State *of* CHARGE

Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings across the United States

Union of Concerned Scientists

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Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

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The **Union of Concerned Scientists** (UCS) is the leading science-based nonprofit working for a healthy environment and a safer world. UCS combines independent scientific research and citizen action to develop innovative, practical solutions and to secure responsible changes in government policy, corporate practices, and consumer choices.

The UCS Clean Vehicles Program develops and promotes strategies to reduce the adverse environmental impacts of the U.S. transportation system.

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Introduction

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Over the past 100 years, we have become increasingly dependent on our cars for meeting life's most basic needs. For most Americans, getting to and from work, bringing food home from the grocery store, or going to the doctor means using one's car. This reliance on the automobile, and on the petroleum-powered internal combustion engine in particular, comes with significant costs. Our dependence on oil makes our overall economy and household budgets highly vulnerable to volatile oil prices. The pollutant emissions from our vehicles contribute to unhealthy air and global climate change. As the search for oil moves to more remote and difficult-to-access locations, the risk of serious accidents increases, as demonstrated by the 2010 Deepwater Horizon oil spill in the Gulf of Mexico. And defending our access to oil is a great burden to our nation's finances, our military men and women, and their families.

Vehicles powered by electricity have the potential to reduce many of these problems. In most places, electric drive lowers the smog-forming and global warming pollution associated with vehicle use, and when powered by *renewable* resources, electric vehicles can nearly eliminate such pollution from vehicular operation. Electric vehicles powered by a clean electricity grid offer a key pathway to achieving the greater than 80 percent reduction in global warming pollution we need by mid-century to avoid the worst consequences of climate change. Powered by domestically produced electricity, electric vehicles (EVs) could be a significant part of reducing our oil dependence.

Today, we are starting to see EVs enter the market as the result of investments and policies to develop vehicles with zero tailpipe emissions. In 2011, U.S. consumers could choose from two mass-produced electric-drive vehicles made by two major auto manufacturers: the fully electric Nissan LEAF, powered solely by batteries, and the plug-in hybrid Chevy Volt, powered both by batteries and an internal combustion engine. In 2012, we expect to see additional options for consumers, including the plug-in versions of the Ford Fusion and Toyota Prius hybrids as well as the Honda Fit and Ford Focus battery-electric vehicles. The number of vehicles capable of being powered wholly or in part by electricity will continue to grow, as automakers plan to introduce more than 30 electric-drive models over the next five years (Baum & Associates 2010).

The wider availability of plug-in EVs is great news, but the growing number of options means that consumers need more information to make the best vehicle choices for their families, our national security, and the planet. For years, the bottom-line advice of the Union of Concerned Scientists (UCS) has been:

When buying a car, purchase the most fuel-efficient, lowest-emissions vehicle that meets the majority of your needs and fits your budget.

But evaluating the emissions and costs of an electric vehicle is not as simple as it is for conventional gasoline vehicles. Consumers need more information, both about the types of vehicles themselves and the electricity that powers them, to make the right choices.

This report aims to make those choices easier. Our analysis should help consumers (a) better understand some of the benefits and costs of owning an electric vehicle and (b) identify what to consider when evaluating EVs for their next car purchase.

The report addresses the following three key questions:

- Is an electric car better than a gasoline vehicle on global warming emissions?
- How much does it cost to charge an electric vehicle in different cities around the country?
- How do EVs such as the Chevy Volt, Mitsubishi "i," and Nissan LEAF compare with each other and with gasoline vehicles on global warming emissions and fueling costs?

To answer these questions, our analysis considers global warming emissions from driving on electricity in different regions across the United States, and compares the cost of driving on electricity with the cost of driving on gasoline in 50 of our largest cities.

Of course, the U.S. electric vehicle fleet will only be as clean and sustainable as the power grid it ultimately plugs into. While our analysis focuses on the global warming emissions of electric vehicles powered by today's electricity grid, power plants also emit other air pollutants and toxics, such as sulfur dioxide, nitrogen oxides, and mercury. As with carbon dioxide, electricity generated from renewable resources will produce substantial reductions in these pollutants. On the other hand, meeting EV electricity demand by increasing fossil fuel electricity generation could lead to local increases in emissions. Existing regulations and standards that place limits on power plant emissions will minimize that potential, but more will have to be done to eliminate it.

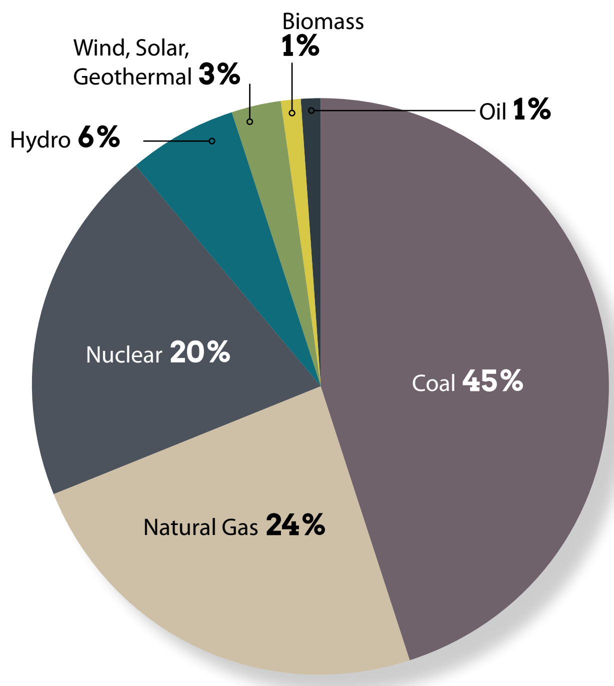
For example, a 2007 study by the Electric Power Research Institute and the Natural Resources Defense Council examined the potential impact of millions of plug-in electric vehicles on air quality through 2030. The study concluded that, even under a scenario of heavy reliance on coal-fired power plants to meet future electricity needs, most regions of the United States would see improvements in air quality, while some might experience increases in air pollutant emissions (EPRI and NRDC 2007b). However, we are already moving away from such a scenario, as projections for new coal-fired power plants have been declining, and in 29 states and the District of Columbia, utilities must increasingly rely on renewable resources for generating electricity (UCS 2011).

A future with greater use of high-emissions coal-powered electricity would not be consistent with our climate change goals. As this report's analysis shows, the benefits of electric vehicles are inherently tied to our electricity grid, and a continued shift from coal-fired power plants to natural gas and cleaner renewables must occur at the same time as our vehicles transition from burning oil to running on electricity. This shift will not only decrease the global warming emissions from electric vehicles but also reduce many of the other pollutants associated with coal-fired electricity.

CHAPTER ONE

Global Warming Emissions of Driving on Electricity

Figure 1.1. 2010 U.S. ELECTRICITY GRID MIX



Note: Estimates are based on calendar year 2010 data available from the U.S. Energy Information Administration (EIA 2011a).

Is driving on electricity instead of gasoline a good choice when it comes to reducing emissions responsible for climate change? The answer is yes. But because different regions of the United States receive their electricity from different mixes of power plant types, *how* good depends on where the vehicle is charged. For example, using wind- or solar-generated electricity to power an electric vehicle can result in almost no global warming emissions. By contrast, the use of coal-generated electricity releases significant amounts of global warming emissions, similar to those from an average gasoline vehicle.

The good news is that no matter where you live in the United States, electric vehicles charged on the power grid have lower global warming emissions than the average gasoline-based vehicle sold today. In some areas—where coal makes up a large percentage of the power plant mix—the most efficient gasoline-powered vehicles will actually deliver greater global warming benefits than EVs. In other areas of the country, however, where cleaner sources of electricity prevail, EVs are far and away the best choice.

Global Warming Emissions of Electricity Generation

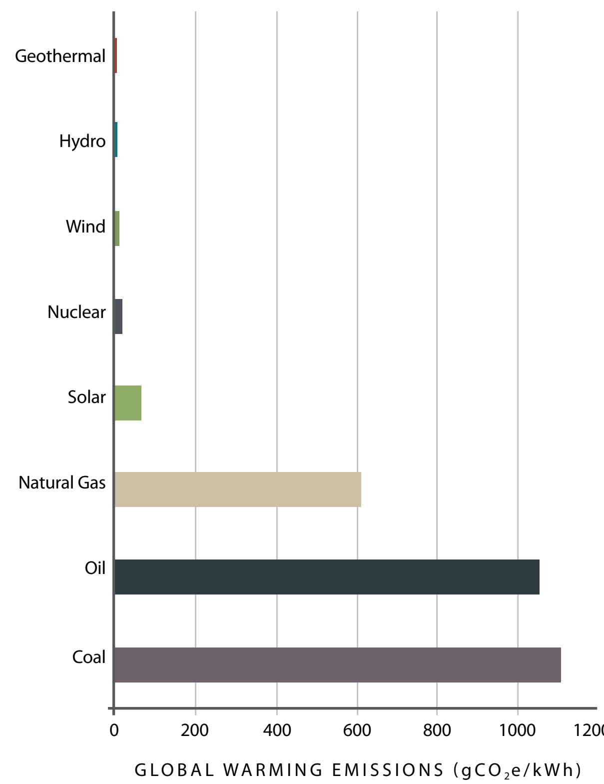
The burning of coal produces the largest fraction of our electricity, accounting for a little less than half of all generation (Figure 1.1). Other major resources are natural gas and nuclear power, followed by hydro and other renewable resources (including wind, solar, geothermal, and biomass). Oil is a very small contributor to U.S. electricity generation, accounting for less than 1 percent of all generation.[1] The share of coal-powered electricity generation has been declining over the past decade, while the shares of natural gas and renewables have grown (UCS 2011).

1 The state of Hawaii is the only region that relies on oil-powered electricity for the majority of its electricity generation. In the coming years, a move away from oil-powered electricity is anticipated as a result of Hawaii's renewable electricity standard, which requires that 40 percent of electricity sales be generated from renewables by 2030.

Figure 1.2 shows the average global warming pollution intensity—the amount of global warming pollution for each kilowatt-hour (kWh) of electricity delivered to consumers—for different sources of electricity.[2] The emissions include those associated with building the power plant, extracting the fuel and transporting it to the plant, converting the fuel into electricity, and delivering the electricity to the point of use. For example, for electricity produced from coal the total emissions include those associated with mining the coal, delivering it to the power plant, and then burning it there. The small percentage of electricity consumed in the transmission from the coal-fired power plant to the point of use, about 6 to 7 percent, is also taken into account.

Coal-fired electricity is the dirtiest source of electricity in the United States, and given coal's large share of the overall grid mix, it dominates the total global warming emissions from electricity generation. Oil is also very dirty, but because it accounts for less than 1 percent of total U.S. generation, oil's impact on overall emissions from that sector is limited. Electricity generated from natural gas has, on average, about half of the global warming pollution intensity of coal-powered electricity, while nuclear and renewables have the lowest global warming pollution intensity. Solar has relatively high manufacturing emissions compared with its electricity output, which results in its having global warming emissions greater than those of other renewables, such as wind. But even with the manufacturing effects taken into account, solar-based electricity still has emissions one-tenth those of natural-gas-generated electricity.

Figure 1.2. GLOBAL WARMING POLLUTION INTENSITY OF ELECTRICITY GENERATION, BY FUEL TYPE



Notes: Estimates are based on electricity delivered to consumers and include the full life-cycle emissions, including those accruing from plant construction and maintenance, fuel production (e.g., coal mining), transportation, fuel combustion, and electricity transmission. Variations in global warming emissions intensity occur within fuel types. These values represent the average emissions intensity across all plants of a given fuel type.

Sources: The GREET1_2011 model of the Argonne National Laboratory (ANL) was used for upstream emissions estimates (ANL 2011); 2009 plant data were used to estimate emissions from generation by fuel source, with an assumed average grid loss factor of 6.5 percent (EPA 2012a); plant construction data were from ANL life-cycle analyses (ANL 2010).

An Apples-to-Apples Comparison of EV and Gasoline Vehicle Global Warming Emissions

To most accurately compare electric and gasoline vehicles, the emissions from producing the fuel as well as from consuming it must be taken into account. For gasoline vehicles, this means including emissions not only from propelling the car—i.e.,

2 These figures represent the average emissions intensity across all electricity generated by a specified feedstock, based on actual plant emissions in 2009. The key word here is "average." Within the category of coal-fired electricity, for example, taking into account the age of the power plant and the technology used to convert coal into electricity results in varying levels of emissions intensity.

by combusting the fuel in the engine—but also the emissions associated with extracting petroleum, refining it, and delivering it to the vehicle. For EVs, no tailpipe emissions occur from consuming electricity to propel the vehicle. However, as described above, there are emissions from producing the electricity. Thus in comparing EVs with gasoline vehicles we include the "wells-to-wheels" emissions, which account for the full fuel cycle.

Standardizing the Units of Comparison: MPG_{ghg}

Most drivers are familiar with the concept of miles per gallon (mpg), the number of miles a car can travel on a gallon of gasoline. The greater the mpg, the less fuel burned and the lower your global warming emissions. But how can such consumption be figured for electric vehicles, which don't use gasoline? One way is by determining how many miles per gallon a gasoline-powered vehicle would need to achieve in order to match the global warming emissions of an EV.

The first step in this process is to evaluate the global warming emissions that would result at the power plant from charging a vehicle with a specific amount of electricity. Then we convert this estimate into a gasoline mile-per-gallon equivalent—designated mpg_{ghg}, where ghg stands for greenhouse gases. If an electric vehicle has an mpg_{ghg} value equal to the mpg of a gasoline-powered vehicle, both vehicles will emit the same amounts of global warming pollutants for every mile they travel.

For example, if you were to charge a typical midsize electric vehicle using electricity generated by coal-fired power plants, that vehicle would have an mpg_{ghg} of 30. In other words, the global warming emissions from driving that electric vehicle would be equivalent to the emissions from operating a gasoline vehicle with 30 mpg fuel economy over the same distance (Table 1.1).[3] Under this equivalency, the cleaner an electricity generation source, the higher the mpg_{ghg}. When charging an EV from resources such as wind or solar, the mpg equivalent is in the hundreds (or thousands) because these resources produce very little global warming emissions when generating electricity.

The average EPA window-sticker fuel economy rating of all compact vehicles sold in 2010 (the most recent year for which data are available) was 27 mpg, while midsize vehicles averaged about 26 mpg (EPA 2010b). This means that even when charging an EV with electricity made only from coal (the dirtiest electricity source), the EV has better emissions than the average new compact gasoline vehicle. Most EVs on the market today, and those expected in the near term, are midsize or smaller, making these four- or five-passenger vehicles a reasonable basis of comparison.[4]

Table 1.1. WELL-TO-WHEELS EV MILES PER GALLON EQUIVALENT (MPG_{ghg}) BY ELECTRICITY SOURCE

Coal	30
Oil	32
Natural Gas	54
Solar	500
Nuclear	2,000
Wind	3,900
Hydro	5,800
Geothermal	7,600

Notes: (1) See Figure 1.2 for further assumptions about electricity emissions by fuel type.
(2) EV efficiency is assumed to be 0.34 kWh/mile, reflective of the Nissan LEAF—a five-passenger EV.
(3) Production and consumption of gasoline are assumed to produce 11,200 grams CO_2e/gallon, based on GREET 1_2011 default values.

Electric Vehicle Energy Efficiency Varies

Slightly complicating the picture is the fact that just as gasoline vehicles vary in how many miles they can travel on a gallon of gasoline, electric vehicles vary in how far they can go on a

3 Note that mpg values in this report refer to combined city/highway operation estimates and that EPA window-label values should be used as the basis of comparison between specific vehicle models.
4 A notable exception is the Toyota RAV4 EV, expected in 2012, which falls into the EPA's midsize SUV category.

kilowatt-hour of electricity. For example, the Nissan LEAF is estimated to consume 0.34 kWh of electricity per mile traveled while the Chevy Volt consumes 0.36 kWh when operating on electricity. To compare electric vehicles with gasoline vehicles, an average EV efficiency of 0.34 kWh/mile is assumed, which is representative of the efficiency of small to midsize electric vehicles available today. EVs that use less electricity per mile will have lower emissions and lower operating costs, while those that use more electricity per mile will have greater emissions and costs.

