



Driving Cleaner

More Electric Vehicles Mean Less Pollution



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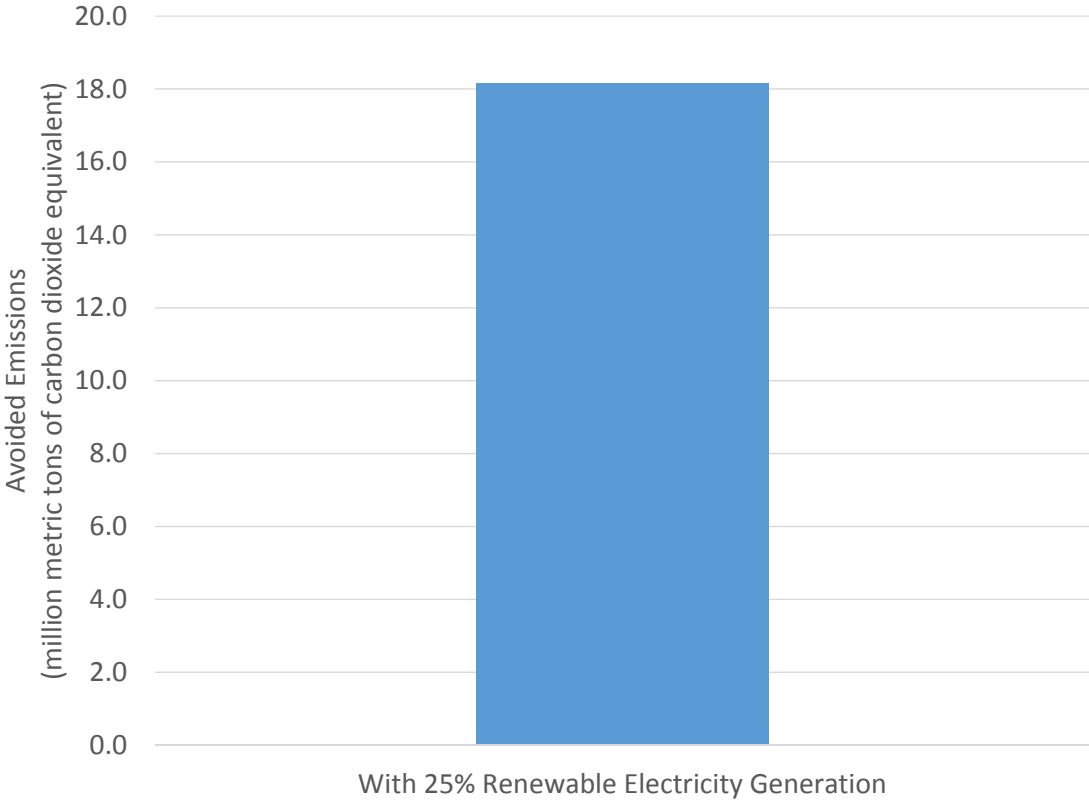
Executive Summary

America's dependence on gasoline as a transportation fuel worsens global warming and threatens public health. Increasing the use of electric vehicles – especially those powered by clean, renewable sources of electricity – can protect the climate and help America get off oil.

More than 190,000 electric vehicles are already on the road in the United States, producing far less global warming pollution per mile than their in-

ternal combustion-engine counterparts. **By 2025, widespread use of electric vehicles, coupled with a cleaner electricity grid, could reduce global warming pollution by 18.2 million metric tons of carbon dioxide equivalent per year, compared to conventional vehicles.** (See Figure ES-1.) That is equal to saving more than 2 billion gallons of gasoline per year or the annual emissions from 3.8 million of today's cars and trucks.

Figure ES-1. Avoided Carbon Dioxide-Equivalent Emissions in 2025 with 13 Million Electric Vehicles on the Road



And that is just the beginning of the climate benefits possible with increased use of electric vehicles and increased use of clean and renewable sources of electricity. Federal and state governments can realize these emission reductions by committing to policies that will increase the number of electric vehicles on the road; speed the growth of clean, renewable electricity; and curtail the use of dirty electricity sources.

Gasoline-powered automobiles contribute to global warming and harm public health.

- In 2012, gasoline used for transportation accounted for about 21 percent of all U.S. emissions of global warming pollution, roughly equal to total emissions from Japan, which is the fifth-most polluting economy in the world.
- Global warming is already seriously impacting the lives of Americans across the country in far-reaching ways, from increased coastal flooding in cities like Miami, to increased crop losses in the Midwest, to a longer wildfire season in California and the Rockies.
- Pollution from burning gasoline also harms public health. Automobile emissions contribute to the formation of ozone and fine particulates, which can cause short- and long-term lung damage. Air pollution from cars, light trucks and larger vehicles causes an estimated 53,000 early deaths each year.

Electric vehicles are far less polluting than conventional cars and trucks.

- An electric vehicle produces less global warming pollution per mile than the average new gasoline vehicle, even when emissions from vehicle production and electricity generation are included.
- Electric vehicles will become even less polluting over time. The cleaner we make our electricity

system – by adding more wind, solar and other pollution-free energy sources – the less global warming pollution electric vehicles will produce. On the other hand, the more that oil companies rely on Canadian tar sands and other hard-to-reach oil deposits, the dirtier conventional cars and trucks will get.

- Rapid growth in electric vehicle penetration is critical. The California Air Resources Board estimates that if the state is to achieve the emission reductions needed to avoid the worst impacts of global warming, electric vehicles and other zero-emission vehicles would need to account for 100 percent of new vehicle sales by 2040.

Increasing the number of electric vehicles on the road would reduce global warming pollution.

- Ten states – California, Connecticut, Maryland, Massachusetts, Maine, New Jersey, New York, Oregon, Rhode Island and Vermont – require auto manufacturers to sell electric vehicles in compliance with the Zero Emission Vehicle program. This law will put more than 3.5 million zero emission vehicles on the road in these states by 2025. Even in a scenario with limited growth in renewable energy, this would prevent 4.7 million metric tons of carbon dioxide-equivalent pollution per year compared with conventional cars. That is equal to the annual emissions of almost 1 million of today's vehicles.
- If every state adopted the Zero Emission Vehicle program, more than 13 million electric vehicles would be on the road by 2025. This would prevent 14.5 million metric tons of carbon dioxide-equivalent pollution in 2025 compared with conventional cars, equal to removing 3 million of today's vehicles from the road or saving 1.6 billion gallons of gasoline. Health-threatening toxic pollution concentrated around urban roadways would also decline.

Electric vehicles could reduce global warming pollution even further with increased generation of electricity from clean, renewable sources of energy.

- Increasing the renewable share of the nation's electricity mix to 25 percent by 2025 would result in 26 percent greater emission reductions than a scenario of slow renewable electricity growth. With 25 percent renewable energy and a nationwide commitment to zero-emission vehicles, America could cut global warming pollution by 18.2 million metric tons of carbon dioxide-equivalent – the equivalent of saving more than 2 billion gallons of gasoline per year or the annual emissions from 3.8 million of today's cars and trucks.
- Deploying electric vehicles may also facilitate increasing penetration of renewable electricity into the electricity system. By connecting their batteries to the grid when parked, electric vehicles may make it possible to capture excess clean electricity when production is high.
- Widespread use of zero-emission vehicles would also deliver broad health benefits. The American Lung Association calculates that the reduced air pollution from using electric vehicles powered by one-third renewable electricity sources would avoid 10,000 asthma attacks annually in California.

Federal and state governments should adopt policies that will increase the number of electric vehicles on the road and clean up the electricity grid. Climate scientists estimate that the United States needs to cut emissions of climate-changing pollution by more than 80 percent by mid-century in order to prevent the most harmful impacts of global warming. To meet that goal, America must get off oil.

Electrifying our transportation is a critical strategy.

- The nation should seek to ensure that all new vehicles are zero emission by 2040.
- Delaware, Pennsylvania and Washington – which have already adopted the Low Emission Vehicle program – should adopt the corresponding Zero Emission Vehicle program that requires auto manufacturers to deploy emission-free cars and trucks.
- All states should adopt policies supporting use of electric vehicles. Supportive policies include standardizing requirements for installation of charging infrastructure, supporting construction of charging infrastructure in multi-family residences and public areas, buying zero-emission vehicles for public fleets, and establishing financial incentives. States should also develop policies to support electrification of buses, garbage trucks and other medium- and heavy-duty vehicles that aren't included in the Zero Emission Vehicle program.
- The federal government should extend policies supporting zero-emission vehicles, including tax credits for the purchase of electric vehicles and plug-in hybrid electric vehicles, investment in research and development of electric vehicle technologies, and promotion of workplace charging infrastructure.
- The nation should reduce global warming pollution from the electricity sector. Steps include setting a goal of generating at least 25 percent of the nation's electricity from clean, renewable sources such as wind and solar energy by 2025, and cutting carbon pollution from new and existing power plants.

Introduction

Photo: cleanfotos/Shutterstock.

The sleek and speedy Tesla Model S. The gleaming, efficient and nearly silent Nissan Leaf. The futuristic Chevy Volt. Increasing numbers of these and many other electric vehicles are appearing on American roads – reducing the climate impact of personal transportation, the amount of pollution in our skies, and our long dependence on dirty fossil fuels.

Fifteen years ago, such battery electric vehicles were exceedingly rare. The first hybrid electric vehicles had only been introduced to American drivers. The Honda Insight was an exotically shaped two-door car, identifiable from a block away, quickly followed onto the market by the Toyota Prius. In the Prius' first year on the market in the United States, Toyota sold fewer than 6,000 of the vehicles.¹

Today, hybrid electric vehicles have become mainstream. In 2012 and 2013, the Prius was the top-selling car in California.² All major carmakers offer at least one hybrid electric vehicle, with dozens of models available for consumers to choose from.³ The development of hybrid electric vehicle technologies in the past 15 years has led to today's battery electric and plug-in hybrid electric vehicles, which are fast and powerful and can travel long distances on a single charge.

