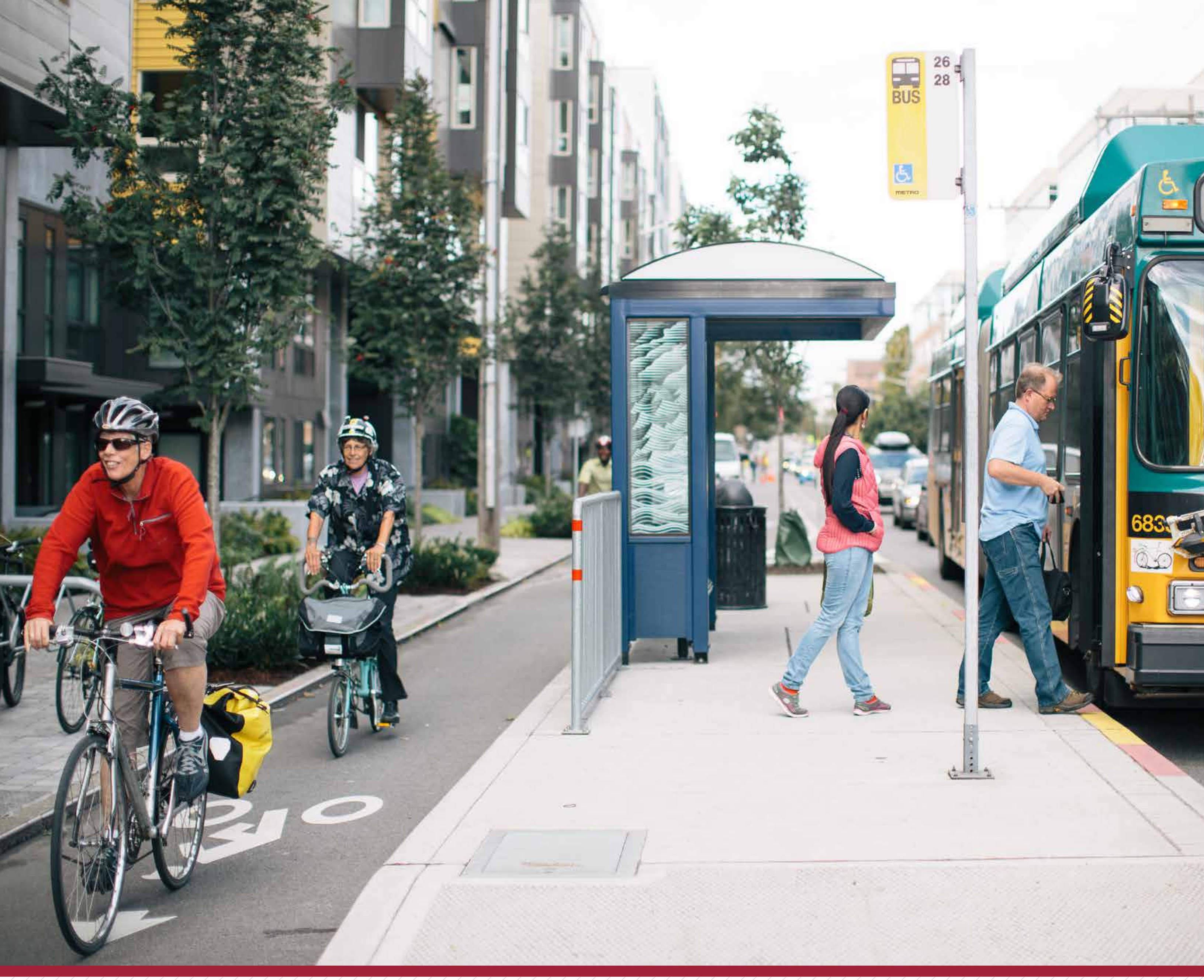


Transform Transportation

Strategies for a Healthier Future

U.S. PIRG Education Fund

FRONTIER GROUP

Transform Transportation

Strategies for a Healthier Future

U.S. PIRG Education Fund

FRONTIER GROUP

WRITTEN BY:

JAMES HORROX AND GIDEON WEISSMAN, FRONTIER GROUP

MATTHEW CASALE AND JOHN STOUT, U.S. PIRG EDUCATION FUND

SPRING 2021

Acknowledgments

The authors wish to thank Steven Higashide, Director of Research, TransitCenter; Veena Dharmaraj, Director of Transportation, Sierra Club; and Julie Chinitz, Policy Director, Alliance for a Just Society, for their review of drafts of this document, as well as their insights and suggestions. Thanks also to Susan Rakov, Tony Dutzik and Elizabeth Ridlington of Frontier Group for editorial support.

The authors bear responsibility for any factual errors. Policy recommendations are those of U.S. PIRG Education Fund. The views expressed in this report are those of the authors and do not necessarily reflect the views of our funders or those who provided review.

U.S. PIRG Education Fund

With public debate around important issues often dominated by special interests pursuing their own narrow agendas, U.S. PIRG Education Fund offers an independent voice that works on behalf of the public interest. U.S. PIRG Education Fund, a 501(c)(3) organization, works to protect consumers and promote good government. We investigate problems, craft solutions, educate the public, and offer meaningful opportunities for civic participation. For more information, please visit our website at www.uspirgedfund.org.

FRONTIER GROUP

Frontier Group provides information and ideas to build a healthier, more sustainable America. We focus on problems that arise from our nation's material and technological wealth – the problems of abundance. We deliver timely research and analysis that is accessible to the public, applying insights gleaned from diverse fields of knowledge to arrive at new paths forward. For more information about Frontier Group, please visit www.frontiergroup.org.

Layout: To the Point Collaborative, tothepointcollaborative.com

Cover: A bike lane and floating bus stop in Seattle. Photo: Adam Coppola Photography via Flickr (public domain)

Contents

Executive summary

AMERICA'S TRANSPORTATION SYSTEM is wrecking our health.

Traffic-related air pollution kills an estimated 58,000 Americans every year, and increases the risk of serious health conditions, including lung cancer, stroke, heart disease, asthma, and even dementia.[1] More than 38,000 people die in vehicle crashes in the U.S. every year and millions more are seriously injured.[2] Even our mental health and the health of our relationships are at risk – the time we spend driving, much less the time we spend stuck in stressful traffic, is time away from family, friends, exercise and leisure pursuits.

These health problems are a direct result of the way we've built our communities and our transportation system to be dependent on travel in fossil fuel-powered cars. Every year, Americans drive more than 3.2 trillion miles – nearly 10,000 miles per person and more miles per capita than people almost anywhere else in the world.[3] Since 1990, the number of vehicle miles traveled by light-duty vehicles like cars and light-duty trucks has risen by more than 46 percent.[4]

There is a better way.

By rebuilding our transportation system to give more people the option to spend less time in a car, by expanding access to active means of travel such as walking and biking, and by adopting zero-emission electric cars and buses, we can make our transportation safer, healthier, cleaner and more efficient.

Transportation is a leading cause of air pollution that shortens lives and makes people sick.

In 2019, the transportation sector produced 55 percent of the nation's emissions of nitrogen oxides (NO_x) – a component of ozone smog – 16 percent of all emissions of volatile organic compounds (VOCs), and 2.7 percent of all emissions of primary particulate matter, often known as soot.[5]

This pollution causes or exacerbates a range of serious health conditions, including:

- **Cancer:** Diesel exhaust is classed as a potential cancer agent by the World Health Organization and the U.S. EPA.[6] Exposure to diesel exhaust has been associated with higher rates of lung cancer and greater risk for bladder cancer.[7] Particulate matter and nitrogen dioxide, emitted in vehicle exhaust, have both been associated with increased risk for lung cancer.[8]
- **Stroke:** Long-term exposure to particulate matter is associated with an up to 21 percent higher risk of stroke.[9]
- **Heart and lung disease:** Exposure to nitrogen dioxide, found in vehicle exhaust, has been linked to heart and lung diseases and premature death.[10] Exposure to particulate matter can result in vascular damage and accelerated decline of lung function.[11]
- **Asthma:** Exposure to vehicle exhaust causes and exacerbates childhood asthma, and recent research suggests it

also damages lung development even in non-asthmatic children, leading to increased risk of respiratory and cardiovascular diseases in later life.[12]

- **Dementia and cognitive decline** among the elderly: One study estimates that between 7 and 11 percent of dementia cases among individuals living within 50 meters of a major road are attributable to traffic exposure.[13]

The 45 million Americans who live in close proximity to busy roads or other traffic-related infrastructure are at increased risk from the health impacts of traffic-related pollution.[14]

- Studies have found increased prevalence of asthma in children living within 100 meters of a freeway.[15] One study estimated that over 27,000 cases of childhood asthma in Los Angeles County were at least partly attributable to pollution associated with living close to a major road.[16]
- Living close to a major road increases the chances of suffering from an ischemic stroke by 42 percent and significantly increases the likelihood of dying as a result.[17]
- Higher levels of noise and air pollution are associated with increases in coronary heart disease (CHD) mortality. One study found that individuals exposed to the highest levels of noise pollution are 22 percent more likely to die as a result of CHD than those exposed to the lowest levels.[18]

American society's dependence on cars puts us at risk every time we take to the roads, whether or not we're in a car ourselves.

- Every year, approximately 38,000 Americans are killed in car crashes, making car crashes the leading cause of death for Americans between the ages of 1 and 54.[19]
- In 2018, nearly 6,300 pedestrians and more than 800 cyclists were killed in traffic-related accidents, with more pedestrian and cyclist fatalities on the roads in 2018 than in any year since 1990.[20]

Driving even takes a toll on the health of drivers themselves. Excessive driving can lead to a range of health impacts, including:[21]

- **Chronic stress and poor mental health:** Commuters who travel to work by car experience substantially higher levels of stress, more negative moods and lower satisfaction with life than those who take active modes of transport.[22]
- **Obesity and high blood pressure:** People with long car commutes are more likely to be obese and to have higher blood pressure. They are also less likely to do the recommended amount of physical activity, putting them at increased risk of diabetes, cardiovascular disease, osteoporosis, metabolic risk syndrome and certain kinds of cancer.[23]

America's transportation system is the nation's number one source of greenhouse gas emissions and the largest single contributor to the climate crisis, which will harm public health for decades to come.

In 2018, transportation accounted for 28 percent of the nation's total greenhouse gas emissions – more than any other sector of the economy.[24] If emissions continue at their current level, the impacts on public health will be severe.[25]

- **Extreme temperatures will kill more people.** As climate change makes extreme variations in temperature more common, deaths and hospitalizations from extreme heat and cold will rise.[26]
- **Shifting weather patterns and high pollution will create high concentrations of ozone** in some areas, causing more premature deaths and hospitalizations due to respiratory illness.[27]

- **Climate change will bring more disease,** as shifting temperatures lead to geographic shifts of disease-carrying insects like ticks and mosquitos.[28] Warmer weather will increase the prevalence of pathogens like *E. coli* and salmonella, which thrive in hot and humid conditions.[29]

To address the health and environmental damage our transportation system causes, we need to completely transform the way we travel. And there are steps we can take right now, using proven policies and existing technology, that can help eliminate traffic-related pollution and move America's transportation system towards a greener, healthier future:

Getting more people moving by foot, bike and transit can immediately reduce both global warming emissions and the toxic pollutants from our car-dependent transportation system. Walking and biking infrastructure has been shown to benefit communities in a variety of ways, including increased safety, improved health and happiness, and more freedom for older adults and people with mobility issues.

The U.S. should at least double the number of people who travel by foot, bike or transit by 2030. To achieve this goal, policymakers should:

- Ensure that walking, biking and transit are safe, affordable, accessible and enjoyable through infrastructure expansion and improvements.
- End subsidies that make driving artificially cheap to help make low-carbon transportation the easiest, cheapest, most convenient option.

Phasing out fossil fuel vehicles can enable the U.S. vehicle fleet to operate with zero greenhouse gas emissions from driving or charging, if such a shift is accompanied by a transition to a grid powered by clean, renewable energy. Electric vehicles also benefit public health, as they do not emit harmful tailpipe emissions that cause cancer, asthma and other health problems.[30]

All new light-duty cars and trucks sold after 2035 should be electric vehicles. To achieve this goal, policymakers should:

- Set requirements to phase out fossil fuel-powered vehicles and adopt EV mandates.
- Make EVs cheaper to buy and own through tax credits and other incentives.
- Expand and improve EV charging infrastructure.

Electrifying and improving transit can create clean transit fleets for cities and schools, particularly if those fleets are powered by clean energy. Electric buses emit no tailpipe pollution and would significantly improve the health of children who take school buses and the urban populations often served by buses.[31]

U.S. transit agencies and school districts should replace all transit and school buses with clean electric buses by 2030. To achieve this goal, policymakers should:

- Adopt electric bus commitments at all levels of government, including at transit agencies and school districts.
- Provide transit agencies with financial and technical assistance to help them make the switch to electric buses while maintaining or increasing service.

Introduction

IN MARCH 2020, the lives of millions of Americans changed in ways we never thought imaginable. The turmoil caused by the arrival of the coronavirus pandemic meant the abrupt suspension of business as usual. Our daily routines suddenly no longer included long, grueling commutes; freeways all over the country emptied, and city centers became eerily devoid of the noise, congestion and air pollution that many of us have come to accept as unavoidable facets of everyday life.[32] Without realizing it, we had embarked on a transportation experiment on a previously inconceivable scale.

As lockdowns kicked in all over the country, a record decline in driving was accompanied by an increase in people walking, cycling and choosing other active modes of transportation.[33] Many of us discovered, with varying degrees of surprise, that our daily car commutes weren't actually necessary after all, and that even amid the stress and uncertainty of the pandemic there are more fulfilling ways of spending those hours than sitting in traffic. While gasoline sales plummeted, sales of bikes and e-bikes skyrocketed, and with fewer cars on the road, our neighborhoods became safer, cleaner and more agreeable places to be – especially in the many towns and cities that rededicated street space for pedestrians and cyclists to enable socially distanced individual mobility.

The environmental impact of this accidental experiment was evident almost immediately. The smog that normally hangs over our cities subsided, and by mid-April, at the height of lockdown, daily carbon dioxide emissions in the U.S. were down by around one-third.[34] Globally, emissions dropped an unprecedented 17 percent from 2019 levels, with almost half of that decrease attributable to the drop in road traffic alone.[35]

As the economy gradually opened up and people began to get back in their cars, it became clear that emissions reductions on the scale seen during March and April were going to be short-lived.[36] Yet driving remains below its pre-COVID levels, and some analysts suggest that more Americans will continue to work from home long after the pandemic is over.[37]

If our travel patterns could change so quickly and dramatically as a result of a pandemic, imagine what could happen if we made a deliberate effort to make it easier for Americans to live their lives without spending so much time in a car.

America's current transportation system has been designed, built and centered around the automobile. And it is a public health disaster. Traffic-related air pollution cuts short an estimated 58,000 American lives every year, and causes or exacerbates serious illnesses ranging from childhood asthma to lung cancer, strokes, heart disease and dementia. Excessive driving, and especially commuting, erodes our mental health, our relationships, and our quality of life – to say nothing of the thousands of people every year killed or injured in vehicle crashes.

The problems of our car-dependent transportation system are staring us in the face – and they have been for years. But the good news is, so are the solutions.

To make matters worse, many of us have no choice but to drive. In large parts of America, public transit simply isn't a viable alternative to personal vehicles. And where walking, cycling and other active modes of transport are an option, the auto-centric design of our streets can make these forms of transport unappealing at best, and at worst, lethal.

The problems of our car-dependent transportation system are staring us in the face – and they have been for years. But the good news is, so are the solutions.

Many of the clean transportation technologies that not so long ago seemed far off on the horizon are now tried and tested and well on their way to becoming mainstream. Zero-emission electric vehicles have proven themselves viable alternatives to the internal combustion engine, and EV ownership is rising rapidly as more and more car manufacturers embrace the reality that the future of the automobile is electric. Cities and school districts that have added electric buses to their transit fleets have found them cheaper, cleaner and more efficient than their old, polluting diesel counterparts and every year brings new commitments from cities all over America to electrify their transit systems. Bike lanes, bike sharing, e-bikes and e-scooters are increasingly common sights in American cities. And it no longer seems so outlandish to imagine a near-future with streets designed for pedestrians and cyclists to coexist safely with cars, giving people the option to spend less time behind the wheel and more time traveling in ways more conducive to safeguarding our health, wellbeing and environment.

There has never been a more important time to fix a transportation system that too often makes us sick and unhappy. In this report, we lay out a vision for creating such a future – one based on zero-emission electric vehicles, expanded public transit, and increased access to active modes of travel like walking and cycling. These are the tools that should be front and center in the effort to free our roads from polluting fossil-fuel-powered vehicles, in a reimagined approach to transportation that puts public health and the environment first.

Our car-dependent transportation system damages our health and wellbeing

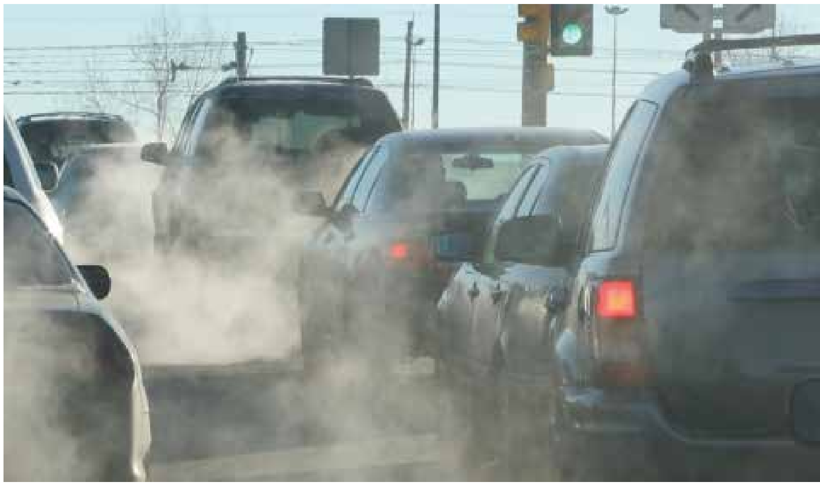
THE CHRONIC CONGESTION of America's roadways is not simply an inconvenience, but a symptom of the failure of our nation's approach to transportation. Every year, Americans drive more than 3.2 trillion miles – nearly 10,000 miles per person and more miles per capita than people almost anywhere else in the world.[38] Among the 22 European countries for which the United Nations Economic Commission for Europe has recent data, no country had even 70 percent as much driving per person as the U.S.[39]

All that driving places an increasingly heavy burden on our health, safety and wellbeing. America's car-dependent transportation system kills tens of thousands of people per year through crashes and exposure to air pollution, and hurts or sickens many more. Car dependence is also a major contributor to the global threat of climate change, which will pose threats to our health and our environment for generations to come.

Traffic-related air pollution harms people of all ages

Every year, approximately 107,000 Americans die as a result of air pollution.[40] Some studies have suggested that figure could be as high as 200,000.[41] According to a recent study by the Massachusetts Institute of Technology, around 58,000 deaths each year are attributable to road transportation emissions specifically, making transportation the largest single contributor to premature deaths from air pollution.[42]

Exhaust from cars, trucks, buses and other diesel- and gasoline-powered vehicles contains dangerous pollutants that have been linked to health impacts including heart, vascular and lung conditions and cancer.[43] Diesel exhaust alone contains more than 40 toxic contaminants, including known or suspected carcinogens such as benzene, arsenic and formaldehyde.[44] It also contains fine particulates (referred to as $PM_{2.5}$) as well as volatile organic compounds (VOCs) and nitrogen oxides (NO_x) (which are both precursors of ground-level ozone), among other pollutants.[45]



Pollutants found in exhaust from fossil-fuel-powered vehicles have been linked to a range of health impacts, including heart, vascular and lung conditions and cancer.

