CLIMATE CENTRAL SOLUTIONS BRIEF: ELECTRIC VEHICLES

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Research brief by
Climate Central

CLIMATE CENTRAL

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Part of the *Climate Solutions* series

INTRODUCTION

To meet the goals of the Paris climate agreement, emissions of carbon dioxide need to reach net zero by around 2050. Achieving that objective will involve shifting to renewable energy sources and increasingly widespread deployment of electric vehicles (EVs) during the current decade. And that could happen, thanks to improvements in technology and falling prices, as electric cars become better performers and cheaper to own than traditional vehicles that run on gasoline or diesel.

Transportation accounts for 29% of U.S. greenhouse gas emissions, the largest share of any sector, according to the EPA. Light-duty vehicles (cars, minivans, pickup trucks, and SUVs) contribute 53% of that amount and medium- and heavy-duty vehicles (delivery vans, buses, and heavy trucks) add another 23%.

Net Zero America (NZA), a research initiative led by scientists and engineers at Princeton University, identified five pathways which could get the U.S. to net-zero emissions by 2050. In this research brief, we explore how the transition to EVs could occur under the high electrification, or E+ scenario. We provide background and resources to understand the EV revolution, and regional story ideas to inform local audiences about how this major change in American could affect us.

Throughout this brief, "EV" will refer to battery-powered electric cars and light-duty trucks unless specified otherwise.

GETTING TO NET ZERO

In order to reach the target of the Paris Climate Agreement to limit global warming to 1.5°C, global greenhouse gas emissions need to be cut in half by 2030, and reach "net zero" by 2050. The term "net zero" simply means that any greenhouse gas emissions released are balanced by an equal amount being taken out of the atmosphere. This is part of a series of climate solutions issue briefs exploring pathways to get to net zero, including carbon-free electricity, electrifying transportation and buildings, and transforming our agriculture and food production.

THE BASICS OF ELECTRIC VEHICLES

Electric vehicles are becoming increasingly popular due to their ability to shrink our carbon footprint, low operating costs, and positive overall driving experience.

In a conventional gas- or diesel-powered vehicle, only 12-30% of the energy from fuel goes into moving the car. The remaining 70-88% is lost as heat, according to the Department of Energy (DOE). Electric motors produce little heat waste and can generate and store electricity from braking. In order to compare the efficiency of alternative fuel or electric vehicles to that of traditional gas-powered cars, the Environmental Protection Agency (EPA) created the MPGe measurement. According to Fueleconomy.gov, the 2021 Tesla Model 3 gets 142 MPGe in combined city and highway driving, the most efficient vehicle on the road today. The average non-plug-in vehicle gets 27 MPG and the most efficient non-plug-in car, a hybrid Hyundai Ioniq Blue, gets 59 MPG.

ELECTRIC VEHICLE TECHNOLOGIES

Hybrid Vehicles (HEVs) run on gasoline and electric drive. The electric drive is powered by a battery that is recharged through regenerative braking. They cannot be plugged in.

Plug-in Hybrid-Electric Vehicles (PHEVs) use gas and electric drive. Their batteries are recharged fully by plugging into the grid or partially through regenerative braking, and can run on gas fuel to extend their range if a charging station isn't available.

Battery Electric Vehicles (BEVs) are all-electric vehicles that must be plugged in to recharge fully.

EVs can accelerate very quickly from a stopped position, but a key factor driving EV adoption are advances in batteries. Batteries are getting more capable, lighter, and less expensive with new technology and increased scale of production. Bloomberg New Energy Finance (BNEF) reported that lithium-ion batteries fell in price from $1,100 per kilowatt hour in 2010 to $137 per kilowatt hour in 2020, and will fall to $100 by 2023—the cost at which EV purchase prices will match those of conventional vehicles, according to BNEF.