The energy efficiencies of electric vehicles can be compared with those of gasoline vehicles in the same way that global warming emissions are compared. The EPA fuel economy labels for electric vehicles carry a mile-per-gallon energy efficiency rating, designated mpge, which reflects the energy consumption of an EV as it relates to a gasoline vehicle. For example, the electric energy consumed by a Nissan LEAF is equivalent to the gasoline energy that would be consumed by a 99 mpg gasoline vehicle. The efficiencies of some of today's electric-drive vehicles are listed in Table 1.2, along with their ratings in terms of miles per gallon of gasoline equivalent.

Table 1.2. ELECTRIC VEHICLE EFFICIENCY RATINGS

2012 MODELS	MITSUBISHI "i"	FORD FOCUS EV	NISSAN LEAF	CHEVY VOLT
ELECTRIC EFFICIENCY (kWh/MILE)	0.3	0.32	0.34	0.36
ENERGY EFFICIENCY RATING (MILES PER GALLON OF GASOLINE EQUIVALENT)	112	105	99	94

Source: *www.fueleconomy.gov*.

Marginal versus Average Emissions

Finally, when estimating emissions from charging an electric vehicle, we use the annual average emissions intensity of electricity. An alternative approach is to look only at the emissions from the power plants that operate to meet new electricity demand on the grid, known as the marginal emissions rate. While the use of the marginal generation mix for electric vehicles is needed for evaluating the implications of a large-scale EV market, average generation mix is adequate for providing information to consumers regarding vehicle purchase and use. Further discussion of this issue is provided in Appendix A.

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Variations in EV Charging Emissions

Because the mix of power plants providing electricity to the grid varies widely across the country, the global warming emissions and hence the global warming benefits of EVs depend on where they are being charged. In some regions, the global warming emissions of the most efficient gasoline vehicle will be as good as or lower than that of an electric vehicle charged on the local electricity grid; in other regions, the electric vehicle will be far superior to any gasoline-powered car on the market.

Regional Variations in EV Charging Emissions

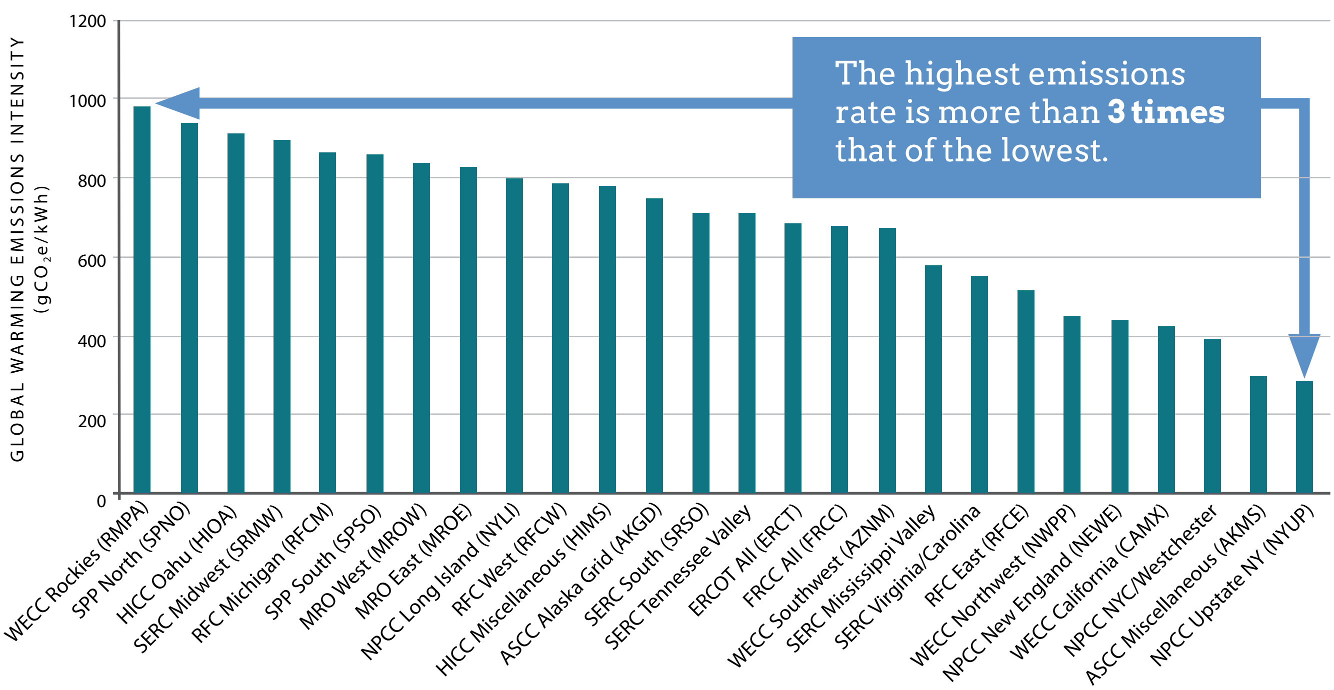
Across the country, grid emissions intensities vary substantially, with the dirtiest grid region having more than three times the emissions intensity of the region with the lowest emissions intensity (Figure 1.3). Grid regions covering California, parts of New York (excluding Long Island), the Northwest, and parts of Alaska have the lowest emissions intensities in the United States, while the coal-dominated grids of the Rockies, Upper Plains, and parts of the Midwest have the highest emissions intensities. The variations in grid mixes and emissions rates across the country mean that consumers need to better understand how the electricity used to charge an EV is generated if they are to know the actual global warming emissions of operating a vehicle.

A closer look at a few regions' grid mixes shows the reason for the major differences in regional emissions intensities. Figure 1.4 (p. 8) shows the grid mix for the three primary electricity grid regions serving the states of Michigan, California, and Texas.

The RFCM grid serves a large portion of Michigan and is dominated by coal-powered electricity, accounting for 70 percent of the total. As a result, the emissions intensity of electricity is 870 gCO_2e/kWh, among the highest in the United States. An electric vehicle powered by the grid in this region will have global warming emissions equivalent to those of a gasoline-fueled vehicle with a fuel economy rating of 38 mpg.

CAMX, the regional grid serving the majority of California, by contrast, has one of the cleanest mixes in the country, with

Figure 1.3. GLOBAL WARMING EMISSIONS INTENSITY OF ELECTRICITY, BY REGION



Notes: Based on 2009 power plant emissions data (EPA 2012a), estimated upstream emissions for each fuel type in the regional grid mix (ANL 2010), and regional grid loss factors (EPA 2012a). See Figure 1.6 for geographical representation of electricity grid regions.

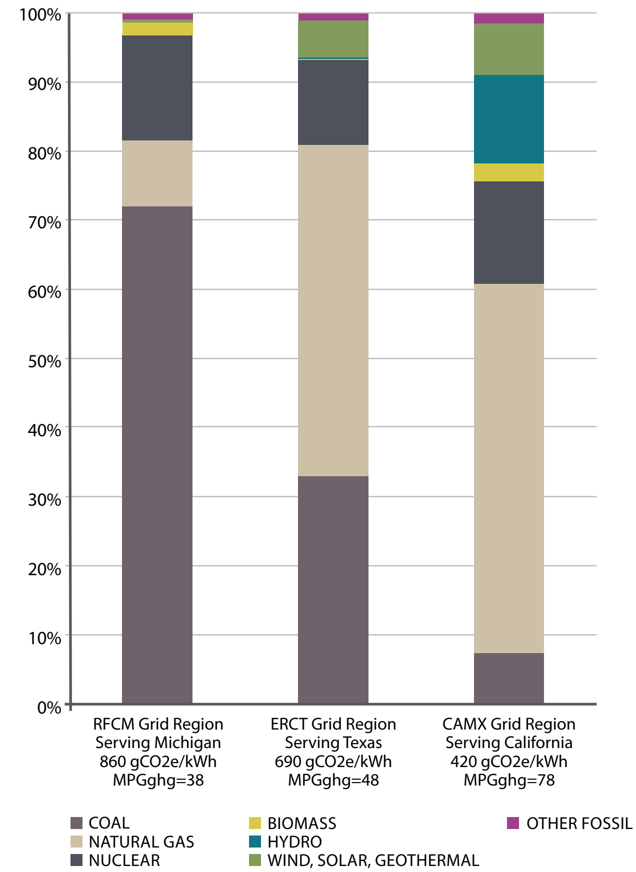
just over half of its electricity coming from natural-gas-fueled power plants and most of the remainder derived from low-carbon resources such as hydro, nuclear, and renewables. In this grid region, an EV's emissions would be equivalent to that of a gasoline vehicle rated at 78 mpg.

The regional electricity grid serving most of Texas, ERCT, has a similar proportion of electricity coming from natural gas, yet the emissions in California are more than 40 percent lower than Texas. The main reason for this difference is that ERCT relies on coal for more than 30 percent of its electricity, compared with CAMX's less than 10 percent. In the Texas region, an EV powered by grid electricity will emit global warming pollutants equivalent to those of a gasoline vehicle with a fuel economy rating of 48 mpg.

Hourly Variations in EV Charging Emissions

Within a region, the grid mix changes throughout the day as additional power plants come online to meet increases in demand and are then brought off-line as demand falls, resulting in variations in the global warming intensity of electricity production. The availability of certain sources of electricity, moreover, varies by season. Hydro, for example, is in greater supply at times of the year when rain or snowmelt is abundant. Intermittent resources such as wind can change by day or by season as

Figure 1.4. GRID-MIX COMPARISON OF THE PRIMARY ELECTRICITY GRIDS SERVING MICHIGAN, TEXAS, AND CALIFORNIA



Note: Based on 2009 power plant data (EPA 2012a).

well. As a result, the global warming emissions intensity of a grid is changeable both over the short and long term.

Average emissions intensity of electricity generation at any given hour of the day, for most regions, shows variations of less than 10 percent from the overall annual average emissions intensity. This is small in comparison with regional variations; the emissions intensities of the cleanest and dirtiest U.S. regions differ by a factor of three. The ranges of hourly variations are

represented as error bars in Figure 1.5, which shows the average daily emissions intensity for 13 regions covering the continental United States.[5]

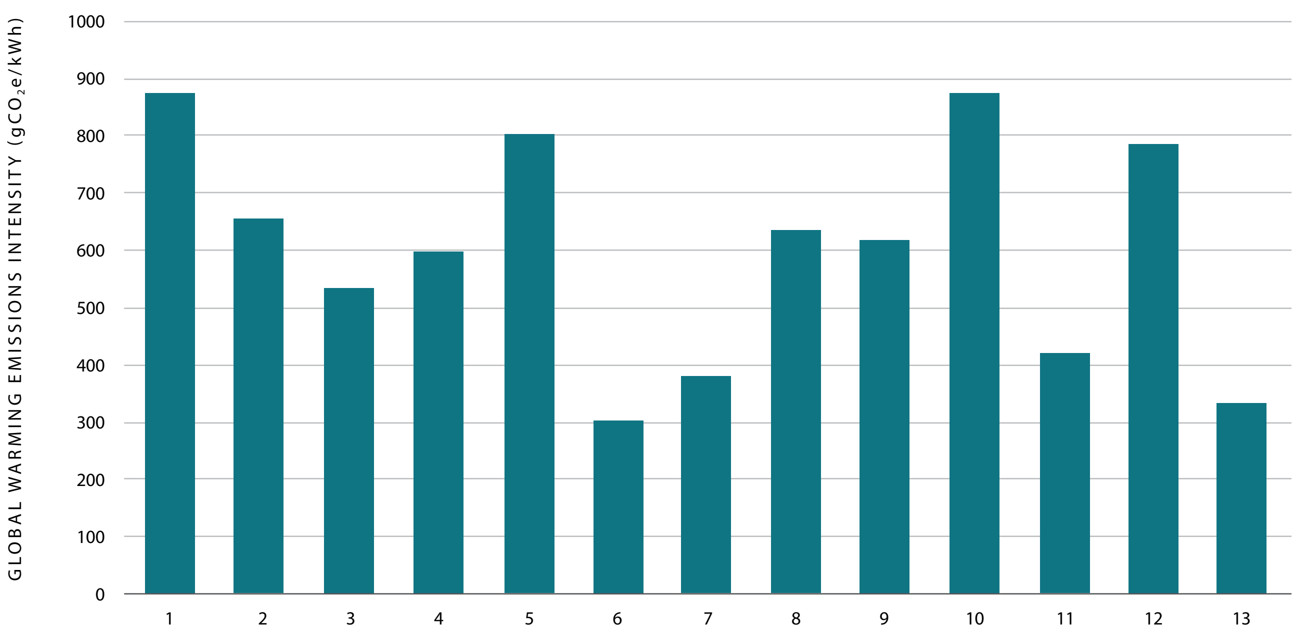
However, if one considers the marginal emissions rate, which is typically dominated by a single fuel type, the emissions at a given time of day vary much more widely. For example, coal-fired plants might be on the margin at one hour of the day and natural gas plants might be on the margin at another time. The marginal emissions intensity of the former case would be about twice as high as the latter.

Because the hourly variations in emissions intensity are not consistent across regions, times of day, or seasons, it is not practical to develop general consumer guidelines on when the lowest emissions intensity will occur throughout the day. For now, we recommend that EV consumers use their regional grid emissions, averaged over the course of the year, as a guide to estimating their personal EV global warming emissions.

There are other reasons, however, for considering what time of day to charge a vehicle—primarily, how much it may cost you. Moreover, avoiding charging during hours when the electricity grid is most strained can help prevent the brownouts that result when demand exceeds supply.

5 The data set used to estimate hourly variations in emissions intensity is different from the data set for regional emissions estimates because the model used to estimate hourly emissions is based on different patterns of regional electricity grid aggregation. See Appendix A for greater detail on the modeling of hourly emissions.

Figure 1.5. VARIATIONS IN EMISSIONS INTENSITY OF ELECTRICITY GENERATION, BY REGION



Notes: Data are based on UCS estimates using a modified version of the ORCED dispatch model developed by the Oak Ridge National Laboratory. Results from the ORCED model are produced for 13 regions covering the continental United States (ORNL 2008a). Other results in this report use eGrid subregions, which provide a greater degree of regional detail, as shown in Table 1.4. See Appendix A for detailed methodology.

Rating the Regions: A Rule of Thumb for the Global Warming Emissions Benefits of EVs

In order to help consumers evaluate the global warming benefits of electric-drive vehicles in comparison with gasoline-powered vehicles, we have developed ratings, described in Table 1.3, based on how EV emissions compare with those of gasoline-powered conventional and hybrid vehicles, and we have applied the ratings to the regional electricity grids across the country. These ratings provide a general rule of thumb for consumers in different regions when evaluating the global warming emissions footprint of an EV powered by grid electricity available today, relative to a gasoline-powered vehicle.

Good

EVs are similar to the best conventional gasoline vehicles and some hybrids (31 to 40 mpg gasoline equivalent). Driving a typical electric vehicle in these regions will result in global warming emissions equivalent to gasoline vehicles with a combined city/highway fuel economy rating between 31 and 40 mpg. This is better than the average compact vehicles on the market today, but the most efficient gasoline hybrid vehicles over 40 mpg will emit lesser amounts of global warming pollutants.

Better

EVs correspond to the most efficient hybrids (41 to 50 mpg gasoline equivalent). Driving a typical electric vehicle in these regions will result in global warming emissions equivalent to gasoline-powered vehicles with a combined city/highway fuel economy rating between 40 and 50 mpg. The most efficient gasoline hybrids, such as the Honda Insight and the Toyota Prius, are in this category.

