vehicle.

METHANE COMBUSTION

$$1{,}000^\circ C: CH_4 + 2H_2O \longrightarrow CO_2 + 4H_2$$

A Better Way?

A better, cleaner way to get hydrogen is from water. This process produces no carbon dioxide, but it takes energy to do this. We need to use solar and wind power to do this in a clean way. As we get more solar and wind on the grid, this could be a very clean source of electricity to fuel this process.



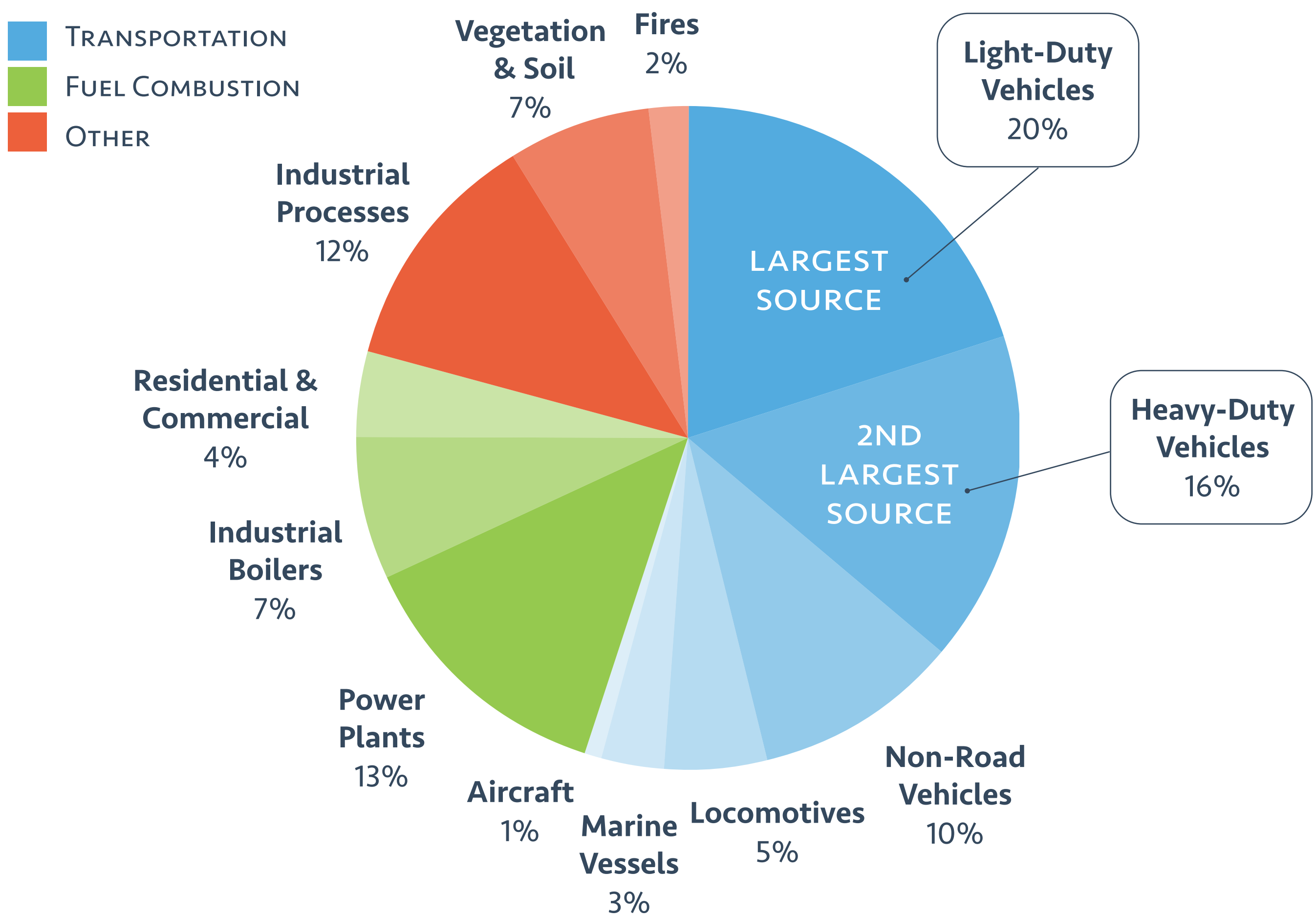
CHEMICAL REACTION TO "SPLIT" WATER

$$2H_2O \longrightarrow 2H_2 + O_2$$

Transportation Is the Largest Source of Nitrogen Oxides in the US

Nitrogen oxides (NO_X) are a precursor to smog and is the main source of pollution in many communities. The majority of NO_X emissions in the US comes from transportation sources.

Emissions of Nitrogen Oxides in the US, by Sector



Heavy-duty freight vehicles are the second largest source of NO_X emissions, but it is important to note that there are many less heavy-duty vehicles than light-duty vehicles. Heavy-duty vehicles make up only 10% of vehicles on the road, but contribute disproportionately more harmful emissions of various kinds (GHGs, NO_X and $PM_{2.5}$). Freight is a very large source of NO_X emissions, even larger than power plants.

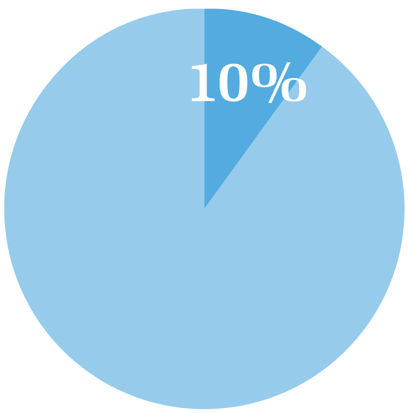
CHART SOURCE: ucsusa.org/resources/ready-work

A Small Number of Freight Vehicles Have a Large Impact on Air Quality

Heavy-Duty Vehicles in the US

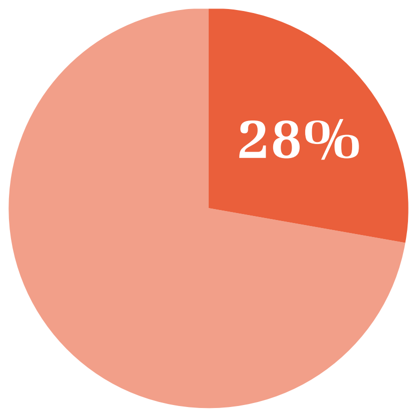
Heavy-duty vehicles are anything from a heavy pickup truck to a semi truck. Heavy-duty vehicles make up about 10% of vehicles on the road.

Vehicle Population



Vehicle Population of the US

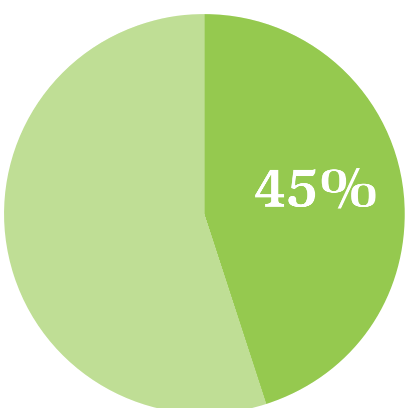
Vehicle GHG



Greenhouse Gas Emissions

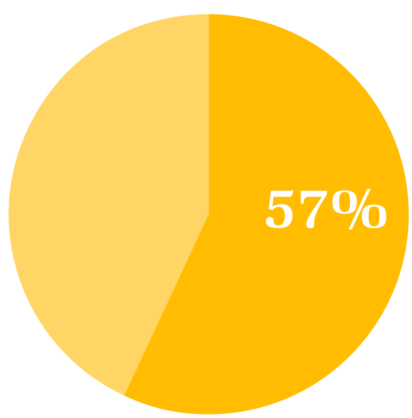
They are responsible for about 28% of greenhouse gas (GHG) emissions, so they disproportionately contribute to climate change.

Vehicle NO_x



Oxides of Nitrogen: NO + NO_2, generically abbreviated as NO_x

Vehicle $PM_{2.5}$



Particulate matter with a diameter less than 2.5 micrometers

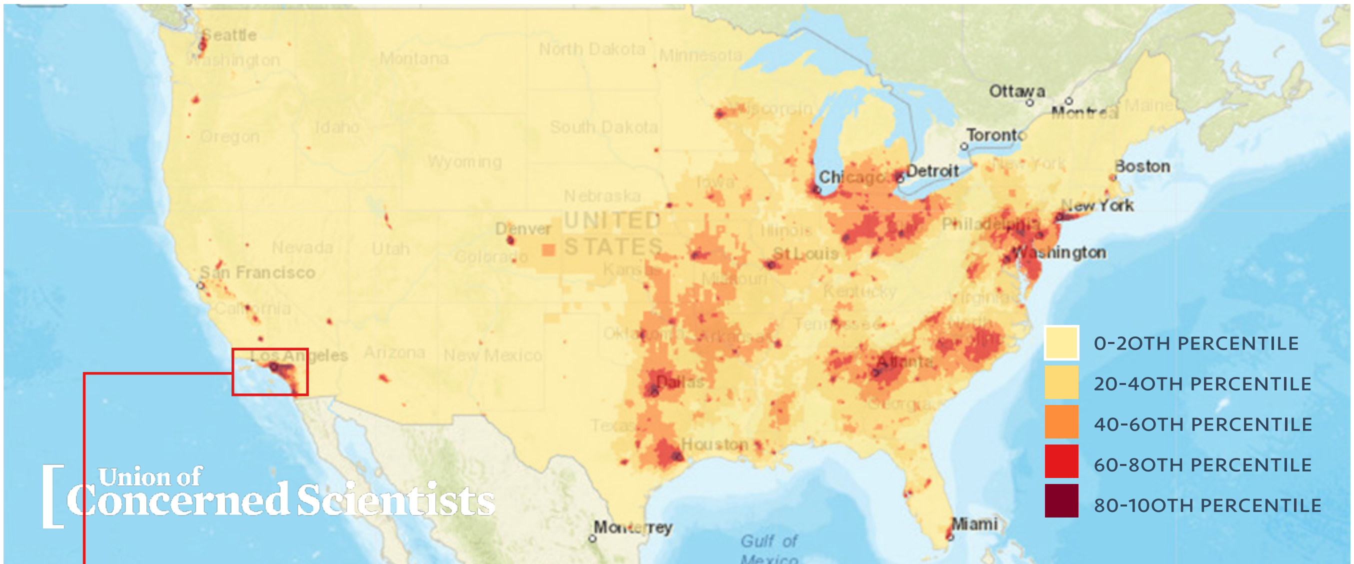
They contribute 45% of the transportation sector's NO_x emissions, and 57% of primary particulate matter ($PM_{2.5}$).

A small number of freight vehicles is having a disproportionate impact on our air quality.

SOURCE: ucsusa.org/resources/ready-work

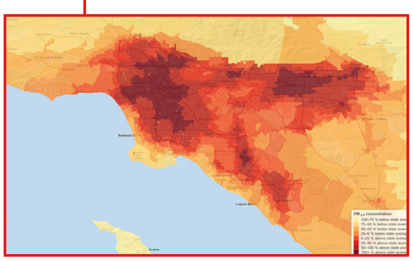
Mapping Exposure to Particulate Matter

EXPOSURE TO $PM_{2.5}$ FROM ON-ROAD VEHICLES BY CENSUS TRACT



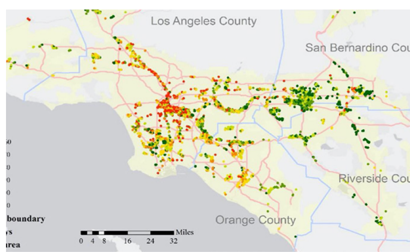
Visit the UCS Blog to see the map where you can zoom in on your city.

CASE STUDY: LOS ANGELES



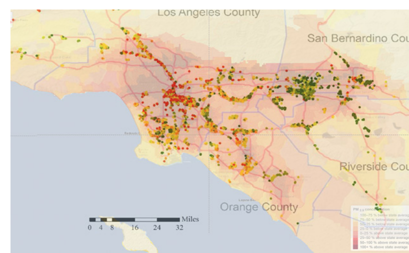
Map 1: Los Angeles $PM_{2.5}$ Exposure

+



Map 2: Warehouses in the Los Angeles Area

=



Map 1 Overlay with Map 2

There are regions in cities that have a higher percentage of $PM_{2.5}$ from vehicles. When the "Map 1: Los Angeles PM 2.5 Exposure" is overlayed with "Map 2: Warehouses in the Los Angeles Area," we see that there is a high correlation between the location of warehouses, freeways, and concentrations of $PM_{2.5}$.

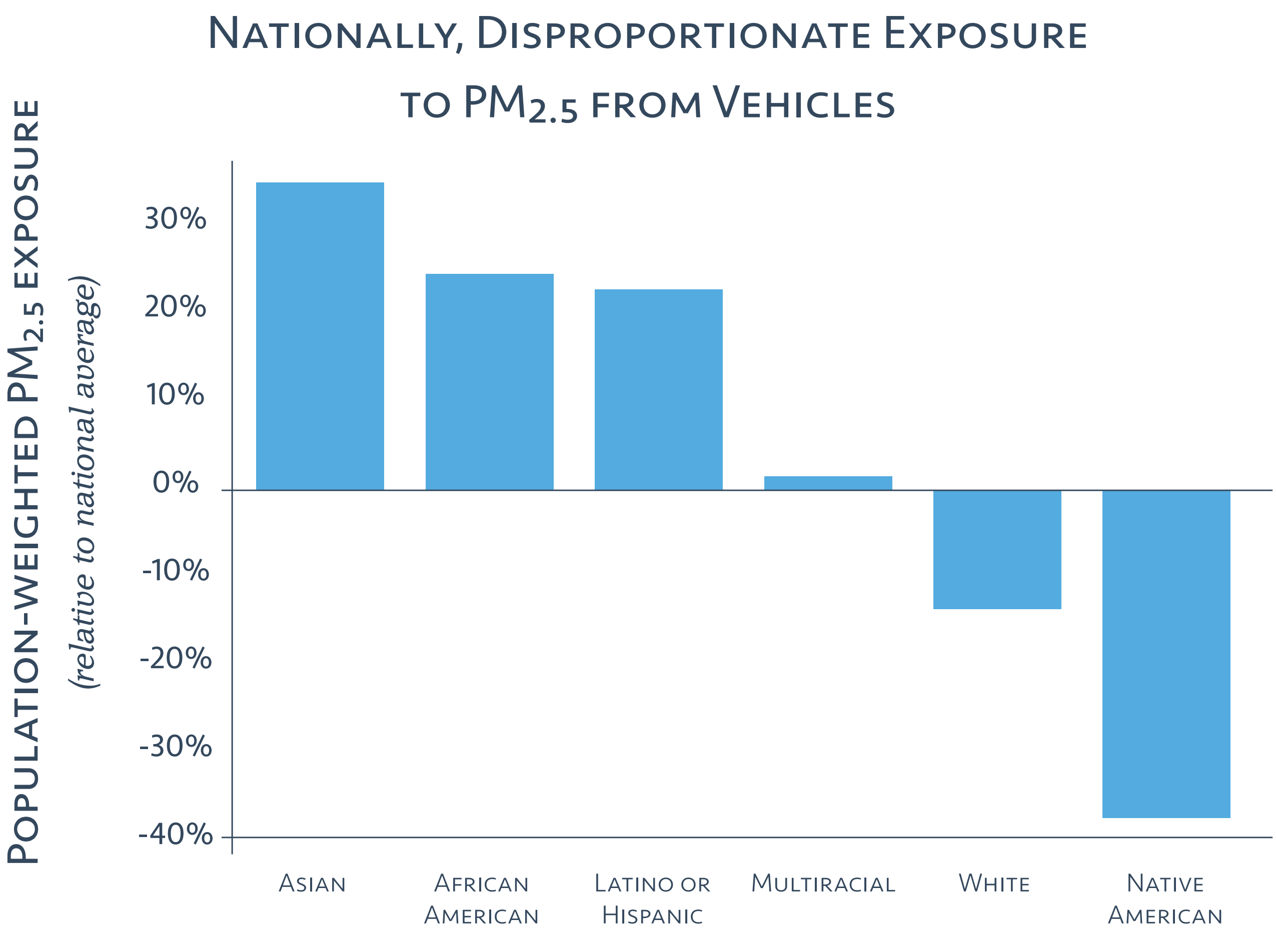
VIEW INTERACTIVE MAP

US MAP & Map 1 SOURCE: Air Pollution from Cars, Trucks, and Buses in the US: Everyone is Exposed, But the Burdens are not Equally Shared

MAP 2 SOURCE: Yuan, Q. "Mega freight generators in my backyard: A longitudinal study of environmental justice in warehousing location," Land Use Policy, 2018.

MORE READING: blog.ucsusa.org/tag/inequitable-exposure-pollution

Inequitable Exposure to Air Pollution

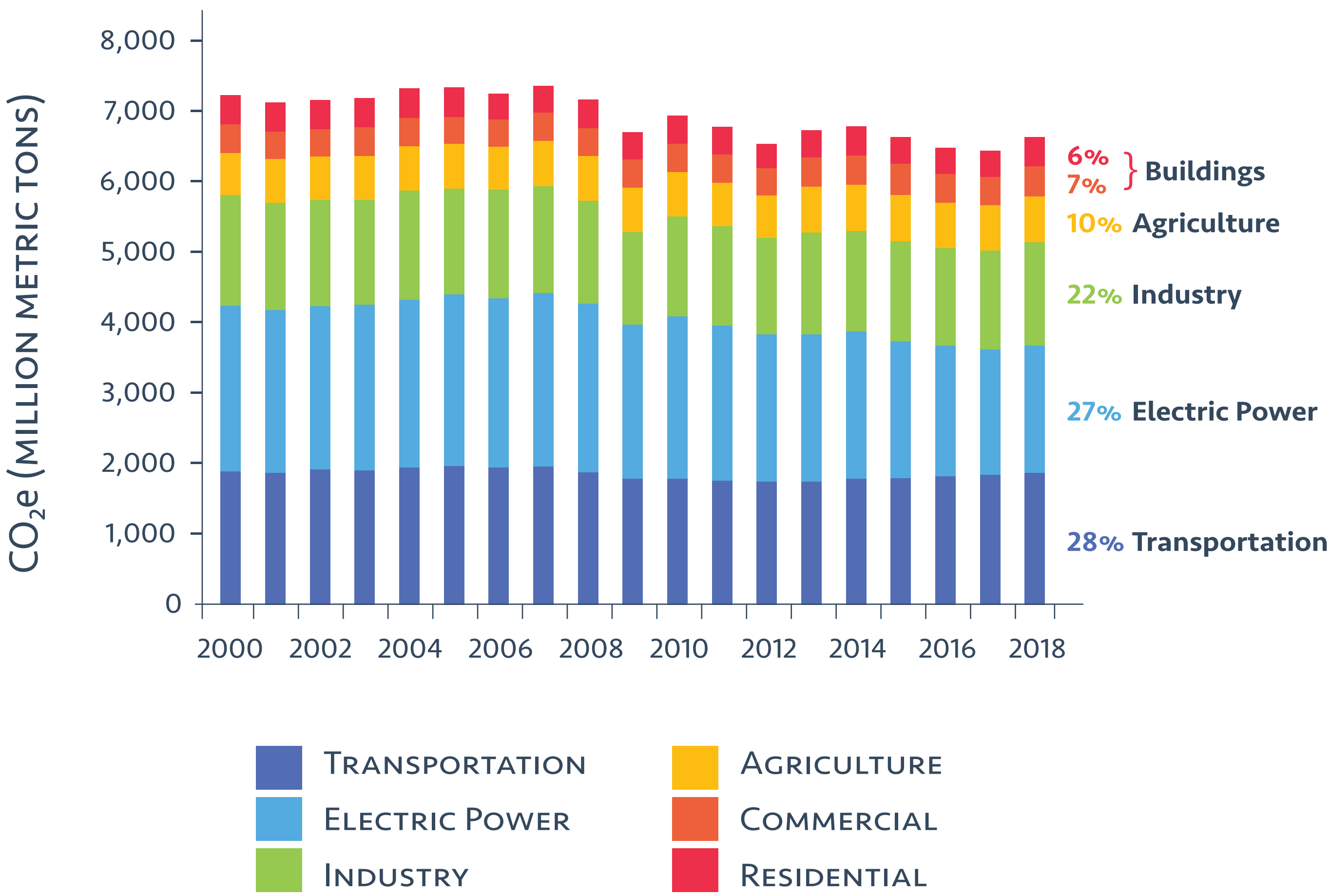


$PM_{2.5}$ pollution burden from cars, trucks, and buses is inequitable when looking at the exposure experienced by racial groups. Asian Americans are, on average, exposed to 34 percent higher $PM_{2.5}$ concentrations than the average person in the US, and African Americans experience concentrations 24 percent higher than average. Latinos (defined as those identifying as Hispanic or Latino) have exposure 23 percent higher than the US population as a whole. Whites have average exposure that is 14 percent lower than the average for the nation. This means that, on average, Asian American and African Americans are exposed to $PM_{2.5}$ pollution that is 56 and 44 percent higher, respectively, than whites.

