ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

DEGREE IN ELECTROMECHANICAL ENGINEERING

# STUDY OF THE $CO_2$ EMISSIONS OF AN EV TO THAT OF A GASOLINE VEHICLE

By

JAVIER SÁNCHEZ GONZÁLEZ

Senior Thesis in Electrical Engineering

University of Illinois at Urbana-Champaign

Advisor: George Gross

Madrid

June 2015

**AUTORIZACIÓN PARA LA DIGITALIZACIÓN, DEPÓSITO Y DIVULGACIÓN EN ACCESO *ABIERTO* (*RESTRINGIDO*) DE DOCUMENTACIÓN**

***1º. Declaración de la autoría y acreditación de la misma.***

El autor D. Javier Sánchez González, como estudiante de Grado en Ingeniería Electromecánica de especialidad eléctrica de la UNIVERSIDAD PONTIFICIA COMILLAS (COMILLAS), **DECLARA**

que es el titular de los derechos de propiedad intelectual, objeto de la presente cesión, en relación con la obra Proyecto Fin de Grado titulado STUDY OF THE $CO_2$ EMISSIONS OF AN EV TO THAT OF A GASOLINE VEHICLE, que ésta es una obra original, y que ostenta la condición de autor en el sentido que otorga la Ley de Propiedad Intelectual como titular único o cotitular de la obra.

En caso de ser cotitular, el autor (firmante) declara asimismo que cuenta con el consentimiento de los restantes titulares para hacer la presente cesión. En caso de previa cesión a terceros de derechos de explotación de la obra, el autor declara que tiene la oportuna autorización de dichos titulares de derechos a los fines de esta cesión o bien que retiene la facultad de ceder estos derechos en la forma prevista en la presente cesión y así lo acredita.

***2º. Objeto y fines de la cesión.***

Con el fin de dar la máxima difusión a la obra citada a través del Repositorio institucional de la Universidad y hacer posible su utilización de *forma libre y gratuita* ( *con las limitaciones que más adelante se detallan*) por todos los usuarios del repositorio y del portal e-ciencia, el autor **CEDE** a la Universidad Pontificia Comillas de forma gratuita y no exclusiva, por el máximo plazo legal y con ámbito universal, los derechos de digitalización, de archivo, de reproducción, de distribución, de comunicación pública, incluido el derecho de puesta a disposición electrónica, tal y como se describen en la Ley de Propiedad Intelectual. El derecho de transformación se cede a los únicos efectos de lo dispuesto en la letra (a) del apartado siguiente.

***3º. Condiciones de la cesión.***

Sin perjuicio de la titularidad de la obra, que sigue correspondiendo a su autor, la cesión de derechos contemplada en esta licencia, el repositorio institucional podrá:

(a) Transformarla para adaptarla a cualquier tecnología susceptible de incorporarla a internet; realizar adaptaciones para hacer posible la utilización de la obra en formatos electrónicos, así como incorporar metadatos para realizar el registro de la obra e incorporar "marcas de agua" o cualquier otro sistema de seguridad o de protección.

(b) Reproducirla en un soporte digital para su incorporación a una base de datos electrónica, incluyendo el derecho de reproducir y almacenar la obra en servidores, a los efectos de garantizar su seguridad, conservación y preservar el formato. .

(c) Comunicarla y ponerla a disposición del público a través de un archivo abierto institucional, accesible de modo libre y gratuito a través de internet.[1]

(d) Distribuir copias electrónicas de la obra a los usuarios en un soporte digital. [2]

***4º. Derechos del autor.***

El autor, en tanto que titular de una obra que cede con carácter no exclusivo a la Universidad por medio de su registro en el Repositorio Institucional tiene derecho a:

a) A que la Universidad identifique claramente su nombre como el autor o propietario de los derechos del documento.

b) Comunicar y dar publicidad a la obra en la versión que ceda y en otras posteriores a través de cualquier medio.

c) Solicitar la retirada de la obra del repositorio por causa justificada. A tal fin deberá ponerse en contacto con el vicerrector/a de investigación (curiarte@rec.upcomillas.es).

d) Autorizar expresamente a COMILLAS para, en su caso, realizar los trámites necesarios para la obtención del ISBN.

d) Recibir notificación fehaciente de cualquier reclamación que puedan formular terceras personas en relación con la obra y, en particular, de reclamaciones relativas a los derechos de propiedad intelectual sobre ella.

[1] En el supuesto de que el autor opte por el acceso restringido, este apartado quedaría redactado en los siguientes términos:

(c) Comunicarla y ponerla a disposición del público a través de un archivo institucional, accesible de modo restringido, en los términos previstos en el Reglamento del Repositorio Institucional

[2] En el supuesto de que el autor opte por el acceso restringido, este apartado quedaría eliminado.

***5º. Deberes del autor.***

El autor se compromete a:

a) Garantizar que el compromiso que adquiere mediante el presente escrito no infringe ningún derecho de terceros, ya sean de propiedad industrial, intelectual o cualquier otro.

b) Garantizar que el contenido de las obras no atenta contra los derechos al honor, a la intimidad y a la imagen de terceros.

c) Asumir toda reclamación o responsabilidad, incluyendo las indemnizaciones por daños, que pudieran ejercitarse contra la Universidad por terceros que vieran infringidos sus derechos e intereses a causa de la cesión.

d) Asumir la responsabilidad en el caso de que las instituciones fueran condenadas por infracción de derechos derivada de las obras objeto de la cesión.

***6º. Fines y funcionamiento del Repositorio Institucional.***

La obra se pondrá a disposición de los usuarios para que hagan de ella un uso justo y respetuoso con los derechos del autor, según lo permitido por la legislación aplicable, y con fines de estudio, investigación, o cualquier otro fin lícito. Con dicha finalidad, la Universidad asume los siguientes deberes y se reserva las siguientes facultades:

a) Deberes del repositorio Institucional:

- La Universidad informará a los usuarios del archivo sobre los usos permitidos, y no garantiza ni asume responsabilidad alguna por otras formas en que los usuarios hagan un uso posterior de las obras no conforme con la legislación vigente. El uso posterior, más allá de la copia privada, requerirá que se cite la fuente y se reconozca la autoría, que no se obtenga beneficio comercial, y que no se realicen obras derivadas.

- La Universidad no revisará el contenido de las obras, que en todo caso permanecerá bajo la responsabilidad exclusiva del autor y no estará obligada a ejercitar acciones legales en nombre del autor en el supuesto de infracciones a derechos de propiedad intelectual derivados del depósito y archivo de las obras. El autor renuncia a cualquier reclamación frente a la Universidad por las formas no ajustadas a la legislación vigente en que los usuarios hagan uso de las obras.

- La Universidad adoptará las medidas necesarias para la preservación de la obra en un futuro.

b) Derechos que se reserva el Repositorio institucional respecto de las obras en él registradas:

- retirar la obra, previa notificación al autor, en supuestos suficientemente justificados, o en caso de reclamaciones de terceros.

Madrid, a 04 de Junio de 2015

**ACEPTA**

Fdo……………………………………………………………

Proyecto realizado por el alumno/a:

Javier Sánchez González

Fdo.: ……………………… Fecha: 04/ Junio / 2015

Autorizada la entrega del proyecto cuya información no es de carácter confidencial

EL DIRECTOR DEL PROYECTO

Professor George Gross

Fdo.:  Fecha: 12 / Mayo / 2015

Vº Bº del Coordinador de Proyectos

Fernando De Cuadra García

Fdo.: …………………… Fecha: ……/ ……/ …

**STUDY OF THE $CO_2$ EMISSIONS OF AN EV TO THAT OF A GASOLINE VEHICLE**


**AUTOR: Sánchez González, Javier**

DIRECTOR: Gross, George

ENTIDAD COLABORADORA: University of Illinois at Urbana-Champaign


SUMMARY OF THE PROJECT:

**Introduction:**

There is growing awareness around the world about energy independence, sustainability and climate change issues produced by $CO_2$ emissions. The United States' dependence on oil makes their overall economy and household budgets highly vulnerable to volatile oil prices. The pollutant emissions from the vehicles contribute to unhealthy air and global climate change. Vehicles powered by electricity have the potential to reduce many of these problems.

Driving on vehicles powered by electricity instead of gasoline vehicles is better when it comes to reducing the emissions responsible for climate change. But the environmental impacts depend on many factors: the resource mix, the weather, resource mix of the generated electricity, etc. The recent developments are not the first time in the history of car manufacturing that Electric Vehicles (*EVs)* have been prominent.

Global warming is real problem in our today's society. Increased drought in dry areas, extreme heat, poor air quality, threats to coastal communities, etc. These are just a few examples of what global warming does and are the reasons all these incentives are on proposed to reduce the $CO_2$ emissions and reduce the global warming.

## Objectives

The aim of this project is to do a detailed comparison study of the $CO_2$ emissions an *EV* emits to that of the emissions of a gasoline vehicle. The scope of our work focuses on 2012 year period. We discuss the $CO_2$ emissions in two different states, California and Illinois. We discuss the main factors that can contribute to the emissions, weather, geography and the energy sources that are used in the different states. We also differentiate between the three phases of the energy path: production, transportation and consumption.

## Methodology

In order to do a detailed comparison, we are going to focus on the $CO_2$ emissions produced from the production of the energy, the transportation and the final consumption.

For the *EVs*, first we study the emissions from the energy production. We have to take into account the different resources mix from the different places. Then, we study the efficiency in the transportation of the energy which is around 92%. And finally, we study the tailpipe $CO_2$ emissions which are 0 for *EVs.*

On the other hand, for the gasoline vehicles, firsts we have to study the $CO_2$ emitted during the petroleum extraction and the $CO_2$ emissions from the energy wasted during the extraction. Then we study the emissions from the energy wasted on the transportation, refining and distribution of the gasoline. And finally, we study the tailpipe $CO_2$ emissions which are around 8.887 grams of $CO_2$ / gallon.

## Results

Taking into consideration all the factors addressed before and inspecting, cleaning, transforming, and modeling the $CO_2$ emissions and energy generation data from the Energy Information Administration (*EIA*) [1] we got to the conclusion that driving EVs is less polluting that driving on gasoline vehicles. Depending on the state, either Illinois or California, we have differentiated depending on how is the energy grid mix from each state.

For *EVs*, we vary the miles per *kWh* from 1.5 to 4, we differentiate also different mileage per year and we calculate the *kWh* per year consumed by a single car in a year. Hereafter, differentiating between lead-acid batteries and lithium batteries we calculated the real *kWh* consumed by an *EV*.

First, we have calculated the metric tons of $CO_2$ per *kWh* each energy source emits. For example, in Illinois the main energy source is coal, which is one of the most polluting sources. This fact will affect considerably the $CO_2$ metric tons emitted.

And then, we have estimated how man *kWh* an EV would drive varying the miles per kWh driven, the different types of batteries efficiencies and the miles driven per year. Obtaining the following results:

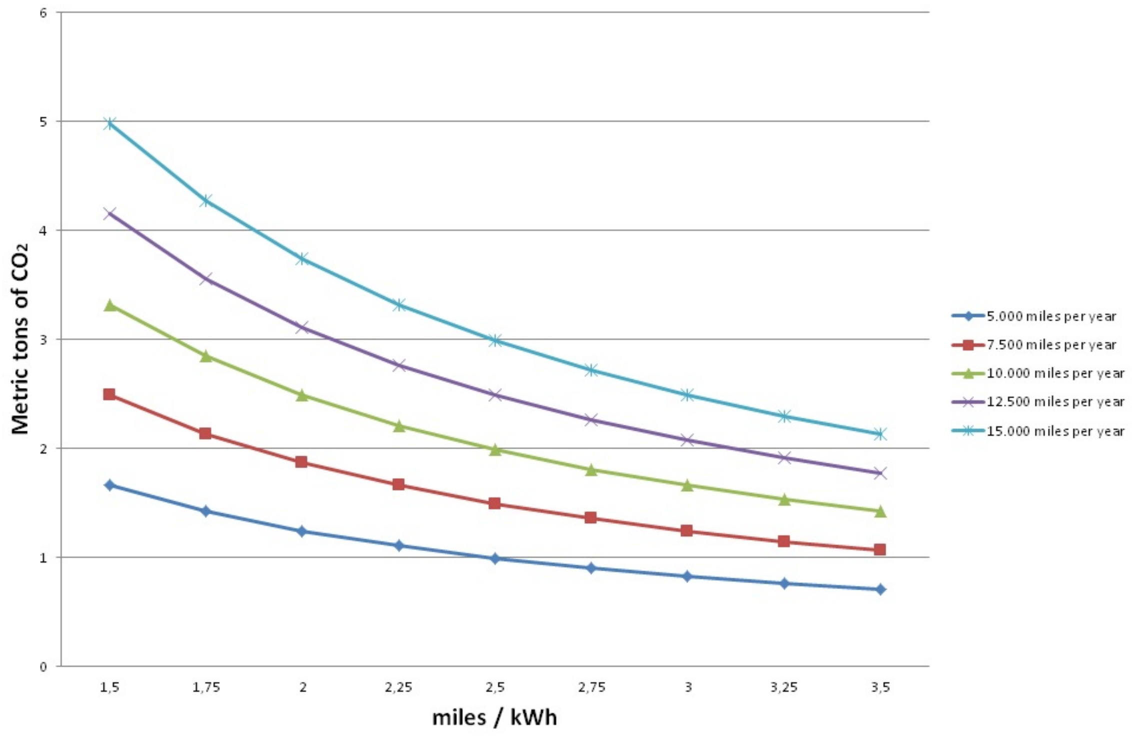



**Figure 1. This figure shows the metric tons of $CO_2$ emitted depending on the miles per *kWh* consumed and varying the mileage per year a single vehicle drives in California**

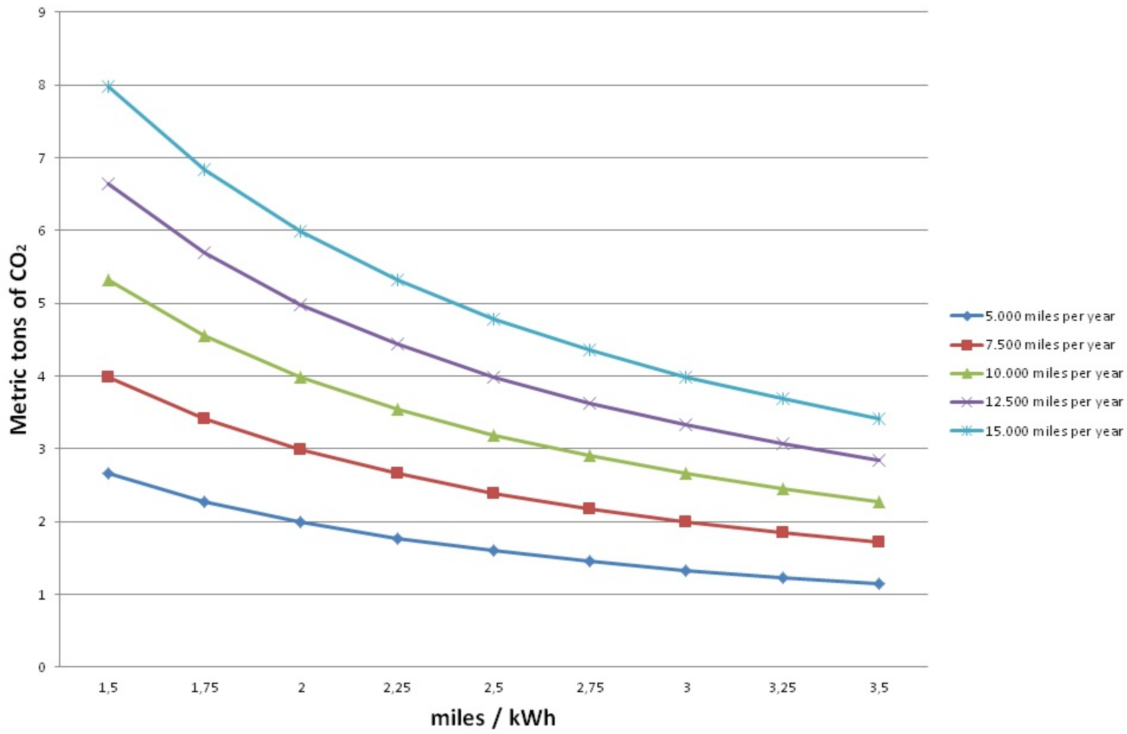



**Figure 2. This figure shows the metric tons of $CO_2$ emitted depending on the miles per *kWh* consumed and varying the mileage per year a single vehicle drives in Illinois**

On the other hand, for the gasoline vehicles we have vary the miles per gallon from 15 to 40, we differentiate also various mileages per year and we calculate the gallons per year consumed by a single car in a year. According to the data from [3] the transportation of the gasoline produces about a 13% of the emissions that the consumption of the gasoline would produce.

According to United States Environmental Protection Agency (*EPA*), to obtain the number of grams of $CO_2$ emitted per gallon of gasoline combusted, the heat content of the fuel per gallon is multiplied by the *kg* $CO_2$ per heat content of the fuel. *EPA* stated that they had agreed to use a common conversion factor of 8,887 grams of $CO_2$ emissions per gallon of gasoline consumed. Obtaining the following results:

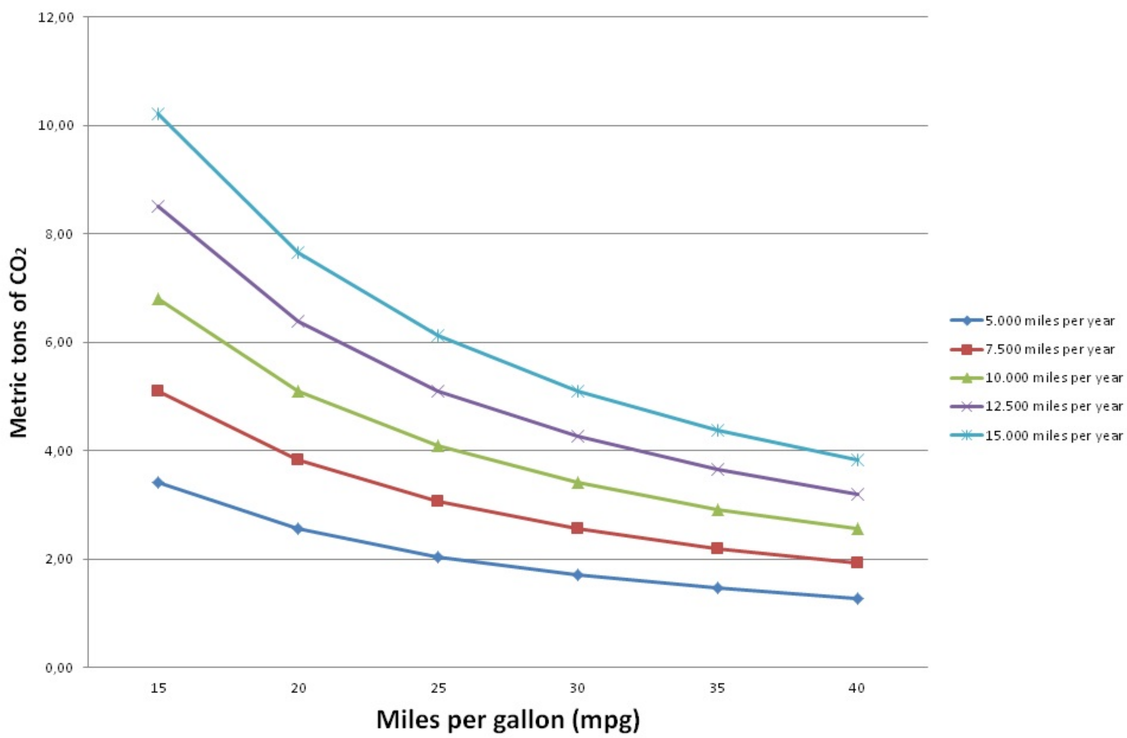



**Figure 3. This figure shows the metric tons of $CO_2$ emitted depending on the miles per gallon consumed and varying the mileage per year a single vehicle**

## Conclusions

The results obtained in this study confirm that driving EVs instead of driving gasoline vehicles is less polluting. But not only we have proved this statement; with this study we have proved that driving on electricity also depended on many factors as weather, the resource mix where the energy comes from, the different types of batteries, etc.

