Resilient Power Project

ELECTRIC VEHICLES AND EQUITY

How EVs Work, Their Pros and Cons, and the Role They Can Play in Making Our Communities Stronger

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ABOUT THIS REPORT

This Clean Energy Group report is a compilation of a four-part blog series exploring the question of whether electric vehicles can play a role in advancing equity in underserved and historically marginalized communities. The report begins with an overview of electric vehicle costs, performance characteristics, and environmental and health impacts, then considers possible pathways for electric vehicles to deliver tangible benefits to communities, including electric school buses and harnessing energy stored in electric vehicle batteries to power critical services in an emergency. It concludes with a discussion of some of the challenges limiting equitable adoption of electric vehicles and potential solutions to help overcome them.

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Contents

Introduction

It's stunning to think how far electric vehicles (EVs) have come in such a short time. It wasn't long ago (not much more than a decade) that EVs seemed like an oddity, the mere toys of tinkerers and wealthy early adopters rather than a serious transportation option. Today, that's no longer true. Hybrid- and all-electric cars have become a common sight on streets and highways.

And yet, it must be said that EVs remain largely peripheral to the daily lives of most people, especially to those living in disadvantaged and economically challenged communities. They're seen as expensive, for one thing, and some of the leading brands are unapologetically aimed at upscale markets. Furthermore, the ways they can benefit local economies, environmental quality, and public health are rarely recognized or discussed.

So, what do EVs really have to offer if you're among the majority of Americans who would find it challenging to purchase a Tesla?

This report tackles this question in several parts.

Part One looks at how EVs work, and it goes into some detail about their overall cost, performance, and environmental and public health impacts (both positive and negative).

Part Two considers the role EVs can play in meeting the economic, environmental, and public-health needs of communities. It looks at initiatives like electric school buses, which represent one of the leading ways EVs can improve the health of children.

Part Three focuses on a new application of EVs that is just now emerging: bidirectional charging, sometimes referred to as vehicle-to-grid (V2G) or vehicle-to-building (V2B), which can help balance the grid and help communities ride through severe weather events and other natural disasters.

Finally, **Part Four** considers some of the challenges to the adoption of EVs in community settings, including inequitable access to resources, inadequate funding for the vehicles and charging infrastructure, and the need for active support by government, community, and utility partners; and it discusses some guiding principles that should be applied as policymakers and stakeholders seek solutions to overcome them.

Part 1
The EV Revolution: Cost, Performance, Safety, and Environmental Impacts

Electric vehicles have been around for as long as their gasoline- and diesel-powered counterparts, but it's only in the last 10–15 years or so that their cost and performance have improved sufficiently compared to conventional cars that they are becoming attractive for everyday driving needs. In 2021, in fact, some 10 percent of all new cars and light-trucks sold in the United States had electric motors, about one-third of which were powered entirely by batteries; and the proportion is growing fast.

However, this growth has not been equal across all communities. EV sales and ownership levels are disproportionately higher in higher-income regions and among upper-income households. Because of this and the marketing of many EV models as luxury items, it can be challenging to envision how EVs might play a role in bridging equity gaps instead of further widening them. Is there a pathway for EVs to help create more just and equitable communities? We can begin to explore this question by looking at the cost, safety, and environmental impacts of EVs.

Types of EVs

EVs come in many types, from trolley cars powered by overhead lines to subway trains drawing their energy from third rails. Here we are concerned with road vehicles, including cars, vans, trucks, and buses. All have the following three main electrical components (Figure 1):

- an electric motor to drive the wheels
- a battery pack to store electricity and send power to the motor
- a charging system that connects to the grid and charges the battery

Hybrid EVs draw supplemental energy from on-board gasoline engines, making it unnecessary to find places to charge them (though many hybrid models now have plug-in options). But an increasing proportion of EVs sold today are "pure" electric vehicles relying solely on their batteries to provide power.

All EVs have, in addition, sophisticated electronics to manage the power flow from battery to motor to wheels and the ability (with regenerative braking) to recover energy and send it back again to the battery; and they are equipped with familiar driver controls that make it easy for anyone who has driven an ordinary car, bus, or truck to manage their EV versions.

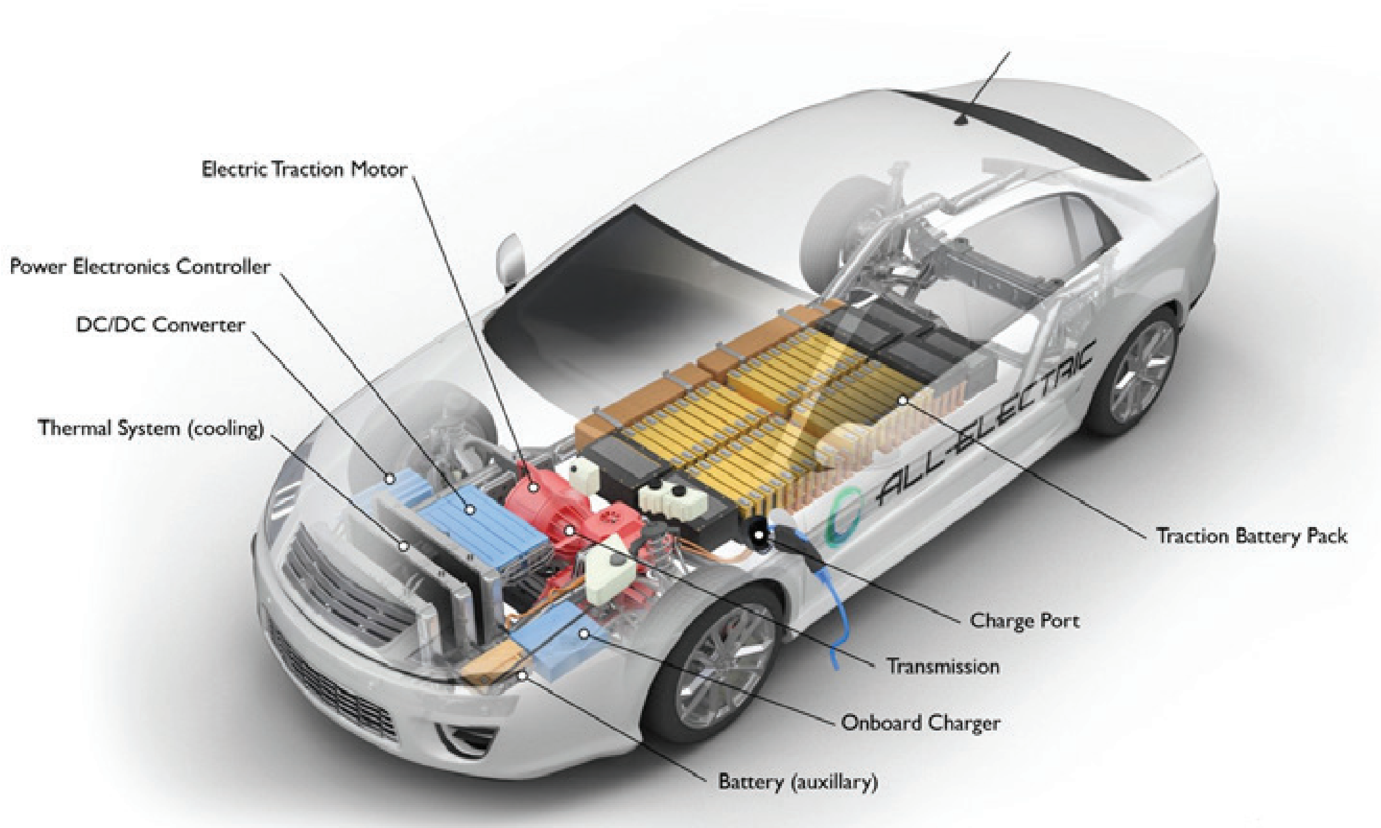

Figure 1. Schematic of an all-electric car including batteries, charging and power conversion system, and electric motor.
Source: US Department of Energy, Alternative Fuels Center.

EVs in the Market

EV sales today are growing rapidly. In 2021, US sales of all-electric vehicles (excluding hybrids) nearly doubled over the previous calendar year, from 238,540 to 459,426, according to US government data (Figure 2, p. 8).[1] Including hybrids, EV sales reached 1.4 million in 2021, 9.5 percent of all car and truck sales in the United States—up from 3.2 percent just five years earlier. The trend is almost certain to continue, and EVs will likely dominate the automotive market within a decade.[2] The State of California, the country's biggest car market, has announced that by 2035, all cars and trucks sold in the state will have to be zero emission vehicles (ZEVs), meaning mainly EVs.[3] And other states are beginning to follow suit.[4]

EV sales reached 1.4 million in 2021, 9.5 percent of all car and truck sales in the United States.

Once popular mainly with environmental first adopters and technology enthusiasts, EVs are spreading to other consumers thanks to their declining cost and improving performance. According to a 2020 survey by Consumer Reports, around a third of American drivers would consider an electric vehicle for their next car or truck purchase.[5] The Federal Government has set a goal that half of all vehicles sold in 2030 will be ZEVs, mainly EVs.

The recent leader in this EV revolution has been Tesla, whose sleek and sporty cars have become a familiar sight on many US roads. But now nearly all auto makers have EV editions of their cars, trucks, buses, and other vehicles. The best-selling vehicle—truck or car—in the US, the Ford F-150, now comes in an EV version, the F-150 Lightning. Other popular examples include early pioneers such as the Nissan Leaf and relative latecomers such as the Hyundai Kona Electric, Kia EV6, and Rivian R1S SUV and R1T pickup truck. Even the iconic Ford Mustang comes in an EV version: the Mach-E, which was named one of Consumer Reports' Top 10 cars of 2022.[6]

1 United States Department of Transportation, "New and Used Passenger Car and Light Truck Sales and Leases," U.S. Bureau of Transportation Statistics, n.d., https://www.bts.gov/content/new-and-used-passenger-car-sales-and-leases-thousands-vehicles (accessed February 15, 2023). Other sources may differ.

2 Brad Plumer, Nadja Popovich and Blacki Migliozzi, "Electric Cars Are Coming. How Long Until They Rule the Road?," The New York Times, March 10, 2021, https://www.nytimes.com/interactive/2021/03/10/climate/electric-vehicle-fleet-turnover.html (accessed February 15, 2023).

3 Office of Governor Gavin Newsom, "California Enacts World-Leading Plan to Achieve 100 Percent Zero-Emission Vehicles by 2035, Cut Pollution," CA.gov, August 25, 2022, https://www.gov.ca.gov/2022/08/25/california-enacts-world-leading-plan-to-achieve-100-percent-zero-emission-vehicles-by-2035-cut-pollution (accessed February 15, 2023).

4 Mercado, Angely, "Washington and Massachusetts Mull Bans of New Gas-Powered Cars, Following California," Gizmodo.com, August 30, 2022, https://gizmodo.com/washington-massachusetts-gas-car-ban-california-1849473603 (accessed February 15, 2023).

5 "New Consumer Reports survey finds majority of drivers are interested in electric vehicles," Consumer Reports Advocacy, December 17, 2020, https://advocacy.consumerreports.org/press_release/new-consumer-reports-survey-finds-most-drivers-are-interested-in-electric-vehicles (accessed February 15, 2023).

6 Healey, James R., "Consumer Reports Rates 10 Best Vehicles for 2021," AARP.org, March 16, 2021, https://www.aarp.org/auto/car-buying/info-2021/consumer-reports-top-vehicles.html (accessed February 15, 2023). Bartlett, Jeff S., "Best Cars of the Year: 10 Top Picks of 2022," ConsumerReports.org, February 16, 2023, https://www.consumerreports.org/cars-best-cars-top-picks-2022 (accessed February 17, 2023).