SOURCE: "Air Pollution from Cars, Trucks, and Buses in the US: Everyone is Exposed, But the Burdens are not Equally Shared" by David Reichmuth

Vehicle Emissions & Global Warming

US Global Warming Emissions over Time, by Sector



Vehicle emissions contribute to global warming & climate change. Transportation recently became the largest contributor to climate change in the US. While our overall emissions that contribute to global warming have been dropping slightly in recent years, we need a 40% drop in emissions in the next decade in order to slow/prevent detrimental climate change results. This will require actions that we've never taken before. We have a lot of work to do on climate change.

SOURCE: EPA, Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2018

Impacts of Climate Change on Coastal Communities

By 2030, all of the East and Gulf coast will experience significant flooding every year as a result of sea level rise due to climate change.

AREAS OF CHRONIC FLOODING IN 2030 WITH HIGH GHG EMISSIONS

View the interactive map to look at different coastal areas.

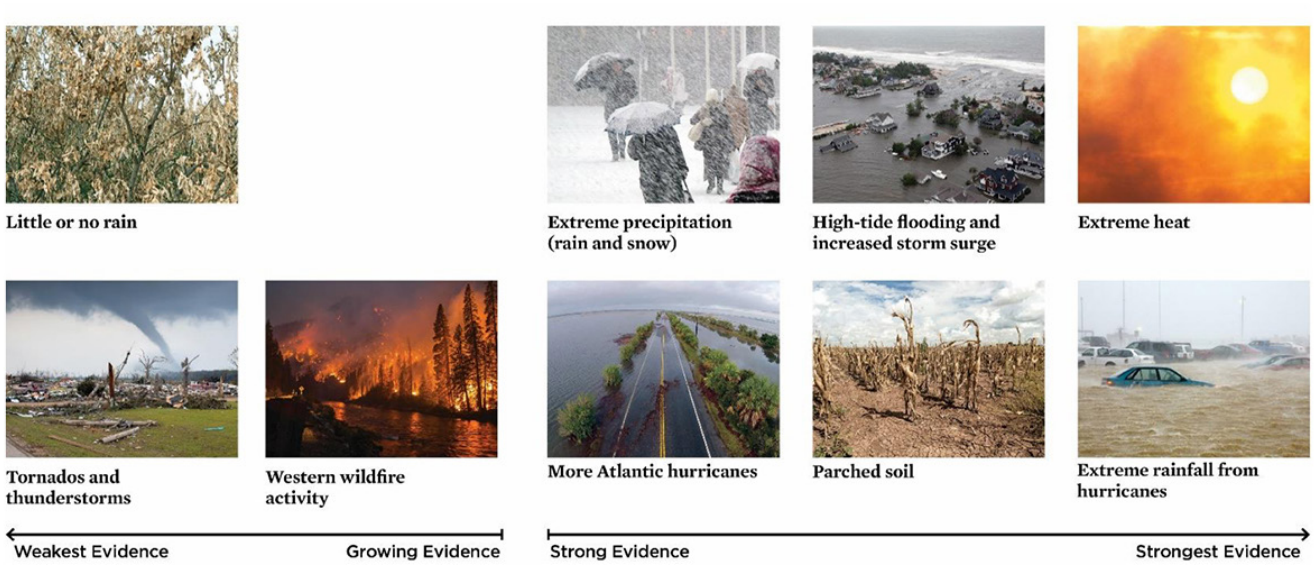
Other weather examples of the impacts of climate change include extreme heat, more hurricanes, extreme rainfall from hurricanes, droughts, flooding, etc.

VIEW INTERACTIVE MAP

SOURCE: ucsusa.org/RisingSeasHitHome

Connection: Extreme Weather & Climate Change

Where Is the Science on Attributing These Extreme Weather Events to Climate Change?



Union of Concerned Scientists

On the right of the graph above are events that have the strongest evidence of being connected to climate change: extreme heat, extreme rainfall from hurricanes, flooding & storm surges, parched soil, extreme precipitation (rain and snow), and more Atlantic hurricanes.

On left of the graph above is the area where the science is still unclear and making the connection to climate change is still being settled.

Note: "Little or no rain" is different than mega-droughts, or droughts that last for years. There is scientific evidence connecting these types of droughts to climate change.

SOURCE/Methodology: ucsusa.org/ClimateAttribution

What Is a Zero-Emissions Vehicle?

A zero-emissions vehicle is a vehicle with zero tailpipe emissions. We do not have 100% renewable energy sources to produce electricity (battery & fuel cell), and we are not using water exclusively as a source for hydrogen (fuel cell). Even though there are some emissions produced to fuel these technologies, there are still significant benefits to battery and fuel cell vehicles.

What Are Life Cycle Emissions?

Life cycle emissions are the "well to wheels" emissions of a vehicle, including each stage of its production and use.

For a diesel/gasoline vehicle, life cycle emissions are based on:

Extraction of Oil

+

Refinement of Oil

+

Transport and Delivery of Fuel to a Vehicle

+

Driving a Vehicle

For an electric vehicle, life cycle emissions are based on:

Extraction of Fossil Fuels

+

Burning Fossil Fuels or Generating Electricity with Wind or Solar

+

Distributing & Transmitting Electricity over the Power Grid

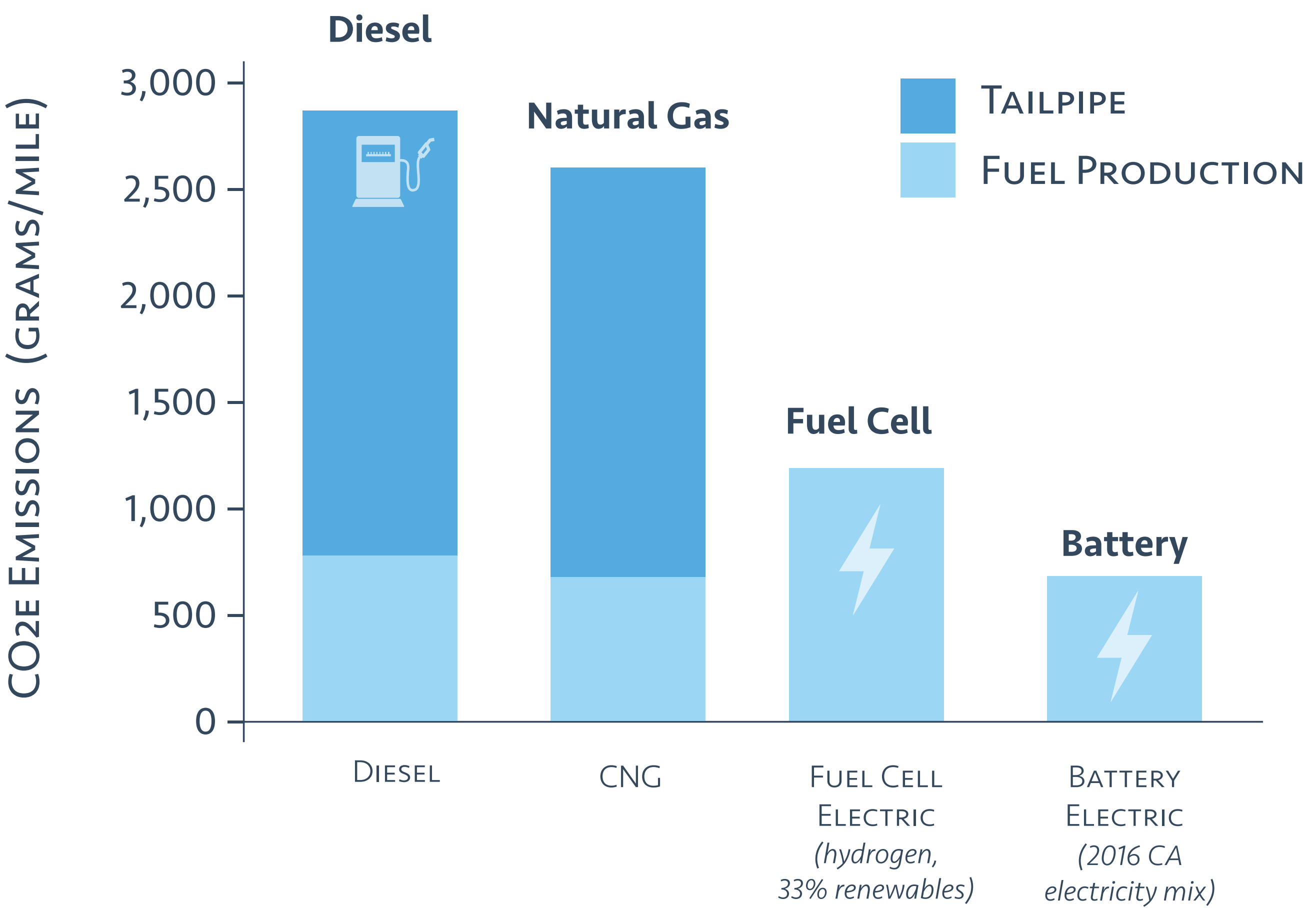
+

Using Electrical Energy to Drive the Vehicle

For a current electric vehicle, the life cycle emissions are based on getting hyrdrogen from water and natural gas, instead of (more ideally) getting all hydrogen from water. There are also emissions associated with mining for and manufacturing the battery.

Global Warming Emissions: Different Types of CA Transit Buses

The life cycle emissions of both battery and fuel cell electric buses are significantly lower than both diesel and natural gas. Using conservative estimates for life cycle impacts, natural gas fuel vehicles have only slightly lower global warming emissions than vehicles fueled with diesel.

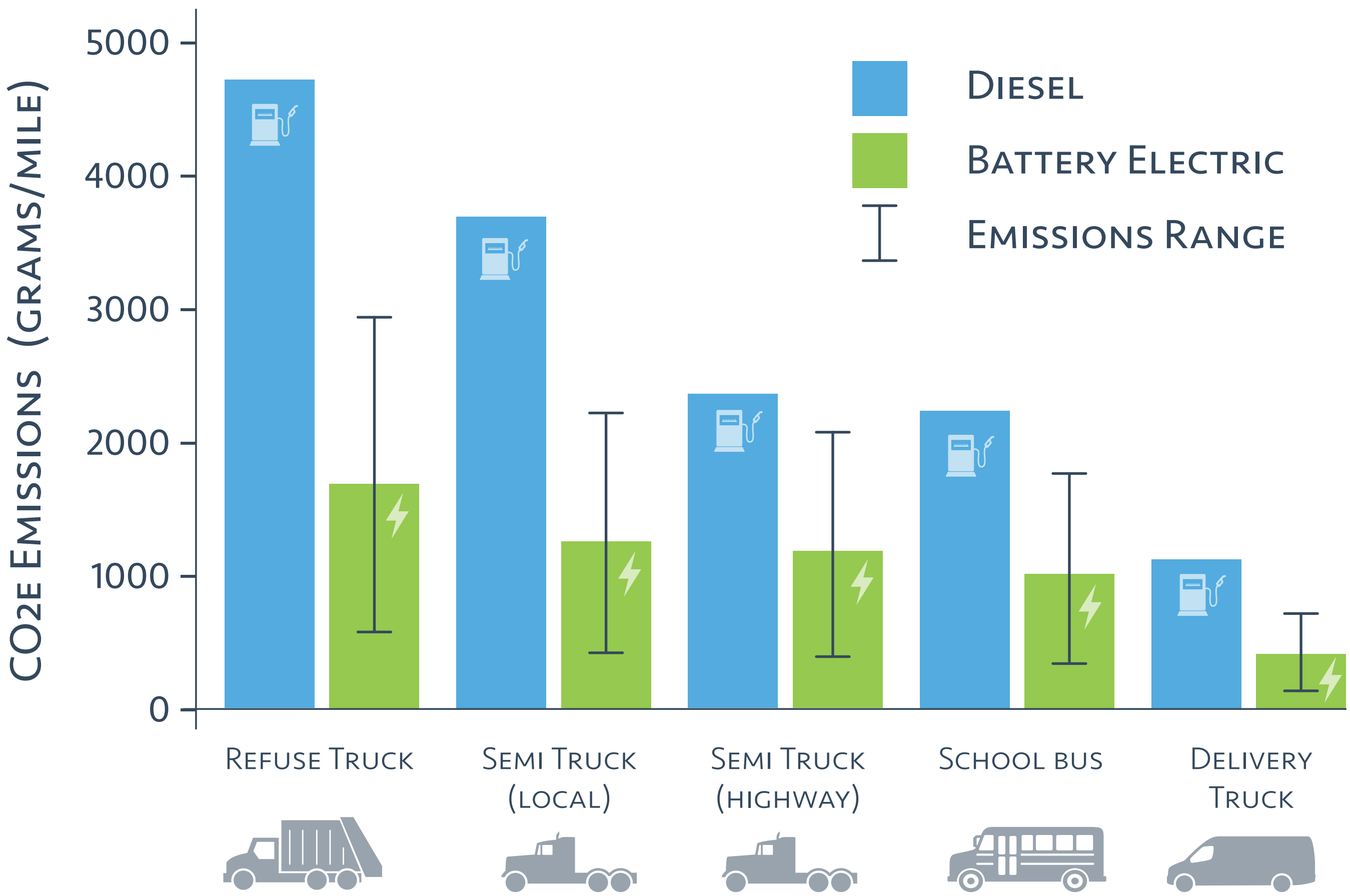


In CA, battery electric buses are about 80% lower than diesel and fuel cell electric buses are 60% lower than diesel.

SOURCE: ucsusa.org/ElectricTrucks

Global Warming Emissions: Other Vehicles, Diesel vs. Electric

Shown in the chart below are life cycle emissions from diesel and electric versions of five common heavy-duty vehicles.



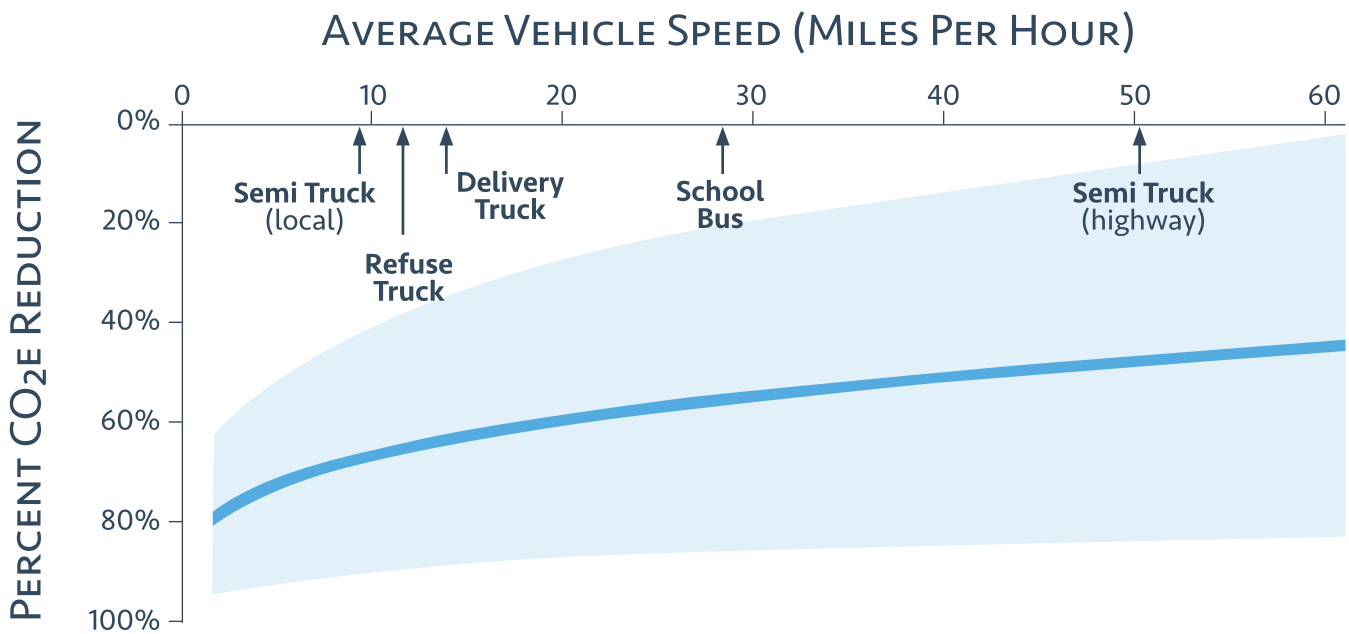
The emissions range is based on the range of various US power grids (some are cleaner, and some are dirtier). No matter the grid that you charge on, you will have much lower emissions with battery electric trucks and buses than diesel.

A semi truck on the highway has less emissions per mile than a semi truck traveling locally because the different fuel economy for these operating scenarios. The starting, stopping, and accelerating nature of local operation take more fuel, and that is the reason emissions are greater.

SOURCE: ucsusa.org/resources/ready-work

Emission Reductions & Average Vehicle Speed

The speed of a vehicle affects the amount of emissions. This chart shows the percent lower that an electric truck's will be compared to a diesel truck based on the vehicle speed.



The light blue band represents emissions reductions from the US electricity grid as a whole, from the most carbon-intensive (top edge) to the least carbon-intensive (bottom edge).

The blue line shows emissions reductions of an electric vehicle on the average grid in the United States.

Arrows show representative average speeds for different types of heavy-duty vehicles.

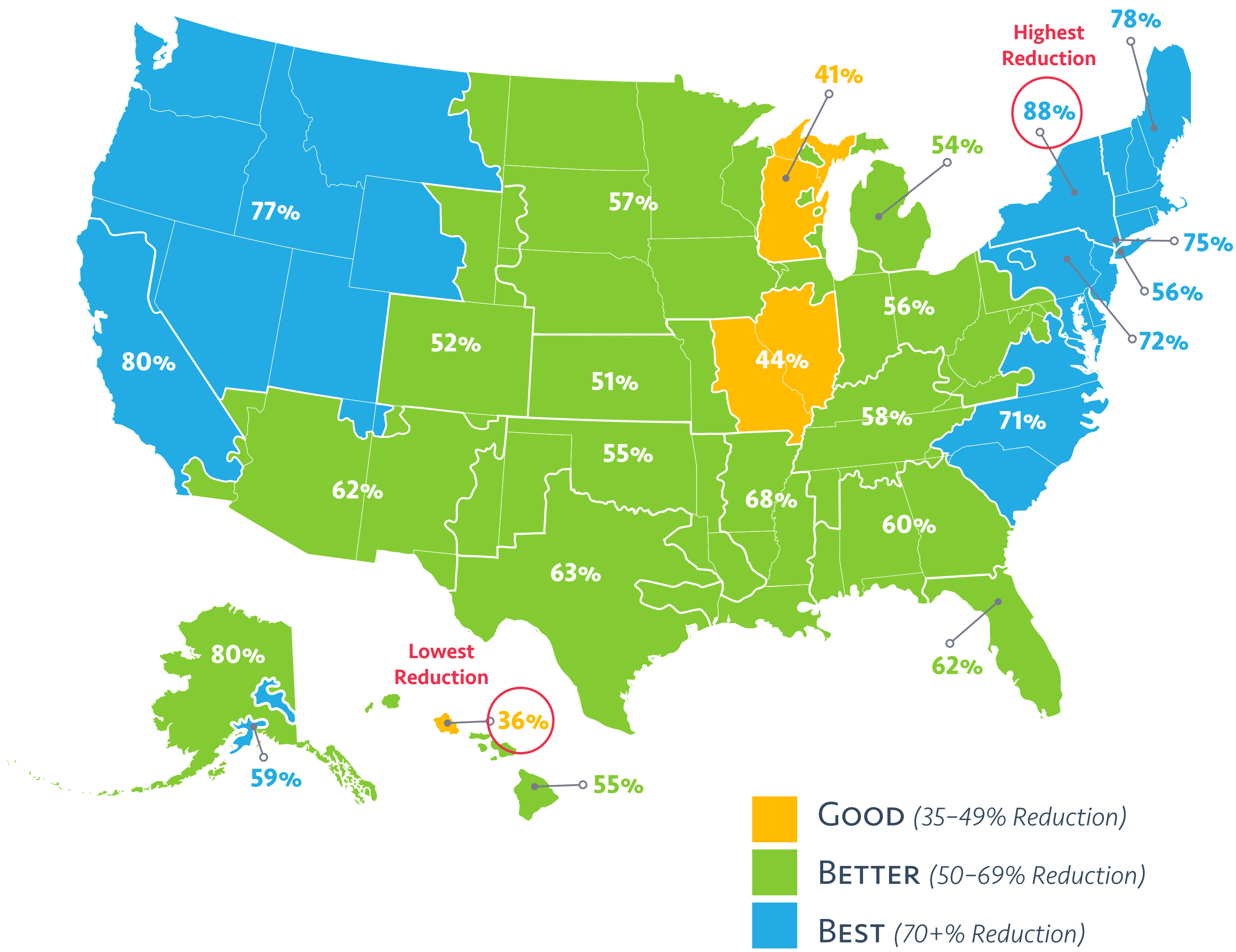
SOURCE: ucsusa.org/resources/ready-work

A Look at US Electric Grids: Where Are the Cleanest/Dirtiest Grids?

This map shows how much better an electric delivery truck is compared to diesel in all these different grids in the US. Dirtiest is Hawaii: 36% better. Cleanist is New York: 88% better.

DELIVERY TRUCK

Percent Lower Global Warming Emissions: Battery Electric vs. Diesel Delivery Truck



SOURCE: ucsusa.org/resources/ready-work

How Clean Is Your Electric Vehicle?