Currently, new EVs cost more to buy, but they may actually cost less to own. EVs do not need oil changes and their regenerative braking systems put little wear on brake pads. *Consumer Reports* analyzed real-life data on repair and operation expenses to compare the total lifetime cost of ownership of EVs to hybrids and gas-powered cars.. The study found that EV's higher purchase prices were fully offset by savings on fuel and lower maintenance and repair costs. EV owners spent half as much in repairs and maintenance. (See Figures 1 & 2)

EVs also break down less often because they have fewer moving parts and their electric motors experience fewer problems. For nine of the most popular EVs under $50,000, lifetime ownership savings for first-time owners amounted to $6,000 to $10,000 (although savings varied regionally). New models of all vehicle types often have issues with initial quality. Since most EVs are relatively new, they're going to have a few more of these issues as manufacturers figure out what they're doing. From a consumer perspective this is less about costs and more about hassle, as a new car warranty should cover any such repair costs.

Ranges and Charging

EV owners do 80% of their charging at home, mostly by plugging in the car at the end of the day (see box on charging). But on road trips, it might be necessary to recharge while traveling. Networks of Level 3 chargers, also called Direct Current Fast Chargers (DCFCs), are rapidly spreading around the U.S.. These are strong enough to produce an 80% charge in some cars in around 30 minutes, although numbers vary widely by the vehicle and the charging facility.

Plug-in hybrid vehicles (PHEVs) don't need on-the-road charging, because they supplement rechargeable batteries with an on-board gasoline engine that can take over after the battery is discharged. A top-selling PHEV, the Honda Clarity, has a battery range of 47 miles with a seven-gallon gas tank taking it another 293 miles. But sales of plug-in hybrids have lagged behind battery electric vehicles, and they don't completely end our reliance on fossil fuels.

READY, SET, CHARGE!

Level 1 Chargers
Typically included with the car. Plugs into a standard 120V electrical outlet. A 20-hour charging session can typically get you over 120 miles.

Level 2 Chargers
Sold separately from the car. Plugs into a 240V outlet (which generally has to be installed by an electrician), it allows 3 to 7 times faster charging, depending on the car and charger.

Level 3 Chargers (Direct Current Fast Chargers)
Publicly available charging stations, can recharge an EV from zero to 80% in as little as 30 minutes. Not recommended for regular use because they impact the life of the battery. And cold temperatures can significantly slow down charge times. Some manufacturers have their own standards. Tesla operates a proprietary network that works only with its vehicles. An emerging international standard, the Combined Charging System (CSS) or SAE Combo, works with most other vehicles. CHAdeMO Level 3 chargers work with some Asian-made autos, like the Nissan Leaf.

Know before you go
There are multiple downloadable apps for your smartphone to help EV owners find charging stations near and far, including PlugShare, ChargeMap, ChargeHub, Chargepoint, and A Better Route Planner (ABRP).

Ownership of EVs has been growing quickly and we can learn a lot from the experience of early adopters. Researchers from the University of California Davis surveyed owners of EVs. They found that owners like EVs' safety, reliability, and low cost of use, but they had concerns with range and charging. EVs can now attain ranges of 170 miles or more, with some high-end models reaching 370 miles. That's more than enough for most driving, since only 5% of trips exceed 30 miles, and just 1% exceed 100 miles, according to U.S. Department of Transportation statistics.

Access to charging is emerging as a key barrier. The UC Davis survey found owners were 53% more likely to be dissatisfied if they lacked a Level 2 charger at home. There are considerable differences in the availability of public charging stations across the United States. California leads the nation with 12,839 public charging stations, over 10,000 more stations than the next state, New York, which had 2,427 as of April 2021.

The Net-Zero America analysis showed that charging infrastructure will have to expand greatly to meet the needs of a rapidly growing electric fleet. The growth in the number of public EV charging stations is likely to be greatest between 2020 and 2030, with a national increase of approximately 2,000% in the number of charging stations. From 2030 to 2040, almost every state could experience an increase of approximately 300 to 340%, followed by a 60% increase from 2040 to 2050.