RESUMEN DEL PROYECTO:

Durante los últimos años ha habido una creciente preocupación por los problemas de la independencia energética, la sostenibilidad y el cambio climático producidos por las emisiones de $CO_2$. La dependencia de Estados Unidos en el petróleo hace que la economía y los presupuestos domésticos sean altamente vulnerables a cambios en los precios del barril de petróleo. Las emisiones contribuyen a la formación de un aire no saludable y al cambio climático global. Los vehículos eléctricos tienen el potencial de reducir estas emisiones entre otros grandes problemas.

Conducir coches propulsados por electricidad en vez de conducir los convencionales coches de gasolina es mejor en términos de reducir las emisiones responsables del cambio climático. Pero no dependiendo de varios factores el impacto medioambiental que pueden tener los coches eléctricos puede variar. Los principales factores estudiados en este proyecto han sido el tiempo meteorológico del lugar donde se conduce, de que fuentes proviene la energía utilizada, las diferentes baterías de los coches eléctricos, etc.

El cambio climático es un problema serio en la sociedad actual; incremento de las sequías en zonas más secas, el calor extremo, la mala calidad del aire, las amenazas de inundaciones en zonas costeras, etc. Estos son solo unos pocos ejemplos de lo que el cambio climático hace y las razones que nos ha llevado a realizar este estudio para reducir las emisiones de $CO_2$ y como consecuencia reducir el calentamiento global.

**Objetivos**

El propósito de este proyecto es hace un estudio comparativo detallado de las emisiones que produce un coche eléctrico con respecto a las que produce uno de gasolina. El ámbito de nuestro trabajo se centra en el año 2012. En el estudio se comparan dos diferentes Estados de los Estados Unidos; California e Illinois. Se han escogido estos dos Estados debido a sus diferentes características, ya sean en el tiempo meteorológico como por sus diferentes fuentes de energía. También se diferencia entre las tres diferentes etapas de la vida energética: producción, transporte y consumo.

**Metodología**

Con motivo de realizar un estudio más detallado, nos hemos centrado en las emisiones de $CO_2$ producidas en cada una de las distintas etapas de la energía. Desde la producción de la energía, su transporte y el final consumo de la misma.

En primer lugar, para los coches eléctricos estudiamos las emisiones de $CO_2$ provenientes de la producción. Teniendo en cuenta las diferentes fuentes de energía dependiendo de los distintos estados. Luego, estudiamos la eficiencia con la que se transporta la energía hasta donde es consumida, estimando esta alrededor de un 92%. Y por último estudiaremos las emisiones producidas durante la conducción de los mismos, la cual es 0 para los coches eléctricos.

Por otro lado para los vehículos de gasolina, siguiendo las tres etapas energéticas, primero estudiaremos las emisiones de $CO_2$ producidas en la extracción del petróleo. Luego, las emisiones de $CO_2$ producidas durante el transporte, refinado del crudo y distribución del mismo. Y por último, estudiaremos las emisiones de $CO_2$ emitidas durante el consumo de la gasolina, estimándolas alrededor de 8.887 gramos de $CO_2$ / galón.

**Resultados**

Teniendo en cuenta los factores listados anteriormente; e inspeccionando, limpiando, transformando y modelando los datos de las emisiones de $CO_2$ y los de la generación de energía obtenidos de la Energy Information Administration (*EIA*) [1] llegamos a la conclusión de que los vehículos eléctricos son menos contaminantes que los de gasolina. Pero esta afirmación depende de diversos factores, depende del estado del que estemos hablando, por ejemplo, en California es menos contaminante conducir un coche eléctrico que en Illinois.

Para estudiar los coches eléctricos, variamos las millas por *kWh* de 1.5 a 4. También diferenciamos el kilometraje (en millas) al año y calculamos los *kWh* consumidos al año por un solo coche. A continuación diferenciamos entre los diferentes tipos de baterías que hay en el mercado, baterías de plomo-ácido y baterías de litio calculando los *kWh* reales consumidos.

Primero, se calculan las toneladas de $CO_2$ por *kWh* producidas por cada diferente fuente de energía, Por ejemplo, en Illinois la principal fuente de energía son las minas de carbón. El carbón es una de las fuentes más contaminantes que podemos encontrar, afectando considerablemente la cantidad de $CO_2$ emitido.

Luego, con las estimaciones realizadas sobre la cantidad de kWh reales consumidos por un coche eléctrico obtenemos los siguientes resultados:

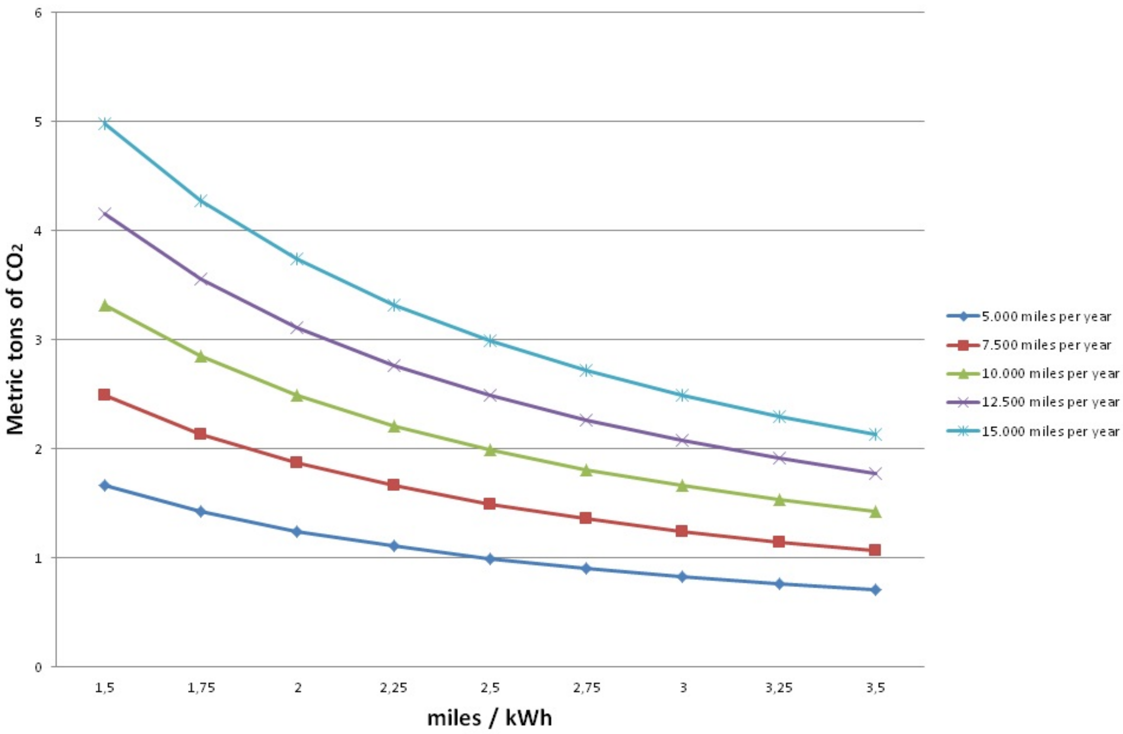



**Figura 1. Esta figura muestra la cantidad de toneladas de $CO_2$ emitidas dependiendo de las millas por kWh consumidas y variando el kilometraje por año que se ha estimado en California**

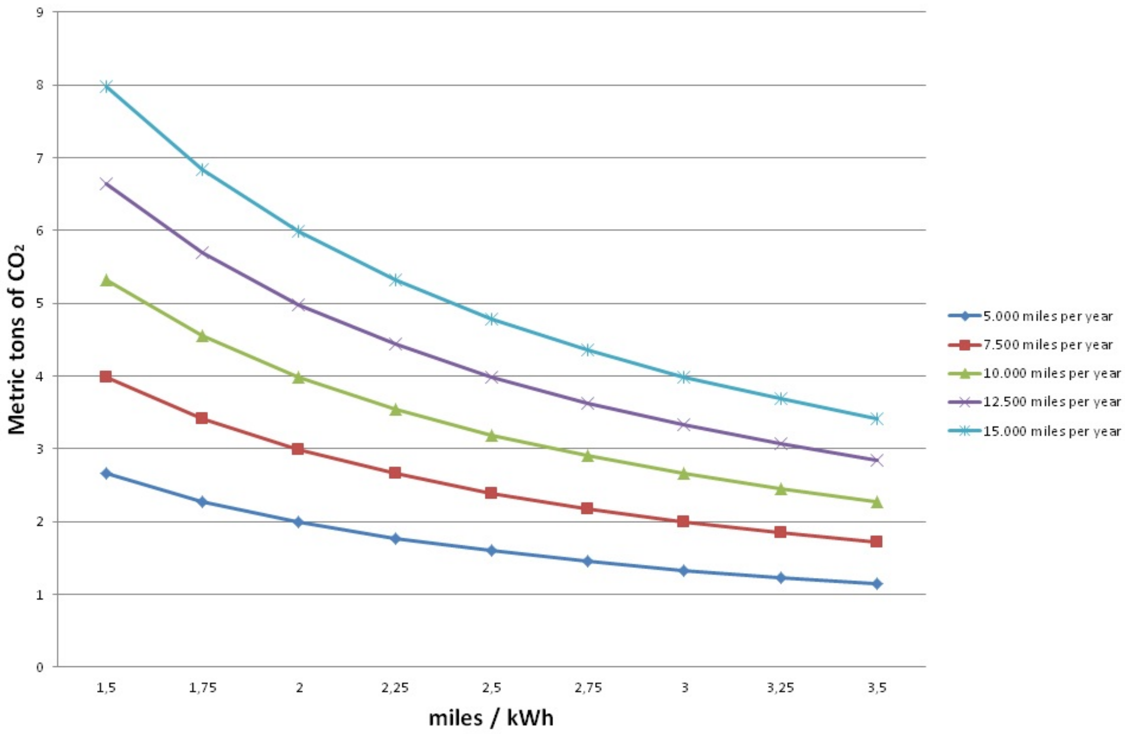



**Figura 2. Esta figura muestra la cantidad de toneladas de $CO_2$ emitidas dependiendo de las millas por kWh consumidas y variando el kilometraje por año que se ha estimado en Illinois**

Por otro lado, para los coches de gasolina variamos de 15 a 40 millas por galón consumido, diferenciando igualmente el número de millas al año por un único coche. De acuerdo con los datos obtenidos de [3] el transporte de la gasolina produce alrededor de un 13% de las emisiones producidas en el consumo de este.

De acuerdo con la agencia United States Environmental Protection Agency (*EPA*), para obtener los gramos de $CO_2$ producidos por cada galón de gasolina quemado, se calcula multiplicando el poder calorífico de un galón del combustible por los kg de $CO_2$ por unidad de poder calorífico de combustible. La agencia EPA, llegaron a un acuerdo para usar el factor de conversión 8.887 gramos de $CO_2$ producidos por cada galón de gasolina quemado; obteniendo los siguientes resultados junto a todas las suposiciones anteriormente propuestas:

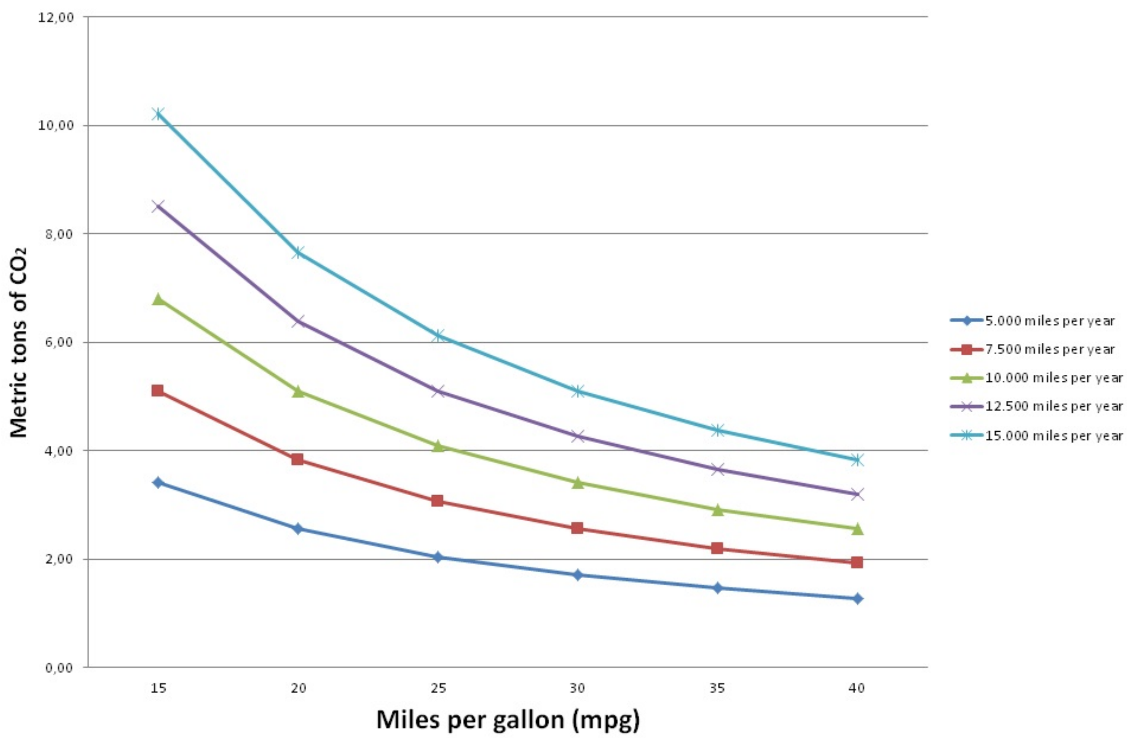



**Figura 3. Esta figura muestra la cantidad de toneladas de $CO_2$ emitidas dependiendo de las millas por galón de gasolina consumidas y variando el kilometraje por año**

## Conclusiones

Los resultados obtenidos en este estudio confirman que conducir vehículos eléctricos en vez de conducir vehículos de gasolina es menos contaminante. Pero después de haber realizado el estudio no solo sacamos esa conclusión. También hemos demostrado que hay muchos factores que influyen a la hora de calcular las emisiones de $CO_2$ producidas por un coche eléctrico. Estos factores pueden ser: el tiempo meteorológico, la geografía, las diferentes fuentes de energía, los tipos de baterías utilizados, etc.

## References

[1] Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923) EIA, U.S. Energy information administration, Independent

[2] P. J. Van Mierlo and Y. Marenne. *European Association for Battery Electric Vehicles*, "Energy consumption, CO2 emissions and other considerations related to Battery Electric Vehicles", April 2009. Available at: http://ec.europa.eu/transport/themes/strategies/consultations/doc/2009_03_27_future_of_transport/20090408_eabev_%28scientific_study%29.pdf

[3] J. Alson, "Overview of Electric Vehicle Market Issues in the U.S", *U.S. Environmental Protection Agency*, EVE Informal Working Group Meeting #2, September 2012

**UNIVERSIDAD PONTIFICIA COMILLAS**

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

GRADO EN INGENIERÍA ELECTROMECÁNICA

# STUDY OF THE $CO_2$ EMISSIONS OF AN EV TO THAT OF A GASOLINE VEHICLE

By

JAVIER SÁNCHEZ GONZÁLEZ

Advisor: George Gross

Madrid

June 2015

# ABSTRACT

This thesis reports on a detailed study of the environmental impacts of an electrical vehicle ($EV$) in comparison with a gasoline vehicle. The project requires an understanding of the three main phases of the energy path: production, transportation and consumption. In each phase we have to differentiate between gasoline vehicles and EVs. For a detailed comparison the study is based only in two states; California, which is one of the cleanest states, and Illinois which has a different energy grid mix and different conditions.

The production study is based on the data from the energy generated by each state in 2012 and the $CO_2$ emissions from each source. The transportation study is based on the efficiency of distributing the energy, whether gasoline or the energy from different sources for the $EVs$. And finally, the consumption is based on the tailpipe $CO_2$ emissions.

Subject Keywords: EVs; $CO_2$ emissions; California; Illinois; Production; Transportation; Consumption.

# ACKNOWLEDGMENTS

I would like to express my sincere gratitude to my thesis advisor, Professor George Gross, for his knowledge and helpful guidance during this year. Doing this research with him was an invaluable experience.

Special thanks to my best friends Cristina and Nicholas, for the continuous encouragement during the hours we spent together doing our senior thesis. I also thank my parents for the unceasing encouragement, support and attention.

And finally, I place on record, my sense of gratitude to one and all, who directly or indirectly, have lent their hand in this venture.

# LIST OF FIGURES

# LIST OF TABLES

# CONTENTS

# CHAPTERS

# 1. INTRODUCTION

In this chapter, we establish the settings for the problems we deal with in the thesis. We start by discussing the background and motivation for the work presented in the thesis. We also present a brief review of the previous work that has been done in this field. We then present the scope and the contributions of this thesis.

## 1.1 Background and motivation

There is growing awareness around the world about energy independence, sustainability and climate change issues produced by $CO_2$ emissions. The United States' dependence on oil makes their overall economy and household budgets highly vulnerable to volatile oil prices. The pollutant emissions from the vehicles contribute to unhealthy air and global climate change. Vehicles powered by electricity have the potential to reduce many of these problems.