Curious about the climate impacts of an electric car charged in your grid region? Use this handy EV calculator tool on the Union of Concerned Scientists website to see how the grid in your area affects your car's life cycle emissions.

USE THE EV TOOL

UCS Electric (EV) Vehicle Tool

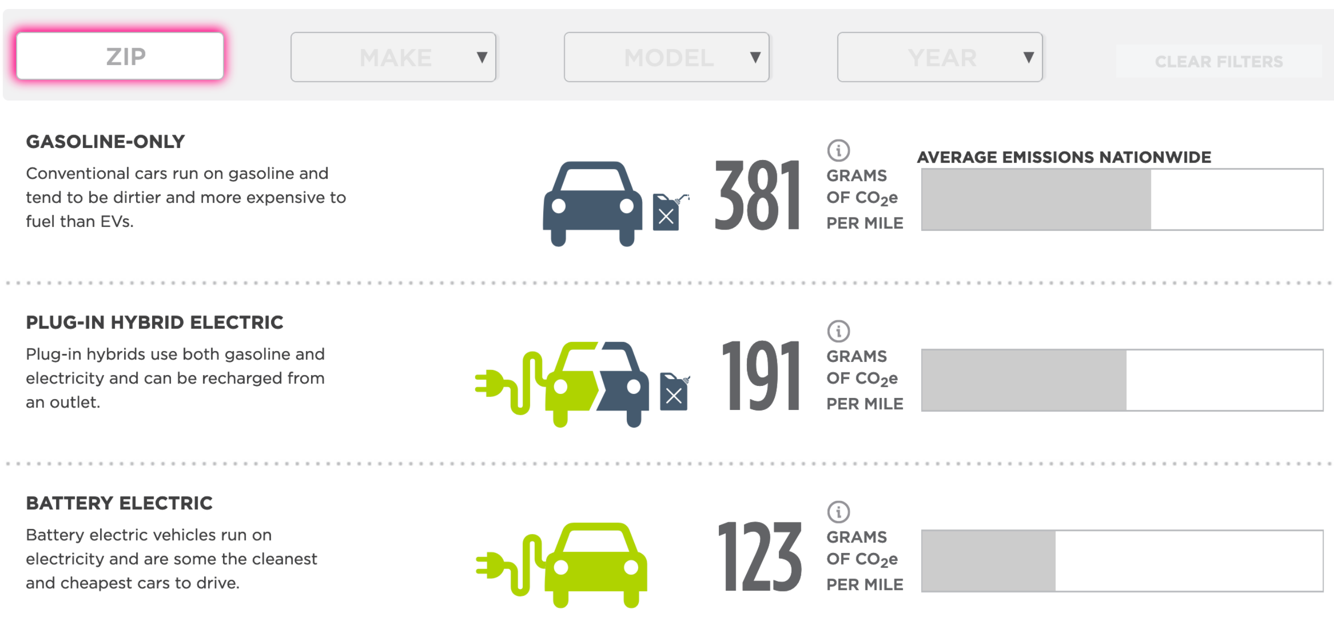
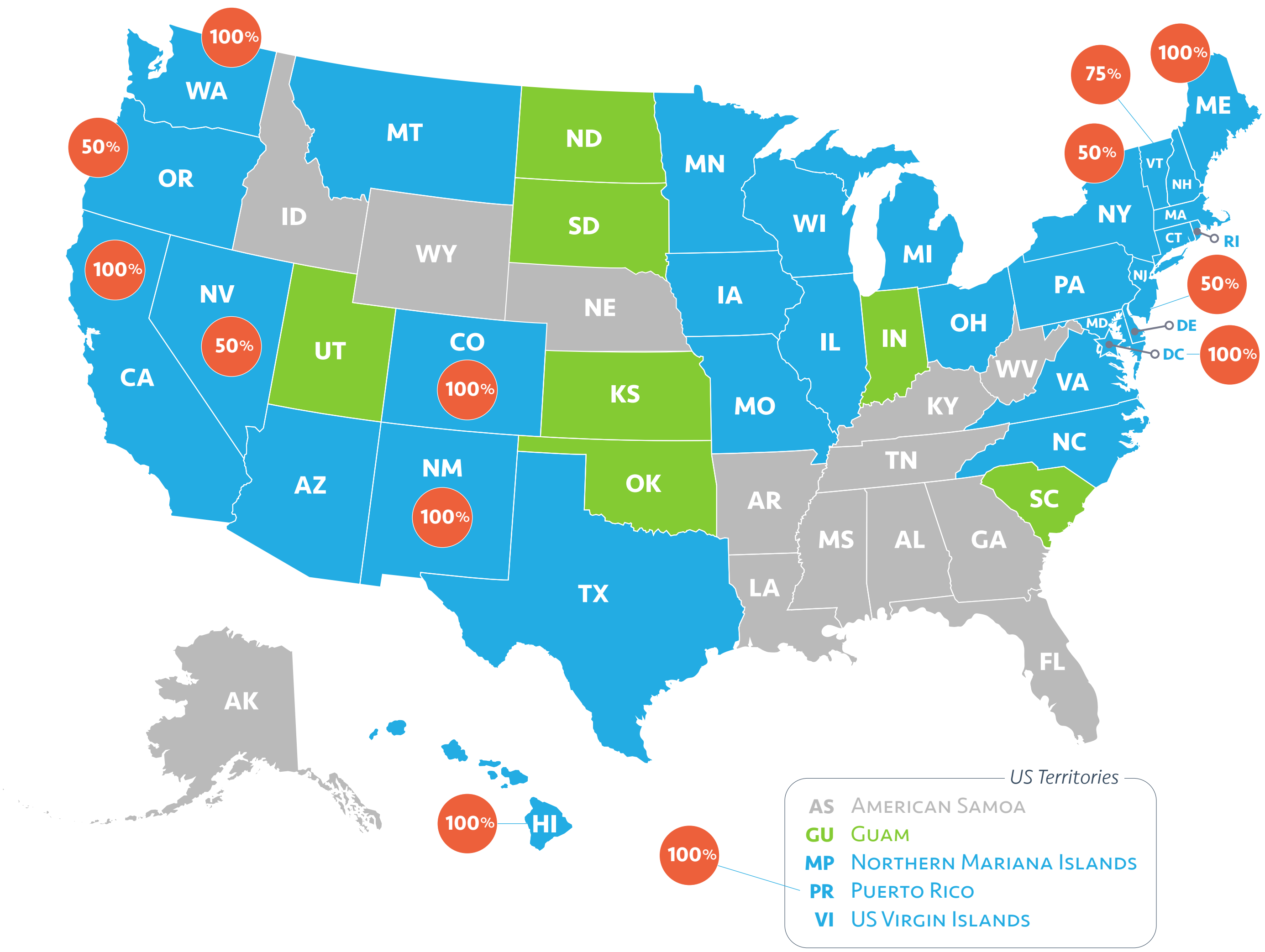


Image above is a graphic of how the EV Tool looks.
To enter data and use the tool, visit: evtool.ucsusa.org

SOURCE: evtool.ucsusa.org

The Grid Is Getting Cleaner

STATES WITH AGGRESSIVE RENEWABLE PORTFOLIO STANDARDS



States and territories with Renewable Portfolio Standards

States and territories with a voluntary renewable energy standard or target

States and territories with no standard or target

The grid is getting cleaner! 14 states—California, Colorado, Hawaii, Maine, Maryland, Massachusetts, Nevada, New Mexico, New Jersey, New York, Oregon, Vermont, Virginia, Washington, as well as Washington, DC, Puerto Rico and the Virgin Islands—have requirements of 50% or greater.

VIEW INTERACTIVE MAP

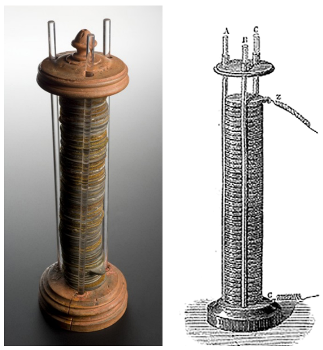
SOURCE: ncsl.org/research/energy/renewable-portfolio-standards.aspx

Early Technology: Invention & Innovation

Batteries and fuel cells have been around a long time...

Battery

Invented in 1800
by Alessandro Volta



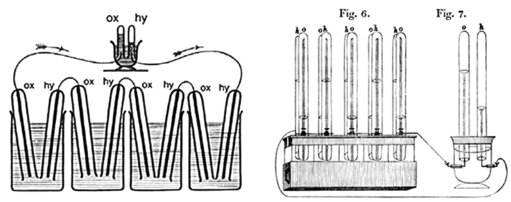
First battery, 1800

Volta invented the first constant-current battery, with moistened pieces of felt between alternating discs of nickel and zinc.

He used copper in later designs, which he found delivered a stronger electrical flow.

Fuel Cell

Invented in 1839
by William Grove

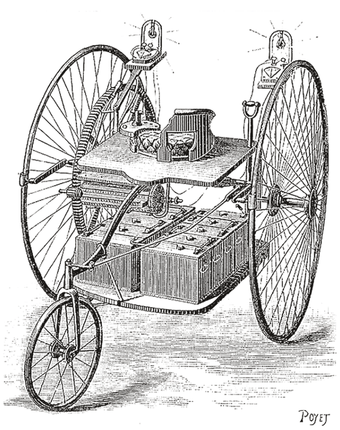


First hydrogen fuel cells, 1839

Grove discovered that four large cells, each containing hydrogen and oxygen, could produce electric power. In his experiments, Grove used the power to split water into different cells.

Battery Electric Vehicles Came First

1880



First Electric Vehicle
25 mile range, 9 mph

1884

First Production Electric Vehicle
50 mile range, 14 mph

1885

First Combustion Vehicle
66 mile range, 10 mph

Photos:https://collection.sciencemuseumgroup.org.uk/objects/co143044/galvanis-voltaic-pile-voltaic-pile
https://de.wikipedia.org/wiki/Datei:Elektrisches_Tricycle.jpg
https://cleantechnica.com/2015/04/26/electric-car-history/
https://upload.wikimedia.org/wikipedia/commons/7/71/1885Benz.jpg

Electric Cars Did Well Early On

1900
Of the 4,192 cars produced in the US, 28% are electric.

1908
Ford introduces the mass-produced, gasoline-powered Model T.

1912
Electric automobile starter invented, i.e., no more hand crank starter.

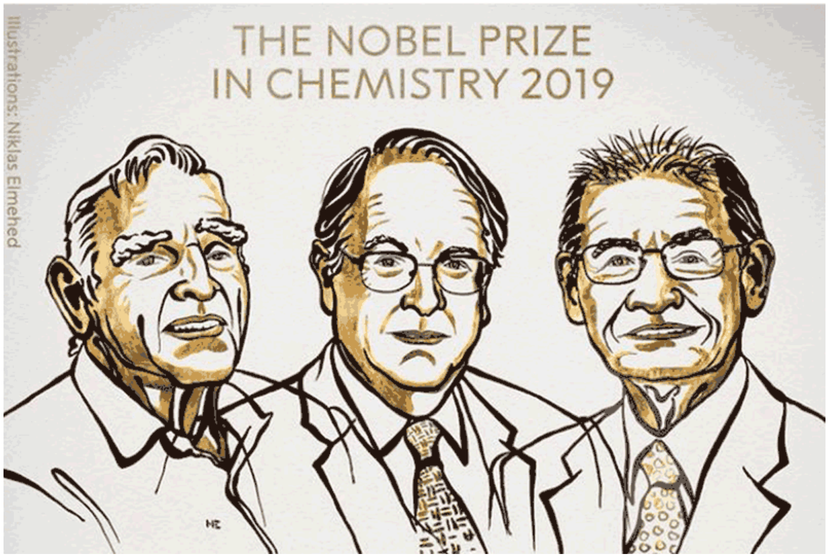
1920s
Electric automobiles no longer competitive.

1966
Bills recommend electric vehicles to reduce air pollution. Poll indicates that 33 million Americans are interested in electric vehicles.

1967
Pictured Above:
"Here Comes the Volts-Wagon" The LA Department of Water & Power introduced an electric-powered truck in 1967 in hopes of reducing smog. Lead-acid batteries ran the vehicle at 25 mph for about 40 to 60 miles. Recharging took 12 hours.

Photo: Los Angeles Times Photographic Archive/UCLA Library

Improvements in Battery Chemistry Have Been Key to Advancing the Technology



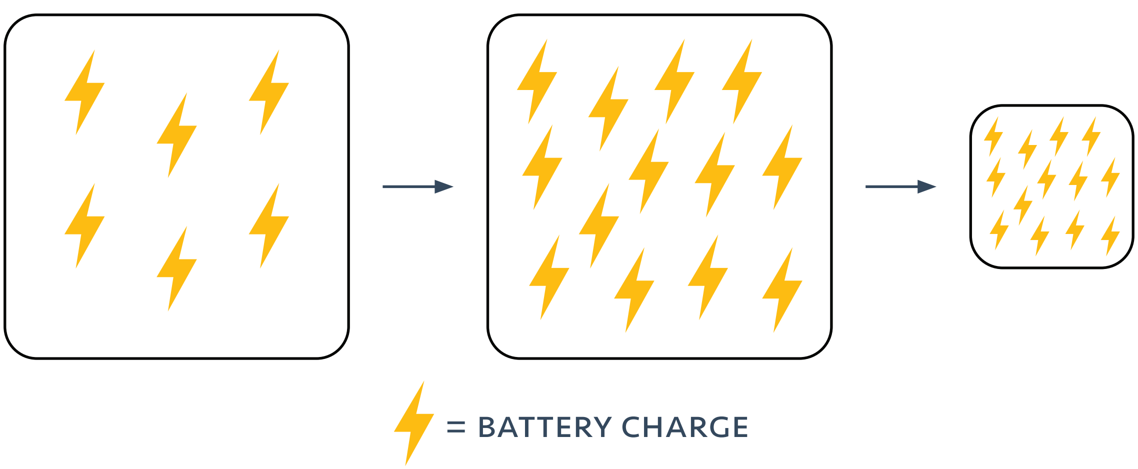
1970s
DISCOVERY

1980s
REFINEMENT

1990s
COMMERCIALIZATION

John Goodenough, M. Stanley Whittingham, and Akira Yoshino received the 2019 Nobel Prize in Chemistry for for the development of lithium-ion batteries.

How to Make a Better Battery



Scientists have worked to find a way to store more energy in a smaller space that weighs less, while keeping costs low and durability high.

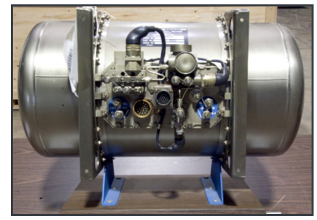
Advances in Fuel Cell Technology

Gemini 6 Spacecraft 1965

Kenworth T680 fuel cell truck, 200-mile range, 2019

A Fuel Cell Bus in the Bay Area, 2020

Fuel cells were first used to power electronics onboard spacecrafts in the 1960s. Now we are starting to see fuel cells being used in heavy-duty vehicles like semis and buses. There are about 70 fuel cell buses operating across the country today.



Spacecraft Motor

Compared to batteries, the major drawback to fuel cell-powered vehicles is cost. For a long time, fuel cells had the advantage of a greater travel range, but now battery technology has closed the gap.

The one big advantage remaining for fuel cells is fast refueling times. A fuel cell-powered bus can be refueled in 10-15 minutes, whereas a battery-powered bus of the same size would take 2+ hours, depending on the charging speed.

An underlying contributor to the progress we are seeing in zero-emissions heavy-duty vehicles has been advances in zero-emissions light-duty vehicles.

SOURCE: Spacecraft Photos: NASA, National Air and Space Museum

Industry Can Impede Progress

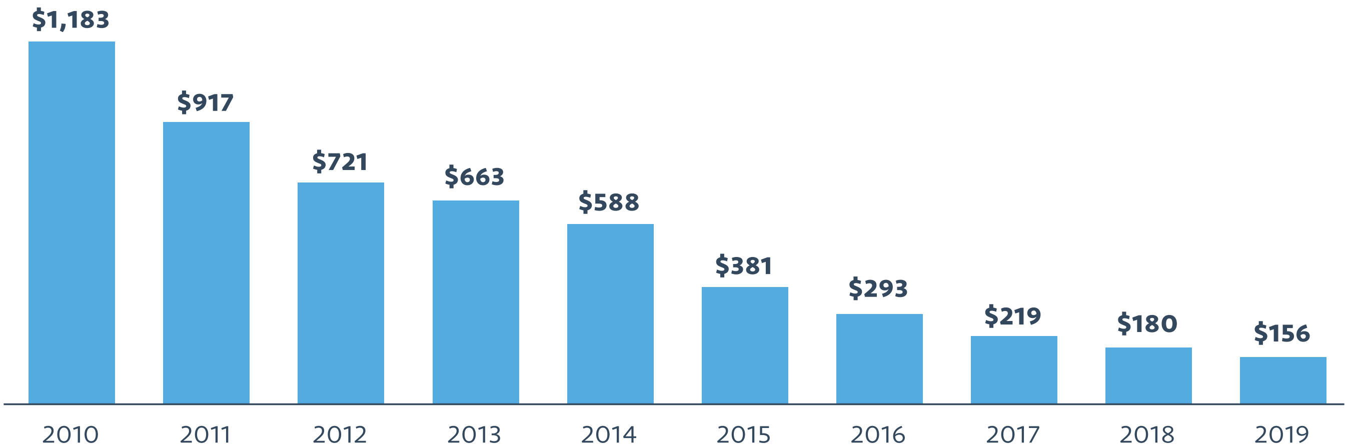
The General Motors EV1

Conversely, industry has done its best to slow down and impede progress of their own technologies. Above is the EV1 electric car produced by GM in the 1990s, which was the subject of the film *Who Killed the Electric Car?* GM took back all the EV1 cars it had leased and destroyed them all, against the wishes of their drivers, who were fond of the car.

Junkyard Filled with Demolished Ev1 Cars

Why Are We Seeing More Electric Vehicles?

Volume-Weighted Lithium-Ion Battery Pack Prices Have Fallen **87% Over the Last 10 Years**



SOURCE: "Electric Vehicle Outlook 2020" BloombergNEF

Every Doubling of EV Population Equals an **18% Reduction in Battery Price**

A large reason is the declining costs in lithium-ion battery pack prices. The chart above shows the different pack prices over time. In 2010, when electric cars were starting to hit the market, battery packs averaged $1,183 per kilowatt-hour (kWh). In 2019, battery packs averaged $156 per kWh. There has been an 87% drop in about 10 years.

Industry Progress in Price Reduction: Case Study

2011 Nissan Leaf

24 kWh battery
73 mi range
$39,700
(in 2020 dollars)

2020 Tesla Model 3

54 kWh battery
250 mi range
$37,900

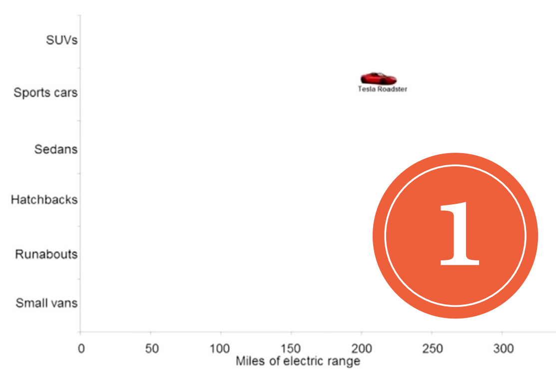
SOURCE: atlasevhub.com/materials/state-ev-sales-and-model-availability/
https://www.kbb.com/nissan/leaf/2011/
https://en.wikipedia.org/wiki/Tesla_Model_3
https://www.tesla.com/model3/design#battery
https://www.bls.gov/data/inflation_calculator.htm

How Many Models of Electric Cars Are Available in the US Today?

Today, depending on what state you live in, 5-17 totally electric light-duty vehicles are available for sale. The numbers of EVs being offered continues to increase globally, although EV sales are still a small portion of the total vehicle sales.

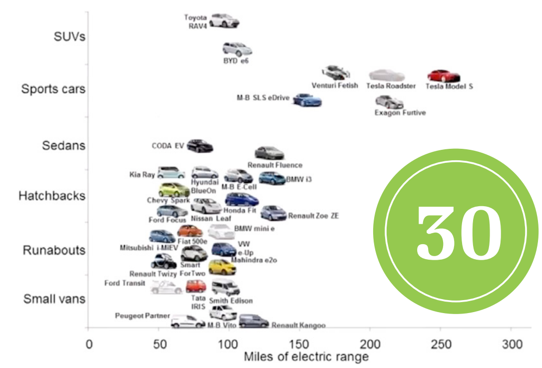
The Worldwide Electric Car Boom

2008



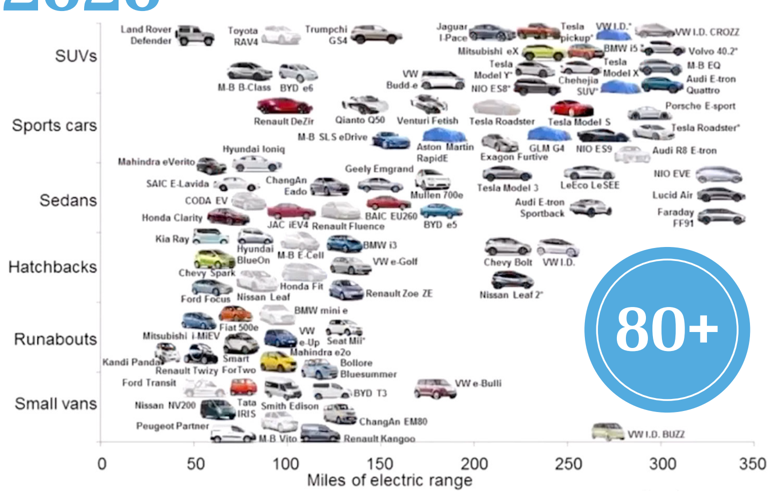
First light-duty passenger model is available, the Tesla Roadster.