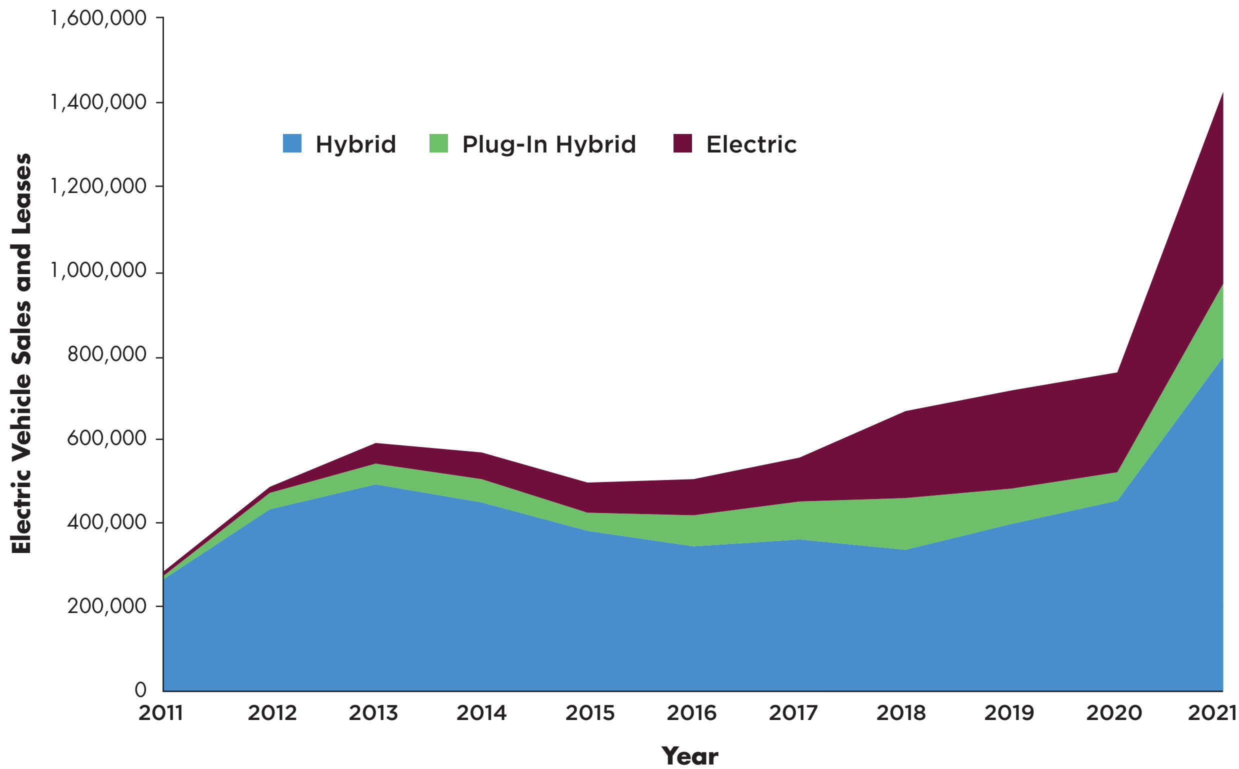

Figure 2. Sales and leases of new electric vehicles in the United States, 2011–2021.
Source: US Bureau of Transportation Statistics.

The Cost of Owning EVs

With their hefty battery packs, electric cars and other vehicles generally cost more upfront than their gasoline- and diesel-powered counterparts. At the same time, they cost less to drive—both in maintenance and in fuel costs. While the comparison depends on details such as financing costs and depreciation, the cost of fuel and electricity, and other factors, studies show that the total lifetime cost of owning gasoline-powered vehicles and EVs are similar. For example, in its 2022 "Your Driving Costs" study, the American Automobile Association (AAA) put electric vehicles in the second-lowest overall total cost category per mile driven, at 60.32 cents/mile, above small sedans (54.56 cents/mile) and below the average car (71.52 cents/mile), for vehicles driven 15,000 miles a year.[7] This comparison includes tax credits that make EVs cheaper for some, but not all, buyers.[8] Excluding tax credits puts the total EV ownership cost in the middle of the pack (Figure 3, p. 9).

7 "Your Driving Costs 2022," aaa.com, August 2022, https://newsroom.aaa.com/wp-content/uploads/2022/08/2022-YourDrivingCosts-FactSheet-7-1.pdf (accessed February 15, 2023). The costs in each type are defined, in accordance with AAA's method, by 5 top-selling vehicle models selected by AAA. AAA provides a driving cost calculator for individual car models at "Check Out the New AAA Used EV Buyer's Guide," aaa.com, n.d., https://www.aaa.com/autorepair/drivingcosts (accessed February 13, 2023).

8 The Federal tax credit for new cars starts at $417 for a car with a 5-kWh battery and increases by $417 for each kilowatt-hour in increased battery capacity, up to $7500. Most standard hybrid cars have much smaller batteries than this, though plug-in hybrids (PHEVs), which are becoming more popular, have larger batteries. A typical all-electric EV has a battery capacity of 50–100 kWh.

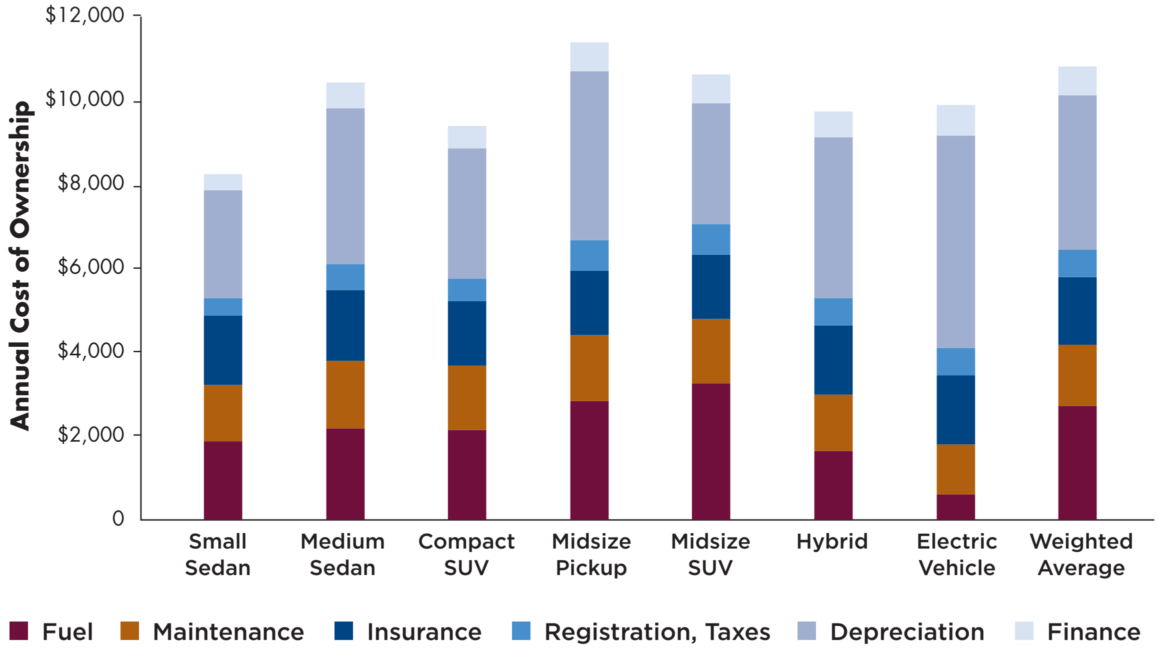

Figure 3. Annual cost of owning a new vehicle for selected vehicle types, broken down by operating costs (fuel and maintenance) and ownership costs (insurance, registration and taxes, depreciation, and finance). Assumes 15,000 miles/year. Following the AAA method, characteristics of a given vehicle type are represented by five top-selling models selected by AAA. To remove the effect of tax credits from the comparison, the registration and tax costs for EVs in this chart have been set equal to those for hybrid cars, whose battery sizes are generally too small to benefit from a significant credit.
Source: American Automobile Association, "Your Driving Costs" (2022).

Let's start with the upfront cost. While it's not always easy to make head-to-head comparisons, new electric cars typically cost about $10,000-$15,000 more to buy than their conventional equivalents. For example, according to Car and Driver, in October 2022, a "basic" Hyundai Kona Electric was priced $12,700 above the conventional Kona, whereas the Ford F-150 Lightning with XLT trim was $13,800 more than the same version of the F-150.[9] On an industry average basis, the gap is larger, in part because many EVs—like Tesla—tend to be aimed at the luxury market. Kelly Blue Book reports that the average new EV sale price reached $65,290 in September 2022, $17,200 more than the industry-average new car.[10]

While the gap is substantial, tax credits and other incentives can help close it. Since 2010, the federal government has offered a tax credit of up to $7,500 for buyers of new electric cars and trucks. This credit, which was due to expire in 2021, was extended another 10 years to 2032 with the passage of the 2022 Inflation Reduction Act (IRA).

9 Not all EVs have conventional equivalents. For those that do, some manufacturers charge a smaller price premium, and others a larger one. See: Roberto Baldwin, Sasha Richie and Dave VanderWerp, "EV vs. Gas: Which Cars Are Cheaper to Own?" CarAndDriver.com, October 28, 2022, https://www.caranddriver.com/shopping-advice/a32494027/ev-vs-gas-cheaper-to-own (accessed February 13, 2023).

10 Cox Automotive, "Data Tables for September 2022 Kelley Blue Book Average Transaction Prices Report," coxautoinc.com, September 10, 2022, https://www.coxautoinc.com/wp-content/uploads/2022/10/Sept-2022-Kelley-Blue-Book-Average-Transaction-Price-data-tables.pdf (accessed February 13, 2023).

The IRA also introduced a one-time tax credit of up to $4,000 for buyers of used electric cars more than two years old, and it expanded the new-vehicle credits to include commercial vehicles for the first time.[11]

On top of the Federal tax credit, 31 states and the District of Columbia offer rebates or other incentives for owning an electric car or plug-in hybrid, according to the North Carolina Clean Energy Center.[12] In Massachusetts, for example, electric car buyers can receive a $2,500 rebate on a new EV if the purchase price is less than $50,000.[13] Combining both federal and state incentives, it may be possible to reduce the typical $10,000–$15,000 gap in up-front cost by one-half or more.

On top of the Federal tax credit, 31 states and the District of Columbia offer rebates or other incentives for owning an electric car or plug-in hybrid.