In the time since the introduction of the first hybrid electric vehicles, the environmental costs of conventional automobile operation – from smog to the carbon emissions that accelerate global warming – have become ever more clear and pressing. Mass-market electric vehicles offer both a viable transportation option and a strategy to deal with our biggest environmental problems.



A battery electric Nissan Leaf charges in downtown Portland, Oregon.

Even better, battery electric and plug-in hybrid electric vehicles are increasingly being connected to power grids driven by clean, renewable sources of energy like wind, geothermal and solar, making electric vehicles even better tools to reduce pollution. As the environmental performance of the American energy grid continues to improve, electric vehicles' potential to reduce our dependence on fossil fuels, help fight global warming, and help clean up the environment will only grow stronger.

It's time to charge ahead.

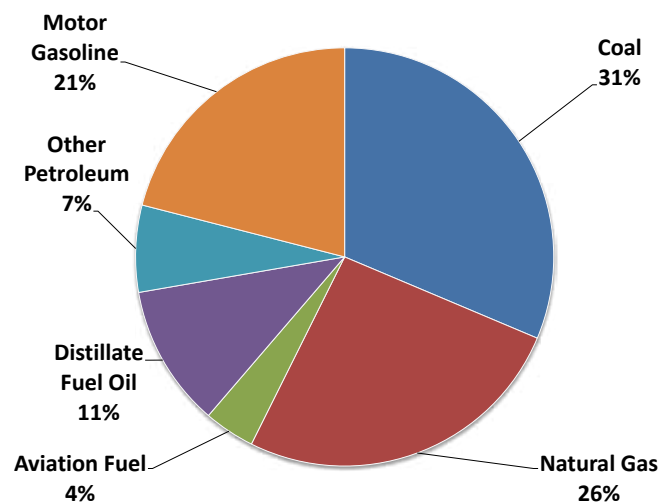
Pollution from Automobiles Harms America's Environment and Health

Conventional vehicles, which burn gasoline or diesel fuel, create unacceptable levels of pollution. Tailpipe emissions worsen global warming and contribute to unhealthy smog pollution.

Automobile Pollution Adds to Global Warming

Automobile engines emit carbon dioxide, the leading cause of global warming. In 2012, motor gasoline accounted for about 21 percent of all U.S. emissions of carbon dioxide pollution from energy use (this figure excludes emissions from ethanol).⁴ That's nearly as much pollution as was released by all economic activity in Japan – the fifth-most polluting country in the world – and more than was released by Germany in 2010.⁵

Figure 1. Sources of Emissions as a Percentage of Total U.S. Carbon Dioxide Emissions⁶



Gasoline use in light-duty vehicles also contributes to the nation's dependence on oil. More than half of the petroleum consumed in the U.S. in 2013 was in the form of motor gasoline, most of which is consumed by light-duty vehicles.⁷

Global Warming Threatens All Americans

Global warming is happening now and it poses a threat to all Americans. It is primarily caused by combustion of coal, oil and gas – which produces carbon dioxide pollution. Carbon dioxide in the atmosphere causes more of the heat from the sun to be trapped in the atmosphere and less to radiate back into space, increasing the temperature of the Earth over time. Because of carbon pollution, the average temperature across the United States has increased by 1.3°F to 1.9°F since 1895, and most of this increase has occurred since 1970.⁸

Global warming is having impacts on Americans across the country, now.

- Higher temperatures are melting ice, driving up sea levels. From 1901 to 2010, global average sea level rose by about 8 inches – a faster change in sea level than at any time in the last 2,000 years.⁹ As a result, coastal flooding is becoming more frequent and more severe. During high tides, ocean water is already flooding low-lying streets in Miami.¹⁰ And warming-induced sea-level rise has doubled the odds of a Hurricane Sandy-scale storm surge flooding coastal infrastructure in the New York area.¹¹

- Heat waves are striking more often and more powerfully, with particularly devastating consequences for areas already prone to drought.¹² In 2012, a catastrophic drought, exacerbated by near-record heat, withered crops across the country; economists estimated losses at \$77 billion.¹³ The 2014 drought in California is widely anticipated to drive up food prices as farmers struggle to get enough water to grow their crops.¹⁴
- Wildfire seasons are becoming longer and more severe. In the western United States, the average area of forest burned has increased by 90,000 acres per year since the mid-1980s.¹⁵ With more people choosing to live in vulnerable areas, home and property losses are mounting.
- Warming has increased evaporation, putting almost 2 trillion extra gallons of water vapor in the atmosphere above the United States since the 1970s – so when it rains, it rains harder.¹⁶ In New England, intense rain and snow storms occurred 85 percent more often in 2011 than they did in 1948.¹⁷ Heavy storms increase the risk of damaging floods, like the one that hit Colorado in 2013, killing eight people.¹⁸

Without a rapid and sharp drop in emissions, the world faces extreme and irreversible changes.

- By the end of the century, climate models predict that the planet may warm by up to 11°F and sea level may rise between two and six feet, reshaping coastlines and wreaking havoc on coastal communities around the world.¹⁹
- Without changes to current climate policies, University of Illinois climate experts predict that the annual acreage lost to wildfires may double by 2043. “You might get to the point where in some parts of the West, there are no more forests,” warned Professor Don Wuebbles, coordinating lead author of the Intergovernmental Panel on Climate Change’s Fifth Assessment Report.²⁰

- Increasing carbon emissions will acidify the oceans, making it harder for animals to make shells or skeletons, and increasing the rate of extinction of important species in the ocean food chain, like krill, oysters, clams and crabs.²¹

Serious impacts from global warming are now inevitable given the accumulation of carbon dioxide in the atmosphere. But if policymakers take action now to reduce climate-altering pollution, there is still time to prevent the worst impacts of global warming.²²

Automobile Pollution Threatens Public Health

In addition to changing the climate, pollution from automobiles damages our health. It contributes to the formation of smog – or ground-level ozone – pollution that causes harm similar to a sunburn on the inside of the lungs. It also creates toxic air pollution that is often concentrated near busy roadways. In total, air pollution from vehicles causes more deaths than do motor vehicle accidents.²³

Ground-level ozone forms when pollutants – nitrogen oxides and hydrocarbons – react with sunlight in the atmosphere.²⁴ Both nitrogen oxides and hydrocarbons are emitted by cars and trucks.

Smog poses both short- and long-term threats to human health. Short-term exposure to ozone can cause lung irritation and inflammation, coughing, and aggravation of lung problems like asthma. Over the longer term, exposure to ozone can increase susceptibility to various lung diseases, such as bronchitis, and cause permanent damage to lung tissue.²⁵

Thanks to the Clean Air Act, communities are reducing smog-forming pollution from cars and power plants. As a result, average ozone levels over the past several decades have declined.²⁶ Despite that improvement, ozone remains a serious public health concern. According to the American Lung Association, more than 40 percent of Americans live in areas where ozone still reaches levels high enough to damage public health.²⁷



People living close to heavily traveled or congested roads are exposed to elevated levels of toxic air pollution from vehicles.

In addition to creating ozone, vehicle air pollutants pose other health risks. Some of the hydrocarbons found in automobile exhaust can cause cancer.²⁸ Nitrogen oxides, meanwhile, can cause lung inflammation in the population at large, and trigger symptoms in people with asthma.²⁹ Vehicle air pollution causes an estimated 53,000 early deaths each year.³⁰

Nationally, 20 percent of Americans live close enough to high-traffic roads to be exposed to elevated levels of toxic air pollution.³¹ This impact is concentrated in urban areas where large numbers of people live within 1,600 feet of busy roads. Air pollution from road transportation – cars, light trucks, and larger vehicles – causes more deaths each year than pollution from electricity generation, in part because pollution from vehicles is emitted in population centers, unlike pollution from power plants that often are located in more rural areas.³²

Electric Vehicles Reduce Pollution and America's Need for Oil

Electric vehicles come in several variations, but they all share one crucial feature: they use electricity as a fuel, reducing or eliminating their need for gasoline. As a result, electric vehicles produce less global warming pollution than conventional gasoline-powered vehicles.

Electric Vehicles Can Travel Without Gasoline

Electric vehicles can complete a full trip on electric power alone, unlike hybrid electric vehicles that need to operate an internal combustion engine in order to drive more than a brief distance. There are several types of electric vehicles on the road today:

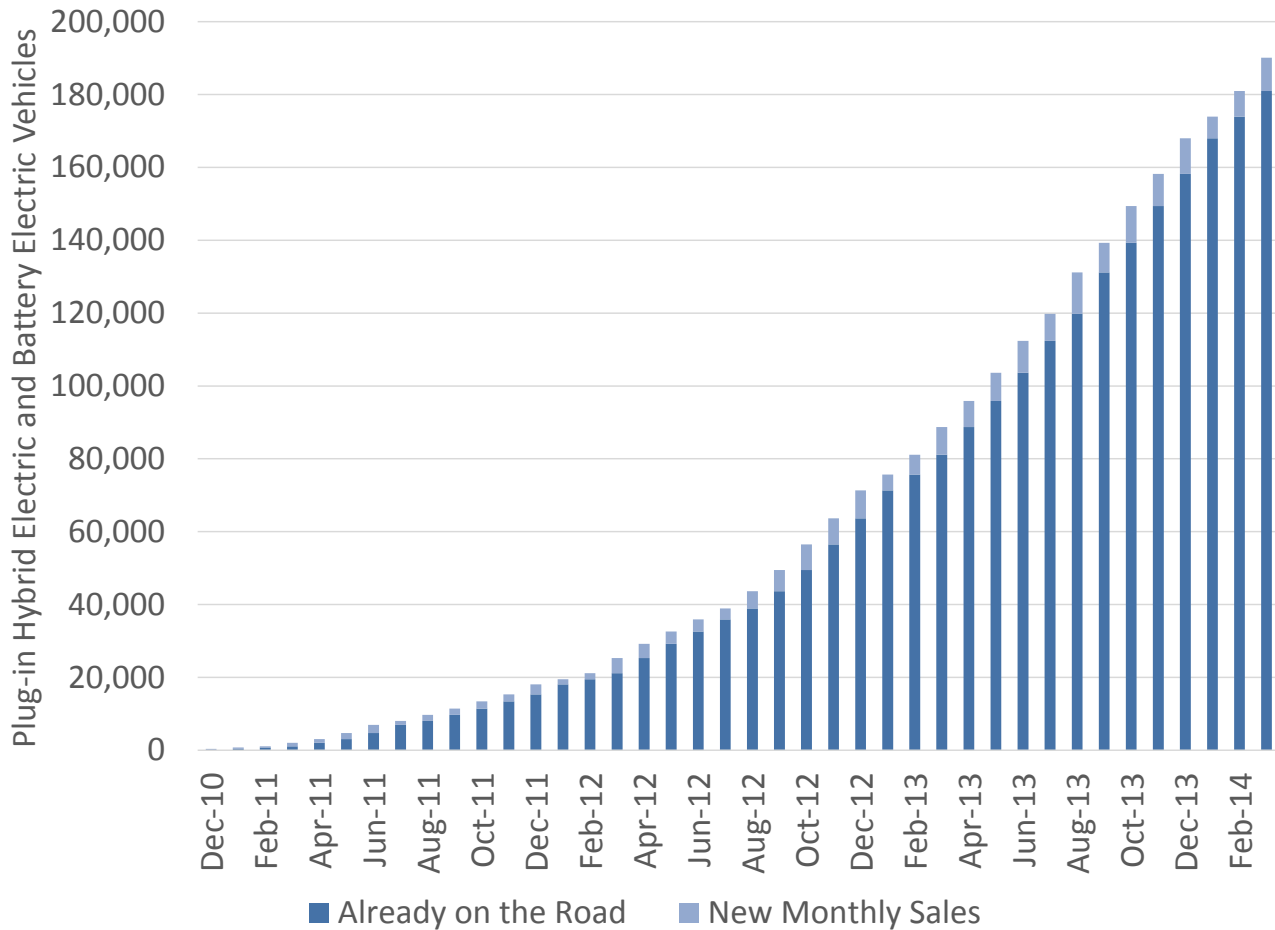
Plug-in hybrid electric vehicles (PHEVs) contain both an electric motor and an internal combustion engine. Plug-in hybrids can be plugged into an external power source to charge their batteries, which allows them to run entirely on battery power over a given range. For example, the Chevy Volt has a 38-mile all-electric range, while the Ford C-Max Energi has a 21-mile all-electric range.³³ Beyond that distance, they engage their internal combustion engine to extend range. Even in regions with relatively dirty power plants generating electricity, plug-in hybrid electric vehicles have lower emissions than do typical vehicles powered solely by gasoline. The Chevy Volt is presently the top-selling plug-in hybrid electric vehicle in the United States, having sold 58,000 cars.³⁴

Photo: Barry Blackburn/shutterstock.



The Chevy Volt, shown on display at a dealership in Virginia, is the best-selling plug-in hybrid electric vehicle in the country.

Figure 2. The Market for Plug-In Hybrid Electric and Battery Electric Vehicles Is New and Growing³⁷



Battery electric vehicles (BEVs) have no internal combustion engine. These vehicles operate entirely on battery power, and can only take trips within the range of their battery charge before stopping to recharge. In the case of the Nissan Leaf, the EPA-estimated range is 84 miles, while the larger Tesla Model S has an EPA-estimated range of up to 265 miles.³⁵ Battery electric vehicles produce no direct emissions because they don't consume any fossil fuels on-board the vehicle, and are cleaner than average gasoline- or diesel-powered cars. The Nissan Leaf is currently the top-selling battery electric vehicle in the United States, with 47,000 sold.³⁶

The market for electric vehicles is growing more quickly than the market for hybrid electric vehicles did in its early years. In slightly more than three years

on the market, 190,000 battery electric vehicles and plug-in hybrid electric vehicles have been sold.³⁸ From 2011 through 2013, annual sales of electric vehicles rose by 500 percent. (See Figure 2.)

Electric Vehicles Are Cleaner than Today's Gas-Powered Vehicles

When compared to traditional gas-powered vehicles, electric vehicles produce considerably less global warming and air pollution. The cumulative emissions of an electric vehicle – including emissions from vehicle production and electricity generation – are significantly lower than emissions from a gasoline vehicle.

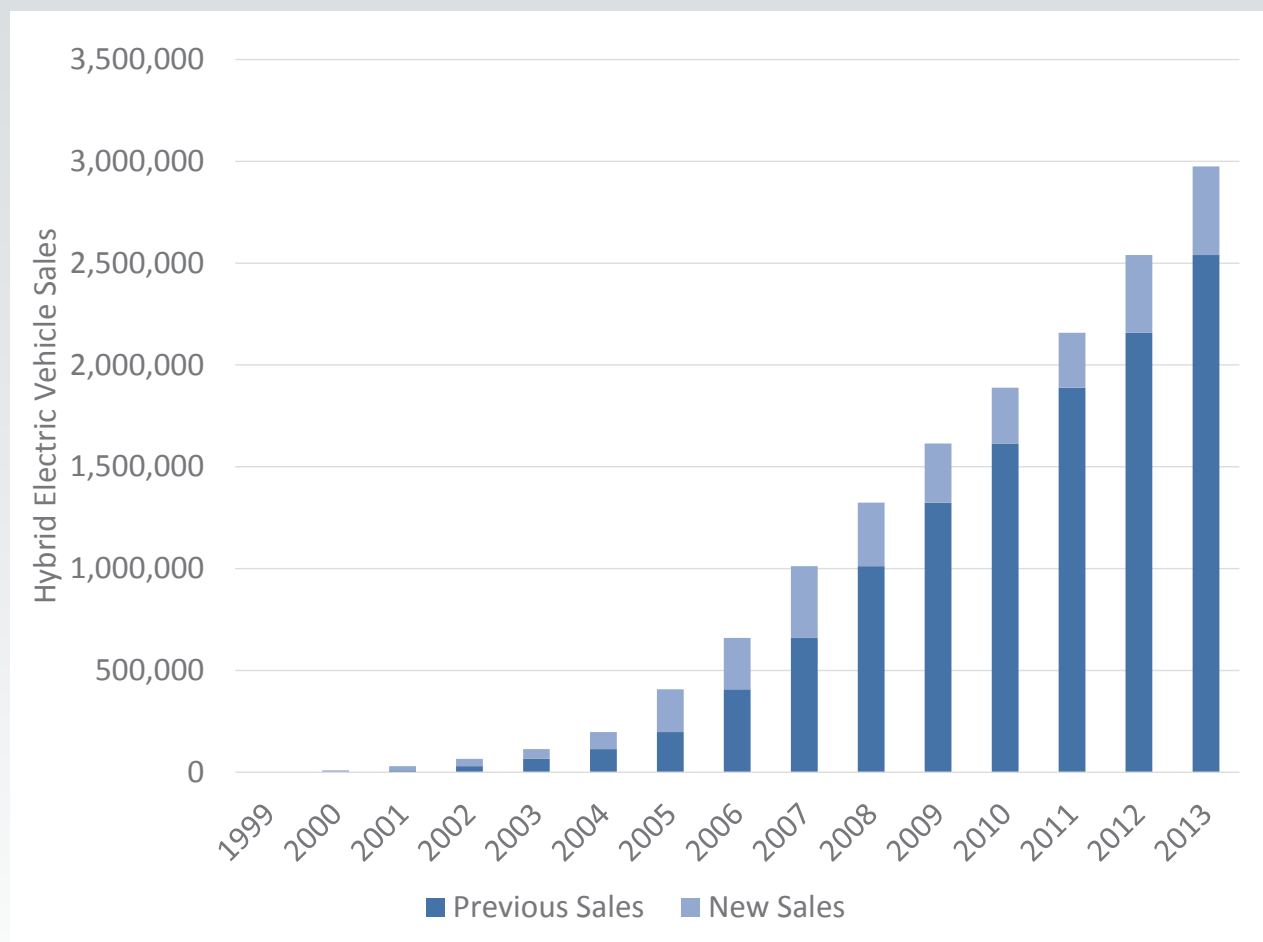
Hybrid Electric Vehicle Sales Have Grown Rapidly

Sales of hybrid electric vehicles demonstrate how quickly cleaner vehicles can become established in the market. Growth of hybrid vehicles suggests zero-emission vehicle sales could also grow quickly.

Partially electric drive trains began to make an impact on the American automobile market in the early 2000s with the introduction of hybrid electric vehicles, like the Ford Escape hybrid and Toyota Prius. These cars have batteries and an electric motor that provide assistance to the gasoline engine. Although they have no source of power beyond the operation of their internal combustion engines, hybrid electric vehicles have a number of features that make them more fuel-efficient than conventional cars.

American drivers purchased nearly 3 million of these vehicles between 1999 and the end of 2013.³⁹ (See Figure 3.) The California Air Resources Board considers hybrid electric vehicles to be established in the marketplace, a vehicle type that manufacturers will continue to produce and sell, regardless of specific policies promoting hybrids.⁴⁰ Navigant Research, a market research firm, forecasts that hybrid electric vehicle sales will expand at an annual rate of 11.5 percent between 2013 and 2020.⁴¹

Figure 3. The Hybrid Electric Vehicle Market Is Well Established⁴²



The total pollution impact of gasoline-powered vehicles can be compared with those of electric vehicles (which produce no tailpipe pollution) by measuring life cycle emissions. Life cycle emissions include pollution emitted during vehicle production, fuel production and transportation, and pollution that is released when the fuel is used. For example, life cycle global warming pollution from a gasoline vehicle includes emissions released during production, refining and transportation of the oil as well as the tailpipe pollution produced from combustion in the vehicle. Though an electric vehicle produces no pollution when it draws electricity from its battery to drive its motor, its life cycle emissions include the global warming pollution released at the power plant that generated the electricity.

Analyses performed by different government agencies, academics and other researchers have confirmed that electric vehicles have lower life cycle emissions than conventional gasoline vehicles, even when charged from a grid heavy with coal-fired power plants.⁴³

In short, driving an electric vehicle or a plug-in hybrid electric vehicle produces less global warming pollution than driving the average gasoline-powered vehicle today.⁴⁴ Electric vehicles will only get cleaner

as the electricity grid from which they draw power includes more renewable electricity sources.⁴⁵ On the other hand, conventional cars could produce increased life cycle emissions as they come to rely on oil extracted from tar sands and other especially polluting sources.