Photo: U.S. Environmental Protection Agency

Transportation is responsible for a large share of the health-threatening pollution that finds its way into America's air. In 2019, the transportation sector produced 55 percent of the nation's total nitrogen oxide (NO_X) emissions, with road traffic accounting for about a third of the national total. The transportation sector as a whole produced 44 percent of the nation's carbon monoxide emissions, with highway vehicles accounting for 26 percent of the nation's total. Transportation produced 2.7 percent of PM_{10} and $PM_{2.5}$ particulate matter emissions and 16 percent of all volatile organic compound emissions, with 8.9 percent of the national total coming from road traffic.[46]

Traffic pollution causes or exacerbates a range of health problems, including asthma, impaired lung function, cardiovascular diseases and premature death.[47] Research has linked exposure to fine particulate matter and ground-level ozone to higher rates of mortality, concluding that exposure to these pollutants, even at levels below national standards, contributes to adverse health impacts.[48] Ultrafine particulate matter (< 0.1 micron in diameter) is especially dangerous since it can enter deep into lower airways, carrying heavy metals that are now linked to Alzheimer's disease, along with odorless, toxic chemicals such as polycyclic aromatic hydrocarbons (PAHs) that irritate the respiratory tract.[49] Ozone and $PM_{2.5}$ from road transportation kill almost 60,000 Americans every year, making road transportation the largest single contributor to mortalities from these pollutants in the U.S.[50]

Specific health impacts of traffic pollution include:

- **Cancer:** Diesel exhaust is classed as a potential cancer agent by the World Health Organization and the U.S. EPA, and at least 19 of the hydrocarbons it contains are known to cause or suspected of causing cancer.[51] VOCs, including benzene, acetaldehyde and 1,3-butadiene, have been linked to various types of cancer.[52] In particular, exposure to diesel exhaust pollution has been associated with higher rates of lung cancer and greater risk for bladder cancer.[53] Particulate matter and nitrogen dioxide have both been associated with increased risk for lung cancer.[54] Exposure to nitrogen dioxide (NO_2) is also known to shorten the life expectancy of people with lung cancer.[55]

- **Heart and lung disease:** Prolonged exposure to nitrogen dioxide has been linked to heart and lung diseases and premature death.[56] Exposure to particulate matter, too – even at relatively low levels – can result in vascular damage and accelerated decline of lung function.[57] $PM_{2.5}$ poses a particular risk to elderly people, children and people with heart or respiratory conditions.[58]

- **Respiratory problems:** Vehicle exhaust has been linked to a range of respiratory problems.[59] Particulate matter can cause inflammation in the respiratory system and long-term exposure to nitrogen dioxide can increase the risk of respiratory infections.[60] VOCs, too, can cause respiratory conditions. In sunlight, VOCs react with nitrogen oxides to form ground-level ozone, a major component of smog, which irritates the respiratory system, causing coughing and reduced lung capacity. NO_X itself can cause lung irritation and weaken the body's defenses against respiratory infections like pneumonia.[61]

- **Asthma:** Air pollution is extremely harmful to children's lungs, and numerous studies have shown that vehicle exhaust can cause and exacerbate childhood asthma.[62] A 2010 study linked exposure to air pollution with altered gene expression among asthmatic children and research in 2013 similarly suggested that diesel pollution increased children's susceptibility to asthma by turning off certain genes.[63] Exposure to NO_2 in early childhood has been shown to increase the likelihood of developing asthma.[64]

- **Strokes:** Higher levels of air pollution have been associated with a higher risk of stroke events. A 2015 meta-analysis of 20 epidemiological studies carried out over the previous decade identified exposure to particulate matter pollution, and especially $PM_{2.5}$, as a risk factor for stroke.[65] The study found that long-term exposure to PM air pollution is associated with an up to 21 percent increased risk of stroke.
- **Dementia and cognitive decline:** Particulate matter has been linked to dementia and cognitive decline among the elderly.[66] People living close to major roads are at higher risk for developing dementia (see below), thought to be due to increased exposure to NO_2 and $PM_{2.5}$ as well as sleep fragmentation due to noise.[67]

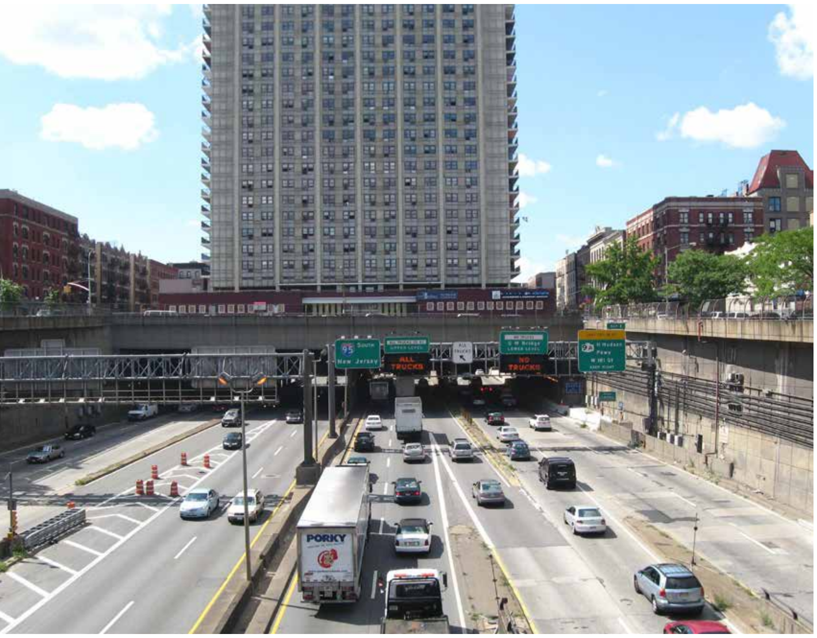
These impacts cause particular harm to vulnerable populations, including children, the elderly, and those with heart or lung conditions.[68] Children especially are at risk, as their respiratory systems are still developing and they inhale more air per pound of body weight than adults.[69] In addition, ethnic minorities and other marginalized groups often tend to bear the brunt of the air pollution in American cities. One study in California showed that African Americans and Latinos suffer disproportionately, being exposed to 40 percent more particulate matter than white Californians.[70] Low income households and those that don't own a car are exposed to 20 percent more pollution than the state average.[71]

Living near transportation infrastructure causes particular damage to health

Much of America's vast – and growing – network of roads traverses communities where people live and breathe. The EPA estimates that more than 45 million Americans live within 300 feet of a busy road, major transportation facility or other traffic-related infrastructure.[72] Unsurprisingly, research shows that those of us who live in close proximity to roads are at a particularly high risk from the health impacts of traffic-related pollution.[73] A growing body of studies shows that long-term residential proximity to busy roads can reduce life expectancy and cause or exacerbate a range of diseases.[74]

A number of studies have found an increased prevalence of **asthma** in children who live near busy roads.[75] A Dutch study of 1,498 children found that asthma and other chronic respiratory symptoms were significantly more prevalent in children who lived within 100 meters of a freeway.[76] A 2017 Rutgers University study of asthmatic children living near an industrial New Jersey seaport with heavy diesel truck traffic found that greater exposure to carbon soot coincided with markers for lung inflammation, and a UK study focusing on traffic within 150 meters of children's family homes found that the risk of respiratory problems markedly increased the closer children lived to a busy road.[77]

Research published in 2012 estimated that over 27,000 cases of childhood asthma in Los Angeles County (8 percent of all cases) were at least partly attributable to pollution associated with residential location within 75 meters of a major road.[78] Another study from Southern California, published in 2006, found that risks for asthma increased more than twofold among those living within 75 meters of a major road. These



Apartments above a New York City freeway. A growing body of research shows that living close to busy roads can reduce life expectancy and cause or exacerbate a range of diseases. Photo: Jim Henderson via Wikimedia Commons

associations, the study concluded, were strongest among children with no parental history of asthma who had lived at the same address since early in life.[79]

Not only does living near busy roads increase a child's likelihood of developing asthma and other respiratory diseases, it also damages lung development even in otherwise healthy, non-asthmatic children. A study published in *The Lancet* in 2007 found that children who lived within 500 meters of a freeway since age 10 had developed "pronounced deficits" in lung function by the age of 18, compared to children living a mile away or more, suggesting that exposure to traffic pollution is dangerous for all children, not just vulnerable subgroups.[80] Poor lung function in later life is known to be a major risk factor for respiratory and cardiovascular diseases.[81]

Living in close proximity to roads also has significant linkages to incidences of **strokes**. One study found that living within 100 meters of a major road increases the chances of suffering from an ischemic stroke by 42 percent.[82] It also increases the likelihood of dying as a result: a 2013 study of 1,683 stroke patients observed that patients living 100 meters or less from busy roads had a 20 percent higher rate of poststroke mortality than those living more than 400 meters away.[83]

Traffic-related noise and air pollution have also been linked to a range of **cardiovascular diseases**. A 2012 study of coronary heart disease (CHD) mortality among urban residents of Vancouver, Canada, for example, found that higher levels of noise and air pollution were associated with higher levels of CHD mortality. Individuals exposed to the most noise were 22 percent more likely to die as a result of CHD than those exposed to the least.[84]

Strong links have also been found between traffic-related air pollutants and heart attacks. Research published in 2007 observed a "significant increase" in the odds of heart attacks associated with increasing exposure to traffic within 100 meters of patients' homes.[85] A 2002 study from the Netherlands found that living within 100 meters of a freeway or 50 meters of a major urban road was associated with increased incidence of death from heart attacks, among other cardiopulmonary conditions.[86]

Living near roads can increase the risk of **cognitive decline** in older adults.[87] A 2012 study among community-dwelling seniors in Boston found that residential proximity to a major roadway was associated with "statistically significantly poorer performance" on cognitive tests of verbal learning and memory, psychomotor speed, language and executive functioning, with participants who lived less than 100 meters from a major road performing worst.[88] A 2017 study of residents of Ontario, Canada, similarly found increased incidence of **dementia** among those who lived in close proximity to heavy traffic.[89] The study found that those most at risk were individuals who lived closest to the roads, who lived in major urban centers and who had never lived elsewhere.[90] The study concluded that among individuals with dementia who live within 50 meters of a major road, between 7 and 11 percent of cases are attributable to traffic exposure.[91]

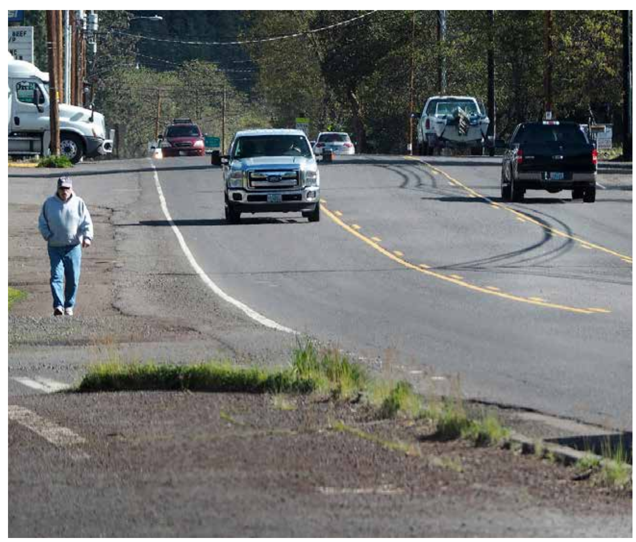
Our dependence on cars has lethal consequences for road users

American society's dependence on cars puts us at risk every time we take to the roads, whether or not we're in a car ourselves. The current design of our roadways puts people who walk or bike in particular danger. Unsafe, car-oriented infrastructure discourages people from biking, walking or using public transit – further cementing car dependence and exacerbating the risks it poses to public health.

Every year, approximately 38,000 Americans are killed in car crashes, making car crashes the leading cause of death for Americans between the ages of 1 and 54.[92] In 2018, nearly 6,300 pedestrians and more than 800 cyclists were killed in traffic-related accidents – increases of 3.4 percent and 6.3 percent, respectively, from 2017.[93] In some urban areas, pedestrian fatalities account for up to 40 percent of all traffic-related deaths.[94] Between 2009 and 2018, pedestrian and cyclist deaths as a proportion of total traffic-related fatalities on America's roads rose by 6 percent, with more pedestrians and cyclists killed in 2018 than in any year since 1990.[95]

Part of the reason for these high levels of fatalities among cyclists and pedestrians has to do with our unsafe infrastructure. High fatality and injury rates for pedestrians and bicyclists are in part the result of road and community design that prioritizes vehicle throughput and speed.[96] The risk of death for a pedestrian hit by a car more than doubles, from 10 percent to 25 percent, if the speed of the car increases from just 23 mph to 32 mph.[97] For a pedestrian hit by a car moving at 42 mph, the risk of death is 50 percent.[98]

Many roads also lack basic infrastructure that improves safety for walking and biking, like sidewalks and bike lanes.[99] A study of pedestrian crashes from the early 1990s found that, of the 2,885 incidents where such data was available, more than 80 percent took place on roads with no sidewalk.[100] Another study found that



Roads without infrastructure for walking and biking make it less safe and more difficult to get around without a car. This area of Shady Cove, Oregon, was later the focus of an improvement project to add sidewalks and bike lanes.

Photo: Oregon Department of Transportation the risk of cycling on roads with physically separated bike lanes was about one ninth that of riding on roads with no bike lanes.[101]

Unsurprisingly, when people perceive that an activity – like walking or biking – is likely to put their safety at risk, they will be less likely to do it. According to a research review by Active Living Research, "[s]afety concerns, both real and perceived, are a major deterrent to active travel."[102]

Driving to work damages our health and makes us less happy with our lives

The public health danger from our dependence on cars doesn't just come from pollution and road accidents. Driving also takes a toll on the health of drivers themselves – and Americans drive a lot.

Around 85 percent of Americans commute by car every day.[103] These commutes take a toll on us, physically and psychologically, leading to health problems ranging from headaches, backaches, digestive problems and concentration issues to a range of potentially extremely serious conditions:[104]

- **Long car commutes can lead to chronic stress and poor mental health.**[105] A 2011 study of New York commuters found that those who travel to work by car experience "significantly higher" levels of stress and more negative moods than those who took active modes of transport.[106] A 2014 study by researchers in Canada found that people with longer commutes had lower satisfaction with life, and a 2011 study – also from Canada – found that traffic congestion and long commutes were associated with higher stress levels.[107] In the latter study, 36 percent of full-time workers with a commute of 45 minutes or more said that most days were "quite or extremely stressful," compared to 23 percent of those with commutes of less than 15 minutes.[108]
- **Longer commutes are linked to poor diet and lack of exercise.** A 2012 study of commuters in Texas found that individuals with longer commutes were less physically active, more likely to be obese, and had greater body mass index (BMI) and waist circumference and higher blood pressure.[109] A commute of 10 miles or more each way is associated with higher blood pressure, the study found, and participants who commuted more than 15 miles were more likely to be obese and less likely to do the recommended amount of physical activity, putting drivers at increased risk of diabetes, cardiovascular disease, osteoporosis, metabolic risk syndrome and certain kinds of cancer.[110] Another study found that every hour sitting in a car was associated with a 6 percent increase in the odds of obesity.[111]
- **Commuting is linked to poor sleep.** A study published in 2018 found that each additional hour of commute time means 15 minutes of sleep loss, and that individuals with longer commutes had greater variability in sleep duration and less stability of sleep rhythms than those with short commutes.[112] The 2012 Regus Work-Life Balance Index found that commutes of more than 45 minutes were associated with poor sleep quality and exhaustion.[113] Sleep loss is in turn linked to a range of health problems, including diabetes and obesity.[114]
- **Commuting by car harms our relationships.**[115] Studies have shown that people with longer commutes are less likely to spend time with family and friends, contributing to higher rates of stress and reduced life satisfaction.[116] An analysis of commuting data from Sweden found that couples with longer commutes are 40 percent more likely to split up than those with shorter commutes.[117] One study on the psychological costs of traffic conges-

tion even found a connection between extreme traffic and higher incidence of domestic violence, with a 9 percent increase in incidents of domestic abuse on days with extreme traffic.[118]

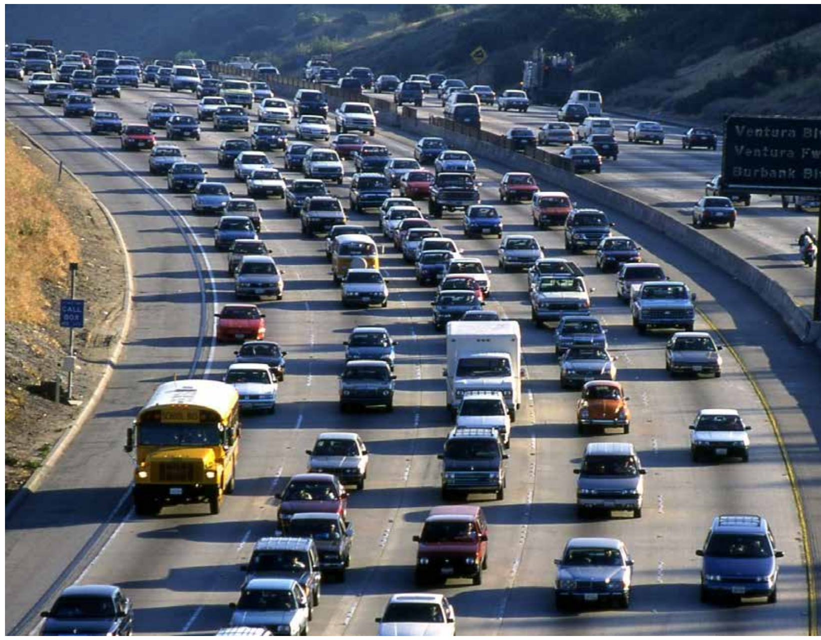
Transportation is the leading source of greenhouse gas emissions

In 2018, America's transportation sector emitted 1,882 million metric tons of greenhouse gases ($MMTCO_2e$), accounting for 28 percent of the nation's total greenhouse gas emissions – more than any other sector of the economy.[119] U.S. transportation emissions now account for approximately 4 percent of total *global* greenhouse gas emissions.[120]

By far the leading sources of U.S. transport emissions are light-duty vehicles like cars and light trucks. In 2017, these vehicles accounted for nearly three-fifths of transport emissions and one-sixth of America's total greenhouse gas emissions.[121] In recent years, emissions from these kinds of vehicles have been on the rise. Between 2013 and 2017, the annual distance Americans drove in light-duty vehicles grew by 200 billion miles, and annual emissions from these vehicles rose by 36 million metric tons.[122]

The typical American vehicle is heavy, inefficient and powered by fossil fuels. An analysis comparing the United States with seven countries plus the European Union found that the average U.S. passenger vehicle emits more CO_2 and consumes more fuel per mile than the average vehicle in all but three countries, and is bigger, heavier and has a more powerful engine than the average vehicle in any other country.[123] For every gallon of gas we put in our cars, we pump roughly 24 pounds of CO_2 and other harmful emissions into our atmosphere.[124]

But the climate impacts of our automobile dependence don't just come from tailpipe emissions. The total carbon footprint of a



Around 85 percent of Americans commute to work by car. Research shows that all this driving takes a toll on our mental and physical health. Photo: prvideotv via Pixabay

vehicle also includes the emissions produced during its production, from the extraction of raw materials to the construction and assembly of its component parts and the extraction and shipping of fuels.[125] Quantifying the impacts of such a sprawling and complex process is difficult, but one recent estimate suggests that almost a quarter of a car's total lifetime carbon emissions are produced before it even hits the road.[126]

The climate impacts of a car-dependent transportation system must also take into account the emissions associated with building and maintaining that system's infrastructure. A 2019 lifecycle analysis of a provincial road in Italy showed the building and maintenance of roadways, including raw materials, fuels, transportation and construction site set-up, are responsible for more than 47 percent of a road's total environmental impact, while the actual use of the road (i.e., environmental impacts from traffic, maintenance and so on) is responsible for the other 53 percent.[127]

This transportation system is a major contributor to our changing climate, and if emissions continue at their current level, the impacts on public health will be severe.[128] Climate change influences human health and disease in a range of different ways, including intensifying existing threats to public health and creating the conditions for new ones to emerge.