Table 1.3. GLOBAL WARMING EMISSIONS RATING SCALE FOR ELECTRIC VEHICLES

	Good	Better	Best
MPG OF A GASOLINE VEHICLE WITH EQUIVALENT GLOBAL WARMING EMISSIONS[a]	31–40 mpg	41–50 mpg	51+ mpg
WHAT DO THE RATINGS IMPLY ABOUT EVs' GLOBAL WARMING EMISSIONS?	EVs have emissions comparable to the best gasoline non-hybrid models available	EVs have emissions comparable to the best gasoline hybrid models available	EVs outperform the best gasoline hybrid models available
PERCENT REDUCTION IN GLOBAL WARMING EMISSIONS COMPARED WITH 27 MPG GASOLINE VEHICLE	11–33%	33–46%	>46%
EXAMPLES OF MODEL YEAR 2012 GASOLINE AND HYBRID VEHICLES IN EACH RANGE[b]	Ford Fiesta (34 mpg), Hyundai Elantra (33 mpg), Chevrolet Cruze Eco (31 mpg)	Toyota Prius (50 mpg), Honda Civic Hybrid (44 mpg), Lexus CT200h (42 mpg)	No gasoline comparisons

Notes: (a) Assumes 11,200 grams of global warming pollution per gallon of gasoline and EV efficiency of 0.34 kWh/mile, equivalent to the efficiency of the Nissan LEAF battery-electric vehicle. (b) Model year 2012 combined city/highway fuel economy window-label value. Data from 2012 Fuel Economy Guide, online at *www.fueleconomy.gov*. All vehicles given as examples are classified by the EPA as midsize or smaller and have automatic transmissions so as to ensure a comparison consistent with the selection of electric vehicle efficiency assumptions. Rating scale is not appropriate for pickup trucks or other large vehicles.

Best

EVs are the best choice today, better than the best hybrids (51+ mpg gasoline equivalent). Driving a typical midsize electric vehicle in these regions will result in global warming emissions equivalent to gasoline-powered vehicles with a combined city/highway fuel economy rating over 50 mpg. Electric vehicles are the hands-down winners in these regions for reducing global warming emissions, with benefits above and beyond the lowest-emissions gasoline hybrid vehicles on the market today.

Main Findings

Table 1.4 and its accompanying map (p. 12) show the ratings and mpg_{ghg} estimates for the grid regions of the United States. The key results include:

Nearly half (45 percent) of Americans live in BEST regions—where an EV has lower global warming emissions than a 50 mpg gasoline-powered vehicle, topping even the best gasoline hybrids on the market. Charging an EV in the cleanest electricity regions, which include California, New York (excluding Long Island), the Pacific Northwest, and parts of Alaska, yields global warming emissions equivalent to a gasoline-powered vehicle achieving over 70 mpg.

Some 38 percent of Americans live in BETTER regions — where an electric vehicle has the equivalent global warming emissions of a 41 to 50 mpg gasoline vehicle, similar to the best gasoline hybrids available today.
For example, charging an EV in Florida and across most of Texas yields global warming emissions equivalent to a 48 mpg gasoline vehicle; this is the fuel economy level of vehicles such as the Honda Civic Hybrid (44 mpg) and Toyota Prius Hybrid (50 mpg).

About 17 percent of Americans live in GOOD regions—where an electric vehicle has the equivalent global warming emissions of a 31 to 40 mpg gasoline vehicle, making some gasoline hybrid vehicles a better choice with respect to global warming emissions. The Rocky Mountain grid region (covering Colorado and parts of neighboring states) has the highest emissions intensity of any regional grid in the United States, which means an EV will produce global warming emissions equivalent to a gasoline vehicle achieving about 34 mpg. Gasoline-powered cars with fuel economy at this level include the Hyundai Elantra (33 mpg) and the Ford Fiesta (34 mpg).

Although this fuel economy level is significantly better than that of the average compact or midsize gasoline vehicle today, it does not approach the 41 to 50 mpg of the best hybrid electric vehicles currently available. As gasoline vehicle efficiency improves under new mpg standards, efforts will be needed in these areas to clean up their electricity grids and thus help to maintain EVs' global warming emissions advantage.

There are no areas of the country where electric vehicles have higher global warming emissions than the average new gasoline vehicle. Coal may once have been king throughout much of the United States, but all regions now have at least some cleaner sources of electricity as part of their grid mix, which keeps the global warming emissions of today's EVs lower than that of the average gasoline vehicle.

Figure 1.6. ELECTRIC VEHICLE GLOBAL WARMING EMISSIONS RATINGS BY POPULATION

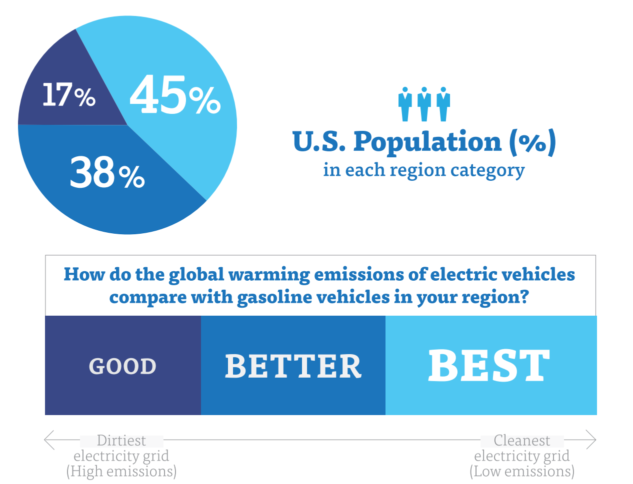
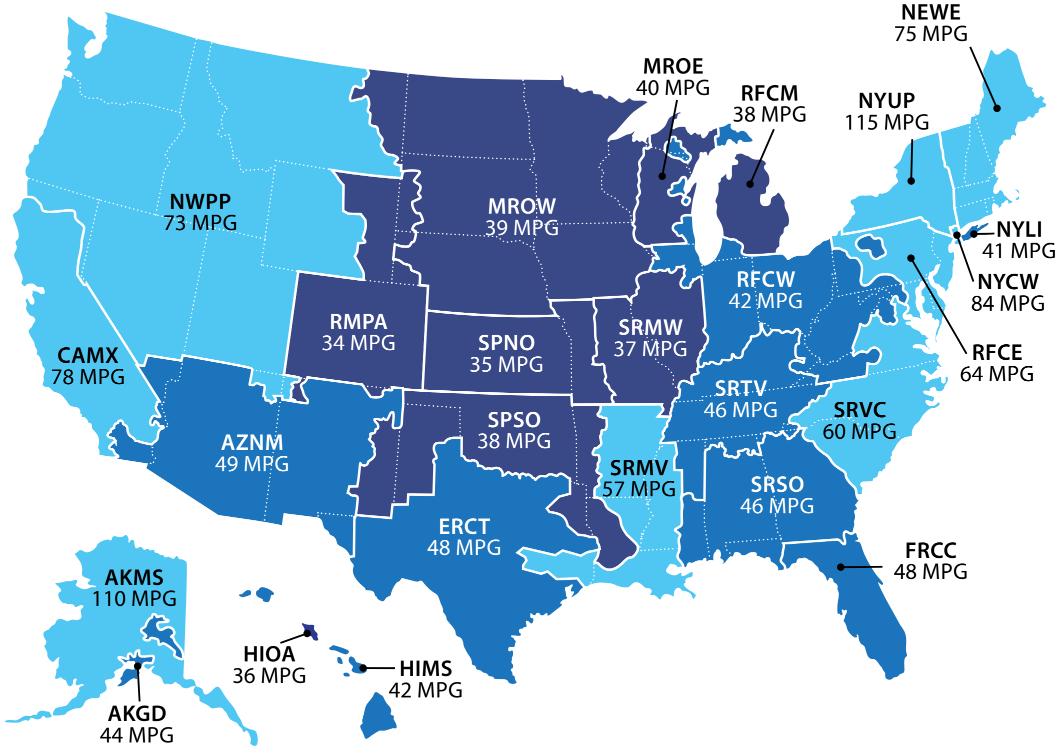


Table 1.4. ELECTRIC VEHICLE GLOBAL WARMING POLLUTION RATINGS AND GASOLINE VEHICLE EMISSIONS EQUIVALENTS BY ELECTRICITY GRID REGION. (The mpg value listed for each region is the combined city/highway fuel economy rating of a gasoline vehicle that would have global warming emissions equivalent to an EV.)



Notes: Cities were assigned to grid regions based on which utilities serve the most customers there, as identified by the EPA's Power Profiler tool. Cities marked with an asterisk (*) are served by multiple utilities, some of which are in different grid regions. This tool, available at *www.epa.gov/cleanenergy/energy-and-you/how-clean.html*, provides a zip code look-up to determine the primary utility and grid region. Regional global warming emissions ratings are based on 2009 power plant data in the EPA's eGRID 2012 database (the most recent available version).

Good	Better	Best
MRO East (MROE) - 40 Madison	**WECC Southwest (AZNM) - 49** Phoenix, El Paso,* Las Vegas, Albuquerque, Tucson	**NPCC Upstate NY (NYUP) - 115** Buffalo
MRO West (MROW) - 39 Omaha, Minneapolis	**FRCC All (FRCC) - 48** Jacksonville,* Miami	**ASCC Miscellaneous (AKMS) - 110** Juneau
SPP South (SPSO) - 38 Oklahoma City, Tulsa	**ERCOT All (ERCT) - 48** Houston, San Antonio, Dallas, Austin, Fort Worth, Arlington	**NPCC NYC/Westchester (NYCW) - 84** New York City
RFC Michigan (RFCM) - 38 Detroit	**SERC Tennessee Valley (SRTV) - 46** Memphis,* Nashville, Louisville*	**WECC California (CAMX) - 78** Los Angeles, San Diego, San Jose, Oakland, San Francisco, Sacramento, Long Beach, Fresno
SERC Midwest (SRMW) - 37 St. Louis	**SERC South (SRSO) - 46** Atlanta	**NPCC New England (NEWE) - 75** Boston
HICC Oahu (HIOA) - 36 Honolulu	**ASCC Alaska Grid (AKGD) - 44** Anchorage	**WECC Northwest (NWPP) - 73** Seattle, Portland
SPP North (SPNO) - 35 Kansas City,* Wichita	**HICC Miscellaneous (HIMS) - 42** Hilo	**RFC East (RFCE) - 64** Philadelphia, Baltimore, Washington, DC*
WECC Rockies (RMPA) - 34 Mesa,* Denver, Colorado Springs	**RFC West (RFCW) - 42** Chicago, Indianapolis, Columbus, Milwaukee, Cleveland	**SERC Virginia/Carolina (SRVC) - 60** Charlotte, Virginia Beach, Raleigh
	NPCC Long Island (NYLI) - 41 Hempstead	**SERC Mississippi Valley (SRMV) - 57** New Orleans

The Role of Utilities in Providing Clean Electricity

Our analysis of the global warming emissions from charging your EV is based on a regional-level look at the electricity grid. This is partly because emissions data at the individual utility level are not readily available across the country.

Regional-level data, which represent the emissions intensity of the electricity delivered to a region as a whole, are reflective of the mix of generation in that area. Particular utilities within these regions may have lower or higher emissions than the regional average, however, based on the types of power purchases they make. Utilities procure electricity from power plants that they own, through direct contracts with owners of other power plants, and through short-term purchases from the regional power grid.

Utilities can help consumers determine how clean their electricity is by disclosing its emissions intensity, or gCO_2eq/kWh. Efforts have been made in this regard, and some utilities also report to their customers the specific mix of energy sources that generate their electricity.[6] However, such disclosures are not consistent across all utilities, and they often do not contain an estimate of the actual emissions intensity of the delivered electricity. Utilities can also make it easier for their customers to support renewable electricity by offering voluntary programs, such as green pricing.

Of course, the best things that utilities could do for consumers would be to make investments in renewable electricity generation, retire the oldest and most polluting power plants, and support regional and federal policies to reduce the global warming emissions from our electricity grid. That way, every region would be a BEST region, and there would be no ambiguity about the carbon footprint of an EV.

Table A.1 in Appendix A provides the grid mix for each region. If a utility does provide a breakdown of its sources of electricity, consumers can compare that utility's mix with the regional mix. As a general rule of thumb, the amount of coal in a utility grid mix relative to the regional grid mix indicates whether the utility is providing electricity that has higher or lower global warming emissions intensity than the regional average.

6 For example, California requires utilities to provide a Power Content Label specifying the mix of generating sources supplying their customers, but no emissions intensity values need be reported. See *www.energy.ca.gov/sb1305/power_content_label.html.*

Advice for Consumers

Based on our analysis of the regional variation of electricity grid emissions, we suggest the following ways for consumers to not only determine the emissions from their own EVs but also help support a general reduction in global warming pollution from the nation's vehicles:

- **Use our regional ratings to estimate global warming emissions.** To estimate the global warming emissions of an EV in your region, use the regional ratings in this analysis as a rule of thumb. For plug-in hybrid electric vehicles, which are powered both by electricity and gasoline, these ratings apply to the portion of miles driven on electricity. Given that we assume an EV with an efficiency of 0.34 kWh/mile, an EV that uses less electricity per mile will have even lower emissions than our ratings imply. And remember that the emissions caused by a vehicle you buy today will likely decrease over its lifetime as the electricity grid becomes cleaner. A look at the grid region map (within Table 1.4) can give you an idea of what region you are in, but use the zip code look-up in the EPA's Power Profiler tool *(www.epa.gov/cleanenergy/energy-and-you/how-clean.html)* just to be sure.

- **Consider your options for buying cleaner electricity, especially in GOOD regions.** Consumer demand for renewable electricity sends a strong signal to business people and policy makers and thus can help to stimulate more investments in renewable energy projects. Increasing GOOD regions' fraction of renewable energy sources and decreasing their reliance on coal-powered electricity help move them into the BETTER and BEST categories (see box, "Options for Buying Cleaner Electricity").

- **Support clean vehicles and clean energy polices.** Support state, regional, and federal policies, such as renewable electricity standards and tax incentives, that increase the level of renewable electricity generation. These policies ensure that your contribution to tackling climate change by investing in an electric vehicle will only grow more significant over time.

Moving Ahead: Fulfilling the Promise of Electric Vehicles Requires a Cleaner and More Sustainable Power Supply

Electric-drive vehicles promise to help take us toward a zero-emissions and oil-free transportation future. Powering an EV with renewable electricity is actually possible today—for example, by pairing rooftop solar power with EV charging.[7] But in order for EVs to deliver the large reductions in global warming emissions of which they are capable, increasing access to clean electricity is necessary. And that means cleaning up our nation's electricity grid.

Tackling our long-term global warming and energy security challenges, however, will require not only improvements to our electricity grid but also the market success of electric vehicles themselves. EVs are still in their infancy, and it also will take time for them to enjoy a major presence in the vehicle market. But as electric vehicles' market penetration improves, we must also phase out the highest-emitting electricity sources, such as coal, and increase the use of cleaner and renewable electricity generation. Only by pursuing both of these objectives in parallel can electric vehicles fulfill their potential.

Current Policies Will Deliver Cleaner Electricity, but More Is Needed

Some efforts are under way around the country to reduce the emissions from electricity, and the emissions intensity of electricity is thus expected to decrease in the coming years. Projections show that the global warming emissions intensity of the nation's electricity grid will drop 11 percent by 2020 (compared with 2010), and in some regions more than 30 percent.[8]

The expected decline in emissions intensity of the U.S. electricity grid is due in large part to state and regional policies and federal tax incentives for increasing the supply of renewable electricity and hastening the retirement of coal-fired plants. More than 70 percent of coal-powered plants in the United States are more than 30 years old. But the percentage of coal in the nation's grid mix has been declining over the past decade, and widespread retirements of existing coal plants are expected by 2020 (UCS 2011). Also, 29 states plus the District of Columbia have adopted renewable electricity standards, which require growing shares of renewables to meet electricity demand—for example, Connecticut intends that 23 percent of its total electricity-generating capacity will be renewable by 2020 (Figure 1.7). Moreover, 24 states have adopted energy efficiency resource standards, which aim to accelerate energy efficiency investments and thereby reduce electricity demand (ACEEE 2011).