Unfortunately, the federal EV tax credit—including the one for used cars—benefits only those buyers who pay enough in federal taxes to be able to use them. Any unused credit cannot be refunded or carried over from one tax year to the next. This leaves many potential buyers—especially those of lower income—having to pay full price for EVs. There is discussion of changing this rule to allow credits to be applied at the point of sale, regardless of income tax owed, but no such change has been implemented yet. On the other hand, the IRA places limits on the maximum adjusted gross income for car buyers and on the purchase price of EVs to qualify for the tax credits, which are intended to encourage sales of less expensive vehicles to middle-income buyers.[14]

At the same time, EVs offer big savings in operating costs. The average cost of "fueling" electric cars is typically one-third that of gasoline and diesel cars, or less, depending on the type of EV and how and where it is recharged, the type of conventional car, and local prices of electricity and gasoline or diesel fuel. Because they have many fewer moving parts (such as pistons and transmissions) requiring lubricating fluids and prone to wearing

11 Unfortunately, the rules governing the new- and used-vehicle credits, which include price caps and local-content requirements, are complicated, and not every electric vehicle qualifies. A good summary of the tax credit rules and list of qualifying 2022 and 2023 vehicle models are available at Doll, Scooter, "Here's every electric vehicle that qualifies for the current US federal tax credit," Elektrek, February 3, 2023, https://electrek.co/2022/11/16/which-electric-vehicles-still-qualify-for-us-federal-tax-credit (accessed February 15, 2023). See also: "Credits for New Electric Vehicles Purchased in 2022 or Before," IRS.gov, n.d., https://www.irs.gov/businesses/plug-in-electric-vehicle-credit-irc-30-and-irc-30d (accessed February 15, 2023).

12 The North Carolina Clean Energy Technology Center maintains a database of available EV financial incentives in the United States. A summary can be found here: "Passenger Electric Vehicle Incentives," North Carolina Clean Energy Technology Center, August 2021, https://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2021/08/DSIRE_EV_August2021.pdf (accessed February 16, 2023). See also: Meyer, Susan, "Going Green: States with the Best Electric Vehicle Tax Incentives," TheZebra.com, July 7, 2022, https://www.thezebra.com/resources/personal-finance/best-ev-tax-rebates-by-state (accessed February 14, 2023).

13 Massachusetts Offers Rebates for Electric Vehicles (MOR-EV), "Frequently Asked Questions," mor-ev.org, n.d., https://mor-ev.org/frequently-asked-questions#Application9 (accessed February 16, 2023).

14 Domonoske, Camila, "Buying an electric car? You can get a $7,500 tax credit, but it won't be easy," NPR.org, February 3, 2023, https://www.npr.org/2023/01/07/1147209505/electric-car-tax-credit-climate-bill-tesla-volkswagen-ev (accessed February 15, 2023).

out or failing, their maintenance costs are also lower than those of conventional cars. AAA estimates the average fueling cost of EVs at 4.04 cents/mile driven, compared to 12.51 cents/mile for the cheapest conventional category, small sedans. Combined with maintenance, the operating cost of EVs is 11.98 cents/mile, nearly 10 cents/mile less than small conventional sedans at 21.38 cents/mile. In a year of driving 15,000 miles, that amounts to an annual average savings of $1,410. Over 10 years, the savings can more than compensate for the additional up-front cost of EVs, especially if incentives such as tax credits are available.

Performance Characteristics

EVs have both positive and negative performance aspects as well. On the plus side, they can achieve better acceleration than most gasoline- and diesel-powered cars, thanks to the high torque generated by electric motors. As of mid-2021, the Tesla Model S "Plaid" held the world time record for 0-60 mph (1.98s), just beating out a number of luxury Ferraris, Porsches, Lamborghinis, and Bugatis.[15] What's more, because their motors work well over a wide range of RPM, they need no transmissions, making them simpler to operate and maintain and less prone to breakdowns.

On the other hand, EVs generally have a shorter driving range than their conventional counterparts. The median range for EV cars on a single charge is 230 miles,[16] whereas a comparable gasoline-powered car can drive about 400 miles on a tank of gasoline. Long-range EVs exist (e.g., the Tesla Model 3 Long Range can go 345 miles on a single charge), but they require more batteries and therefore cost more. Their limited range and the lack of public charging options in some areas can create "range anxiety" among EV owners and prospective buyers, which discourages EV use.

For most everyday driving needs, the usual EV range is more than enough, especially if the car or truck can be plugged in at a home or at a commuter charging station.

The challenge of limited range is compounded by the fact that it can take much longer to fully charge an EV than to fill the tank of a conventional car or truck. The fastest-charging "Level 3" stations can charge a typical EV in 15 minutes to an hour, but they are still relatively uncommon. "Level 2" stations offer a full charge in several hours and are becoming more widespread at sites where commuters and employees can leave their cars plugged in much of the day (see Figure 4, p.8). "Level 1" chargers run off standard house current and are the slowest, typically requiring 1-2 days for a full charge.

However, for most everyday driving needs, the usual EV range is more than enough, especially if the car or truck can be plugged in at a home or at a commuter charging

15 Seabaugh, Christian, "2022 Tesla Model S Plaid First Test: 0–60 MPH in 1.98 Seconds*!," MotorTrend.com, June 17, 2021, https://www.motortrend.com/reviews/2022-tesla-model-s-plaid-first-test-review (accessed February 15, 2023).

16 Elfalan, Jonathan, "Edmunds Tested: Electric Car Range and ConsumptionReal World vs. EPA," edmunds.com, February 9, 2021, https://www.edmunds.com/car-news/electric-car-range-and-consumption-epa-vs-edmunds.html (accessed February 15, 2023).

Figure 4. Two approaches to EV charging: Left: The Tesla network of Level 3 fast charging stations can deliver 100 miles of range in 10 minutes, ideal for highway settings. Right: Community curbside charging, such as this prototype Level 2 charger from Itselectric, delivers the same range in about 4 hours, and is more suited to workplace and home.

Left: 24K-Production/Bigstock. Right: Itselectric, used with permission.

station from time to time. The average daily driving distance in the United States is only about 40 miles, just a fifth of a typical EV's range.[17] Consequently, a once- or twice-a-week charging schedule works for most people.

At the same time, the availability of Level 2 and Level 3 charging stations is rapidly increasing. Some EV manufacturers, like Tesla and Ford, have invested in their own Level 3 networks to encourage vehicle sales. In addition, the federal National Electric Vehicle Infrastructure (NEVI) Formula program, signed into law in 2021, is providing $5 billion to fund a fast-charging Level 3 network every 50 miles of national highway. So far, 35 state plans have been approved to receive funding.[18]

A variety of state and local initiatives are also under way to make publicly accessible Level 2 chargers more widely available. New York City, for example, has deployed over 100 public Level 2 chargers in curbside and other accessible locations.[19] Smaller towns such as Malden, Massachusetts, are following suit.[20] A federal fund of $2.5 billion (the Discretionary Grant Program for Charging and Fueling Infrastructure) is aimed specifically at funding these initiatives, with 40 percent being reserved for disadvantaged communities.

17 The average annual driving distance is 15,000 miles, implying an average daily distance of about 40 miles.

18 For a summary of Federal funding programs for EV charging, see: "Federal Funding Programs," U.S. Department of Transportation, February 2, 2022, https://www.transportation.gov/rural/ev/toolkit/ev-infrastructure-funding-and-financing/federal-funding-programs (accessed February 16, 2023), and Federal Highway Administration, "Biden-Harris Administration Announces Approval of First 35 State Plans to Build Out EV Charging Infrastructure Across 53,000 Miles of Highways," U.S. Department of Transportation, September 14, 2022, https://highways.dot.gov/newsroom/biden-harris-administration-announces-approval-first-35-state-plans-build-out-ev-charging (accessed February 15, 2023).

19 "New York City Department of Transportation, "Motorists & Parking: Electric Vehicles," nyc.gov, 2023, https://www.nyc.gov/html/dot/html/motorist/electric-vehicles.shtml#/find/nearest (accessed February 15, 2023).

20 "Electric Vehicle Charging Stations," cityofmalden.org , n.d., https://www.cityofmalden.org/963/Electric-Vehicle-Charging-Stations (accessed February 15, 2023).

Aside from these public initiatives, many home and business owners are opting to install Level 1 and 2 chargers on their own property. The cost need not be prohibitive. The average installation cost for a Level 1 charger – which can be plugged into any 120V outlet —is just $300–$600, according to Fixr.com. A Level 2 charger, which requires a 240V outlet, is pricier at $600–$1,200. Additional costs may be incurred if work is needed to install an outlet near where the EV is parked.[21]

And yet, home-based charging is not an option for many renters and apartment dwellers, as well as others without a garage or private parking space. This has led to what some observes call a "desert" of low-cost charging options in urban centers as well as economically challenged and historically marginalized communities.[23] Along with the higher up-front cost of EVs and the limited applicability of tax credits, this further discourages the adoption of EVs by people living in such communities. Focused effort and targeted resources are needed to address this gap.

Safety Considerations

The main difference between conventional and electric vehicles from a safety standpoint is that EVs have battery packs, whereas conventional cars have fuel tanks. News stories about battery fires tend to grab the public's attention, but gasoline and diesel fuel carry their own safety risks. Conventional cars sometimes catch fire (over 100,000 automotive fires occur each year),[23] and gasoline alone is implicated in over 10,000 deaths annually, mainly from burns and chemical poisonings.[24] In the long run, reducing the use and prevalence of gasoline and other petroleum products in our transportation economy may be one of the most significant health and safety benefits of the EV revolution.

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However, EV batteries also present safety hazards, notably related to fire and electric shock. Lithium-ion batteries store an enormous amount of energy in a relatively small package, and consequently, battery fires can be very difficult to extinguish. In one much-publicized incident, the battery pack in a Tesla car that had been damaged in an accident caught fire weeks later in a California junkyard. After

21 Reviewed by Paul Schwalbe, "How Much Does It Cost to Install an Electric Vehicle Charging Station at Home?," Fixr.com, November 30, 2022, https://www.fixr.com/costs/home-electric-vehicle-charging-station (accessed February 16, 2023).

22 Englund, Will, "Without access to charging stations, Black and Hispanic communities may be left behind in the era of electric vehicles," WashingtonPost.com, December 9, 2021, https://www.washingtonpost.com/business/2021/12/09/charging-deserts-evs (accessed February 15, 2023).

23 Dyer, Ezra, "No, Millions of Cars Are Not Catching Fire Every Year," CarAndDriver.com, June 2, 2022, https://www.caranddriver.com/news/a40163966/cars-catching-fire-new-york-times-real-statistics (accessed February 14, 2023).

24 Drago, Dorothy A., "Gasoline-related injuries and fatalities in the United States, 1995-2014," International Journal of Injury Control and Safety Promotion, February 12, 2018, https://www.tandfonline.com/doi/full/10.1080/17457300.2018.1431947 (accessed February 15, 2023).

multiple attempts to put the 3,000°F fire out, the local fire department finally had to submerge the car in a pit filled with water.[25]

Such incidents are nonetheless rare. Though objective data are elusive, the risk of fire appears to be far lower for EVs than for conventional vehicles. Tesla claims a rate of one vehicle fire per 210 million miles driven for its cars compared to one fire per 19 million miles for conventional cars.[26] One reason this may be is that gasoline catches fire much more easily than batteries do: all that is needed is a spark coming into contact with fuel from a ruptured tank. Another reason may be that battery packs are encased in crash-resistant housings which protect them from damage in most accidents. The shock risk is also low, as the high-voltage circuitry (ranging from 100 to 600 volts dc) of EVs is shielded by insulation and designed to shut down immediately when there is a disruption.

Environmental Benefits and Risks of EVs

Performance, price, and cost of ownership are not the only things consumers care about when they consider buying an EV.

A big reason EVs are becoming popular is their substantial environmental benefits. Since they don't burn fuel, EVs emit no tailpipe pollution that might be breathed in by their passengers or other motorists and pedestrians. The American Lung Association

25 Mark, Julian, "A Tesla was in a junkyard for three weeks. Then it burst into flames," WashingtonPost.com, June 22, 2022, https://www.washingtonpost.com/nation/2022/06/22/tesla-fire-sacramento (accessed February 16, 2023).