2013



Thirty models have been available, with an increase in model variety.

2020



Over eighty models have been available, with an increase in range and model variety.

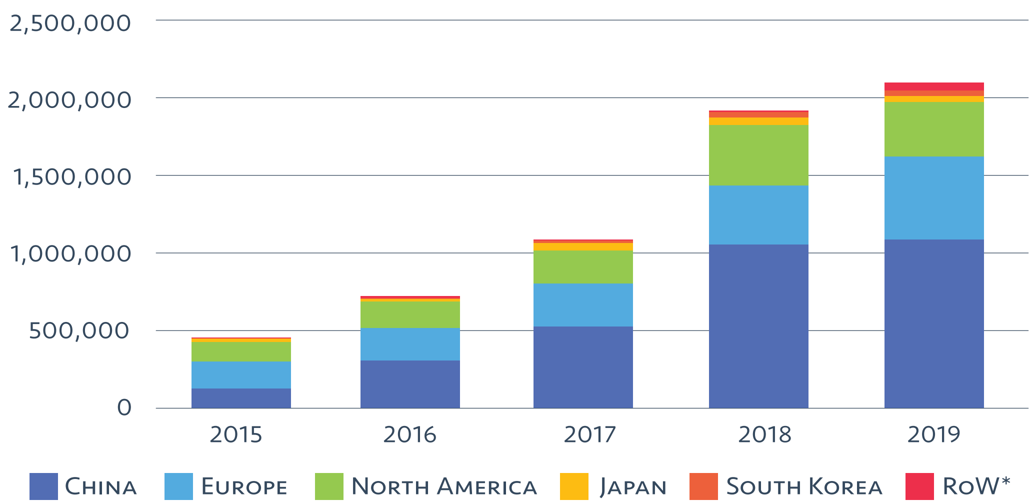
Commercially available light-duty cars by style and range available worlwide 2008 through 2020. These charts are pulled from a movie by Nick Albanese of BloombergNEF.

[See the complete movie repesenting all the years (2008 to 2020) here].

Passenger EV Sales Have Grown Quickly

We are seeing signifcant growth in sales worldwide. In 2015, just under 500,000 electric vehicles were sold. In 2019, there were over 2 million worldwide sales.

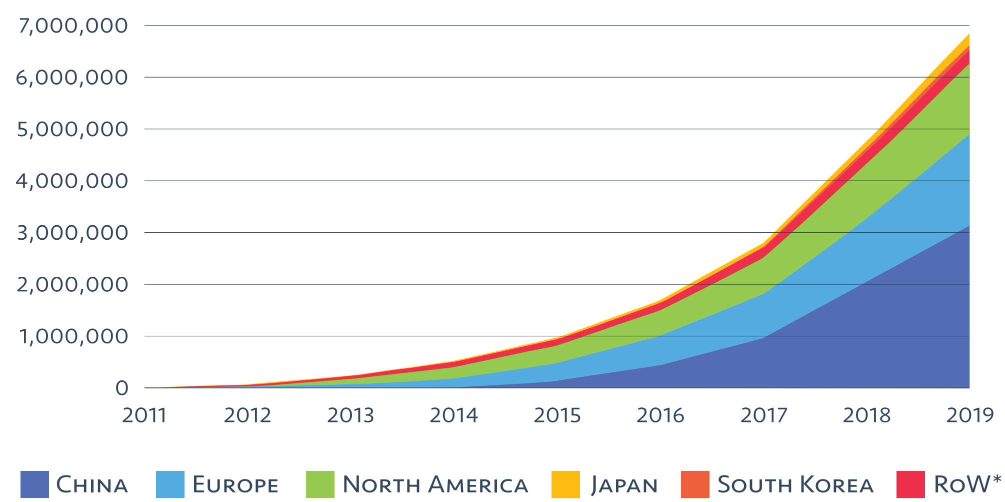
Annual BEV + PHEV Sales by Market



The Global Passenger EV Fleet More Than Doubles in Two Years

In 2015, there were 1 million light-duty electric vehicles on roads worldwide. 2 million was hit after 2016, and 3 million in 2017. There are about 9 million EVs on the road worldwide in 2020.

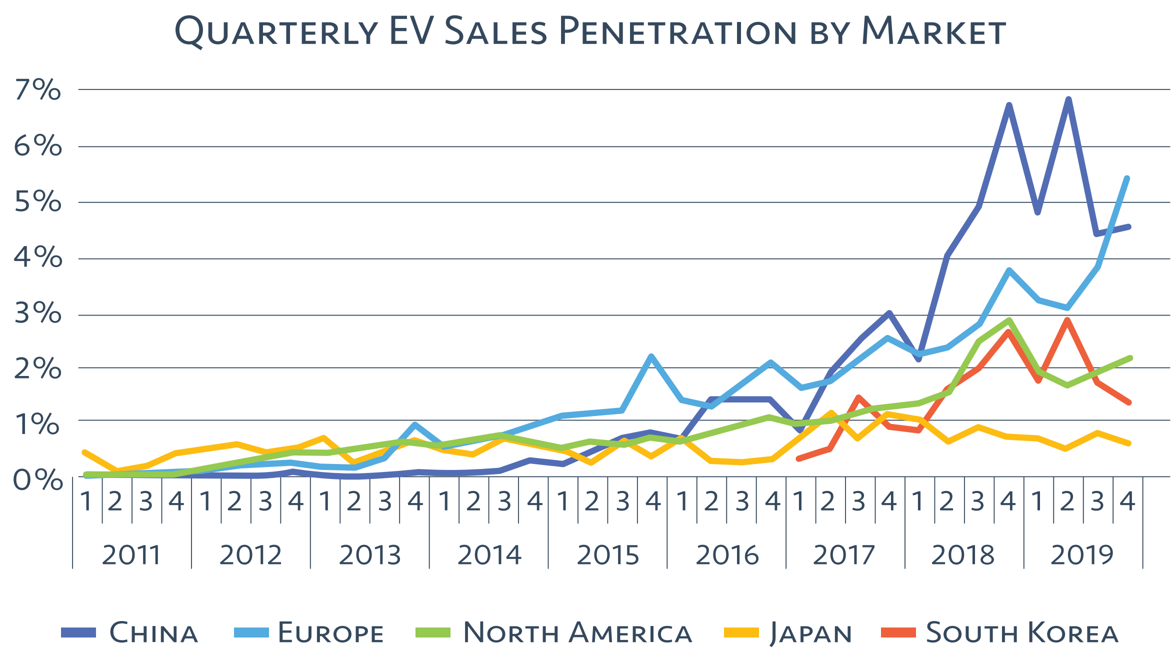
Cumulative BEV + PHEV Sales by Market



SOURCE: "Electric Vehicle Outlook 2020" BloombergNEF
** RoW=Rest-of-the-World*

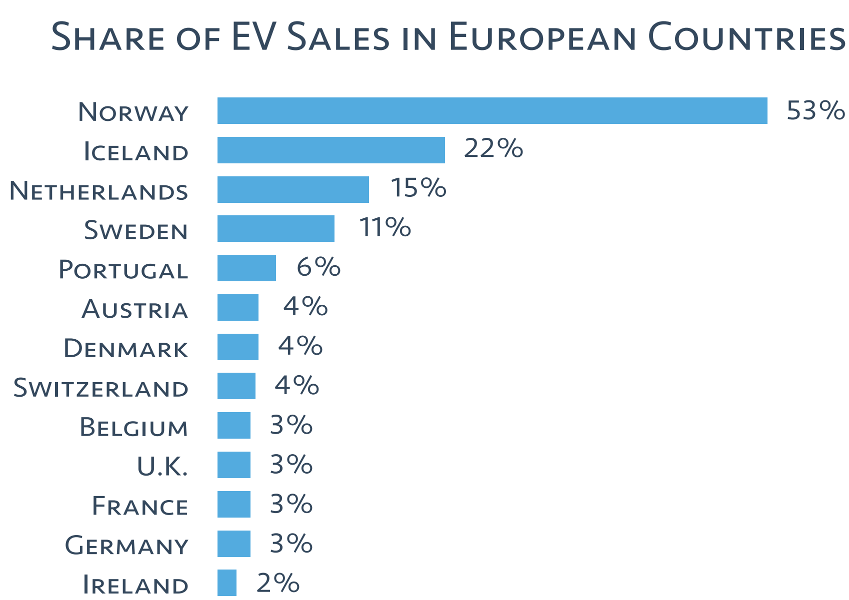
Passenger EVs Are Just 2-5% of Annual Sales in Most Major Auto Markets

This chart shows annual sales of electric passenger vehicles for different regions of the world. China has had the highest sales (7%), which is still relatively low.



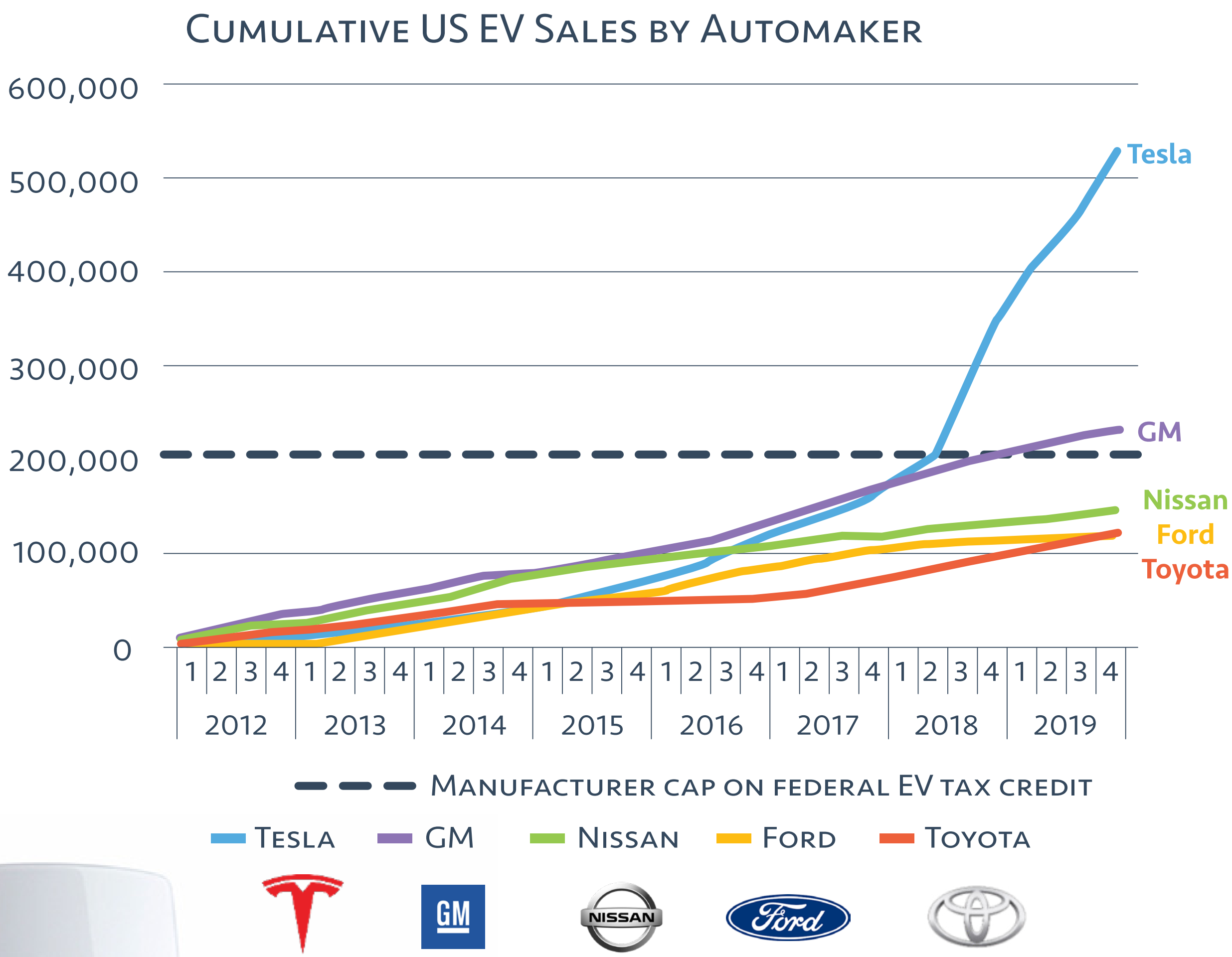
Some Countries Are Further Ahead

Some regions, particularly in Europe, are doing quite well with EV sales. Of Norway's total vehicle sales in 2019, 53% of the sales were EV.



SOURCE: "Electric Vehicle Outlook 2020" BloombergNEF

The Electric Car Market is 1-Sided in the US



Currently Tesla is driving the US market.

A 2018 surge in Tesla purchases was due to the expiration of Tesla vehicles being eligible for a tax credit, leading to record sale of EVs at the end of the year, when EVs made up 10% of all car sales in the 4th quarter of 2018.

We still have lot of work to do to increase the sales market and to diversify the popularity of brands and manufacturers.

How Do EV Car Sales Compare to EV Truck Sales?

In California, a landmark policy was recently passed that required truck manufacturers to sell zero-emissions trucks in California. The required percentage of zero-emissions trucks sold increases each year up to 2035, but tops out at about 60% of sales annually across all types of trucks, indicating plenty of room for additional progress.

The New York Times

New Rule in California Will Require Zero-Emissions Trucks

More than half of trucks sold in the state must be zero-emissions by 2035, and all of them by 2045.

An Amazon warehouse in the Inland Empire of California last year. Philip Cheung for The New York Times

By Hiroko Tabuchi

June 25, 2020

42

Part of the reason for a lower percentage of zero-emissions trucks in the entire population of trucks on the road (see next page) is due to the age of trucks on the road (many trucks are 15 years old or older).

How Will This Policy Change Sales Numbers?

Zero-Emissions Truck Sales % Required by New California Policy

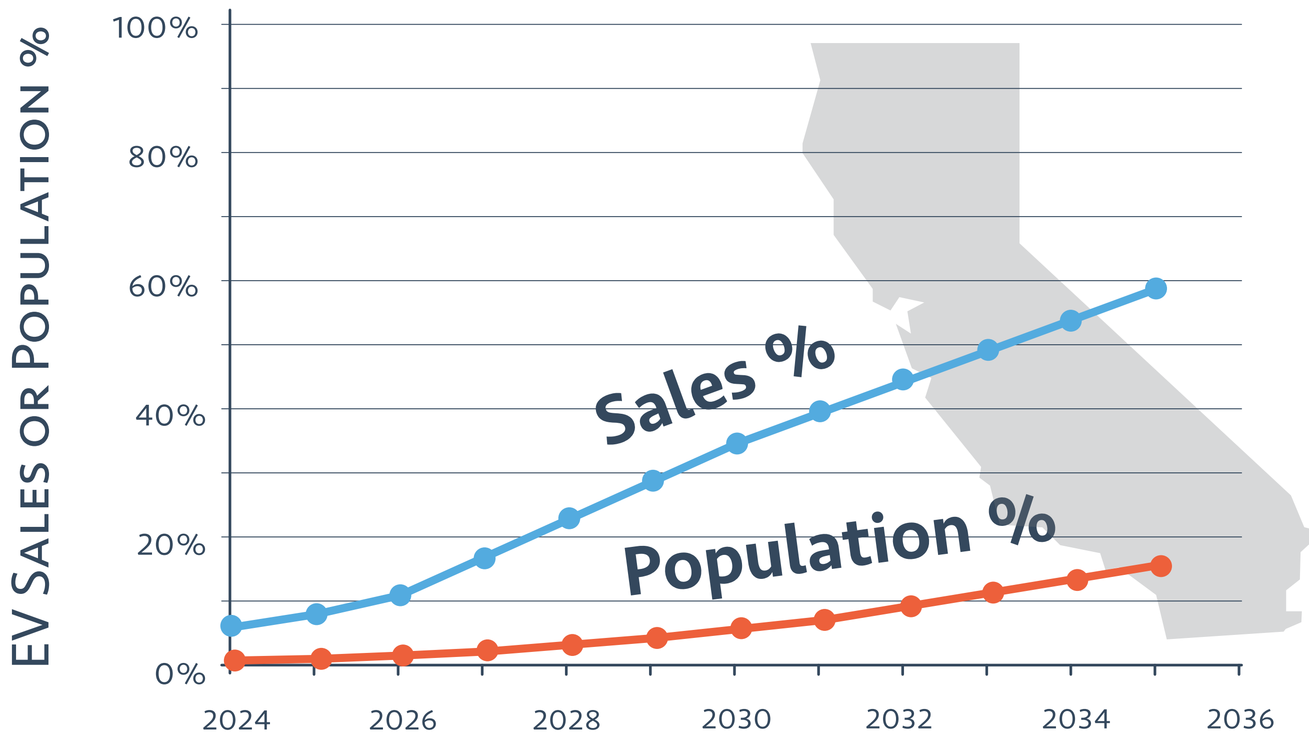
Year	Class 2B-3	Class 4-8 Straight Trucks	Class 7-8 Tractors	Average Sales
2024	5%	9%	5%	6%
2025	7%	11%	7%	8%
2026	10%	13%	10%	11%
2027	15%	20%	15%	16%
2028	20%	30%	20%	22%
2029	25%	40%	25%	28%
2030	30%	50%	30%	34%
2031	35%	55%	35%	39%
2032	40%	60%	40%	44%
2033	45%	65%	40%	49%
2034	50%	70%	40%	54%
2035	55%	75%	40%	58%

Vehicle class is defined by vehicle weight. Class 2B are heavier pickup trucks and smaller delivery vans. Class 4-8 "straight trucks" are heavier delivery trucks. Class 7-8 "tractors" (i.e., semi trucks) are the heaviest category.

SOURCE: https://blog.ucsusa.org/jimmy-odea/the-biggest-step-to-date-on-electric-trucks

How Will the New CA Policy Affect General Truck Population?

Zero-Emissions Truck Sales % and Resulting ZE Truck Population %



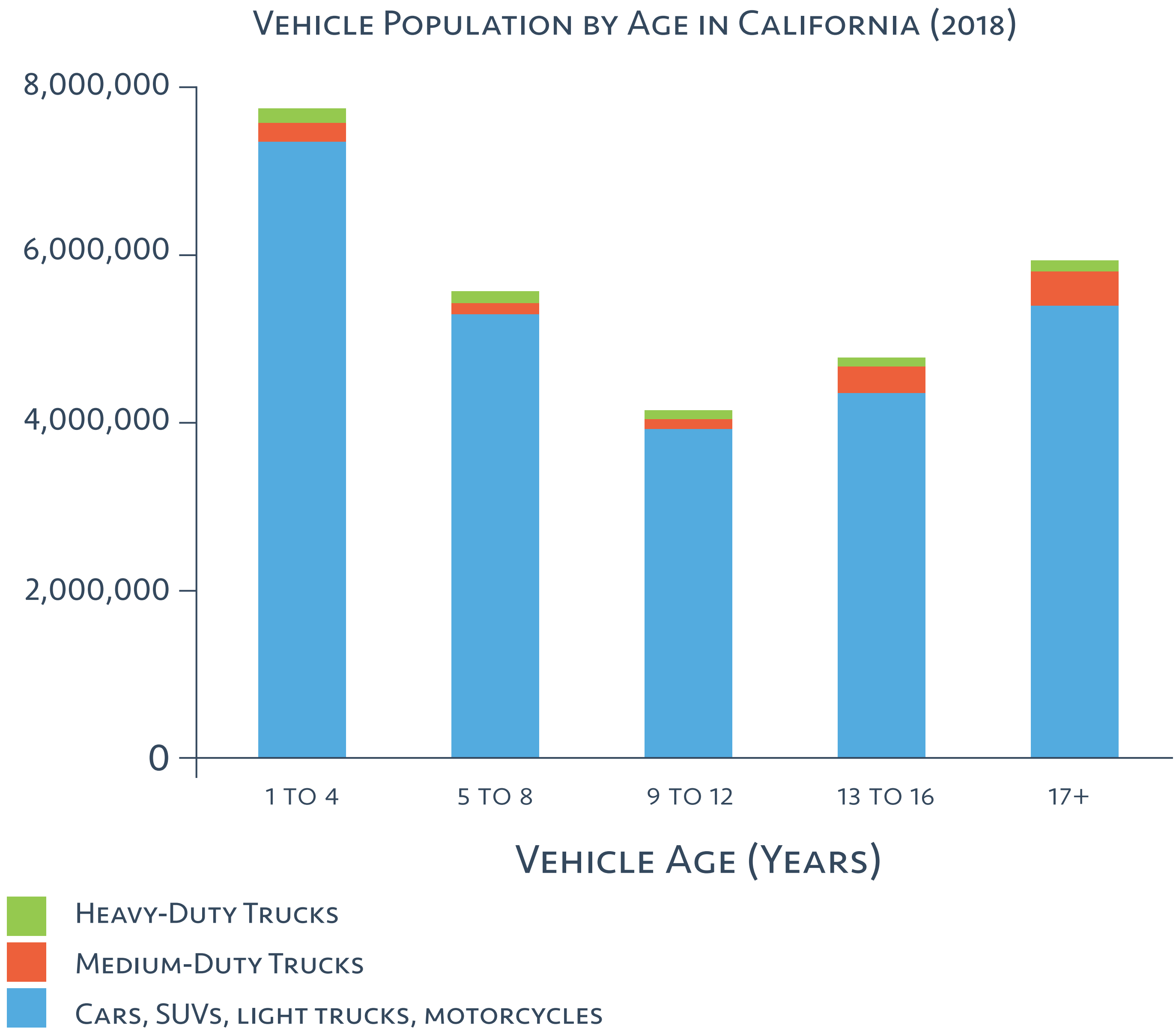
Blue line represents the sales required by new CA policy: 5% by 2024 to 60% by 2035, when averaged across all truck categories.