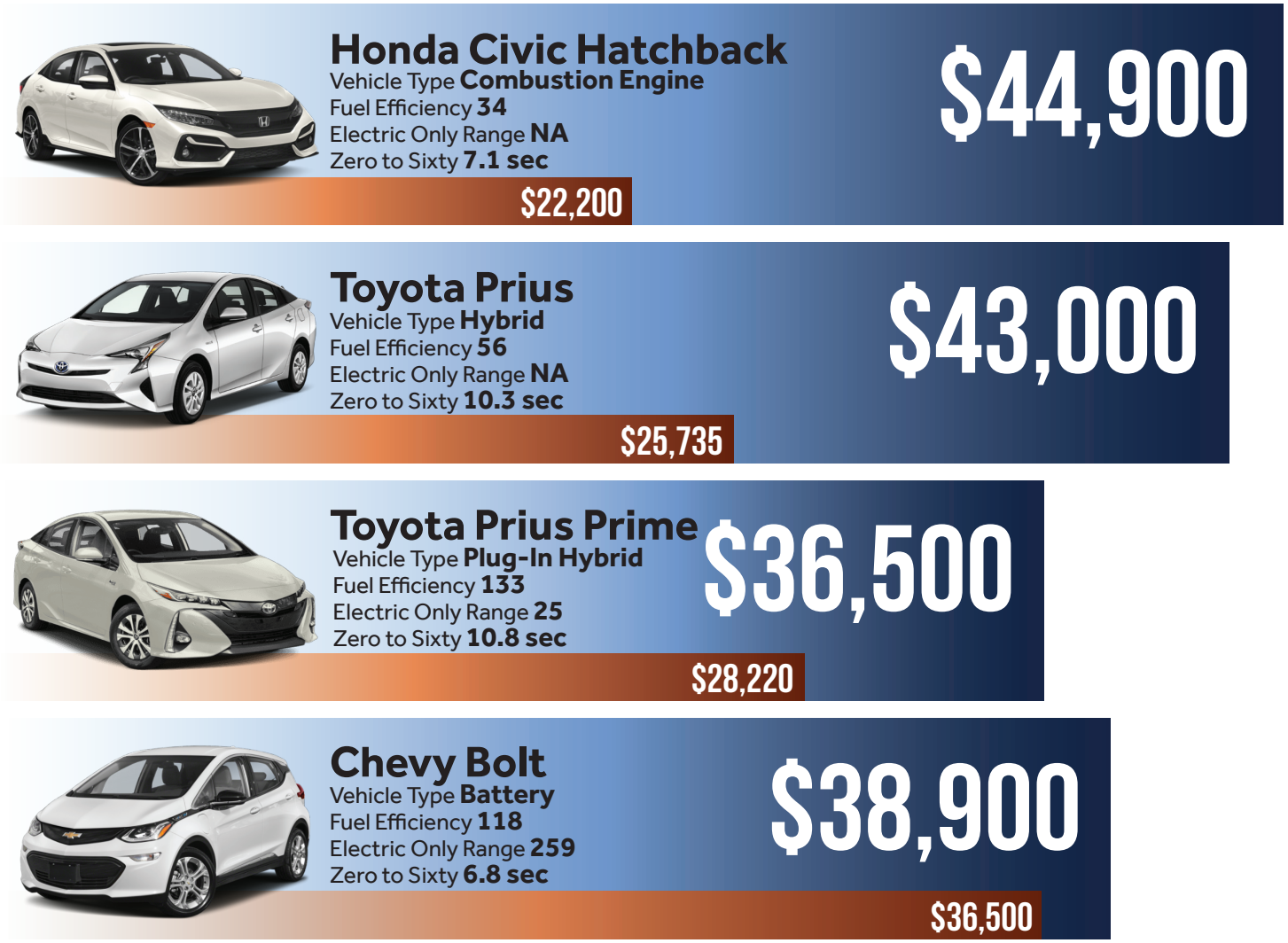
THE CHANGE OVER IS COMING

Despite all their advantages, sales of battery-powered electric vehicles comprised only 1.7% of U.S. light-duty vehicle sales, according to the DOE. But U.S. automakers expect that number to rise fast. They have committed investments of $140 billion to electrification and are currently offering 50 light-duty EV models, a number expected to increase to 130 models by 2023, according to 2021 research led by Mattee Muratori of the National Renewable Energy Laboratory (NREL).

A full switch-over to EVs would lower vehicle emissions to near zero if electric generation also decarbonized with renewable sources of power such as wind and solar. In April, the Biden administration set a goal to reach 100 percent carbon pollution-free electricity by 2035.

Charging EVs from today's fossil-fuel-generated electricity does cause emissions at the power plant, but EVs are cleaner because they are approximately 3 to 4 times more efficient than comparable ICEVs. They will also benefit from the increase in renewable electricity which will make the grid cleaner. Unlike gas-powered vehicles, EVs don't produce tailpipe fumes, leading to less smog and cleaner, healthier air, especially in cities. EVs reduce air pollution that disproportionately affects low-income groups and communities of color.

Figure 1. EVs by the numbers - Hatchbacks



Sources: Total ownership cost is the amount to purchase a new vehicle and operate it for 200,000 miles, including energy and maintenance, less federal incentives for plug-in vehicles. Costs and other statistics: Consumer Reports' Electric Vehicle Ownership Costs: Today's Electric Vehicles Offers Consumers Big Savings, October 2020. MSRPs: manufacturer websites. Fuel efficiency: DOE's Fuel Economy.gov.