Extreme temperatures will kill more people. Many cities have seen sharp increases in fatality rates during heat waves in recent years, including from heat stroke and related problems, as well as cardiovascular, respiratory and cerebrovascular diseases.[129] Extreme heat also brings a rise in hospital admissions for cardiovascular, kidney and respiratory disorders.[130] As the frequency and intensity of extreme temperatures increase in the coming decades as a result of climate change, these numbers will rise.[131]

Climate change will create high concentrations of ground-level ozone and air pollution. Ozone will increase in some areas and decrease in others, as the climate crisis will affect the weather patterns in different regions differently. Exposure to ozone is linked to premature deaths and hospitalizations due to various respiratory illnesses.[132] Estimates suggest that, by 2050, climate change could lead to as many as 4,300 additional premature deaths every year in the U.S. from the health effects of ozone and particulate matter pollution.[133]

Climate change will bring more severe natural disasters. Larger floods, wildfires and winter storms can result in death and injury and cause major damage to infrastructure. Droughts can devastate water quality and have negative impacts on respiratory health, as can wildfires.[134] Wildfire smoke contains particulate matter, carbon monoxide, nitrogen oxides and VOCs and can significantly damage air quality.[135]

Climate change will bring more disease. Shifting temperatures will also lead to geographic shifts of disease-carrying insects like ticks and mosquitos.[136] Changes in air and water temperatures and other climatic conditions can affect the transmission of the pathogens that cause diarrheal diseases, such as salmonellosis and campylobacteriosis.[137] Warmer weather will increase the prevalence of pathogens like *E. coli* and salmonella, which thrive in hot and humid conditions, and warming seas will see an increase in bacteria in seafood. Climate change may even bring about new diseases.[138]

* * *

According to the EPA's 2019 Automotive Trends report, new vehicles are at a historic low in terms of the grams per mile of CO_2 they produce and a historic high in terms of fuel efficiency.[139] Since 2004, new vehicles' CO_2 emissions have decreased 23 percent and fuel economy has increased 30 percent.[140] And yet, over this period, there has been no corresponding reduction in total greenhouse gas emissions from transportation.[141] Instead, over the last decade, emissions from the transportation sector have been on the rise.[142]

This is largely because we're driving more. In other words, making our vehicles cleaner and more energy efficient – while important – isn't enough to address our transportation system's role in accelerating climate change. To mitigate our impact on the climate, and to alleviate the many other health impacts of a transport system centered around fossil-fuel-powered vehicles, we need to completely overhaul the way we travel.

We can transform America's transportation system

TRANSFORMING OUR transportation system into one that is safe, healthy and environmentally friendly is a huge and complicated endeavor. But there are several steps we can take right now, using tools and technologies already available, that can do the bulk of the heavy lifting. Three goals, which are achievable with proven policies and existing technology, can help eliminate pollution from cars and light trucks and move America's transportation system towards a greener, healthier future:

- Doubling the number of people who travel by walking, biking and public transit by 2030.
- Ensuring that all personal vehicles sold after 2035 are electric.
- Expanding public transportation and electrifying all transit and school buses by 2030.

By rebuilding our transportation system to give people the option to spend less time in a car and more time traveling by healthy means such as walking and biking, and by adopting clean vehicle technologies that do not produce the dangerous emissions of fossil-fuel-powered vehicles, we can reduce the health and environmental impacts of our car-dependent transportation system and build healthier, safer, better connected communities.

Give more people the option to travel by foot, bike and transit

In 2017, more than four in five trips taken by Americans were made by car, pickup truck, SUV or van.[143] Shifting some of these trips to transit, walking and cycling is an important way to reduce air pollution and greenhouse gas emissions from transportation, even if all vehicles are eventually powered by electricity from renewable sources.

Shifting modes of travel can make an immediate impact on air pollution and health, even as the nation transitions its automobile fleet to electric vehicles, builds its infrastructure for charging them, and transitions to an electricity system powered by 100 percent clean energy. Shifting from driving to transit, cycling and walking creates an opportunity to address the many other impacts of widespread automobile dependence, including dangerous and congested streets. Improved walking and transit infrastructure can bring vital accessibility improvements for older adults and people with mobility issues.[144]

Making it easier for people to travel without a car brings valuable benefits for our health and the health of our communities. Research shows that communities with more walking and biking see more user enjoyment, better health, improved economic activity, stronger communities resulting from positive interactions between neighbors, and more neighborhood security.[145] A 2014 study from the UK found that commuters who stopped driving and started walking or cycling to work experienced higher levels of wellbeing, with the likelihood of feeling constantly under strain or unable to concentrate at least 13 percent higher when commuting by car.[146] Walking and cycling can also provide the proven health benefits that come from increased physical activity:

- Research published in *The American Journal of Preventive Medicine* in 2013 found that people who walk to work are 17 percent less likely to have high blood pressure than those who drive, and people who commute by bike are around half as likely to have diabetes as those who drive. The study also found that cycling, walking and using public transit were all associated with lower risk of obesity than driving.[147] A 2012 study showed that an hour of walking each day can even help override the effects of a genetic predisposition to obesity.[148]
- A recent study from the UK found that commuters who walked, cycled or took public transit at least part of the way to work were 11 percent less likely to develop cardiovascular disease and 30 percent less likely to die from it than people who commuted solely by car.[149]
- Research published in the *British Medical Journal* in 2017 found that, compared to those who drive or take public transit, cycle commuters were 41 percent less likely to die prematurely, 46 percent less likely to develop heart disease and 52 percent less likely to die from it, and 45 percent less likely to develop cancer and 40 percent less likely to die from it. The same study found that those who walk to work have a 27 percent lower risk of developing cardiovascular disease and a 36 percent lower risk of dying from it.[150]

Reducing driving will also reduce car crashes, which take an enormous toll, both economically and in terms of lost lives. There were more than 36,000 people killed in crashes in 2018.[151] And in 2010, the last year for which data is available, the total economic impact of car crashes including lost lives, injuries and property damage amounted to $242 billion.[152]

THE GOAL

The U.S. should at least double the number of people who travel by foot, bike or transit by 2030.

Doubling the number of people who travel by foot or bike or on transit by 2030 is the beginning of the kind of transformative change that is needed if the United States is going to end its damaging dependence on the automobile. It is, however, an ambitious mid-term goal – one that can drive emission reductions in the short term and push the nation to build more sustainable communities with more transportation options in the long run.

By doubling the number of people who travel primarily on foot, bike or public transit, America can improve public health, reduce emissions, enhance communities, and substantially ease the task of moving to a zero-emissions transportation system. Specifically, achieving this goal would:

- Increase walking, biking and transit travel by more than 100 billion miles, assuming that the current distance traveled by these modes were to double.[153] If this increase were to be matched by a parallel decrease in miles traveled by car, vehicle carbon dioxide emissions would be reduced by approximately 32 million metric tons.[154] While this does not take into account potential increases in emissions from new transit routes, a rapid transition to electric buses would reduce the greenhouse gas impacts of those additional trips.

- Reduce overall transportation energy use, making the task of repowering the transportation system with clean energy far easier.
- Benefit public health and wellbeing. Studies have found that people who walk or bike to work are happier with their commutes.[155] If the U.S. were to double walking and biking mileage, Americans would burn an extra 2.7 trillion calories in 2030.[156]

GETTING THERE

To double the number of people who travel by foot, bike and transit, the U.S. must make these forms of travel the cheapest, easiest, most comfortable and safest options available.[157] That will mean undertaking a variety of initiatives, including providing better infrastructure and changes to transportation finance.

While policies for encouraging increased transit use and active forms of transport are varied, they can also reinforce each other and make the path forward far easier. For example, the design changes that make cycling safer also typically make walking more pleasant.[158] Because around 90 percent of transit trips are accompanied with walking trips for a part of the journey, improved walking conditions make transit more accessible. Similarly, increased transit ridership will mean more people walking to and from rail and bus stops.[159] And policies that reduce subsidies to driving can make all forms of non-auto transportation more attractive, particularly if paired with increased funding for those modes.

Ensure that walking, biking and transit are safe, affordable, accessible and enjoyable

Ensuring that active transportation options and public transit are safe, affordable, accessible and enjoyable is key to increasing the number of people who travel without a car.[160] Places that have invested in improved infrastructure and better service have seen subsequent improvements in safety and increased transit ridership. Two approaches in particular – adopting "complete streets" principles and investing in transit improvements – can get more people traveling by foot, bike and transit.

Create "complete streets" that work for everyone

There are a wide variety of design and policy factors that affect the safety and quality of walking and cycling, ranging from road design, to speed limits, to infrastructure elements like sidewalks and bus and bike lanes.[161] Many of these elements fall under the concept of "complete streets," which, as described by the U.S. Department of Transportation, are "streets designed and operated to enable safe use and support mobility for all users," including "people of all ages and abilities, regardless of whether they are travelling as drivers, pedestrians, bicyclists, or public transportation riders."[162] By the end of 2018, nearly 1,500 communities across the U.S. – primarily towns and small suburbs – had adopted "complete streets" policies.[163]

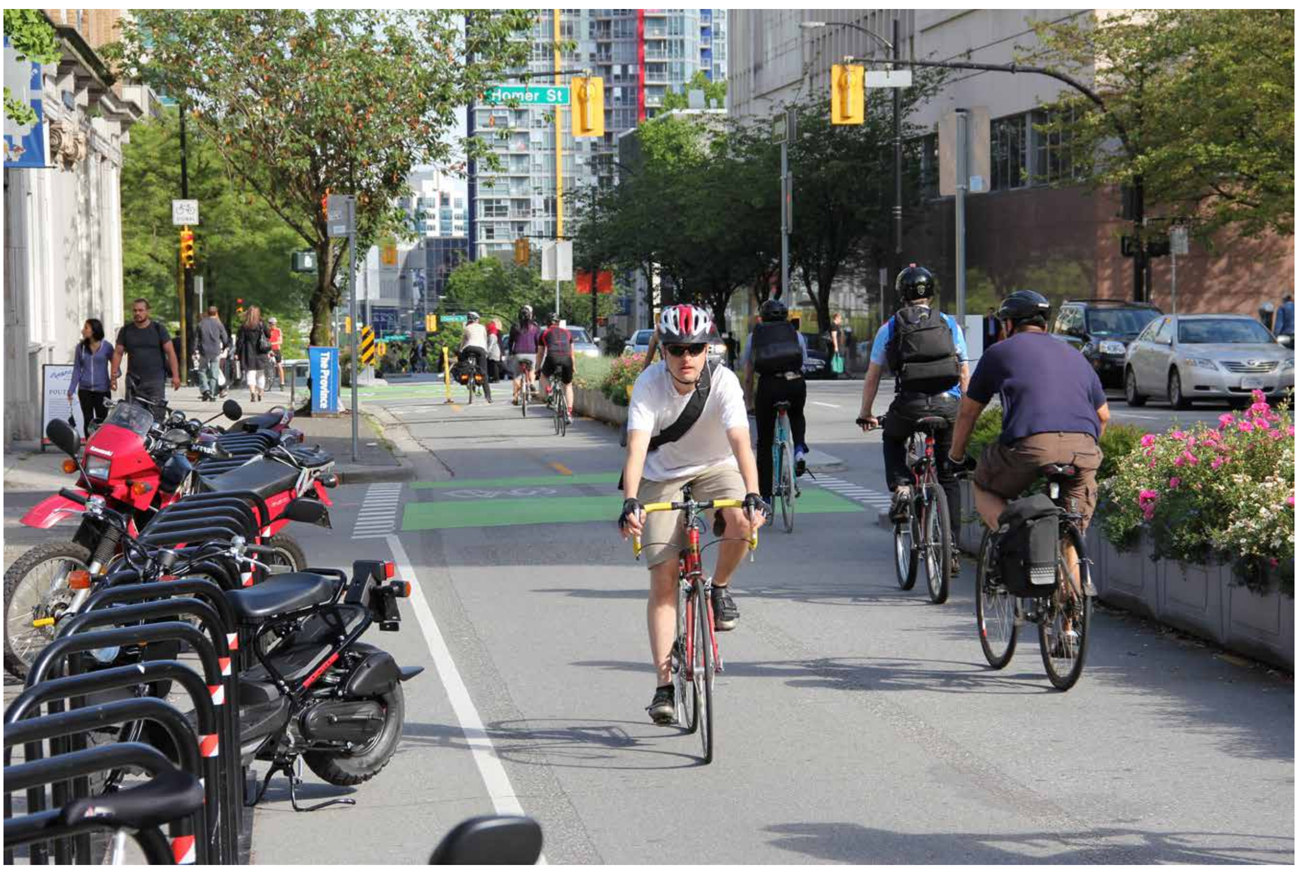
Cities that have implemented complete streets policies typically see more walking and biking, and less driving.[164] Good bicycle infrastructure, including separated bike lanes, is associated with both greater cyclist safety and higher rates of cycling.[165] Research has found that, for U.S. cities with over 250,000 people, each additional mile of bike lane per square mile increases the share of people who bike by about 1 percent.[166]

Complete streets also increase safety. A study published in the *American Journal of Public Health* found that protected bike lanes can reduce injury risk by almost 90 percent.[167] Another study assessed impacts of adding complete street elements – including a raised median, redesigned intersections and sidewalks – to a suburban four-lane road in New Jersey. The study found that after the changes were implemented, pedestrian "exposure risk" – the time it takes pedestrians to cross a street, where they are exposed to oncoming traffic – dropped by 28 percent.[168] As more people use the roads for walking and biking, safety likely increases further: A study in the journal *Injury Prevention* determined that there is "safety in numbers" for pedestrians and bicyclists, and that "[p]olicies that increase the numbers of people walking and bicycling appear to be an effective route to improving the safety of people walking and bicycling."[169]

Complete streets policies can be particularly effective when tied to a broader strategy to improve safety, including so-called "vision zero" strategies to eliminate all traffic fatalities. "Vision zero" strategies include not just complete streets and other improvements to the built environment, but also engagement with public health officials, law enforcement and community members, the collection and application of data on traffic deaths, and a focus on safe speed limits.[170]

Expand and improve transit

Cities and transit agencies need to maintain, expand and improve public transit service. There are many ways to do this, including



By designing streets to serve pedestrians, bicyclists and transit – including by adding infrastructure like this separated bike lane in Vancouver – cities can encourage low-carbon transportation and make streets safer for everyone. Photo: Paul Krueger via Flickr, CC BY 2.0

adding routes, building better platforms and transit stations, allocating dedicated bus lanes and reducing the cost of riding. Improving frequency, reducing passenger crowding, and ensuring safety and reliability are all important ways to improve rider satisfaction.[171] With local transit systems facing serious revenue crises due to the sharp drop-off in ridership during the coronavirus pandemic, enabling cities to undertake these improvements will require significant – and immediate – investment of federal funds.[172]

Experience shows that this investment is worthwhile. While every region is different, the evidence is clear that when transit service is expanded or improved, more people ride. A TransitCenter analysis of the National Transit Database found that in 2018, transit ridership increased in seven of the 35 regions with the highest transit usage.[173] Of those seven regions, six – Seattle, Houston, Austin, San Antonio, Las Vegas and Pittsburgh – had either substantially increased transit service since 2013, or had recently reoriented their transit networks to meet growing demand.[174]

In Seattle, for example, ridership levels have increased since 2014, when voters approved the Seattle Transportation Benefit District Proposition 1 to generate about $50 million each year to invest in the city's transit system. The initiative has added nearly 7,000 weekly bus trips to the city. It has provided every public high school student with free, unlimited transit passes.[175] Perhaps most importantly, the initiative has given more people access to high-frequency transit service, increasing the percentage of households that live within a 10 minute walk of "10-minute service" (a route with an average of a trip every 10 minutes in each direction) from 25 percent to 67 percent.[176]

As service has expanded and improved, Seattle has seen an increase in transit use, as well as other low-carbon modes, and a decrease in driving. From 2010 to 2017, the percentage of commuters getting to downtown Seattle via transit grew from 42 percent to 48 percent, while the share of trips in single-occupancy vehicles fell from 35 percent to 25 percent.[177]

Maintaining, improving and expanding public transit should begin with ensuring maintenance of existing systems. Among other things, this will require increasing funding to the Federal Transit Administration's "State of Good Repair" program to address the current $98 billion backlog in needed transit repairs, while also investing more in other funding mechanisms to allow for the expansion and construction of new public transit.[178] Grants or loan assistance programs, such as competitive programs like Better Utilizing Investments to Leverage Development (BUILD) grants and Capital Investment Grants, are another opportunity to fund more low-carbon transportation options.

Allocation of federal grant money for transit projects can be expedited by easing federal red tape for small-scale transit projects with clear environmental benefits. Federal funding programs that are currently limited to capital expenditures could be expanded to also support operating expenses, encouraging transit agencies to increase service on already-existing bus and rail lines. Funding programs should include requirements that hold states accountable for setting and meeting goals that reduce per capita miles driven, and the allocation of federal funding should favor direct financial support to local governments pursuing innovative land-use and demand management transportation programs. In addition, increased federal funding – for example through the Passenger Rail Improvement, Modernization and Expansion (PRIME) federal grant program – should be allocated for railway improvement and expansion, including for the electrification of rail lines across the country.

Covering transit operating costs for every American city costs money. Estimates vary as to the precise amount. The Urban Institute recently estimated that $16.7 billion in annual operating support would be sufficient to ensure that every urban area with 100,000 residents or more is able to provide high-quality public transit service, and Transit Center has called for $20 billion in operating assistance as part of an overall increase in federal transit spending to $50 billion a year.[179]

Incentivize strategies for vehicle sharing and micromobility

Cities, employers and college campuses should pursue policies that encourage forms of shared micromobility, such as car-, bike- and scooter-sharing, which give people short-term access to transportation on an 'as-needed' basis.[180] Such programs have been proven to help people lead lifestyles that don't require owning a car, or that require owning fewer cars.

Programs that promote forms of shared micromobility, like bike-sharing, have been proven to help people reduce their reliance on cars. Photo: Aaron Doucett via Unsplash

Studies have shown that roundtrip car-sharing, for example, reduces the number of vehicles on the road, as well as VMT, greenhouse gas emissions and individual transportation costs.[181] Research published in 2015 on members of car-sharing company Zipcar found that 40 percent of users of the company's Zipcar for Business package either sold or opted not to buy a vehicle due to shared vehicle access through their employers.[182] Another study similarly found that 30 percent of users of the now defunct San Francisco service City CarShare relinquished one or more of their own personal vehicles, and two-thirds decided to postpone buying another vehicle after using the service for two years.[183] A 2011 study of roundtrip carsharing programs in the U.S. and Canada found that a quarter of the study participants sold a vehicle and another quarter put off buying a new vehicle as a result of carsharing.[184] The latter study found that one carsharing vehicle replaced between nine and 13 vehicles among carsharing members. With this came an up to 43 percent decline in household annual VMT and an up to 41 percent reduction in annual household greenhouse gas emissions.[185]

End subsidies that make driving artificially cheap

All efforts to increase the number of people who switch to transit and active modes of travel will be made easier by ending subsidies that make driving artificially cheap. Every year, for example, the U.S. government spends more than $7 billion to encourage people to drive to work through the federal income tax exclusion for employer-provided and employer-paid commuter parking.[186] Other examples of subsidies for driving include free on-street parking, subsidized municipal parking, and subsidies for the fossil fuel industry that contribute to artificially low fuel prices.[187] This heavy subsidization is an important factor underlying high levels of driving in the U.S. A 2011 study comparing U.S. and German residents found that Americans are more likely to drive since U.S. subsidies encourage and incentivize driving even in places where walking, biking or transit are available.[188]

Policies that raise the cost of accessing roadways or parking make the financial cost of driving come closer to reflecting its true costs and increase the attractiveness of walking, biking and transit. Increasing the gas tax or imposing carbon fees or taxes can help to ensure that the price people pay for driving corresponds to the damage it inflicts on the environment, society and our infrastructure.

One example is congestion pricing, which refers to tolling methods that take a market-based approach to managing congestion, often with tolls that vary by time of day or traffic level. Particularly when paired with expanded transit service, congestion pricing has proven to be an effective policy for increasing transit ridership.[189]

Low-carbon transportation can likely be further encouraged with more fundamental changes to the U.S. system of transportation finance. To date, taxes on drivers have been seen primarily as a way to raise money for transportation. But they can fill a more important purpose by being used to recoup some of the costs drivers impose on society and improve the efficiency of the transportation system. Congestion pricing, parking pricing, pollution-based charges and similar charges can encourage transportation choices that deliver the greatest benefits to or impose the least costs on society – even if every penny of revenue from those fees is returned to taxpayers or used for purposes other than transportation.