Red line shows what fraction of the total truck population will be electric trucks, based on those sales, and shows how much work we have left. Even in 2035, only 15% of trucks will be zero-emissions. We still need to address the other 85% and this will take strong policy actions to achieve.

SOURCE: https://blog.ucsusa.org/jimmy-odea/the-biggest-step-to-date-on-electric-trucks

Long Vehicle Life Leads to Slow Turnover to Zero-Emissions

Part of the reason for a lower percentage of zero-emissions trucks in the entire population of trucks on the road is due to the age of trucks on the road (many trucks are 15+ years old)



About 30% of all vehicles are 15 years or older in CA.

Source: UCS analysis of CARB's EMFAC 2017 database

Where Is Truck Technology at Today?

The mileage range for EV trucks and buses continues to improve. The number of zero-emissions trucks and buses on the road today is not huge yet, but models are increasingly available, and the technology works today. We are also seeing a lot of EVs being used at ports.

2012

Progress happens on pilots and demos of electric trucks. Above is a yard hostler carrying containers around at a southern California port in 2012. This was a demo project funded by the state and the local air district.

2013

An early electric delivery truck. 700 trucks were made that big companies like Coca-Cola, Staples, and Frito-Lay were using.

75 MILES

2019

We are starting to see more electric vehicles on the road, particularly buses, both transit and school buses.

328 MILES

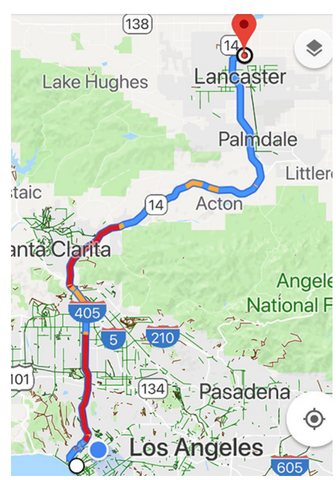
120 MILES

230 MILES

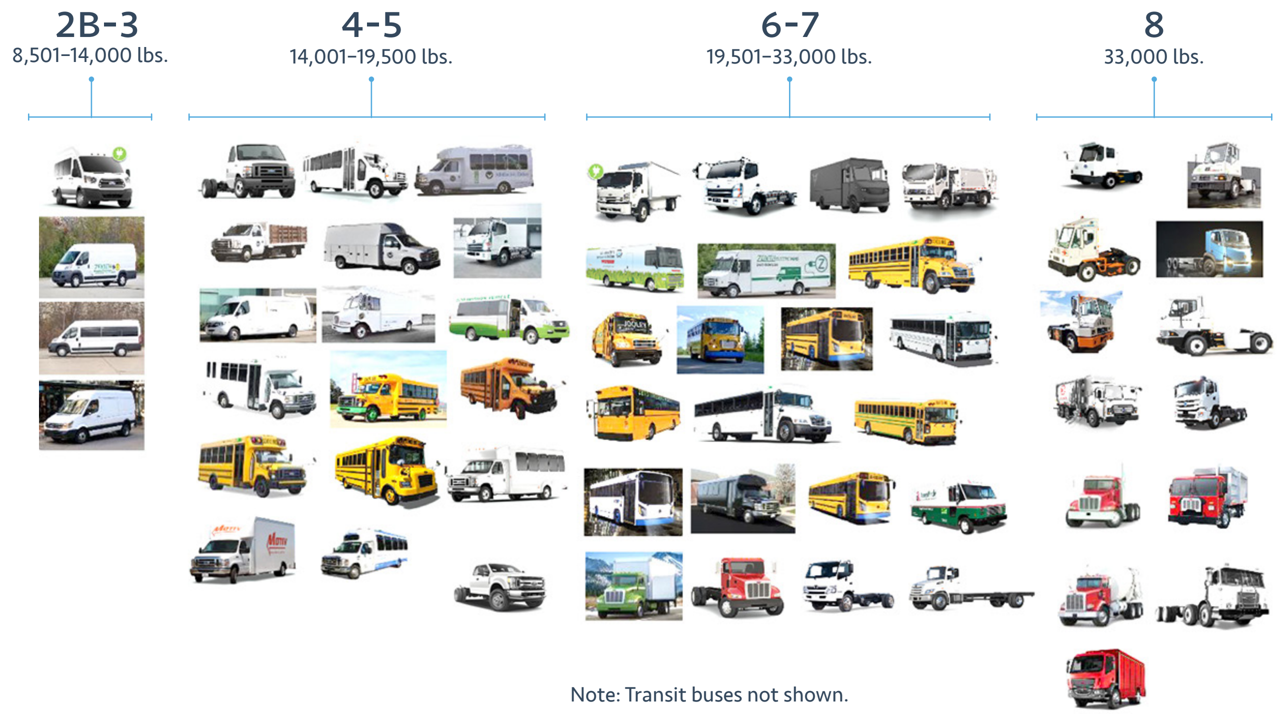
Case study:
LA Transit Bus

BYD

The blue bus above traveled from the beach in Santa Monica to the bus company (BYD) headquarters in Lancaster, 72 miles away. The same bus made this 72 mile trip four times in one day = 288 miles, charging once in between trips.



Commercially Available Zero-Emissions Trucks & Buses



Summary by CARB (California Air Resources Board)

Progress in Delivery Truck Sector

The range of battery electric delivery trucks can meet the needs of most uses today. Most delivery truck are not driving more than 100 miles per day, and many are driving about 50 miles per day. With a 100 mile battery range, you can cover a lot of routes.

124 Miles

120 Miles

90 Miles

150 Miles

CHART SOURCE: carb.ca.gov/sites/default/files/2020-02/200212presentation_ADA_1.pdf

Same Truck, Different Applications

The same vehicle chassis can be used for many different applications. If you can electrify one truck chassis you can actually electrify many more trucks, because they are the same build underneath.

Motiv Truck Chassis, 105 mile range (127 kWh)

Above is an example of a truck chassis by Motiv. This same exact chassis has been used in all 4 of these truck builds:

Box Truck

School Bus

Shuttle Bus

Work Truck

SOURCE: motivps.com/products/epic-e450/

Progress at Ports: EV Yard Hostlers

We are also seeing a lot of EVs being used at ports. There are at least 3 companies making yard hostlers: BYD, Kalamar, and OrangeEV.

The Main Target: Big Trucks

The big goal is to get more semi trucks/long-haul trucks to be zero-emissions vehicles, especially trucks carrying cargo to and from ports and warehouses and through surrounding communities. The good news is that electric technology is here for big trucks.

Start-up Company Makes a Truck with Range of 300 Miles

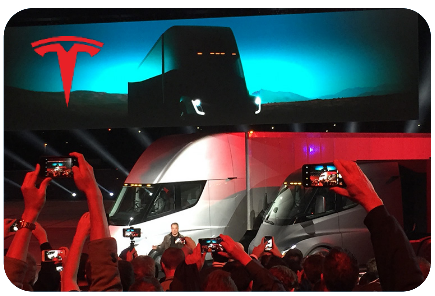
Xos is just a start-up company but they already have an electric truck protype with a 300 mile range. A few years ago that would have been unheard of for not just a small company but any truck company!

A Variety of EV Big Trucks and Ranges

BYD 125 Miles

Volvo 175 Miles

Freightliner 250 Miles


Tesla 500+ Miles


Nikola 500+ Miles


Toyota 300 Miles

Lion 250 Miles

Mitsubishi 220 Miles


Xos 300 Miles

Please note: Ranges represent manufacturer or other industry estimates, but do not necessarily represent testing under the same conditions across manufacturers.

Industry Summary: EV Trucks & Buses

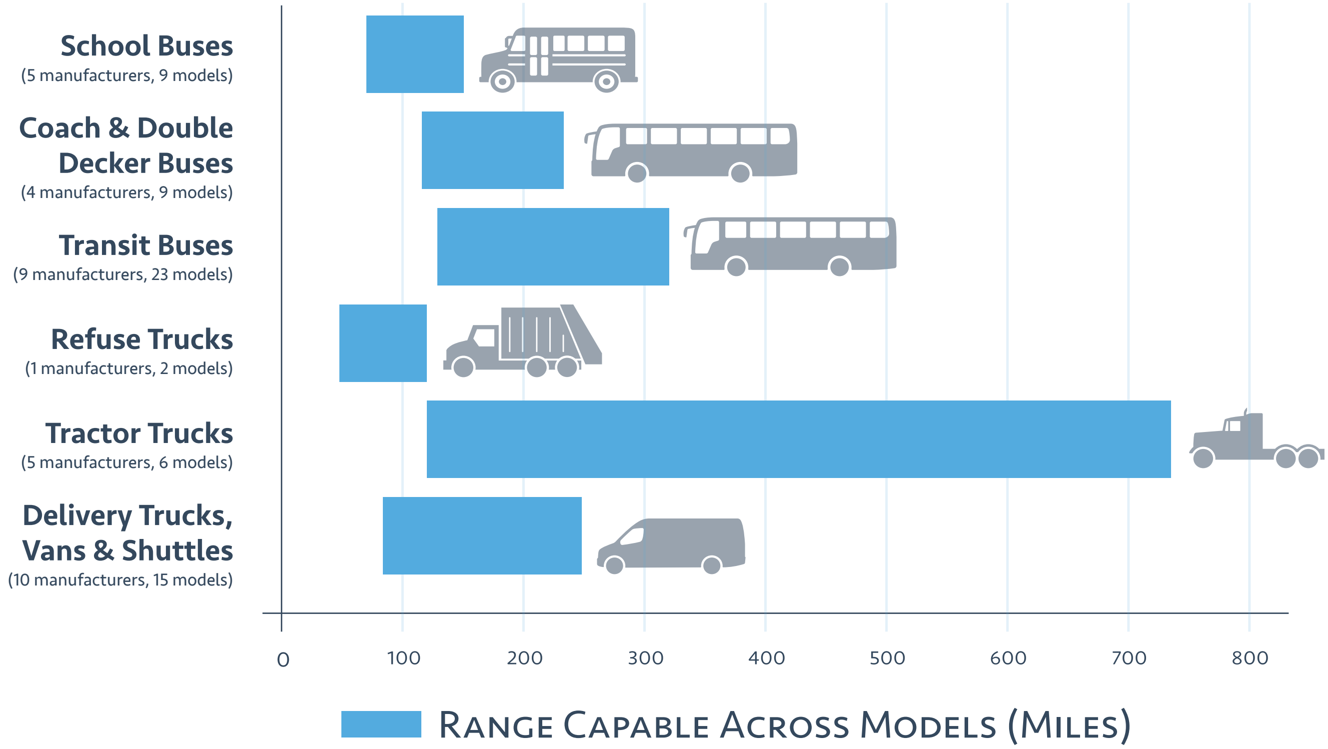


Table Chart of Current EV Trucks & Buses

TABLE 1. **Availability of electric trucks and buses in the United States as of November 2019**

Manufacturer	Model	Range	Battery or H_2 Capacity	Availability
Delivery Vans, Shuttles, and Straight Trucks				
BYD	6F	124 miles	221 kWh	Today
Chanje	V8100	150 miles	100 kWh	Today
Freightliner (Daimler)	eM2	230 miles	325 kWh	Production in 2021
GreenPower	EV Star Cargo	150 miles	118 kWh	Today
International (Navistar)	eMV	250 miles	321 kWh	Production in 2021
Lightning Systems	Ford Transit 350HD Ford E-450 Ford F-59 Chevy 6500XD	120 miles 110 miles 110 miles 130 miles	86 kWh 129 kWh 128 kWh 192 kWh	Today Today Today Today
Lion	Lion8	Unknown	480 kWh	TBD
Mitsubishi Fuso (Daimler)	eCanter	80 miles	83 kWh	Demonstration
Motiv	Ford E-450 Ford F-53 Ford F-59	100 miles 125 miles 90 miles	127 kWh 127 kWh 127 kWh	Today Today Today
Peterbilt (Paccar)	Model 220EV	100 miles	148 kWh	Demonstration
Phoenix Motor Cars	Ford E-450	100 miles	105 kWh	Today
Rivian	Unknown	Unknown	Unknown	Deployment in 2021
Workhorse	C1000	125 miles	70 kWh	TBD
Xos	Medium Duty	200 miles	Unknown	Today
Tractor Trucks				
BYD	8TT	125 miles	409 kWh	Today
Freightliner (Daimler)	eCascadia	250 miles	550 kWh	Production in 2021
Nikola	Nikola One (sleeper) Nikola Two (day)	750 miles 400 miles	80 kg H_2 1,000 kWh	Production in 2022 Production in 2022
Peterbilt (Paccar)	Model 579	250 miles	352 kWh	Demonstration
Tesla	Semi	500 miles	Unknown	Production in 2020
Toyota/Kenworth (Paccar)	T680	300 miles	60 kg H_2	Demonstration
Volvo Group	VNR	Unknown	Unknown	Production in 2020
Xos	ET One	300 miles	Unknown	Demonstration

[Download the "Availability of Electric Trucks and Buses in the United States as of November 2019"]

Document includes category, manufacturer, model, range, battery or H_2 capacity, & availability.

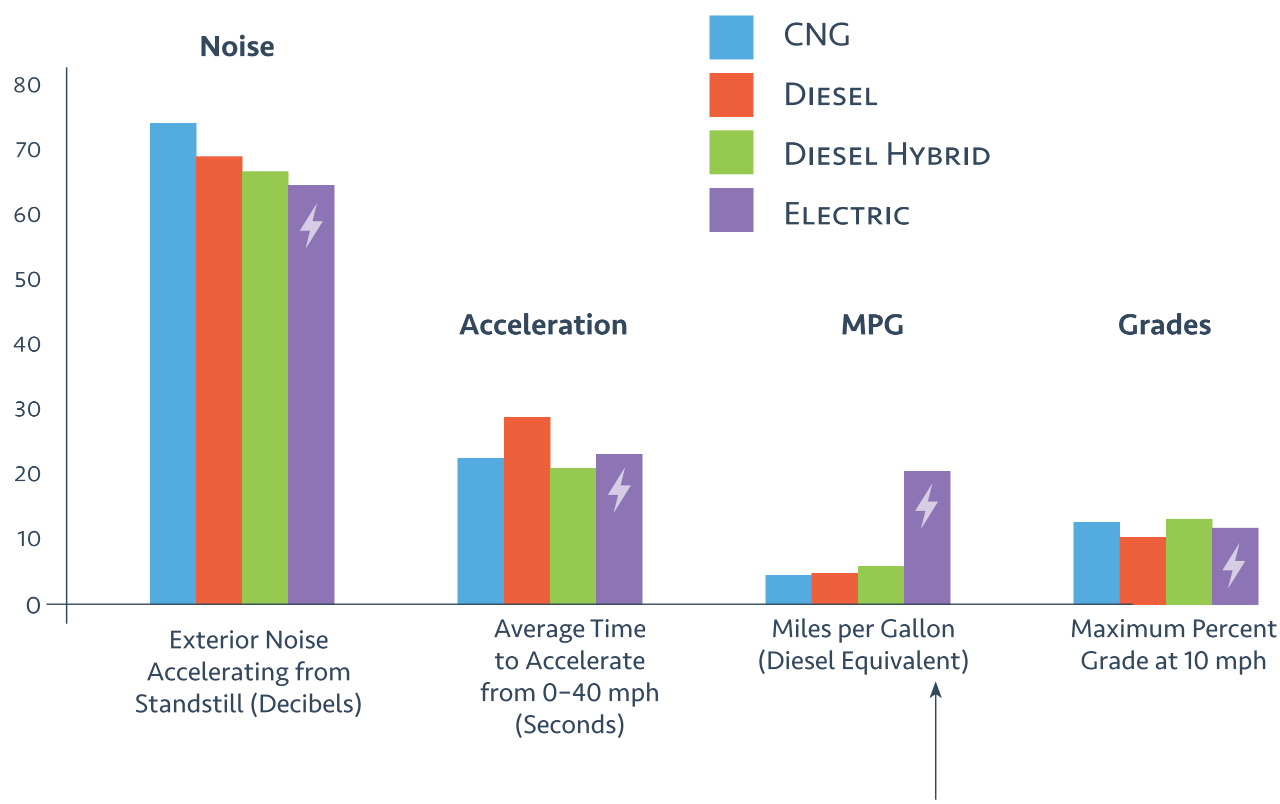
DOWNLOAD PDF

Please note: Models and manufacturers are changing constantly with improvements in technology or changes in product offerings. This report reflects the industry in fall of 2019.

How Well Do Electric Trucks & Buses Perform?

Electric trucks and buses have similar, if not better performance as other trucks and buses. They are significantly quieter, have significantly higher fuel efficiency, and have little to no losses in acceleration times or hill-climbing abilities. With fewer moving parts, no oil to change, and lower maintenance costs, electric vehicles have the potential for much greater "up time" than their diesel counterparts.

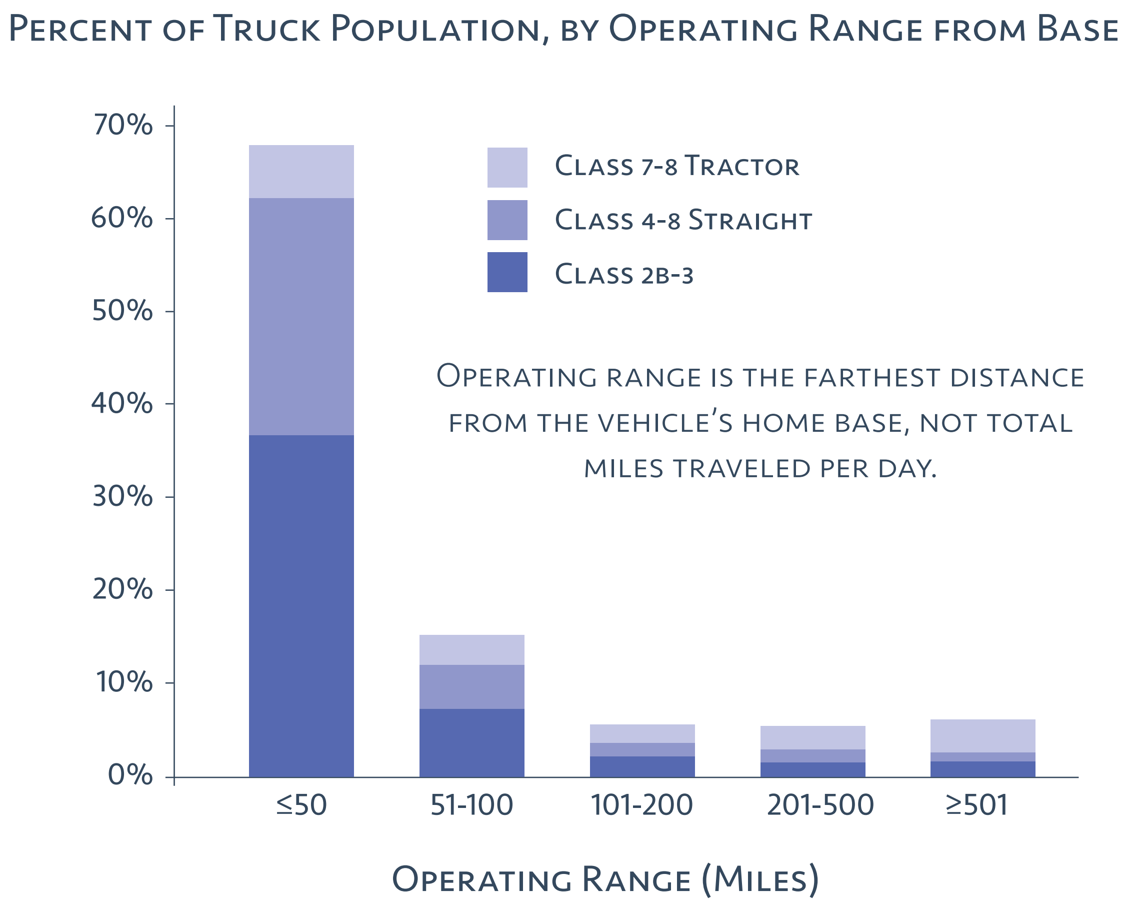
Transit Bus Comparison:
Noise, Acceleration, Fuel Efficency, Hill Climbing



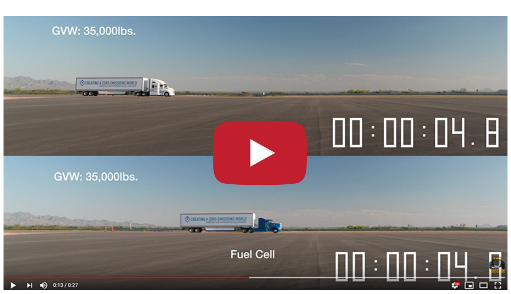
An Electric Truck or Bus is 4-5x More Fuel Efficient than One Fueled by Diesel or Natural Gas

Do Electric Trucks Have Enough Range?