Sales will have to ramp up quickly to meet the 2050 goal. The need for this rapid increase is the longevity of fossil-fuel cars and the lag time to retire them—currently, the average light-duty vehicle on road is 12 years old, according to the Bureau of Transportation Statistics. Princeton's NZA modeling in the high electrification scenario has sales of light-duty EVs exceeding fuel-burning vehicles by 2030. The rate of adoption will vary slightly, with rural and northern states slower to cross over. By the end of this decade, 17 of the lower 48 states and the District of Columbia will see more EV sales. By 2035, EV sales will outpace conventional cars in another 32 states.

EV sales are expected to rise rapidly because of their desirable qualities and declining prices, according to research led by Muratori. Up to now, technology advances and sales have surpassed predictions. Prices for lithium-ion batteries—the critical cost item in EVs—fell 90% in the last 10 years. And their size, weight and energy storage capacity have all improved faster than expected. That technological momentum is continuing with major investments by industry and governments. EV sales could also be pushed by increasing choices, more charging stations, and government incentives.

When the switch happens, the experience of owning a car will change. Home charging will replace gas station pit stops for day-to-day activities and auto maintenance will become less frequent. There will be a different mix of jobs and businesses to support the EV industry. The natural resources for the auto sector will change, from oil to lithium and other exotic metals. And if EV opportunities are implemented in an equitable way by making them easier to afford and to charge, air quality could improve in lower-income communities now impacted by vehicle emissions.

Figure 2. EVs by the numbers - Sedans

Sources: Total ownership cost is the amount to purchase a new vehicle and operate it for 200,000 miles, including energy and maintenance, less federal incentives for plug-in vehicles. Costs and other statistics: Consumer Reports' Electric Vehicle Ownership Costs: Today's Electric Vehicles Offers Consumers Big Savings, October 2020. MSRPs: manufacturer websites. Fuel efficiency: DOE's Fuel Economy.gov.