Oil Is Getting Dirtier Because of Tar Sands and Other Unconventional Fuel Sources

As conventional, easy-to-access supplies of oil become harder to find, oil companies have begun to tap oil reserves in more remote locations and to turn to unconventional sources of oil. The result is that the average barrel of oil from these sources produces more global warming pollution and causes broader environmental harm than has historically been the case with conventional oil supplies.

Oil companies are increasingly tapping into two unconventional supplies of oil that release more global warming pollution than conventional oil: oil extracted from tar sands and oil obtained through fracking. Tar sands-based oil releases 14 to 25 percent more global warming pollution than conventional oil.⁴⁶ The U.S. Energy Information Administration (EIA) projects that production of tar sands oil will triple over the

How Using Oil from Tar Sands Could Increase Emissions: A Case Study from the Northeast

Increasing the amount of tar sands-derived oil refined into gasoline for consumption in the U.S. could measurably increase life cycle emissions from light-duty vehicles. The Natural Resources Defense Council estimated how the Northeast's supply of gasoline might change if the Keystone XL pipeline is approved and refineries that supply the region begin processing tar sands oil.⁴⁹

In the region stretching from Maryland to Maine, the increased use of tar sands-based gasoline could result in emissions from light-duty vehicles increasing by 16 percent in 2025, compared to using gasoline from conventional sources.⁵⁰ The potential increase in global warming pollution from tar-sands based gasoline adds additional urgency to the efforts of the Mid-Atlantic and New England states to promote electric vehicles.

next 25 years, from 1.5 million barrels per day to 4.8 million barrels per day.⁴⁷

Fracking is an energy- and water-intensive method of reaching oil and natural gas deposits. Recent studies have found that fracking results in extensive leaks of methane, a powerful greenhouse gas, thus raising the total global warming pollution attributable to fuels obtained through fracking.⁴⁸

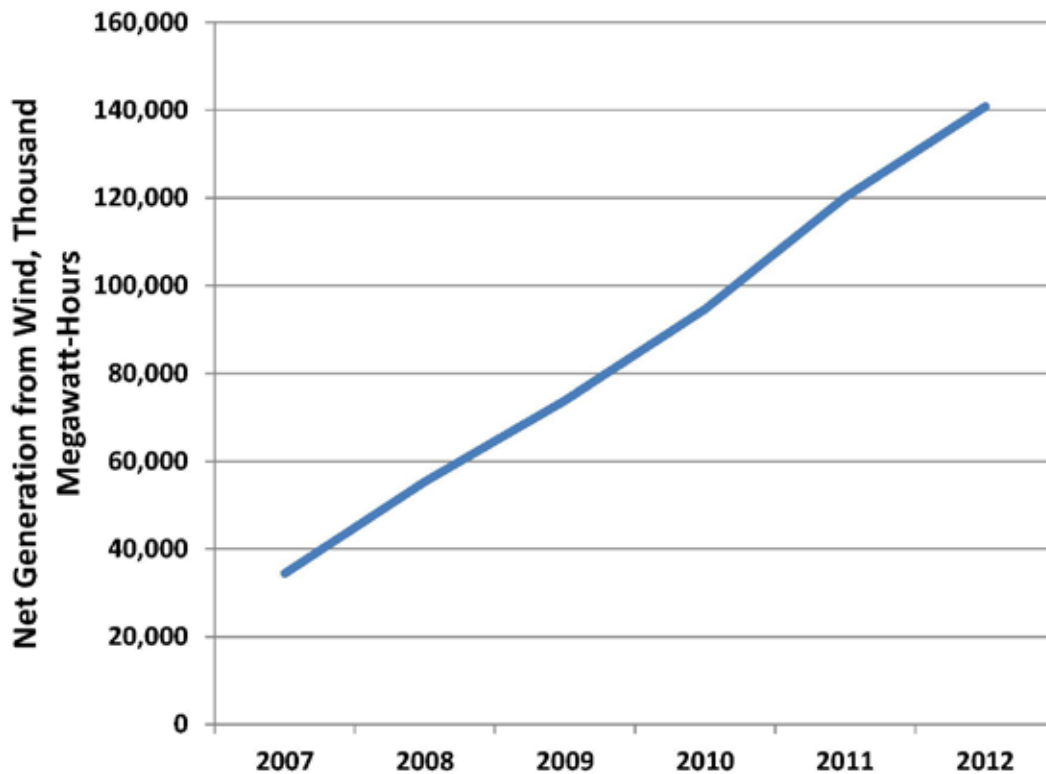
Unconventional and hard-to-reach oil sources also produce other extensive environmental damage. Deepwater oil drilling can lead to massive oil spills: when the Deepwater Horizon oil drilling rig exploded in the Gulf of Mexico in 2010, it dumped more than 200 million gallons of oil into the Gulf. Since 2005, fracking has damaged more than 350,000 acres of land and led to the release of 450,000 tons of hazardous air pollutants into the atmosphere. In 2012 alone, fracking for oil and gas generated over 280 billion gallons of toxic wastewater.⁵¹

Electricity Is Getting Cleaner Due to Renewable Energy

While our future oil supplies are getting dirtier, our sources of electricity are getting cleaner. Twenty-nine states plus the District of Columbia currently have some version of a renewable electricity standard requiring that utilities generate an increasing percentage of electricity from renewable energy sources.⁵² As a result of these policies and federal incentives, the amount of electricity generated from wind increased four-fold from 2007 to 2012.⁵³ (See Figure 4.) Utility-scale solar energy generation increased at least seven-fold.

With the right policies in place, we can achieve much greater increases in renewable generation of electricity, further strengthening the environmental benefits of electric vehicles.

Figure 4. Net Generation of Electricity from Wind Increased Four-Fold from 2007 to 2012⁵⁴



Electric Vehicles Are Essential to Meeting Climate Protection Goals

Electric vehicles produce relatively little global warming pollution and health-threatening air pollution, making them a critical tool for addressing the environmental impacts of our transportation system.

By mid-century, climate scientists estimate that the United States needs to cut emissions of global warming pollution by more than 80 percent.⁵⁵ To reach that goal, electric vehicles, plug-in hybrid electric vehicles and fuel-cell vehicles will need to dominate the light-duty vehicle fleet – and those vehicles will need to be powered almost exclusively by emission-free electricity and other clean fuel sources. In California, for example, researchers have concluded that if the state is to achieve the emission reductions needed to avoid the worst impacts of global warming, electric vehicles and other zero-emission vehicles will need to account for 100 percent of new vehicle sales by 2040 and those vehicles will need to be charged with clean energy sources.⁵⁶

Using more electric vehicles powered by clean electricity can reduce health-threatening air pollution. The American Lung Association calculates that an all-electric vehicle fleet, powered by one-third clean electricity sources, could cut air pollution enough to avoid more than 10,000 asthma attacks per year in California.⁵⁷ The number of days at school and work missed because of health impacts of poor air quality could decline by 75 percent.

Transforming the nation's fleet to include entirely zero-emission vehicles won't happen over the course of just a few years. It will require long-term commitment and investment to refine vehicle technologies, add new charging infrastructure, and replace dirty vehicles with clean ones when aging vehicles are retired. Increasing the number of zero-emission vehicles on the road by 2025 is a critical first step to meeting long-term emission reduction goals.

Increasing the number of zero-emission vehicles on the road by 2025 is a critical first step to meeting long-term emission reduction goals.

The Benefits of Putting More Electric Vehicles on the Road

From battery electric vehicles like the Nissan Leaf to plug-in hybrid electric vehicles like the Chevy Volt, electric vehicles are already helping to cut global warming pollution. Boosting the number of electric vehicles in the nation's fleet can help cut global warming pollution by reducing reliance on gasoline and increasing the use of electricity as a vehicle fuel. Simultaneously adding more renewable electricity sources to the nation's grid and retiring more polluting sources, such as coal and natural gas, can help drive emissions even lower.

Emission Reductions from More Electric Vehicles in 10 States

Thirteen states have adopted all or part of the Clean Cars Program, which is a policy aimed at reducing health-threatening and climate-changing pollution from passenger vehicles. These states are California, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Jersey, New York, Rhode Island, Pennsylvania, Oregon, Vermont and Washington. All of these states – except for Washington, Pennsylvania and Delaware – have also adopted the Zero Emission Vehicle (ZEV) component of the Clean Cars Program, which pushes automakers to produce ever-cleaner vehicles with new technology and to sell a rising number of advanced vehicles, including battery electric and plug-in hybrid electric vehicles. The ZEV requirement, originally developed in 1990, spurred manufacturers to develop the hybrid electric vehicles that are common today, and is designed to lead to the same growth in battery electric vehicles, plug-in hybrid electric vehicles, and fuel cell vehicles (FCVs). (See "The Clean Cars Program" text box for more background about the entire program.)

Already, manufacturers are expanding their offerings of electric vehicles, giving consumers more options and broadening the reach of the electric vehicle market. In 2014 alone, Chevrolet plans to release the subcompact Spark EV, BMW will launch the i3, Kia will unveil the Soul EV, Mercedes-Benz will produce its B-Class EV, Volkswagen will reveal its eGolf, and Tesla will branch out with its Model X sport utility vehicle, designed to appeal to a broader consumer base.⁵⁸ However, not all vehicles may be available nationally, as automakers sometimes limit sales to states with zero-emission vehicle requirements.