Such changes will likely become more important with increased adoption of efficient electric vehicles, which could significantly reduce the per-mile cost of driving. If reduced cost leads to more driving, that additional driving could offset some of the climate benefits of cleaner and more efficient vehicles.[190]

Electrifying public transportation

Enabling more Americans to shift from driving to public transit is a crucial step toward reducing emissions from the transportation sector. But while riding the bus or train has substantial environmental benefits compared to relying on private vehicles, most of America's buses and trains are still powered by polluting fossil fuels, such as diesel. Although buses emit far less pollution per passenger than personal vehicles per mile of travel, they emit significant quantities of both global warming emissions and air pollutants that pose a threat to public health.[191] By electrifying public transit – including the nation's school buses – public transportation can eventually be powered with clean, renewable energy, creating a transit system that would emit no pollution either from charging or driving.

Across the country, cities and school districts are considering a shift from diesel to electric buses. By eliminating diesel exhaust emissions, particulate pollution and pollutants that contribute to the formation of ground-level ozone, electric buses improve the air quality in our communities.[192] Replacing diesel buses with electric ones would bring major public health benefits to the densely populated areas that transit buses often serve. The state of California estimated that, under a state law that requires bus electrification, cumulative nitrogen oxide and particulate matter emissions would be reduced by 7,000 tons and 40 tons, respectively, from 2020 to 2050.[193]

They also produce significantly lower greenhouse gas emissions than their fossil-fuel-powered counterparts. Replacing all of the country's diesel-powered transit buses with electric ones could eliminate more than 2 million tons of greenhouse gas emissions each year, and replacing all school buses with electric models could avoid an average of 5.3 million tons of emissions each year.[194] Benefits would continue to increase as America transitions to clean, renewable energy.[195]

A 2018 study by the Union of Concerned Scientists found that electric buses produce significantly lower greenhouse gas emissions than diesel, diesel hybrid and natural gas-powered buses over their entire life cycle, including the process of generating the electricity that powers them, and that there are benefits across the country, even in places where the electric grid is carbon intensive.[196] Buses charged on California's clean electric grid, for example, had 70 percent lower life-cycle emissions than diesel or natural gas buses, but the study found that electric buses consistently produce lower emissions than both diesel and natural gas-powered buses in every area of the country.[197] Over its entire life cycle, an electric bus charged with the national electricity mix produces less than half of the carbon dioxide-equivalent (CO_2e) emissions per mile as are produced by natural gas or diesel-hybrid buses.[198]

By switching to electric buses, transit agencies and school districts can help individual towns and cities reduce their contribution to global warming. For example:

- If the Chicago Transit Authority were to replace its entire diesel fleet with electric buses it would avert nearly 55,000 tons of greenhouse gas emissions each year, equivalent to taking more than 10,000 cars off the roads.

- The transit agency serving Philadelphia, the Southeastern Pennsylvania Transportation Authority, could avert 22,000 tons of greenhouse gas emissions every year, akin to taking more than 4,000 cars off the roads.

- Replacing Denver's diesel buses would avert nearly 47,000 tons of greenhouse gas emissions each year, equivalent to taking more than 9,000 cars off the road.[199]

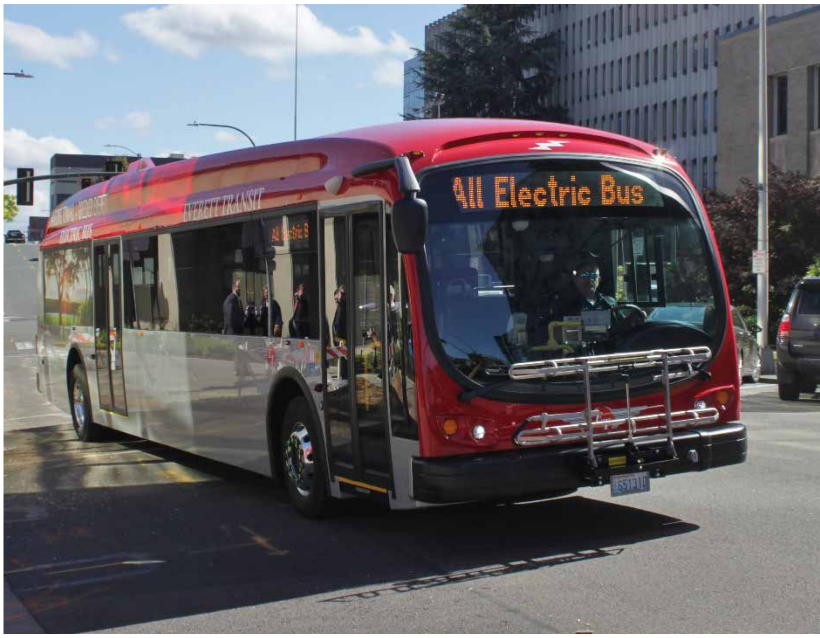
Electric buses provide other benefits, too. They are quiet, and can help bring down noise levels in urban environments. Traffic-related noise pollution has been associated with adverse health effects including strokes and cardiovascular disease, as well as cardiovascular and all-cause mortality.[200] They also have lower operational costs, and can provide cities and school districts with long-term financial savings.[201]

Electric buses are a relatively new technology, and over the last two decades the cities and school districts pioneering this technology, in collaboration with electric bus manufacturers, have worked to overcome the inevitable challenges and hurdles that come with such technology.[202] The technology has improved exponentially, but there are a number of things policymakers can do to further minimize operational difficulties. These include providing grant programs and subsidies for agencies to go electric, and financing programs whereby states front the initial investment for electric buses and allow cities and school districts to pay back on utility bills as they save on fuel and maintenance costs. These "pay as you save" financing programs can help agencies overcome the higher upfront costs of electric buses and deliver immediate monetary savings. In addition, public officials and utilities should provide discounted off-peak charging rates, limit excessive demand charges, and experiment with policies and practices that allow battery-electric buses to be used for energy storage.[203] With proper policy support, electrification need not come at the expense of service. Both should be prioritized.

The switch to electric buses needs to be in the context of a broader shift toward the electrification of other forms of transit –

including rail. Rail is already one of the most environmentally friendly modes of travel and the most energy-efficient means of motorized passenger transport.[204] However, while the sector produces lower emissions than other forms of transport, diesel-powered locomotives still emit soot, VOCs, nitrogen oxides and other dangerous pollutants found in diesel exhaust.[205] Switching to electric trains would reduce this pollution – which is especially important since many rail lines pass through urban areas. Electric trains even now emit up to 35 percent less carbon per passenger mile than their diesel counterparts, and when powered by renewable energy can provide carbon-free transit.[206]

Connecting major cities with electric high-speed electric rail will reduce the need for short-distance air travel, reducing carbon emissions from the aviation sector. Research suggests that high-speed rail lines can reduce aviation transport on the same routes by up to 80 percent.[207] According to the International Energy Agency, a new high-speed line can produce "almost immediate" net CO_2 benefits by reducing air and car journeys.[208] Electric engines are also 35 percent cheaper to operate than diesel and transport freight five times more efficiently than trucks.[209] Per ton-mile, they also cause only about one-eighth as many fatalities as truck freight.[210] In addition, as residents and businesses cluster around rail transit hubs, the expansion of high-speed rail will promote more walkable, transit-oriented development.[211]



Electric buses reduce greenhouse gas emissions and bring important public health benefits both to the densely populated areas that transit buses often serve, and to young people who ride school buses.

Photo: SounderBruce via Flickr, CC BY-SA 2.0

THE GOAL

U.S. transit agencies and school districts should replace all transit and school buses with clean electric buses by 2030, while also electrifying other transit services.

By electrifying all transit and school buses, America can ensure that public transit, which is already cleaner and more efficient than personal vehicles, contributes to a healthy, zero-emissions transportation system. Specifically, accomplishing this goal would:

- Improve air quality and public health. Electrifying buses would eliminate harmful street-level emissions from diesel combustion in buses, including particulate matter and nitrogen oxides. This would benefit the health of anyone who would otherwise be exposed to bus exhaust, including the 25 million children who ride school buses each day, and the urban populations often served by buses.[212]
- Eliminate the approximately 17 million metric tons of greenhouse gas emissions that transit and school buses currently emit each year if buses are charged using clean, renewable energy.[213] As America expands public transit, these emissions benefits will grow.

GETTING THERE

Achieving 100 percent electric buses by 2030, and electrifying other forms of transit, can be achieved using technology that is available today and with which transit agencies are gaining increasing levels of experience. To make the switch, however, policymakers must help agencies access the know-how and financial resources they need to adopt electric buses.

Transit agencies and governments around the country have already begun to explore a future of electric buses. By the end of 2018, 13 percent of transit agencies had either already deployed or ordered an electric bus.[214]

Nevertheless, American electric bus adoption is still in its early stages. As of November 2020, only around 650 of the more than 65,000 transit buses currently in use in the U.S. were electric – a significant jump from previous years, yet still accounting for just 1 percent of all transit buses.[215] Among the 480,000 school buses currently in use, data on the number of electric buses is not available, although as of July 2019 the Lion Electric Company had deployed more than 200 electric school buses in North America.[216]

Fortunately, buses provide a key opportunity for rapid electrification. Most buses on the road are owned and operated by transit agencies and school districts that can make wholesale commitments to shifting their fleets.[217] Transit agencies and school districts also have important reasons to adopt electric buses. Buses often drive in stop-and-go traffic, where diesel engines waste energy and electric buses can use regenerative braking.[218] Transit agencies and school districts typically have central depots where buses can charge.[219] And there are major cost savings to be made by adopting electric buses, which can be much cheaper to fuel and maintain than fossil fuel-powered buses.[220]

Electric buses are also ready for widescale adoption. They have already been deployed successfully in communities around the U.S., and there are now more than 500,000 buses on the road worldwide, mostly in China.[221]

Other forms of electric transit – including electric trains, trams and trolleybuses – have been in existence for more than a century and can also encourage the shift away from fossil fuel-powered transportation.

Adopt electric bus commitments

By adopting commitments to transition their fleets, transit agencies, school districts, cities and states can put America on the path to a fully electrified bus system. By doing so quickly, transit agencies and school districts could electrify their entire bus fleets by 2030 with only minimal premature retirements of fossil fuel-powered buses. According to the Federal Transit Administration (FTA), the minimum useful life of buses ranges from five years for medium-size, light-duty buses to 12 years for large, heavy-duty transit buses.[222] The average age of full-size buses in service was 7.6 years in 2017.[223]

Transit agencies, cities and states have already begun making commitments for fully electrified fleets. The three largest bus transit systems in the country – New York City's Metropolitan Transportation Authority (MTA), the Los Angeles County Metropolitan Transportation Authority (LA Metro) and the Chicago Transit Authority (CTA) – have plans to transition to all-electric bus fleets.[224] The LA Metro plans to transition to an all-electric fleet by 2030, and has begun procuring and testing electric buses.[225] The agency deployed its first 60-foot electric bus in July 2020.[226] The MTA, which operates the nation's largest bus fleet and buys approximately one out of every 10 buses sold in North America each year, plans to transition its entire fleet by 2040 and to add 1,800 electric buses to its fleet within 10 years.[227] By moving to all-electric fleets, the MTA, LA Metro, and the CTA would move the entire U.S. fleet toward electrification and could prompt other transit systems to make similar commitments.

In the state of California, the California Air Resources Board has adopted a policy that will require 100 percent of new buses purchased by transit agencies to be electric by 2029, and has set a statewide goal of a fully electrified bus fleet by 2040.[228] The California policy sets different timelines for large and small transit agencies, allowing smaller agencies to make a somewhat slower transition.[229]

Provide financial and technical assistance

The work of electrifying bus fleets operated by America's more than 1,000 bus transit agencies and 14,000 school districts can be helped considerably by assistance from the federal and state levels.[230]

Financial assistance programs have been important in getting the first generation of electric buses on the road. While electric buses tend to save money over vehicle lifetimes, they are more expensive to purchase, and going electric creates additional costs, including charging infrastructure.

The Federal Transit Administration's Low or No Emission Vehicle Program, for example, has funded dozens of electric bus projects around the country. Since 2016, the program has provided nearly $280 million in funding primarily for electric buses and related infrastructure.[231] In FY2019, all 38 projects that received program funding were for bus electrification, in 38 different states.[232] In 2010, funding from the program helped the city of Seneca, South Carolina, develop the first scalable model of an all-electric bus transit system in the U.S. With funding help from the program, along with a mix of state and local funding, in 2014 Seneca became the first city in the world to launch an all-electric municipal bus fleet.[233]

The Volkswagen Environmental Mitigation Trust, formed with nearly $3 billion as part of VW's settlement over emission violations, has served as another important funding source for bus electrification. A study by the U.S. PIRG Education Fund in 2019 found that 30 states have prioritized electric bus projects with the funding, based on a review of each state's funding goals and actual project funding.[234] In Virginia in 2019, for example, Governor Ralph Northam announced an initiative to use $20 million from the Volkswagen Environmental Mitigation Trust to reimburse school districts for spending on electric school buses and charging infrastructure.[235] Virginia's Department of Environmental Quality will begin accepting applications in the spring of 2021.[236]

Also in Virginia, the electric utility Dominion Energy has announced a novel approach that it claims will help the state achieve 100 percent electric school buses by 2030. The program will, according to the utility, "offset the additional costs of an electric school bus, including charging infrastructure, above the standard cost for a diesel bus."[237] Dominion expects that a network of electric school buses will help the utility deploy renewable energy resources, by using bus batteries "to store and inject energy onto the grid during periods of high demand when the buses are not needed for transport."[238]

In addition to providing financial support, the federal and state governments can also play a role in providing technical assistance. In a report by the World Resources Institute, lack of technical knowledge was identified as a key barrier to city and transit agency adoption of electric buses.[239] Government assistance can help with a wide variety of technical challenges and questions. States can ensure that cities and transit agencies understand the benefits of and opportunities for deploying electric buses. They can help states plan charging networks, route adjustments and vehicle procurement. And once cities have an electric fleet running, states can ensure cities have the tools they need they need to manage charging, collect data, and optimize operations.

Electric vehicles

A healthy, zero-carbon transportation system requires that the U.S. eliminate emissions from light-duty vehicles. To do so, the U.S. must end the use of fossil fuel-powered vehicles. That means reducing our dependence on motorized transportation where possible and shifting our remaining travel to vehicles powered by electricity.

A shift to electric vehicles won't meaningfully reduce the threat of death or injury from traffic crashes, or other threats to health and safety that stem from the act of driving itself. However, because electric vehicles are efficient and can be powered by clean energy, electrification can reduce energy use, greenhouse gas emissions and emissions of many of the toxic pollutants of fossil-fuel-powered vehicles into the atmosphere.[240]

A study published in 2020 by Environmental Defence and the Ontario Public Health Association projected that replacing all cars and SUVs in the Greater Toronto area with electric vehicles would avoid 313 deaths from air pollution in Toronto every year. If all buses were replaced with electric buses as well, that figure increases to 456.[241] A study from China estimates that if just 27 percent of private cars and a slightly larger percentage of commercial vehicles were electric, the reduction in annual concentrations of fine particulate matter, nitrogen dioxide and summer concentrations of ozone in the air by 2030 could avoid almost 17,500 deaths across China every year.[242]

While there are environmental costs to manufacturing EVs, an electric vehicle powered by wind turbines or solar power emits no pollution from fossil fuel combustion.[243] A detailed study by the Electric Power Research Institute and the Natural Resources Defense Council concluded that "electrification is an essential strategy for achieving deep GHG emission reductions in the transportation sector."[244] That study found that, under a scenario in which electricity powers 53 percent of personal vehicle-miles traveled, transportation emissions would be reduced by 52 percent to 60 percent, depending on the share of the grid powered by low- or zero-emission energy sources.[245] As penetration of electric vehicles and clean energy increases, so do the climate benefits.

Electric cars are more than three times as energy efficient as cars powered by fossil fuels, which means that replacing the current fleet of vehicles with electric ones will lead to a large reduction in overall energy use and greenhouse gas emissions.[246] Gas-powered vehicles waste large amounts of energy; they lose about 60 percent of the energy they consume just to engine heat loss.[247] EVs, on the other hand, waste little thermal energy, waste almost no energy from idling, and can recover energy using regenerative braking.[248] As a result, EVs are able to convert more than 77 percent of electrical energy to power at the wheels, while gasoline-powered vehicles are only able to convert between 12 and 30 percent of the energy stored in gasoline.[249] In large part because of their efficiency, even today's EVs powered by a largely fossil fuel grid are reducing emissions and cleaning the air. The U.S. Department of Energy's Argonne National Laboratory found that, through 2017, U.S. plug-in electric vehicles had offset 2.6 million metric tons of carbon dioxide emissions, even after accounting for emissions from generating the electricity to charge the vehicles.[250]

Since electric vehicles are significantly quieter than internal combustion engines and their exhaust systems, switching to electric vehicles will also reduce noise pollution.

This electric vehicle charging station is powered by solar panels installed on a parking canopy. Because electric vehicles can be powered by clean energy sources including wind and solar power, they can enable a transition to a zero-carbon transportation future. Photo: Dennis Schroeder, National Renewable Energy Laboratory

A growing body of research links noise pollution to a wide range of serious health impacts.[251] These include increased risk for cardiovascular disease and atrial fibrillation – which can increase the risk of heart failure and stroke – elevated stress levels, and impaired mental health.[252]

Battery technology is also flexible and well-suited for small, efficient vehicles ranging from scooters to "neighborhood electric vehicles," or NEVs, which are golf-cart sized vehicles with low top speeds.[253] Compared to full-size vehicles, NEVs have smaller batteries and use less energy to charge and manufacture.[254] Lighter weights and slower speeds may also reduce risks to pedestrians and bicyclists on residential streets, helping encourage those other forms of low carbon transportation.[255]

THE GOAL

All new light-duty cars and trucks sold after 2035 should be electric vehicles and all new medium and heavy-duty trucks sold by 2040 should be electric.

By phasing out sales of fossil fuel vehicles by 2035, including federal, state and municipal fleets, as well as private and business fleets (such as delivery trucks and ride hailing fleets that have high VMT), the U.S. can help create a clean, emission-free transportation system. Specifically, achieving this goal would:

- Help ensure that, by 2050, almost all cars on American roads produce zero emissions. The average age of light-duty vehicles on the road is 11.9 years.[256] If every car sold by 2035 is an electric vehicle, by 2050 the vast majority of cars on the road will be electric, with only a small number of aging fossil fuel vehicles left on the road, barring proposals to ban or accelerate the retirement of such vehicles.

- Improve air quality and public health. Replacing gasoline vehicles with electric ones would reduce the harmful street-level emissions currently produced by internal combustion engines, including eliminating the particulate matter and nitrogen oxides released in vehicle exhaust. A 2019 study found that electrification of passenger vehicles would lead to modest improvements in air quality with the current grid and dramatic air quality improvements when EVs are powered by clean, renewable energy sources.[257]
- Eliminate the vast majority of carbon emissions from personal vehicles by 2050. Replacing the vehicle fleet alone will not eliminate all transportation emissions, because EVs need to be charged from the electric grid. But an entirely electric fleet paired with a zero-emission grid would mean zero fuel-related emissions from charging or driving.

GETTING THERE

Getting to 100 percent EV sales by 2035 can be achieved with existing technology and proven policy pathways. Today's EVs have a great enough range to serve the vast majority of the trips most Americans take. A 2016 study found that the 2013 Nissan Leaf, with a range far below most EVs on the market today, could "replace 87% of vehicles driven on a given day without recharging."[258]

Americans are already adopting EVs in large numbers: nearly 330,000 electric vehicles were sold in 2019 alone, accounting for more than 2 percent of all vehicle sales.[259] To date, a total of more than 1 million battery-powered and plug-in hybrid EVs have been sold cumulatively across the U.S.[260] Eliminating sales of fossil fuel vehicles by 2035, however, will require a rapid transformation of the vehicle market, with the share of vehicle sales accounted for by EVs needing to expand 50-fold in just 15 years.[261]

The hundreds of thousands of electric vehicles on the road today are there in large part thanks to policy support from cities, states and the federal government. Accomplishing the growth necessary to achieve 100 percent EV sales will require building on those policies in the years ahead.