CHALLENGES AND OPPORTUNITIES

Sourcing of metals

A surge in lithium demand is projected to create a huge deficit in world production, with a 42-fold increase needed by 2040 to meet the goals of the Paris agreement, according to a 2021 report by the International Energy Agency. The metal is abundant, but the U.S. lags other nations in mining and processing, with investors holding back in part because of expectations that new battery technology could supplant lithium within 20 years. And lithium mining threatens water supplies in the West, where water shortages are widespread. Cobalt, which is also used in the batteries, comes mainly from the politically unstable Democratic Republic of Congo, where some production relies on child labor and involves other human rights abuses. The need for cobalt could eventually be addressed with recycling or new battery innovations that reduce or eliminate need for the metal. Rare earth metals used in magnets for electric motors also pose a challenge, especially neodymium, because state-supported Chinese companies dominate mining and processing and do not enforce environmental regulations.

Changes in the trucking and delivery industries

Companies that operate large fleets of trucks for deliveries and short hauls are projected to rapidly adopt electric vehicles to capture significant cost savings. Vans and trucks that operate on set routes during the day and sit at centralized depots at night—often traveling no more than 100 miles daily—are considered ideal for electrification. Companies such as UPS and Amazon have ordered electric delivery fleets, while Ford and GM, and lesser-known companies, have announced electric vans and delivery trucks for sale in 2021. GM claims its new BrightDrop EV600 electric commercial van will save owners $7,000 a year over a diesel model. The picture is more complicated for long-haul highway trucks, which must refuel or recharge en route and in some cases are driven almost constantly (about 10% of trucks fall in this category). Some experts have maintained trucking company economics won't work if heavy batteries reduce truck payload and recharging adds downtime, but the Lawrence Berkeley National Laboratory released an analysis in 2021 showing that new battery advances should eliminate these concerns. At present, however, electric heavy trucks with long-range capability are not widely available, nor have charging stations been deployed that are powerful enough for their huge batteries.