Table 1. Electric Vehicles Currently Offered by Carmakers⁵⁹

| Vehicle | Type |
|-----------------------------|-------------------------|
| Cadillac ELR | Plug-in Hybrid Electric |
| Chevrolet Spark | Electric |
| Chevrolet Volt | Plug-in Hybrid Electric |
| Fiat 500E | Electric |
| Ford C-MAX Energi | Plug-in Hybrid Electric |
| Ford Focus Electric | Electric |
| Ford Fusion Energi | Plug-in Hybrid Electric |
| Honda Accord | Plug-in Hybrid Electric |
| Honda Fit EV | Electric |
| Mitsubishi i-MiEV | Electric |
| Nissan LEAF | Electric |
| Porsche Panamera S E-Hybrid | Plug-in Hybrid Electric |
| Smart for Two EV | Electric |
| Tesla Model S | Electric |
| Toyota Prius Plug-in | Plug-in Hybrid Electric |
| Toyota RAV4 | Electric |



The Smart fortwo electric vehicle has been available to customers in the U.S. since 2012.

To ensure the success of the ZEV program, governors in eight states have pledged to enact policies placing 3.3 million zero-emission vehicles on the road by 2025. At that point, battery electric vehicles, plug-in hybrid electric vehicles and fuel cell vehicles will account for more than 15 percent of new vehicle sales in participating states.⁶⁰ The coalition of states – California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island and Vermont – plans to boost adoption of ZEVs with a suite of policies designed to make the transition to electric vehicles smoother and more attractive for consumers. Among the policies agreed to by the coalition are reforming building codes to facilitate the construction of electric charging stations; investing in research and infrastructure necessary to sustain hydrogen fuel cell vehicles; purchasing zero-emission vehicles for state fleets; considering fiscal incentives to help consumers manage the higher up-front capital costs of electric vehicles, including reduced toll rates and access to

carpool lanes; and harmonizing electric vehicle networks to make ownership of electric vehicles smoother and more efficient across state lines.⁶¹

Implementation of the ZEV program in 10 states – the eight that have signed the agreement, plus New Jersey and Maine, which have adopted the ZEV requirement but have not yet signed the agreement – would cut global warming pollution by 4.7 million metric tons of carbon dioxide equivalent (MMTCO₂e) in 2025 compared with emissions from conventional cars.⁶² In other words, the use of battery electric vehicles, plug-in hybrid electric vehicles, and fuel cell vehicles instead of conventional gas-powered vehicles would reduce pollution relative to conventional cars by the same amount as removing 1 million of today's cars from the road. That's equal to emissions from burning more than 500 million gallons of gasoline, enough to drive from New York City to Los Angeles 4 million times.⁶³

Table 2. Global Warming Pollution Avoided in 2025 in 10 States Due to the ZEV Program

| State | Number of BEVs, PHEVs, and FCVs on the Road | Pollution Prevented (MMT _{CO₂e}) |
|---------------|---|---|
| California | 1,414,000 | 1.80 |
| Connecticut | 146,000 | 0.24 |
| Massachusetts | 286,000 | 0.48 |
| Maryland | 282,000 | 0.20 |
| Maine | 48,000 | 0.08 |
| New Jersey | 475,000 | 0.35 |
| New York | 803,000 | 1.35 |
| Oregon | 123,000 | 0.15 |
| Rhode Island | 41,000 | 0.07 |
| Vermont | 33,000 | 0.06 |
| TOTAL | 3,652,000 | 4.77 |

Electric vehicle sales may be used by automakers to comply with federal standards limiting global warming pollution from cars. By selling more zero-emission vehicles, automakers could technically sell a corresponding number of dirty vehicles, as long as the automakers meet the fleet average emission standard. Increasing sales of electric vehicles will help achieve the global warming emission reductions promised under the federal standards while also positioning the nation for further emission reductions as the electric grid becomes cleaner in the years to come.

Increasing the number of electric vehicles will also help reduce health impacts of vehicle pollution. Vehicle tailpipe emissions have a disproportionate impact on people who live near freeways and other heavily traveled roads. Greater use of electric vehicles will reduce pollution levels in those concentrated areas.

The Clean Cars Program

The Clean Cars Program originated as a state-level vehicle emission standard, designed by California and adopted by a dozen other states with air pollution problems. The program initially targeted air pollutants that contribute to the formation of smog and soot. Policymakers expanded the program in 2002 to include global warming pollution. The program's reach grew again in 2009 when the Obama administration committed to national adoption of a modified version of the Low Emission Vehicle portion of the program.

In addition to limiting emissions from automobiles in use today through low emission vehicles, the Clean Cars Program seeks to advance clean car technology through its Zero-Emission Vehicle (ZEV) requirement. The ZEV program's goal is to increase the number of vehicles with zero tailpipe emissions, such as battery electric vehicles and fuel cell vehicles. Designed and regularly updated by the California Air Resources Board, the ZEV program offers auto manufacturers flexibility in how they meet the program's requirements. Car companies can comply by developing and selling vehicles that aren't zero emission but that will facilitate a technological and infrastructural transition to zero-emissions vehicles.

For example, plug-in hybrid electric vehicles require batteries with bigger capacity than do hybrid vehicles, thereby spurring innovations in battery technology. And, as plug-in hybrid electric vehicles become more common, demand will rise for charging infrastructure at homes and businesses, an investment that will make battery electric vehicles more appealing to drivers.

Another vehicle type that complies with the ZEV program is the fuel cell vehicle (FCV). A hydrogen-powered fuel cell provides electricity to drive a motor, powering the vehicle and releasing no global warming pollution from the tailpipe. The first fuel cell light-duty vehicles are scheduled to become commercially available in June of this year.⁶⁴ Though charging stations currently are few and far between, more are being built, with California planning to open 45 additional stations by the end of 2015.⁶⁵

Emission Reductions from More Electric Vehicles in All 50 States

Putting more electric vehicles on the road will prevent more global warming pollution. If the Clean Cars Program's ZEV requirement were adopted in all 50 states plus Washington, D.C., an estimated 13.2 million battery electric vehicles, plug-in hybrid electric vehicles and fuel cell vehicles would be on the road in 2025. By replacing that many gasoline-powered vehicles with less polluting vehicles, global warming pollution would be cut by 14.5 million metric tons of carbon dioxide equivalent relative to emissions from conventional cars.⁶⁶ That's as much pollution as is released in a year by 3 million of today's vehicles.⁶⁷ (Appendix A shows state-by-state savings.)

Emission Reductions from Electric Vehicles Powered by Clean Electricity

Electric vehicles can achieve greater reductions in global warming pollution if the electricity that powers them comes from cleaner sources.

In 2013, 13 percent of the nation's electricity was generated from renewable energy sources such as hydropower, wind and solar.⁷¹ The U.S. Energy Information Administration estimates that by 2025 renewable electricity generation will increase modestly to produce nearly 15 percent of the nation's electricity.⁷² This growth results from federal policies subsidizing construction of new renewable electricity facilities and state renewable electricity standards. Twenty-nine states have established requirements that a certain percentage of electricity sold in the state come from wind, solar and other clean, renewable sources. Many of these policies have requirements that rise annually until a target year is reached.

The best renewable electricity policies ensure that states will obtain more than 30 percent of their electricity from renewable sources by the end of this decade. For example, California requires utilities to obtain 33 percent of their electricity from renewable sources by 2020, and Colorado's requirement is 30 percent by 2020.⁷³ Illinois, Minnesota, Nevada and Oregon each have a requirement of 25 percent by 2025.⁷⁴ However, because relatively few states have adopted such strong renewable electricity requirements, by 2025 the total national share of electricity from renewable sources is forecast by the EIA to be only 15 percent.⁷⁵

Stronger state and federal policies to promote wind, solar and other clean sources of power could enable the nation to obtain 25 percent of its electricity from renewables by 2025. With more clean, renewable power generation, less electricity would be needed from coal- and natural gas-fired power plants and average emissions from electricity generation – and the vehicles powered by electricity – would decline.

Expanding the number of electric vehicles on the road in every state (as envisioned in "Emission Reductions from More Electric Vehicles in All 50 States") and increasing the amount of electricity produced from renewable sources to 25 percent would cut global warming pollution from light-duty vehicles by 18.2 million metric tons of carbon dioxide equivalent in 2025 compared to conventional vehicles.⁷⁶ That is equal to the global warming pollution released by 3.8 million of today's vehicles in a year, or the amount of pollution released by burning 2 billion gallons of gasoline.⁷⁷

This is a 26 percent increase in emission savings over a situation of slow renewable energy growth.

Electric Vehicles as Shared Use Vehicles

Electric vehicles provide benefits by displacing miles that would otherwise be driven in gasoline-powered vehicles. One key place for this to happen is in car-sharing services, where vehicles receive frequent, short-term use and often are parked in designated areas where charging infrastructure can be installed.

Car-sharing services, such as Zipcar, have become popular in urban areas where many residents can complete their daily commutes and errands without a car, but periodically need access to a car for a few hours. Shared-use vehicles are typically available for rental by the minute or by the hour, and then are parked for the next customer. Some car-sharing services require that the shared-use vehicle be returned to original location, necessitating a roundtrip by the driver, while other services permit one-way trips and allow the vehicle to be left in any part of the city served by the car-sharing service. Multiple customers may rent a car in a single day, resulting in significant local mileage for each vehicle.

This use pattern is well-suited to electric vehicles. The high mileage in shared-use vehicles means that electric vehicles displace a large number of miles in gasoline vehicles. Multiple local trips ensure regular opportunities to recharge the battery. In addition, because car-sharing companies, not drivers, pay for fuel in shared-use vehicles, fleet operators may have an incentive to purchase electric vehicles (which are cheaper to operate per mile than gasoline vehicles) and to install charging stations.

Electric vehicles are already in use by car-sharing services. Zipcar offers Honda Fit electric vehicles in some cities and DriveNow provides only BMW electric vehicles.⁶⁸ In France, car-sharing service Autolib allows users to rent electric cars at one of a number of curbside charging stations and return them to any station with an available parking space.⁶⁹ The company that created Autolib will soon offer 500 electric vehicles for rent from 200 locations throughout Indianapolis.⁷⁰

Photo: Mario Roberto Duran Ortiz, via Wikimedia, under Creative Commons license.



Indianapolis will become the first American city with an electric vehicle sharing service – a business model pioneered by Paris' Autolib program (above).



Increasing the amount of electricity produced from renewable sources to 25 percent provides greater reductions in global warming pollution.