We must differentiate between all-electric vehicles (*EVs*), hybrid vehicles (*HEVs*), plug-in hybrid vehicles (*PHEVs*) and battery vehicles (*BVs*). EVs are the vehicles that run on electricity only. *HEVs* have two complementary drive systems, an electric motor, battery and controls, and a gasoline engine and a fuel tank. *PHEVs* are hybrids with batteries that can be charged by plugging them into a charging station. On the contrary, *BVs* have no internal combustion engine but rather a more versatile battery.

Driving on vehicles powered by electricity instead of gasoline vehicles is better when it comes to reducing the emissions responsible for climate change. But the environmental impacts depend on many factors: the resource mix, the weather, resource mix of the generated electricity, etc. For example, using renewables energies to generate electricity to power an electric vehicle can result in almost no global warming. Such awareness and the success of the Toyota Prius – with over 500,000 units sold by 2007 in the *US* [1] – are major drivers in spearheading the popularity of battery vehicles (*BVs*) around the world. Today, electric vehicles (*EVs*) are gaining strength in the *U.S.* market as the result of investments and policies to develop vehicles with zero tailpipe emissions.

The success of the Toyota Prius in the past decade has been a motivation for car manufactures to invest on the development of *EVs*. In 2011, in the *U.S.* market, the *PHEV* Chevy Volt powered by batteries and an internal combustion engine, and the fully electric Nissan LEAF powered solely by batteries are the two *EVs* most used by costumers.

The recent developments are not the first time in the history of car manufacturing that *EVs* have been prominent. The very first *EV* appeared in the early 1830s, after a series of breakthroughs – from the battery to the electric motor – that led to the first *EV* on the road. During the $19^{th}$ century the *EV* was one of the primary modes of transportation – around one third of the vehicles on the road were *EVs* [2]. At the turn of the $20^{th}$ century, when the internal combustion engine was developed, the *EV* usage fell. Interest in electric vehicles died down after the long gas lines of the 1970s. But new federal and state regulations have brought about change in the scenario. The passage of the 1990 Clean Air Act Amendment and the 1992 Energy Policy Act -- plus new transportation emissions regulations issued by the California Air Resources Board -- helped create a renewed interest in electric vehicles in the *U.S.* Apart from these regulations, in 2006, Tesla Motors started producing luxury electric sport cars with improved characteristics – the car could go more than 200 miles on a single charge – which helped to reshape the concept costumers had of *EVs*.

The *CARB* (California Air Resources Board) played an important role adopting the zero emissions vehicle *(ZEV)*, requiring the automakers include 2% *ZEVs* in 1998, 5% *ZEVs* in 2001 and 10% *ZEVs* in 2003.

It is hard to tell where the future will take electric vehicles, but it is clear that *EV* can create a more sustainable future. In 2012, President Obama launched the *EV* Everywhere Grand Challenge [3] to help achieve this sustainable future. The *EV* Everywhere Grand Challenge is a Department of Energy initiative that brings together America's best scientists, engineers and businesses to make *PHEVs* more affordable than today's gasoline-powered vehicles by 2022.

In 2015, *BMW* in partnership with California-based Pacific Gas and Electric Company (*PG&E*) launched the *BMW* i Charge Forward Program. Based in the San Francisco Bay

Area, this revolutionary 18-month pilot study aims to better understand the relationship between home *EV* charging and the energy grid [4].

Global warming is real problem in our today's society. Increased drought in dry areas, extreme heat, poor air quality, threats to coastal communities, etc. These are just a few examples of what global warming does and are the reasons all these incentives are on proposed to reduce the $CO_2$ emissions and reduce the global warming.

## 1.2 Review of the previous work

Several studies have explored the impacts of the $CO_2$ emissions produced by gasoline vehicles in comparison with the *EVs*. The study [5] discusses three main points which will be considered in the thesis. First, it describes that the *EVs* consume less primary energy and substantially less final energy. Then, it discusses that *EVs* generate less $CO_2$ emissions than gasoline vehicles of the same weight and performances. And finally, the study shows that the energy consumed by *EVs* is much less than the gasoline vehicles. The work in [6] reviews that it is necessary to take into account the emissions emitted in electricity generation, since the tailpipe emissions from *EVs* are zero. It also discusses the different types of batteries (lithium-ion, lead-acid or nickel-metal-hydride) used for *EVs*. Finally, it discusses how the energy efficiency is calculated for the different types of cars. The paper [7] provides information about what factors can affect the fuel economy and how they change the energy consumption and $CO_2$ emissions, for example, driving in cold or hot weather and the geographic location of the study. The study [8] addresses three main points. First, it discusses the benefit of driving on electricity as opposed to gasoline, in terms of $CO_2$ emissions. Second, it estimates the costs to charge an electric vehicle in different cities around the country. And finally, it compares two *EVs*, the Nissan LEAF and the Chevy Volt Mitsubishi, with a gasoline vehicle in terms of global warming emissions and fueling costs.

## 1.3 Scope and contribution of this thesis

In this thesis we study the $CO_2$ emissions of an *EV* in comparison to a gasoline vehicle. The scope of our work focuses on 2012 year period. We discuss the $CO_2$ emissions in two different states, California and Illinois. We discuss the main factors that can contribute to the emissions, weather, geography and the energy sources that are used in the different states. We also differentiate between the three phases of the energy path: production, transportation and consumption.

The thesis has four more chapters. Chapter 2 gives an overview over the nature of an *EV* and detailed characteristics of the *EV* in comparison to a gasoline vehicle. It also takes into account the *U.S.* government incentives to encourage the drivers to use more *EVs*. In Chapter 3, we discuss the factors to take into account on the study and we provide general information of the procedure followed during the study. Chapter 4 gives a detailed explanation of the data used for the study and presents the results obtained differentiating not only between gasoline vehicles and *EVs*, but also differentiation between states, California and Illinois. In chapter 5 we present future studies that could change the course of the vehicles history and help to solve the problem of global warming.

# 2. ELECTRICAL VEHICLES

In this chapter we provide an overview of an electric vehicle (*EV*). We review the characteristics of an *EV* taking into account the different types of vehicles. We explain briefly the difference between a gasoline vehicle and an *EV*.

## 2.1 Nature of an EV

*EVs* and gasoline vehicles may have a similar look; the only difference is that the gasoline-powered vehicle has a tail pipe. Internally, *EVs* and gasoline vehicles are very different. According to *CALSTART* (California Shock Trauma Air Rescue), 70% of the components in their internal structure are different. These unique components are different, but serve the same function as the gasoline-powered vehicle's components. Moreover, comparison reveals that the numbers of moving parts are also different. The gasoline-powered vehicle has more moving parts than the electric vehicle, which only has only one, the motor. All the moving parts in the gasoline-powered vehicle require much more maintenance, filter replacements, oil changes, and exhaust system repairs among others.

Since the electric vehicle only has one moving part, it requires less maintenance and therefore it is more reliable and maintenance costs are lower. The moving part in the motor is the shaft, and the controller and charger have no moving parts. All the components, the motor, the charger, the controller and the battery require little or no maintenance. Batteries only require periodic replacements due to its final life. The driving range between recharging is 100 to 300 miles with current batteries.

Another challenge is the requirement of infrastructure to charge the batteries, with maximum voltage and current. Such infrastructure exists only at strategic locations. Improvements in battery technology can eliminate the need to replace the battery pack during the life of an electric vehicle.  Since electric vehicles require low cost maintenance, their operation is more efficient and inexpensive.

On the other hand, challenges for the owner of an electric vehicle persist. One of the challenges that owners have to face is the availability of technicians with the appropriate skills to maintain the electric vehicles. Today, training programs are being developed to meet growing demand.

## 2.2 EV Characteristics

There are various designs for the electric motor in the vehicle: a single electric motor, an electric motor in each of the guide wheels, a motor for each rear wheel and one motor per wheel. One or various electric motors and a combustion engine compose the *PHEVs* infrastructure. Current *PHEVs* reduces the fuel consumption and start from an initial situation of charged batteries.

Today the possibility of using electric vehicles and *PHEV* with renewable energy is open to debate. It has been proposed to use the *EV* as a storage resource when connected to the grid. The *EV* can provide ancillary services to the grid operator. For an implementation of the proposed system, it is very important to carefully study the batteries, charges, and the location of the charge points and the standardization of the connectors.

### 2.2.1 Battery parameters

- Battery voltages: when the battery charges the voltage increases, and the voltage decreases when the battery is delivering power.

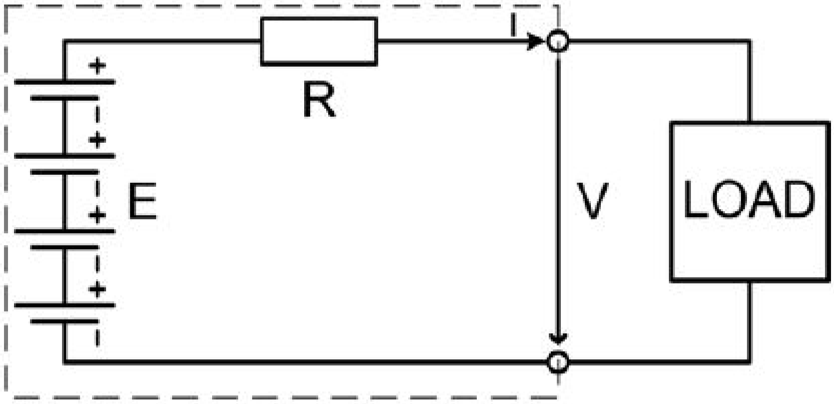



Figure 2.1. This figure shows the equivalent circuit of an electric battery

- Capacity (*Ah*): is the amount of electric charge it can deliver at the rated voltage. It depends directly in the way the energy is extracted, the fastest the energy is extracted, the less capacity the battery has.
- Energy stored (*Wh*): The energy stored measures the quantity of energy the battery can have. Energy cannot be created or destroyed, but it can be saved in various forms. One way to store it is in the form of chemical energy in a battery. When connected in a circuit, a battery can produce electricity. The autonomy of the vehicle and depends directly on its energy stored, and it is proportional to its voltage and capacity.
- Specific energy (*Wh*kg*): It is the energy stored per kilogram.
- Specific power (*W/kg*): It is the amount of power obtained for each kilogram. Sometimes specific power and specific energy can be confusing. The main difference is that specific energy is the amount of energy the battery can store but does not mean that this amount of energy stored can be provided in a fast way, which means it has a high specific power. Therefore specific energy is “amount of energy” and specific power “provide the energy in a fast way”.

### 2.2.2 Review of batteries

The main types of batteries that can be implemented in an *EV* and for commercial use are: *lead-acid* battery, *Ni-Cd* battery, *Ni-MH* battery and l*i-ion* battery. Table 2.1 presents the main characteristics of each type. Lead-acid is the cheapest option but at the same time has the lowest specific energy which makes this type of battery inadequate for EVs and PHEVs. Ni-Cd battery is better than the lead-acid battery but still has a low specific energy and therefore still inadequate for EVs and PHEVs. The best batteries are Ni-MH and Li ion has a high specific energy.

The batteries used in this study are the lead-acid and the li-ion battery. All the data used for this batteries was collected from reports [13] and [5]

Table 2.1 Characteristics of the batteries used in this study

| | **Lead-acid** | **Li ion** |
|---|---|---|
| **Cost** | Low | Very High |
| **Specific Energy (*Wh/kg*)** | 30-50 | 160 |
| **Voltage per cell** | 2 | 3,6 |
| **Charge current** | Low | High |
| **Cycle number (Charge/ Discharge)** | 200-500 | 1200 |

### 2.2.3 Charging station

Charging station installation should guarantee:

- ❑ Safety of the equipment and of the people.
- ❑ Easy replication of the stations
- ❑ Easy expansion of functions through a modular design
- ❑ Interoperability between the stations and electric vehicles.

It is important to know the main components in a charging station installation:

- Link Station connecting the user installation with the General Protection Panel (*GPP*) therefore the link station begins at the end of the electrical.
- Charging Station: this is where to plug the electric vehicle in order to charge it; designed to provide *AC* to *EV*.
- Control Center: this is where statistical data and incidents are managed.

Most electric cars can be charged overnight in a standard 120V household outlet. Nearly all models can be recharged quickly – approximately 5 hours – in a 240V outlet, which is the same type of outlet needed for domestic clothes dryers. We differentiate between:

- AC Level 1 charging, a regular three-prong household wall socket of 110/120V. Most PHEVs can be totally recharged overnight.
- AC Level 2 charging is 220/240V charging, the type found at most charging stations and easily installed in most homes.
- DC level or "fast" charger is typically 480V and it has been developed to enable quick charging in as little as a half-hour.

## 2.3. U.S. government incentives

In response to the economic crisis and as a stimulus, in March 2012, the Reinvestment Act and the American Recovery were signed, investing $2 billion in grants for advanced manufacturing and recycling and electric drive component manufacturing. Another $400 million were invested for transportation electrification program. Investment funds in research and development programs such as introducing *EVs* everywhere as a challenge were announced in March 2012, $4 million were invested to develop a wireless charging system for *EVs*.

In order to promote consumer interest in *EVs* and *PHEVs* primary economic incentives were applied and federal tax credit such as $2500 credit for *EV* and *PHEV* with battery capacity of 4*kWh*, $7500 for battery capacity of 16*kWh*, $417 for every *kWh* in excess of 4 *kWh* and credit begins to phase down when sales reaches 200.000 units. Additional incentives were given to promote *EVs* and *PHEVs*. The incentives included access to High-occupancy vehicle lanes which are accessible to vehicles that carry a certain minimum number of passengers. More than 11 stated allowed the use of these lanes to *EVs* and *PHEVs* such us New York, New Jersey, Florida and Illinois among others…

### 2.3.1 Market Drivers

A vehicle owner has direct benefits such as refuelling at home, avoiding gasoline stations, and lower, more predictable fuel prices. The less gasoline consumed the lower the $CO_2$ emissions to the environment which means not only benefits to the owner; it also means benefits to society; and less noise coming from the vehicle. Oil savings can also reduce oil prices and therefore reduce the trade deficit.

### 2.3.2 Market Barriers

Due to the high price of the batteries, the electric vehicles price increase. Other inconveniences for the owner are the great refuelling time and that there are not many public charging infrastructures. These market barriers are trying to be overtaken by incentives and promoting the move to green energy sources, renewable sources.

# 3. COMPARISON OF EVs AND GASOLINE VEHICLES ON BASIS OF $CO_2$ EMISSIONS

This chapter describes the factors under consideration for comparison of the environmental impacts of an *EV* to that of a gasoline vehicle. We look into the resource mix, the weather and the efficiency, both the well to tank and the tank to wheel efficiency. For a more detailed comparison, we have chosen California, which is one of the cleanest states in the *U.S.*, and Illinois which has a different resource mix so we can make a better study. And finally, in this chapter also summarizes the procedure followed in the comparison.

## 3.1 Factors under consideration

The factors to be taken into account are: resources mix, weather and efficiency.

### 3.1.1 Resources mix

The resource mix of the electricity produced varies from one location to another. The mix depends in part on from the electricity comes from, whether imported from other states or countries. For example, in Illinois the energy comes mainly from Coal. The environmental hazard is that Illinois imports around 90 percent of the coal burned in its power plants. The cost of importing coal to Illinois is a great problem on his economy. Coal is also one of the heavily polluting sources, and produces 1.093 *kg* of $CO_2$ / *kWh* generated (as given by data from Illinois).

For California, the main energy source is natural gas, which produces 0.467 *kg* of $CO_2$ / *kWh* generated in California, followed by hydroelectric energy and nuclear which do not contribute to producing $CO_2$.

### 3.1.2 Weather

The weather has an impact on the driving conditions and consequently on the quantity of $CO_2$ a vehicle emits. According to the official *U.S.* government source for fuel economy information [7] – a conventional fossil fuel car's mileage is about 12% lower at 20ºF than it would be at 77º. This effect is even worse for hybrids, their fuel economy can drop by a 31% to 34% in cold conditions. Cold weather also affects the vehicle in more ways. The fuel economy of a vehicle is defined as the fuel efficiency relationship between the distance traveled and the amount of fuel consumed by the vehicle [7].

- The friction between the transmission and the engine increases in cold temperatures due to cold engine oil and other drive-line fluids.
- There is an increase in rolling resistance due to lower tire pressure in cold temperatures.
- It takes longer for the engine to reach its most fuel efficient temperature.
- It is harder for the alternator to keep the battery charged, due to decreased battery performance in cold weather.

On the other hand, hot weather can increase fuel economy. The engine warms up to an efficient temperature faster. Summer grades of gasoline can have slightly more energy. And warm air causes less aerodynamic drag than cold air. Weather has an effect on your fuel economy.

### 3.1.3 Efficiency

Electric vehicles consume less primary energy and significantly less final energy than fossil fuel vehicles of the same weight and performance. [5] Primary energy refers to indicate the sum of production and imports subtracting exports and storage changes and final energy refers to the electricity the consumer gets.

- Fossil Fuel vehicle:

  i. Tank to wheel energy efficiency.

  Taking into account the best internal combustion vehicles operating in normal conditions, the efficiency is 22% for diesel vehicles and 18% for gasoline (the rest is lost as heat). These efficiencies could vary a lot depending on the driving conditions. They are quite lower in congested urban traffic since the engine varies a lot from operating at low speeds to high speeds.

  ii. Well-to-Tank energy efficiency.

  The efficiency from the primary energy source to the fuel tank takes into account the energy wasted on the extraction of the crude oil, the transportation, refining (distillation process, conversion process and blending process) and distribution. Its efficiency is around 83%.

  iii. Well-to-wheel energy efficiency.

  The well to wheel energy efficiency of a vehicle is the ratio between the final energy transmitted to the wheels divided by the primary energy at the source. And it is equal to the well-to-tank efficiency multiplied by the tank-to-wheel.

$$\text{Well to wheel efficiency} = \text{Well to tank efficiency x Tank to wheel efficiency}$$

$$\text{Diesel}_{\text{Well to wheel}}\ \text{efficiency} = 22\%\ \text{x}\ 83\% = 18\%$$

$$\text{Petrol}_{\text{Well to wheel}}\ \text{efficiency} = 18\%\ \text{x}\ 83\% = 15\%$$

- Electric vehicle:

i. Tank-to-wheel energy efficiency.

For the electrical vehicles, we have to differentiate between lead-acid batteries and the lithium batteries. We also have to take into account the charger efficiency, the charging and discharging cycle efficiency, the engine management efficiency and the electric motor efficiency (which is very high).

All of them together make 60% efficiency with lead-acid batteries and 72% with lithium batteries.

As we can see, the tank-to-wheel energy efficiency of an electric vehicle is around three times better than that of fossil fuel vehicles.

ii. Well to Tank energy efficiency.