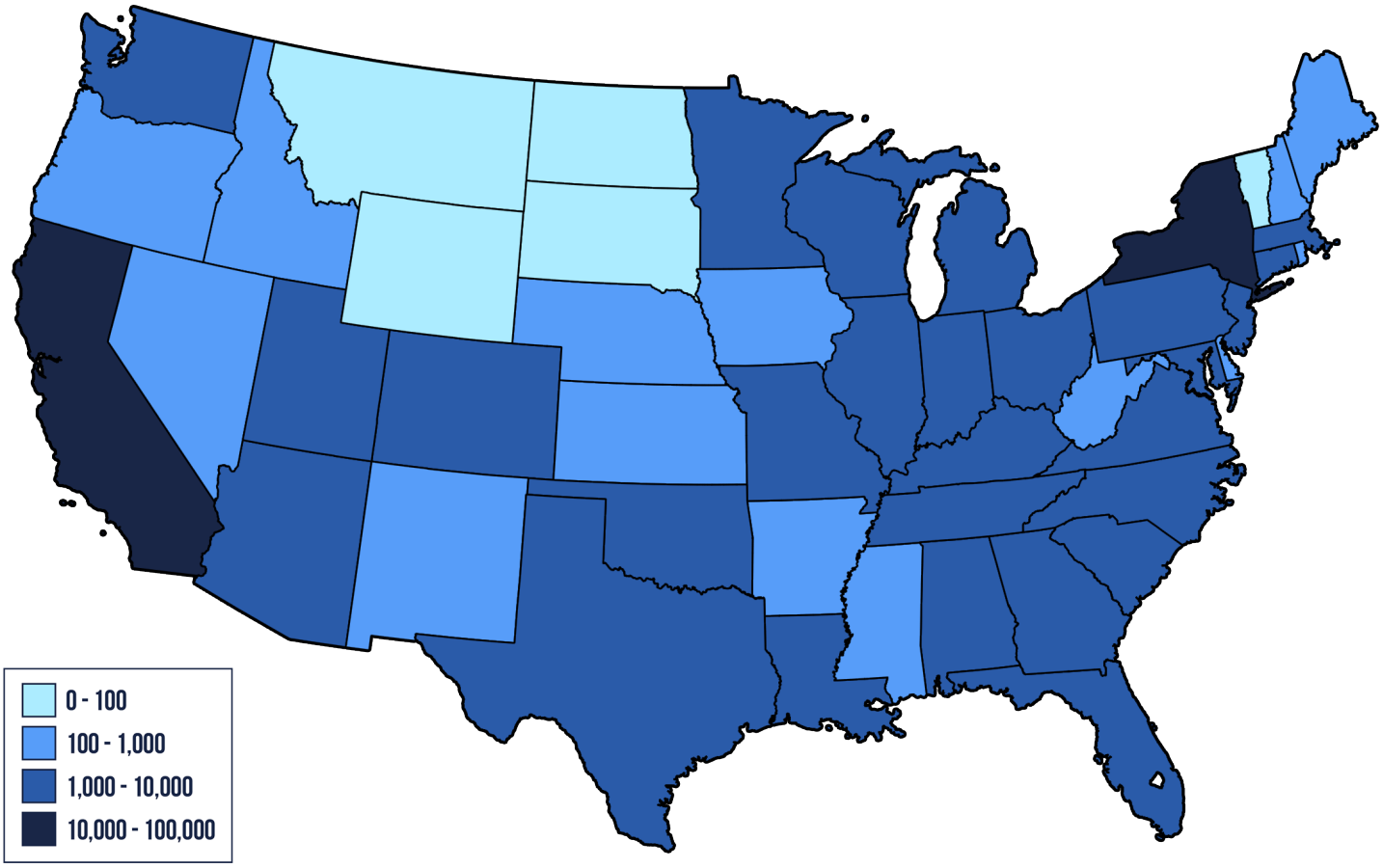
Jobs

Electric vehicles are creating jobs, but the transition to full electrification may lead to less employment in the auto industry as a whole. According to E2, a non-partisan business environmental organization, employment in EV and plug-in hybrid vehicle manufacturing grew 6% in 2020 in the U.S., despite the general employment losses during the pandemic. Work on EVs alone—including manufacturing, distribution, and maintenance—employed 83,733 Americans in 2020. As EVs replace conventional vehicles, employment in manufacturing and auto repair may not keep pace. Building an EV requires fewer workers, and repairs and upkeep are half as expensive. However, new jobs will be created for installing charging devices and upgrading electrical services in addition to jobs associated with the build out of clean energy. Domestic manufacturing of batteries and the mining and processing of their raw materials would increase jobs as well, but these sectors would need government support to keep pace with other countries.

Health and Environmental Considerations

In addition to reducing greenhouse gas emissions, converting to EVs would save thousands of lives by reducing air pollution on roadways, one of several benefits environmental justice experts see for communities of color. Princeton's NZA modeling shows approximately 400,000 avoided premature deaths by 2050 with the full adoption of EVs and renewable energy sources, with avoided costs of $3.5 trillion. From transportation changes alone, more than 165,000 deaths could be averted in total by 2050. States that accrue the most health benefits primarily have dense urban areas, where traffic pollution is worst today, such as California, New York, and Florida. (see Figures 3 & 4)