Set goals to phase out conventional vehicles and require increased sales of EVs

Sales goals and requirements for electric vehicles can drive car companies to sell zero-emission vehicles, contribute to continued advances in technology, and create certainty in the market for electric vehicles that can unleash investment in public chargers and other supporting infrastructure.

State policies that require EV sales have already helped put hundreds of thousands on the road. The Zero-Emission Vehicle (ZEV) program, a California state regulation that has been adopted by 10 other states, requires that automakers sell a set percentage of electric cars and trucks.[262] In 2017, the California Air Resources Board found that the program had helped result "in over 215,000 ZEVs and [plug-in hybrid electric vehicles (PHEVs)] being placed in California over the last five years and an expansion from 25 models offered today to over 70 unique ZEV and PHEV models expected in the next five years."[263] In September 2020, California Governor Gavin Newsom issued an executive order requiring 100 percent of in-state sales of new passenger cars and trucks be zero-emission by 2035.[264]

Achieving 100 percent EV sales nationally will also likely require action at the federal level. Indeed, while a transition to all-electric vehicles by 2035 would enable the U.S. to achieve a zero- or near-zero carbon transportation system by 2050, some elected officials and political candidates have proposed more ambitious plans for a complete shift to zero-emission light-duty vehicle sales by 2030.[265] If successful, such plans would help the U.S. achieve even more rapid reductions in greenhouse gas emissions and pollution.

A federal EV goal would align with other efforts from the international community. Policymakers in eight countries have already set goals to completely phase out fossil fuel vehicles, although most have not been accompanied by binding legislation.[266]

Reduce financial hurdles to EV adoption

As the result of low fuel and maintenance costs, EVs are typically cheaper to own than conventional vehicles over the vehicle's lifetime.[267] In the face of higher upfront costs and the usual uncertainty surrounding new technologies, however, financial incentives are an important tool for increasing EV sales. [268]

Financial incentives are proven tools to increase adoption of electric vehicles.[269] To date, the Federal Plug-In Electric Drive Vehicle Credit has been perhaps the most important program in the United States for boosting sales of electric vehicles. A 2016 study by the Institute of Transportation Studies at University of California-Davis attributed 30 percent of all plug-in electric vehicle sales to the tax credit.[270] The tax credit was found to be particularly important for sales of lower-cost EVs, buyers of which tend to be price sensitive.[271]

Perhaps the strongest evidence that tax credits are important for electric vehicle sales has been the effect of their removal. In Georgia, sales of electric vehicles dropped precipitously following the removal of the state's EV rebate program.[272]

Programs that bring down the already-low cost of owning an electric vehicle can also be important tools to encourage EV purchases. Such programs include those that reduce the cost of charging an EV, or that give EV owners opportunities to sell EV batteries into a secondary market where they can be reused for grid storage or other purposes. Similarly, used EV programs such as California's Clean Vehicle Rebate Project (CVRP) can help make EVs more accessible for low income residents. Rebates should be available at point of purchase.[273]

Incentives can be more effective when paired with consumer education, including through initiatives that help car dealerships effectively promote and sell EVs. In Columbus, Ohio, the Electrified Dealer program provides benefits to car dealerships that pass a certification program. To pass, dealerships must meet criteria including keeping EVs in inventory for test drives, installing charging stations on-site, training sales staff and offering educational materials.[274] Within the first five months of the program, 13 dealerships were certified, carrying a total of 16 models of EVs and plug-in hybrid electric vehicles.[275]

Just as it is crucial to subsidize electric car ownership, encouraging people to switch from gasoline-powered vehicles to cleaner modes of transport can also be facilitated by subsidizing other electric modes of personal transport. The rise of the e-bike, for example, provides such an opportunity. In 2018, e-bike sales in the U.S. were up 79 percent over 2017 levels, prompting some industry experts to suggest that America could be on the brink of an "e-bike revolution."[276] Those predictions appear to have been confirmed since.

During the coronavirus pandemic e-bike use has skyrocketed, with some manufacturers reporting sales three times those of 2019.[277] Given that almost 60 percent of vehicle trips in the U.S. are less than six miles, many of those trips can easily be done on e-bikes.[278] In a 2018 survey, e-bike owners reported that more than 75 percent of their e-bike trips would have otherwise been made by car.[279] However, for many people, the high cost of e-bikes is an obstacle to e-bike ownership.[280] Currently neither the federal government nor any states provide any kind of tax credit for purchasing an e-bike. Where e-bike buying incentive programs have been put in place, however, research shows that they are successful in encouraging people to buy and use them.[281] To get people out of their cars, e-bikes should be included in clean vehicle incentive programs.

Expand and improve the EV charging network

For electric vehicles to become mainstream, they need to be easy to charge. But today, in many parts of the country, EV chargers can be both hard to find and hard to use. One 2019 survey found that a majority of consumers considering an EV purchase believed there were too few charging stations around their home and work areas, suggesting that lack of a ubiquitous charging network presents a barrier to widescale adoption.[282]

States have already demonstrated effective policies to boost the number of charging stations. In Connecticut, the EVConnecticut Electric Vehicle Charging Station Incentive Program has provided $1.1 million to partially fund 336 charging outlets at 214 locations, for both the public and private sector.[283] A similar program in New Jersey has used funding from the Volkswagen "Dieselgate" settlement to award charging station grants through the state's "It Pay$ to Plug In" program.[284] And on the West Coast, California, Oregon and Washington, along with British Columbia, have collaborated on the "West Coast Electric Highway," which the project describes as "an extensive network of electric vehicle (EV) DC fast charging stations located every 25 to 50 miles along Interstate 5, Highway 99, and other major roadways."[285]

States and cities can also ensure that new homes and buildings are constructed with EV charging equipment installed, or with the necessary wiring to accommodate future installation of EV charging equipment. For example, the city of Atlanta passed an ordinance requiring that all new homes and parking structures be ready to accommodate EV charging equipment.[286]

Policies can also help make charging an electric vehicle as quick and easy as filling up a gas-powered one, something that today is often not the case. A 2019 report by Environment America Research & Policy Center and Frontier Group found that, in California, the day-to-day experience of EV drivers seeking to charge up their vehicles "has a long way to go to match the ease and convenience of refueling a gasoline-powered car – especially when it comes to public charging."[287] The report found that many stations are not open 24 hours a day, are incompatible with different car types, or require a membership to use.[288] Moreover, instead of accepting payments through a commonly accepted method such as cash, credit or debit, some charging stations require users to take out a subscription while others allow users to pay for individual charges with a credit card. The fact that many of these services are incompatible with one another represents a further inconvenience for users.[289]

The convenience and comfort of owning an EV can be improved by setting basic standards for charging stations. In Europe, for example, countries including Norway and the Netherlands have worked to ensure a high level of interoperability.[290] In the Netherlands, EV drivers can use any public charging station in the country with a fob or key card from any network, as the system is entirely interoperable.[291] In addition to setting these kinds of common standards, cities should take a strategic approach to locating publicly available chargers, including shopping centers, workplaces, apartment buildings and other locations where people leave their cars for extended periods of time. Utility rate structure reform, such as limiting excessive demand charges, and time of use pricing, such as discounted off-peak charging rates, will incentivize EV adoption.

Conclusion

AMERICA'S CAR-DEPENDENT transportation system is a public health disaster. Our cars and trucks put our lives and health on the line every day – from crashes on the roads to pollution in the air we breathe. We need to transform transportation to give Americans new freedom to travel in ways that are clean, convenient and beneficial to our health and our communities.

The technologies of a clean transportation future are already here. The pathways to that future are increasingly self-evident. What's feeded now in order to achieve the sweeping changes necessary to protect our health, wellbeing and environment is a fundamental shift in thinking at the policy level regarding transportation infrastructure, land use, clean energy, pricing and more, as part of a new approach to transportation that puts public health and the environment first.

Notes

1. 58,000 air pollution deaths: Approximately 53,000 $PM_{2.5}$-related deaths and 5,000 ozone-related deaths per year. Fabio Caiazzo et al., "Air Pollution and Early Deaths in the United States. Part I: Quantifying the Impact of Major Sectors in 2005," *Atmospheric Environment*, 79: 198-208, doi: https://doi.org/10.1016/j.atmosenv.2013.05.081, November 2013.

2. 38,000 vehicle crash deaths: 25-year average for the years 1994-2018, calculated from statistics available via the National Highway Traffic Safety Administration, accessed 20 January 2021, archived at http://web.archive.org/web/20210127234432/https://www-fars.nhtsa.dot.gov/Main/index.aspx. See also: Association for Safe International Road Travel, *Road Safety Facts,* accessed June 2020, archived at https://web.archive.org/web/20200728205805/https://www.asirt.org/safe-travel/road-safety-facts/. Approximately 3 million nonfatally injured: Centers for Disease Control and Prevention, *Motor Vehicle Injury,* accessed 20 January 2021, available at https://www.cdc.gov/publichealthgateway/didyouknow/topic/vehicle.html.

3. Vehicle miles traveled for 2018: Federal Highway Administration, *December 2018 Traffic Volume Trends*, accessed 31 May 2019, archived at http://web.archive.org/web/20190531131845/https://www.fhwa.dot.gov/policyinformation/travel_monitoring/18dectvt/. International comparison: Vehicle miles traveled converted from vehicle kilometers traveled, United Nations Economic Commission for Europe, *Motor Vehicle Movements on National Territory by Road (Vehicle-Kms)*, accessed 26 October 2019 at https://w3.unece.org/PXWeb2015/pxweb/en/STAT/STAT__40-TRTRANS__02-TRROAD/01_en_TRRoadVehKm_r.px/. Country population data for 2017: The World Bank, *World Development Indicators – Population*, downloaded 26 October 2019 from https://data.worldbank.org/indicator/sp.pop.totl?name_desc=false.

4. U.S. Environmental Protection Agency, *Sources of Greenhouse Gas Emissions: Transportation Sector Emissions*, accessed 28 January 2021, archived at https://web.archive.org/web/20210201032453/https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#transportation.

5. U.S. Environmental Protection Agency, *Multi-Pollutant Comparison* data downloaded from https://web.archive.org/web/20201102235925/https://19january2017snapshot.epa.gov/air-emissions-inventories/multi-pollutant-comparison_.html.

6. U.S. Environmental Protection Agency, *Integrated Risk Information System: Diesel Engine Exhaust; CASRN N.A*, 28 February 2003.

7. Lung cancer: Debra T. Silverman, "Diesel Exhaust Causes Lung Cancer – Now What?" *Occupational Environmental Medicine,* 74(4):233-234, doi: 10.1136/oemed-2016-104197, 2017. Bladder cancer: Lidija Latifovic et al., "Bladder Cancer and Occupational Exposure to Diesel and Gasoline Engine Emissions among Canadian Men," *Cancer Medicine,* 4(12):1948-62, doi: 10.1002/cam4.544, December 2015.

8. Lung cancer: Ibid. Particulate matter links to lung cancer: Neil J. Hime et al., "A Comparison of the Health Effects of Ambient Particulate Matter Air Pollution from Five Emission Sources," *International Journal of Environmental Research and Public Health,* 15(6):1206, https://doi.org/10.3390/ijerph15061206, 2018. Nitrogen Dioxide: Richard W. Atkinson et al., "Long-term Concentrations of Nitrogen Dioxide and Mortality: A Meta-analysis of Cohort Studies," *Epidemiology,* 29(4):460–472, doi: 10.1097/EDE.0000000000000847, 1 June 2018.

9. Hans Scheers et al., "Long-Term Exposure to Particulate Matter Air Pollution Is a Risk Factor for Stroke," *Stroke*, 46(11), https://doi.org/10.1161/STROKEAHA.115.009913, October 2015.

10. Richard W. Atkinson et al., "Long-term Concentrations of Nitrogen Dioxide and Mortality: A Meta-analysis of Cohort Studies," *Epidemiology,* 29(4):460–472, doi: 10.1097/EDE.0000000000000847, 1 June 2018.

11. Vascular damage: Neil J. Hime et al., "A Comparison of the Health Effects of Ambient Particulate Matter Air Pollution from Five Emission Sources," *International Journal of Environmental Research and Public Health*, 15(6):1206, doi: https://doi.org/10.3390/ijerph15061206, 2018. Lung function decline: Mary B. Rice et al., "Long-term Exposure to Traffic Emissions and Fine Particulate Matter and Lung Function Decline in the Framingham Heart Study," *American Journal of Respiratory and Critical Care Medicine*, 191(6):656–664, doi: 10.1164/rccm.201410-1875OC, January 2015.

12. Asthma: e.g., Neil J. Hime et al., "A Comparison of the Health Effects of Ambient Particulate Matter Air Pollution from Five Emission Sources," *International Journal of Environmental Research and Public Health*, 15(6):1206, doi: https://doi.org/10.3390/ijerph15061206, 2018. U.S. Environmental Protection Agency, *Basic Information about NO_2*, accessed 4 January 2021 at https://www.epa.gov/no2-pollution/basic-information-about-no2. Damages lung development: W. James Gauderman et al., "Effect of Exposure to Traffic on Lung Development from 10 to 18 Years of Age: A Cohort Study," *The Lancet*, doi: https://doi.org/10.1016/S0140-6736(07)60037-3, January 2007. Increased risk of disease in later life: W. James Gauderman, Associate Professor of Preventive Medicine at the Keck School of Medicine, quoted in Jennifer Chan, "Living Near Highways Can Stunt Lungs," *USC News*, 25 January 2007, archived at https://web.archive.org/web/20210127221024/https://news.usc.edu/19557/Living-Near-Highways-Can-Stunt-Lungs/.

13. Hong Chen et al., "Living Near Major Roads and the Incidence of Dementia, Parkinson's Disease, and Multiple Sclerosis: a Population-based Cohort Study," *The Lancet*, 389(10070):718-726, doi: https://doi.org/10.1016/S0140-6736(16)32399-6, February 2017, available at http://uploads.tapatalk-cdn.com/files-1235/roads.pdf. See also: Christopher Ingraham, "Air Pollution Is Getting Worse, and Data Show More People are Dying," *Washington Post*, 23 October 2019, archived at https://web.archive.org/web/20200728232746/https://www.washingtonpost.com/business/2019/10/23/air-pollution-is-getting-worse-data-show-more-people-are-dying/.

14. U.S. Environmental Protection Agency, *Research on Near Roadway and Other Near Source Air Pollution*, accessed 14 December 2020 at https://www.epa.gov/air-research/research-near-roadway-and-other-near-source-air-pollution. *Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects*. Health Effects Institute: Boston, 2010.

15. P. van Vliet, "Motor Vehicle Exhaust and Chronic Respiratory Symptoms in Children Living near Freeways," *Environmental Research*, 74(2):122-32, doi: 10.1006/enrs.1997.3757, 1997. N. Ji et al., "Personal Exposure to Black Carbon, Nitrogen Dioxide, and Chronic Psychosocial Stress: Impacts on Childhood Asthma Exacerbation in a Seaport-Adjacent Community," *American Journal of Respiratory and Critical Care Medicine,* 195:A4803, 2017, available at American Thoracic Society International Conference Abstracts, http://www.atsjournals.org/doi/abs/10.1164/ajrccm-conference.2017.195.1_MeetingAbstracts.A4803. Andrea J Venn et al., "Living Near a Main Road and the Risk of Wheezing Illness in Children," *American Journal of Respiratory and Critical Care Medicine*, 164(12), doi: https://doi.org/10.1164/ajrccm.164.12.2106126, 2001.

16. Laura Perez et al., "Near-Roadway Pollution and Childhood Asthma: Implications for Developing 'Win-Win' Compact Urban Development and Clean Vehicle Strategies," *Environmental Health Perspectives*, 120(11):1619–1626, doi: 10.1289/ehp.1104785, 2012.

17. 42 percent: Erin Kulick et al., "Residential Proximity to Major Roadways and Risk of Incident Ischemic Stroke in NOMAS (The Northern Manhattan Study)," *Stroke*, 49(4):835–841, doi: https://doi.org/10.1161/STROKEAHA.117.019580Stroke, March 2018. Post-stroke mortality: Elissa H. Wilker et al., "Residential Proximity to High-traffic Roadways and Poststroke Mortality," *Journal of Stroke and Cerebrovascular Diseases*, 22(8):e366-72, doi: 10.1016/j.jstrokecerebrovasdis.2013.03.034, 2013.

18. Wen Qi Gan et al., "Association of Long-term Exposure to Community Noise and Traffic-related Air Pollution with Coronary Heart Disease Mortality," *American Journal of Epidemiology*, 175(9):898-906, doi: 10.1093/aje/kwr424, April 2012. For a detailed overview of current research on the health effects of traffic-related noise pollution, see Thomas Münzel et al., "The Adverse Effects of Environmental Noise Exposure on Oxidative Stress and Cardiovascular Risk," *Antioxidants and Redox Signaling*, 28(9):873–908, doi: 10.1089/ars.2017.7118, March 2018.

19. 38,000 vehicle crash deaths: see note 2. Leading cause of death: Association for Safe International Road Travel, *Road Safety Facts,* accessed June 2020, archived at https://web.archive.org/web/20200728205805/https://www.asirt.org/safe-travel/road-safety-facts/.

20. 6,300 pedestrians, 800+ cyclists: National Highway Traffic Safety Administration, *2018 Fatal Motor Vehicle Crashes: Overview*, October 2019, available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812826. U.S. Department of Transportation National Highway Traffic Safety Administration, *Pedestrian Safety*, accessed 27 January 2021, archived at https://web.archive.org/web/20210127234553/https://www.nhtsa.gov/road-safety/pedestrian-safety.

21. Annette Schaefer, "Commuting Takes Its Toll," *Scientific American*, 1 October 2005, archived at https://web.archive.org/web/20210127235034/https://www.scientificamerican.com/article/commuting-takes-its-toll/.

22. Higher levels of stress and more negative moods: R.E. Wener at al., "Comparing Stress of Car and Train Commuters," *Transportation Research Part F: Traffic Psychology and Behaviour*, 14(2):111–116, doi: 10.1016/j.trf.2010.11.008, March 2011. Lower satisfaction with life: Margo Hilbrecht et al., "Highway to Health? Commute Time and Well-being Among Canadian Adults," *World Leisure Journal*, 56(2):151-163, doi:10.1080/16078055.2014.903723, 2014. See also Amy Morin, "Your Commute Could Be Killing Your Happiness," *Psychology Today*, 30 June 2015, available at https://www.psychologytoday.com/us/blog/what-mentally-strong-people-dont-do/201506/your-commute-could-be-killing-your-happiness.

23. Obesity/exercise/blood pressure: C.M. Hoehner et al., "Commuting Distance, Cardiorespiratory Fitness, and Metabolic Risk," *American Journal of Preventive Medicine*, 42(6), doi: 10.1016/j.amepre.2012.02.020, June 2012. Diabetes, cardiovascular disease, osteoporosis, metabolic risk syndrome: M. Hilbrecht et al., "Highway to Health? Commute Time and Well-being Among Canadian Adults," *World Leisure Journal*, 56(2):151-163, doi: https://doi.org/10.1080/16078055.2014.903723, 2014, 153. Cardiovascular disease, diabetes and cancers: Reuters Staff, "Long Commutes May Be Bad for Health: Study," *Reuters*, 8 May 2012, archived at https://web.archive.org/web/20210128003742/https://www.reuters.com/article/us-commuting/long-commutes-may-be-bad-for-health-study-idUSBRE8470U520120508. Lawrence Frank et al., "Obesity Relationships with Community Design, Physical Activity, and Time Spent in Cars," *American Journal of Preventive Medicine*, 27(2):87–96, doi: 10.1016/j.amepre.2004.04.011, 2004.

24. U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, accessed 29 January 2021, archived at https://web.archive.org/web/20210129222917/https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

25. U.S Global Change Research Program, *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, April 2016, available at https://health2016.globalchange.gov/high/ClimateHealth2016_FullReport.pdf.

26. Ibid.

27. Ibid.

28. Ibid.

29. Ibid.

30. Jordan Schnell et al., "Air Quality Impacts from the Electrification of Light-Duty Passenger Vehicles in the United States," *Atmospheric Environment*, 208:95-102, doi: 10.1016/j.atmosenv.2019.04.003, 1 July 2019.

31. California Air Resources Board, *California Transitioning to All-Electric Public Bus Fleet by 2040*, 14 December 2018, archived at http://web.archive.org/web/20191004045224/https://ww2.arb.ca.gov/news/california-transitioning-all-electric-public-bus-fleet-2040.