The well-to-tank energy efficiency depends on the type of power plant where the energy came from. A good average that is usually considered is 40%. Apart from that, we must take into account the energy efficiency of distribution which is around 92.5% (92.5% of the energy produced on the power plant is distributed to the consumer, and the rest of it is lost in heat).

$$\text{Well to tank efficiency} = \text{Efficiency}_{\text{Type of power plant}} \text{x } \text{Efficiency}_{Distribution}$$

$$\text{Well to tank efficiency} = 40\% \text{ x } 92.5\% \sim 37\%$$

iii. Well to wheel energy efficiency.

Knowing both the well-to-tank efficiency and the tank-to-wheel efficiency:

$$\text{Well to wheel efficiency} = \text{Well to tank efficiency x Tank to wheel efficiency}$$

$$\text{Lead}_{\text{acid}}\text{batteries}_{\text{Well to wheel}} \text{ efficiency} = 60\% \text{ x } 37\% = 22\%$$

$$\text{Lithium batteries}_{\text{Well to wheel}} \text{ efficiency} = 72\% \text{ x } 37\% = 27\%$$

## 3.2 Procedure

Table 3.1 Procedure followed in the comparison

| Gasoline Vehicle | *EV* |
|---|---|
| **Petroleum extraction**<br>Energy wasted on the extraction of the crude oil | **Energy generation**<br>Taking into account the different resources mix from the different places |
| ↓ | ↓ |
| **Petroleum transportation**<br>Energy wasted on the transportation, refining and distribution of the gasoline | **Energy transportation**<br>The energy efficiency of distribution is around 92.5% |
| ↓ | ↓ |
| **Tailpipe $CO_2$ emissions**<br>8.887 grams of $CO_2$ /gallon | **Tailpipe $CO_2$ emissions**<br>0 emissions.<br>Battery type causes change in consumption of electricity. |

## 3.3 Comparison

To compare the environmental impact of an *EV* to that of a gasoline vehicle we focus on two states, California and Illinois. In order to do a detailed comparison, we are going to focus on the $CO_2$ emissions produced from the production of the energy, the transportation and the final consumption.

For an electrical vehicle, we will focus on the different energy sources that each state has. According to the data in Table 3.2, collected from the United States Environmental Protection Agency, in California the main sources used is natural gas, followed by hydroelectric, nuclear, wind and geothermal. In contrast, Illinois generates its electricity from nuclear, coal, natural gas and wind (Table 3.3). Depending on how the energy is generated, more or less $CO_2$ is generated by the different states. Table 3.2 and 3.3 represent the energy generated by source and the metric tons of $CO_2$ generated by source.

**Table 3.2 California's Energy generation and metric tons of $CO_2$ emitted by source in 2012**

| ENERGY SOURCE | GENERATION (Megawatthours) | METRIC TONS OF $CO_2$ |
|---|---|---|
| Coal | 1.375.083 | 2.602.767 |
| Geothermal | 12.518.999 | 321.626 |
| Hydroelectric | 26.837.370 | 0 |
| Natural Gas | 119.668.329 | 55.860.447 |
| Nuclear | 18.507.408 | 0 |
| Other Biomass | 2.513.721 | 162.541 |
| Solar Thermal and Photovoltaic | 1.382.300 | 0 |
| Wind | 9.754.230 | 0 |
| Wood Derived Fuels | 3.797.596 | 0 |

Table 3.3 Illinois's Energy generation and metric tons of $CO_2$ emitted by source in 2012

| ENERGY SOURCE | GENERATION (Megawatthours) | METRIC TONS OF $CO_2$ |
|---|---|---|
| Coal | 80.826.778 | 88.362.022 |
| Hydroelectric Conventional | 111.208 | 0 |
| Natural Gas | 11.188.975 | 5.973.289 |
| Nuclear | 96.401.309 | 0 |
| Other Biomass | 615.193 | 0 |
| Solar Thermal and Photovoltaic | 30.657 | 0 |
| Wind | 7.726.810 | 0 |

For gasoline vehicles we must focus on the petroleum generation and $CO_2$ emissions, as shown in Table 3.4.

Table 3.4 California and Illinois petroleum's production and metric tons of $CO_2$ emitted in 2012

| STATE | GENERATION (Megawatthours) | METRIC TONS OF $CO_2$ |
|---|---|---|
| CA | 289.823 | 251.176 |
| IL | 71.382 | 58.253 |

Once we have studied the production's emissions of $CO_2$ during the electricity generation and the $CO_2$ emissions generated in the production of the gasoline, we have to study the emissions produced in the transportation of the electricity and gasoline respectively.

For $CO_2$ emissions calculations produced by the transportation of the electricity we have to take into account the electricity distribution efficiency, which is estimated around 92.5%. This means that 92.5% of the energy produced on the power plant is distributed to the consumer, while the rest of it is lost in heat. Similarly, for gasoline vehicles, the efficiency from the primary energy source to the fuel tank takes into account the energy wasted on the extraction of the crude oil, the transportation, refining (distillation process, conversion process and blending process) and distribution. Its efficiency is estimated around 83%.

Finally, we have to calculate the $CO_2$ emissions produced during the consumption, namely, the tailpipe emissions of a vehicle.

For an electric vehicle there are no tailpipe emissions, although we must differentiate here between the different types of batteries used for the *EVs*. As stated previously, it is said, the two main battery types are:

- Lead-acid batteries with 60% efficiency.
- Lithium batteries with 75% efficiency.

On the other hand, for gasoline vehicles we have to analyze the grams of $CO_2$ generated per gallon of gasoline consumed. According to United States Environmental Protection Agency (*EPA*), to obtain the number of grams of $CO_2$ emitted per gallon of gasoline combusted, the heat content of the fuel per gallon is multiplied by the *kg* $CO_2$ per heat content of the fuel. *EPA* stated that they had agreed to use a common conversion factor of 8,887 grams of $CO_2$ emissions per gallon of gasoline consumed.

# 4 ANALYSIS AND RESULTS

Our focus in this chapter is on the study of the $CO_2$ emissions data from California and Illinois taking into consideration all the factors addressed before by inspecting, cleaning, transforming, and modeling the $CO_2$ emissions and energy generation data from the Energy Information Administration (*EIA*). We vary from different mileage to study the $CO_2$ emissions assuming different mileages per year, different miles per gallon for gasoline vehicles and different miles per *kWh*. We simulate the data in order to study the $CO_2$ emissions produced by an *EV* or a gasoline vehicle.

## 4.1 Data description

All the data in this study are taken from *U.S.* Energy Information and Administrations reports published by *EIA* [10]. Each report consists of a spreadsheet that provides the following data:

- Electricity net generation (*MWh*) data by state and by energy source ;
- U.S. Electric Power Industry Estimated Emissions (Metric tons of $CO_2$) by State.

The data used is the data from year 2012, which was the most recent year with all the detailed data. All the data available at the time of this study from the *IEA* reports were analyzed. The Appendix A is an example of data used for the thesis once it was studied, analyzed, inspected, modeled and cleaned.

## 4.2 Analysis of the data

In this section we analyze data on annual energy generation quantities and annual metric tons of $CO_2$ emitted. As stated before, California and Illinois differ on how the electricity is produced. For this study we have made certain assumptions in order to give a detailed explanation:

- The average mileage per year in the *U.S.* is 12.500 miles
- The average consumption of a gasoline vehicle is 35.5 miles per gallon
- The average energy consumption of an *EV* is 3.25 miles per *kWh*
- The grams of $CO_2$ per gallon emitted by U.S. is 8.887 $g\ CO_2/gallon$
- The efficiency of lead-acid batteries is about 60% and 72% for lithium batteries.
- The efficiency due to the transportation of the gasoline is 87%
- In order to make a more accurate comparison we are differentiating: variable mileage per year driven, miles per *kWh* consumed by an *EV* and miles per gallon consumed by a gasoline vehicle.
- We assume how much would improve to change from polluting energy sources to clean energy sources in the future.

As stated in the section 3.3 Comparison, in 2012 in Illinois around 41% of the annual energy generation comes from coal and around a 6% comes from natural gas. In California 60% of the annual generation comes from natural gas and less than 1% comes from coal. Coal electricity is the most polluting source.

The following is an elaboration of how we proceeded in the studying differentiating from EVs and gasoline vehicles.

### 4.1.1 Electric vehicles

For the calculations of the $CO_2$ emissions an *EV* has in a year we must differentiate between the three main phases of the energy path: production, transportation and consumption. The data analyzed includes both production and transportation together. The consumption emissions are the tailpipe emissions and for *EV* is zero.

We vary the miles per *kWh* from 1.5 to 4, we differentiate also different mileage per year and we calculate the *kWh* per year consumed by a single car in a year. Hereafter, differentiating between lead-acid batteries and lithium batteries we calculated the real *kWh* consumed by an *EV*.

From the data reports from [10], the annual energy generation from source and the $CO_2$ emissions by source, we calculate the metric tons of $CO_2$ emitted by *kWh* generated by source.

Table 4.1 Metric tons of $CO_2$ emitted per *kWh* generated by source

| STATE | Coal | Natural Gas |
|---|---|---|
| CA | 0,001892807 | 0,000466794 |
| IL | 0,001093227 | 0,000533855 |

Once we know the *kWh* consumed by a single car in a year and the metric tons of $CO_2$ emitted by source we calculate the metric tons of $CO_2$ emitted by driving only on one source. For example, driving only on coal in Illinois with an average mileage of 12.500 per year and driving at the average 3.25 miles/*kWh* would produce 7,0078659 metric tons of $CO_2$ while in California would emit 12,133377 metric tons of $CO_2$.

As previously stated California and Illinois have different grid mix and taking into account those different grid mixes we calculate the $CO_2$ emitted by a single car in a year.

The average mileage per year in the *U.S.* is 12.500 miles. As reported in U.S. Department of transportation Federal Highway Administration [12]. Figure 4.1 and figure 4.2

show how the $CO_2$ emissions change by varying the mileage per year from a vehicle depending on the miles per gallon consumed.

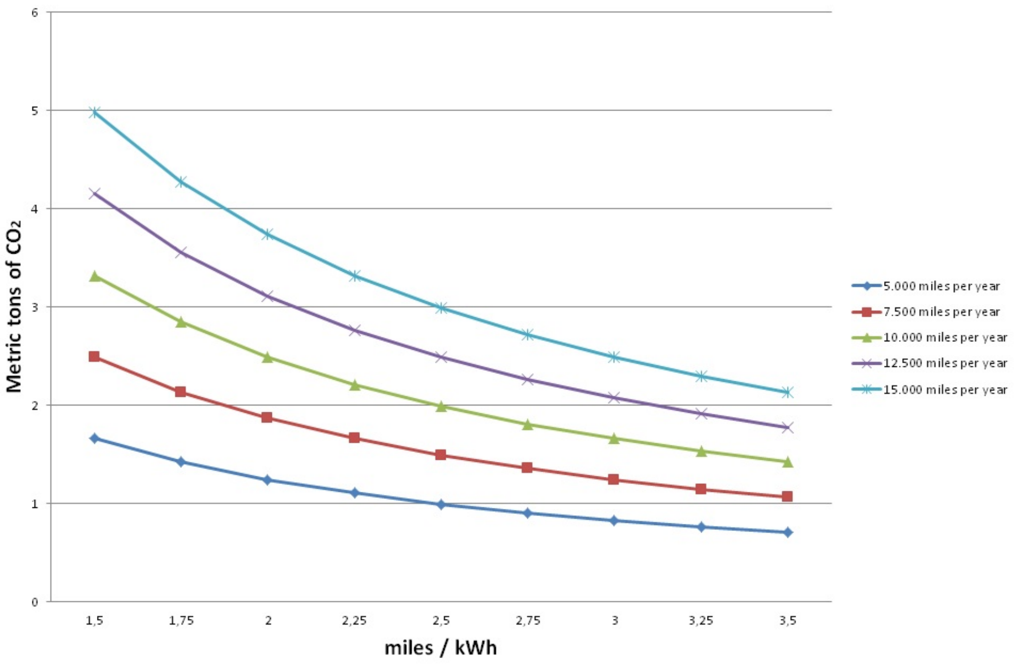



**Figure 4.1. This figure shows the metric tons of $CO_2$ emitted depending on the miles per $kWh$ consumed and varying the mileage per year a single vehicle drives in California**

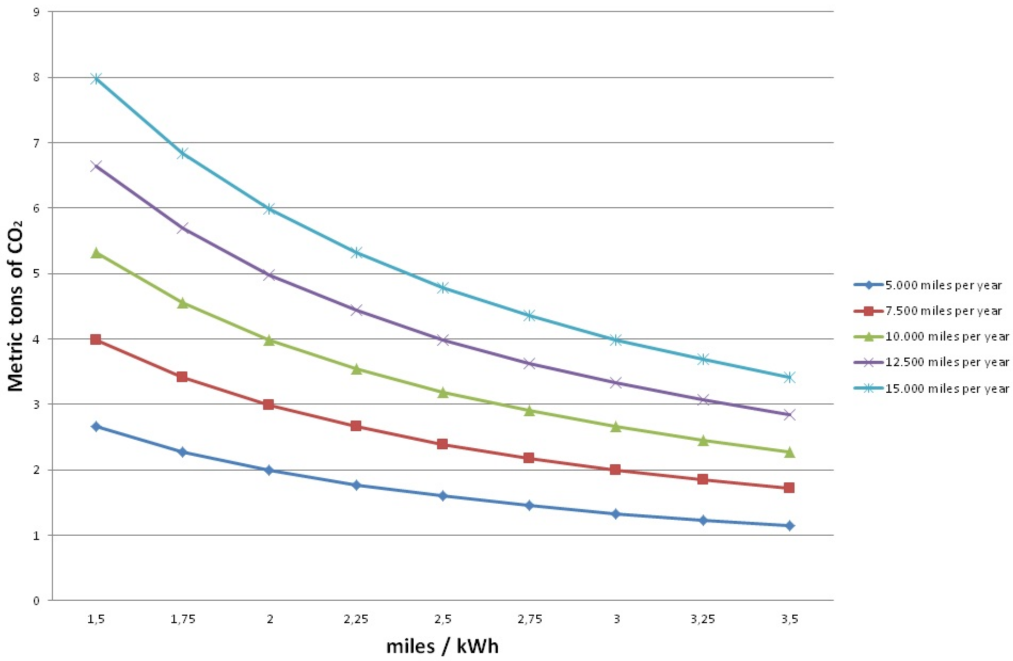



**Figure 4.2. This figure shows the metric tons of $CO_2$ emitted depending on the miles per $kWh$ consumed and varying the mileage per year a single vehicle drives in Illinois**

As figure 4.1 and figure 4.2 show it is less polluting to drive on electricity in California than in Illinois.

We also have to differentiate between the two main types of batteries, lead-acid batteries with 60% efficiency and lithium batteries with *75%* efficiency. Figure 4.3 shows the importance of improving the batteries in order not to emit an excess of $CO_2$. We can appreciate that the lithium battery is better than the lead-acid battery.

Doing the same procedure as stated before, we obtain figure 4.3.

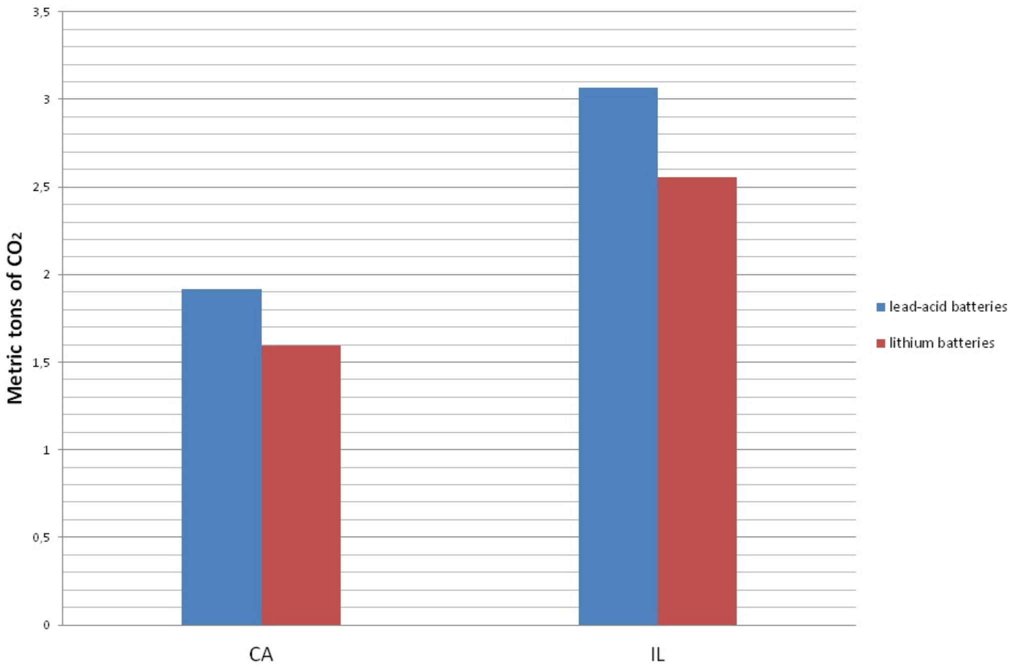



**Figure 4.3. This figure shows the metric tons of $CO_2$ emitted depending on the type of battery of an *EV* in the year 2012**

### 4.1.2 Gasoline vehicles

For the $CO_2$ emissions calculations a gasoline vehicle has in a year as we have done with the *EVs*, we must differentiate between the three main phases of the energy path: production, transportation and consumption.

The production of the gasoline does not represent an important percentage in the total $CO_2$ emissions. Table 4.2 shows the $CO_2$ emissions from gasoline production depending on where it was produced.

Table 4.2 $CO_2$ emissions from gasoline production

| State | Total $CO_2$ (Metric Tons) | Total Cars | $CO_2$ by Car (Metric Tons) |
|---|---|---|---|
| CA | 251.176 | 29.177.000 | 0,0086087 |
| IL | 58.253 | 10.440.000 | 0,0055798 |

We have to take into account that the production of gasoline in Illinois is less than in California, but Illinois imports its gasoline from other states and countries, Canada is the main distributor of oil to Illinois. These $CO_2$ emissions derived for the gasoline imports are included in the transportation and consumption data.

We study the effect of the variation of the miles per gallon from 15 to 40, we differentiate also various mileages per year and we calculate the gallons per year consumed by a single car in a year. According to the data from [5] the transportation of the gasoline produces about a 13% of the emissions that the consumption of the gasoline would produce. We calculate the real gallons of gasoline a car consumes every year. According to United States Environmental Protection Agency (*EPA*), to obtain the number of grams of $CO_2$ emitted per gallon of gasoline combusted, the heat content of the fuel per gallon is multiplied by the *kg* $CO_2$ per heat content of the fuel. *EPA* stated that they had agreed to use a common conversion factor of 8,887 grams of $CO_2$ emissions per gallon of gasoline consumed.

Figure 4.4 show how the $CO_2$ emissions change by varying the mileage per year from a vehicle depending on the miles per gallon consumed.