Electric Vehicles Can Help Clean up the Power Grid

As electric vehicles become more common, their batteries will begin to offer the electrical grid something it has never before possessed – a modular and widely dispersed significant volume of storage capacity for power – contributing to the ability to integrate greater amounts of solar and wind energy into the nation’s electric system.

At present, electricity production has to be closely matched to demand throughout the day. That means that while some large power plants run night and day, others are switched on and off to match the variation in demand that occurs over the course of 24 hours.

The incorporation of additional renewable energy sources into the grid presents a challenge for grid managers, and the storage capacity provided by electric vehicle batteries may help incorporate intermittent sources of power, like wind and solar energy, into the grid. Renewable energy sources produce power when the sun shines or the wind blows, which may not always align with periods of high electricity demand. Smart charging of electric vehicles allows grid managers to coordinate vehicle charging with renewable electricity output.⁷⁸ Smart charging can be accomplished through strategies such as customer education, time-of-day electricity pricing, or advanced controls that allow the utility to determine when a vehicle should start charging.

In the long-term, electric vehicles – and their batteries – may provide an additional benefit by feeding stored power back into the grid during times of high demand. Batteries can be charged when renewable energy sources generate more power than required by users, then discharge energy back into the grid during times of lower renewable output. Multiple demonstration projects are under way in the U.S. to explore the opportunities and challenges of enabling batteries in electric vehicles and plug-in hybrid electric vehicles to store electricity from the grid.⁷⁹ Denmark, which has led the world in developing wind power, plans to use electric vehicles to allow it to incorporate levels of wind power above what an unimproved grid would be capable of carrying into its electrical system.⁸⁰ In the future, a significant fleet of electric vehicles could allow the United States to do the same thing, making possible a cleaner electrical grid.

Policy Recommendations

Climate scientists estimate that the United States and other industrialized nations need to cut emissions of climate-changing pollution by more than 80 percent by mid-century in order to prevent the most harmful impacts of global warming.⁸¹ To meet that goal, America must get off oil. Transitioning our transportation system to run on electricity rather than gasoline is a critical component of an overall strategy to protect future generations from the worst impacts of climate change.

Electric vehicles have the potential to provide meaningful reductions in global warming pollution in the short- and long-term. State and federal policy should aim to accelerate the development and deployment of electric cars and trucks, with the long-term goal of eliminating our dependence on oil.

Accelerate the Deployment of Electric Vehicles

The nation should seek to ensure that all new vehicles are zero emission by 2040.

Delaware, Pennsylvania and Washington – which have already adopted the Low Emission Vehicle program, but not its related zero-emission counterpart – should adopt the ZEV program. Other states also could adopt the program or could otherwise set goals for adoption of zero-emission vehicles.

States should adopt policies supporting use of electric vehicles and collaborate to accelerate electric vehicle deployment. States can:

- Modify building codes to require construction of charging infrastructure in new or renovated buildings, especially in multi-family residences and public areas. Both renters and homeowners need access to charging facilities.
- Ensure that utilities offer electricity pricing schedules tailored to electric vehicle owners. For example, both Georgia Power and Indianapolis Power & Light offer such options for individuals and companies that need to charge a vehicle.⁸²
- Buy zero-emission vehicles for public fleets and build charging infrastructure to support those vehicles. This lead-by-example strategy can replace a large number of miles that would be driven in gasoline-powered vehicles, increase public familiarity with electric vehicles, introduce fleet drivers to electric vehicles and perhaps encourage them to purchase such vehicles for their personal use, and potentially increase the number of publicly accessible charging stations.
- Offer rebates or tax credits to individuals or companies that buy or lease zero-emission vehicles. For example, Georgia offers up to a \$5,000 tax credit and Colorado offers up to a \$6,000 tax credit, while Washington offers a sales tax exemption for electric vehicles.⁸³
- Offer other incentives for purchases of clean vehicles, such as HOV lane access, preferential parking and reduced tolls. In California, for example, access to HOV lanes motivates many purchases of electric vehicles.⁸⁴

Federal policies also can support the use of electric vehicles.

- The federal government currently offers tax credits of up to \$7,500 to purchasers of electric vehicles and plug-in hybrid electric vehicles. The size of the tax credit depends on the battery capacity of the vehicle.⁸⁵ The credit will be phased out for each manufacturer as the automaker achieves sales of 200,000 electric and plug-in hybrid electric vehicles.⁸⁶ As more manufacturers approach this sales threshold, it may be appropriate to extend the cap to ensure the continued sales growth of electric and plug-in hybrid electric vehicles.
- The federal Department of Energy promotes electric vehicles through the EV Everywhere Grand Challenge and the Workplace Charging Challenge. EV Everywhere supports technological progress and commercialization to make electric vehicles and charging infrastructure widespread and affordable.⁸⁷ Research and development investments by the Department of Energy have helped to cut the cost of battery technology in half compared to 2010.⁸⁸ The Workplace Charging Challenge seeks to increase the number of employers offering workplace charging ten-fold within five years.⁸⁹ These efforts should be continued.

States should develop policies to support electrification of buses, garbage trucks and other heavy-duty vehicles that aren't included in the zero-emission vehicle program. Many of the same policies that influence the light-duty vehicle fleet can be used for medium- and heavy-duty vehicles, such as financial incentives. For instance, California offers a Hybrid Truck & Bus Voucher Incentive Project to offset the higher purchase price of a hybrid or electric bus or truck.⁹⁰ The fleets of both UPS and Coca-Cola include hybrid electric trucks that have helped cut diesel consumption and global warming pollution.⁹¹

Finally, states should consider adopting a low-carbon fuel standard to limit the use of fuels – such as oil from tar sands – that produce large amounts of global warming pollution. Since electricity is a relatively clean fuel, a low-carbon fuel standard can help accelerate the growth of the electric vehicle market.

Limit Carbon Pollution from Transportation

All states should create programs designed to limit global warming pollution from transportation. For example, under California's landmark global warming pollution reduction law, AB32, the state will be implementing a cap on pollution from the transportation sector beginning in 2015. Under the cap, distributors of transportation fuels must obtain allowances for carbon pollution through auction. The state should use a portion of the resulting auction revenues to accelerate electric vehicle deployment, in addition to other measures to reduce transportation emissions.

All other states should establish analogous programs, aimed at reducing transportation sector emissions by more than 80 percent by 2050.

Cut Global Warming Pollution from Electricity Generation

To obtain the maximum benefit from the growing number of electric vehicles on the road, the nation's electricity grid should be cleaned up by increasing production from clean, renewable sources and limiting carbon pollution from fossil-fuel-fired power plants.

Expanded renewable electricity standards can promote widespread adoption of renewable energy, while policies targeting solar energy and offshore wind power will help develop technologies that have the potential to meet a large share of our future power needs.

- **Increase renewable electricity generation:** The nation should seek to obtain 25 percent of its electricity from renewable sources such as wind, solar and geothermal energy by 2025, a stepping stone on our way to generating all of our electricity from renewable energy. The 29 states with existing renewable electricity standards should strengthen their goals and establish high targets beyond 2025. Other states and the federal government should adopt their own renewable electricity policies.
- **Cut pollution from new power plants:** The EPA has drafted rules to reduce global warming pollution from new power plants. The agency's proposal builds on the policies developed by states. EPA Administrator Gina McCarthy announced rules in September 2013 that would limit new power plants to emissions of no more than 1,100 pounds of carbon dioxide per megawatt-hour – significantly less than the average coal-fired plant, which emits 1,800 pounds of carbon dioxide per megawatt-hour.⁹² EPA should finalize these rules as soon as possible.
- **Clean up existing power plants:** The EPA published the first-ever federal rules to cut carbon pollution from existing power plants on June 2, using the authority of the Clean Air Act.⁹³ The World Resources Institute finds that through swift enactment of a strong policy, the nation could reduce global warming pollution from existing power plants by 38 percent below 2012 levels by 2020.⁹⁴ Such a reduction would increase the pollution reduction benefits of electric vehicles. EPA should finalize these rules as soon as possible and all states should cooperate with EPA and develop effective compliance plans to ensure timely reductions in power plant carbon pollution.
- **Enact supportive policies:** Renewable electricity standards will be more effective and the nation's ability to develop renewable energy sources will be greater with the support of additional policies. The federal production and investment tax credits (PTC/ITC) are two of the most important tools that have helped grow the renewable energy industry in the United States. Their effectiveness, however, has been hamstrung by their "here today, gone tomorrow" inconsistency. The United States should make a long-term commitment to renewable energy with a long-term renewal of the PTC and ITC. Strong solar energy policies, particularly at the state and local levels, have helped unlock America's solar potential. To continue the nation's solar energy momentum, federal and state policymakers can set goals within a renewable electricity standard for how much power should come from solar energy and adopt policies such as net metering that help level the financial playing field for solar energy. Policies encouraging the development of offshore wind, smart grid and energy storage technologies are essential to ensuring the continued growth of renewable electricity generation in the decades to come.

Methodology

The purpose of this report is to quantify the contribution of electric vehicles to reducing emissions of global warming pollution relative to conventional vehicles. The report does not attempt to model total emissions from the transportation sector. Such an analysis would have to make assumptions about the character of all vehicle sales. That is because under federal laws limiting global warming pollution from cars and trucks, automakers must achieve a fleet average emission rate. By selling more zero-emission vehicles, automakers technically could sell a corresponding number of dirty vehicles, as long as the manufacturer meets the fleet average emission standard.

Emissions from the light-duty vehicle fleet were calculated as a function of the number of vehicles, the amount of energy (in Btu) consumed by each vehicle each year, and the global warming pollution per Btu of fuel used. Inputs for each component of the calculation are described below.

Vehicle Fleet Scenarios

Baseline Scenario

To estimate the impact of increasing the number of electric vehicles on the road, we first created a scenario that excluded from federal projections of future energy use the impact of any policies designed to accelerate electric vehicle market penetration. For this scenario, we adjusted the 2025 baseline scenario in U.S. Energy Information Administration, *Annual Energy Outlook Early Release (AEO2014)*, 16 December 2013 to remove the direct impact of the ZEV requirement in the Clean Cars Program.