32. Zoë Ettinger, "Eerie Photos Show Empty Airports, Trains, and Roads Across the World as People Stay Home Amid the Coronavirus Outbreak," *Business Insider*, 23 March 2020, archived at https://web.archive.org/web/20201030230946/https://www.businessinsider.com/photos-empty-airports-trains-roads-during-coronavirus.

33. Justin Fox, "Americans Are Driving Less Than Before Pandemic, and It's Permanent," *Bloomberg Businessweek*, 5 October 2020, archived at http://web.archive.org/web/20201011164213/https://www.bloomberg.com/news/articles/2020-10-05/americans-are-driving-less-than-before-pandemic-and-it-s-permanent. Report: *Automotive's New Reality: Fewer trips, fewer miles, fewer cars?* KPMG, 2020, accessed 27 January 2021, 1, archived at https://web.archive.org/web/20201011081028/https://advisory.kpmg.us/content/dam/advisory/en/pdfs/2020/automotives-new-reality.pdf.

34. Doyle Rice, "Coronavirus Lockdowns Have Caused a Whopping 17% drop in Global Carbon Emissions," *USA Today*, 19 May 2020, archived at http://web.archive.org/web/20200913051323/https://www.usatoday.com/story/news/health/2020/05/19/coronavirus-has-caused-whopping-17-drop-global-carbon-emissions/5219885002/. See also Corinne Le Quéré et al., "Temporary Reduction in Daily Global CO_2 Emissions During the COVID-19 Forced Confinement," *Nature Climate Change*, 10, doi: https://doi.org/10.1038/s41558-020-0797-x, May 2020; University of East Anglia, "COVID Lockdown Causes Record Drop in Carbon Emissions for 2020," *Stanford Earth*, 10 December 2020, archived at https://web.archive.org/web/20210122005701/https://earth.stanford.edu/news/covid-lockdown-causes-record-drop-carbon-emissions-2020#gs.s3rq1g.

35. Corinne Le Quéré et al., "Temporary Reduction in Daily Global CO_2 Emissions During the COVID-19 Forced Confinement," *Nature Climate Change*,10, doi: https://doi.org/10.1038/s41558-020-0797-x, May 2020.

36. Data from the Federal Highway Administration's *Traffic Volume Trends Report*, March-August 2020, available at https://web.archive.org/web/20201108121820/https://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm.

37. See e.g. Justin Fox, "Americans Are Driving Less Than Before Pandemic, and It's Permanent," *Bloomberg Businessweek*, 5 October 2020, archived at http://web.archive.org/web/20201101045301/https://www.bloomberg.com/news/articles/2020-10-05/americans-are-driving-less-than-before-pandemic-and-it-s-permanent. Adie Tomer et al., "Coronavirus Has Shown us a World Without Traffic. Can we Sustain It?" *Brookings*, 1 May 2020, archived at http://web.archive.org/web/20201030014235/https://www.brookings.edu/research/coronavirus-has-shown-us-a-world-without-traffic-can-we-sustain-it/.

38. Vehicle miles traveled for 2018: Federal Highway Administration, *December 2018 Traffic Volume Trends*, accessed 31 May 2019, archived at http://web.archive.org/web/20190531131845/https://www.fhwa.dot.gov/policyinformation/travel_monitoring/18dectvt/.

39. Vehicle miles traveled converted from vehicle kilometers traveled: United Nations Economic Commission for Europe, *Motor Vehicle Movements on National Territory by Road (Vehicle-Kms)*, accessed 26 October 2019 at https://w3.unece.org/PXWeb2015/pxweb/en/STAT/STAT__40-TRTRANS__02-TRROAD/01_en_TRRoadVehKm_r.px/. Country population data for 2017: The World Bank, *World Development Indicators – Population*, downloaded on 26 October 2019 from https://data.worldbank.org/indicator/sp.pop.totl?name_desc=false.

40. Alan Neuhauser, "100,000 Americans Die from Air Pollution, Study Finds," *U.S. News and World Report*, 8 April 2019.

41. Benjamin Bowe et al., "Burden of Cause-Specific Mortality Associated with $PM_{2.5}$ Air Pollution in the United States," *JAMA Network Open*, 2(11):e1915834, doi: 10.1001/jamanetworkopen.2019.15834, 2019, cited in Rosie McCall, "Around 200,000 Americans Die Every Year from Air Pollution That Meets EPA Standard," *Newsweek*, 21 November 2019.

42. Fabio Caiazzo et al., "Air Pollution and Early Deaths in the United States. Part I: Quantifying the Impact of Major Sectors in 2005," *Atmospheric Environment*, 79: 198-208, doi: https://doi.org/10.1016/j.atmosenv.2013.05.081, November 2013.

43. Neil J. Hime et al., "A Comparison of the Health Effects of Ambient Particulate Matter Air Pollution from Five Emission Sources," *International Journal of Environmental Research and Public Health*, 15(6):1206, https://doi.org/10.3390/ijerph15061206, 2018.

44. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, "Health Effects of Diesel Exhaust," 21 May 2001, accessed 12 January 2018 at https://oehha.ca.gov/air/health-effects-diesel-exhaust.

45. İbrahim Aslan Reşitoğlu et al., "The Pollutant Emissions from Diesel-engine Vehicles and Exhaust Aftertreatment Systems," *Clean Technologies and Environmental Policy,* 17(1):15-27, January 2015. Jo-Yu Chin et al., "Gaseous and Particulate Emissions from Diesel Engines at Idle and under Load: Comparison of Biodiesel Blend and Ultralow Sulfur Diesel Fuels," *Energy & Fuels* 26(11):6737-6748, doi: 10.1021/ef300421h, 2012.

46. See note 5.

47. *Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects*. Health Effects Institute: Boston, January 2010.

48. Qian Di et al., "Air Pollution and Mortality in the Medicare Population," *The New England Journal of Medicine*, 376:2513-2522, doi: 10.1056/NEJMoa1702747, 29 June 2017.

49. Sandro Steiner et al., "Diesel Exhaust: Current Knowledge of Adverse Effects and Underlying Cellular Mechanisms," *Archives of Toxicology,* 90:1541–1553, doi: 10.1007/s00204-016-1736-5, May 2016. Damian Carrington, "Toxic Air Pollution Particles Found in Human Brains," *The Guardian*, 5 September 2016.

50. See note 1.

51. See note 6.

52. Benzene: U.S. Environmental Protection Agency, *Benzene*, factsheet, available at https://www.epa.gov/sites/production/files/2016-09/documents/benzene.pdf; Acetaldehyde: U.S. Environmental Protection Agency, *Acetaldehyde*, factsheet, available at https://www.epa.gov/sites/production/files/2016-09/documents/acetaldehyde.pdf; 1,3-Butadiene: U.S. Environmental Protection Agency, *1,3-Butadiene*, factsheet, available at https://www.epa.gov/sites/production/files/2016-08/documents/13-butadiene.pdf.

53. See note 7.

54. See note 8.

55. American Lung Association, *Nitrogen Dioxide*, accessed 20 January 2021, archived at https://web.archive.org/web/20201002064551/https://www.lung.org/clean-air/outdoors/what-makes-air-unhealthy/nitrogen-dioxide.

56. See note 10.

57. Vascular damage: See note 43. Accelerated decline of lung function: Mary B. Rice et al., "Long-term Exposure to Traffic Emissions and Fine Particulate Matter and Lung Function Decline in the Framingham Heart Study," *American Journal of Respiratory and Critical Care Medicine*, 191(6):656–664, doi: 10.1164/rccm.201410-1875OC, January 2015.

58. See note 43. U.S. Environmental Protection Agency, *Particle Pollution and Your Health*, accessed 9 January 2021, available at https://nepis.epa.gov/Exe/ZyPDF.cgi/P100RQ5N.PDF?Dockey=P100RQ5N.PDF.

59. See note 43. U.S. Environmental Protection Agency, *Basic Information about NO_2*, accessed 4 January 2021 at https://www.epa.gov/no2-pollution/basic-information-about-no2.

60. Inflammation: See note 43. Nitrogen dioxide and respiratory infections: U.S. Environmental Protection Agency, *Basic Information about NO_2*, accessed 4 January 2021 at https://www.epa.gov/no2-pollution/basic-information-about-no2.

61. Union of Concerned Scientists, "Cars, Trucks, Buses and Air Pollution," 23 July 2008 (updated 19 July 2018), available at https://www.ucsusa.org/resources/cars-trucks-buses-and-air-pollution.

62. See note 43. U.S. Environmental Protection Agency, *Basic Information about NO_2*, accessed 4 January 2021 at https://www.epa.gov/no2-pollution/basic-information-about-no2. See also: Alana Miller et al., *Electric Buses: Clean Transportation for Healthier Neighborhoods and Cleaner Air*, May 2018.

63. 2010 study: K. Nadeau et al., "Ambient Air Pollution Impairs Regulatory T-cell Function in Asthma," *Journal of Allergy and Clinical Immunology*, 126(4):845-852.e10, doi: 10.1016/j.jaci.2010.08.008, October 2010. 2013 study: K.J. Brunst et al., "Forkhead Box Protein 3 (FOXP3) Hypermethylation Is Associated with Diesel Exhaust Exposure and Risk for Childhood Asthma," *Journal of Allergy and Clinical Immunology,* 131(2):592-4.e1-3, doi: 10.1016/j.jaci.2012.10.042, February 2013.

64. NO_2: See note 55. K.J. Brunst et al., "Forkhead Box Protein 3 (FOXP3) Hypermethylation Is Associated with Diesel Exhaust Exposure and Risk for Childhood Asthma," *Journal of Allergy and Clinical Immunology,* 131(2):592-4.e1-3, doi: 10.1016/j.jaci.2012.10.042, February 2013.

65. See note 9.

66. "Air Pollution Is Getting Worse, and Data Show More People Are Dying," *Washington Post,* 23 October 2019, archived at https://web.archive.org/web/20200728232746/https://www.washingtonpost.com/business/2019/10/23/air-pollution-is-getting-worse-data-show-more-people-are-dying/.

67. See note 43. NO_2, PM and sleep fragmentation: See note 13.

68. See note 43.

69. Janvier Gasana et al., "Motor Vehicle Air Pollution and Asthma in Children: A Meta-analysis," *Environmental Research*, 117:36-45, doi: 10.1016/j.envres.2012.05.001, 2012.

70. Claudia Boyd-Barrett, "People of Color and the Poor Disproportionately Exposed to Air Pollution, Study Finds," *California Health Report,* 8 February 2019.

71. Ibid.

72. U.S. Environmental Protection Agency, *Research on Near Roadway and Other Near Source Air Pollution*, accessed 14 December 2020 at https://www.epa.gov/air-research/research-near-roadway-and-other-near-source-air-pollution.

73. See note 47.

74. See e.g. G. Hoek et al., "Association Between Mortality and Indicators of Traffic-related Air Pollution in the Netherlands: a Cohort study," *The Lancet*, 360(9341):1203-9, doi: 10.1016/S0140-6736(02)11280-3, October 2002. Murray Finkelstein et al., "Traffic Air Pollution and Mortality Rate Advancement Periods," *American Journal of Epidemiology*, 160(2):173–177, doi: https://doi.org/10.1093/aje/kwh181, July 2004.

75. T. Nicolai et al., "Urban Traffic and Pollutant Exposure Related to Respiratory Outcomes and Atopy in a Large Sample of Children," *European Respiratory Journal*, 21:956-963; doi: 10.1183/09031936.03.00041103a, June 2003.

76. P. van Vliet, "Motor Vehicle Exhaust and Chronic Respiratory Symptoms in Children Living near Freeways," *Environmental Research*. 74(2):122-32, doi: 10.1006/enrs.1997.3757, 1997.

77. Rutgers study: N. Ji et al., "Personal Exposure to Black Carbon, Nitrogen Dioxide, and Chronic Psychosocial Stress: Impacts on Childhood Asthma Exacerbation in a Seaport-Adjacent Community," *American Journal of Respiratory and Critical Care Medicine,* 195:A4803, 2017, available at American Thoracic Society International Conference Abstracts, http://www.atsjournals.org/doi/abs/10.1164/ajrccm-conference.2017.195.1_MeetingAbstracts.A4803. UK study: Andrea J Venn et al., "Living Near a Main Road and the Risk of Wheezing Illness in Children," *American Journal of Respiratory and Critical Care Medicine*, 164(12), doi: https://doi.org/10.1164/ajrccm.164.12.2106126, 2001.

78. See note 16.

79. Rob McConnell et al., "Traffic, Susceptibility, and Childhood Asthma," *Environmental Health Perspectives*, 114(5), https://doi.org/10.1289/ehp.8594, May 2006.

80. W. James Gauderman et al., "Effect of Exposure to Traffic on Lung Development from 10 to 18 Years of Age: A Cohort Study," *The Lancet*, doi: https://doi.org/10.1016/S0140-6736(07)60037-3, January 2007.

81. W. James Gauderman, Associate Professor of Preventive Medicine at the Keck School of Medicine, quoted in Jennifer Chan, "Living Near Highways Can Stunt Lungs," *USC News*, 25 January 2007, archived at https://web.archive.org/web/20210127221024/https://news.usc.edu/19557/Living-Near-Highways-Can-Stunt-Lungs/.

82. Erin Kulick et al., "Residential Proximity to Major Roadways and Risk of Incident Ischemic Stroke in NOMAS (The Northern Manhattan Study)," *Stroke*, 49(4):835–841, doi: https://doi.org/10.1161/STROKEAHA.117.019580Stroke, March 2018.

83. Elissa H. Wilker et al., "Residential Proximity to High-traffic Roadways and Poststroke Mortality," *Journal of Stroke and Cerebrovascular Diseases*, 22(8):e366-72, doi: 10.1016/j.jstrokecerebrovasdis.2013.03.034, 2013.

84. See note 18.

85. Cathryn Tonne et al., "A Case-Control Analysis of Exposure to Traffic and Acute Myocardial Infarction," *Environmental Health Perspectives*, 1159(1), doi: https://doi.org/10.1289/ehp.9587, January 2007.

86. G. Hoek et al., "Association Between Mortality and Indicators of Traffic-related Air Pollution in the Netherlands: a Cohort study," *The Lancet*, 360(9341):1203-9. doi: 10.1016/S0140-6736(02)11280-3, October 2002.

87. Melinda C. Power et al., "Traffic-related Air Pollution and Cognitive Function in a Cohort of Older Men," *Environmental Health Perspectives*, 119(5):682-7, doi: 10.1289/ehp.1002767, May 2011.

88. Gregory Wellenius et al., "Residential Proximity to Nearest Major Roadway and Cognitive Function in Community-dwelling Seniors: Results from the MOBILIZE Boston Study," *Journal of the American Geriatrics Society*, 60(11):2075-2080, https://doi.org/10.1111/j.1532-5415.2012.04195.x, November 2012.

89. Hong Chen et al., "Living Near Major Roads and the Incidence of Dementia, Parkinson's Disease and Multiple Sclerosis: A Population-based Cohort Study," *Lancet*, 389(10070):718-726, doi: 10.1016/S0140-6736(16)32399-6, February 2017.

90. Ibid.

91. Ibid.

92. See note 19.

93. National Highway Traffic Safety Administration, *2018 Fatal Motor Vehicle Crashes: Overview*, October 2019, available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812826.

94. Downloadable from https://www.nap.edu/download/25808.

95. See note 93. National Highway Traffic Safety Administration, *Pedestrian Safety*, accessed 27 January 2021, archived at https://web.archive.org/web/20210127234553/https://www.nhtsa.gov/road-safety/pedestrian-safety.

96. Heather Zaccaro et al., Smart Growth America and National Complete Streets Coalition, *Dangerous By Design 2019*, 2019, archived on 18 March 2019 at http://web.archive.org/web/20190318105125/https://smartgrowthamerica.org/app/uploads/2019/01/Dangerous-by-Design-2019-FINAL.pdf.

97. Brian Tefft, AAA Foundation for Traffic Safety, *Impact Speed and a Pedestrian's Risk of Severe Injury or Death*, September 2011, available at https://aaafoundation.org/impact-speed-pedestrians-risk-severe-injury-death/.

98. Ibid.

99. Federal Highway Administration, *An Analysis of Factors Contributing to "Walking Along Roadway" Crashes: Research Study and Guidelines for Sidewalks and Walkways*, 22 February 2002, archived at https://web.archive.org/web/20191005205631/https://ntlrepository.blob.core.windows.net/lib/19000/19900/19995/PB2003102002.pdf.

100. William Hunter et al., Highway Safety Research Center, *Pedestrian and Bicycle Crash Types of the Early 1990s*, 1 June 1996, available at https://rosap.ntl.bts.gov/view/dot/38569.

101. Kay Teschke et al., "Route Infrastructure and the Risk of Injuries to Bicyclists: A Case-Crossover Study," *American Journal of Public Health*, doi: 10.2105/AJPH.2012.300762, 1 December 2012.

102. Active Living Research, *Moving Toward Active Transportation: How Policies Can Encourage Walking and Bicycling*, January 2016, archived at http://web.archive.org/web/20191007140619/https://activelivingresearch.org/sites/activelivingresearch.org/files/ALR_Review_ActiveTransport_January2016.pdf.

103. 76 percent alone and 9 percent carpooling. Adie Tomer, "America's Commuting Choices: 5 Major Takeaways from 2016 Census Data," *Brookings*, 3 October 2017, archived at https://web.archive.org/web/20201002175045/https://www.brookings.edu/blog/the-avenue/2017/10/03/americans-commuting-choices-5-major-takeaways-from-2016-census-data/.

104. See note 21.

105. Amy Morin, "Your Commute Could Be Killing Your Happiness," *Psychology Today*, 30 June 2015, available at https://www.psychologytoday.com/us/blog/what-mentally-strong-people-dont-do/201506/your-commute-could-be-killing-your-happiness.

106. R.E. Wener at al., "Comparing Stress of Car and Train Commuters," *Transportation Research Part F: Traffic Psychology and Behaviour*, 14(2):111–116, doi: 10.1016/j.trf.2010.11.008, March 2011.

107. 2014 study: M. Hilbrecht et al., "Highway to Health? Commute Time and Well-being Among Canadian Adults," *World Leisure Journal*, 56(2):151-163, doi:10.1080/16078055.2014.903723, 2014. Martin Turcotte, "Commuting to Work: Results of the 2010 General Social Survey," *Canadian Social Trends*, 24 August 2011, 34, available at https://www150.statcan.gc.ca/n1/pub/11-008-x/2011002/article/11531-eng.pdf.

108. Martin Turcotte, "Commuting to Work: Results of the 2010 General Social Survey," *Canadian Social Trends*, 24 August 2011, 34, available at https://www150.statcan.gc.ca/n1/pub/11-008-x/2011002/article/11531-eng.pdf.

109. C.M. Hoehner et al., "Commuting Distance, Cardiorespiratory Fitness, and Metabolic Risk," *American Journal of Preventive Medicine*, 42(6), doi: 10.1016/j.amepre.2012.02.020, June 2012.

110. Diabetes, cardiovascular disease, osteoporosis, metabolic risk syndrome: Margo Hilbrecht et al., "Highway to Health? Commute Time and Well-being Among Canadian Adults," *World Leisure Journal*, 56(2):151-163, doi: https://doi.org/10.1080/16078055.2014.903723, 2014, 153. Cardiovascular disease, diabetes and cancers: Reuters Staff, "Long Commutes May Be Bad for Health: Study," *Reuters*, 8 May 2012, accessed 21 January 2021, archived at https://web.archive.org/web/20210128003742/https://www.reuters.com/article/us-commuting/long-commutes-may-be-bad-for-health-study-idUSBRE8470U520120508.

111. Lawrence Frank et al., "Obesity Relationships with Community Design, Physical Activity, and Time Spent in Cars," *American Journal of Preventive Medicine*, 27(2):87–96, doi: 10.1016/j.amepre.2004.04.011, 2004.

112. Megan Petrov, "Commuting and Sleep: Results From the Hispanic Community Health Study/Study of Latinos Sueño Ancillary Study," *American Journal of Preventive Medicine*, 54(3):e49-e57, doi: 10.1016/j.amepre.2017.11.006, March 2018.