26 Kane, Mark, "Statistically, Tesla Car Fires Are Less And Less Frequent," May 9, 2022, insideevs.com, https://insideevs.com/news/584722/tesla-car-fires-statistic-2021 (accessed February 14, 2023).

(ALA), among other public health groups, has estimated the health damage of automotive air pollution (including nitrogen oxides, volatile organic compounds, and fine particulate matter) and the potential benefits to human health of replacing gasoline- and diesel-powered vehicles with electric vehicles.[27] They find that over the 30-year period from 2020 to 2050, transitioning to EVs and non-combustion sources of electricity would avoid 110,000 premature deaths, 2.7 million asthma attacks, and 13.4 million lost work days, as well as some $1.2 trillion in economic damage. According to the ALA study, the transition to EVs would disproportionately benefit low- and medium-income communities and people of color, who are more likely to live in densely populated areas and near transportation corridors.

Even considering the emissions from power plants that generate the power used by EVs, they are much cleaner than conventional cars.[28] Per mile driven, for example, EVs are typically responsible for less than half the greenhouse gas (GHG) emissions of gasoline powered cars. This is both because power plants run more efficiently than gasoline engines, and because a portion of the electricity we use comes from non-fossil-fuel sources (hydro, renewables, and nuclear). In fact, if they are recharged entirely from renewable energy sources such as wind and solar, the GHG emissions of EVs drop to zero. Hence, moving from conventional vehicles to EVs not only directly benefits human health, but it also helps mitigate climate change.

Like every technology, EVs have negative environmental impacts as well. Just like conventional cars and trucks, they are made of steel, plastics, and other materials whose manufacture consumes energy and produces pollution. In addition, almost all EVs today employ lithium-ion batteries. The mining of lithium and other materials in these batteries can have severe impacts on local communities, including the diversion of scarce water supplies from human needs and toxic chemical spills, as well as (in some countries) abusive labor practices such as the use of child labor.[29] The recycling and safe disposal of used lithium and other battery materials such as nickel and cobalt are also lagging the rapid growth in EV use.

Despite the issues with lithium-ion batteries, many environmental advocates support transitioning to EVs while also urging the industry to accelerate the development of more efficient recycling processes and more sustainable battery alternatives.

27 "Zeroing in on Healthy Air," American Lung Association, 2022, https://www.lung.org/getmedia/13248145-06f0-4e35-b79b-6dfacfd29a71/zeroingin-on-healthy-air-report-2022 (accessed February 14, 2023). In the ALA base case scenario, it is assumed that 100% of new light-duty vehicles (including cars, vans, and pickup trucks) sold will be all-electric by 2035, medium- and heavy-duty vehicles (including buses and trucks) will reach that milestone by 2040.

28 "Electric Vehicle Myths," United States Environmental Protection Agency, December 22, 2022, https://www.epa.gov/greenvehicles/electric-vehicle-myths (accessed February 14, 2023). This online emissions calculator allows the GHG emissions of different EV models to be compared with conventional cars: "Greenhouse Gas Emissions from Electric and Plug-In Hybrid Vehicles – Results," United States Department of Energy - Office of Energy Efficiency & Renewable Energy and United States Environmental Protection Agency, n.d., https://www.fueleconomy.gov/feg/Find.do?year=2022&vehicleId=45140&zipCode=02446&action=bt3 (accessed February 17, 2023).

29 Katwala, Amit, "The spiraling environmental cost of our lithium battery addiction," wired.co.uk, May 8, 2018, https://www.wired.co.uk/article/lithium-batteries-environment-impact (accessed February 17, 2023).

Part 2
Electric Vehicles in the Community: Benefits and Barriers

When environmental problems and disasters strike, they often hit disadvantaged communities the hardest. Whether it's diesel fumes from aging school buses or hurricanes causing massive flooding and power outages, communities that are home to predominantly low-income people and people of color often bear the brunt of the consequences.[30]

EVs for community use—including electric buses, vans, trucks, and ordinary passenger cars—represent an important opportunity for mitigating these problems. They can help lower the costs of delivering community services while reducing the exposure of children, the elderly, and other vulnerable groups to harmful air pollutants. With two-way charging,

30 Sellers, Chris, "Storms hit poorer people harder, from Superstorm Sandy to Hurricane Maria," TheConversation.org, November 19, 2017, https://theconversation.com/storms-hit-poorer-people-harder-from-superstorm-sandy-to-hurricane-maria-87658 (accessed March 30, 2023). Masri, Shahir et al, "Disproportionate Impacts of Wildfires among Elderly and Low-Income Communities in California from 2000–2020," International Journal of Environmental Research and Public Health, April 8, 2021, https://www.mdpi.com/1660-4601/18/8/3921 (accessed March 30, 2023).

they can even help make electric power grids more resilient and protect against extended power outages, which can leave communities without access to health services, safe food, drinking water, medicines, and other essentials.

This section delves into the opportunities for EVs that are within reach for many communities and the economic, environmental, and public health benefits they can provide.

Air Pollution and Public Health

People from all walks of life care deeply about the effects of pollution, specifically air pollution, on their health and wellbeing. According to Gallup, for example, some 75 percent of Americans surveyed in 2018 report being concerned either a "great deal" or a "fair amount" by air pollution.[31] Air pollution is typically viewed as more urgent and having a greater immediate impact on health and wellbeing than other issues such as climate change.

Public concern reflects the reality that—although pollution levels have come down enormously in the decades since the Clean Air Act was passed in 1963—air pollution still causes significant health problems. According to the Environmental Protection Agency (EPA), over 100 million Americans (nearly one in three) live in counties where the air quality fails to meet health standards.[32] Studies show that fine particulate matter ($PM_{2.5}$) and ozone (O_3), two especially harmful byproducts of combustion, cause some 100,000–200,000 premature deaths in the United States annually.[33] About a quarter of these deaths are due to emissions from road vehicles. Air pollutants, most importantly fine particulates, are also responsible for millions of asthma attacks and other respiratory health complications every year and are implicated in delayed cognitive development and growth in children.[34]

Lower income households and communities of color often experience greater exposure to air pollutants and, just as important, have fewer resources to address their health impacts.

31 "Environment," Gallup.com, 2023, https://news.gallup.com/poll/1615/environment.aspx (accessed March 30, 2023).

32 "Air Quality—National Summary," United States Environmental Protection Agency, June 21, 2022, https://www.epa.gov/air-trends/air-quality-national-summary (accessed March 30, 2023).

33 Caiazzo ,Fabio, et al, Air pollution and early deaths in the United States. Part I: Quantifying the impact of major sectors in 2005," Atmospheric Environment, November 2013, https://www.sciencedirect.com/science/article/pii/S1352231013004548 (accessed March 30, 2023). Fann, Neal, et al, "Estimating the national public health burden associated with exposure to ambient $PM_{2.5}$ and ozone," Society for Risk Analysis, January 2012, https://pubmed.ncbi.nlm.nih.gov/21627672 (accessed March 30, 2023). These estimates are based on pollution levels in 2005. The great majority—around 95%—of estimated premature mortality is caused by particulate matter.

34 "Air Pollution and Your Health," National Institute of Environmental Health Sciences, March 23, 2023, https://www.niehs.nih.gov/health/topics/agents/air-pollution/index.cfm (accessed March 30, 2023). "Health and Environmental Effects of Particulate Matter (PM)," United States Environmental Protection Agency, August 30, 2022, https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm (accessed March 30, 2023). "Zeroing in on Healthy Air," American Lung Association, 2022, https://www.lung.org/getmedia/13248145-06f0-4e35-b79b-6dfacfd29a71/zeroingin-on-healthy-air-report-2022 (accessed March 30, 2023).

As bad as that sounds, the American Lung Association observes that "the burden of air pollution is not evenly shared."[35] Lower income households and communities of color often experience greater exposure to air pollutants and, just as important, have fewer resources to address their health impacts. An EPA-funded study published in 2019 concluded that people of color, on average, are exposed to about 25 percent more fine particulate matter than Whites.[36] Among Blacks, average exposure is 34 percent higher than for Whites. Nor do the averages tell the whole story: The research shows that people of color are over *three times* more likely to be exposed to the highest concentrations of harmful air pollutants than Whites.[37]

In the transportation sector, replacing diesel trucks and buses with EVs presents one of the biggest single opportunities for reducing pollutant exposures in communities

The disparity in exposure is not primarily driven by income, as some might assume. As one of the co-authors of the EPA-funded study notes, "Because the data shows that the racial disparities hold for all income levels, our study reinforces previous findings that race/ethnicity, independently of income, drives air pollution-exposure disparities." Compared to Whites, people of color tend to be more exposed to pollutants associated with industrial and urban activity. As another co-author stated, "The inequities we report are a result of systemic racism: Over time, people of color and pollution have been pushed together, not just in a few cases but for nearly all types of emissions."[38] (See Figure 5. p.19.)

While road vehicles are not the only source of harmful air pollution—industry, coal-fired power generation, and construction make important contributions—they are one source of pollution that communities can take direct action to address. Lacking tailpipes, electric vehicles—including school buses, vans, and passenger vehicles—directly eliminate harmful pollutant emissions including particulates, ozone, carbon monoxide, and nitrogen oxides. In the transportation sector, replacing diesel trucks and buses with EVs presents one of the biggest single opportunities for reducing pollutant exposures in communities, for they produce far more fine particulates than do gasoline vehicles.

35 "Disparities in the Impact of Air Pollution," American Lung Association, November 17, 2022, https://www.lung.org/clean-air/outdoors/who-is-at-risk/disparities (accessed March 30, 2023).

36 Tessum, Christopher W., et al, "PM2.5 polluters disproportionately and systemically affect people of color in the United States," Science Advances, April 28, 2021, https://www.science.org/doi/10.1126/sciadv.abf4491 (accessed March 30, 2023). "Study Finds Exposure to Air Pollution Higher for People of Color Regardless of Region or Income," United States Environmental Protection Agency, September 20, 2021, https://www.epa.gov/sciencematters/study-finds-exposure-air-pollution-higher-people-color-regardless-region-or-income (accessed March 30, 2023).

37 "State of the Air 2021," American Lung Association, 2021, https://www.lung.org/getmedia/17c6cb6c-8a38-42a7-a3b0-6744011da370/sota-2021.pdf (accessed March 30, 2023).

38 "Study Finds Exposure to Air Pollution Higher for People of Color Regardless of Region or Income," United States Environmental Protection Agency, September 20, 2021, https://www.epa.gov/sciencematters/study-finds-exposure-air-pollution-higher-people-color-regardless-region-or-income (accessed March 30, 2023).