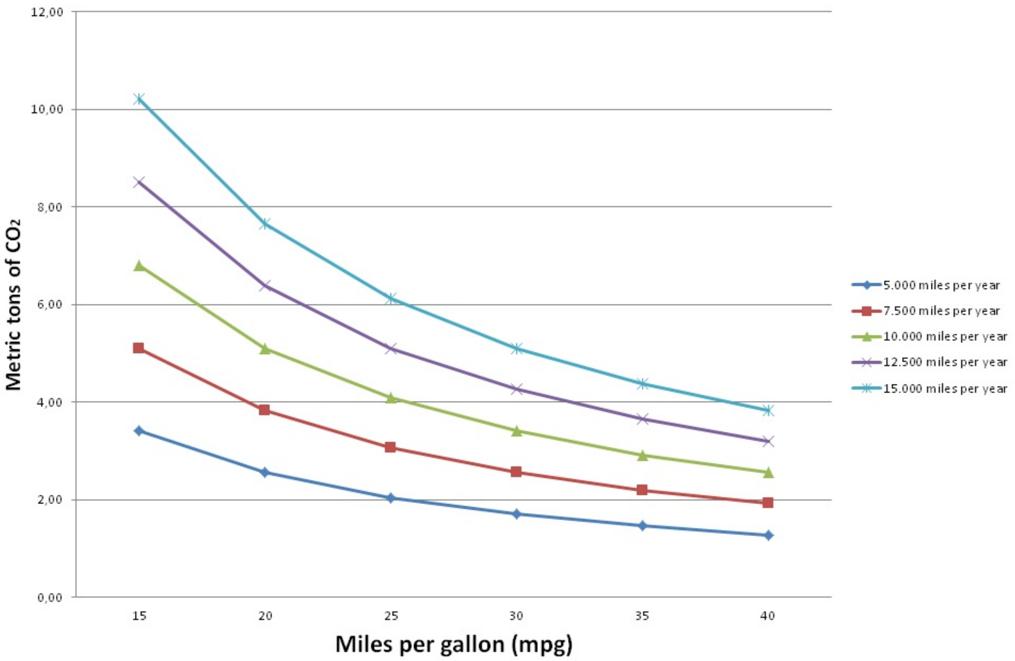



**Figure 4.4. This figure shows the metric tons of $CO_2$ emitted depending on the miles per gallon consumed and varying the mileage per year a single vehicle**

# 5 CONCLUDING REMARKS

In this thesis we focused on the analysis and quantification of the $CO_2$ emissions of an *EV* in comparison to a gasoline vehicle. Our study of the 2012 period provided a good basis for analyzing the $CO_2$ emissions and energy generation data by considering all the factors addressed before by inspecting, cleaning, transforming, and modeling the $CO_2$ emissions and energy generation data.

In the analysis of the $CO_2$ emissions data we found that driving on electricity rather on gasoline is less polluting. We can affirm that *EVs* have a great margin for improvement. Its improvement is straightly related to the energy generation grid mix. Driving an *EV* with the electricity generated from renewable sources can be considerate as a non-polluting vehicle.

As a further study, we have made a study on how many years will it take to achieve this magnificent opportunity. By changing every year only 2% of the total energy generation from coal burning or natural gas to renewable sources we will be able to drive without any $CO_2$ emissions. Figure 5.1 shows how different would it be depending on the state we are driving, California or Illinois.

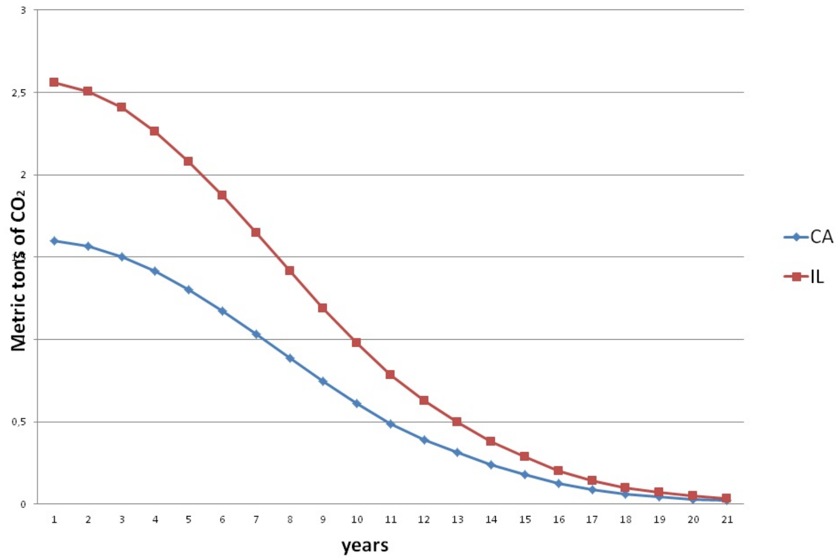



**Figure 5.1. This figure shows the metric tons of $CO_2$ emitted by a single car in a year if changing the energy grid mix**

# REFERENCES

# REFERENCES

[1] "TOYOTA PRIUS" Available at: http://self.gutenberg.org/articles/toyota_prius

[2] ENERGY.GOV (September 2014). HISTORY OF THE EV. Available at: http://energy.gov/articles/history-electric-car

[3] ENERGY.GOV (June-July 2012). EV EVERYWHERE GRAND CHALLENGE: DOE'S 10-YEAR VISION FOR PLUG-IN ELECTRIC VEHICLES. Available at: http://energy.gov/eere/vehicles/ev-everywhere-grand-challenge-does-10-year-vision-plug-electric-vehicles

[4] BMW of North America, LLC. [Online]. INTRODUCING THE BMW I CHARGEFORWARD PROGRAM. Available at: http://www.bmwichargeforward.com/

[5] P. J. Van Mierlo and Y. Marenne. *European Association for Battery Electric Vehicles*, "Energy consumption, CO2 emissions and other considerations related to Battery Electric Vehicles", April 2009. Available at: http://ec.europa.eu/transport/themes/strategies/consultations/doc/2009_03_27_future_of_transport/20090408_eabev_%28scientific_study%29.pdf

[6] M. Eberhard and M. Tarpenning, " The 21st Century Electric car", Tesla Motors Inc. 2006.

[7] U.S. Department of Energy. Energy Efficiency and Renewable Energy. [Online]. Available at: http://www.fueleconomy.gov/

[8] D. Anair and A. Mahmassani, "State of Charge. Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings across the United States", June 2012. Available at: http://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_vehicles/electric-car-global-warming-emissions-report.pdf

[9] Union of Concerned Scientist (2010). Illinois' Dependence on Imported Coal. Burning Coal, Burning Cash. Available at: http://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_energy/UCS-BCBC-factsheet-Illinois.pdf

[10] Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923) EIA, U.S. Energy information administration, Independent

Statistics and Analysis [Online]. Available at: http://www.eia.gov/electricity/data/state/

[11] U.S. Electric Power Industry Estimated Emissions by State (EIA-767, EIA-906, EIA-920, and EIA-923) EIA, U.S. Energy information administration, Independent Statistics and Analysis [Online]. Available at: http://www.eia.gov/electricity/data/state/

[12] United States department of transportation, Research, Statistics and Technology. Available at: http://www.dot.gov/

[13] U.S. Department of transportation. Federal Highway Administration. Available at: http://www.fhwa.dot.gov/

[14] E. Valsera-Naranjo, A. Sumper, P. Lloret-Gallego, R. Villafáfila and A. Sudria-Andreu, "Electrical vehicles: State of Art and issues for their Connection to the network", *IEEE International Conference on Electrical Power Quality and Utilisation*, pp. 1-3, September 2009.

[15] J. Alson, "Overview of Electric Vehicle Market Issues in the U.S", *U.S. Environmental Protection Agency*, EVE Informal Working Group Meeting #2, September 2012

[16] "How do gasoline & electric vehicles compare?". Advanced Vehicle Testing Agency, Idaho National Laboratory. Available at: http://www.avt.inl.gov/

# APPENDIX

# APPENDIX A

These tables represent the $CO_2$ emissions data from California and Illinois taking into consideration all the factors addressed before by inspecting, cleaning, transforming, and modeling the $CO_2$ emissions and energy generation data from the Energy Information Administration (*EIA*).

| STATE | Miles per *kWh* | Mileage per ye | *kWh* per yea | Battery efficienc | Real *kWh* | Coal (Metric tons of CO2/ *kWh*) | Natural Gas (Metric tons of CO2/ *kWh*) | CO2 only on Coal | CO2 only on Natural G | TOTAL According to Grid mix CA(2012 |
|---|---|---|---|---|---|---|---|---|---|---|
| CA | 1,5 | 5.000 | 3.333 | 0,6 | 5555,56 | 0,001892807 | 0,000466794 | 10,5155937 | 2,5932995 | 1,66113564 |
| CA | 1,75 | 5.000 | 2.857 | 0,6 | 4761,90 | 0,001892807 | 0,000466794 | 9,01336604 | 2,22282814 | 1,42383055 |
| CA | 2 | 5.000 | 2.500 | 0,6 | 4166,67 | 0,001892807 | 0,000466794 | 7,88669528 | 1,94497462 | 1,24585173 |
| CA | 2,25 | 5.000 | 2.222 | 0,6 | 3703,70 | 0,001892807 | 0,000466794 | 7,01039581 | 1,72886633 | 1,10742376 |
| CA | 2,5 | 5.000 | 2.000 | 0,6 | 3333,33 | 0,001892807 | 0,000466794 | 6,30935622 | 1,5559797 | 0,99668138 |
| CA | 2,75 | 5.000 | 1.818 | 0,6 | 3030,30 | 0,001892807 | 0,000466794 | 5,73577839 | 1,414527 | 0,90607398 |
| CA | 3 | 5.000 | 1.667 | 0,6 | 2777,78 | 0,001892807 | 0,000466794 | 5,25779685 | 1,29664975 | 0,83056782 |
| CA | 3,25 | 5.000 | 1.538 | 0,6 | 2564,10 | 0,001892807 | 0,000466794 | 4,85335094 | 1,19690746 | 0,76667799 |
| CA | 3,5 | 5.000 | 1.429 | 0,6 | 2380,95 | 0,001892807 | 0,000466794 | 4,50668302 | 1,11141407 | 0,71191527 |
| CA | 1,5 | 7.500 | 5.000 | 0,6 | 8333,33 | 0,001892807 | 0,000466794 | 15,7733906 | 3,88994925 | 2,49170345 |
| CA | 1,75 | 7.500 | 4.286 | 0,6 | 7142,86 | 0,001892807 | 0,000466794 | 13,5200491 | 3,33424221 | 2,13574582 |
| CA | 2 | 7.500 | 3.750 | 0,6 | 6250,00 | 0,001892807 | 0,000466794 | 11,8300429 | 2,91746194 | 1,86877759 |
| CA | 2,25 | 7.500 | 3.333 | 0,6 | 5555,56 | 0,001892807 | 0,000466794 | 10,5155937 | 2,5932995 | 1,66113564 |
| CA | 2,5 | 7.500 | 3.000 | 0,6 | 5000,00 | 0,001892807 | 0,000466794 | 9,46403434 | 2,33396955 | 1,49502207 |
| CA | 2,75 | 7.500 | 2.727 | 0,6 | 4545,45 | 0,001892807 | 0,000466794 | 8,60366758 | 2,1217905 | 1,35911098 |
| CA | 3 | 7.500 | 2.500 | 0,6 | 4166,67 | 0,001892807 | 0,000466794 | 7,88669528 | 1,94497462 | 1,24585173 |
| CA | 3,25 | 7.500 | 2.308 | 0,6 | 3846,15 | 0,001892807 | 0,000466794 | 7,28002641 | 1,79536119 | 1,15001698 |
| CA | 3,5 | 7.500 | 2.143 | 0,6 | 3571,43 | 0,001892807 | 0,000466794 | 6,76002453 | 1,66712111 | 1,06787291 |
| CA | 1,5 | 10.000 | 6.667 | 0,6 | 11111,11 | 0,001892807 | 0,000466794 | 21,0311874 | 5,186599 | 3,32227127 |
| CA | 1,75 | 10.000 | 5.714 | 0,6 | 9523,81 | 0,001892807 | 0,000466794 | 18,0267321 | 4,44565628 | 2,84766109 |
| CA | 2 | 10.000 | 5.000 | 0,6 | 8333,33 | 0,001892807 | 0,000466794 | 15,7733906 | 3,88994925 | 2,49170345 |
| CA | 2,25 | 10.000 | 4.444 | 0,6 | 7407,41 | 0,001892807 | 0,000466794 | 14,0207916 | 3,45773267 | 2,21484752 |
| CA | 2,5 | 10.000 | 4.000 | 0,6 | 6666,67 | 0,001892807 | 0,000466794 | 12,6187124 | 3,1119594 | 1,99336276 |
| CA | 2,75 | 10.000 | 3.636 | 0,6 | 6060,61 | 0,001892807 | 0,000466794 | 11,4715568 | 2,829054 | 1,81214797 |
| CA | 3 | 10.000 | 3.333 | 0,6 | 5555,56 | 0,001892807 | 0,000466794 | 10,5155937 | 2,5932995 | 1,66113564 |
| CA | 3,25 | 10.000 | 3.077 | 0,6 | 5128,21 | 0,001892807 | 0,000466794 | 9,70670188 | 2,39381492 | 1,53335597 |
| CA | 3,5 | 10.000 | 2.857 | 0,6 | 4761,90 | 0,001892807 | 0,000466794 | 9,01336604 | 2,22282814 | 1,42383055 |
| CA | 1,5 | 12.500 | 8.333 | 0,6 | 13888,89 | 0,001892807 | 0,000466794 | 26,2889843 | 6,48324875 | 4,15283909 |
| CA | 1,75 | 12.500 | 7.143 | 0,6 | 11904,76 | 0,001892807 | 0,000466794 | 22,5334151 | 5,55707035 | 3,55957636 |
| CA | 2 | 12.500 | 6.250 | 0,6 | 10416,67 | 0,001892807 | 0,000466794 | 19,7167382 | 4,86243656 | 3,11462932 |
| CA | 2,25 | 12.500 | 5.556 | 0,6 | 9259,26 | 0,001892807 | 0,000466794 | 17,5259895 | 4,32216583 | 2,76855939 |
| CA | 2,5 | 12.500 | 5.000 | 0,6 | 8333,33 | 0,001892807 | 0,000466794 | 15,7733906 | 3,88994925 | 2,49170345 |
| CA | 2,75 | 12.500 | 4.545 | 0,6 | 7575,76 | 0,001892807 | 0,000466794 | 14,339446 | 3,5363175 | 2,26518496 |
| CA | 3 | 12.500 | 4.167 | 0,6 | 6944,44 | 0,001892807 | 0,000466794 | 13,1444921 | 3,24162437 | 2,07641955 |
| CA | 3,25 | 12.500 | 3.846 | 0,6 | 6410,26 | 0,001892807 | 0,000466794 | 12,1333774 | 2,99226865 | 1,91669497 |
| CA | 3,5 | 12.500 | 3.571 | 0,6 | 5952,38 | 0,001892807 | 0,000466794 | 11,2667075 | 2,77853518 | 1,77978818 |
| CA | 1,5 | 15.000 | 10.000 | 0,6 | 16666,67 | 0,001892807 | 0,000466794 | 31,5467811 | 7,7798985 | 4,98340691 |
| CA | 1,75 | 15.000 | 8.571 | 0,6 | 14285,71 | 0,001892807 | 0,000466794 | 27,0400981 | 6,66848443 | 4,27149164 |
| CA | 2 | 15.000 | 7.500 | 0,6 | 12500,00 | 0,001892807 | 0,000466794 | 23,6600858 | 5,83492387 | 3,73755518 |
| CA | 2,25 | 15.000 | 6.667 | 0,6 | 11111,11 | 0,001892807 | 0,000466794 | 21,0311874 | 5,186599 | 3,32227127 |
| CA | 2,5 | 15.000 | 6.000 | 0,6 | 10000,00 | 0,001892807 | 0,000466794 | 18,9280687 | 4,6679391 | 2,99004415 |
| CA | 2,75 | 15.000 | 5.455 | 0,6 | 9090,91 | 0,001892807 | 0,000466794 | 17,2073352 | 4,243581 | 2,71822195 |
| CA | 3 | 15.000 | 5.000 | 0,6 | 8333,33 | 0,001892807 | 0,000466794 | 15,7733906 | 3,88994925 | 2,49170345 |
| CA | 3,25 | 15.000 | 4.615 | 0,6 | 7692,31 | 0,001892807 | 0,000466794 | 14,5600528 | 3,59072238 | 2,30003396 |
| CA | 3,5 | 15.000 | 4.286 | 0,6 | 7142,86 | 0,001892807 | 0,000466794 | 13,5200491 | 3,33424221 | 2,13574582 |