More than 80 percent of all heavy-duty trucks have a primary operating range of less than 100 miles; nearly 70 percent have an operating range of less than 50 miles.

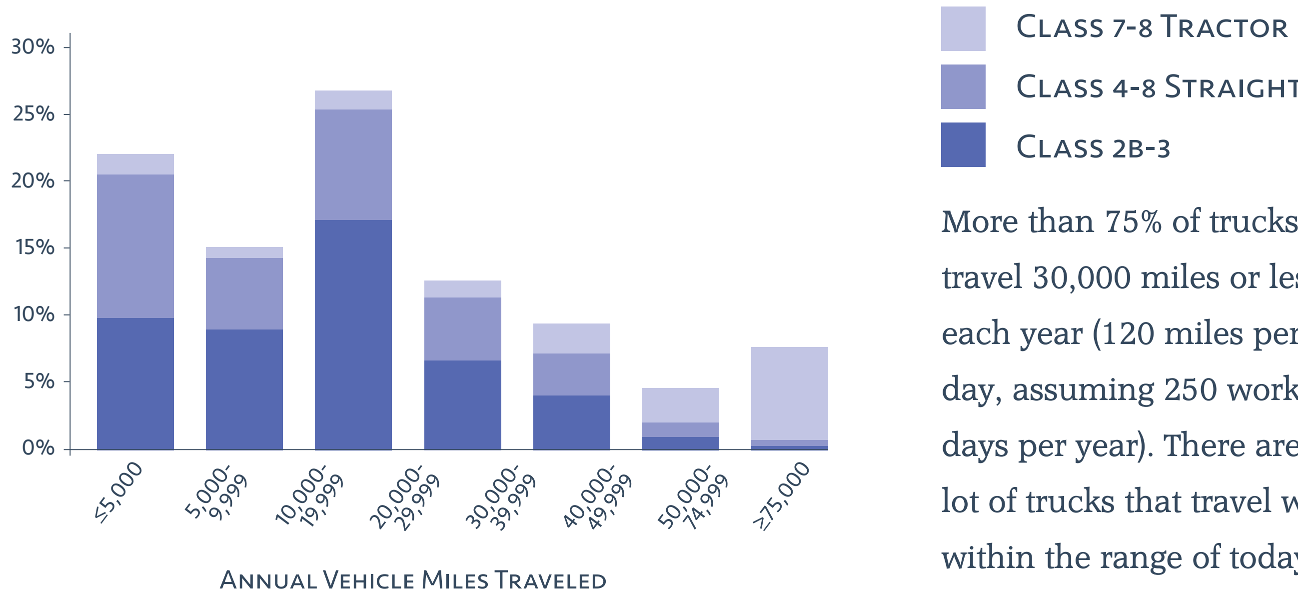


Truck Acceleration Test: Hydrogen vs. Diesel



Watch a video: "Toyota Portal Project Concept Hydrogen Truck vs. Diesel Truck" to see how a diesel truck and a fuel cell truck compare.

How Far Do Most Trucks Travel?

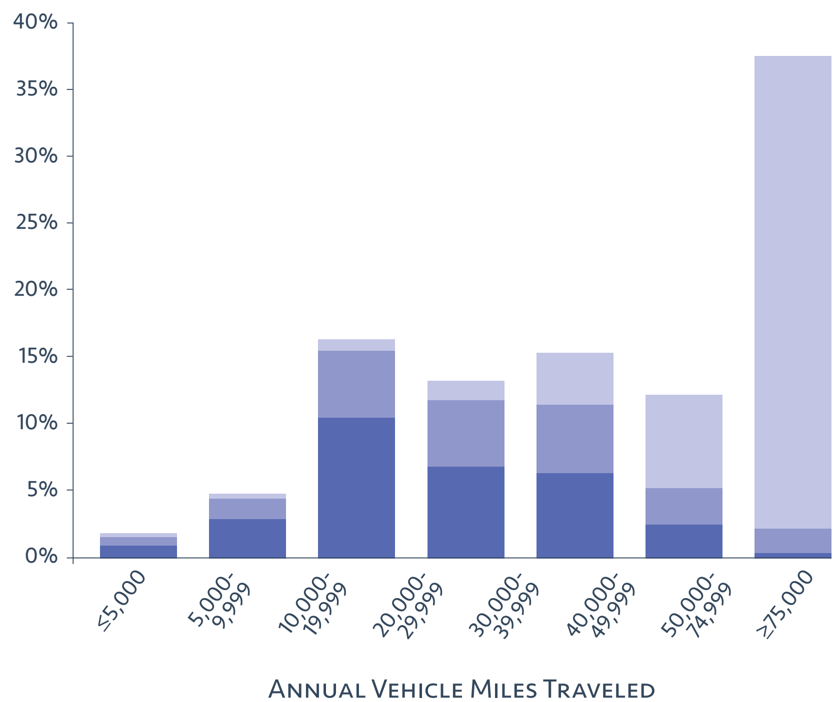


More than 75% of trucks travel 30,000 miles or less each year (120 miles per day, assuming 250 work days per year). There are a lot of trucks that travel well within the range of today's electric vehicles.

A Small Amount of Trucks Clock Most Mileage

A small number of trucks contribute a large fraction of miles traveled by all trucks. These are the long-haul semi trucks.

Trucks with annual mileages greater than 50,000 miles (200 miles per day) make up 50% of the total miles traveled by trucks.



Key Point: A lot of trucks don't travel that far each day, but a small number of trucks drive a lot.

How Are Companies Investing in Electric?

In September 2020, the global electric fleet of electric cars surpassed 9 million vehicles. In September 2015, the global electric fleet consisted of only 900,000, so much of the increase has been in the past 5 years.

Highlighting Big Fleets: Recent Announcements

- Uber and Lyft announce plans to electrify all rides in the US by 2030. *(2020)*
- California announced all drayage and last-mile delivery trucks must be zero-emissions by 2035. (2020)
- Walmart commits to a 100% zero-emission truck fleet by 2040. (2020)
- UPS orders 10,000 electric delivery vans from Arrival. *(2020)*
- Amazon announced that it will order 100,000 electric delivery vans from start-up Rivian by 2030. *(2020)*

While electrification targets are important, these announcements do not negate changes companies need to make around fair treatment and pay of workers and other commitments to justice and sustainability.

Caution: Announcements Can Be Misleading

Concept Car in 2011

Still a Concept Car in 2020

A corporate announcement is only as good as the action behind it. For example, Volkswagen has claimed since 2011 that they would release an electric bus. The latest annoucement is that the vehicle will be available in 2022. Companies will make announcements for good press, but sometimes they do not take as much action as promised.

Will Electric Trucks Work for Every Application?

When you advocate and talk about electric trucks, inevitably, at least one person will challenge you with the claim that they are not ready for every application today. There is some truth to this and one classic example is a snow plow.

A large vehicle, like a snow plow might take 3 hours or more to charge, which might not be fast enough due to the need. Snow plows and emergency vehicles are good candidates for the fuel cell electric option, because they refuel quickly. Hydrogen fuel cells take about 10 minutes to refuel.

When They Go Snow, We Go High

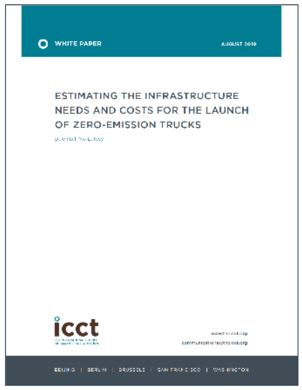
30 MINUTE FLIGHT
BY A BATTERY ELECTRIC PLANE

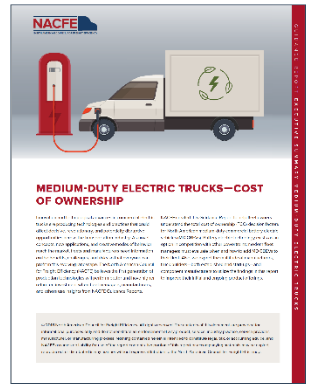
Electric airplanes are now being tested. In the summer of 2020, a modified 9-passenger Cessna Caravan 208B powered by an electric battery completed a 30-minute flight. Technology is improving in ways people did not anticipate.

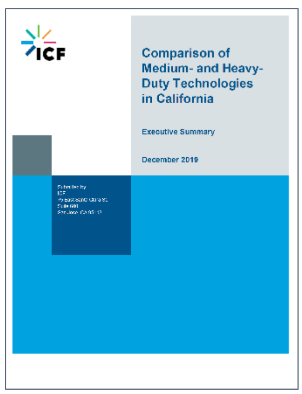
The price of flying the electric plane for 30 minutes was $6. If they used conventional engine fuel, the 30-minute flight would have cost $300-400.

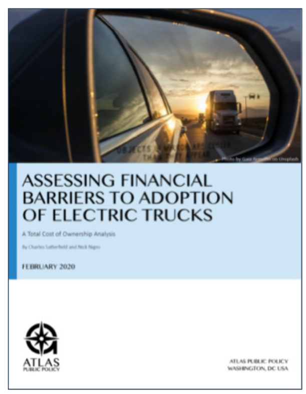
PLOW PHOTO: By SnowKing1 - CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=4747960
PLANE PHOTO: bbc.com/future/article/20200617-the-largest-electric-plane-ever-to-fly

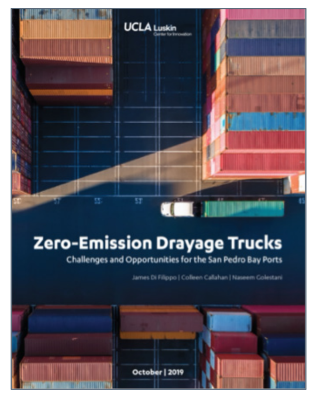
Cost Competitiveness of Battery Electric Trucks Observed in Several Studies

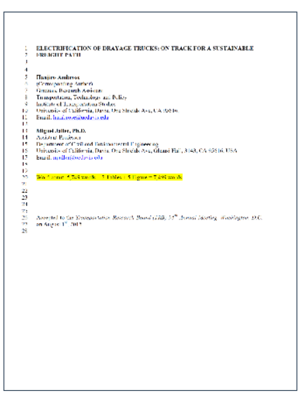


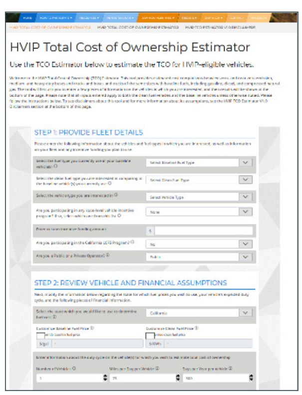










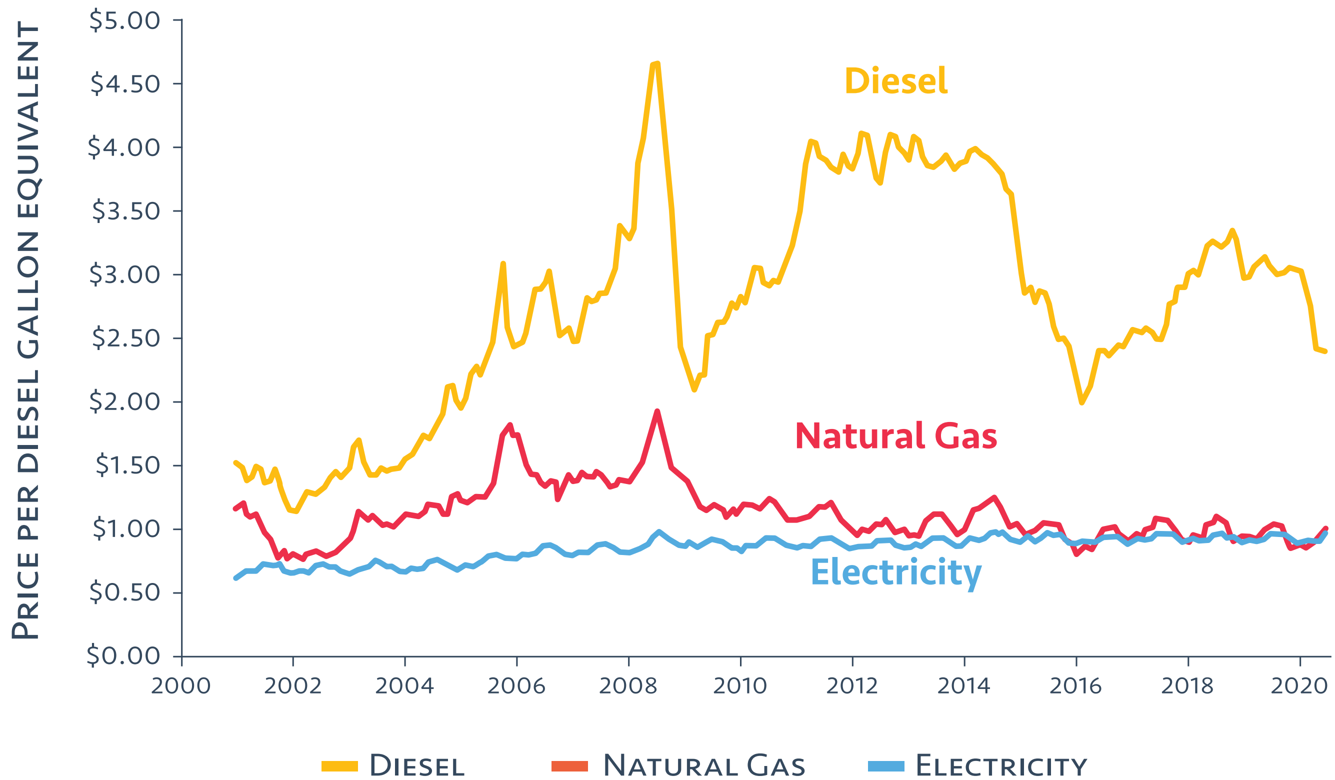


Above are cover thumbnails of 10 recent studies which have looked at the economics and cost of zero-emissions technology for buses and trucks. Essentially, they are all coming a similar conclusion, that zero-emissions technology is becoming cost competitive. It is not just one study coming to this conclusion, it's many studies, by different, reputable researchers, coming to the same conclusion. Let's take a look at some of these studies.

Electricity Proves To Be Less Expensive and More Consistently Priced Than Diesel

Below is a national comparison of natural gas, diesel, and electricity over the past 20 years. There is a lot of variation based on electricity rates in different regions, but the cost of electricity is less expensive and more consistent than diesel. For a fleet, electric can be more predictable for expenses.

Cost Comparison of Diesel, Natural Gas, and Electricity (2000–2020)

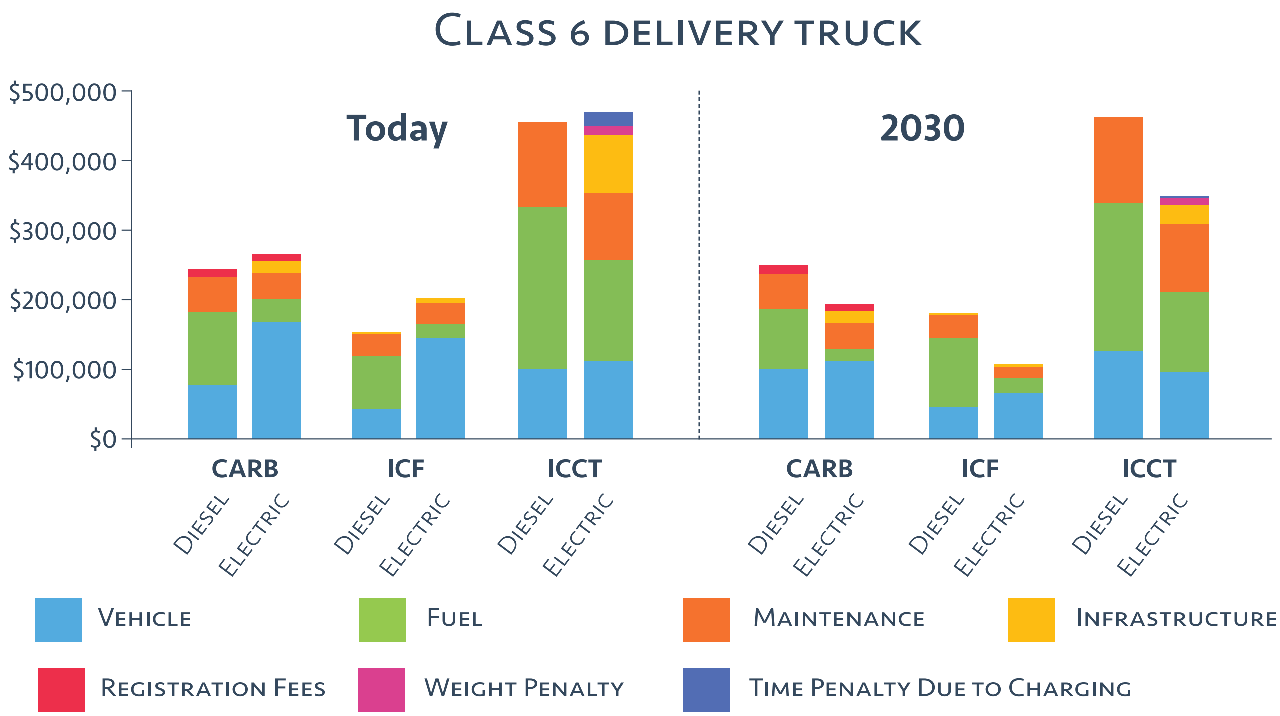


When advocating for this technology, be mindful of electricty rates in your areas. Electricity offers the potential for significant cost savings, but utilities and rates were not designed with electric trucks in mind. There could be hidden fees associated with utilities, but as electric vehicles gain popularity, changes are being made to utility rates.

Source: UCS analysis of EIA data

Three Studies Compare Delivery Truck Cost

Three different studies compare a diesel and battery electric version of a delivery truck. The chart below plots the three diffent studies (CARB, ICF, ICCT) for a class 6 delivery truck.



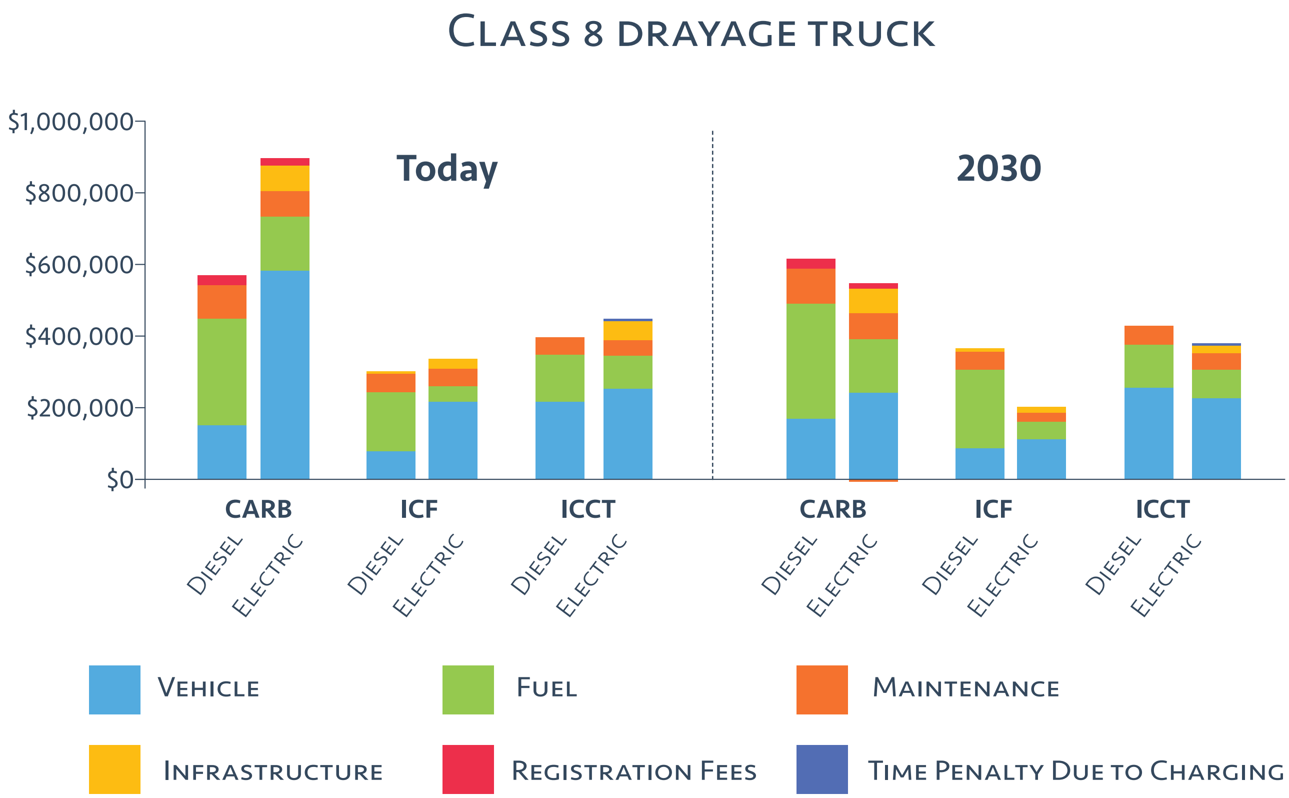
The total costs vary across studies primarily because the different studies assumed different annual vehicle mileages. These studies are California-based and use the cost of electricity in CA, which is a very high cost compared to most of the country.