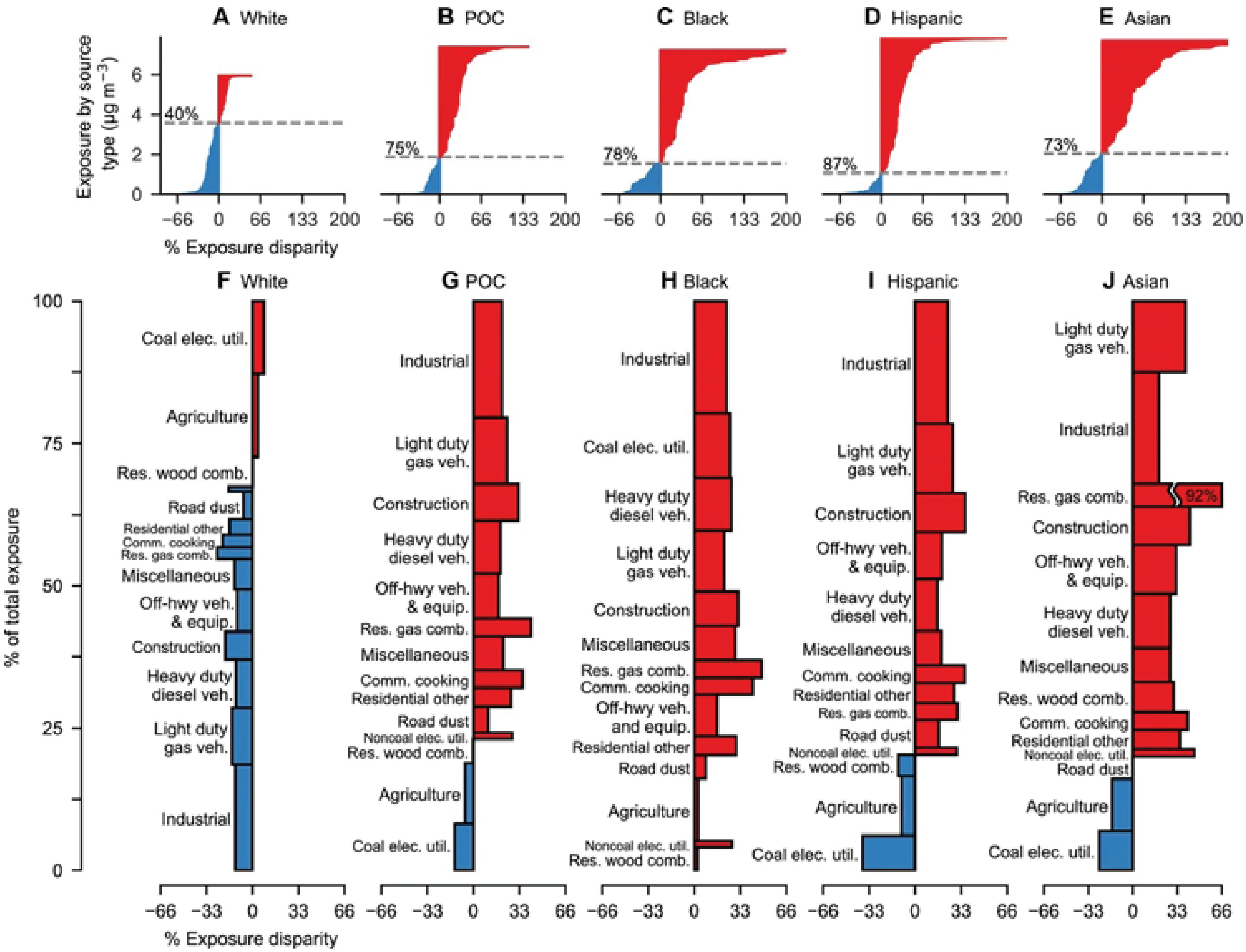

Figure 5. Results of an EPA-funded study by researchers at several universities, which estimated the relative exposure to $PM_{2.5}$ of people in 5 groupings: White, People of Color, Black, Hispanic, and Asian. The charts show the proportion of members of each group exposed to above-average (red bars) or below-average (blue bars) concentrations of pollutants both in absolute (charts A–E) and relative (charts F–J) terms.

Source: https://www.science.org/doi/10.1126/sciadv.abf4491

Cost Savings

Besides addressing an important public health hazard, electric vehicles can help communities meet their budget challenges. They can lower vehicle fueling costs by half, or more, thanks to their higher efficiency and the lower cost of electricity per unit of energy delivered compared to gasoline or diesel fuel. Counting all operating expenses including insurance, tires, registration, and maintenance, they are typically 25 percent less expensive to run than their conventional equivalents. As an illustration, Table 1 (p. 20) compares the operating characteristics of two vehicle types with gasoline and EV versions: the Ford F-150 pickup and the Hyundai Kona.

Vehicle	Annual Fuel Use (gallons)	Annual Electricity Use (kWh)	Annual Fuel /Electricity Cost	Annual Operating Cost	Cost Per Mile	Annual Emissions (lbs CO_2)
2022 Ford F-150 Lightning 4WD EV	0	6,069	$1,182	$3,290	$0.27	3,276
2022 Ford F-150 Pickup 4WD Gasoline	586	0	$2,262	$4,523	$0.38	14,062
2022 Hyundai Kona Electric EV	0	3,452	$672	$2,780	$0.23	1,864
2022 Hyundai Kona AWD Gasoline	392	0	$1,515	$3,776	$0.31	9,418

Table 1. Comparison of fuel and operating costs of EV and gasoline versions of two leading vehicle models. Assumptions: Gasoline $3.86/gallon (national average price for mid-grade gasoline as of February 10, 2023, according to the American Automobile Association). Electricity $0.195/kWh (based on New York State prices). Annual miles driven: 12,000 (5,316 city, 6,684 highway).

Source: US DOE Alternative Fuels Data Center calculator (2023).

As discussed in Part 1, the upfront cost of EVs tends to be higher than for conventional vehicles, but the total cost of ownership is generally similar. What's more, the greater the annual and cumulative mileage, the more the cost comparison favors EVs. For the vehicles shown in Figure 6 (p. 21), the Hyundai Kona EV is more expensive to own than the conventional Kona over the first 12 years, after that becoming less expensive, whereas the F-150 Lightning is less expensive to own than the conventional F-150 over nearly the entire life of the vehicles. These comparisons assume no incentives, such as tax credits or grants, to reduce the purchase cost. Where such incentives are available, EV ownership can be very attractive indeed.

EVs can create opportunities for additional operating cost savings when recharged with cheaper power, which is often available at night when most community-serving vehicles are not being used. Under some utility rate programs, the power stored in EV batteries can be sold back to the grid when not needed if the vehicles are equipped with two-way, or bidirectional, charging systems (see Part 3 for more on bidirectional charging). School buses and other community vehicles have daily use profiles that are well suited to such "peak-shaving" strategies, which increase the reliability of the grid and lower electricity costs for all community members.

Transitioning to EVs: Progress and Barriers

Like many consumers, communities are beginning to realize the potential opportunities offered by EVs for addressing their public health and economic needs. Two important strategies are, first, encouraging the adoption of EVs by community residents and businesses, and second, transitioning community-owned vehicle fleets to EVs. Unfortunately, progress toward adoption of EVs at the community level is slow and uneven due to a variety of challenges and barriers.

Nowhere are the advantages of EVs and the opportunities for community adoption more attractive than with electric school buses. They have become the focal point for a nationwide push led by the EPA and other state, federal, and local agencies, which is now reaching hundreds of school districts.

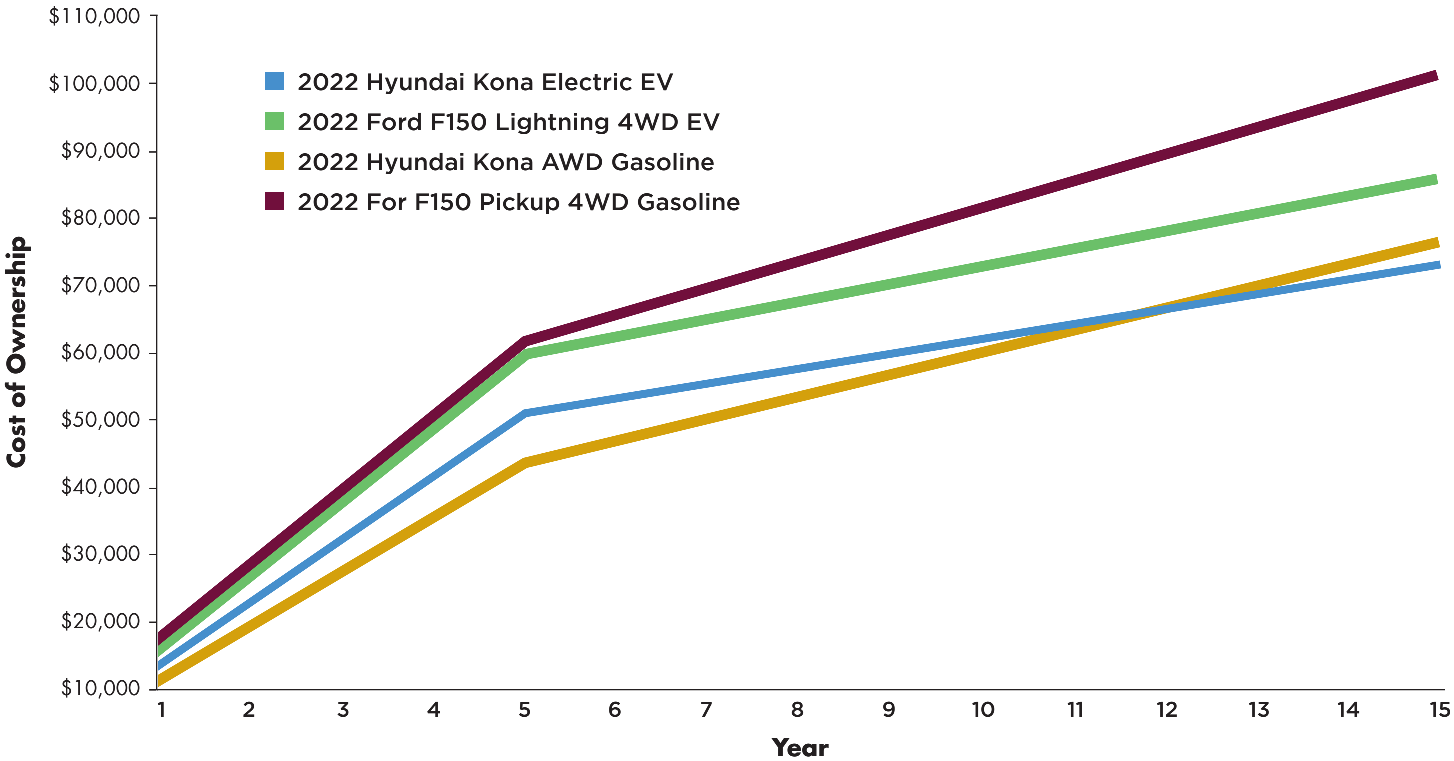

Figure 6. Cumulative total cost of ownership over 15 years for the same four vehicles shown in Table 1, assuming they are driven 15,000 miles per year. The purchase price of each vehicle is assumed to be financed over five years with 10 percent down payment. The chart assumes no tax credits or other incentives for EV ownership.
Source: US DOE Alternative Fuels Data Center calculator (2023).

The public health case for electric school buses is strong. Every school day, some 20 million children are exposed to harmful fumes from school buses. A study by the Natural Resources Defense Council highlights the following finding:

> We estimate that for every one million children riding the school bus for 1 or 2 hours each day during the school year, 23 to 46 children may eventually develop cancer from the excess diesel exhaust they inhale on their way to and from school. This means a child riding a school bus is being exposed to as much as 46 times the cancer risk considered "significant" by EPA and under federal law.[39]

Most school buses run on diesel fuel, and the particulate matter emitted from their tailpipes (which can accumulate inside the buses) is believed likely to affect brain development and contribute to asthma and other ailments that take children out of school.[40] Sadly, the very means many children use to get to school may affect their ability to thrive there.

39 MacMillan, Amanda, "The Long Road to Safer School Buses," National Resources Defense Council, March 15, 2016, https://www.nrdc.org/stories/long-road-safer-school-buses (accessed March 30, 2023). "Emissions From School Buses Increase Pollution Levels Inside The Bus," Environmental Defense Fund, n.d., https://www.edf.org/sites/default/files/5342_School_bus_pollution_studies.pdf (accessed March 30, 2023).