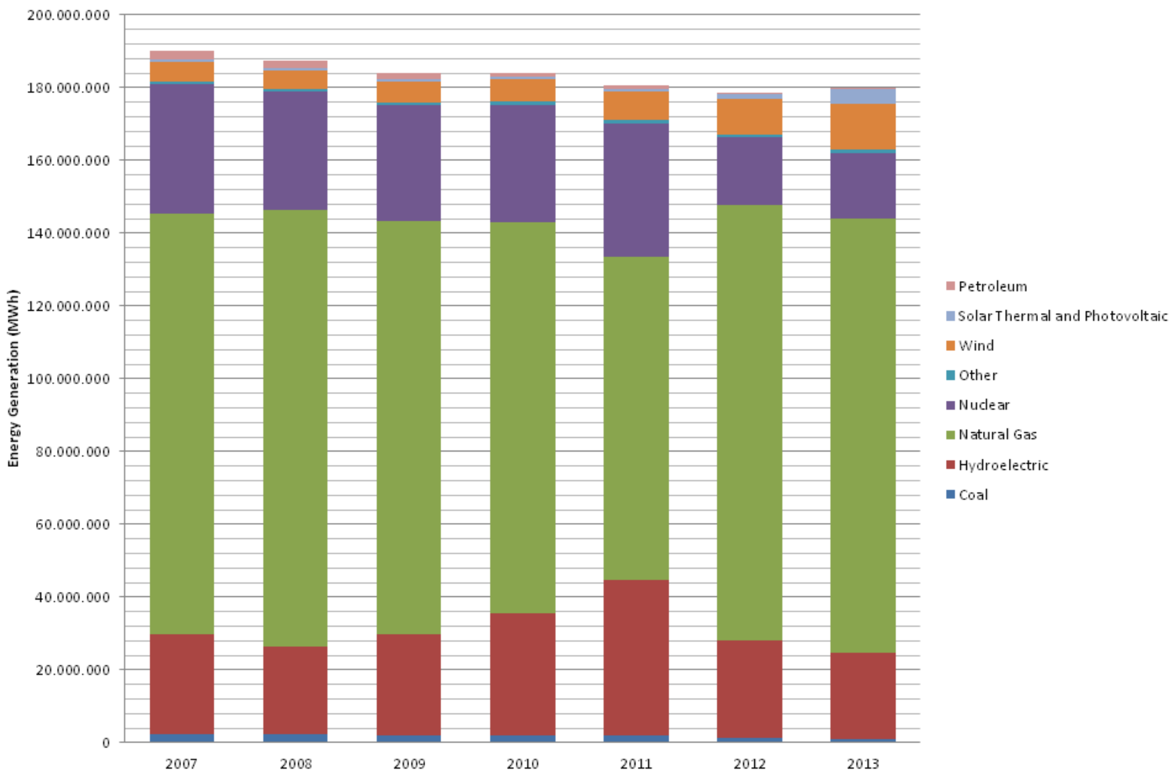
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| CA | 1,5 | 12.500 | 8.333 | 0,72 | 11574,07 | 0,001892807 | 0,000466794 | 21,9074869 | 5,40270729 | 3,46069924 |
| CA | 1,75 | 12.500 | 7.143 | 0,72 | 9920,63 | 0,001892807 | 0,000466794 | 18,7778459 | 4,63089196 | 2,96631364 |
| CA | 2 | 12.500 | 6.250 | 0,72 | 8680,56 | 0,001892807 | 0,000466794 | 16,4306152 | 4,05203047 | 2,59552443 |
| CA | 2,25 | 12.500 | 5.556 | 0,72 | 7716,05 | 0,001892807 | 0,000466794 | 14,6049913 | 3,60180486 | 2,30713283 |
| CA | 2,5 | 12.500 | 5.000 | 0,72 | 6944,44 | 0,001892807 | 0,000466794 | 13,1444921 | 3,24162437 | 2,07641955 |
| CA | 2,75 | 12.500 | 4.545 | 0,72 | 6313,13 | 0,001892807 | 0,000466794 | 11,9495383 | 2,94693125 | 1,88765413 |
| CA | 3 | 12.500 | 4.167 | 0,72 | 5787,04 | 0,001892807 | 0,000466794 | 10,9537434 | 2,70135364 | 1,73034962 |
| CA | 3,25 | 12.500 | 3.846 | 0,72 | 5341,88 | 0,001892807 | 0,000466794 | 10,1111478 | 2,49355721 | 1,5972458 |
| CA | 3,5 | 12.500 | 3.571 | 0,72 | 4960,32 | 0,001892807 | 0,000466794 | 9,38892295 | 2,31544598 | 1,48315682 |
| CA | 1,5 | 5.000 | 3.333 | 0,72 | 4629,63 | 0,001892807 | 0,000466794 | 8,76299476 | 2,16108292 | 1,3842797 |
| CA | 1,75 | 5.000 | 2.857 | 0,72 | 3968,25 | 0,001892807 | 0,000466794 | 7,51113836 | 1,85235678 | 1,18652545 |
| CA | 2 | 5.000 | 2.500 | 0,72 | 3472,22 | 0,001892807 | 0,000466794 | 6,57224607 | 1,62081219 | 1,03820977 |
| CA | 2,25 | 5.000 | 2.222 | 0,72 | 3086,42 | 0,001892807 | 0,000466794 | 5,8419965 | 1,44072194 | 0,92285313 |
| CA | 2,5 | 5.000 | 2.000 | 0,72 | 2777,78 | 0,001892807 | 0,000466794 | 5,25779685 | 1,29664975 | 0,83056782 |
| CA | 2,75 | 5.000 | 1.818 | 0,72 | 2525,25 | 0,001892807 | 0,000466794 | 4,77981532 | 1,1787725 | 0,75506165 |
| CA | 3 | 5.000 | 1.667 | 0,72 | 2314,81 | 0,001892807 | 0,000466794 | 4,38149738 | 1,08054146 | 0,69213985 |
| CA | 3,25 | 5.000 | 1.538 | 0,72 | 2136,75 | 0,001892807 | 0,000466794 | 4,04445912 | 0,99742288 | 0,63889832 |
| CA | 3,5 | 5.000 | 1.429 | 0,72 | 1984,13 | 0,001892807 | 0,000466794 | 3,75556918 | 0,92617839 | 0,59326273 |
| CA | 1,5 | 7.500 | 5.000 | 0,72 | 6944,44 | 0,001892807 | 0,000466794 | 13,1444921 | 3,24162437 | 2,07641955 |
| CA | 1,75 | 7.500 | 4.286 | 0,72 | 5952,38 | 0,001892807 | 0,000466794 | 11,2667075 | 2,77853518 | 1,77978818 |
| CA | 2 | 7.500 | 3.750 | 0,72 | 5208,33 | 0,001892807 | 0,000466794 | 9,8583691 | 2,43121828 | 1,55731466 |
| CA | 2,25 | 7.500 | 3.333 | 0,72 | 4629,63 | 0,001892807 | 0,000466794 | 8,76299476 | 2,16108292 | 1,3842797 |
| CA | 2,5 | 7.500 | 3.000 | 0,72 | 4166,67 | 0,001892807 | 0,000466794 | 7,88669528 | 1,94497462 | 1,24585173 |
| CA | 2,75 | 7.500 | 2.727 | 0,72 | 3787,88 | 0,001892807 | 0,000466794 | 7,16972298 | 1,76815875 | 1,13259248 |
| CA | 3 | 7.500 | 2.500 | 0,72 | 3472,22 | 0,001892807 | 0,000466794 | 6,57224607 | 1,62081219 | 1,03820977 |
| CA | 3,25 | 7.500 | 2.308 | 0,72 | 3205,13 | 0,001892807 | 0,000466794 | 6,06668868 | 1,49613433 | 0,95834748 |
| CA | 3,5 | 7.500 | 2.143 | 0,72 | 2976,19 | 0,001892807 | 0,000466794 | 5,63335377 | 1,38926759 | 0,88989409 |
| CA | 1,5 | 10.000 | 6.667 | 0,72 | 9259,26 | 0,001892807 | 0,000466794 | 17,5259895 | 4,32216583 | 2,76855939 |
| CA | 1,75 | 10.000 | 5.714 | 0,72 | 7936,51 | 0,001892807 | 0,000466794 | 15,0222767 | 3,70471357 | 2,37305091 |
| CA | 2 | 10.000 | 5.000 | 0,72 | 6944,44 | 0,001892807 | 0,000466794 | 13,1444921 | 3,24162437 | 2,07641955 |
| CA | 2,25 | 10.000 | 4.444 | 0,72 | 6172,84 | 0,001892807 | 0,000466794 | 11,683993 | 2,88144389 | 1,84570626 |
| CA | 2,5 | 10.000 | 4.000 | 0,72 | 5555,56 | 0,001892807 | 0,000466794 | 10,5155937 | 2,5932995 | 1,66113564 |
| CA | 2,75 | 10.000 | 3.636 | 0,72 | 5050,51 | 0,001892807 | 0,000466794 | 9,55963064 | 2,357545 | 1,51012331 |
| CA | 3 | 10.000 | 3.333 | 0,72 | 4629,63 | 0,001892807 | 0,000466794 | 8,76299476 | 2,16108292 | 1,3842797 |
| CA | 3,25 | 10.000 | 3.077 | 0,72 | 4273,50 | 0,001892807 | 0,000466794 | 8,08891824 | 1,99484577 | 1,27779664 |
| CA | 3,5 | 10.000 | 2.857 | 0,72 | 3968,25 | 0,001892807 | 0,000466794 | 7,51113836 | 1,85235678 | 1,18652545 |
| CA | 1,5 | 15.000 | 10.000 | 0,72 | 13888,89 | 0,001892807 | 0,000466794 | 26,2889843 | 6,48324875 | 4,15283909 |
| CA | 1,75 | 15.000 | 8.571 | 0,72 | 11904,76 | 0,001892807 | 0,000466794 | 22,5334151 | 5,55707035 | 3,55957636 |
| CA | 2 | 15.000 | 7.500 | 0,72 | 10416,67 | 0,001892807 | 0,000466794 | 19,7167382 | 4,86243656 | 3,11462932 |
| CA | 2,25 | 15.000 | 6.667 | 0,72 | 9259,26 | 0,001892807 | 0,000466794 | 17,5259895 | 4,32216583 | 2,76855939 |
| CA | 2,5 | 15.000 | 6.000 | 0,72 | 8333,33 | 0,001892807 | 0,000466794 | 15,7733906 | 3,88994925 | 2,49170345 |
| CA | 2,75 | 15.000 | 5.455 | 0,72 | 7575,76 | 0,001892807 | 0,000466794 | 14,339446 | 3,5363175 | 2,26518496 |
| CA | 3 | 15.000 | 5.000 | 0,72 | 6944,44 | 0,001892807 | 0,000466794 | 13,1444921 | 3,24162437 | 2,07641955 |
| CA | 3,25 | 15.000 | 4.615 | 0,72 | 6410,26 | 0,001892807 | 0,000466794 | 12,1333774 | 2,99226865 | 1,91669497 |
| CA | 3,5 | 15.000 | 4.286 | 0,72 | 5952,38 | 0,001892807 | 0,000466794 | 11,2667075 | 2,77853518 | 1,77978818 |

| STATE | Miles per $kWh$ | Mileage per ye | $kWh$ per yea | Battery efficienc | Real $kWh$ | Coal (Metric tons of CO2/ $kWh$) | Natural Gas (Metric tons of CO2/ $kWh$) | CO2 only on Coal | CO2 only on Natural G | TOTAL According to Grid mix IL(2012) |
|---|---|---|---|---|---|---|---|---|---|---|
| IL | 1,5 | 5.000 | 3.333 | 0,6 | 5555,56 | 0,001093227 | 0,000533855 | 6,07348377 | 2,96586051 | 2,65918239 |
| IL | 1,75 | 5.000 | 2.857 | 0,6 | 4761,90 | 0,001093227 | 0,000533855 | 5,20584323 | 2,54216615 | 2,2792992 |
| IL | 2 | 5.000 | 2.500 | 0,6 | 4166,67 | 0,001093227 | 0,000533855 | 4,55511283 | 2,22439538 | 1,9943868 |
| IL | 2,25 | 5.000 | 2.222 | 0,6 | 3703,70 | 0,001093227 | 0,000533855 | 4,04898918 | 1,97724034 | 1,77278826 |
| IL | 2,5 | 5.000 | 2.000 | 0,6 | 3333,33 | 0,001093227 | 0,000533855 | 3,64409026 | 1,7795163 | 1,59550944 |
| IL | 2,75 | 5.000 | 1.818 | 0,6 | 3030,30 | 0,001093227 | 0,000533855 | 3,31280933 | 1,61774209 | 1,45046312 |
| IL | 3 | 5.000 | 1.667 | 0,6 | 2777,78 | 0,001093227 | 0,000533855 | 3,03674188 | 1,48293025 | 1,3295912 |
| IL | 3,25 | 5.000 | 1.538 | 0,6 | 2564,10 | 0,001093227 | 0,000533855 | 2,80314635 | 1,3688587 | 1,22731495 |
| IL | 3,5 | 5.000 | 1.429 | 0,6 | 2380,95 | 0,001093227 | 0,000533855 | 2,60292162 | 1,27108307 | 1,1396496 |
| IL | 1,5 | 7.500 | 5.000 | 0,6 | 8333,33 | 0,001093227 | 0,000533855 | 9,11022565 | 4,44879076 | 3,98877359 |
| IL | 1,75 | 7.500 | 4.286 | 0,6 | 7142,86 | 0,001093227 | 0,000533855 | 7,80876485 | 3,81324922 | 3,41894879 |
| IL | 2 | 7.500 | 3.750 | 0,6 | 6250,00 | 0,001093227 | 0,000533855 | 6,83266924 | 3,33659307 | 2,99158019 |
| IL | 2,25 | 7.500 | 3.333 | 0,6 | 5555,56 | 0,001093227 | 0,000533855 | 6,07348377 | 2,96586051 | 2,65918239 |
| IL | 2,5 | 7.500 | 3.000 | 0,6 | 5000,00 | 0,001093227 | 0,000533855 | 5,46613539 | 2,66927446 | 2,39326415 |
| IL | 2,75 | 7.500 | 2.727 | 0,6 | 4545,45 | 0,001093227 | 0,000533855 | 4,96921399 | 2,42661314 | 2,17569469 |
| IL | 3 | 7.500 | 2.500 | 0,6 | 4166,67 | 0,001093227 | 0,000533855 | 4,55511283 | 2,22439538 | 1,9943868 |
| IL | 3,25 | 7.500 | 2.308 | 0,6 | 3846,15 | 0,001093227 | 0,000533855 | 4,20471953 | 2,05328804 | 1,84097243 |
| IL | 3,5 | 7.500 | 2.143 | 0,6 | 3571,43 | 0,001093227 | 0,000533855 | 3,90438242 | 1,90662461 | 1,7094744 |
| IL | 1,5 | 10.000 | 6.667 | 0,6 | 11111,11 | 0,001093227 | 0,000533855 | 12,1469675 | 5,93172101 | 5,31836479 |
| IL | 1,75 | 10.000 | 5.714 | 0,6 | 9523,81 | 0,001093227 | 0,000533855 | 10,4116865 | 5,0843323 | 4,55859839 |
| IL | 2 | 10.000 | 5.000 | 0,6 | 8333,33 | 0,001093227 | 0,000533855 | 9,11022565 | 4,44879076 | 3,98877359 |
| IL | 2,25 | 10.000 | 4.444 | 0,6 | 7407,41 | 0,001093227 | 0,000533855 | 8,09797836 | 3,95448068 | 3,54557653 |
| IL | 2,5 | 10.000 | 4.000 | 0,6 | 6666,67 | 0,001093227 | 0,000533855 | 7,28818052 | 3,55903261 | 3,19101887 |
| IL | 2,75 | 10.000 | 3.636 | 0,6 | 6060,61 | 0,001093227 | 0,000533855 | 6,62561866 | 3,23548419 | 2,90092625 |
| IL | 3 | 10.000 | 3.333 | 0,6 | 5555,56 | 0,001093227 | 0,000533855 | 6,07348377 | 2,96586051 | 2,65918239 |
| IL | 3,25 | 10.000 | 3.077 | 0,6 | 5128,21 | 0,001093227 | 0,000533855 | 5,60629271 | 2,73771739 | 2,4546299 |
| IL | 3,5 | 10.000 | 2.857 | 0,6 | 4761,90 | 0,001093227 | 0,000533855 | 5,20584323 | 2,54216615 | 2,2792992 |
| IL | 1,5 | 15.000 | 10.000 | 0,6 | 16666,67 | 0,001093227 | 0,000533855 | 18,2204513 | 8,89758152 | 7,97754718 |
| IL | 1,75 | 15.000 | 8.571 | 0,6 | 14285,71 | 0,001093227 | 0,000533855 | 15,6175297 | 7,62649845 | 6,83789759 |
| IL | 2 | 15.000 | 7.500 | 0,6 | 12500,00 | 0,001093227 | 0,000533855 | 13,6653385 | 6,67318614 | 5,98316039 |
| IL | 2,25 | 15.000 | 6.667 | 0,6 | 11111,11 | 0,001093227 | 0,000533855 | 12,1469675 | 5,93172101 | 5,31836479 |
| IL | 2,5 | 15.000 | 6.000 | 0,6 | 10000,00 | 0,001093227 | 0,000533855 | 10,9322708 | 5,33854891 | 4,78652831 |
| IL | 2,75 | 15.000 | 5.455 | 0,6 | 9090,91 | 0,001093227 | 0,000533855 | 9,93842799 | 4,85322628 | 4,35138937 |
| IL | 3 | 15.000 | 5.000 | 0,6 | 8333,33 | 0,001093227 | 0,000533855 | 9,11022565 | 4,44879076 | 3,98877359 |
| IL | 3,25 | 15.000 | 4.615 | 0,6 | 7692,31 | 0,001093227 | 0,000533855 | 8,40943906 | 4,10657609 | 3,68194485 |
| IL | 3,5 | 15.000 | 4.286 | 0,6 | 7142,86 | 0,001093227 | 0,000533855 | 7,80876485 | 3,81324922 | 3,41894879 |
| IL | 1,5 | 12.500 | 8.333 | 0,6 | 13888,89 | 0,001093227 | 0,000533855 | 15,1837094 | 7,41465127 | 6,64795599 |
| IL | 1,75 | 12.500 | 7.143 | 0,6 | 11904,76 | 0,001093227 | 0,000533855 | 13,0146081 | 6,35541537 | 5,69824799 |
| IL | 2 | 12.500 | 6.250 | 0,6 | 10416,67 | 0,001093227 | 0,000533855 | 11,3877821 | 5,56098845 | 4,98596699 |
| IL | 2,25 | 12.500 | 5.556 | 0,6 | 9259,26 | 0,001093227 | 0,000533855 | 10,1224729 | 4,94310085 | 4,43197066 |
| IL | 2,5 | 12.500 | 5.000 | 0,6 | 8333,33 | 0,001093227 | 0,000533855 | 9,11022565 | 4,44879076 | 3,98877359 |
| IL | 2,75 | 12.500 | 4.545 | 0,6 | 7575,76 | 0,001093227 | 0,000533855 | 8,28202332 | 4,04435524 | 3,62615781 |
| IL | 3 | 12.500 | 4.167 | 0,6 | 6944,44 | 0,001093227 | 0,000533855 | 7,59185471 | 3,70732563 | 3,32397799 |
| IL | 3,25 | 12.500 | 3.846 | 0,6 | 6410,26 | 0,001093227 | 0,000533855 | 7,00786589 | 3,42214674 | 3,06828738 |
| IL | 3,5 | 12.500 | 3.571 | 0,6 | 5952,38 | 0,001093227 | 0,000533855 | 6,50730404 | 3,17770769 | 2,84912399 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| IL | 1,5 | 5.000 | 3.333 | 0,72 | 4629,63 | 0,001093227 | 0,000533855 | 5,06123647 | 2,47155042 | 2,21598533 |
| IL | 1,75 | 5.000 | 2.857 | 0,72 | 3968,25 | 0,001093227 | 0,000533855 | 4,33820269 | 2,11847179 | 1,899416 |
| IL | 2 | 5.000 | 2.500 | 0,72 | 3472,22 | 0,001093227 | 0,000533855 | 3,79592736 | 1,85366282 | 1,661989 |
| IL | 2,25 | 5.000 | 2.222 | 0,72 | 3086,42 | 0,001093227 | 0,000533855 | 3,37415765 | 1,64770028 | 1,47732355 |
| IL | 2,5 | 5.000 | 2.000 | 0,72 | 2777,78 | 0,001093227 | 0,000533855 | 3,03674188 | 1,48293025 | 1,3295912 |
| IL | 2,75 | 5.000 | 1.818 | 0,72 | 2525,25 | 0,001093227 | 0,000533855 | 2,76067444 | 1,34811841 | 1,20871927 |
| IL | 3 | 5.000 | 1.667 | 0,72 | 2314,81 | 0,001093227 | 0,000533855 | 2,53061824 | 1,23577521 | 1,10799266 |
| IL | 3,25 | 5.000 | 1.538 | 0,72 | 2136,75 | 0,001093227 | 0,000533855 | 2,3359553 | 1,14071558 | 1,02276246 |
| IL | 3,5 | 5.000 | 1.429 | 0,72 | 1984,13 | 0,001093227 | 0,000533855 | 2,16910135 | 1,0592359 | 0,949708 |
| IL | 1,5 | 7.500 | 5.000 | 0,72 | 6944,44 | 0,001093227 | 0,000533855 | 7,59185471 | 3,70732563 | 3,32397799 |
| IL | 1,75 | 7.500 | 4.286 | 0,72 | 5952,38 | 0,001093227 | 0,000533855 | 6,50730404 | 3,17770769 | 2,84912399 |
| IL | 2 | 7.500 | 3.750 | 0,72 | 5208,33 | 0,001093227 | 0,000533855 | 5,69389103 | 2,78049423 | 2,49298349 |
| IL | 2,25 | 7.500 | 3.333 | 0,72 | 4629,63 | 0,001093227 | 0,000533855 | 5,06123647 | 2,47155042 | 2,21598533 |
| IL | 2,5 | 7.500 | 3.000 | 0,72 | 4166,67 | 0,001093227 | 0,000533855 | 4,55511283 | 2,22439538 | 1,9943868 |
| IL | 2,75 | 7.500 | 2.727 | 0,72 | 3787,88 | 0,001093227 | 0,000533855 | 4,14101166 | 2,02217762 | 1,81307891 |
| IL | 3 | 7.500 | 2.500 | 0,72 | 3472,22 | 0,001093227 | 0,000533855 | 3,79592736 | 1,85366282 | 1,661989 |
| IL | 3,25 | 7.500 | 2.308 | 0,72 | 3205,13 | 0,001093227 | 0,000533855 | 3,50393294 | 1,71107337 | 1,53414369 |
| IL | 3,5 | 7.500 | 2.143 | 0,72 | 2976,19 | 0,001093227 | 0,000533855 | 3,25365202 | 1,58885384 | 1,424562 |
| IL | 1,5 | 10.000 | 6.667 | 0,72 | 9259,26 | 0,001093227 | 0,000533855 | 10,1224729 | 4,94310085 | 4,43197066 |
| IL | 1,75 | 10.000 | 5.714 | 0,72 | 7936,51 | 0,001093227 | 0,000533855 | 8,67640538 | 4,23694358 | 3,79883199 |
| IL | 2 | 10.000 | 5.000 | 0,72 | 6944,44 | 0,001093227 | 0,000533855 | 7,59185471 | 3,70732563 | 3,32397799 |
| IL | 2,25 | 10.000 | 4.444 | 0,72 | 6172,84 | 0,001093227 | 0,000533855 | 6,7483153 | 3,29540056 | 2,9546471 |
| IL | 2,5 | 10.000 | 4.000 | 0,72 | 5555,56 | 0,001093227 | 0,000533855 | 6,07348377 | 2,96586051 | 2,65918239 |
| IL | 2,75 | 10.000 | 3.636 | 0,72 | 5050,51 | 0,001093227 | 0,000533855 | 5,52134888 | 2,69623682 | 2,41743854 |
| IL | 3 | 10.000 | 3.333 | 0,72 | 4629,63 | 0,001093227 | 0,000533855 | 5,06123647 | 2,47155042 | 2,21598533 |
| IL | 3,25 | 10.000 | 3.077 | 0,72 | 4273,50 | 0,001093227 | 0,000533855 | 4,67191059 | 2,28143116 | 2,04552492 |
| IL | 3,5 | 10.000 | 2.857 | 0,72 | 3968,25 | 0,001093227 | 0,000533855 | 4,33820269 | 2,11847179 | 1,899416 |
| IL | 1,5 | 12.500 | 8.333 | 0,72 | 11574,07 | 0,001093227 | 0,000533855 | 12,6530912 | 6,17887606 | 5,53996332 |
| IL | 1,75 | 12.500 | 7.143 | 0,72 | 9920,63 | 0,001093227 | 0,000533855 | 10,8455067 | 5,29617948 | 4,74853999 |
| IL | 2 | 12.500 | 6.250 | 0,72 | 8680,56 | 0,001093227 | 0,000533855 | 9,48981839 | 4,63415704 | 4,15497249 |
| IL | 2,25 | 12.500 | 5.556 | 0,72 | 7716,05 | 0,001093227 | 0,000533855 | 8,43539412 | 4,1192507 | 3,69330888 |
| IL | 2,5 | 12.500 | 5.000 | 0,72 | 6944,44 | 0,001093227 | 0,000533855 | 7,59185471 | 3,70732563 | 3,32397799 |
| IL | 2,75 | 12.500 | 4.545 | 0,72 | 6313,13 | 0,001093227 | 0,000533855 | 6,9016861 | 3,37029603 | 3,02179818 |
| IL | 3 | 12.500 | 4.167 | 0,72 | 5787,04 | 0,001093227 | 0,000533855 | 6,32654559 | 3,08943803 | 2,76998166 |
| IL | 3,25 | 12.500 | 3.846 | 0,72 | 5341,88 | 0,001093227 | 0,000533855 | 5,83988824 | 2,85178895 | 2,55690615 |
| IL | 3,5 | 12.500 | 3.571 | 0,72 | 4960,32 | 0,001093227 | 0,000533855 | 5,42275337 | 2,64808974 | 2,37426999 |
| IL | 1,5 | 15.000 | 10.000 | 0,72 | 13888,89 | 0,001093227 | 0,000533855 | 15,1837094 | 7,41465127 | 6,64795599 |
| IL | 1,75 | 15.000 | 8.571 | 0,72 | 11904,76 | 0,001093227 | 0,000533855 | 13,0146081 | 6,35541537 | 5,69824799 |
| IL | 2 | 15.000 | 7.500 | 0,72 | 10416,67 | 0,001093227 | 0,000533855 | 11,3877821 | 5,56098845 | 4,98596699 |
| IL | 2,25 | 15.000 | 6.667 | 0,72 | 9259,26 | 0,001093227 | 0,000533855 | 10,1224729 | 4,94310085 | 4,43197066 |
| IL | 2,5 | 15.000 | 6.000 | 0,72 | 8333,33 | 0,001093227 | 0,000533855 | 9,11022565 | 4,44879076 | 3,98877359 |
| IL | 2,75 | 15.000 | 5.455 | 0,72 | 7575,76 | 0,001093227 | 0,000533855 | 8,28202332 | 4,04435524 | 3,62615781 |
| IL | 3 | 15.000 | 5.000 | 0,72 | 6944,44 | 0,001093227 | 0,000533855 | 7,59185471 | 3,70732563 | 3,32397799 |
| IL | 3,25 | 15.000 | 4.615 | 0,72 | 6410,26 | 0,001093227 | 0,000533855 | 7,00786589 | 3,42214674 | 3,06828738 |
| IL | 3,5 | 15.000 | 4.286 | 0,72 | 5952,38 | 0,001093227 | 0,000533855 | 6,50730404 | 3,17770769 | 2,84912399 |