Today, the purchase cost of vehicles is higher for electric than diesel. Fuel costs are more for diesel than electric. Maintenance costs are less for electric. In applications like the delivery truck above, total costs of ownership for electric vehicles are competitive with diesel today and are expected to be much lower than diesel by 2030 as the cost of electric vehicles continues to go down.

A note about hydrogen fuel cells: Both the vehicle and fuel (hydrogen, H2) for fuel cell powered cars are more expensive today than battery electric vehicles. The study above represents battery electric only.

Three Studies Compare Semi Truck Cost

Three different studies compare a diesel and battery electric version of a drayage (semi truck) truck (port to warehouse). The chart below plots the three diffent studies (CARB, ICF, ICCT) for a class 8 drayage truck.



The total costs vary across studies primarily because the different studies assumed different annual vehicle mileages. These studies are California-based and use the cost of electricity in CA, which is a very high cost compared to the majority of the country.

Today, the total cost of electric drayage trucks is estimated to be higher than diesel, but not by as much as you might expect. The good news is where we are headed. By 2030, all 3 studies expect electric drayage to be cheaper than diesel.

A note about hydrogen fuel cells: Both the vehicle and fuel (hydrogen, H2) for fuel cell powered cars are more expensive today than batter electric vehicles and electricity. The study above represents battery electric only.

Faster Charging = More Expensive

The faster you charge your electric vehicle, the more expensive the electricity will be. It's helpful to think of your internet bill, which is a simliar case: the faster you want your internet, the more expensive your plan will be. Faster is more expensive for electricity too and there might be some hidden fees.

How to Determine (Watts)

A standard cell phone charger is a 5 Watt charger. You can see the Watts by looking at the fine print on your charger.

This Apple iPhone charger reads:
5 Volts + 1 Amp.
Watts equals Volts multiplied by Amps,
so this charger is 5 Watts.

Three Levels of Charging

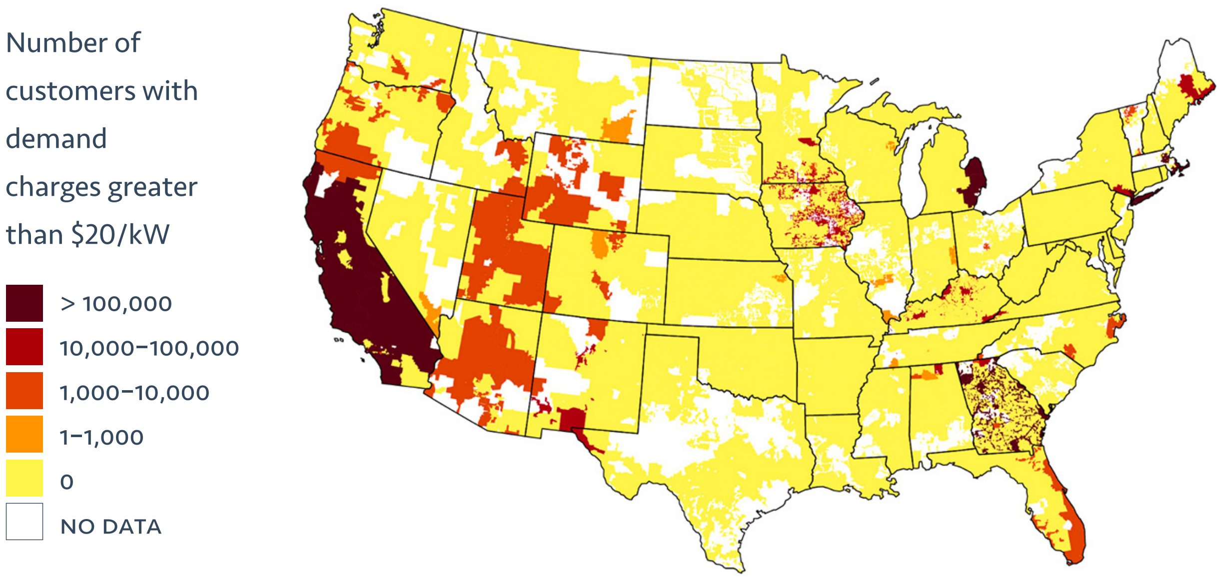
Level 1
Wall Charger
1.5 kW
Too slow to charge trucks on this and it is not ideal for most EV cars (for cars, 1 hour would get you 4 miles).

Level 2
Washer/Dryer
7-19 kW
Can be used for smaller trucks. A smaller delivery truck can charge overnight on a level 2 charger.

Level 3
DC Fast Charging
50-500 kW
Used for bigger trucks with bigger batteries.

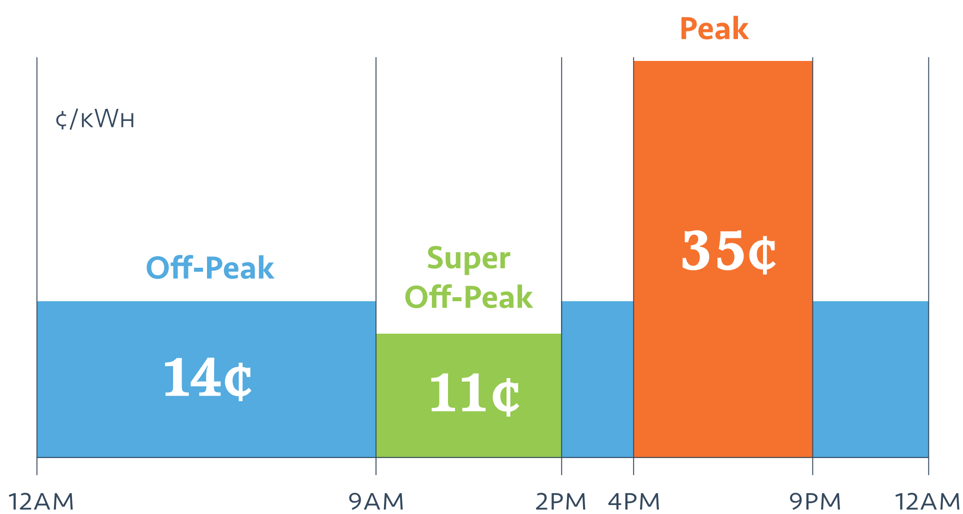
Extent of Demand Charges Varies by Utility

The map below plots different demand charges. These are additional fees utility companies often charge commercial customers based on peak electricity usage. CA has the highest demand charges, but they do exist elsewhere in country too.



Electricity Rates Can Vary By Time of Day

Charging rates vary by time of day. This sample commerical electricity rate in California costs more in the late afternoon/evening and cheaper during the middle of the day when there is excess energy from solar panels.



The time of day is a consideration for when to charge vehicles. If you charge during lower demand times, you can save money.

nrel.gov/solar/assets/pdfs/2017-us-demand-charges-webinar.pdf

https://www.pge.com/en_US/small-medium-business/energy-alternatives/clean-vehicles/ev-charge-network/electric-vehicle-rate-plans.page

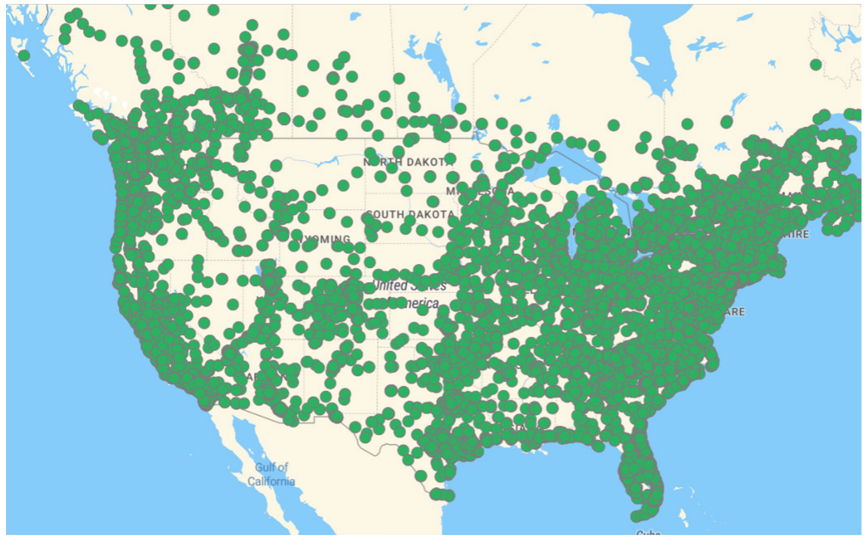
A Look at Charging Stations

To realize this massive transformation to zero-emissions trucks, we need a lot of charging stations. The US map shows progress made for car chargers across the US. There are 30,000 public locations with level 2 or faster charging for cars at present. Electricians should see an increase in job opportunities as demand for car and truck charging infrastructure increases.

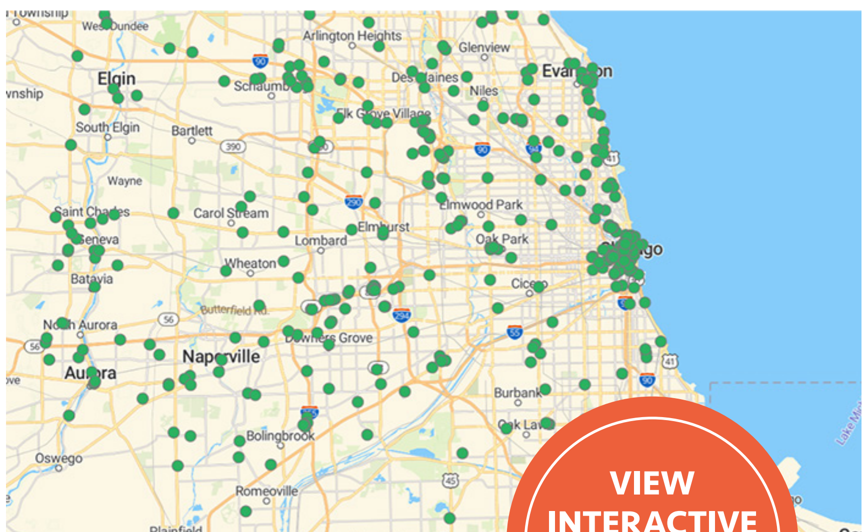
Looking at the Chicago area for example, you can see there is a relatively sparse distribution, especially in disadvantaged areas.

Use the [US Department of Energy interactive map] to view charging stations in your area.

Car Charging:
30,000+ Locations with 90,000 Charging Ports (Level 2+)



Chicago Area Map



VIEW INTERACTIVE MAP

How Many Chargers Do We Need?

A rough rule of thumb so far is to have one charging port for every two electric trucks.

afdc.energy.gov/stations/#/find/nearest?fuel=ELEC
efiling.energy.ca.gov/getdocument.aspx?tn=234209

Role of Utilities

Utilities have a big role to play in building the infrastructure for trucks and cars. We've seen recent changes in California and New York through policies being approved to invest in infrastructure.


Union of Concerned Scientists
Science for a healthy planet and safer world
SEARCH
[BLOG] UNION OF CONCERNED SCIENTISTS

A 700 Million Dollar Policy for Electric Vehicles that you Probably Haven't Heard Of

JIMMY O'DEA, SENIOR VEHICLES ANALYST | DECEMBER 12, 2017, 4:08 PM EDT

California will invest $700 million across three big utility companies across 5 years to build charging infrastructure just for trucks.


BRIEF

New York investor-owned utilities to fund $701M make-ready EV infrastructure program

geograph

New York will also invest $701 million in a similar program for cars and trucks.

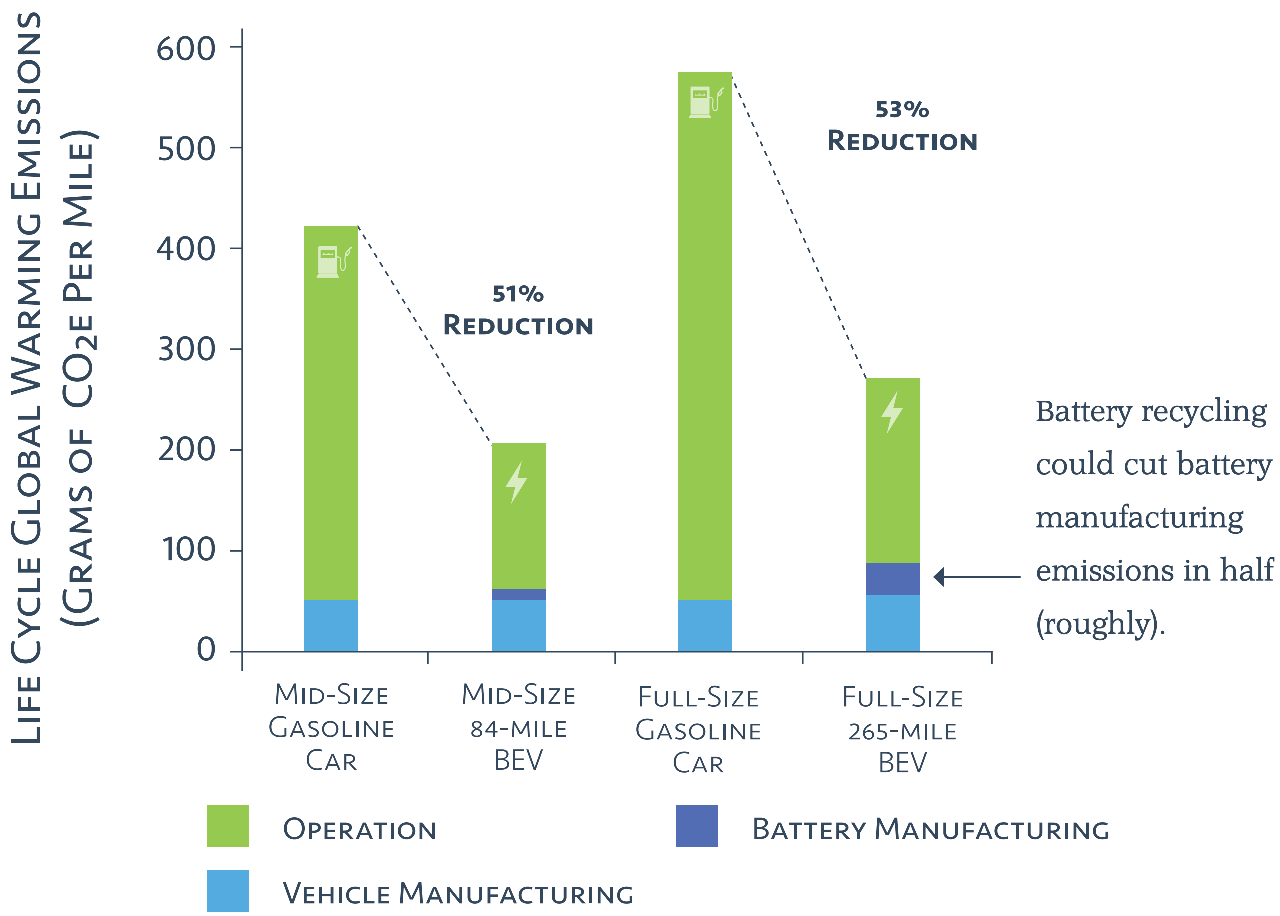
blog.ucsusa.org/jimmy-odea/a-billion-dollar-policy-for-electric-vehicles-that-you-probably-havent-heard-of

Life-Cycle Implications of Batteries

There's no denying that taking natural materials out of the ground will have consequences on the environment. Let's take a look at how can we minimize impacts.

What About Battery Manufacturing?

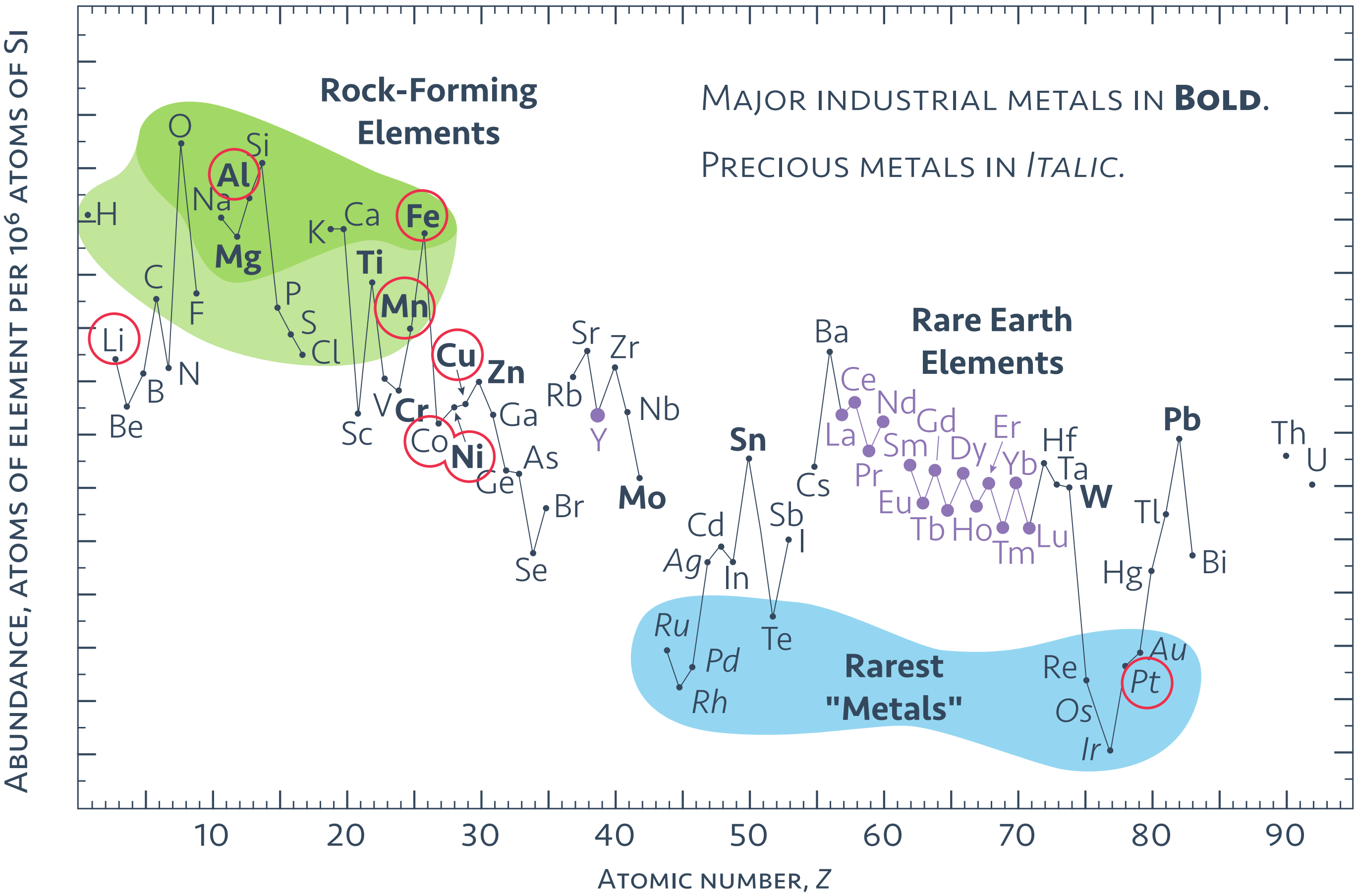
This chart shows emissions from both operating a vehicle, including extracting the fuels to generate energy, as well as manufacturing the vehicle. There are two vehicle sizes represented: a mid-size car, like the Nissan Leaf, and a full-size car, like a Tesla Model S.



The taller bars show emissions from cars with internal combustion engines. The shorter bars show emissions from electric vehicles. There are battery manufacturing emissions associated with the electric vehicles, but they are small compared to the overall emissions of operating the vehicle.