Even with substantial progress around the country expected in coming years, much more is needed to move our electricity sector to a cleaner and more sustainable future. Reducing global warming emissions 80 percent by 2050 compared with 1990 levels will be necessary to prevent the worst consequences of climate change.[9] Even states such as California, which is charging ahead with a 33 percent renewable electricity standard by 2020, will need to go further in order to achieve this level of overall reduction.[10]

The strengthening of current policies and the implementation of new ones will be needed to achieve these goals, including a nationwide cap on carbon emissions, a national renewable energy standard, and building and appliance efficiency standards, among others.[11] To meet the challenges of climate change and our nation's oil dependence, continuing to run our cars and trucks on petroleum-based fuels is not an option. Notably, electric vehicles coupled with a clean and sustainable electricity grid have the promise to be an important part of the solution.

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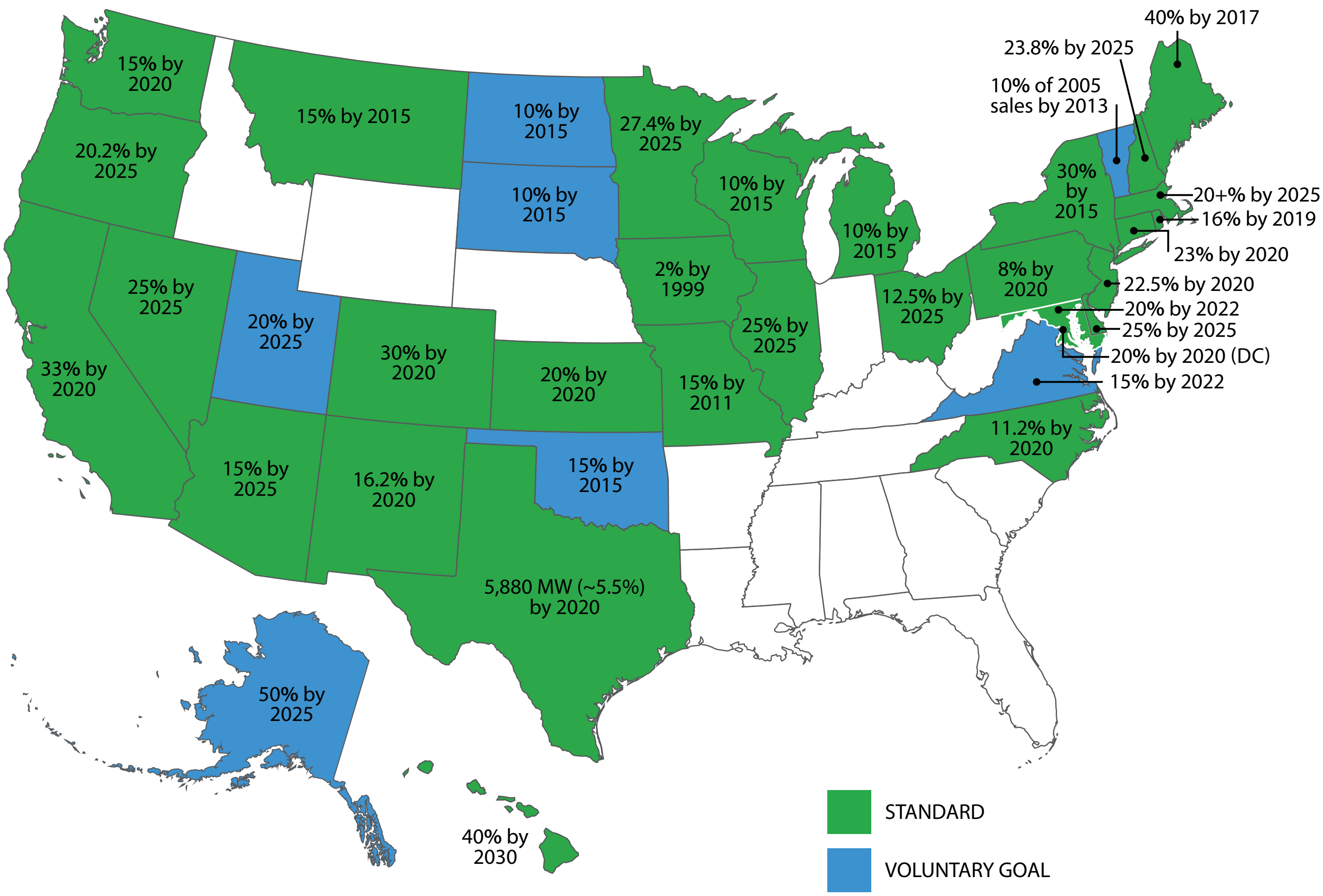
7 Thirty-three percent of respondents to a survey by the California Center for Sustainable Energy, which administers California's Clean Vehicle Rebate Project, indicated they own rooftop solar electric systems (CCSE 2011).
8 Based on data from the U.S. Energy Information Administration's (EIA's) Annual Energy Outlook 2011 (EIA 2011b).
9 See *www.ucsusa.org/assets/documents/global_warming/emissions-target-report.pdf.*
10 California adopted a 33 percent by 2020 renewables standard in 2011. A recent study published in *Science* indicates the vast majority of California's electricity will need to achieve zero emissions by 2050 to reach an 80 percent target (Williams et al. 2012).
11 For further details, see *Climate 2030: A National Blueprint for a Clean Energy Economy* (UCS 2009).

Figure 1.7. STATE RENEWABLE ELECTRICITY STANDARDS (INCLUDING THE DISTRICT OF COLUMBIA)



Options for Buying Cleaner Electricity

Most consumers have limited choices when it comes to selecting a utility and the source of their electricity. However, consumers do have some options to help increase demand for cleaner sources of electricity as well as to help reduce the emissions of future EV charging.

Generate your own renewable electricity

Installing solar panels to provide electricity is an alternative being considered by an increasing number of people for at least some of their home's electrical needs. Among EV owners with existing solar electric systems, increasing the size of these systems may be an option for generating the electricity that would otherwise have to be purchased to charge their vehicle.

Green power programs

Participating in a green power program offered by your utility or independently purchasing renewable energy certificates are two ways of supporting renewable power.

According to the U.S. Department of Energy, more than 860 utilities across the nation are offering some type of green pricing program.[12] These initiatives allow consumers, by paying a premium for renewable electricity, to support their utility's greater investment in renewables.[13] The types of renewables and program details vary by utility.[14]

In some deregulated utility markets, consumers have the ability to choose their power provider. In those locales, choosing a provider that supplies electricity from renewable sources or that maintains a green pricing program may be distinct options. States offering this type of choice for at least some consumers include California, Illinois, Maryland, New Jersey, New York, Pennsylvania, Texas, Virginia, Connecticut, Maine, Massachusetts, and Rhode Island. The District of Columbia offers such a choice as well.[15]

Purchasing renewable energy certificates (RECs), which are available nationwide, is another option. RECs are directly tied to electricity generated by renewable sources and are sold in a voluntary market.[16] Purchasing RECs can help to increase demand for renewable electricity generation by providing additional revenue for renewable energy projects (NREL 2011).

When reviewing options for buying green power, consumers should look for the Green-E certification label, which indicates that the products have been independently verified (***www.green-e.org***).

12 See *www.epa.gov/greenpower/pubs/gplocator.htm.*
13 See *www.nrel.gov/docs/fy01osti/29831.pdf.*
14 See the EPA's Green Power Locator to get details on local programs, online at *epa.gov/greenpower/pubs/gplocator.htm.*
15 See *apps3.eere.energy.gov/greenpower/markets/marketing.shtml.*
16 See the Center for Resources Solutions website for additional information: *www.resource-solutions.org.*

CHAPTER TWO

Charging Costs of Electric Vehicles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Driving on electricity instead of gasoline can save thousands of dollars in fueling costs over the life of a car. But electric vehicles currently cost more to buy than their internal combustion counterparts, though prices are expected to decline as investments in EV technology and manufacturing ramp up. New EV buyers may also need to prepare their homes for charging their vehicle, thereby adding some additional up-front expenses.[17] Given these added costs, the ability to save money on fueling is an important incentive for potential EV owners. The information in this chapter will help consumers understand how much in savings can be expected and how to maximize those savings by choosing the best utility rate plan for their needs.

Electric vehicles need to be plugged in, often for many hours, to fully recharge a depleted battery. As a result, EV owners will most likely choose to charge their vehicle at home while the car is parked in the driveway or garage. Adding an EV to a home's electrical load will have an impact on the total amount of electricity consumed—i.e., higher monthly electric bills. For example, a typical midsize EV driven 30 miles daily will require about 10 kWh of electricity to be fully recharged each day, or about 300 kWh per month. This load can amount to a 25 to 60 percent increase in monthly electricity consumption for the average household.[18]

But higher monthly electricity bills don't mean that EVs won't save you money on fueling costs. An owner of a compact vehicle with average fuel economy will buy more than 6,000 gallons of gasoline and spend $18,000 on this fuel over the vehicle's 15-year lifetime, assuming a gas price of $3.50 per gallon. As shown in Figure 2.1 (p. 18), with a national average price for electricity of about 11 cents/kWh a typical midsize EV could save nearly $13,000.[19] Most electric vehicles being offered by automakers today are small to midsize cars, a trend expected to continue over the next few years, so fuel-cost savings from EVs are compared with the average new compact gasoline vehicle, which has an EPA city/highway fuel economy rating of 27 mpg.[20] Even compared with the cost of fueling a 50 mpg gasoline vehicle, an EV could save more than $4,500—going a long way toward offsetting the additional cost of the vehicle and any home-based charging equipment.

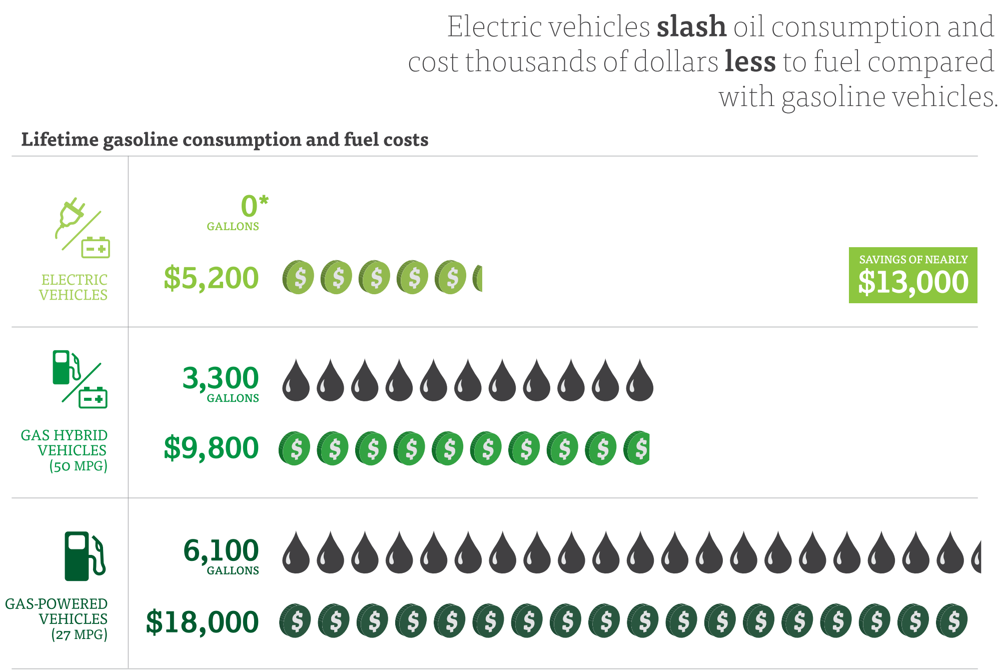
17 Cost estimates of home charging equipment range from $1,500 to $2,200 for Level 2 (240-volt) charging, according to data provided by the websites of Ford, Nissan, Chevrolet, and their preferred EV service providers. Level 1 (120-volt) charging may not require any home preparation if an appropriate outlet is available. See Chapter 4 for further information on charging levels.

18 Range of percent increase is based on 2009 average monthly residential electricity consumption by state, as reported by the EIA (EIA 2010).

19 Annual Energy Outlook 2011 estimates an average residential electricity rate of 10.7 cents/kWh in 2011, expressed in year 2009 dollars (EIA 2011b).

20 Based on new vehicle sales in 2010, the most recent year for which data are available.

Figure 2.1. COMPARISON OF LIFETIME VEHICLE FUEL/CHARGING COSTS AND GASOLINE CONSUMPTION



*Electric vehicles consume no gasoline and contribute very little to oil consumption, since less than 1 percent of U.S. electricity is generated with petroleum.
Note: Assumptions include gasoline cost of $3.50 per gallon, a national average electricity price of 11 cents/kWh, a discount rate of 3 percent applied to future savings, cumulative lifetime mileage of 166,000 miles, and annual travel that starts at 15,000 miles per year and declines 4.5 percent per year over 15 years. Electric-drive efficiency is that of the Nissan LEAF (0.34 kWh/mile) and is representative of today's small to midsize EVs. Greater annual mileage or higher electric efficiency would result in increased cost-savings estimates.

However, electricity prices vary across the country. A closer look at the costs of charging an EV at home in 50 major U.S. cities shows that decisions on rate plans and when you charge can significantly alter the amount you will pay to power your EV.

Understanding Different Types of Rate Plans

Residential consumers of electricity are typically billed each month for their electricity consumption. The amount of the bill is determined by the rate plan, which can be straightforward, with a specific cost per unit of electricity consumed (measured in cents per kilowatt-hour). But in some cases, standard residential rate plans are more complex. And utilities may also offer rate plans for residential consumers that can benefit EV owners. Described below are two of the most common alternatives to a flat electricity rate.

Tiered rates. On a tiered rate plan, the price of the electricity changes as a function of how much of it is consumed. For example, a consumer may pay 10 cents/kWh for the first 300 kWh per month and 15 cents/kWh for electricity consumed beyond the 300 kWh threshold. Tiered electricity rates can encourage consumers to use electricity more efficiently, as its cost increases as more of it is consumed. A tiered utility rate plan may have only two tiers or many tiers.

Time-of-use (TOU) rates. TOU rate plans are typically structured to have higher costs during hours of peak electricity demand, while offering very low rates during off-peak times—

typically overnight. Figure 2.2 shows a typical TOU rate structure. These rate plans usually provide an economic incentive to use electricity when demand on the grid is lowest.

Though uncommon for residential electricity service, some utilities have rate plans that also apply a "demand charge"—an additional cost based on the "peak power demand," which is the maximum amount of energy consumed at a given time. For example, if you run your dishwasher, clothes washer, clothes dryer, pool pump, and air conditioner all at once, you will pay more than if you ran them one after the other. These types of charges can be pertinent when adding an EV to your home's electrical load. The power required to charge your EV depends on how fast you recharge the batteries. The faster the charge, the higher your power demand will be. In the utility rate plans evaluated in this analysis, only the rates in Chicago, Charlotte, and Raleigh are affected by demand charges.