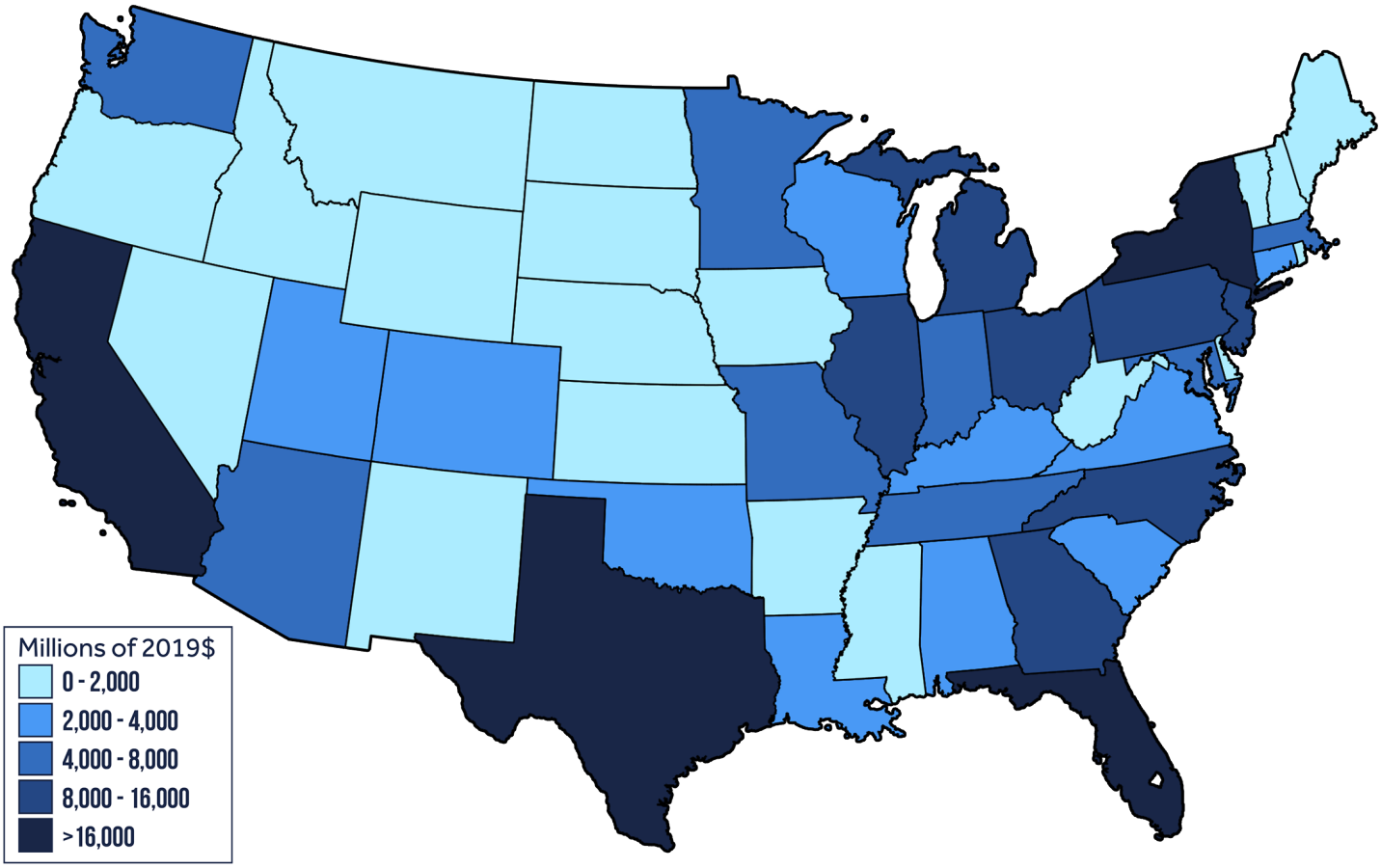
Figure 3. Avoided deaths through 2050, NZA E+ Scenario



Other research suggests particular benefits for communities of color who have higher exposure to hazardous air pollution than white populations because of where they live, often because of past housing policies such as redlining.

In Southern California, 1.2 million residents live within 500 feet of a freeway, according to Coltura, a West Coast nonprofit that advocates for EVs as an environmental justice solution. On average, African-American and Latino Californians are exposed to dangerous levels of small air particles at a rate about 40% higher than that for white Californians. In addition to reducing air pollution and noise, EVs would improve quality of life and property value for communities of color near highways, according to Coltura president Carlos Manzanedo, and would create new job opportunities that could not be sent offshore, such as installing charging stations and improving electrical connections.