SOURCE: ucsusa.org/resources/cleaner-cars-cradle-grave

Abundance Of Elements In Earth's Upper Crust



Minerals Used in Battery & Fuel Cell Manufacturing

Lithium (Li)
Aluminum (Al)
Manganese (Mn)
Iron (Fe)
Cobalt (Co)
Nickel (Ni)
Copper (Cu)
Platinum (Pt)*

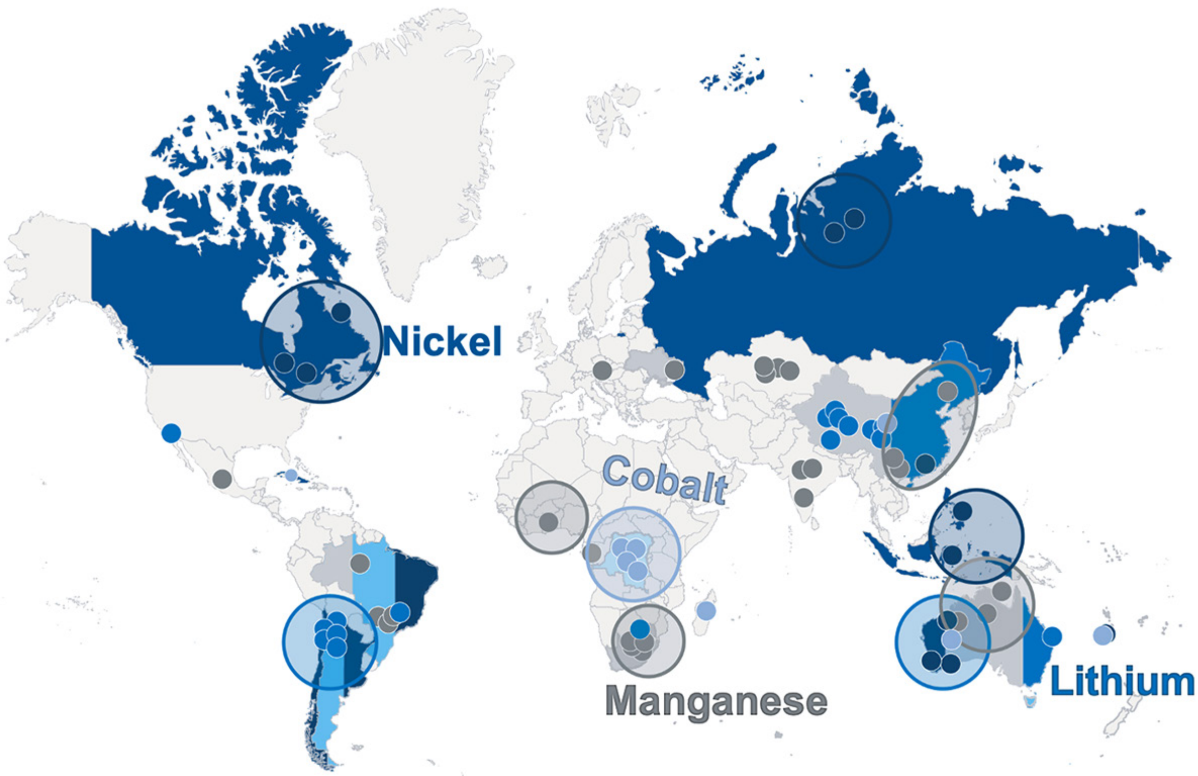
This chart shows all the elements in the Earth's crust, with periodic table abbreviations. The higher the element appears on the chart, the more abundant it is.

Many of the minerals used in batteries are more abundant than you may think. Generally, more abundant elements are less expensive to extract. This graph doesn't speak to the environmental consequences of extracting different materials.

* Fuel cells use platinum and this is a main reason why fuel cells are more expensive.

SOURCE: Haxel, G. B.; Hedrick, J. B.; Orris, G. J. Rare Earth Elements - Critical Resources for High Technology; USGS, (2002).

Geographic Availability Of Some Minerals Used In Batteries



Lithium primarily comes from Australia. The demand for lithium primarily comes from the battery manufacturing industry.

Cobalt primarily comes from the Democratic Republic of Congo. Cobalt is the most concentrated of battery materials in one region. 70% comes from the Congo. About 50% of the demand for cobalt comes from the battery manufacturing industry. There are a lot of labor and human rights issues associated with mining in the DRC.

Nickel is regionally spread out in terms of availabilty. The demand for nickel primarily comes from the stainless steel industry (78%). A smail percent is used in batteries, but it is an important component.

SOURCE: weforum.org/docs/WEF_A_Vision_for_a_Sustainable_Battery_Value_Chain_in_2030_Report.pdf

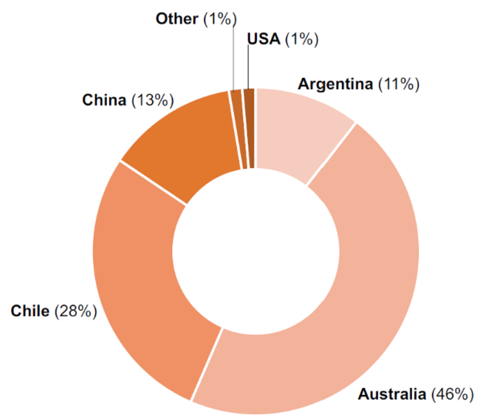
Supply & Demand: Lithium, Cobalt, Nickel

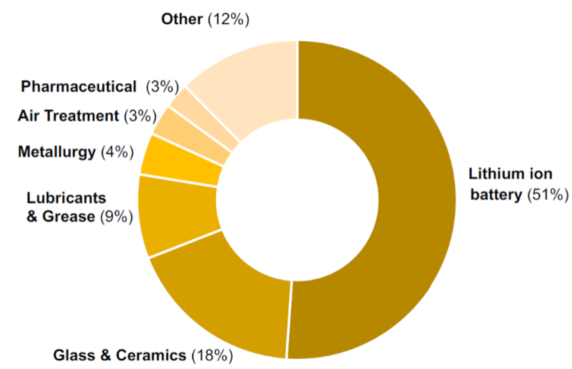
BENCHMARK MINERAL INTELLIGENCE

Supply Regions

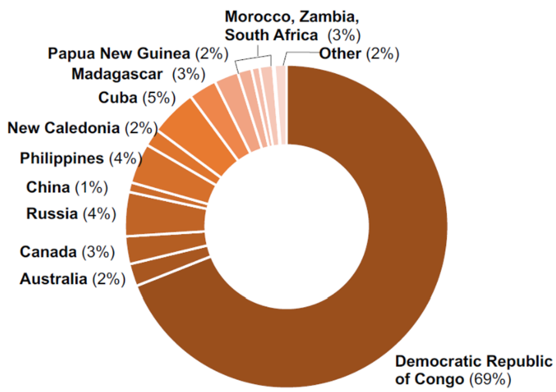
Industry Demand

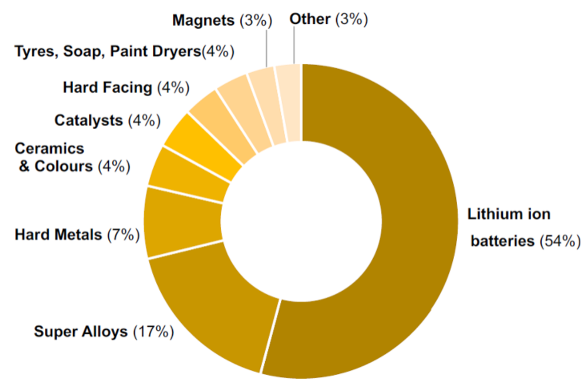
Lithium



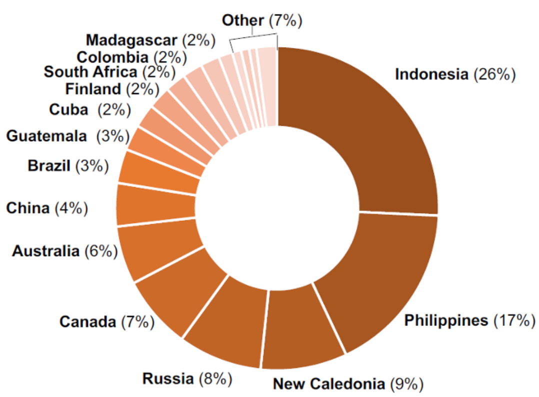


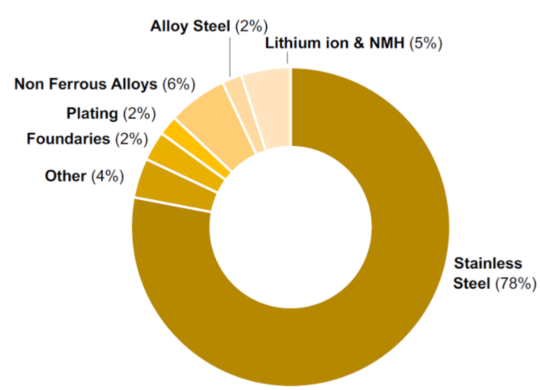
Colbalt





Nickel





SOURCE: *Benchmark Mineral Intelligence*

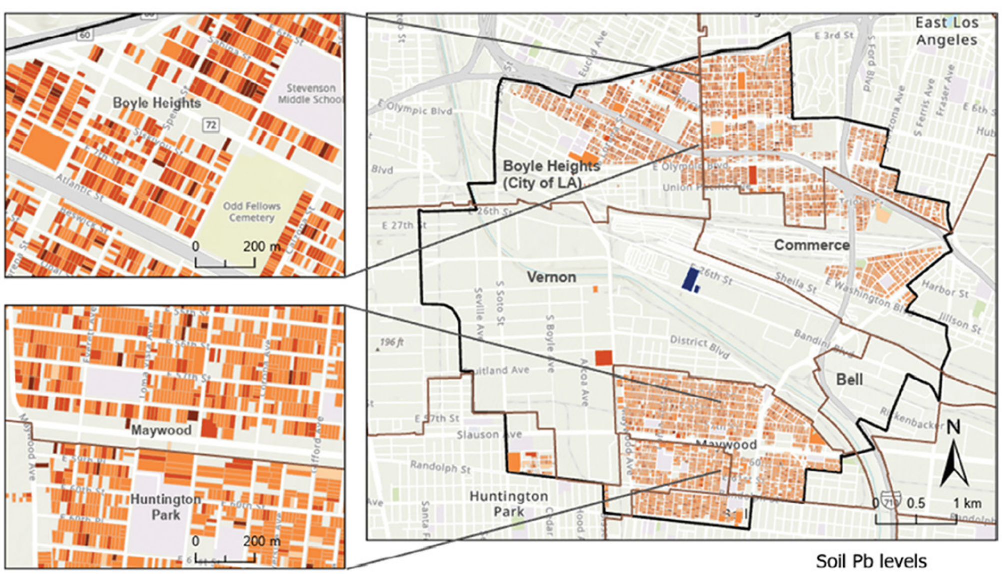
Demand For Batteries Will Increase: Recycling Can Offset Some Demand, But Not All

Many studies aim to estimate future battery demand and how much of that can be offset by recycling. Demand for batteries is going to increase and recycling can offset some of this demand, but probably not all of it.

Lead Acid Battery Recycling Has Had Tragic Impacts On Communities

Recycling lead acid batteries, has had tragic impacts to the environment and communities adjacent to the recycling facilities. A prominent case is in southeastern Los Angeles County, where lead contamination in the soil has been a particular concern near a lead-acid battery smelter, Exide Technologies (now closed), in the city of Vernon. The plant emitted toxic metal dust over decades that contaminated as many as 10,000 homes in half a dozen working-class, Latino communities near the plant.

Residential Communities Affected by Lead Contamination



Lead acid batteries are very different from lithium-ion batteries. Lead is a very toxic material. There are still consequences with recycling lithium-ion batteries, but not on the same magnitude as with lead batteries.

SOURCE: An-Min Wu, Jill Johnston; Assessing Spatial Characteristics of Soil Lead Contamination in the Residential Neighborhoods Near the Exide Battery Smelter. Case Studies in the Environment 31 December 2019; 3 (1): 1–9. https://doi.org/10.1525/cse.2019.002162

Ways to Recycle a Lithium-Ion Battery

Melt It

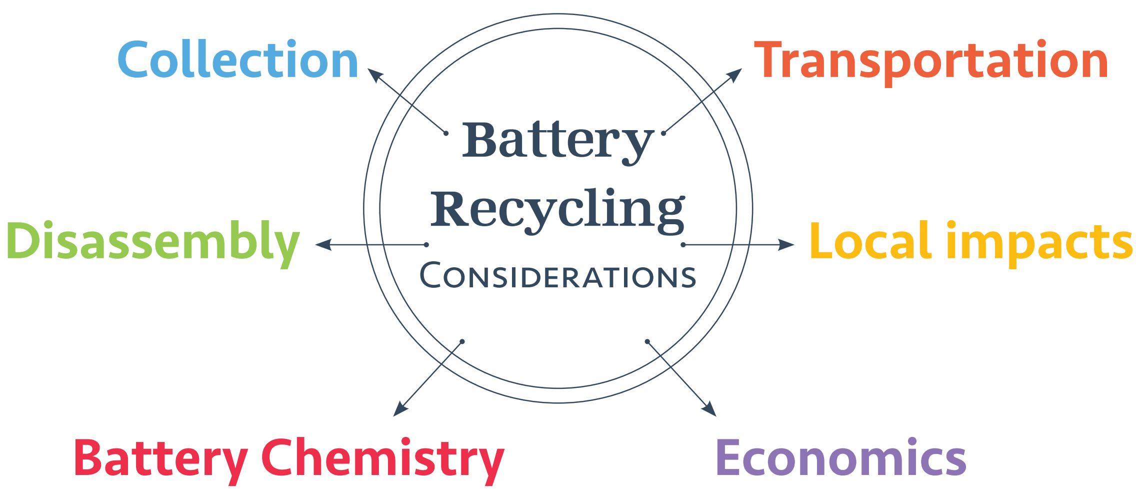
You can melt, or smelt (technical term) the battery. This is what is done for lithium-ion batteries today. Any time you heat something up, it can become airborne and that's a potential health risk, especially if what you are melting is toxic, like lead acid batteries. Lithium-ion batteries don't have lead or the same level of toxic material as lead acid batteries, but we do need to control for airborne emissions.

Dissolve It

Here you would dissolve the battery, like in an acid, and seperate that solution out. This is good because it can handle different chemistries from different manufacturers. More environmentally-friendly than melting.

Scavenge & "Refill" It

The cheapest & lowest impact would be to not destroy the battery, but scavenge & "refill" the battery. You could harvest the good and expensive parts, instead of totally breaking it down. More environmentally-friendly than melting, but limited by chemistry.



Keypoints Summary

Things to know about zero-emissions technology:

1. **It's not just about technology**

   Advocacy, lived experiences, and the stories of communites are just as important to getting electric vehicles on the road.

2. **Addresses significant source of emissions**

   Diesel trucks are major sources of NOx, PM2.5, and global warming emissions.

3. **Life cycle emissions significantly lower**

   Battery and fuel cell electric vehicles have zero tail pipe emissions and lower life cycle emissions than diesel.

4. **Technology is here today**

   Major manufacturers and new entrants alike are offering electric trucks for sale today. Policies are helping to increase availability.

5. **Cost competitive today if not soon**

   Advocacy, lived experiences, and the stories of communites are just as important to getting electric vehicles on the road.

6. **Batteries can be recycled**

   Recycling is critical to reducing the impacts of electric vehicles.

Glossary

Battery Technology
Refers to the different types of battery types and their properties, characteristics, and impacts.

BEV
Battery electric vehicle. A vehicle that runs on electricity stored in batteries and has an electric motor rather than an internal combustion engine. BEVs are one of two types of zero-emissions vehicles.

Biofuel
"Biofuels" refers to a broader type of liquid or gaseous fuels from plant or animal matter, e.g., ethanol derived from corn that is added to gasoline is a biofuel; so is biodiesel, which resembles the chemical structure of fossil diesel fuel. One type of biofuel, biomethane, is just methane from bio sources.

Chassis Cab
A chassis cab, also called a half truck, is a type of vehicle construction, often found in medium-duty truck commercial vehicles. The customer is given the vehicle with chassis rails and a cab. This allows the customer to customize for their specific cargo and transport needs.

CH_4 (Methane)
One atom of carbon and four atoms of hydrogen. Methane is a potent greenhouse gas that traps more heat than carbon dioxide (CO_2). When combusted, methane produces carbon dioxide, a major source of climate change, and air pollutants.

Combustion
The act or process of burning something. In combustion vehicles (those that operate on diesel, gasoline, or natural gas), this represents the burning of the air/fuel mixture within the engine's combustion chambers that powers the vehicle.

Combustion Vehicles
Vehicles such as those that run on diesel and gasoline use internal combustion engines. Diesel vehicles typically use compression-ignited systems whereas gasoline vehicles use a spark-ignited internal combustion engine.

CNG
CNG just refers to "compressed natural gas," which describes natural gas being compressed to high pressures in tanks used to power vehicles that run on natural gas.

Drayage
Drayage is the transport of goods over a short distance in the shipping and logistics industries. Drayage is often a smaller part of a longer overall move, such as from a ship to a warehouse.

Diesel/Gasoline
Fuels made from crude oil and composed of carbon compounds.

Emissions
The term used to describe the gases and particles which are put into the air or emitted by various sources.

EV
An electric vehicle. Can be either fuel cell or battery electric.

FCEV/FCV
Fuel cell electric vehicle/fuel cell vehicle. A zero-emissions vehicle that runs on compressed hydrogen fed into a fuel cell "stack" that produces electricity to power the vehicle.

Glossary of Terms

Fuel Cell Technology
Refers to the different types of fuel cell devices and their properties, characteristics, and impacts. Fuel cells are devices used for generating electricity by the chemical combination of hydrogen fuel and oxygen.

Heavy-Duty Vehicles
Larger commercial freight vehicles including trucks, buses, refuse trucks, delivery trucks, semi trucks, big rigs, etc. Delivery vans, mid-sized delivery trucks, and large pickup trucks are included in this category in this document, but can also be described as medium-duty vehicles.

HEV
Hybrid electric vehicle. These feature both a full-size internal combustion engine, along with a small battery to reduce the use of the combustion engine.

Life Cycle Emissions
The complete fuel cycle, aka "well to wheels." Life cycle emission are all the emissions created from extracting, refining, and transporting a fuel to using it.

Light-Duty Vehicles
Refers to passenger cars, SUVs, or small pickup trucks..

Long-Haul Truck
Long-haul trucking is any form of trucking where drivers are typically traveling more than 500 miles per trip and often spending the night away from home, as the journey is too long to be made in a day. Long-haul truck drivers operate tractor-trailers (semi trucks) with a gross vehicle weight rating of 33,001 lbs or more.

Natural Gas
Natural gas is a fossil energy source that formed deep beneath the earth's surface. Toxic pollutants that harm health and climate are released throughout all stages of natural gas production and use. It is composed of mainly methane. Methane is a potent greenhouse gas that traps more heat than carbon dioxide (CO_2). When combusted, methane produces carbon dioxide, a major source of climate change, and air pollutants.

The natural gas industry has a wide array of marketing strategies to make their products appear sustainable and innovative, and other strategies that push officials to pursue natural gas alternatives over zero-emissions technologies. Other names for natural gas include: Clean Natural Gas or Compressed Natural Gas, Near Zero, Net Zero, Liquid Natural Gas, Renewable Natural Gas, Biomethane.

NO_X (Nitrogen Oxides)
A precursor to smog, a source of air pollution. Freight is the 2nd largest contributor to NO_X emissions, after light-duty vehicles in US (passenger vehicles).

PHEV
Plug-in hybrid electric vehicles. These hybrid vehicles have large enough batteries that they needed to be charged with a plug, rather than just the energy from braking as in regular hybrids.

Particulate Matter
Also called particle pollution; the term for a mixture of solid particles and liquid droplets

found in the air. Particulate matter contains microscopic solids or liquid droplets that are so small that they can cause serious health problems when inhaled.

$PM_{2.5}$

Particulate matter less than 2.5 micrometers in diameter, also known as fine particles, pose the greatest risk to health, as they can get deep into your lungs and some may even get into your bloodstream.

Straight Truck

A straight truck is one in which all axles are attached to a single frame. It has front and rear wheels. Examples include typical U-Haul trucks and many types of delivery trucks. A straight truck is different (and almost always smaller) than a tractor (semi) truck that pulls a trailer.

Tractor Truck

A tractor-trailer truck has two distinct parts that can detach. The tractor is the front part with an engine, front wheels, and rear wheels and a fifth wheel hitch plate. The trailer hooks to the tractor. Tractor is synomous with "semi" and "big-rig." A tractor pulling a trailer or "van" is an "18-wheeler."

VMT

Vehicle miles traveled (VMT) refers to the annual mileage of a single vehicle, a group of vehicles, or even the average of vehicles. The average VMT for passenger vehicles in the US is roughly 11,500 miles per year. Trucks typically average much higher VMTs, including over 100,000 miles per year for many long-haul trucks.

Yard Hostler

Yard hostling is moving cargo containers around ports, railyards, and warehouses to position, and park trailers/ containers/cargo. "Yard hostler" can refer to the specialized truck designed for the job or the job position.

Zero-Emissions

Zero-emissions refers to processes that produce useful energy without emitting waste products that pollute the environment or disrupt the climate.

Zero-Emissions

Technology

In vehicle & freight transportation, there are two types of zero-emissions technologies: battery & fuel cell. Fuel cells and batteries both work by converting chemical energy into electrical energy. Both are electric.

Zero-Emissions Vehicles

All zero-emissions vehicles have zero harmful tailpipe emissions. Fuel cells produce small amounts of water vapor during operation. All vehicles and manufactured goods have life cycle emissions that depend on the manufacturing process, extraction of materials and fuel, and sources of electricity.