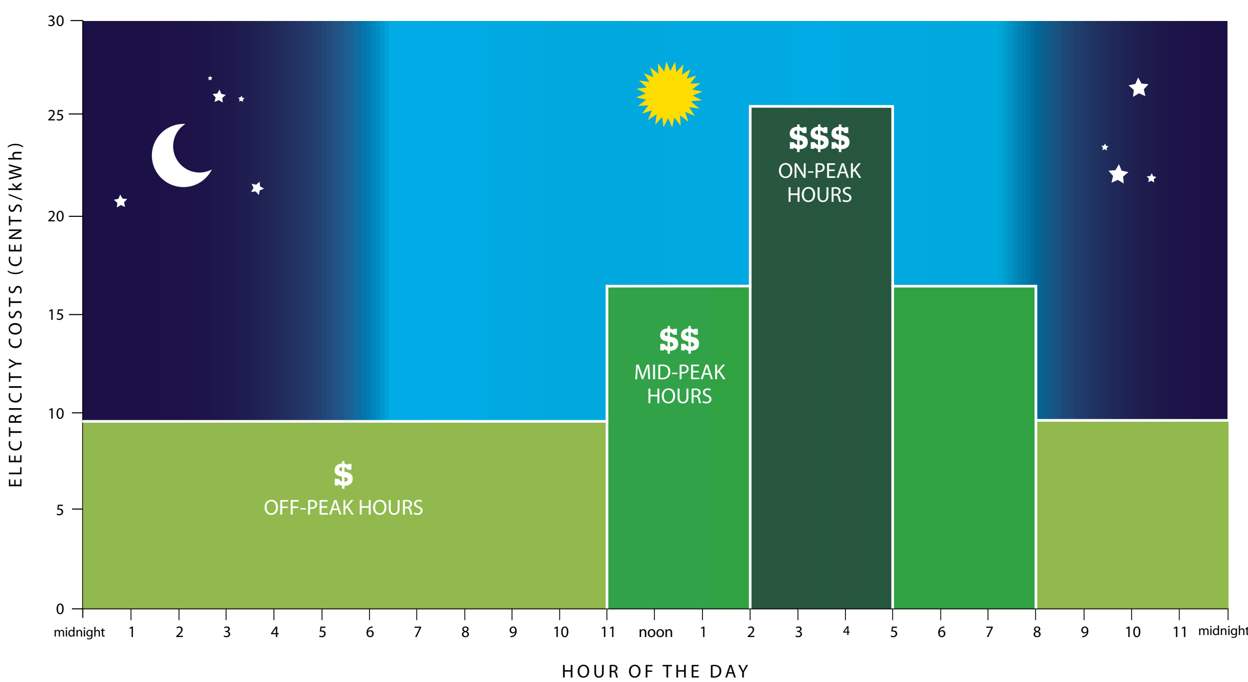
How Much Will It Cost to Charge My Vehicle?

To gain a better understanding of how vehicle charging costs vary throughout the United States, we evaluated the utility rate plans offered in the 50 most populous cities of the lower 48 states. We examined the cost of charging an EV based on the standard residential rate plans and, where they were offered, we also evaluated the cost of charging an EV on TOU plans.

Typically, TOU rate plans apply to either the total household and EV-charging electricity consumption or, if a separate meter is installed, to EV charging alone.[21] The cost to charge an EV

21 In some cases, tiered rates and time-of-use rates can be combined—e.g., the TOU rates will change after a certain level of electricity consumption has been reached each month. The only utility rate plan in our analysis for which this applies is Southern California Edison.

Figure 2.2. LOS ANGELES DEPARTMENT OF WATER AND POWER'S TIME-OF-USE RATE FOR EV CHARGING



Note: Rates are for summertime weekday electricity consumption and include taxes and fees.

can vary, depending on which of these setups apply, so TOU rates are separated into two categories for this analysis. TOU rates attained using a single utility electric meter—and that apply to the EV charging and the home electricity consumption together—are designated "TOU whole-house" (or TOU-WH). TOU rates attained using a utility meter that is distinct from the one serving the home are designated "TOU EV-only" (or TOU-EV).

Main Findings

Evaluation of utility rate plans available across the 50 largest U.S. cities resulted in the following key findings:

When charging on the lowest-cost electricity plan, EV owners can save $750 to $1,200 per year in fuel costs compared with the cost of operating the average compact gasoline vehicle (27 mpg) at gasoline prices of $3.50 per gallon (Table 2.1; Figure 2.3, p. 23). This finding represents a reduction in fueling costs of 50 to 85 percent every year. In the cities with the lowest-cost electricity, such as Oklahoma City and Indianapolis, an EV owner could save more than $1,200 a year. Even in Philadelphia, which offers the most modest savings among the 50 cities evaluated, an EV owner could still save more than $750 per year in fuel costs.

Even when their electric vehicles are compared with a 50 mpg gasoline-powered vehicle, EV owners can save $100 to $570 per year in fuel costs when using the lowest-cost rate plans. This means a cutting of fuel costs by 10 to 75 percent relative to today's most fuel-efficient gasoline-powered vehicle.

In every one of the 50 cities, EV owners will save money on fueling costs compared with the average compact gasoline vehicle, even without changing to the lowest-rate plans. In 44 of the 50 largest cities (88 percent), the standard electricity rate plan offers savings compared with even the best gasoline hybrid (50 mpg). The only exceptions are some California cities, where a switch to time-of-use plans is necessary to top the best gasoline hybrid (assuming a gas price of $3.50 per gallon).

Switching from a standard rate plan to a time-of-use rate plan and then primarily charging the car when electricity is cheapest can mean hundreds of dollars in additional savings per year, especially in California cities (Table 2.2, p. 25). Time-of-use rates often offer the best EV charging costs. Thirty-nine of the 56 utilities serving the 50 cities evaluated offer TOU rates, and all but four are estimated to save money on EV charging compared with the standard rate. In many California cities, EV owners paying TOU rates could realize savings of more than $500 per year compared with staying on standard residential rate plans.

The above savings estimates assume EV owners drive 11,000 miles per year, but those who drive more than that can expect even greater savings.[22]

The biggest savings from the switch to a TOU rate plan from a standard rate plan occurs in California. In cities served by Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), Southern California Edison, and the Sacramento Municipal Utility District, customers can save an estimated $200 to $1,000 each year by choosing a TOU rate. Many of the standard residential rates in California have multiple tiers, with electricity rates increasing substantially after a baseline quantity is consumed. As a result, adding the electricity demand from EV charging pushes monthly electricity demand into the higher-cost tiers on the standard rates plans, making TOU rates a good option.[23]

It is important to note that the greatest cost savings for customers served by PG&E in California are available only as a TOU-EV rate, meaning a second electricity meter needs to be installed. The TOU-WH rate offers less than half the savings because it is still subject to tiered pricing. At the end of 2011, PG&E proposed new rates for EV charging that would eliminate the tiers on time-of-use plans, but these rates had not been finalized at the time of publication.

CONTINUED ON P. 24

22 Our mileage estimate of 11,000 miles per year is based on the average miles traveled per household vehicle, which is approximately 30 miles per day. However, new cars can average 15,000 miles annually (about 40 miles per day) (DOE 2011). Early Nissan LEAF ownership data show an average of about 31 miles per day (INL 2011).

23 Some utility TOU rate plans, such as those of Southern California Edison and PG&E, also have tiers, which can limit savings.

Table 2.1. ANNUAL FUEL-COST SAVINGS OF AN EV COMPARED WITH A 27 MPG GASOLINE-POWERED VEHICLE ON THE LOWEST-COST ELECTRICITY RATE IN 50 CITIES

Regional Global Warming Emissions Rating Good Better Best

CITY	UTILITY	ANNUAL SAVINGS COMPARED WITH A 27 MPG GASOLINE VEHICLE ($/YR)		
		Standard Rate Plan	TOU-WH	TOU-EV
Albuquerque	Public Service Company of New Mexico	900	1,110	1,110
Arlington	TXU Energy	1,010		
Atlanta	Georgia Power	1,000	1,140	1,140
Austin	Austin Energy	1,020		
Baltimore	Baltimore Gas and Electric Company	1,020	1,080	1,080
Boston	NSTAR	850	950	950
Charlotte	Duke Energy	1,090	1,030	1,030
Chicago	ComEd	990	1,020	
Cleveland	Cleveland Public Power	980		
Cleveland	First Energy—The Illuminating Company	1,140		
Colorado Springs	Colorado Springs Utilities	1,080	1,160	1,160
Columbus	AEP Ohio (Columbus Southern Power Company)	1,140	1,140	1,140
Columbus	City of Columbus	1,030		
Dallas	TXU Energy	1,010		
Denver	Xcel Energy	990	1,060	1,060
Detroit	DTE Energy Company	880	1,000	1,020
El Paso*	The Electric Company (El Paso Electric)	1,010	1,060	1,060
Fort Worth	TXU Energy	1,010		
Fresno	Pacific Gas and Electric Company	250	650	1,190
Houston	Entergy Texas	1,080	1,150	1,150
Houston	TXU Energy	1,000		
Indianapolis	Indianapolis Power and Light Company	1,180		1,220
Jacksonville*	Jacksonville Electric Authority	970	1,050	
Kansas City*	Kansas City Power and Light	1,150	1,110	1,110
Las Vegas	NV Energy	970	1,180	1,220
Long Beach	Southern California Edison	150	690	930
Los Angeles	Los Angeles Department of Water and Power	840	1,030	1,030

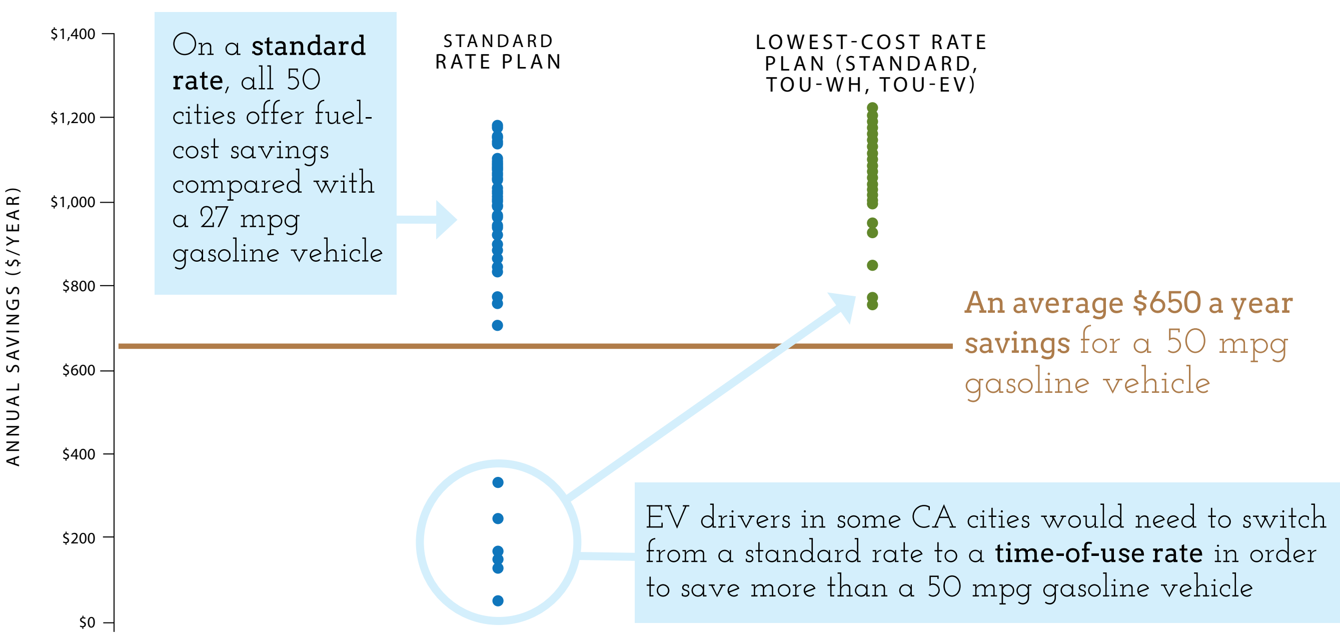
Continued on next page

Table 2.1 (CONTINUED)

CITY	UTILITY	ANNUAL SAVINGS COMPARED WITH A 27 MPG GASOLINE VEHICLE ($/YR)		
		Standard Rate Plan	TOU-WH	TOU-EV
Louisville*	Louisville Gas and Electric	1,140	1,200	1,200
Memphis*	Memphis Light, Gas and Water Division	1,100		
Mesa*	City of Mesa	1,050		
Miami	Florida Power and Light Company	940	1,050	1,050
Milwaukee	WE Energies	920	1,140	1,140
Minneapolis	Xcel Energy	1,030	1,180	1,180
Nashville	Nashville Electric Service	1,050		
New York City	ConEdison	710	1,050	1,050
Oakland	Pacific Gas and Electric Company	50	500	1,120
Oklahoma City	Oklahoma Gas and Electric Company	1,160	1,220	1,140
Omaha	Omaha Public Power District	1,070		
Philadelphia	PECO Energy Company	770		
Phoenix	APS	870	1,130	1,090
Portland	Portland General Electric	990	1,110	1,140
Portland	Pacific Power	1,010	1,040	1,040
Raleigh	Duke Energy	1,090	1,030	1,030
Raleigh	Progress Energy	1,060	1,170	1,170
Raleigh	Piedmont Electric Membership Corporation	1,010	1,150	1,150
Sacramento	Sacramento Municipal Utility District	840	1,070	1,070
San Antonio	San Antonio Public Service (CPS Energy)	1,090		
San Diego	San Diego Gas and Electric	330	850	840
San Francisco	Pacific Gas and Electric Company	130	560	1,140
San Jose	Pacific Gas and Electric Company	170	590	1,170
Seattle	Seattle City Light	1,060		
Tucson	Tucson Electric Power	1,020	1,070	1,150
Tulsa	Public Service Company of Oklahoma	1,170	1,200	1,170
Virginia Beach	Dominion Virginia Power	1,080	1,180	1,180
Washington, DC*	Pepco	950	840	840
Wichita	Westar Energy	1,100		

Table 2.1 Notes:
(1) Cost savings on standard rate and TOU-WH assume EV charging is added to the average household electricity consumption. This consumption is based on state-level data (except for California) from the U.S. Energy Information Administration. In California cities, baseline electricity usage was estimated on the basis of tiered-rate assumptions.
(2) Vehicle assumptions: Electric vehicle efficiency of 0.34 kWh/mile, gasoline vehicle efficiency of 27 miles per gallon, 11,200 grams CO_2 equivalent per gallon of gasoline, and 11,000 miles per year of driving.
(3) Charging assumptions: 3.3 kW Level 2 (from a 240-volt outlet). The amount of off-peak charging varies by utility and rate plan, ranging from 76 percent for the rate plan with the shortest window of off-peak times (five hours for San Diego Gas and Electric) to 94 percent for the rate plan with the longest window of off-peak times (Las Vegas has a 19-hour off-peak period). The remainder of charging is distributed equally throughout the rest of the day. See the methodology in Appendix B for further details.
(4) Based on an inquiry to ComEd in Chicago, the TOU rate is available only on a whole-house basis. Jacksonville Electric Authority also offers only a TOU-WH rate.
(5) TOU-WH rates do not include estimates to changes in household electricity-consumption costs that may occur as a result of switching from a standard rate plan.
(6) TOU rates for Pacific Gas and Electric are under review and are expected to change in the spring of 2012.
(7) The regional electricity emissions data used in this analysis are based on the most recent version of the EPA's eGRID database (which includes power plant emissions from 2009) available at the time of publication. Utility rate information was collected between March 2011 and January 2012.
* These cities are served by multiple utilities in different electricity grid regions. The electricity grid regions assigned to these cities were determined by the utility listed.

Figure 2.3. FUEL-COST SAVINGS OF ELECTRIC VEHICLES COMPARED WITH A 27 MPG GASOLINE VEHICLE IN 50 U.S. CITIES AT GASOLINE PRICES OF $3.50 PER GALLON



Notes:
(1) Data points represent EV fuel-cost savings on rate plans of 56 utilities serving the 50 most populous cities in the United States. The same utility serving more than one city is shown as separate. See Table 2.1 for a list of all 50 cities.
(2) We assume 30 miles per day of travel and EV efficiency of 0.34 kWh/mile. Home charging equipment costs are not included. Time-of-use whole-house (TOU-WH) rates do not include estimates of changes in household electricity-consumption costs.