Figure 4. Avoided monetary damages from air pollution through 2050, NZA E+ Scenario



Manzanedo said EVs could also reduce the cost of mobility for low-income residents, since EVs are cheaper to operate and rarely need repairs. In a study that looked at vehicle operating costs and depreciation, savings doubled or tripled for buyers of seven-year-old EVs, because they did not have to pay the premium purchase price for a new vehicle but still enjoyed the benefits of EV reliability and low operating costs.

Manzanedo said used EVs are for sale for as little as $10,000, but charging is not often available for residents of multi-unit housing or people who park on the street. Experts point to the need for new building codes and incentives to encourage installation of charging in parking stalls at apartment buildings, workplaces, and shopping centers so EVs can become a practical alternative for low- and moderate-income drivers. Some states have made progress on addressing equity in charging investments, but many have not.

WHERE WILL EV METALS COME FROM?

Building EVs requires different natural resources than conventional vehicles, especially metals for lithium-ion batteries and rare earth metals used in magnets and other components. Journalists may find economic and environmental stories related to new mines and processing centers for these resources. In the U.S., *Physics Today* notes lithium mining projects are active or planned in Arizona, Arkansas, California, Nevada, and North Carolina. Rare earth metal mining prospects exist in Wyoming, Texas, and California, as reported by CNBC and the Wall Street Journal, with research on processing and recycling happening in Iowa and Idaho (where researchers are even looking at using potato wastewater to help recycle rare earth metals).

Rural and colder northern states

Auto registration data gathered by the DOE shows EVs are more popular on the coasts and in more densely populated states, with fewer registrations in colder northern states and large western states. NREL's interactive atlas shows that charging stations remain far apart in the wide, rural spaces of the West. In addition, EVs perform best at temperatures near 70°F, and lose range in hot or cold weather, according to a study by GeoTab, a vehicle analytics firm. At a temperature of 5°F, a typical EV loses 54% of its range, and EVs have a smaller loss on very hot days, too. At lower temperatures, the electrolyte fluid inside the battery cells becomes more sluggish. In conventional ICEVs, waste heat is available to warm the cabin, but efficient EVs produce little waste heat and must use some electricity to keep passengers comfortable. A 2015 study by engineers at Carnegie Mellon University maps how regional climate affects EV range across the U.S., with less range in the north and the hottest regions of the south. But EVs can be popular in cold places if the necessary infrastructure is in place: In Norway, more than 50% of light-duty vehicles sales are battery-electrics.

HOW MUCH DO EVS REDUCE CARBON EMISSIONS IN EACH STATE?

As an EV owner, the amount of pollution you avoid depends on where the power comes from to charge your car. Ultimately, EVs could be powered by renewable energy sources everywhere, but currently fossil fuels still generate 60% of electricity in the U.S. according to the Energy Information Agency (renewables produce 20% and nuclear 20%). On average, even with the current electrical grid, EVs are winners for reducing carbon emissions, but the mix varies widely among the states. The DOE provides a tool that compares carbon emissions for each kind of vehicle in each state. In West Virginia, where 88% of electricity comes from coal, a hybrid is currently a cleaner choice than an EV or plug-in hybrid, but in Vermont, where almost no fossil fuels are used for power generation, EVs produce zero carbon emissions.

GLOSSARY

Battery-Electric Vehicle (BEV) - Runs entirely on stored electricity.

Hybrid (HEV) - Has a battery that is charged by a gasoline or diesel engine and by regenerative braking. Battery cannot be charged from outside the vehicle.

Internal combustion engine vehicle (ICEV) - Runs on a conventional engine powered by gasoline or diesel.

Plug-in Hybrid Vehicle (PHEV) - Can be charged from outside the vehicle to run on electricity, but also has an engine fueled by gasoline or diesel.