40 Brockmeyer, Sam and Amedeo D'Angiulli, "How air pollution alters brain development: the role of neuroinflammation," Translational Neuroscience, March 21, 2016, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5017593 (accessed March 30, 2023).

According to the World Resource Institute's (WRI's) Electric School Bus Initiative, over 400 school districts have committed to deploying at least one electric school bus.[41] This represents only 2 percent of all 19,954 districts in the WRI database, and the number of electric buses so far committed—over 12,000—is likewise small compared to the 500,000 school buses across the United States. Still, it's a substantial development, and one that should accelerate as the cost of electric school buses declines, more funding becomes available to offset the cost of purchase, and their benefits for student and community health and district operating budgets become more widely known.

According to the World Resource Institute's Electric School Bus Initiative, over 400 school districts have committed to deploying at least one electric school bus.

The Stockton Unified School District (SUSD) in California is a leading example of how districts serving disadvantaged communities can embrace electric vehicles to address health problems among their student populations. Some 78 percent of the SUSD population is classified as low income, and 80 percent are eligible for free or reduced-price lunches. The students are about 80 percent non-white (including Latinx). As in many lower-income populations, exposure to pollutants in Stockton is high, as is the incidence of associated health problems. According to the California State Government, Stockton residents are in the 96th percentile for exposure to particulate matter in the air. At the same time, the city is in the 100th percentile for incidence of asthma.[42] Clearly, air quality is a vital concern for the city.

Consequently, both the state and city have made it a priority to reduce the pollution burden on Stockton residents, and especially their children. The district has already deployed 11 electric buses on school routes, representing 12 percent of its fleet of 90 buses, and a total of 24 are planned in the initial phase of the program. Funding to pay for the buses and the charging stations they will need – a total of $8.3 million – has come from a wide variety of sources, including the California Air Resources Board, California Energy Commission, San Joaquin Valley Air Pollution Control District, and Pacific Gas & Electric, among others.

Such funding is essential, since full-size electric school buses, which are still manufactured in small numbers, presently cost around $350,000-$400,000 each, roughly twice their diesel equivalents. Despite an annual savings of $5,000-$10,000 in fuel and maintenance costs, incentives are needed to make their purchase affordable and accessible to all communities.[43] Some states are rising to the challenge. For example, the California Energy Commission created the School Bus Replacement program to subsidize the replacement of aging diesel buses with new electric buses. In New Jersey, school districts receive support

41 "Dataset of Electric School Bus Adoption in the United States," World Resources Institute, March 29, 2023, https://datasets.wri.org/dataset/electric_school_bus_adoption (accessed March 30, 2023).

42 "CalEnviroScreen Score and Census Tract Information," California Office of Environmental Health Hazard Assessment, 2023, https://oehha.ca.gov/calenviroscreen/census-tract/6077000100 (accessed March 30, 2023).

43 "California Electric School Bus FAQ," Advanced Energy Economy, March 2022, https://info.aee.net/hubfs/California%20Electric%20School%20Bus%20FAQ.pdf (accessed March 30, 2023).

for bus electrification from the Regional Greenhouse Gas Initiative (RGGI), a carbon-allowance trading program. Funds from the Volkswagen "Dieselgate" settlement can also be used to subsidize community electric vehicle initiatives.

Beyond school buses, towns and cities are moving to embrace electric vehicles. New York City has committed to creating a green transportation system for its residents, notably including:

- 100 percent electric city fleet by 2040
- 100 percent electric school bus fleet by 2035
- 1,000 curbside chargers by 2025, increasing to 10,000 by 2030
- 6,000 publicly accessible fast chargers by 2030[44]

Other communities are moving in a similar direction. For example, Sacramento, California, is making shared electric cars available to the public, along with zero-emission buses and an on-demand electric van. Indianapolis, Indiana, created an electric bus line, the IndyGo Red Line, connecting underserved parts of the city to high-employment areas.[45] Los Angeles, California, plans to convert its entire fleet of transit buses to electric buses by 2030, part of a broad package of sustainability measures.[46]

Beyond school buses, towns and cities are moving to embrace electric vehicles.

44 "Electrifying New York: An Electric Vehicle Vision Plan for New York City," New York City Mayor's Office of Climate and Sustainability and New York City Department of Transportation, September 2021, https://www.nyc.gov/html/dot/downloads/pdf/electrifying-new-york-report.pdf (accessed March 30, 2023).

45 Sisson, Patrick, "9 Cities With Smart Ideas To Improve Transportation," Curbed.com, September 18, 2018, https://archive.curbed.com/2018/9/18/17873726/transportation-best-cities-bus-scooter-light-rail-public-transit (accessed March 30, 2023).

46 "We Are Moving Beyond Sustainability: Sustainability Strategic Plan 2020," Los Angeles County Metropolitan Transportation Authority, 2020, https://www.transit.dot.gov/sites/fta.dot.gov/files/2022-03/LA-Metro-Sustainability-Strategic-Plan-2020.pdf (accessed March 30, 2023).

Part 3
Electric Vehicles and the Case for Resilience

Resilience is something you usually don't know you need – until you do. When Hurricane Sandy hit the Northeast in late October 2012, floods and high winds caused huge damage to homes, businesses, and infrastructure, including the power grid. Two weeks after the storm passed, 5 percent of New York residents were still without power.[47] Other major storms, such as hurricanes Katrina, Rita, Wilma, and Ike, also led to weeks-long outages.[48] It took more than a year for some households in Puerto Rico to have power restored after Hurricane Maria decimated that island's grid in 2017.

The effects of such long outages on everyday life make a long list—particularly for lower-income individuals and households who can't afford to be off work or to move temporarily

47 The Associated Press, "Restoring power to Hurricane Sandy victims takes days to weeks; 'it's hard, grueling work'," PennLive.com, November 16, 2012, https://www.pennlive.com/midstate/2012/11/restoring_power_to_hurricane_s.html (accessed March 30, 2023).

48 "Length of outage after Sandy not unusual," SFGate.com, November 16, 2012, https://www.sfgate.com/nation/article/Length-of-outage-after-Sandy-not-unusual-4045567.php (accessed March 30, 2023).

to other areas. Without power, food rots quickly, essential medicines degrade, heat and air conditioning fail, businesses close and jobs are lost, and communications become difficult. The impacts on human health can be severe. In Texas, the extended blackouts that followed the winter storms of February 2021 claimed 246 lives. Winter blackouts could be repeated in coming years in that state, leaving residents who rely on electric heat again at grave risk.[49]

Widespread use of EVs could also help avoid blackouts and brownouts by shifting power supply from low-demand to high-demand periods.

Severe heat waves and cold spells can also cause transient problems by boosting power demand beyond what the grid can supply and by making the grid more vulnerable to individual failures of generators and transmission lines. Parts of the West, Midwest, and South are at growing risk of rolling blackouts and brownouts (drops in voltage and frequency) caused by demand for air conditioning during heat waves as well as a drop in available hydropower during extended droughts.[50] While not as dangerous as extended blackouts, such transient events can have a significant impact on daily life and can cause health problems as vulnerable residents are forced to cut back their use of air conditioning or heat.

How Bidirectional Charging Can Enhance Resilience

EVs can help mitigate the risks of severe weather events. Equipped with appropriate bidirectional (two-way) charging equipment, they can provide a backup source of power to keep disaster shelters, community centers, medical offices, emergency services, and other services in operation. Their very mobility is one of their biggest advantages. EVs can drive to areas where there is no outage or there is a source of resilient local generation, such as an EV charging station powered by solar, to be recharged, and then return to the community and resume delivering power. They need no special shipments of generators or fuel. They can even be deployed to neighborhoods to serve as mobile charging hubs for cell phones and medical devices. Widespread use of EVs could also help avoid blackouts and brownouts by shifting power supply from low-demand to high-demand periods. This is why many electric utilities are actively supporting early-stage vehicle-to-grid programs.

While the technology of bidirectional charging is not yet widely adopted, EVs with the capability of sending power to the grid are already on the road (Table 2, p. 26). Nissan was one of the first car companies to equip its EV, the Leaf, with bidirectional chargers, and others are following suit. Ford has made the F-150 Lightning's ability to keep the lights on when the grid goes dark a key message of the truck's marketing campaign.[51]

49 "NERC Warns of Regional Reliability Risk this Winter; Stresses Readiness Planning," North American Electric Reliability Corporation, November 8, 2021, https://www.nerc.com/news/Headlines%20DL/WRA_final%2018NOV21.pdf (accessed March 30, 2023).

50 "2022 Summer Reliability Assessment," North American Electric Reliability Corporation, May 2022, https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SRA_2022.pdf (accessed March 30, 2023).

51 Stumpf, Rob, "The Electric Ford F-150 Can Power Your Entire House for Three Days on a Single Charge," The Drive, May 19, 2021, https://www.thedrive.com/tech/40695/the-electric-ford-f-150-can-power-your-entire-house-for-three-days-on-a-single-charge (assessed April 4, 2023)

Bluebird, a leading electric school bus manufacturer in the US, likewise offers two-way charging in its electric buses. This bus—like the F-150—contains a relatively large battery pack (roughly twice the size of that on most electric cars) which can provide power for up to several days depending on the size of the load. Other electric bus manufacturers offer the same capability.

Electric Cars and Trucks with Bidirectional Charging	
Make	**Model**
BYD (China)	Atto 3 and Han EV
Ford	F-150 Lightning
Hyundai	Ioniq 5
KIA	EV6
MG	ZS EV
Mitsubishi	Outlander PHEV
Nissan	Leaf ZE1
Volkswagen	ID.4

Table 2. List of electric cars and light trucks equipped with bidirectional charging/discharging as of 2022. The list may not be complete.
Source: EV Connect (2023).

There are three main ways EVs can be used to feed power to other systems and networks: Vehicle-to-Grid (V2G), in which the vehicle connects directly to the power grid, just like a small power plant; Vehicle-to-Home (V2H) or Vehicle-to-Building (V2B), in which the vehicle connects to the power distribution within a home or business, behind the utility meter; and Vehicle-to-Load (V2L), in which the vehicle connects directly to a set of devices such as lighting and appliances (Figure 7, p. 27). The simplest of these is V2L: it suffices to plug the appliance directly into the charger that's connected to the vehicle. V2H/B and V2G require additional equipment and software to manage the power flows and interactions with the grid.

Numerous demonstration projects have been or are being performed to show that bidirectional technology in its various forms works. For instance, Electric Frog Company is providing free use of a Nissan Leaf to the Burrillville Wastewater Treatment Facility in Rhode Island. When not in use by Burrillville employees, the EV will be plugged into a bidirectional charger, with the ability to feed power back to the grid to help meet peak loads.[52] Among other programs, the California Energy Commission recently approved three "vehicle-to-grid integration (VGI)" pilots focused on residential, commercial, and microgrid applications in the Pacific Gas & Electric utility area;[53] the charging company EV Connect is partnering with Indiana's Battery Innovation Center and Energy Systems Network to demonstrate bidirectional technology for school buses and heavy-duty truck fleets;[54] and even the Department of Defense is getting in on the act with an initiative to test between 100–500 EVs in bidirectional applications at military bases.[55]

52 Clarion Energy Content Directors, "V2G pilot project with National Grid to help combat summer peak loads in New England," Power Grid International, June 30, 2021, https://www.power-grid.com/der-grid-edge/v2g-pilot-project-with-national-grid-to-help-combat-summer-peak-loads-in-new-england/#gref (accessed March 30, 2023).