CONTINUED FROM P. 20

EV owners on TOU plans can maximize their cost savings by charging only during off-peak times. Our estimates of charging costs on TOU rates assume that most charging occurs during off-peak times (76 to 94 percent), when electricity rates are at their lowest; the remainder of charging occurs at other times during the day when rates may be higher.[24] For EV owners who can limit their charging to off-peak hours, switching to the lowest-cost TOU rate plan may provide additional savings.

Most TOU rate plans can be accessed without installing a separate electricity meter, but all of a household's electricity will be subject to the TOU rates. In nine of the 50 cities evaluated, the lowest charging costs are achieved when the EV is metered separately from the household electricity. This means that to access the lowest rates, consumers in San Francisco, Oakland, San Jose, Fresno, Long Beach, Las Vegas, Portland, Detroit, and Tucson must have a separate meter installed. In most other cases, consumers will have to decide whether placing their entire house on the TOU plan or installing a separate meter dedicated to EV charging will give them access to the cheapest rate plan. For detailed comparisons of the estimated charging costs on different rate plans, see Table B.4 in Appendix B.

Adding a separate meter may include charges from utility companies for installation and require additional home wiring, thus increasing the overall cost of preparing a home for vehicle charging.

Advice for Consumers

This analysis of EV charging costs and rate plan options across the country provides a snapshot of what's available to consumers today. Many utilities are ramping up their efforts in preparation for a major rollout of electric vehicles, so their rate plans are likely to evolve. Interested consumers should keep the following in mind:

- **Use our charging costs as an estimate, but contact your utility for more information.** If you live in one the 50 cities we evaluated for charging costs (or live nearby and are served by the same utility),[25] use our estimates for an idea of how much you might expect to save. But be sure to contact your utility for the latest information on rate plan options for EV charging and to get estimates of charging costs and any up-front costs that might be involved.

- **Consider switching to a time-of-use rate plan, especially in California.** TOU rates typically offer cheaper rates in the early-morning hours, so if vehicle charging is primarily overnight, as is likely for many EV owners, a TOU plan can be a good option. Some current EV models come equipped with a feature for programming charging times, which can be set to match off-peak hours; charging a vehicle need not, therefore, require a late-night trip to the garage.

    - **TOU-WH.** Putting your home and EV together on a single meter often allows the cheapest TOU rates to be accessed without having to install a separate meter, but this merging will change how much you pay for the electricity throughout your house. If you can shift your household electricity consumption to off-peak times (the timers built into some dishwashers and washing machines can make this task easier), you may be able to save even more on your electric bill. Customers can contact the utility for an estimate of how switching to a whole-house TOU rate will affect monthly expenses.[26] Smart-meter technology, which can track hourly consumption of electricity, should also allow for better estimates of the savings associated with switching to whole-house TOU rates.

    - **TOU-EV.** If your home's electricity consumption is high during the day when TOU rates are also

24 Data collected as part of the EV Project show the vast majority of vehicle charging is occurring in the early-morning hours coincident with off-peak times (EV Project 2011). Personal communication with SDG&E also confirmed that EV customers on TOU rates in San Diego are charging more than 80 percent of the time during off-peak times.
25 Note that local taxes can vary by city, which could have a small effect on cost-savings estimates.
26 Some utilities, such as Portland General Electric, have online calculators to help their customers estimate the impact of switching to TOU plans (see *www.portlandgeneral.com/residential/your_account/billing_payment/time_of_use/calculator.aspx).*

Table 2.2. CITIES WHERE SWITCHING TO A TOU PLAN FROM THE STANDARD RATE MAY SAVE AN ADDITIONAL $100 PER YEAR OR MORE ON VEHICLE CHARGING (23 OF 50 CITIES)

CITY	UTILITY	CHEAPEST RATE PLAN	Savings Realized in Switching to TOU-WH from Standard Rate ($/year)	Savings Realized in Switching to TOU-EV from Standard Rate ($/year)
Oakland	Pacific Gas and Electric Company	TOU-EV	$452	$1,068
San Francisco	Pacific Gas and Electric Company	TOU-EV	$427	$1,007
San Jose	Pacific Gas and Electric Company	TOU-EV	$421	$1,006
Fresno	Pacific Gas and Electric Company	TOU-EV	$400	$940
Long Beach	Southern California Edison	TOU-EV	$543	$779
San Diego	San Diego Gas and Electric	TOU-WH	$512	$508
New York City	Con Edison	TOU-WH or TOU-EV	$342	$342
Phoenix	APS	TOU-WH	$264	$226
Las Vegas	NV Energy	TOU-EV	$207	$248
Sacramento	Sacramento Municipal Utility District	TOU-WH or TOU-EV	$234	$234
Milwaukee	WE Energies	TOU-WH or TOU-EV	$214	$214
Albuquerque	Public Service Company of New Mexico	TOU-WH or TOU-EV	$207	$207
Los Angeles	Los Angeles Department of Water and Power	TOU-WH or TOU-EV	$196	$196
Portland	Portland General Electric	TOU-EV	$115	$145
Minneapolis	Xcel Energy	TOU-WH or TOU-EV	$143	$143
Raleigh	Piedmont Electric Membership Corporation	TOU-WH or TOU-EV	$143	$143
Atlanta	Georgia Power	TOU-WH or TOU-EV	$142	$142
Detroit	DTE Energy Company	TOU-EV	$116	$135
Tucson	Tucson Electric Power	TOU-EV	$58	$132
Raleigh	Progress Energy	TOU-WH or TOU-EV	$110	$110
Miami	Florida Power and Light Company	TOU-WH or TOU-EV	$109	$109
Virginia Beach	Dominion Virginia Power	TOU-WH or TOU-EV	$101	$101
Boston	NSTAR	TOU-WH or TOU-EV	$100	$100

Notes:
Gasoline vehicle: 27 mpg, 30 miles per day, gasoline fuel price of $3.50 per gallon.
Electric vehicle: Electric efficiency of 0.34 kWh/mile, 30 miles per day.
Charging: All cost estimates assume Level 2 (from a 240-volt outlet) 3.3 kW charging and 300 kWh/month of consumption, which is in addition to average household electricity consumption. Changes to household electricity costs from TOU rates applied to household electricity consumption (TOU-WH) are not evaluated. To estimate average costs of charging on TOU rates, 76 to 94 percent of charging is assumed to occur off-peak, with a greater percentage occurring on plans with longer periods of off-peak hours. The remaining charging is assumed to be equally distributed throughout the remainder of the day. See the methodology in Appendix B for further details.
Exceptions: TOU-WH rates are generally available for EV plus whole-house or for dedicated EV charging on a separate meter. However, the TOU rates of ComEd in Chicago and the Jacksonville Electric Authority are only available as whole-house rates and do not allow separate metering. In deregulated markets where consumers have a choice of energy providers, the default provider was used to estimate the charging costs.

high, consider charging the electric vehicle on a TOU-EV rate. The cost of adding a separate meter varies by utility and your home's particulars, so in some cases that expense could be significant.[27] Make sure to obtain an estimate from the utility or an electrician on the costs of installing a second meter and any additional electrical work that will be required.

- **Remember: even on standard rate plans, EV charging is cheaper than fueling the average compact gasoline vehicle.** EV owners should get educated on what options, such as TOU plans, are available from their utility, but also keep in mind that most "plain vanilla" standard rate plans across the country will still deliver significant fuel-cost savings compared with operating the average compact gasoline vehicle. EV owners can see how their charging costs are adding up over the first few months of owning the vehicle and then decide if switching to another rate is worth it. In California cities and other locales where TOU rates offer hundreds of dollars in annual savings, getting all the details from your utility early on is worth the effort.

Moving Ahead: Making Lower Rates More Accessible to EV Owners

When utilities make TOU rates readily accessible to EV owners, this can provide a lower-cost charging option, and the utilities themselves are better able to manage EV-charging electricity loads. Access to lower-cost rates during off-peak times encourages owners to charge their vehicles when electricity demand is low and electric generating capacity is underutilized. However, TOU rates are not readily available across all utilities. Two ways in which utilities and regulators can help increase consumer access to low-cost vehicle-charging rates are to (1) make TOU rates that offer greater savings for off-peak charging available to more consumers, and (2) make it easier to separate EV charging from household electricity consumption.

Increase Access to TOU Rate Plans

In only 23 of the 50 largest cities do local utilities offer TOU rate plans that would result in costs savings of $100 or more per year over the standard rate plan. In too many regions, therefore, EV owners do not have access to lower-cost off-peak electricity rates and consequently have no incentive for charging during off-peak times when electricity grid utilization is low. Utilities should thus be motivated to work with regulators and consumers to offer rate plans that make charging EVs more affordable and encourage charging behavior that allows better management of the electricity grid.

Enable Lower-Cost Solutions to Separate EV Charging from Household Electricity Use

Uncertainty about increases in costs, whether from installing a second meter or putting a household on a TOU rate, may be preventing many EV owners from choosing TOU rates and thus from maximizing the potential fuel-cost savings from EV ownership.[28] Some early data from EV charging in Pacific Gas and Electric territories in California show that only 37 percent of potential customers have switched to TOU rates, even though our analysis suggests that the remainder could also be potentially saving hundreds of dollars per year.[29]

Allowing the use of alternative metering options could help make TOU rates a viable solution for more EV owners. One program run by the Sacramento Municipal Utility District, for example, involves a lower-cost sub-meter installed between the main electrical meter and the EV charger. San Diego Gas

27 For example, the utility may cover some of the cost of installing a second meter, but it may not cover expenses related to underground wiring, if needed. According to Pacific Gas and Electric's EV rate calculator, the cost of adding a separate meter could be as high as $2,000 to $10,000. See *www.pge.com/cgi-bin/pevcalculator/PEV.*

28 An analysis on why more consumers have not chosen TOU rates has not been performed. Costs and uncertainty of household impacts are two potential reasons, and there may be others, such as a need for greater consumer education.

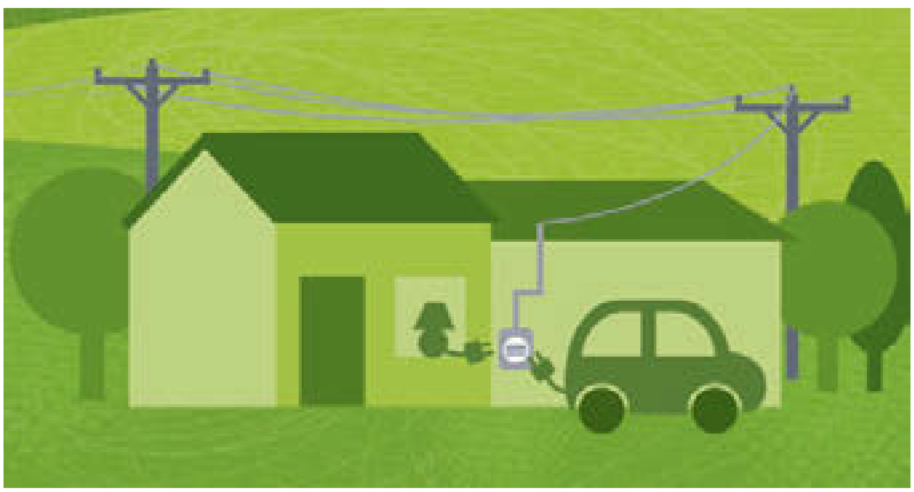
29 Data shared with UCS by Pacific Gas and Electric suggested that in November 2011 more than half of its customers were on the standard rate plan despite the potential savings of switching to a TOU option. Specifically, out of a sample of 2,092 residential EV owners, 1,192 remained on the standard rate plan.

and Electric also uses sub-meters (Pointon 2011), which can measure electricity consumption at the point of use—in this case, where the vehicle is plugged in—thus allowing utilities to bill that consumption separately from overall household consumption. And given that the charging equipment and the vehicles themselves also have the capability of metering the electricity used to charge the vehicle, they themselves may provide a mechanism for billing EV charging without adding a second utility meter.

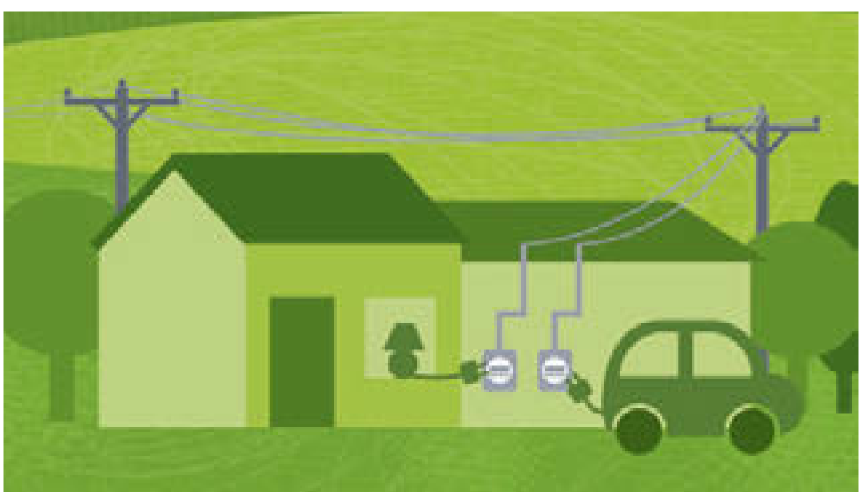
Giving consumers the ability to separate their EV charging from other household electricity uses, together with cost incentives to charge at certain times, will help to manage demands on the electricity grid and could also facilitate the increased use of intermittent renewable energy sources such as wind.[30] Utilities should work with regulators, vehicle manufacturers, and charging-equipment service providers to develop lower-cost sub-metering options; these alternatives will avoid the added cost of installing separate electricity meters while retaining the ability to set TOU rates that apply to EV charging.[31]

30 A recent project in Germany, directed by BMW and Vattenfall, is exploring vehicle-charging options coordinated with wind energy availability. The project is motivated by the fact that the significant presence of wind resources on Germany's electricity grid results in excess capacity during off-peak periods. For further information see *www.vattenfall.com/en/mini-e-berlin-powered-by-vatt_107362.htm*.

31 The California Public Utilities Commission has directed the state's investor-owned utilities to propose a sub-metering protocol by July 2012 (CPUC 2011).



A single electricity meter can be used for both a home's electricity consumption and electric vehicle charging. This configuration is used to access standard electricity rate plans and time-of-use whole-house (TOU-WH) electricity plans.



A second electricity meter can be used to separate EV charging from household electricity consumption. This configuration allows access to time-of-use EV-only (TOU-EV) electricity rate plans.

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CHAPTER THREE

Evaluating Today's Electric-Drive Vehicles for Meeting Your Needs

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The analyses presented so far in this report involve consumer understanding of the global warming emissions and charging costs that derive from owning and operating a grid-powered electric vehicle. But consumers also have to determine how much more they may pay for an EV, choose a vehicle that meets their needs, and select and install a home charger. In this chapter we provide some basic advice on these latter considerations for consumers considering a fully battery-electric or plug-in hybrid EV.

Vehicle Cost

Like many new technologies, EVs come with a cost premium compared with what they replace, in this case gasoline-powered vehicles. With sustained investments in research and manufacturing of electric-drive components, EV prices are expected to decline (ICCT 2011). Meanwhile, consumers can help by supporting the early market for electric vehicles, thereby showing automakers that there is a strong demand for these products.

The cost of an EV can be offset by incentives both for purchasing the vehicle and installing home charging equipment. For example, the U.S. government currently offers a $7,500 tax credit for electric-drive vehicles that meet certain performance criteria. There are many state and local incentives as well, including rebates, car-pool-lane access, free parking, and sales tax waivers.[32] Some companies also offer incentives to their employees.[33]

The cost of battery-electric vehicles is highly dependent on the capacity of the battery. The larger the battery capacity, the greater the range per charge—but the higher the up-front cost.