# APPENDIX B

These graphs represent the energy grid mix of Illinois and California from 2007 to 2013. The first graph corresponds to the state of California and the second graph corresponds to the state Illinois energy grid mix.




Energy Generation (MWh)
200.000.000
150.000.000
100.000.000
50.000.000
0
2007
2008
2009
2010
2011
2012
2013
Petroleum
Wind
Other
Nuclear
Natural Gas
Hydroelectric
Coal

# APPENDIX C

The following appendix represents electricity laws and incentives in California and Illinois. Each state has different laws and incentives that will help the consumer to promote the use of *EVs.*

# Illinois Laws and Incentives for Electricity

The list below contains summaries of all Illinois laws and incentives related to Electricity.

## Laws and Regulations

**Plug-in Electric Vehicle (PEV) Promotion and Coordination**
The Illinois Electric Vehicle Advisory Council (Council) was established to investigate and recommend strategies that the governor and the general assembly can implement to promote the use of PEVs, including potential infrastructure improvements. The Council published recommendations in its Final Report (http://www.illinois.gov/dceo/AboutDCEO/ReportsRequiredByStatute/20111230EVACFinalReport.pdf). An Electric Vehicle Coordinator now serves as the point of contact for related policies and activities in the state. (Reference House Bill (http://www.ilga.gov/) 2902, 2011)

**Electric Vehicle Supply Equipment (EVSE) Installation Requirements**
Vendors that install EVSE must comply with Illinois Commerce Commission (ICC) certification requirements. For specific requirements, see the ICC EVSE Installer Certification (http://www.icc.illinois.gov/electricity/EVCStationInstallerCert.aspx) website. (Reference 220 Illinois Compiled Statutes (http://www.ilga.gov/legislation/ilcs/ilcs.asp) 5/16-128A; 5/3-105; and 5/16-102)

**State Government Energy Initiative**
The Green Governments Illinois Act (Act) demonstrates the state's commitment to reduce negative environmental impacts, reduce greenhouse gases, and preserve resources for current and future generations. The Act also aims to strengthen the capacity of local governments and educational institutions to enable a more environmentally sustainable future. The Act established the Green Governments Coordinating Council (Council) to fully integrate cost-effective environmental sustainability measures into the ongoing management systems, long-range planning, and daily operations of state agencies. Initially, the Council will focus on initiatives that relate to energy efficiency, renewable energy, and alternative fuel vehicles. Local governments and educational institutes are not required to participate in the provisions of the Act. (Reference 20 Illinois Compiled Statutes (http://www.ilga.gov/legislation/ilcs/ilcs.asp) 3954/1 to 3954/45)

**Public Utility Definition**
An entity that owns, controls, operates, or manages a facility that supplies electricity to the public exclusively to charge battery electric and plug-in hybrid electric vehicles or compressed natural gas to fuel natural gas vehicles is not defined as a public utility. (Reference 220 Illinois Compiled Statutes (http://www.ilga.gov/legislation/ilcs/ilcs.asp) 5/3-105, and 20 Illinois Compiled Statutes (http://www.ilga.gov/legislation/ilcs/ilcs.asp) 627/10)

**Fuel-Efficient Vehicle Acquisition Goals**
To help achieve the statewide goal of reducing petroleum use by 20% by July 1, 2012, as compared to 2008 petroleum use, Illinois state agencies must work towards meeting the following goals:

- By July 1, 2015, at least 20% of new passenger vehicles purchased must be hybrid electric vehicles (HEVs) and 5% must be battery electric vehicles (EVs); and
- By July 1, 2025, at least 60% of new passenger vehicles purchased must be HEVs and 15% must be EVs.

Agencies that operate medium- and heavy-duty vehicles must implement strategies to reduce fuel consumption through diesel emission control devices, HEV and EVs technologies, alternative fuel use, and fuel-efficient technologies. Agencies must also implement strategies to promote the use of biofuels in state vehicles; reduce the environmental impacts of employee travel; and encourage employees to adopt alternative travel methods, such as carpooling.

(Reference Executive Order (http://www.illinois.gov/Government/ExecOrders/Pages/default.aspx) 11, 2009)

**Highway Electric Vehicle Supply Equipment (EVSE) Installation Requirements**
The Illinois Department of Transportation (Department) must install at least one EVSE at each interstate highway rest area where electrical service will reasonably permit by January 1, 2016, or as soon as possible thereafter. The Department may adopt specifications detailing the type of EVSE and rules governing station siting, user fees, and maintenance.

The Illinois State Toll Highway Authority (ISTHA) must also construct and maintain at least one EVSE at any location along toll highways where it has entered into an agreement with an entity for the purposes of providing motor fuel service stations and facilities, garages, stores, or restaurants. ISTHA may charge a fee for the use of the EVSE to offset the costs of construction and maintenance. ISTHA may also adopt rules regarding station siting, user fees and maintenance.

(Reference 601 Illinois Compiled Statutes (http://www.ilga.gov/legislation/ilcs/ilcs.asp) 5/223)

## State Incentives

**Electric Vehicle (EV) Registration Fee Reduction**
The owner of a dedicated EV may register for a discounted registration fee not to exceed $35 for a two-year registration period. The registration fee for an EV may not exceed $18 per year. To qualify for the reduced fee, the EV must weigh 8,000 pounds or less. For more information, see the Electric Vehicle License Plate Guide (http://www.cyberdriveillinois.com/departments/vehicles/license_plate_guide/electric_vehicle.html) website. (Reference 625 Illinois Compiled Statutes (http://www.ilga.gov/legislation/ilcs/ilcs.asp) 5/3-805)

**Electric Vehicle Emissions Inspection Exemption**
Vehicles powered exclusively by electricity are exempt from state motor vehicle emissions inspections. For more information, see the Illinois Environmental Protection Agency's Vehicle Emissions Testing Program (http://www.epa.state.il.us/air/vim/index.html) website. (Reference 625 Illinois Compiled Statutes (http://www.ilga.gov/legislation/ilcs/ilcs.asp) 5/13)

**Fleet User Fee Exemption**
Fleets with 10 or more vehicles located in defined areas of the state must pay an annual user fee of $20 per vehicle. Owners of electric vehicles and owners of state, county, or local government vehicles are exempt from this fee. The Office of the Illinois Secretary of State will deposit all fees into the Alternate Fuels Fund. (Reference 415 Illinois Compiled Statutes (http://www.ilga.gov/legislation/ilcs/ilcs.asp) 120/35)

**Electric Vehicle Supply Equipment (EVSE) Rebates**
The Illinois Department of Commerce and Economic Opportunity (Department) provides rebates to offset the cost of Level 2 EVSE. Rebates cover 50% of the cost of equipment and installation (including materials and labor), up to $3,750 per networked single station; $3,000 per non-networked single station; $7,500 per networked dual station; and $6,000 per non-networked dual station. The maximum possible total rebate award is $49,000 or 50% of the total project cost for up to 15 EVSE, whichever is less. Eligible applicants include government entities, private businesses, educational institutions, non-profit organizations, and individual residents of Illinois. The fall funding cycle is open until April 16, 2015 (verified October 2014) Program requirements are subject to change with each new funding period. For more information, including the application, deadlines, and eligibility requirements, see the Department's Electric Vehicles in Illinois (http://www.illinois.gov/dceo/whyillinois/KeyIndustries/Energy/Pages/ev.aspx) website.

**Smart Grid Infrastructure Development and Support**
The Illinois Science and Energy Innovation Trust (Trust) will provide financial and technical support to public and private entities within the state for programs and projects that support, encourage, or utilize innovative technologies and methods to modernize the state's electric grid. Technologies may include advanced electricity storage and peak-shaving technologies, such as plug-in electric vehicles (PEVs) or devices that allow PEVs to engage in smart grid functions. The Trust also offers assistance for standards development for communication and interoperability of appliances and equipment connected to the electric grid. Electric utilities may voluntarily commit to investments in smart grid advanced metering infrastructure deployment. Participating utilities must consult with the Smart Grid Advisory Council and file a Smart Grid Advanced Metering Infrastructure Deployment Plan with the Illinois Commerce Commission. (Reference 220 Illinois Compiled Statutes (http://www.ilga.gov/legislation/ilcs/ilcs.asp) 5/16-108.5 through 108.7)

**School Bus Retrofit Reimbursement**
The Illinois Department of Education will reimburse any qualifying school district for the cost of converting gasoline buses to more fuel-efficient engines or to engines using alternative fuels. Restrictions may apply. For more information, see the Illinois Clean School Bus Program (http://www.epa.state.il.us/air/cleanbus/). (Reference 105 Illinois Compiled Statutes (http://www.ilga.gov/legislation/ilcs/ilcs.asp) 5/29-5)

**Alternative Fuel Vehicle (AFV) and Alternative Fuel Rebates**
The Illinois Alternate Fuels Rebate Program provides a rebate for 80%, up to $4,000, of the incremental cost of purchasing an AFV; 80%, up to $4,000, of the cost of converting a conventional vehicle to an AFV using a federally certified conversion; and the incremental cost of purchasing alternative fuels. Eligible fuels for the program include E85, fuel blends containing at least 20% biodiesel (B20), natural gas, propane, electricity, and hydrogen. A vehicle may receive one rebate in its lifetime. Only AFVs purchased from an Illinois-based company or vendor may qualify, except if the vehicle is a heavy-duty specialty vehicle that is not sold in Illinois. To qualify for a fuel rebate, the entity or individual must purchase the majority of E85 or biodiesel fuel from Illinois retail stations or fuel suppliers. The E85 fuel rebate is up to $450 per year (depending on vehicle miles traveled) for up to three years for each flexible fuel vehicle that uses E85 at least half the time. The biodiesel fuel rebate (for B20 and higher blends) is for 80% of the incremental cost of the biodiesel fuel, as compared to conventional diesel. Rebates are part of the Illinois Green Fleets Program and are available to all qualified Illinois residents, businesses, government units (except federal government), and organizations located in Illinois. This program is suspended indefinitely (confirmed March 2015). For more information, including a list of eligible vehicles, see the Illinois Alternate Fuels Rebate Program (http://www.illinoisgreenfleets.org/). (Reference 415 Illinois Compiled Statutes (http://www.ilga.gov/legislation/ilcs/ilcs.asp) 120/30)

***Point of Contact***
Darwin Burkhart
Manager, Clean Air Programs
Illinois Environmental Protection Agency
Phone: (217) 524-5008
Fax: (217) 557-2559
darwin.burkhart@illinois.gov (mailto:darwin.burkhart@illinois.gov)
http://www.illinoisgreenfleets.org (http://www.illinoisgreenfleets.org)

**Alternative Fuel Vehicle (AFV) Fleet Incentives**
The Illinois Green Fleets Program recognizes and provides additional marketing opportunities for fleets in Illinois that have a significant number of AFVs and use clean, domestically produced fuels. For more information, see the Illinois Green Fleets Program (http://www.illinoisgreenfleets.org/) website.

***Point of Contact***
Darwin Burkhart
Manager, Clean Air Programs
Illinois Environmental Protection Agency
Phone: (217) 524-5008
Fax: (217) 557-2559
darwin.burkhart@illinois.gov (mailto:darwin.burkhart@illinois.gov)
http://www.illinoisgreenfleets.org (http://www.illinoisgreenfleets.org)

Illinois ▾ GO

**More Laws and Incentives**
To find laws and incentives for other alternative fuels and advanced vehicles, search all laws and incentives (/laws/).

# California Laws and Incentives for Electricity

The list below contains summaries of all California laws and incentives related to Electricity.