53 Balaraman, Kavya, "California approves $11.7M vehicle-to-grid pilots in PG&E footprint," Utility Dive, April 1, 2022, https://www.utilitydive.com/news/california-approves-117m-vehicle-to-grid-pilots-in-pge-footprint/621393 (accessed March 30, 2023).

54 Hanley, Steve, "EV Connect Pilots Large US V2G Project," CleanTechnica.com, March 17, 2021, https://cleantechnica.com/2021/03/17/ev-connect-pilots-large-us-v2g-project (accessed March 30, 2023).

55 Gorguinpour, Camron, "The DOD V2G Pilot Project Overview," United States Department of Defense, 2013, http://electricvehicle.ieee.org/files/2013/03/DoD-Plug-In-Electric-Vehicle-Program.pdf (accessed March 30, 2023).

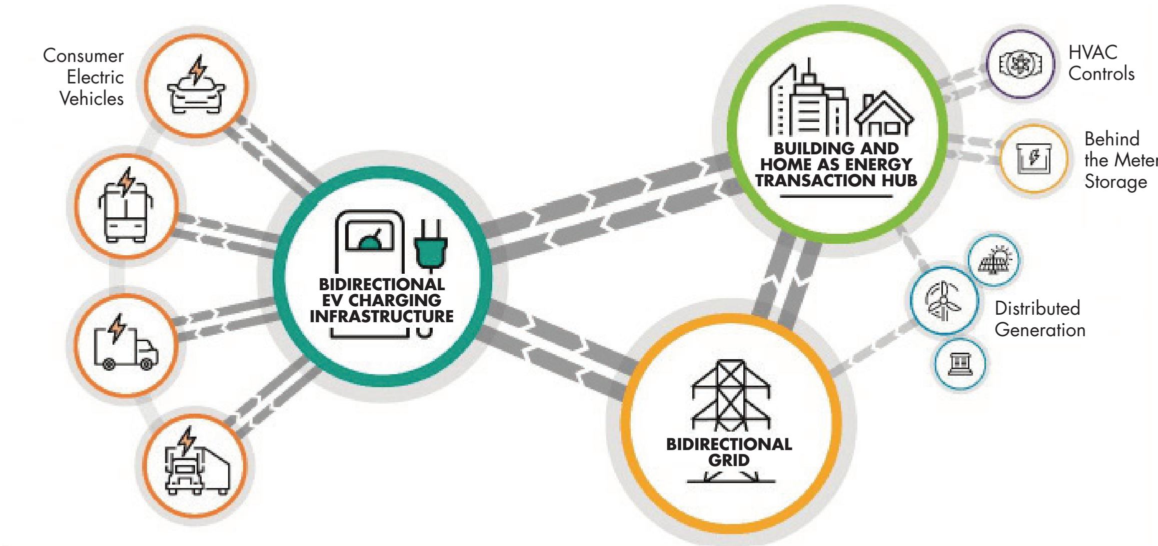

Figure 7: Bidirectional Electric Vehicle and Charging Framework.
Source: Argonne National Lab (2023)

How to Implement Bidirectional EV Charging

Making use of bidirectional EVs to offset peak loads or keep the lights on in a blackout requires not only an appropriately equipped vehicle, but also a charging point that can receive power from it and deliver the power to where it is needed. Even if your home or business is equipped with a standard charging station, you cannot use it to run your lights and appliances when the grid is out. It just won't work.

One reason is that batteries use direct current (DC), rather than the alternating current (AC) used in homes and businesses. This means they cannot directly power most services such as refrigerators, lights, and televisions. Batteries need an inverter to convert between DC and AC, which can be either on the vehicle or in the charging station. For bidirectional charging, the inverter must be able to operate in both directions. These components are often part of what are called "smart" charging systems because they use computers and sensors to decide when and how much power to deliver in either direction.

There are several different bidirectional charging systems on the market, with more in development. Unfortunately, they are not all compatible with one another. Tesla and Ford maintain their own charging networks with their own standards. This can result in confusion, so it is best to consult the vehicle manufacturer to make sure a particular vehicle's charging system works safely with the receiving station.

Over time, as the technology matures, the industry should coalesce around a standard that makes most bidirectional EVs and EV chargers mutually compatible.

What Services Can Bidirectional EVs Support—and How Long?

With the right charging equipment, an EV can provide 110-volt or 220-volt AC power that can support most services—such as lighting, A/C, refrigeration, and computers—for as long as its battery lasts. But how long is that? That depends mainly on three things: the size of the battery, the size of the load (the total amount of power required), and whether there is additional on-site power, such as from a solar array, to satisfy part of the load and replenish the EV battery.

Let's start with a single-family household. Energy use for any specific household can vary a lot depending on its size, type of construction, location, climate, heating and cooling systems, and other factors. The average American home consumes about 11,000 kWh per year, at an average power draw of 1.25 kW.[56] A typical electric car battery stores up to about 50-75 kWh, implying that it could supply such a home at its regular usage rate for about two days—plenty for a brief outage. A larger vehicle like the F-150 Lightning, on the other hand, with its 134-kWh battery, could power the same home for around 4.5 days. That's without any solar on the house.

In an emergency, power demand could be reduced, thereby extending the time it takes to discharge the battery. If the same household used full power only for water heating, lighting, and refrigeration, cut power use in half for air conditioning and heat, and shut off all other uses, a typical electric car could power the home for around 3.5 days, and a vehicle like the F-150 for just over a week. This is enough to get through most extended blackouts.

A typical electric car could power the home for around 3.5 days, and a vehicle like the F-150 for just over a week.

On a larger scale, fleets of electric cars, vans, and buses could power many essential community services almost indefinitely, thanks to their mobility. To take an example: A police station in Washington, DC, consumes an average of about 125 kW to keep its services running around the clock.[57] A single electric passenger bus with 200-300 kWh storage could power full operations of one such station for around two hours. A fleet of, say, four buses taking turns and driving to be recharged in another city or at an emergency power station could keep it in operation almost indefinitely (depending on distance to the recharging point).

Most community emergency shelters, such as school gymnasiums and churches, require less power than a police station, and so could be powered longer by a single vehicle. Actual power usage varies widely, of course, depending on the building size, local climate, and types of services delivered. Any community considering using bidirectional charging should carefully study the requirements to incorporate it into their emergency planning. Organizations like the Federal Emergency Management Agency (FEMA) can provide useful guidance.[58]

56 "Use of energy explained," U.S. Energy Information Administration, May 19, 2019, https://www.eia.gov/energyexplained/use-of-energy/electricity-use-in-homes.php (accessed March 30, 2023).

57 "Police Stations," District of Columbia Department of Energy & Environment, n.d., https://doee.dc.gov/sites/default/files/dc/sites/ddoe/publication/attachments/Pdf9-Police_Stations_Benchmark_Page.pdf (accessed March 30, 2023). Metropolitan police stations use relatively large amounts of power for their round-the-clock operations.

58 Applied Technology Council, "Emergency Power Systems for Critical Facilities: A Best Practices Approach to Improving Reliability," Federal Emergency Management Agency, September 2014, https://www.wbdg.org/FFC/DHS/femap1019.pdf (accessed March 30, 2023).

Pilot Projects

Electric school buses are the “point of the spear” in expanding the use of community EVs. Initiatives like that of the Stockton Union School District in California envision eventually using their school buses and other municipal electric vehicles to support the power grid and earn revenue during peak load periods and to provide backup power during outages caused by events such as wildfires. However, it will require further work and investment to provide essential infrastructure, such as schools and emergency services, with the equipment to receive power from the buses.

One of the main lessons learned from these initiatives is the importance of optimizing charging strategies to minimize the number and capacity (in kW) of chargers required, avoid overtaxing the power grid, and take advantage of off-peak electricity rates. The Mobility House, a private consulting firm based in Germany, advised the SUSD on its charging strategy, and claims to have reduced the peak capacity requirement for the current fleet of 11 electric buses from 317 kW to 79 kW and to have decreased the annual charging cost by $25,700 per year, compared to an unmanaged strategy.

Several pilot projects demonstrate the potential to use electric school buses to feed power into the grid in the Northeast. In one located in Beverly, Massachusetts, a Thomas Built Buses electric school bus helped the local utility, National Grid, meet peak loads over the course of 30 events during the summer of 2021.[59] In another, located in White Plains,

59 “Massachusetts electric school bus delivered power back to grid for 50+ hours over the summer; V2G,” Green Car Congress, October 14, 2021, https://www.greencarcongress.com/2021/10/20211014-proterrav2g.html (accessed March 30, 2023).

New York, five electric school buses built by Lion Electric Company of Quebec have demonstrated the ability to feed power to the ConEdison grid in a pilot program that started in 2018.[60]

In both cases, the goal is to demonstrate how electric buses can help utilities meet peak loads and so reduce the need for costly peaking power. In fact, the main instigator of such initiatives has not been school districts or town governments; it has been the utility companies who face high costs and a growing risk of outages due to rising peak loads. Nonetheless, the towns stand to receive an economic benefit, as well, as they can be reimbursed for the power provided to the grid at a much higher rate than they pay for charging the buses at night and, in some cases, generate revenue through participation in utility demand response programs that are beginning to explore EV participation.

By supplying power during periods of peak demand, EVs such as buses can be an important part of an overall strategy to replace peaking power plants with clean energy solutions, with important environmental justice benefits. According to analysis by Clean Energy Group, a disproportionate number of peaking power plants are in lower income communities and communities of color. These plants also tend to emit harmful pollutants at higher rates, potentially impacting the health of residents in surrounding communities. Clean Energy Group's "Phase Out Peakers" initiative seeks to call attention to the pollution and cost impacts of fossil peaking units and accelerate the transition to clean alternatives, including EVs providing demand response.[61]

At the same time, the pilot programs provide confidence that bidirectional charging would work in the event of a grid outage. However, that application requires additional investments in "smart grid" equipment, which after sensing a grid failure can isolate the buildings or services from the grid and deliver electricity from the buses to power essential services.

Other organizations—not just towns and school districts—are seeking to incorporate EVs into complete resilient power solutions for their communities. The Glad Tidings International church, for example, is planning to build a "clean energy hub" that includes 668 kW of solar, ten Level 2 and four Level 3 (fast) bidirectional charging points, and a combination of stationary batteries and EVs able to supply power for the Glad Tidings campus for 3 days without sun, and indefinitely with sun. Bidirectional EVs (2 Nissan Leafs and a Kia EV6) are a critical part of their plan and provide the bulk of the storage capacity.[62]

60 Benoit, Charles, "Electric V2G school bus pilots grow, but schools asleep at the wheel," Electrek.com, August 23, 2019, https://electrek.co/2019/08/23/electric-v2g-school-bus-pilots-grow (accessed March 30, 2023). Lewis, Michell, "New York's vehicle-to-grid e-school bus pilot program is a success," Electrek.com, December 14, 2020, https://electrek.co/2020/12/14/new-york-vehicle-to-grid-school-bus-pilot-program-success (accessed March 30, 2023).

61 "Phase Out Peakers," Clean Energy Group, n.d., https://www.cleanegroup.org/ceg-projects/phase-out-peakers (accessed March 30, 2023).