Vehicle Utility

Battery-Electric Vehicles (BEVs)

When evaluating whether a BEV is a good option, potential owners should take the following into account:

Consider a vehicle that meets the majority of your daily driving needs, as opposed to the needs of the exceptional trip. For example, if your regular commute is 40 miles in each direction, you will require either a BEV with a range of at least 80 miles or access to a vehicle charger at or near your workplace.

32 See *www.hybridcars.com/local-incentives/region-by-region.html.*
33 See *www.hybridcars.com/corporate-incentives.html.*

Consider all your transportation options. Don't just address whether a BEV will directly replace your existing vehicle; explore how the BEV could fit into your household's overall transportations needs. For example, most households in the United States have more than one vehicle (DOE 2011). Consider swapping cars with other household members for the occasional trip beyond the range of your BEV. Also consider how other alternatives might apply. Car-sharing programs provide additional options when you require a larger vehicle or have to take a longer trip. Public transit, car pooling, or occasionally renting a car might also be options for meeting the rest of your needs.

Plug-In Hybrid Electric Vehicles (PHEVs)

Plug-in hybrids come with different all-electric ranges—again, depending on battery capacity. When the batteries are exhausted, an internal combustion engine takes over; the PHEV temporarily operates as a gasoline vehicle, providing additional range until you are able to recharge it.[34] These vehicles could actually run entirely on gasoline without ever needing to be plugged in, but then they would have no benefits compared with a gasoline vehicle of the same fuel economy.

How much of your driving falls within the electric range of the PHEV? When driven within their all-electric range, PHEVs can provide gasoline savings and reduced global warming emissions similar to those of a BEV. However, when your trip exceeds the all-electric range, the PHEV behaves more like a gasoline vehicle. As a consumer you will want to consider how many of your gasoline miles you want to replace with electricity when choosing among PHEVs.

Charging Options

Besides considering the cost of the vehicle, EV owners need to have a convenient place to plug it in. There is a network of public charging stations that is expanding, but most EV owners will want the convenience of a home charging option.

Most electric cars or plug-in hybrids come equipped for charging via a conventional 120-volt electrical outlet, referred to as Level 1 charging. In the more-limited-range vehicles, such as the upcoming plug-in Toyota Prius (with an estimated electric range of about 11 miles), the battery system can fully charge in about three hours with Level 1 charging. By contrast, battery-electric vehicles can take as much as 15 to 20 hours to fully recharge, depending on how much driving was done that day (less driving means a quicker charge and a smaller environmental footprint).

Most EVs also have the capacity to be charged more quickly via outlets rated at 240 volts (the same level as larger home appliances, such as clothes dryers), known as Level 2. Typical power ratings for Level 2 chargers include 3.3 kW and 6.6 kW. The higher-kilowatt chargers allow for faster charging, but the home wiring and vehicle-charging equipment must be compatible. Charging at higher kilowatt levels can result in higher utility bills where demand charges apply, though these charges are rare for residential electricity customers.

Plug-in hybrids with limited EV range, because of their smaller battery packs, may be able to rely on 120-volt recharging, but they can also use the higher level for a quicker charge. In many cases, home wiring can be upgraded to support Level 2 charging. Table 3.1 shows typical charging times for an EV and the miles of range for each hour of charging. Level 1 charging may be sufficient for some BEV owners, but long

34 Because different configurations of PHEVs exist, some may use the internal combustion engine under certain conditions while in the nominally all-electric range.

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charging times on Level 1 may make it difficult to restrict EV charging to off-peak times, when rates on TOU plans are lowest.

To complement home charging, an infrastructure of commercial charging stations is developing in some parts of the country. Vehicle and charging-station manufacturers have agreed on standard plugs and outlets for Level 1 and 2 charging, so all electric vehicles should be compatible with all charging stations. Some of these stations also offer higher currents, known as Level 3 or "DC fast charge," that can fully recharge an electric vehicle in as little as 30 minutes depending on the voltage and battery. But Level 3 connections may not be standard on all vehicle models or may be available as an option.[35]

Meanwhile, some companies are considering, or moving ahead with, carports and charging stations outside their buildings to allow their employees and customers to charge while at work or shopping. This network of charging stations is still in its very early stages.

EV buyers should consult with their auto dealer and utility about current charging options, including incentives that may be available to help offset the cost of buying and installing home charging equipment. Cost estimates from major vehicle manufacturers now range from about $1,500 to $2,200 for Level 2 charging, while Level 1 charging may not require any additional cost if a standard outlet is available where the vehicle will be charged.[36] Starting out with Level 1 charging before investing in a Level 2 charger may be a good option for EV owners who do not expect to drive more than 30 to 40 miles per day.[37]

35 For example, the 2012 Nissan LEAF fast-charge connection is sold as an option (see *www.nissanusa.com*). CODA's EV sedan will not be equipped with a fast-charge option.

36 See *www.plugincars.com/chevy-volt-home-charging-unit-cost-about-2000-equipment-and-installation-87653.html*.

37 Early data on charging behavior show that vehicles are being charged at Level 2 for an average of about two hours, but are often parked for 10 hours. These data seem to indicate that slower Level 1 charging may suffice for some consumers (EV Project 2011).

Table 3.1. RESIDENTIAL CHARGING OPTIONS

	LEVEL 1 (1.6 kW)	LEVEL 2 (3.3 kW)	LEVEL 2 (6.6 kW)
MILES OF RANGE PER HOUR OF CHARGE	≈4–5 miles	≈9–11 miles	≈17–22 miles
TIME REQUIRED TO RECHARGE AFTER 30 MILES OF DRIVING	6–8 hours	2.5–3.5 hours	1–2 hours
EQUIPMENT	Standard dedicated 120-volt outlet with GFCI protection	240-volt electric circuit and home charging equipment compatible with 3.3 kW charging	240-volt electric circuit and home charging equipment compatible with 6.6 kW charging
APPROXIMATE TIME TO FULLY RECHARGE A BEV	15–20 hours	7–8 hours	3–4 hours

Note: Assumes battery pack with 24 kWh capacity for a BEV.

CHAPTER FOUR

Vehicle Comparison: Nissan LEAF, Mitsubishi "i," and Chevy Volt

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In the earlier part of this analysis, we evaluated the global warming emissions of a typical small to midsize electric vehicle compared with a gasoline vehicle, and we derived estimates of fuel-cost savings in 50 of the largest cities in the United States. The efficiency performance of electric-drive vehicles (which include fully battery-electric vehicles and plug-in hybrid electric vehicles) on the market today do vary, however. And because plug-in hybrids are powered both by electricity and gasoline, their overall emissions performance and cost savings will depend on how much driving is done on electricity versus gasoline. In the following two sections we show the differences in global warming emissions and fueling costs of some of the vehicles available in showrooms today. But first we refer the reader to Table 4.1 (p. 32), which summarizes the data on three commercially available vehicles together with our related findings.

Global Warming Emissions

In the cleanest regions of the United States, the Nissan LEAF and Mitsubishi "i" battery-electric vehicles have the global warming emissions equivalent of a gasoline vehicle with a fuel economy rating over 100 mpg, far higher than the 50 mpg Toyota Prius—the most efficient hybrid electric vehicle available today (Table 4.2, p. 33). The "i" uses less electricity per mile than the LEAF (0.30 kWh/mile versus 0.34 kWh/mile), giving the "i" a smaller global warming footprint.

The Chevy Volt plug-in hybrid, which can travel about 35 miles on electricity before having to switch to the gasoline engine, has slightly higher global warming emissions compared with the battery-electric LEAF and "i" when operating in electric mode, given the Volt's lower efficiency (0.36 kWh/mile). When the gasoline engine takes over, it delivers a fuel economy rating of 37 mpg. The actual ratio of a Volt driver's all-electric versus gasoline driving will change the vehicle's overall global warming emissions.

In Table 4.2, the Volt's overall global warming emissions estimates are based on the assumption that 64 percent of its miles traveled are on electricity alone. This percentage derives from the split between electric-powered and gasoline-powered miles expected from a plug-in hybrid with a 35-mile all-electric range, as determined by the Society of Automotive Engineers' analysis of gasoline-vehicle driving data. Volt owners who are able to drive 64 percent of their miles on electricity alone can expect to have global warming emissions equivalent to a gasoline vehicle of about 60 mpg (in the cleanest-electricity region).

In the region with the highest electricity-based global warming emissions, the LEAF, "i," and Volt achieve emissions levels similar to gasoline vehicles, with fuel economy ratings ranging from about 33 to 38 mpg.

CONTINUED ON P. 34

Table 4.1. VEHICLE SPECIFICATIONS AND SUMMARY OF RESULTS

2012 MODEL YEAR BATTERY-ELECTRIC AND PLUG-IN HYBRID VEHICLES	NISSAN LEAF BATTERY- ELECTRIC VEHICLE	MITSUBISHI "I" BATTERY-ELECTRIC VEHICLE	CHEVY VOLT PLUG-IN HYBRID
			
MSRP STICKER PRICE	$35,200 (Eligible for $7,500 Federal Tax Credit)	$29,125 (Eligible for $7,500 Federal Tax Credit)	$39,145 (Eligible for $7,500 Federal Tax Credit)
GASOLINE MPG (CITY/HWY/COMB)	N/A	N/A	35/40/37
ELECTRIC-DRIVE EFFICIENCY (kWh/100 MILES; CITY/HWY/COMB)	32/37/34	27/34/30	36/37/36
ELECTRIC RANGE ON A FULL CHARGE (EPA ESTIMATE)	73 miles	62 miles	35 miles
TIME TO CHARGE BATTERIES WHEN FULLY DEPLETED (BASED ON MANUFACTURER WEBSITES)	Level 1: ≈20 hours Level 2: ≈7–8 hours	Level 1: ≈22 hours Level 2: ≈7 hours	Level 1: ≈10 hours Level 2: ≈4 hours
FUEL TYPE	Electricity	Electricity	Premium gasoline and electricity
MILES PER GALLON OF A GASOLINE VEHICLE WITH EQUIVALENT GLOBAL WARMING EMISSIONS[1]	Dirtiest electric grid: 34 Cleanest electric grid: 115	Dirtiest electric grid: 38 Cleanest electric grid: 130	64 percent of miles are electric: Dirtiest electric grid: 33 Cleanest electric grid: 64 Under electric option only: Dirtiest electric grid: 32 Cleanest electric grid: 109
RANGE OF ANNUAL FUEL-COST SAVINGS ACROSS 50 LARGEST CITIES ON LOWEST-COST RATE PLAN[2] (compared with 27 mpg gasoline vehicle, $3.50 gasoline, and 11,000 miles of driving per year)	$770–$1,220	$850–$1,250	$580–$890

Notes:
(1) Results are presented for a combination of electric power and gasoline power, assuming 64 percent of miles are powered by electricity, consistent with U.S. EPA use of SAE J2841 multiday individual utility factors. Results are also presented for operating on electricity alone. Volt owners who are able to drive more than 64 percent of their miles on electric power will achieve emissions closer to the values presented for electric operation only.
(2) Volt savings estimates assume $3.70 for premium gasoline cost and 64 percent of miles powered by electricty. Greater electric miles will increase cost savings, given that per-mile costs of driving on electricity are lower than on gasoline.
Vehicle specifications were gathered from *www.fueleconomy.gov* and manufacturer websites.

Table 4.2. GLOBAL WARMING EMISSIONS OF ELECTRIC-DRIVE VEHICLES (PRESENTED AS THE COMBINED CITY/HIGHWAY MPG RATING THAT A GASOLINE-POWERED VEHICLE WOULD NEED TO ACHIEVE EQUIVALENT GLOBAL WARMING EMISSIONS)

ELECTRICITY GRID REGION[a]	NISSAN LEAF BATTERY-ELECTRIC VEHICLE	MITSUBISHI "i" BATTERY ELECTRIC VEHICLE	CHEVY VOLT PLUG-IN HYBRID (Combined estimate assumes 64 percent of miles are all-electric)[b]
NYUP	115	130	64 (Electricity: 109, Gasoline: 37)
CAMX	78	88	54 (Electricity: 74, Gasoline: 37)
NYCW	84	95	56 (Electricity: 79, Gasoline: 37)
NWPP	73	83	52 (Electricity: 69, Gasoline: 37)
NEWE	75	85	53 (Electricity: 71, Gasoline: 37)
RFCE	64	72	49 (Electricity: 60, Gasoline: 37)
SRMV	57	65	46 (Electricity: 54, Gasoline: 37)
SRVC	60	68	47 (Electricity: 57, Gasoline: 37)
AZNM	49	55	42 (Electricity: 46, Gasoline: 37)
FRCC	48	55	42 (Electricity: 46, Gasoline: 37)
ERCT	48	54	42 (Electricity: 45, Gasoline: 37)
AKGD	44	50	40 (Electricity: 42, Gasoline: 37)
HIMS	42	48	39 (Electricity: 40, Gasoline: 37)
SRSO	46	52	41 (Electricity: 44, Gasoline: 37)
SRTV	46	53	41 (Electricity: 44, Gasoline: 37)
RFCW	42	47	39 (Electricity: 40, Gasoline: 37)
NYLI	41	47	38 (Electricity: 39, Gasoline: 37)
RFCM	38	43	36 (Electricity: 36, Gasoline: 37)
HIOA	36	41	35 (Electricity: 34, Gasoline: 37)
SPSO	38	43	36 (Electricity: 36, Gasoline: 37)
MROE	40	45	37 (Electricity: 38, Gasoline: 37)
MROW	39	45	37 (Electricity: 37, Gasoline: 37)
SRMW	37	42	35 (Electricity: 35, Gasoline: 37)
SPNO	35	40	35 (Electricity: 33, Gasoline: 37)
RMPA	34	38	33 (Electricity: 32, Gasoline: 37)

Notes: (a) Global warming emissions based on 2009 regional power plant data (EPA 2012a); for approximate geographic area covered by each region, see Figure 4.1. (b) Plug-in hybrid vehicle results are presented for operation on electricity grid power only, gasoline only, and an average combined estimate. The combined estimate is based on the split between electric-powered and gasoline-powered miles expected from a plug-in hybrid, as determined by SAE J2841 utility factors consistent with U.S. EPA vehicle labeling.

CONTINUED FROM P. 31

Fuel-Cost Savings

Because it is cheaper across the country to refuel with electricity than gasoline, the fully electric LEAF and "i" offer greater fuel-cost savings than the plug-in hybrid Volt, which is powered both by electricity and gasoline (the Volt requires premium unleaded fuel). However, all three vehicles offer significant annual savings compared with the average new compact gasoline vehicle. The LEAF and "i" could produce fuel-cost savings of more than $1,200 per year in cities with the lowest-cost electricity, while the Volt (assuming 64 percent of miles driven are electric) would save nearly $900 per year. Even in cities with higher electricity costs, all three vehicles would save well over $500 per year (Table 4.3).

Gasoline consumption with the Volt, compared with that of the average compact gasoline vehicle, would be reduced by 290 gallons per year—with greater or lesser savings possible, depending on the number of electric miles driven. The LEAF and the "i" would eliminate gasoline consumption entirely, saving about 400 gallons of gasoline per year.

These savings estimates are based on an average of 30 miles driven per day, or 11,000 miles per year. This is significantly less than the estimated 15,000 miles per year traveled on average by new vehicles (DOE 2011). In any case, EV owners who drive more than 11,000 miles per year would realize even greater savings than those presented here.