113. *Regus Work-Life Balance White Paper*, May 2012, available at https://www.slideshare.net/REGUSmedia/regus-worklife-balance-white-paper, 15. See also Carolyn Kylstra, "10 Things Your Commute Does to Your Body," *Time*, 26 February 2014.

114. H.R. Colten and B.M. Altevogt (eds.), "Extent and Health Consequences of Chronic Sleep Loss and Sleep Disorders," in *Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem*, Institute of Medicine (U.S.) Committee on Sleep Medicine and Research; Washington (DC): National Academies Press (US), 2006. Available at https://www.ncbi.nlm.nih.gov/books/NBK19961/.

115. See note 21.

116. See note 105.

117. Eric Jaffe, "People with Long Commutes Have a 40% Higher Risk of Separating from their Spouses," *Quartz*, 9 August 2013, available at https://qz.com/113897/people-with-long-commutes-have-a-40-higher-risk-of-separating-from-their-spouses/.

118. Louis-Philippe Beland et al., "Traffic and Crime," *Journal of Public Economics*, 160:96-116, https://doi.org/10.1016/j.jpubeco.2018.03.002, April 2018.

119. 1,882 million metric tons: U.S. Environmental Protection Agency, *Greenhouse Gas Inventory Data Explorer*, accessed 25 January 2021, archived at http://web.archive.org/web/20210124151754/https://cfpub.epa.gov/ghgdata/inventoryexplorer/.

120. Climate Watch, *Data Explorer*, accessed 6 January 2020 at https://www.climatewatchdata.org/data-explorer/historical-emissions.

121. U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017*, 11 April 2019, available at https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

122. Light-duty vehicle miles traveled: U.S. Federal Highway Administration, *Highway Statistics Table VM-1* (2013 and 2017 editions), March 2019, available at https://www.fhwa.dot.gov/policyinformation/statistics/2017/vm1.cfm. Emissions: See note 121.

123. Zifei Yang et al., The International Council on Clean Transportation, *Light-Duty Vehicle Greenhouse Gas and Fuel Economy Standards - 2017 Global Update*, 2017, archived 1 December 2017 at http://web.archive.org/web/20171201182639/http://www.theicct.org/sites/default/files/publications/2017-Global-LDV-Standards-Update_ICCT-Report_23062017_vF.pdf.

124. Union of Concerned Scientists, *Car Emissions and Global Warming*, 18 July 2014, available at https://www.ucsusa.org/resources/car-emissions-global-warming.

125. "The environmental impacts of cars, explained," *National Geographic*, accessed 28 January 2021, archived at https://web.archive.org/web/20210128081547/https://www.nationalgeographic.com/environment/green-guide/buying-guides/car/environmental-impact/.

126. Antony Ingram, "Buying a New Car is Greener than Driving an Old One… Really," *Green Car Reports*, 24 August 2014, archived at http://web.archive.org/web/20201127210517/https://www.greencarreports.com/news/1093657_buying-a-new-car-is-greener-than-driving-an-old-one-really.

127. Giampiero Trunzo et al., "Life Cycle Analysis of Road and Construction Use," *Sustainability*, 11(2):377, doi:10.3390/su11020377, 2019.

128. See note 25.

129. Centers for Disease Control and Prevention, *Climate and Health: Temperature Extremes*, archived at https://web.archive.org/web/20201103234747/https://www.cdc.gov/climateandhealth/effects/temperature_extremes.htm.

130. Ibid.

131. Ibid. See note 25.

132. See note 25.

133. Centers for Disease Control and Prevention, *Climate and Health: Air Pollution*, archived at https://web.archive.org/web/20201104000241/https://www.cdc.gov/climateandhealth/effects/air_pollution.htm.

134. See note 25.

135. Centers for Disease Control and Prevention, *Climate and Health: Wildfires*, archived at http://web.archive.org/web/20201103125828/https://www.cdc.gov/climateandhealth/effects/wildfires.htm.

136. See note 25.

137. Centers for Disease Control and Prevention, *Climate and Health: Food and Waterborne Diarrheal Disease*, archived at http://web.archive.org/web/20201103125823/https://www.cdc.gov/climateandhealth/effects/food_waterborne.htm.

138. See note 25.

139. U.S. Environmental Protection Agency, *The 2019 EPA Automotive Trends Report: Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975, Executive Summary*, March 2020, 3, available online at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100YVK3.pdf.

140. Ibid.

141. See note 119.

142. Ibid.

143. Federal Highway Administration, *2017 National Household Travel Survey: Person Trips by Transportation Mode*, archived 27 April 2018 at http://web.archive.org/web/20180427204718/https://nhts.ornl.gov/person-trips.

144. Todd Litman, Victoria Transport Policy Institute, *Evaluating Active Transport Benefits and Costs*, 16 July 2019, archived at http://web.archive.org/web/20190807185130/https://www.vtpi.org/nmt-tdm.pdf.

145. Ibid.

146. Adam Martin et al., "Does Active Commuting Improve Psychological Wellbeing? Longitudinal Evidence from Eighteen Waves of the British Household Panel Survey," *Preventive Medicine*, 69:296–303. doi: 10.1016/j.ypmed.2014.08.023, December 2014.

147. Imperial College London, *Walking to Work Cuts Risk of Diabetes and High Blood Pressure* (press release), 6 August 2013, available at https://www.eurekalert.org/pub_releases/2013-08/icl-wtw080513.php. Study abstract: Anthony Laverty et al., "Active Travel to Work and Cardiovascular Risk Factors in the United Kingdom," *American Journal of Preventive Medicine*, 45(3):282-288, doi: https://doi.org/10.1016/j.amepre.2013.04.012, 2013.

148. American Heart Association, *Walking May Lessen the Influence of Genes on Obesity by Half* (press release), 14 March 2012, available at https://www.eurekalert.org/pub_releases/2012-03/aha-wml030912.php.

149. Jenna Panter et al., "Using Alternatives to the Car and Risk of All-cause, Cardiovascular and Cancer Mortality," *Heart*, 104:1749-1755, doi: http://dx.doi.org/10.1136/heartjnl-2017-312699, 2018.

150. Kevin Murnane, "New Research Indicates Cycling to Work Has Extraordinary Health Benefits," *Forbes*, 25 April 2017, archived at https://web.archive.org/web/20181208160155/https://www.forbes.com/sites/kevinmurnane/2017/04/25/new-research-indicates-cycling-to-work-has-extraordinary-health-benefits/. BMJ study: Carlos Celis-Morales et al., "Association Between Active Commuting and Incident Cardiovascular Disease, Cancer, and Mortality: Prospective Cohort Study," *British Medical Journal*, 357, doi: https://doi.org/10.1136/bmj.j1456, 2017.

151. See note 93.

152. Lawrence Blincoe et al., National Highway Traffic Safety Administration, *The Economic and Societal Impact of Motor Vehicle Crashes*, 2010 (Revised), May 2015, archived at http://web.archive.org/web/20190818174210/https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013.

153. Based on 2017 mileage via the modes of "Walk," "Bicycle," "Subway / elevated / light rail / street car," and "Public or commuter bus," from: Federal Highway Administration, *2017 National Household Travel Survey: Person Miles of Travel (Travel Day PMT, annualized)*, archived at https://web.archive.org/web/20191010180305/https://nhts.ornl.gov/tables09/ae/work/Job85390.html.

154. Assuming that person miles traveled by the following modes, as categorized by National Household Transportation Survey, would double: "walk," "bicycle," "public or commuter bus," and "subway / elevated / light rail / street car;" and assuming that travel by car would see a corresponding decrease of 111.7 billion miles. Assuming 404 grams of emissions per mile of vehicle travel, based on: U.S. Environmental Protection Agency, *Greenhouse Gas Emissions from a Typical Passenger Vehicle*, archived on 27 October 2019 at http://web.archive.org/web/20191027222115/https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle. Assuming that vehicle miles traveled see a reduction of 0.71 miles for every one mile reduction in person miles traveled by vehicle, based on the ratio of car miles traveled to person miles traveled in cars, from: Federal Highway Administration, *2017 National Household Travel Survey: Tables Person Miles of Travel (Travel Day PMT, annualized)* and *Vehicle Miles of Travel (Travel Day VMT, annualized)*, archived at https://web.archive.org/web/20191010180305/https://nhts.ornl.gov/tables09/ae/work/Job85390.html and https://web.archive.org/web/20191010191214/https://nhts.ornl.gov/tables09/ae/work/Job85391.html.

155. Liang Ma et al., "Does Daily Commuting Behavior Matter to Employee Productivity?" *Journal of Transport Geography*, doi: 10.1016/j.jtrangeo.2019.03.008, April 2019.

156. Assuming that biking burns 40 calories per mile and walking burns 70 calories per mile, based on rates reported by: Ellen Douglas, Livestrong, *Which Burns More Calories: Walking or Biking?*, 19 June 2019, archived at http://web.archive.org/web/20171002191433/http://www.livestrong.com:80/article/292096-which-burns-more-calories-walking-or-biking/.

157. U.S. Department of Transportation, *Status of the Nation's Highways, Bridges and Transit: Conditions and Performance 23rd Edition*, November 2019, archived at https://web.archive.org/web/20200103185535/https://www.fhwa.dot.gov/policy/23cpr/pdfs/23cpr.pdf.

158. Michael Anderson, People for Bikes, *It Turns Out That Protected Bike Lanes Are Fantastic for Walking Safety, Too*, 14 November 2014, archived at http://web.archive.org/web/20190917224401/https://peopleforbikes.org/blog/it-turns-out-that-protected-bike-lanes-are-fantastic-for-walking-safety-too/.

159. Ralph Sims et al., Intergovernmental Panel on Climate Change, *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change - 2014: Transport*, 2014, available at https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter8.pdf.

160. See note 102.

161. Ibid.

162. U.S. Department of Transportation, *Complete Streets*, archived 28 June 2019 at http://web.archive.org/web/20190628214455/https://www.transportation.gov/mission/health/complete-streets.

163. Natasha Riverón, Smart Growth America, *The Best Complete Streets Policies of 2018*, May 2019, available at https://smartgrowthamerica.org/resources/the-best-complete-streets-policies-of-2018/.

164. Smart Growth America, *Complete Streets Change Travel Patterns*, date unknown, available at https://smartgrowthamerica.org/resources/complete-streets-change-travel-patterns/.

165. Peter Furth, *City Cycling – Chapter 6: Bicycling Infrastructure for Mass Cycling: A Transatlantic Comparison*, (MIT Press, 2012), 105-108.

166. Ibid.; Jennifer Dill and Theresa Carr, "Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them," *Transportation Research Record: Journal of the Transportation Research Board*, doi: 10.3141/1828-14, 1 January 2013.

167. See note 101.

168. Michael King, "Pedestrian Safety through a Raised Median and Redesigned Intersections," *Transportation Research Board*, 2003, archived at http://web.archive.org/web/20150321094922/http://nacto.org/docs/usdg/pedestrian_safety_through_raised_median_redesigned_intersections_king.pdf.

169. Peter Lyndon Jacobsen, "Safety in Numbers: More Walkers and Bicyclists, Safer Walking and Bicycling," *Injury Prevention,* doi: 10.1136/ip.9.3.205rep, 21 July 2015.

170. Vision Zero Network, *A Primer on Vision Zero,* date not given, archived at https://web.archive.org/web/20191118024454/https://visionzeronetwork.org/wp-content/uploads/2018/05/What-is-VZ_FINAL.pdf.

171. Steven Higashide and Mary Buchanan, Transit Center, *Who's On Board 2019: How to Win Back America's Transit Riders*, February 2019, archived at http://web.archive.org/web/20190918223416/https://transitcenter.org/wp-content/uploads/2019/02/TC_WhosOnBoard_Final_digital-1-1.pdf.

172. Jeff Davis, "How Should Future COVID Mass Transit Aid Be Distributed?" Eno Center for Transportation, 14 August 2020, archived at https://web.archive.org/web/20201103023017/https://www.enotrans.org/article/how-should-future-covid-mass-transit-aid-be-distributed/.

173. TransitCenter, *There's a Reason Transit Ridership is Rising in These 7 Cities*, 27 February 2019, available at https://transitcenter.org/theres-a-reason-transit-ridership-is-rising-in-these-7-cities/.

174. Ibid.

175. City of Seattle, *Seattle Transportation Benefit District Year 3 Performance Report*, Fall 2018, archived at http://web.archive.org/web/20190331021133/http://www.seattle.gov/Documents/Departments/Transit/2018STBDAnnualReport_FINALv2.pdf.

176. Ibid.

177. Ibid.

178. Transit maintenance backlog: Federal Highway Administration, *Status of the Nation's Highways, Bridges, and Transit - Conditions & Performance 23rd Edition*, p.6-26, 2020, archived at https://web.archive.org/web/20201116161521/https://www.fhwa.dot.gov/policy/23cpr/pdfs/pdf/23cpr.pdf.

179. Yonah Freemark, Urban Institute, "What would Providing Every City with High-quality, Zero-emissions Public Transportation Look Like?" Urban Institute blog, 23 November 2020, archived at http://web.archive.org/web/20201208042424/https://www.urban.org/urban-wire/what-would-providing-every-city-high-quality-zero-emissions-public-transportation-look. Transit Center, *A Green New Deal for City and Suburban Transportation*, March 2020, 11, archived at http://web.archive.org/web/20200829065339/https://transitcenter.org/wp-content/uploads/2020/03/20.03_GND-Transit_use_v4.pdf.

180. Susan Shaheen et al., "Chapter 13 - Sharing Strategies: Carsharing, Shared Micromobility (Bikesharing and Scooter Sharing), Transportation Network Companies, Microtransit, and Other Innovative Mobility Modes," *Transportation, Land Use, and Environmental Planning* 2020, 237-262, https://doi.org/10.1016/B978-0-12-815167-9.00013-X. Full text available at https://www.researchgate.net/publication/338312881_Sharing_strategies_carsharing_shared_micromobility_bikesharing_and_scooter_sharing_transportation_network_companies_microtransit_and_other_innovative_mobility_modes.

181. A mode of micromobility which gives users access to a fleet of shared vehicles on an hourly basis, and users must return the vehicle to the location from where it was picked up. In 2016, such programs were in use by around 1 million people across North America. Shaheen et al., 2018b, quoted in note 180.

182. Shaheen and Stocker (2015), as cited in note 180, 5.

183. Cervero and Tsai (2004), as cited in note 180, 4.

184. Martin & Shaheen (2011), as cited in note 180, 5.

185. Ibid.

186. Tony Dutzik et al., Frontier Group and TransitCenter, *Who Pays for Parking?* 12 September 2017, available at https://frontiergroup.org/reports/fg/who-pays-parking.

187. Gregory Shill, "Should Law Subsidize Driving?" *New York University Law Review*, 498, doi: 10.2139/ssrn.3345366, 4 March 2019. David Coady et al., International Monetary Fund, *Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates*, 2 May 2019, available at https://www.imf.org/en/Publications/WP/Issues/2019/05/02/Global-Fossil-Fuel-Subsidies-Remain-Large-An-Update-Based-on-Country-Level-Estimates-46509.

188. Ralph Buehler, "Determinants of Transport Mode Choice: A Comparison of Germany and the USA," *Journal of Transport Geography*, doi: 10.1016/j.jtrangeo.2010.07.005, July 2011.

189. Federal Highway Administration, *Congestion Pricing: A Primer*, December 2006, available at https://ops.fhwa.dot.gov/publications/congestionpricing/index.htm; Federal Highway Administration, *Benefits of Congestion Pricing*, archived 6 April 2019 at http://web.archive.org/web/20190406141452/https://ops.fhwa.dot.gov/congestionpricing/cp_benefits.htm.

190. See note 159.

191. Federal Transit Administration, *Public Transportation's Role in Responding to Climate Change*, January 2010, available at https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/ PublicTransportationsRoleInRespondingToClimateChange2010.pdf.

192. Vermont Energy Investment Corporation, *Electric School Bus Pilot Project Evaluation*, 20 April 2018, archived at http://web.archive.org/web/20190920175702/https://www.mass.gov/files/documents/2018/04/30/Mass%20DOER%20EV%20school%20bus%20pilot%20final%20report_.pdf.

193. See note 31.

194. Emissions savings calculated using Argonne National Laboratory's Heavy-Duty Vehicle Emissions Calculator available at https://afleet-web.es.anl.gov/hdv-emissions-calculator.

195. Ibid. Emissions are lower in areas with cleaner electricity grids. Therefore, as grids across the country transition to renewable sources, emissions will drop.

196. Jimmy O'Dea, Union of Concerned Scientists, *Electric vs. Diesel vs. Natural Gas: Which Bus is Best for the Climate?* 19 July 2018, archived at https://web.archive.org/web/20190920232331/https://blog.ucsusa.org/jimmy-odea/electric-vs-diesel-vs-natural-gas-which-bus-is-best-for-the-climate?

197. Ibid.

198. A natural gas bus produces 2,364 grams carbon dioxide-equivalent (CO_2e) per mile and a diesel-hybrid 2,212 grams CO_2e per mile. An electric bus, charged with the national electricity mix, produces 1,078 grams CO_2e per mile. See note 196.

199. Alana Miller et al., *Electric Buses: Clean Transportation for Healthier Neighborhoods and Cleaner Air*, May 2018. Variations in emissions reductions are the result of state electricity mixes. See Appendix A for emissions savings projections for America's 50 largest transit agencies.

200. See note 82.

201. James Horrox et al., *Electric Buses in America: Lessons from Cities Pioneering Clean Transportation*, October 2019, available at https://frontiergroup.org/sites/default/files/reports/Electric%20Buses%20in%20America%20-%20National%20%28web%29.pdf.

202. Ibid.

203. Ibid.

204. Jocelyn Timperley, "Eight Charts Show How 'Aggressive' Railway Expansion Could Cut Emissions," *Carbon Brief*, 30 January 2019, archived at http://web.archive.org/web/20201003181456/https://www.carbonbrief.org/eight-charts-show-how-aggressive-railway-expansion-could-cut-emissions.

205. Lower emissions: Andreas Hoffrichter, "Rail Travel Is Cleaner than Driving or Flying, but Will Americans Buy In?" *The Conversation*, 1 April 2019, accessed 28 January 2021, archived at https://web.archive.org/web/20210128220152/https://theconversation.com/rail-travel-is-cleaner-than-driving-or-flying-but-will-americans-buy-in-112128.

206. UK Department for Transport, quoted in Leo Hickman, "How Green Are Electric Trains?" *The Guardian*, 16 July 2012, archived at http://web.archive.org/web/20200709203905/https://www.theguardian.com/environment/blog/2012/jul/16/electric-trains-diesel-green-carbon.

207. See note 204.

208. Ibid.

209. Stephen Miller, "Electric Trains Everywhere: A Solution to Crumbling Roads and Climate Crisis," *Yes! Magazine*, 30 May 2017, archived at https://web.archive.org/web/20200618210438/https://www.yesmagazine.org/issue/sanctuary/2017/05/30/electric-trains-everywhere-a-solution-to-crumbling-roads-and-climate-crisis/.

210. Environmental and Energy Study Institute, *Electrification of U.S. Railways: Pie in the Sky, or Realistic Goal?* 30 May 2018, archived at http://web.archive.org/web/20201101002250/https://www.eesi.org/articles/view/electrification-of-u.s.-railways-pie-in-the-sky-or-realistic-goal.

211. R. Sean Randolph, "Opinion: California Should Invest in High-speed Rail," *Mercury News*, 25 October 2008, available at https://www.mercurynews.com/2008/10/25/opinion-california-should-invest-in-high-speed-rail/.

212. National Association for Pupil Transportation, *American School Bus Council Partnership*, accessed 9 October 2019 at https://www.napt.org/asbc.

213. This is based on the 2016 share of petroleum consumed by transit and school buses (as opposed to intercity buses), based on data from table 1.16 of the Transportation Energy Data Book. Share of petroleum: Oak Ridge National Laboratory, *Transportation Energy Data Book – Table 1.16*, 30 August 2016, available at https://tedb.ornl.gov/data/; in total, buses emitted 20.4 $MMTCO_2e$ in 2017: see note 121.

214. EBStart, *Electric Bus Industry Continues to Make Strides in 2018* (press release), 31 January 2019, archived at http://web.archive.org/web/20190930235534/https://www.ebstart.co/press-release-1-31-2019.