62 "Glad Tidings: How a California Congregation Is Pioneering a New Model by Building a Clean Energy Hub with Solar and Electric Vehicles," Clean Energy Group, August 31, 2022, https://www.cleanegroup.org/webinar/glad-tidings (accessed March 30, 2023).

Part 4
Electric Vehicles in the Community: Challenges and Solutions

The opportunities presented by electric EVs to improve the environment, economy, health, and resilience of communities are substantial. What, then, is discouraging many communities—especially lower-income communities and communities disproportionately impacted by vehicle emissions—from embracing EVs?

Challenges to Equitable EV Expansion

One of the first challenges a community is likely to encounter is the capital investment required to pay for EVs. Replacing aging school buses, community vans, and municipal vehicles is always expensive; despite recent cost reductions, replacing them with electric vehicles is still more so without grants or subsidies. Beyond the vehicles themselves, the charging infrastructure—charging stations for vehicles as well as bidirectional V2G ports for powering essential services in the event of a blackout—adds to the cost. Unfortunately, financing options that are available for private car owners, such as tax credits and rebates, often cannot be used by government agencies, schools, or nonprofit institutions.

There are public mechanisms that can help fund community EV initiatives, however. For example, with $5 billion in funding available over five years, the EPA's Clean School Bus Program presents an enormous opportunity to make school bus fleets green. $1 billion in funding has already been made available in the form of rebates through October 2022, which will fund 2,600 clean school buses, 95 percent of them electric.[63] Notably, low-income, rural, and tribal school districts receive priority, meaning they can receive up to 50 percent more funding per bus purchased than other qualifying applicants.

Nevertheless, navigating the EPA's application process (and that of other agencies, state or federal, with similar programs) can be complicated and intimidating, and once grants are awarded, the reporting requirements can be onerous. As one site devoted to school transportation noted, "there's no such thing as a free electric school bus."[64]

Sometimes funding can come from private sources. In Virginia, for example, the Fairfax County Public Schools (FCPS) received $1.968M to cover the additional cost of eight electric school buses and charging infrastructure from the local utility company, Dominion Energy. (An additional $2.65M was awarded by the Virginia Department of Environmental Quality for ten more buses.) As part of the arrangement, Dominion owns the bus batteries and motors as well as the charging infrastructure and retains the right to use the buses for supplying grid power when needed. In this way, both Dominion's and FCPS's goals are met.[65]

Low-income communities and communities of color are often at a particular disadvantage when it comes to designing, funding, and implementing EV transportation initiatives.

Another example of how community institutions can fund green transportation initiatives is the Glad Tidings Church in California, which is financing its clean energy hub through a combination of grants, energy savings, and revenue generated from EV charging services.[66]

Low-income communities and communities of color are often at a particular disadvantage when it comes to designing, funding, and implementing EV transportation initiatives. As noted in previous sections, low-income households may not be able to afford many of the

63 "Clean School Bus Program," United States Environmental Protection Agency, updated May 12, 2023, https://www.epa.gov/cleanschoolbus (accessed May 23, 2023). "EPA Clean School Bus Program Second Report to Congress: Fiscal Year 2022," United States Environmental Protection Agency, February 2023, https://www.epa.gov/system/files/documents/2023-02/420r23002.pdf (accessed May 23, 2023). "2022 Clean School Bus Rebates: How to Apply w/ Live Q&A!," United States Environmental Protection Agency, June 29, 2022, https://www.epa.gov/system/files/documents/2022-06/clean-schl-bus-rebates-how-to-apply-2022-06-29.pdf "Webinar" (accessed May 23, 2023).

64 Newton, Claudia, "There's No Such Thing As A Free Electric School Bus, Webinar Says," School Transportation News, June 21, 2022, https://stnonline.com/news/theres-no-such-thing-as-a-free-electric-school-bus-webinar-says (accessed May 23, 2023).

65 Huntington, Alissa, "The Electric School Bus Series: An Electrifying Partnership in Fairfax County, Virginia," World Resources Institute, May 13, 2022, https://www.wri.org/update/electric-school-bus-series-electrifying-partnership-fairfax-county-virginia (accessed May 23, 2023).

66 Robbins, Shelley, "Glad Tidings: How a California Congregation Is Pioneering a New Model by Building a Clean Energy Hub with Solar and Electric Vehicles," Clean Energy Group, August 31, 2022, https://www.cleanegroup.org/webinar/glad-tidings (accessed May 23, 2023).

EVs on the market today, and, lacking sufficient taxable income, cannot take advantage of the full value of tax credits. Historically marginalized communities often lack the necessary investment in EV charging infrastructure as well, leading to EV "charging deserts."[67] In neighborhoods with a high proportion of renters compared to homeowners, access to overnight charging often depends on landlords taking an interest. Where there is revenue to be earned or incentives offered, it's often the property owner who receives the benefit, further reducing the financial incentive for renters to own EVs.

At the same time, resources aimed at delivering the benefits of EVs to historically marginalized communities are becoming more widely available. Forty percent of the Federal $2.5 billion Discretionary Grant Program for Charging and Fueling Infrastructure is reserved for qualifying lower-income communities. Unlike the more widely known National Electric Vehicle Infrastructure program supporting high-speed charging on highways, this initiative emphasizes Level 2 chargers appropriate for residential areas. Electric utilities also often set aside funding for infrastructure investments in currently underserved communities as well. Southern California Edison, for example, plans to dedicate 50 percent of its EV charging spending to disadvantaged communities and has reached out to these communities to prioritize public fast-charging investments.[68]

Beyond the funding challenges, green transportation initiatives can be technically complex and require cooperation and engagement by other institutions, private and public.

67 Englund, Will, "Without access to charging stations, Black and Hispanic communities may be left behind in the era of electric vehicles," The Washington Post, December 9, 2021, https://www.washingtonpost.com/business/2021/12/09/charging-deserts-evs (accessed May 23, 2023).

68 Huether, Peter, Charlotte Cohn, and Ben Jennings, "Utility Transportation Electrification Planning—Emerging Practices to Support EV Deployment," American Council for an Energy-Efficient Economy, September 2022, https://www.aceee.org/sites/default/files/pdfs/t2201.pdf (accessed May 23, 2023).

For example:

- Local utility involvement is critical to create a fleet charging infrastructure and to allow V2G or V2B bidirectional charging where desirable. Ideally, the utility will charge a lower price for charging during off-peak periods and will buy back power from the community EVs at a premium price when needed in peak times and create opportunities for additional revenue generation by compensating EV owners for participation in demand response and other types of grid-services programs.
- Designing, planning, and installing the optimal fleet charging infrastructure can be a technically challenging task. With expert analysis, it is often possible to design a charging strategy that greatly reduces the infrastructure cost compared to a simple one-charger-per-vehicle approach. A combination of mostly overnight (Level 2) charging points with a small number of fast (Level 3) charging points will often do the trick. In some cases, installing stationary energy storage systems may be beneficial to facilitate interconnection of EV charging infrastructure on the distribution system and lower demand charges for customers hosting fast chargers.
- Expertise is also required to plan for V2G/V2B backup power. Key community services to be protected need to be identified, their typical loads and daily load profiles measured, and V2G charging stations with smart capabilities to cut off the power from the grid in times of outages need to be installed and integrated into existing building energy systems.

Considering challenges such as these, successful community transportation electrification initiatives often must entail partnerships among representatives from many different groups: program funders; electric utilities; town and state government; school and/or community service agencies; EV and EV charger manufacturers; installation contractors; various experts on design, engineering, and installation of EV infrastructure; and civic leaders and other stakeholders among the general public, such as parents of school-age children and community members dependent on public transportation. To drive such a complex initiative, a community will benefit greatly from having an effective "champion"—someone like Gil Rosas, who now leads Modesto, California's electric bus initiative, and the organization Moms Out Front (MOF), which solicited support from the Fairfax County Public Schools board to create that district's successful EV program.

Without targeted, intentional strategies and interventions, the adoption of electric vehicles and deployment of EV charging infrastructure will not occur equally or equitably among all communities.

Overcoming Barriers to Equitable EV Adoption

Without targeted, intentional strategies and interventions, the adoption of electric vehicles and deployment of EV charging infrastructure will not occur equally or equitably among all communities. Those communities most impacted by vehicle emissions today, largely lower-income communities and communities of color living near highways and transportation hubs, will be left behind as wealthier communities reap the benefits of available incentives and easier access to financing and investment. These discrepancies have nothing

to do with differing levels of interest in EV adoption. A recent Consumer Reports study found that respondents of color were just as interested in purchasing or leasing an EV as White consumers.[69] The report found that, in addition to cost concerns, lack of access to public charging was one of the most significant barriers preventing greater EV adoption. No single incentive or strategy necessarily represents the best approach to achieve more equitable EV deployment. It will take a multifaceted effort, which will differ depending on each community and the barriers they face. The following represent a few initial considerations for essential components to promote greater equity in EV planning and deployment processes.

- **Transparent and Inclusive:** Federal, state, community, and utility EV planning efforts must prioritize transparent and inclusive processes. Communities that may be impacted by EV and EV charging deployment efforts or that are currently being negatively impacted by transportation emissions should be engaged early on and throughout the process. Planning documents and decision-making processes must be easily accessible, and planners must commit to hearing, responding to, and incorporating the goals and concerns of all community members. Educational materials and listening sessions designed to inform and address the needs and concerns of historically marginalized communities are essential to ensure more equitable participation in planning processes.

69 Survey Says: Considerable Interest in Electric Vehicles Across Racial, Ethnic Demographics," Consumer Reports, Union of Concerned Scientists, Evnoire and Green Latinos, September 2022, https://advocacy.consumerreports.org/wp-content/uploads/2022/09/EV-Demographic-Survey-English-final.pdf (accessed May 23, 2023).

- **Comprehensive and Flexible:** EV planning must consider the needs and impacts of all types of transportation, not just single-family passenger vehicles. All too often, EV incentives and programs are focused primarily on single-family households that own their homes, deepening existing income-based and racial inequities. EV planning should explore high impact, though at times more challenging, applications, such as public transit and rideshare vehicles, as well as electrification of heavy transportation responsible for a higher proportion of harmful local emissions. EV charging planning must prioritize the developing of accessible and reliable public charging infrastructure and target deployment in currently underserved areas. Additionally, planning processes should be constantly evaluating the impact and outcomes of EV deployment measures to determine where benefits are flowing and if adjustments need to be made.
- **Center Equity from the Start:** Equity-based goals and how achievement of those goals will be tracked and measured over time must be established before the launch of new EV programs. EV incentives and financing initiatives must be available to all community members, with a focus on serving those facing the greatest barriers to EV adoption. Program goals and how they will be measured should be determined in partnership with the communities they are intended to benefit, and mechanisms need to be put in place to ensure that program administrators are held accountable for meeting established milestones.

EV incentives and financing initiatives must be available to all community members, with a focus on serving those facing the greatest barriers to EV adoption.

EVs have the potential to be a transformative technology for the transportation sector, the energy system, and environmental justice, as they can significantly reduce greenhouse gas and local pollutant emissions, decrease the overall cost of mobility, and help address the climate crisis. However, there are numerous equity concerns that must be addressed to ensure that the benefits of electric vehicles are distributed fairly and that historically marginalized communities are not again left behind. Policymakers must take a proactive approach and adopt inclusive processes to address these concerns by investing in charging infrastructure in low-income communities and communities of color and providing targeted incentives and innovative financing options to address EV affordability issues faced by lower-income households and community-serving nonprofits. Only when equity is genuinely centered and prioritized will the full potential of electric vehicles be realized to achieve a sustainable transportation system.

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