The ZEV component of the Clean Cars Program is factored into *AEO2014* based on the August 2004 rules issued by the California Air Resources Board, not the updated rules issued in 2012. The August 2004 rules allow vehicle manufacturers to comply with the program by selling large numbers of conventional vehicles with low emissions and hybrid electric vehicles (HEVs), and a relatively small number of ZEVs. This is very different from the updated rules, which do not allow automakers to count sales of conventional vehicles or HEVs toward compliance with the ZEV program.

We created an adjusted baseline that removes battery electric vehicles and fuel cell vehicles linked to the ZEV program. *AEO2014* shows that the West South Central region has no vehicles sold to comply with the ZEV program, and therefore that region provides a baseline fleet penetration rate for fuel cell vehicles, battery electric vehicles, plug-in hybrid electric vehicles and hybrid electric vehicles.

Specifically:

- We obtained forecasts of vehicle sales by vehicle type by region for 2009 to 2025. Data for 2011 to 2025 came from *AEO2014* Supplemental Tables 48 to 56. Data from 2009 and 2010 came from the corresponding tables in *AEO2012*. We summed vehicle sales from 2009 to 2025 by type and region, producing a national sales figure approximately equal to the projected size of the national vehicle fleet in 2025. We assumed that no pre-2009 vehicles will remain on the road by 2025. While some older vehicles will remain in use, older vehicles are driven fewer miles than new ones (per

Anup Bandivadekar, et al., Laboratory for Energy and the Environment, Massachusetts Institute of Technology, *On the Road in 2035: Reducing Transportation's Petroleum Consumption and GHG Emissions*, July 2008), and therefore account for a small percentage of total fuel use.

- We adjusted battery electric, fuel cell, plug-in hybrid electric and hybrid electric vehicle sales totals so that all regions matched the alternative vehicle penetration rate in the West South Central region. ZEV program vehicles were assumed to be replaced by conventional vehicles, meaning the total number of vehicles remained the same.
- We adjusted the national vehicle fleet forecast in *AEO2014* to reflect the changes made to the regional vehicle type sales mix.
- We calculated the percentage of each type of vehicle in the overall regional vehicle mix – conventional vehicles, HEVs, etc.
- We applied the regional vehicle mix percentages to the national total fleet figure to obtain number of vehicles by type by region.
- We split the regional vehicle data out to individual states using data from National Automobile Dealers Association, *NADA DATA 2013*, accessed at www.nada.org/nadadata, 6 April 2014. Data on total light-duty vehicles in operation in 2012 were used to determine each state's share of its region's vehicle fleet. This share was applied to the regional vehicle count information to determine the number of vehicles by type projected to be on the road in each state in 2025.

10-State ZEV Program Scenario

The baseline was compared to a scenario in which the 10 states that have adopted the ZEV program follow through and implement it completely. The states are California, Connecticut, Massachusetts, Maryland, New York, Oregon, Rhode Island and Vermont, all of

which have signed a memorandum of understanding signaling their intent to cooperate across state lines to implement the ZEV program, plus Maine and New Jersey, which have formally adopted the ZEV program but did not sign the memorandum of understanding.

The estimate of how automakers might comply with the ZEV program in 2025 is based on California Air Resources Board (CARB), *Staff Report: Initial Statement of Reasons, Advanced Clean Cars, 2012 Proposed Amendments to the California Zero Emission Vehicle Program Regulations*, 7 December 2011, Table 3.6. CARB presents one scenario of how vehicle manufacturers might use credit provisions in the ZEV regulations and sell a mix of fuel cell vehicles, battery electric vehicles and plug-in hybrid electric vehicles from 2018 to 2025 in California.

We assumed that manufacturers would sell the same mix of vehicles in other ZEV states. Using data on new light-duty vehicle registrations by state in 2012 from National Automobile Dealers Association, *NADA DATA 2013*, accessed at www.nada.org/nadadata, 6 April 2014, we applied CARB's estimated cumulative 2025 fuel cell, battery electric and plug-in hybrid electric vehicle mix to other states. Within the battery electric and plug-in hybrid electric vehicle classes, we maintained the two-to-one ratio of plug-in hybrid electric vehicles with a 40-mile range and with a 10-mile range from the baseline scenario in *AEO2014*. We assumed that all battery electric vehicles will have a 100-mile range.

In the 10 ZEV states, we compared emissions from battery electric, plug-in hybrid electric and fuel cell vehicles to emissions from conventional internal combustion engine vehicles, as described in the baseline scenario.

50-State ZEV Program Scenario

We compared the baseline to a scenario in which all states adopt and implement the ZEV program. The vehicle fleet mix was adjusted for each state as described in the "10-State ZEV Program Scenario."

For the past three years, Oklahoma's figures for new vehicle registrations are very high as a percentage of all vehicles in the state, compared to the percentage rates in other states, as reported in National Automobile Dealers Association, *NADA DATA 2013*, accessed at www.nada.org/nadadata, 6 April 2014. This high vehicle turnover rate in Oklahoma has the result that the state is projected to have a remarkably high number of electric vehicles in 2025, given the size of the state.

Energy Consumption by Vehicle Type

We obtained estimated energy consumption by vehicle type in 2025 from *AEO2014*. Supplemental Table 47 provides energy consumption by vehicle type for all light-duty vehicles in 2025. We divided that by the number of light-duty vehicles (both passenger cars and light-duty trucks combined) from Supplemental Table 58 to provide data on energy consumption per vehicle by vehicle type. (This calculation incorporates, without adjustment, assumptions in *AEO2014* regarding vehicle miles of travel.)

We assumed that gasoline-powered vehicles consume gasoline and ethanol, per U.S. Energy Information Administration, *Assumptions to the Annual Energy Outlook 2013*, 14 May 2013. The *Assumptions* document says that the fuel blend is 10 percent or 15 percent ethanol, but does not provide further guidance. We assumed a 10 percent blend. We assumed that ethanol flex-fuel internal combustion engine vehicles are operated on the same fuel blend as gasoline-powered vehicles, and do not use a higher proportion of ethanol. (See Andrew Childers, "Carmakers' Greenhouse Gas Reductions Greater than Required for 2012, EPA Says," *Bloomberg.com*, 2 May 2014.)

We assumed that battery electric vehicles and plug-in hybrid electric vehicles consume electricity from the grid and that fuel-cell vehicles are hydrogen based, per California Air Resources Board, *Staff Report: Initial*

Statement of Reasons, Advanced Clean Cars, 2012 Proposed Amendments to the California Zero Emission Vehicle Program Regulations, 7 December 2011. Battery chargers operate at 85 percent efficiency, per A. Elgowainy, et al., Argonne National Laboratory, *Well-to-Wheels Analysis of Energy Use and Greenhouse Gas Emissions of Plug-in Hybrid Electric Vehicles*, June 2010. Transmission and distribution losses in supplying electricity to vehicles were assumed to be 6.5 percent, per University of Chicago/Argonne National Lab, *The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model*, v. 2, 2012.

Plug-in hybrid electric vehicles with a 10-mile all-electric range are assumed to consume 76 percent of their Btu as gasoline and 24 percent as electricity, while plug-in hybrid electric vehicles with a 40-mile all-electric range are assumed to use 57 percent gasoline and 43 percent electricity, per University of Chicago/Argonne National Lab, *The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model*, v. 2, 2012.

Carbon Intensity of Fuels

We calculated all global warming emissions from consumption of transportation fuels on a life cycle basis to include both well-to-tank and tank-to-wheels emissions.

Baseline Liquid Fuels Scenario

Tank-to-wheels carbon dioxide emissions from gasoline come from U.S. Energy Information Administration, *Greenhouse Gas Report*, accessed from www.eia.gov/oiaf/1605/ggrpt/excel/co2_coefs_09_v2.xls, 6 April 2014. Adding well-to-tank emissions incorporates other global warming pollutants and increases emissions from gasoline by 26 percent from the 2005 U.S. tank-to-wheels average, per U.S. Department of State, *Keystone XL Draft Supplemental Environmental Impact Statement, Appendix W: Life-Cycle Greenhouse Gas Emissions*, March 2013.

Carbon dioxide-equivalent life cycle emission rates for diesel, CNG and hydrogen come from California Air Resources Board, *Table 6. Carbon Intensity Lookup Table for Gasoline and Fuels that Substitute for Gasoline* and *Table 7. Carbon Intensity Lookup Table for Diesel and Fuels that Substitute for Diesel*, accessed at www.arb.ca.gov/fuels/lcfs/lu_tables_11282012.pdf, 6 April 2014.

High-Carbon Liquid Fuels

Increased use of unconventional fuels such as tar sands-based oil could increase the emissions intensity of gasoline above baseline levels. In its analysis of the potential impact of approving the Keystone XL pipeline, the U.S. Department of State calculates the increased life cycle global warming pollution that would result from tar sands-derived gasoline. Incorporating the well-to-tank emissions of producing gasoline from tar sands increases carbon dioxide-equivalent emissions by 46 percent above the 2005 U.S. tank-to-wheels average, per U.S. Department of State, *Keystone XL Draft Supplemental Environmental Impact Statement, Appendix W: Life-Cycle Greenhouse Gas Emissions*, March 2013. We applied this factor to the tank-to-wheels carbon dioxide emissions from gasoline, per U.S. Energy Information Administration, *Greenhouse Gas Report*, accessed from www.eia.gov/oiaf/1605/ggrpt/excel/co2_coeffs_09_v2.xls, 6 April 2014.

Baseline Electricity Scenario

To estimate global warming emissions from electric vehicles, we assumed that any electricity used in electric vehicles would increase emissions at the average emission rate of power plants in the region in which the state resides. To obtain region-specific emission factors for electricity generation, we relied on *AEO 2014 Early Release*, Tables 73-94, for data on forecast 2025 electricity generation for each EIA electricity market module (EMM) region.