215. 650: Mordor Intelligence, LLP, *North America Electric Bus Market - Growth, Trends, and Forecast (2020-2025)*, October 2020, archived at https://web.archive.org/web/20210125205826/https://www.reportlinker.com/p05986874/North-America-Electric-Bus-Market-Growth-Trends-and-Forecast.html. Increase over previous years: see note 214; number of transit buses in use: American Public Transportation Association, *2018 Public Transportation Fact Book*, December 2018, archived at http://web.archive.org/web/20190729181313/https://www.apta.com/wp-content/uploads/Resources/resources/statistics/Documents/FactBook/2018-APTA-Fact-Book.pdf.

216. 480,000 school buses: New York School Bus Contractors Association, *School Bus Fast Facts*, archived at http://web.archive.org/web/20201008022823/https://www.nysbca.com/fastfacts.html; see note 214; Lion Electric: The Lion Electric Co., *The Lion Electric Co. Awarded by the California Energy Commission for the School Bus Replacement Program* (press release), 17 July 2019, archived at https://web.archive.org/web/20191206210201/https://www.prnewswire.com/news-releases/the-lion-electric-co-awarded-by-the-california-energy-commission-for-the-school-bus-replacement-program-300886378.html.

217. While many school buses are owned by the school districts themselves, around 40 percent of the school buses currently operating in the U.S. are operated by contractors.

218. See note 31.

219. Ibid.

220. Ibid.

221. Bloomberg New Energy Finance, *Electric Vehicle Outlook 2020*, accessed 25 January 2021, archived at https://web.archive.org/web/20210130035156/https://about.bnef.com/electric-vehicle-outlook/. Brian Eckhouse, "The U.S. Has a Fleet of 300 Electric Buses. China Has 421,000," *Bloomberg*, 15 May 2019, available at https://www.bloomberg.com/news/articles/2019-05-15/in-shift-to-electric-bus-it-s-china-ahead-of-u-s-421-000-to-300.

222. Federal Transit Administration, *Circular: Subject: Award Management Requirements*, 21 March 2017, archived at http://web.archive.org/web/20170731225821/https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/Grant%20Management%20Requirements%20Circular_5010-1E_1.pdf.

223. Federal Transit Administration, *2017 National Transit Database: 2017 Vehicles*, 2017, downloaded from https://www.transit.dot.gov/ntd/data-product/2017-vehicles-0, 3 December 2019.

224. New York: Clayton Guse, "MTA's Two-decade Plan for All-electric Fleet Lacks Details, Transit Advocates Say," *NY Daily News*, 25 April 2019, available at https://www.nydailynews.com/new-york/ny-electric-buses-mta-2040-20190425-week2bdqzvhd5ibo253j5g5qle-story.html; while New York's all-electric fleet plan is not fully defined, the MTA says that it will add 200 electric buses to its fleet within five years, and another 1,600 buses within 10 years: Metropolitan Transportation Authority, *NYC Transit Releases Comprehensive Plan to Modernize All Services for the 21st Century* (press release), 23 May 2018, archived at http://web.archive.org/web/20190319150544/http://www.mta.info:80/press-release/nyc-transit/nyc-transit-releases-comprehensive-plan-modernize-all-services-21st; Chicago: Mischa Wanek-Libman, "Chicago City Council Approves Transition to 100 Percent Renewable Energy," *Mass Transit Magazine*, 15 April 2019, available at https://www.masstransitmag.com/bus/vehicles/hybrid-hydrogen-electric-vehicles/article/21076292/chicago-city-council-approves-transition-to-100-percent-renewable-energy.

225. Los Angeles County Metropolitan Transportation Authority, *Metro Takes Delivery of First 60-foot Zero Emission Electric Bus for Orange Line* (press release), 25 July 2019, archived at https://web.archive.org/web/20191204020443/https://www.metro.net/news/simple_pr/metro-takes-delivery-first-60-foot-zero-emission-e/.

226. Los Angeles County Metropolitan Transportation Authority, *Metro Deploys First 60-foot Zero Emission Electric Bus for Revenue Service on the G Line (Orange) in the San Fernando Valley* (press release), 27 July 2020.

227. The MTA says that it will add 200 electric buses to its fleet within five years, and another 1,600 buses within 10 years: Metropolitan Transportation Authority, *NYC Transit Releases Comprehensive Plan to Modernize All Services for the 21st Century* (press release), 23 May 2018, archived at http://web.archive.org/web/20190319150544/http://www.mta.info:80/press-release/nyc-transit/nyc-transit-releases-comprehensive-plan-modernize-all-services-21st; one in 10 buses: Clayton Guse, "MTA's Two-decade Plan for All-electric Fleet Lacks Details, Transit Advocates Say," *NY Daily News*, 25 April 2019, available at https://www.nydailynews.com/new-york/ny-electric-buses-mta-2040-20190425-week2bdqzvhd5ibo253j5g5qle-story.html.

228. See note 31.

229. Ibid.

230. Number of agencies: American Public Transportation Association, *2018 Public Transportation Fact Book*, December 2018, archived at http://web.archive.org/web/20190729181313/https://www.apta.com/wp-content/uploads/Resources/resources/statistics/Documents/FactBook/2018-APTA-Fact-Book.pdf. Number of school districts: U.S. Census Bureau, *2017 Census of Governments - Table 9. Public School Systems by Type of Organization and State*, 2017, available at 14census.gov/data/tables/2017/econ/gus/2017-governments.html.

231. Federal Transit Administration, *Low or No Emission Vehicle Program - 5339(c)*, archived 25 September 2019 at http://web.archive.org/web/20190925203415/https://www.transit.dot.gov/funding/grants/lowno.

232. Federal Transit Administration, *Fiscal Year 2018 Low or No-Emission (Low-No) Bus Program Projects*, archived 3 December 2018 at http://web.archive.org/web/20181203193527/https://www.transit.dot.gov/funding/grants/fiscal-year-2018-low-or-no-emission-low-no-bus-program-projects.

233. See note 201.

234. Based on a review of the study scorecard. The scorecard does not include Florida, which did not have a published plan at the time of the study. Matt Casale and Brendan Mahoney, U.S. PIRG Education Fund, *Volkswagen Settlement State Scorecard*, May 2019.

235. Governor of Virginia, *Governor Northam Announces $20 Million Electric School Bus Initiative* (press release), 24 September 2019, archived at http://web.archive.org/web/20190930161236/https://www.governor.virginia.gov/newsroom/all-releases/2019/september/headline-847559-en.html.

236. Virginia Department of Environmental Quality, *Volkswagen Settlement Agreement*, accessed 28 January 2021 at https://www.deq.virginia.gov/get-involved/newsroom/current-issues/volkswagen-settlement-agreement.

237. Dominion Energy, *Dominion Energy Proposes Largest Electric School Bus Initiative in the Country*, 29 August 2019, available at https://news.dominionenergy.com/2019-08-29-Dominion-Energy-Proposes-Largest-Electric-School-Bus-Initiative-in-the-Country.

238. Ibid.

239. Ryan Sclar et al., World Resources Institute, *Barriers to Adopting Electric Buses*, May 2019, available at https://www.wri.org/publication/barriers-adopting-electric-buses.

240. Andrew Twite, "Electric Vehicles: Good for Public Health and the Planet," *Fresh Energy*, 20 June 2017, available at https://fresh-energy.org/electric-vehicles-good-for-public-health-and-the-planet/.

241. Bradley Berman, "New Study: Every Electric Car Brings $10,000 in Life-saving Benefits," *Electrek*, 3 June 2020, archived at https://web.archive.org/web/20210128222109/https://electrek.co/2020/06/03/new-study-every-electric-car-brings-10000-in-life-saving-benefits/.

242. Xinyu Liang et al., "Air Quality and Health Benefits from Fleet Electrification in China," *Nature Sustainability*, 2:962–971, doi: https://doi.org/10.1038/s41893-019-0398-8, October 2019.

243. There are, however, a number of strategies to reduce environmental costs associated with manufacturing. For example, see: International Council on Clean Transportation, *Effects of Battery Manufacturing on Electric Vehicle Life-Cycle Greenhouse Gas Emissions*, February 2018, archived at http://web.archive.org/web/20190725101755/https://theicct.org/sites/default/files/publications/EV-life-cycle-GHG_ICCT-Briefing_09022018_vF.pdf.

244. Electric Power Research Institute and Natural Resources Defense Council, *Environmental Assessment of a Full Electric Transportation Portfolio: Volume 2: Greenhouse Gas Emissions*, September 2015, available at https://www.epri.com/#/pages/product/000000003002006876/?lang=en-US.

245. Ibid.

246. More than three times: U.S. Department of Energy, *All-Electric Vehicles*, archived 2 December 2019 at http://web.archive.org/web/20191202234600/https://www.fueleconomy.gov/feg/evtech.shtml. Heavy-duty electric vehicles can have even higher relative efficiency compared to fossil fuel-powered vehicles: Leslie Eudy and Matthew Jeffers, National Renewable Energy Laboratory, *Foothill Transit Battery Electric Bus Demonstration Results: Second Report*, June 2017, archived at http://web.archive.org/web/20180713202843/https://www.nrel.gov/docs/fy17osti/67698.pdf.

247. U.S. Department of Energy, *FOTW #1044, August 27, 2018: 12-30% of Energy Put into a Conventional Car Is Used to Move the Car Down the Road*, 27 August 2018, archived at https://web.archive.org/web/20181230213311/https://www.energy.gov/eere/vehicles/articles/fotw-1044-august-27-2018-12-30-energy-put-conventional-car-used-move-car-down.

248. U.S. Department of Energy, *Where the Energy Goes: Electric Cars*, archived 25 September 2019 at http://web.archive.org/web/20190925172731/https://www.fueleconomy.gov/feg/atv-ev.shtml.

249. U.S. Department of Energy, *All-Electric Vehicles*, archived on 29 January 2021 at https://web.archive.org/web/20210131194453/https://www.fueleconomy.gov/feg/evtech.shtml. Various other estimates are available. According to the IPCC, "BEVs operate at a drive-train efficiency of around 80% compared with about 20–35% for conventional ICE LDVs." See note 159.

250. David Gohlke and Yan Zhou, Argonne National Laboratory, *Impacts of Electrification of Light-Duty Vehicles in the United States, 2010-2017*, January 2018, available at https://publications.anl.gov/anlpubs/2018/01/141595.pdf.

251. Knvul Sheikh, "Noise Pollution Isn't Just Annoying — It's Bad for Your Health," *BrainFacts*, 27 June 2018, archived at http://web.archive.org/web/20200623013112/https://www.brainfacts.org/thinking-sensing-and-behaving/diet-and-lifestyle/2018/noise-pollution-isnt-just-annoying-its-bad-for-your-health-062718.

252. Cardiovascular problems: Thomas Münzel et al., "Environmental Noise and the Cardiovascular System," *Journal of the American College of Cardiology*, 71(6):688–697, February 2018. Atrial fibrillation: Omar Hahad et al., "Annoyance to Different Noise Sources Is Associated with Atrial Fibrillation in the Gutenberg Health Study," *International Journal of Cardiology*, 29 March 2018, doi: https://doi.org/10.1016/j.ijcard.2018.03.126. Mental health: Friederike Hammersen et al., "Environmental Noise Annoyance and Mental Health in Adults: Findings from the Cross-Sectional German Health Update (GEDA) Study 2012," *International Journal of Environmental Research and Public Health*, 13(10):954, doi: 10.3390/ijerph13100954, 2016.

253. Idaho National Laboratory, *About Neighborhood Electric Vehicles*, archived 25 January 2017 at http://web.archive.org/web/20170125124737/https://avt.inl.gov/sites/default/files/pdf/nev/aboutnev.pdf.

254. South Bay Cities Council of Governments, *Zero Emission Local Use Vehicles the Neglected Sustainable Transportation Mode*, 30 June 2013, available at https://e3vehicles.com/wp-content/uploads/2018/02/LUV-Report.pdf.

255. Ibid.

256. Colin Beresford, "Average Age of Vehicles on the Road is Approaching 12 Years," *Car and Driver*, 29 July 2020, archived at https://web.archive.org/web/20210131224151/https://www.caranddriver.com/news/a33457915/average-age-vehicles-on-road-12-years/.

257. See note 30.

258. Zachary Needell et al., "Potential for Widespread Electrification of Personal Vehicle Travel in the United States," *Nature Energy*, doi: 10.1038/nenergy.2016.112, 15 August 2016.

259. Bureau of Transportation Statistics, "Hybrid-Electric, Plug-in Hybrid-Electric and Electric Vehicle Sales," available at https://www.bts.gov/content/gasoline-hybrid-and-electric-vehicle-sales.

260. Mark Kane, Inside EVs, *U.S. Plug-In Electric Car Sales Charted: 2019,* 18 January 2020, available at: https://insideevs.com/news/393629/us-plugin-sales-charted-2019/; Auto Alliance, *Advanced Technology Vehicle Sales Dashboard,* accessed 3 September 2020 at https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/. US Department of Energy, *U.S. Plug-in Electric Vehicle Sales by Model,* January 2020, available at https://afdc.energy.gov/data/10567.

261. EV sales in 2018: Electric Drive Transportation Association, *Electric Drive Sales Dashboard*, archived 23 September 2019 at http://web.archive.org/web/20190923121551/https://electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952. There were 17.2 million light-weight vehicle sales in 2018: Federal Reserve Bank of St. Louis, *Light Weight Vehicle Sales (LTOTALNSA)*, accessed 10 October 2019 at https://fred.stlouisfed.org/series/LTOTALNSA.

262. California Air Resources Board, *Zero-Emission Vehicle Program*, archived 31 July 2019 at http://web.archive.org/web/20190731202302/https://ww2.arb.ca.gov/our-work/programs/zero-emission-vehicle-program/about.

263. California Air Resources Board, *California's Advanced Clean Cars Midterm Review*, 18 January 2017, archived at https://web.archive.org/web/20191008161124/https://ww3.arb.ca.gov/msprog/acc/mtr/acc_mtr_summaryreport.pdf?_ga=2.150321471.821143643.1570550545-78330230.1570550545.

264. CA.gov, Office of Governor Gavin Newsom, *Governor Newsom Announces California Will Phase Out Gasoline-Powered Cars & Drastically Reduce Demand for Fossil Fuel in California's Fight Against Climate Change* (press release), 23 September 2020.

265. Julia Pyper, "Are 100% Zero-Emission Vehicle Targets the Hot New Energy Policy Trend?," *Greentech Media,* 24 May 2019, available at https://www.greentechmedia.com/squared/electric-avenue/are-100-zero-emission-vehicle-targets-the-new-energy-policy-trend.

266. Bill Canis et al., Congressional Research Service, *Vehicle Electrification: Federal and State Issues Affecting Deployment*, 3 June 2019, https://web.archive.org/web/20191006235923/https://fas.org/sgp/crs/misc/R45747.pdf.

267. U.S. Department of Energy, *Saving on Fuel and Vehicle Costs*, archived 29 October 2019 at http://web.archive.org/web/20191029131623/https://www.energy.gov/eere/electricvehicles/saving-fuel-and-vehicle-costs.

268. William Sierzchula et al., "The Influence of Financial Incentives and Other Socio-Economic Factors on Electric Vehicle Adoption," *Energy Policy*, doi: 10.1016/j.enpol.2014.01.043, May 2014.

269. Ibid.

270. Gil Tal and Michael Nicholas, "Exploring the Impact of the Federal Tax Credit on the Plug-In Vehicle Market," *Transportation Research Board*, doi: 10.3141/2572-11, 1 January 2016.

271. Ibid.

272. Gil Tal, Plug-in Hybrid and Electric Vehicle Center of ITS-Davis, Austin Brown, UC Davis Policy Institute for Energy, Environment, and the Economy, *Credits and Rebates Play a Key Role in Building Consumer Market for Cleaner Electric Vehicles*, date unknown, archived at https://web.archive.org/web/20191101203637/https://its.ucdavis.edu/wp-content/uploads/Credits-and-Rebates-Gil-Tal.pdf.

273. California Clean Vehicle Rebate Project, *State and Federal Electric Vehicle Incentives*, archived at http://web.archive.org/web/20201201213817/https://cleanvehiclerebate.org/eng/ev/incentives/state-and-federal.

274. Smart Columbus, *Electrified Dealer*, date not given, archived at https://web.archive.org/web/20191117205351/https://d2rfd3nxvhnf29.cloudfront.net/legacy/uploadedfiles/playbook-assets/electric-vehicle-consumer-adoption/electrified-dealer-program-updated.pdf.

275. Smart Columbus, *How the Electrified Dealer Program Boosts EV Sales*, accessed on 3 December 2019 at https://smart.columbus.gov/playbook-assets/electric-vehicle-consumer-adoption/how-the-electrified-dealer-program-boosts-ev-sales.

276. John Burke, "The Checklist That Could Change our Industry," *Bicycle Retailer*, 15 February 2019, archived at http://web.archive.org/web/20201014144441/https://www.bicycleretailer.com/opinion-analysis/2019/02/14/john-burke-checklist-could-change-our-industry.

277. Micah Toll, "Get 'em While They're Hot! E-bike and E-motorcycle Manufacturers Set to Triple Sales in 2020," *Electrek*, 10 September 2020, archived at https://electrek.co/2020/09/10/get-em-while-theyre-hot-e-bike-and-e-motorcycle-manufacturers-set-to-triple-sales-in-2020/.

278. Energy.gov, *FOTW #1042, August 13, 2018: In 2017 Nearly 60% of All Vehicle Trips Were Less than Six Miles*, 13 August 2018, archived at http://web.archive.org/web/20201016224952/https://www.energy.gov/eere/vehicles/articles/fotw-1042-august-13-2018-2017-nearly-60-all-vehicle-trips-were-less-six-miles.

279. Selene Yeager, "E-Bikes Are Getting More People Out of Their Cars," *Bicycling*, 21 March 2018, archived at http://web.archive.org/web/20200819072719/https://www.bicycling.com/news/a20049844/ebike-study-car-trips/.

280. Richard Shrubb, "Getting More People Riding with Electric Bike Incentives," *Electric Bike Report*, 25 June 2019, archived at http://web.archive.org/web/20191206155330/https://electricbikereport.com/electric-bike-incentives/.

281. Ibid.

282. Cox Automotive, *Evolution of Mobility: The Path to Electric Vehicle Adoption*, August 2019, available at https://d2n8sg27e5659d.cloudfront.net/wp-content/uploads/2019/08/2019-COX-AUTOMOTIVE-EVOLUTION-OF-MOBILITY-THE-PATH-TO-ELECTRIC-VEHICLE-ADOPTION-STUDY.pdf.

283. Lakiesha Christopher, Supervising Analyst for the Mobile Sources Group, Connecticut Department of Energy and Environmental Protection, personal communication, 10 October 2019.

284. New Jersey Department of Environmental Protection, *DEP to Use First Round of Volkswagen Settlement Funds for Electric Vehicle Charging Stations, NJ Transit Electric Buses* (press release), 28 February 2019, archived at http://web.archive.org/web/20191010200922/https://www.nj.gov/dep/newsrel/2019/19_0011.htm.

285. West Coast Green Highway, *West Coast Electric Highway*, archived 27 July 2019 at http://web.archive.org/web/20190727071039/http://www.westcoastgreenhighway.com/electrichighway.htm.

286. City of Atlanta, Georgia, *Ordinance 17-O-1654*, 2017, available at http://atlantacityga.iqm2.com/Citizens/Detail_LegiFile.aspx?MeetingID=2068&ID=13626&Print=Yes.

287. Alana Miller, Frontier Group et al., *Ready to Charge: Five Ways California Can Improve Charging to Unleash the Power of Electric Cars*, 4 April 2019, available at https://frontiergroup.org/reports/fg/ready-charge.

288. Ibid.

289. Bradley Berman, "EV Public Charging Getting Easier with Universal Payments," *Sierra Club Electric Vehicle Guide*, archived at https://web.archive.org/web/20201123234944/https://content.sierraclub.org/evguide/blog/2013/10/ev-public-charging-getting-easier-universal-payments.

290. See note 287.

291. Dale Hall and Nic Lutsey, The International Council on Clean Transportation, *Emerging Best Practices for Electric Vehicle Charging Infrastructure*, October 2017.