Figure 4.1. U.S. ELECTRICITY GRID REGIONS

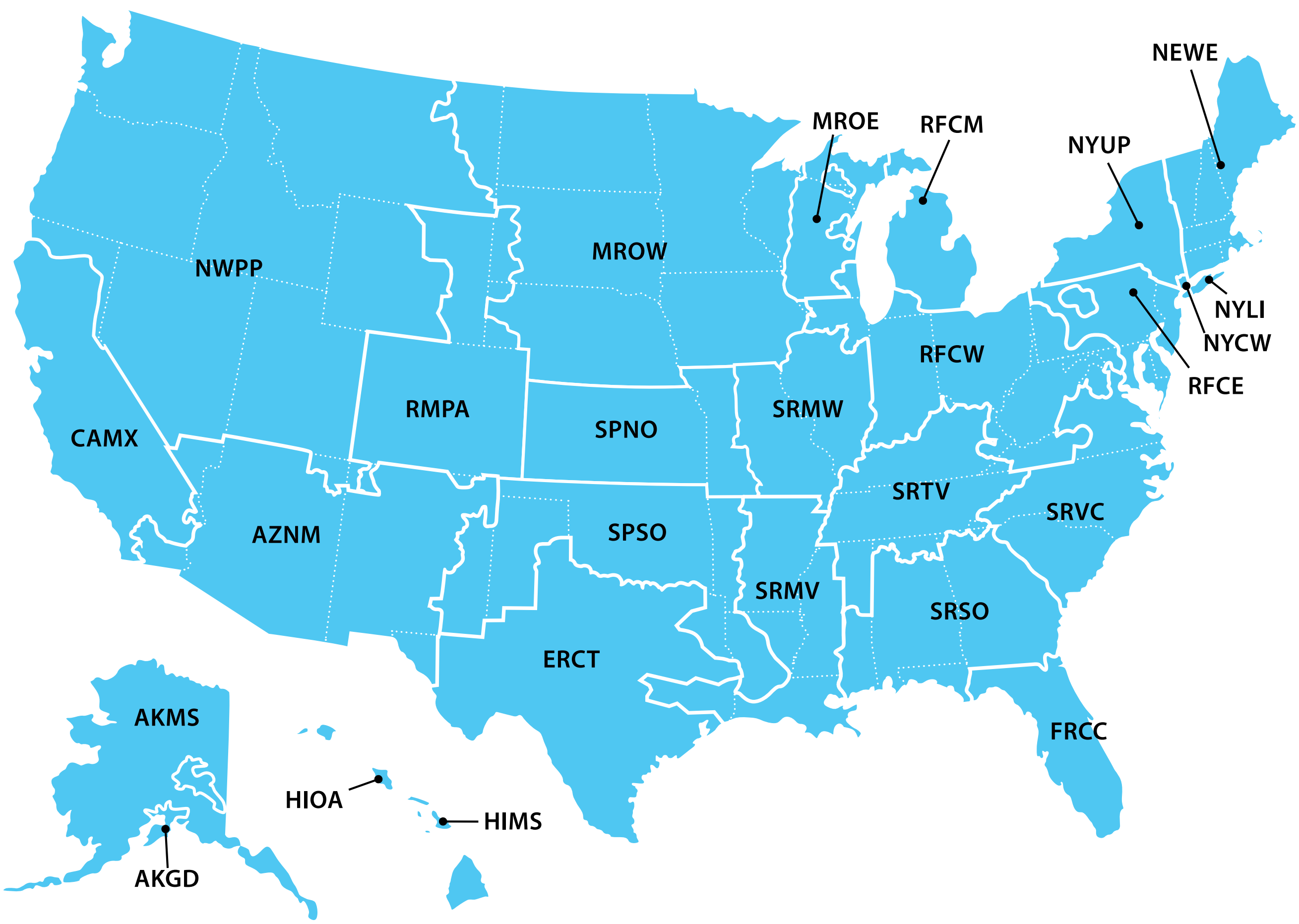

Table 4.3. FUELING COSTS AND SAVINGS OF TODAY'S ELECTRIC-DRIVE VEHICLES

CITY	UTILITY	LOWEST-COST RATE PLAN	NISSAN LEAF BATTERY-ELECTRIC VEHICLE		MITSUBISHI "i" BATTERY-ELECTRIC VEHICLE		CHEVY VOLT PLUG-IN HYBRID	
			cents/mile	Annual Fuel-Cost Savings (Gallons of Gasoline Saved = 400)	cents/mile	Annual Fuel-Cost Savings (Gallons of Gasoline Saved = 400)	cents/mile E=Electricity G=Gasoline	Annual Fuel-Cost Savings (Gallons of Gasoline Saved = 260)
Albuquerque	Public Service Company of New Mexico	TOU-WH or TOU-EV	2.9	1,110	3.0	1,140	5.6 (E:3, G:10)	810
Arlington	TXU Energy	Standard	3.8	1,010	4.0	1,050	6.2 (E:4, G:10)	740
Atlanta	Georgia Power	TOU-WH or TOU-EV	2.5	1,140	2.7	1,180	5.3 (E:2.7, G:10)	840
Austin	Austin Energy	Standard	3.6	1,020	3.8	1,070	6.1 (E:3.8, G:10)	750
Baltimore	Baltimore Gas and Electric Company	TOU-WH or TOU-EV	3.1	1,080	3.3	1,120	5.8 (E:3.3, G:10)	790
Boston	NSTAR	TOU-WH or TOU-EV	4.3	950	4.6	1,000	6.6 (E:4.6, G:10)	700
Charlotte	Duke Energy	Standard	3.0	1,090	3.2	1,130	5.7 (E:3.2, G:10)	800
Chicago	ComEd	TOU-WH	3.6	1,020	3.8	1,070	6.1 (E:3.8, G:10)	750
Cleveland	Cleveland Public Power	Standard	4.0	980	4.2	1,030	6.3 (E:4.2, G:10)	730
Cleveland	First Energy—The Illuminating Company	Standard	2.6	1,140	2.7	1,170	5.4 (E:2.7, G:10)	830
Colorado Springs	Colorado Springs Utilities	TOU-WH or TOU-EV	2.4	1,160	2.5	1,190	5.3 (E:2.5, G:10)	840
Columbus	AEP Ohio (Columbus Southern Power Company)	TOU-WH or TOU-EV	2.5	1,140	2.7	1,170	5.4 (E:2.7, G:10)	830
Columbus	City of Columbus	Standard	3.6	1,030	3.8	1,080	6 (E:3.8, G:10)	760
Dallas	TXU Energy	Standard	3.7	1,010	4.0	1,060	6.2 (E:4, G:10)	740
Denver	Xcel Energy	TOU-WH or TOU-EV	3.2	1,060	3.4	1,110	5.8 (E:3.4, G:10)	780
Detroit	DTE Energy Company	TOU-EV	3.7	1,020	3.9	1,070	6.1 (E:3.9, G:10)	750
El Paso	The Electric Company (El Paso Electric)	TOU-WH or TOU-EV	3.3	1,060	3.5	1,100	5.9 (E:3.5, G:10)	780
Fort Worth	TXU Energy	Standard	3.7	1,010	4.0	1,060	6.2 (E:4, G:10)	740
Fresno	Pacific Gas and Electric Company	TOU-EV	2.1	1,190	2.3	1,210	5.1 (E:2.3, G:10)	860
Houston	Entergy Texas, Inc.	TOU-WH or TOU-EV	2.4	1,150	2.6	1,180	5.3 (E:2.6, G:10)	840
Houston	TXU Energy	Standard	3.8	1,000	4.0	1,050	6.2 (E:4, G:10)	740
Indianapolis	Indianapolis Power and Light Company	TOU-EV	1.8	1,220	1.9	1,250	4.8 (E:1.9, G:10)	890
Jacksonville	Jacksonville Electric Authority	TOU-WH	3.4	1,050	3.6	1,090	5.9 (E:3.6, G:10)	770
Kansas City	Kansas City Power and Light	Standard	2.5	1,150	2.6	1,180	5.3 (E:2.6, G:10)	840
Las Vegas	NV Energy	TOU-EV	1.8	1,220	1.9	1,240	4.9 (E:1.9, G:10)	880
Long Beach	Southern California Edison	TOU-EV	4.5	930	4.8	990	6.7 (E:4.8, G:10)	690
Los Angeles	Los Angeles Department of Water and Power	TOU-WH or TOU-EV	3.5	1,030	3.7	1,080	6 (E:3.7, G:10)	760
Louisville	Louisville Gas and Electric	TOU-WH or TOU-EV	2.0	1,200	2.1	1,230	5 (E:2.1, G:10)	870
Memphis	Memphis Light, Gas and Water Division	Standard	2.9	1,100	3.1	1,140	5.6 (E:3.1, G:10)	810

Continued on next page

Table 4.3 (CONTINUED)

CITY	UTILITY	LOWEST-COST RATE PLAN	NISSAN LEAF BATTERY-ELECTRIC VEHICLE		MITSUBISHI "i" BATTERY-ELECTRIC VEHICLE		CHEVY VOLT PLUG-IN HYBRID	
			cents/mile	Annual Fuel-Cost Savings (Gallons of Gasoline Saved = 400)	cents/mile	Annual Fuel-Cost Savings (Gallons of Gasoline Saved = 400)	cents/mile E=Electricity G=Gasoline	Annual Fuel-Cost Savings (Gallons of Gasoline Saved = 260)
Mesa	City of Mesa	Standard	3.4	1,050	3.6	1,100	5.9 (E:3.6, G:10)	770
Miami	Florida Power and Light Company	TOU-WH or TOU-EV	3.4	1,050	3.6	1,090	5.9 (E:3.6, G:10)	770
Milwaukee	WE Energies	TOU-WH or TOU-EV	2.6	1,140	2.7	1,170	5.4 (E:2.7, G:10)	830
Minneapolis	Xcel Energy	TOU-WH or TOU-EV	2.2	1,180	2.3	1,210	5.1 (E:2.3, G:10)	860
Nashville	Nashville Electric Service	Standard	3.4	1,050	3.6	1,090	5.9 (E:3.6, G:10)	770
New York City	Con Edison	TOU-WH or TOU-EV	3.4	1,050	3.6	1,090	5.9 (E:3.6, G:10)	770
Oakland	Pacific Gas and Electric Company	TOU-EV	2.8	1,120	2.9	1,150	5.5 (E:2.9, G:10)	820
Oklahoma City	Oklahoma Gas and Electric Company	TOU-WH	1.8	1,220	1.9	1,250	4.9 (E:1.9, G:10)	890
Omaha	Omaha Public Power District	Standard	3.2	1,070	3.4	1,110	5.8 (E:3.4, G:10)	790
Philadelphia	PECO Energy Company	Standard	5.9	770	6.3	850	7.6 (E: 6.3, G:10)	580
Phoenix	APS	TOU-WH	2.6	1,130	2.8	1,160	5.4 (E:2.8, G:10)	830
Portland	Portland General Electric	TOU-EV	2.6	1,140	2.7	1,170	5.4 (E:2.7, G:10)	830
Portland	Pacific Power	TOU-WH or TOU-EV	3.4	1,040	3.6	1,090	6 (E:3.6, G:10)	770
Raleigh	Duke Energy	Standard	3.0	1,090	3.2	1,130	5.7 (E:3.2, G:10)	800
Raleigh	Progress Energy	TOU-WH or TOU-EV	2.3	1,170	2.5	1,200	5.2 (E:2.5, G:10)	850
Raleigh	Piedmont Electric Membership Corporation	TOU-WH or TOU-EV	2.5	1,150	2.6	1,180	5.3 (E:2.6, G:10)	840
Sacramento	Sacramento Municipal Utility District	TOU-WH or TOU-EV	3.2	1,070	3.4	1,110	5.8 (E:3.4, G:10)	780
San Antonio	San Antonio Public Service (CPS Energy)	Standard	3.0	1,090	3.2	1,130	5.7 (E:3.2, G:10)	800
San Diego	San Diego Gas and Electric	TOU-WH	5.2	850	5.5	910	7.2 (E:5.5, G:10)	630
San Francisco	Pacific Gas and Electric Company	TOU-EV	2.6	1,140	2.7	1,170	5.4 (E: 2.7, G:10)	830
San Jose	Pacific Gas and Electric Company	TOU-EV	2.2	1,170	2.4	1,200	5.2 (E:2.4, G:10)	850
Seattle	Seattle City Light	Standard	3.3	1,060	3.4	1,110	5.8 (E:3.4, G:10)	780
Tucson	Tucson Electric Power	TOU-EV	2.5	1,150	2.6	1,180	5.3 (E:2.6, G:10)	840
Tulsa	Public Service Company of Oklahoma	TOU-WH	2.0	1,200	2.1	1,230	5 (E:2.1, G:10)	870
Virginia Beach	Dominion Virginia Power	TOU-WH or TOU-EV	2.2	1,180	2.3	1,210	5.1 (E:2.3, G:10)	860
Washington, DC	Pepco	Standard	4.3	950	4.6	1,000	6.6 (E:4.6, G:10)	700
Wichita	Westar Energy	Standard	2.9	1,100	3.1	1,140	5.6 (E:3.1, G:10)	800

Notes: (1) Assumes average compact gasoline vehicle (27 mpg) fuel costs of $1,420 per year and 12.9 cents/mile. (2) Plug-in hybrid vehicle results are presented for operation on electricity grid power only, gasoline only, and an average combined estimate. The combined estimate is based on the split between electric-powered and gasoline-powered miles expected from a plug-in hybrid, as determined by SAE J2841 utility factors consistent with U.S. EPA vehicle labeling.

CHAPTER FIVE

Conclusion

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To meet the challenge of climate change and reduce our nation's dependence on oil, continuing to run our cars and trucks predominantly on oil-based fuels is not an option. On the other hand, electric vehicles—coupled with clean and sustainable electricity—are important parts of the solution. Driving on electricity is a reality; it provides global warming benefits today and throughout the United States.

Nearly half of Americans live in regions where driving an electric vehicle means lower global warming emissions than driving even the best hybrid gasoline vehicle available. Over the lifetime of an EV, the owner can save more than 6,000 gallons of gasoline—a significant contribution to U.S. energy security. But our nation's reliance on coal-powered electricity limits electric vehicles from delivering their full potential. Only by making improvements to our electricity grid—by decreasing the use of coal and increasing the use of clean and renewable sources of electricity—will electric vehicles deliver their greatest global warming and air pollution benefits. Initiatives to clean up the electricity grid are occurring around the country, but additional efforts are needed both at the state and national level to ensure continued progress.

Of course, cleaning up the nation's electricity production won't deliver large reductions in the transportation sector's emissions and oil consumption unless electric vehicles become a market success. While they are now coming onto the market in a much bigger way than ever before, EVs still face many hurdles, including higher up-front costs than gasoline vehicles. Lower fueling costs for EVs, however, provide an important incentive for purchasing them, and our cost analysis of 50 cities across the country shows that EV owners can start saving money immediately on fuel costs by using electricity in place of gasoline. Meanwhile, utilities' leaders and government policy makers have important roles to play: they must ensure electricity rate plans motivate EV ownership, and they must encourage charging behavior that supports lower emissions and a robust electricity grid.

To prevent the worst consequences of global warming, the automotive industry must deliver viable alternatives to the oil-fueled internal-combustion engine—i.e., vehicles boasting zero or near-zero emissions. Such alternative technologies must become market successes in the next 10 to 15 years if they are to comprise the majority of vehicles on the road by 2050—a critical element to reaching an 80 percent reduction in global warming emissions by that year. EVs promise to be one of those technologies, but their success is not assured. To turn the nascent EV market into a mainstream phenomenon over the coming years, continued investments are needed for improving EVs' performance and costs, incentivizing consumers and manufacturers, expanding accessible charging infrastructure, and reducing barriers to low-cost home charging.

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Appendix A

See *www.ucsusa.org/clean_vehicles.*

Appendix B

See *www.ucsusa.org/clean_vehicles.*

State of CHARGE

Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings across the United States

This report is available on the UCS website at www.ucsusa.org/clean_vehicles.

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