We calculated emissions for each region using emissions factors for various fuels from U.S. Energy Information Administration, *Greenhouse Gas Report*, accessed from www.eia.gov/oiaf/1605/ggrpt/excel/co2_coeffs_09_v2.xls, 6 April 2014, adjusted for feedstock emissions from University of Chicago/Argonne National Lab, *The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model*, v. 2, 2012.

We assigned each EMM region to one of the interconnection regions identified by the North American Electric Reliability Corporation (NERC), using maps of EMM regions and NERC regions.⁹⁵ We estimated an emissions factor for each NERC region, using the generation and emissions data for the constituent EMM regions.

To arrive at an emissions factor for each state, we determined the percentage of electricity sales in each state that come from within each NERC region, using data from U.S. Department of Energy, Energy Information Administration, *Electric Power Sales, Revenue, and Energy Efficiency Form EIA-861*, 29 October 2013. NERC regions could not be identified for utilities responsible for a total of 1.5 percent of electricity sales nationally. The majority of those sales were in Texas. State emission factors were created by multiplying each state's percent of sales per NERC region by each region's emission factor.

For Alaska and Hawaii, which are not included in the NERC regions, we calculated an emissions factor using 2011 data on total electricity generation and total carbon dioxide emissions from electricity generation in each state. Generation data came from U.S. Department of Energy, Energy Information Administration, *Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923)*, December 2013. Emissions data came from U.S. Department of Energy, Energy Information Administration, *U. S. Electric Power Industry Estimated Emissions by State, Back to 1990 (EIA-767 and EIA-906)*, February 2013.

The use of a constant emission factor for each state masks hourly variations in the carbon intensity of electricity on the grid, meaning that the estimates in this report do not fully reflect the hourly dispatch of different electricity generators in each region of the country.

Electricity with Increased Renewables

The scenario with increased renewables reaches 25 percent renewable generation nationally in 2025. To achieve this, all regions would need to increase renewable electricity generation well above the *AEO 2014 Early Release* baseline renewable generation estimate. In regions with the lowest baseline levels of renewable energy, renewable sources increased up to 125 percent. In other regions with higher baseline levels, renewables increased by a smaller amount, keeping total renewable generation below 50 percent, with one exception. For the Northwest Power

Pool, where the *AEO 2014 Early Release* baseline shows renewable electricity generation will be 57 percent, the growth in the renewable energy share of total generation was set at 10 percentage points. We did not increase renewables for Alaska or Hawaii.

Added renewable energy was assumed to displace electricity from other sources. Half of the additional electricity from renewable sources was assumed to reduce electricity generated from coal and the other half from natural gas. In some regions, the amount of coal or natural gas generating capacity was less than half the amount of renewable electricity added. In those instances, the smaller fossil fuel resource was zeroed out and the larger fossil fuel resource was reduced by more than half of the amount of renewable electricity added. No adjustment was made to nuclear generation.

State emissions were determined from NERC regions as described above in “Baseline Electricity Scenario.”

Appendix: Avoided Emissions by State

Emissions avoided from higher penetration of battery electric vehicles, plug-in hybrid electric vehicles, and fuel cell vehicles, compared to conventional vehicles in 2025.

| State | With 15% Renewable Electricity | | | With 25% Renewable Electricity | | |
|---------------|---------------------------------------|---|---|---------------------------------------|---|---|
| | Metric Tons CO ₂ e Avoided | Equal to Emissions from This Many of Today's Cars | Equal to Emissions from This Many Gallons of Gasoline | Metric Tons CO ₂ e Avoided | Equal to Emissions from This Many of Today's Cars | Equal to Emissions from This Many Gallons of Gasoline |
| Alaska | 25,000 | 5,000 | 2,813,000 | 25,000 | 5,000 | 2,813,000 |
| Alabama | 174,000 | 37,000 | 19,579,000 | 212,000 | 45,000 | 23,855,000 |
| Arkansas | 91,000 | 19,000 | 10,240,000 | 125,000 | 26,000 | 14,065,000 |
| Arizona | 379,000 | 80,000 | 42,647,000 | 473,000 | 100,000 | 53,224,000 |
| California | 2,030,000 | 427,000 | 228,424,000 | 2,524,000 | 531,000 | 284,010,000 |
| Colorado | 292,000 | 61,000 | 32,857,000 | 365,000 | 77,000 | 41,071,000 |
| Connecticut | 268,000 | 56,000 | 30,156,000 | 314,000 | 66,000 | 35,333,000 |
| DC | 13,000 | 3,000 | 1,463,000 | 16,000 | 3,000 | 1,800,000 |
| Delaware | 33,000 | 7,000 | 3,713,000 | 40,000 | 8,000 | 4,501,000 |
| Florida | 1,007,000 | 212,000 | 113,312,000 | 1,104,000 | 232,000 | 124,226,000 |
| Georgia | 348,000 | 73,000 | 39,158,000 | 429,000 | 90,000 | 48,273,000 |
| Hawaii | 28,000 | 6,000 | 3,151,000 | 28,000 | 6,000 | 3,151,000 |
| Iowa | 77,000 | 16,000 | 8,664,000 | 147,000 | 31,000 | 16,541,000 |
| Idaho | 50,000 | 11,000 | 5,626,000 | 63,000 | 13,000 | 7,089,000 |
| Illinois | 464,000 | 98,000 | 52,211,000 | 571,000 | 120,000 | 64,251,000 |
| Indiana | 149,000 | 31,000 | 16,766,000 | 188,000 | 40,000 | 21,154,000 |
| Kansas | 61,000 | 13,000 | 6,864,000 | 107,000 | 23,000 | 12,040,000 |
| Kentucky | 120,000 | 25,000 | 13,503,000 | 147,000 | 31,000 | 16,541,000 |
| Louisiana | 161,000 | 34,000 | 18,116,000 | 216,000 | 45,000 | 24,305,000 |
| Massachusetts | 535,000 | 113,000 | 60,200,000 | 624,000 | 131,000 | 70,215,000 |
| Maryland | 227,000 | 48,000 | 25,543,000 | 281,000 | 59,000 | 31,619,000 |
| Maine | 86,000 | 18,000 | 9,677,000 | 101,000 | 21,000 | 11,365,000 |

Continued on page 32

Continued from page 31

| State | With 15% Renewable Electricity | | | With 25% Renewable Electricity | | |
|----------------|---------------------------------------|---|---|---------------------------------------|---|---|
| | Metric Tons CO ₂ e Avoided | Equal to Emissions from This Many of Today's Cars | Equal to Emissions from This Many Gallons of Gasoline | Metric Tons CO ₂ e Avoided | Equal to Emissions from This Many of Today's Cars | Equal to Emissions from This Many Gallons of Gasoline |
| Michigan | 345,000 | 73,000 | 38,821,000 | 434,000 | 91,000 | 48,835,000 |
| Minnesota | 144,000 | 30,000 | 16,203,000 | 273,000 | 57,000 | 30,719,000 |
| Missouri | 214,000 | 45,000 | 24,080,000 | 287,000 | 60,000 | 32,294,000 |
| Mississippi | 94,000 | 20,000 | 10,577,000 | 115,000 | 24,000 | 12,940,000 |
| Montana | 66,000 | 14,000 | 7,427,000 | 84,000 | 18,000 | 9,452,000 |
| North Carolina | 325,000 | 68,000 | 36,570,000 | 401,000 | 84,000 | 45,122,000 |
| North Dakota | 24,000 | 5,000 | 2,701,000 | 46,000 | 10,000 | 5,176,000 |
| Nebraska | 50,000 | 11,000 | 5,626,000 | 94,000 | 20,000 | 10,577,000 |
| New Hampshire | 139,000 | 29,000 | 15,641,000 | 162,000 | 34,000 | 18,229,000 |
| New Jersey | 401,000 | 84,000 | 45,122,000 | 493,000 | 104,000 | 55,474,000 |
| New Mexico | 83,000 | 17,000 | 9,339,000 | 113,000 | 24,000 | 12,715,000 |
| Nevada | 145,000 | 31,000 | 16,316,000 | 181,000 | 38,000 | 20,367,000 |
| New York | 1,506,000 | 317,000 | 169,461,000 | 1,758,000 | 370,000 | 197,817,000 |
| Ohio | 369,000 | 78,000 | 41,521,000 | 462,000 | 97,000 | 51,986,000 |
| Oklahoma | 428,000 | 90,000 | 48,160,000 | 751,000 | 158,000 | 84,505,000 |
| Oregon | 170,000 | 36,000 | 19,129,000 | 213,000 | 45,000 | 23,968,000 |
| Pennsylvania | 446,000 | 94,000 | 50,186,000 | 552,000 | 116,000 | 62,113,000 |
| Rhode Island | 75,000 | 16,000 | 8,439,000 | 88,000 | 19,000 | 9,902,000 |
| South Carolina | 149,000 | 31,000 | 16,766,000 | 185,000 | 39,000 | 20,817,000 |
| South Dakota | 26,000 | 5,000 | 2,926,000 | 46,000 | 10,000 | 5,176,000 |
| Tennessee | 245,000 | 52,000 | 27,568,000 | 299,000 | 63,000 | 33,645,000 |
| Texas | 1,372,000 | 289,000 | 154,383,000 | 1,686,000 | 355,000 | 189,715,000 |
| Utah | 134,000 | 28,000 | 15,078,000 | 168,000 | 35,000 | 18,904,000 |
| Virginia | 320,000 | 67,000 | 36,008,000 | 396,000 | 83,000 | 44,559,000 |
| Vermont | 61,000 | 13,000 | 6,864,000 | 72,000 | 15,000 | 8,102,000 |
| Washington | 288,000 | 61,000 | 32,407,000 | 362,000 | 76,000 | 40,734,000 |
| Wisconsin | 125,000 | 26,000 | 14,065,000 | 211,000 | 44,000 | 23,743,000 |
| West Virginia | 61,000 | 13,000 | 6,864,000 | 76,000 | 16,000 | 8,552,000 |
| Wyoming | 32,000 | 7,000 | 3,601,000 | 41,000 | 9,000 | 4,613,000 |
| TOTAL | 14,455,000 | 3,043,000 | 1,626,533,000 | 18,149,000 | 3,817,000 | 2,042,196,000 |

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