## Laws and Regulations

**Electric Vehicle Supply Equipment (EVSE) Policies for Multi-Unit Dwellings**
A common interest development, including a community apartment, condominium, and cooperative development, may not prohibit or restrict the installation or use of EVSE in a homeowner's designated parking space. These entities may put reasonable restrictions on EVSE, but the policies may not significantly increase the cost of the EVSE or significantly decrease its efficiency or performance. If installation in the homeowner's designated parking space is not possible, with authorization, the homeowner may add EVSE in a common area for their use. The homeowner must obtain appropriate approvals from the common interest development association and agree in writing to comply with applicable architectural standards, engage a licensed installation contractor, provide a certificate of insurance, and pay for the electricity usage associated with the EVSE. Any application for approval should be processed by the common interest development association without willful avoidance or delay. The homeowner and each successive homeowner of the parking space equipped with EVSE is responsible for the cost of the installation, maintenance, repair, removal, or replacement of the station, as well as any resulting damage to the EVSE or surrounding area. The homeowner must also maintain a $1 million umbrella liability coverage policy and name the common interest development as an additional insured entity under the policy. If EVSE is installed in a common area for use by all members of the association, the common interest development must develop terms for use of the EVSE. (Reference California Civil Code (http://www.oal.ca.gov/) 4745 and 6713)

**Access to Plug-In Electric Vehicle (PEV) Registration Records**
The California Department of Motor Vehicles may disclose to an electrical corporation or local publicly owned utility a PEV owner's address and vehicle type if the information is used exclusively to identify where the PEV is registered. (Reference California Vehicle Code (http://www.oal.ca.gov/) 1808.23)

**Zero Emission Vehicle (ZEV) Promotion Plan**
All state agencies must support and facilitate the rapid commercialization of ZEVs in California. In particular, the California Air Resources Board, California Energy Commission, Public Utilities Commission, and other relevant state agencies must work with the Plug-in Electric Vehicle Collaborative and the California Fuel Cell Partnership to establish benchmarks to achieve targets for ZEV commercialization. These targets include:

- By 2015, all major metropolitan areas in California will be able to accommodate ZEVs and have infrastructure plans and streamlined permitting in place;
- By 2020, the state will have established adequate infrastructure to support one million ZEVs;
- By 2025, there will be 1.5 million ZEVs on the road in California and clean, efficient vehicles will displace 1.5 billion gallons of petroleum fuels annually; and
- By 2050, greenhouse gas emissions from the transportation sector will be 80% less than 1990 levels.

The ZEV promotion plan also directs the state fleet to increase the number of ZEVs in the fleet through gradual vehicle replacement. By 2015, ZEVs should make up at least 10% of fleet light-duty vehicle (LDV) purchases and by 2020, at least 25% of fleet LDV purchases should be ZEVs. Vehicles with special performance requirements necessary for public safety and welfare are exempt from this requirement.

(Reference Executive Order (http://gov.ca.gov/s_executiveorders.php) B-16, 2012)

**Public Utility Definition**
A corporation or individual that owns, controls, operates, or manages a facility that supplies electricity to the public exclusively to charge light-duty battery electric and plug-in hybrid electric vehicles, or compressed natural gas to fuel natural gas vehicles, is not defined as a public utility. (Reference California Public Utilities Code (http://www.oal.ca.gov/) 216)

**Plug-In Electric Vehicle (PEV) Infrastructure Information Resource**
The California Energy Commission, in consultation with the Public Utilities Commission, must develop and maintain a website containing specific links to electrical corporations, local publicly owned electric utilities, and other websites that contain information specific to PEVs, including the following:

- Resources to help consumers determine if their residences will require utility service upgrades to accommodate PEVs;
- Basic charging circuit requirements;
- Utility rate options; and
- Load management techniques.

(Reference California Public Resources Code (http://www.oal.ca.gov/) 25227)

**Plug-In Electric Vehicle (PEV) Charging Requirements**
New PEVs must be equipped with a conductive charger inlet port that meets the specifications contained in Society of Automotive Engineers (SAE) standard J1772. PEVs must be equipped with an on-board charger with a minimum output of 3.3 kilovolt amps. These requirements do not apply to PEVs that are only capable of Level 1 charging, which has a maximum power of 12 amperes (amps), a branch circuit rating of 15 amps, and continuous power of 1.44 kilowatts. (Reference California Code of Regulations (http://www.oal.ca.gov/) Title 13, Section 1962.3)

**Plug-In Electric Vehicle (PEV) Infrastructure Evaluation**
The California Public Utilities Commission (PUC), in consultation with the California Energy Commission (CEC), California Air Resources Board, electrical corporations, and the motor vehicle industry, evaluated policies to develop infrastructure sufficient to overcome barriers to the widespread deployment and use of PEVs. The PUC must adopt rules to address the following:

- The impacts on electrical infrastructure and any infrastructure upgrades necessary for widespread use of PEVs, including the role and development of public charging infrastructure;
- The impact of PEVs on grid stability and the integration of renewable energy resources;
- The technological advances necessary to ensure the widespread use of PEVs and what role the state should take to support the development of this technology;
- The existing code and permit requirements that will impact the widespread use of PEVs and any recommended changes to existing policies that may be barriers to the widespread use of PEVs;
- The role the state should take to ensure that technologies employed in PEVs work harmoniously and across service territories; and
- The impact of widespread use of PEVs on achieving the state's greenhouse gas emissions reductions goals and renewables portfolio standard program, and what steps should be taken to address the possibility of shifting emissions reductions responsibilities from the transportation sector to the electrical industry.

A copy of the infrastructure assessment report is available on the CEC (http://www.energy.ca.gov/2014publications/CEC-600-2014-003/CEC-600-2014-003.pdf) website.

(Reference California Public Utilities Code (http://www.oal.ca.gov/) 740.2)

**Alternative Fuel Vehicle (AFV) Parking Incentive Programs**
The California Department of General Services (DGS) and California Department of Transportation (DOT) must develop and implement AFV parking incentive programs in public parking facilities operated by DGS with 50 or more parking spaces and park-and-ride lots owned and operated by DOT. The incentives must provide meaningful and tangible benefits to drivers, such as preferential spaces, reduced fees, and fueling infrastructure. Fueling infrastructure built at park-and-ride lots is not subject to restricted use by those using bicycles, public transit, or ridesharing. (Reference California Public Resources Code (http://www.oal.ca.gov/) 25722.9)

**State Agency Electric Vehicle Supply Equipment (EVSE) Installation**
State Agency Electric Vehicle Supply Equipment (EVSE) Installation California state agencies must actively identify and pursue opportunities to install EVSE, and accommodate future EVSE demand, at state employee parking facilities in new and existing agency buildings. (Reference Executive Order (http://gov.ca.gov/s_executiveorders.php) B-18-12, 2012)

**Zero Emission Vehicle (ZEV) Initiative**
The California Air Resources Board's (ARB) Charge Ahead California Initiative will work toward a goal of placing in service at least 1 million ZEVs and near-zero emission vehicles in California by January 1, 2023. In consultation with the State Energy Resources Conservation and Development Commission, ARB will prepare a funding plan that includes a market and technology assessment, assessments of existing zero and near-zero emission funding programs, and programs that increase access to disadvantaged, low-income, and moderate-income communities and consumers. Potential programs include those involving innovative financing, car sharing, charging infrastructure in multi-unit dwellings in disadvantaged communities, and public transit. The funding plan must be updated at least every three years through January 1, 2023. (Reference Senate Bill (http://www.legislature.ca.gov/>Assembly Bill</a> 8 and <a href=) 1275, 2014, and California Health and Safety Code (http://www.oal.ca.gov/) 44258.4)

**Electric Vehicle Supply Equipment (EVSE) Policies for Residential and Commercial Renters**
Effective July 1, 2015, the lessor of a dwelling or commercial property must approve written requests from a lessee to install EVSE at a parking space allotted for the lessee on qualified properties. Certain exclusions apply to residential dwellings and commercial properties. All modifications and improvements must comply with federal, state, and local laws and all applicable zoning and land use requirements, and covenants, conditions, and restrictions. The lessee of the parking space equipped with EVSE is responsible for the cost of the installation, maintenance, repair, removal, or replacement of the equipment, electricity consumption, as well as any resulting damage to the EVSE or surrounding area. The lessee must also maintain a $1 million umbrella liability coverage policy and name the common interest development as an additional insured entity under the policy. (Reference Assembly Bill (http://www.legislature.ca.gov/) 2565, 2014, and California Civil Code (http://www.oal.ca.gov/) 1947.6 and 1952.7)

**Plug-In Electric Vehicle (PEV) Charging Electricity Exemption**
Electricity used to charge PEVs at a state-owned parking facility is exempt from California law prohibiting gifting public money or things of value. (Assembly Bill (http://www.leginfo.ca.gov/) 2414, 2014, and California Government Code (http://www.oal.ca.gov/) 14678)

**Establishment of a Zero Emission Medium- and Heavy-Duty Vehicle Program**
The California Clean Truck, Bus, and Off-Road Vehicle and Equipment Technology Program (Program) will provide funding for zero and near-zero emission heavy-duty vehicles, including vocational trucks, short- and long-haul trucks, buses, and eligible off-road vehicles and equipment. The Program is expected to provide $12 million to $20 million in funding annually through January 1, 2018. At least 20% of allocated funds must go towards early commercial deployment of eligible vehicles and equipment. The California Air Resources Board and the State Energy Resources Conservation and Development Commission will develop and administer the Program. Remanufactured and retrofitted vehicles meeting warranty and emissions requirements may also qualify for funding. (Reference Senate Bill (http://www.oal.ca.gov/) 1204, 2014, and California Health and Safety Code (http://www.oal.ca.gov/) 39719.2)

**Zero Emission Vehicle (ZEV) Deployment Support**
California joined Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont in signing a memorandum of understanding

California joined Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont in signing a memorandum of understanding (http://www.nescaum.org/documents/zev-mou-8-governors-signed-20131024.pdf/) (MOU) to support the deployment of ZEVs through involvement in a ZEV Program Implementation Task Force (Task Force). In May 2014, the Task Force published a ZEV Action Plan (http://www.nescaum.org/documents/multi-state-zev-action-plan.pdf/) (Plan) identifying 11 priority actions to accomplish the goals of the MOU, including deploying at least 3.3 million ZEVs and adequate fueling infrastructure within the signatory states by 2025. The Plan also includes a research agenda to inform future actions. On an annual basis, each state must report on the number of registered ZEVs, the number of public electric vehicle supply equipment (EVSE) and hydrogen fueling stations, and available information regarding workplace fueling for ZEVs. Each state also committed to:

- Support ZEV commercialization through consistent statewide building codes and standards for installing EVSE, streamlined metering options for homes equipped with EVSE, opportunities to reduce vehicle operating costs, increased electric system efficiency through time-of-use electricity rates and net metering for electric vehicles, and integrating ZEVs with renewable energy initiatives;
- Establish ZEV purchase targets for governmental agency fleets, explore opportunities for coordinated vehicle and fueling station equipment procurement, work to provide public access to government fleet fueling stations, and include commitments to use ZEVs in state contracts with auto dealers and car rental companies where appropriate;
- Evaluate the need for, and effectiveness of, monetary incentives to reduce the upfront purchase price of ZEVs as well as non-monetary incentives, such as high occupancy vehicle lane access, reduced tolls, and preferential parking, and pursue these incentives as appropriate;
- Work to develop uniform standards to promote ZEV consumer acceptance and awareness, industry compliance, and economies of scale, including adopting universal signage, common methods of payment and interoperability of EVSE networks, and reciprocity among states for non-monetary ZEV incentives;
- Cooperate with vehicle manufacturers, electricity and hydrogen providers, the fueling infrastructure industry, corporate fleet owners, financial institutions, and others to encourage ZEV market growth;
- Share research and develop a coordinated education and outreach campaign to highlight the benefits of ZEVs, including collaboration with related national and regional initiatives; and
- Assess and develop potential deployment strategies and infrastructure requirements for the commercialization of hydrogen fuel cell vehicles.

**Electric Vehicle Supply Equipment (EVSE) Open Access Requirements**
EVSE service providers may not charge a subscription fee or require membership for use of their public charging stations. In addition, providers must disclose the actual charges for using public EVSE at the point of sale; allow at least two options for payment; and disclose the EVSE geographic location, schedule of fees, accepted methods of payment, and network roaming charges to the National Renewable Energy Laboratory. Exceptions apply.

If a national standards organization has not adopted interoperability billing standards by January 1, 2015, the California Air Resources Board may adopt such standards for network roaming payment methods for EVSE. Providers would be required to meet these standards within one year of adoption.

(Reference California Health and Safety Code (http://www.oal.ca.gov/) 44268 and 44268.2)

**Mandatory Electric Vehicle Supply Equipment (EVSE) Building Standards**
The California Building Standards Commission (Commission) published mandatory building standards for EVSE installation in parking spaces at multi-family dwellings and non-residential developments in the 2013 edition of the California Building Standards Code within the California Green Building Standards Code. The standard will go into effect on July 1, 2015. For more information, see the California Building Codes Standards Commission Approved Standards (http://www.bsc.ca.gov/Rulemaking/adoptcycle/2013CodeCycle/Appstndrds2013.aspx) website. (Reference California Health and Safety Code (http://www.oal.ca.gov/) 18941.10)

**Low Emission Vehicle (LEV) Standards**
California's LEV II exhaust emissions standards apply to Model Year (MY) 2004 and subsequent model year passenger cars, light-duty trucks, and medium-duty passenger vehicles meeting specified exhaust standards. The LEV II standards represent the maximum exhaust emissions for LEVs, Ultra Low Emission Vehicles, and Super Ultra Low Emission Vehicles, including flexible fuel, bi-fuel, and dual-fuel vehicles when operating on an alternative fuel. MY2009 and subsequent model year passenger cars, light-duty trucks, and medium-duty passenger vehicles must meet specified fleet average greenhouse gas (GHG) exhaust emissions requirements. Each manufacturer must comply with these fleet average GHG requirements, which are based on California Air Resources Board calculations. Bi-fuel, flexible fuel, dual-fuel, and grid-connected hybrid electric vehicles may be eligible for an alternative compliance method.

In December 2012, ARB finalized regulatory requirements, referred to as LEV III, which allow vehicle manufacturer compliance with the U.S. Environmental Protection Agency's GHG requirements for model years 2017-2025 to serve as compliance with California's adopted GHG emissions requirements for those same model years. See the LEVII (http://www.arb.ca.gov/msprog/levprog/levii/levii.htm) and LEV III Program (http://www.arb.ca.gov/regact/2012/leviiidtc12/leviiidtc12.htm) website for more information. (Reference California Code of Regulations (http://www.oal.ca.gov/) Title 13, Section 1961-1961.3)

**State Transportation Plan**
The California Department of Transportation (Caltrans) must update the California Transportation Plan (Plan) by December 31, 2015, and every five years thereafter. The Plan must address how the state will achieve maximum feasible emissions reductions, taking into consideration the use of alternative fuels, new vehicle technology, and tailpipe emissions reductions. Caltrans must prepare and submit an interim report to the California Transportation Commission and to the Senate and Assembly committees related to transportation, environmental quality, natural resources, and local government by December 31, 2012. Caltrans must consult and coordinate with related state agencies, air quality management districts, public transit operators, and regional transportation planning agencies. Caltrans must also provide an opportunity for general public input. Caltrans must submit a final draft of the Plan to the legislature and governor. A copy of the interim report is available on the Caltrans (http://www.dot.ca.gov/hq/tpp/californiatransportationplan2040/index.shtml) website. (Reference California Government Code (http://www.oal.ca.gov/) 65070-65073)

**Zero Emission Vehicle (ZEV) Production Requirements**
The California Air Resources Board (ARB) certifies new passenger cars, light-duty trucks, and medium-duty passenger vehicles as ZEVs if the vehicles produce zero exhaust emissions of any criteria pollutant (or precursor pollutant) under any and all possible operational modes and conditions. Manufacturers with annual sales greater than 60,000 vehicles must produce and deliver for sale in California a minimum percentage of ZEVs for each model year as follows:

| Model Year (MY) | ZEV Requirement |
|---|---|
| 2010-2011 | 11% |
| 2012-2014 | 12% |
| 2015-2017 | 14% |

Manufacturers with annual sales between 4,501 and 60,000 vehicles may comply with the ZEV requirements through multiple alternative compliance options that include producing low emission vehicles and obtaining ZEV credits. Manufacturers with annual sales of 4,500 vehicles or less are not subject to this regulation.

ARB's emissions control program for MY 2017 through 2025 combines the control of smog, soot, and greenhouse gases (GHGs) and requirements for ZEVs into a single package of standards called Advanced Clean Cars. In December 2012, ARB finalized new regulatory requirements that allow vehicle manufacturer compliance with the U.S. Environmental Protection Agency's GHG requirements for MY 2017 through 2025 to serve as compliance with California's adopted GHG emissions requirements for those same model years.

The accounting procedures for MY 2018 through 2025 are based on a credit system as shown in the table below. The minimum ZEV requirement for each manufacturer includes the percentage of passenger cars and light-duty trucks produced by the manufacturer and delivered for sale in California. The legislation also includes opportunities for compliance with transitional zero emission vehicles (TZEVs), which must demonstrate certain exhaust emissions standards, evaporative emissions standards, on-board diagnostic requirements, and extended warranties.

| MY | ZEV Requirement |
|---|---|
| 2018 | 4.5% |
| 2019 | 7% |
| 2020 | 9.5% |
| 2021 | 12% |
| 2022 | 14.5% |
| 2023 | 17% |
| 2024 | 19.5% |
| 2025 | 22% |

For more information, see the ZEV Program (http://www.arb.ca.gov/msprog/zevprog/zevprog.htm) website. (Reference California Code of Regulations (http://www.oal.ca.gov/) Title 13, Section 1962 -1962.2)

**Fleet Vehicle Procurement Requirements**
When awarding a vehicle procurement contract, every city, county, and special district, including school and community college districts, may require that 75% of the passenger cars and/or light-duty trucks acquired be energy-efficient vehicles. By definition, this includes hybrid electric vehicles and alternative fuel vehicles that meet California's advanced technology partial zero emission vehicle (AT PZEV) standards. Vehicle procurement contract evaluations may consider fuel economy and lifecycle factors for scoring purposes. (Reference California Public Resources Code (http://www.oal.ca.gov/) 25725-25726)

**Mobile Source Emissions Reduction Requirements**
Through its Mobile Sources Program, the California Air Resources Board (ARB) has developed programs and policies to reduce emissions from on-road heavy-duty diesel vehicles through the installation of verified diesel emission control strategies (VDECS) and vehicle replacements.

An on-road heavy-duty diesel vehicle rule (http://www.arb.ca.gov/msprog/onrdiesel/onrdiesel.htm) (truck and bus regulation) requires the retrofit and replacement of nearly all privately owned vehicles operated in California with a gross vehicle weight rating (GVWR) greater than 14,000 pounds. School buses owned by private and public entities and federal government owned vehicles are also included in the scope of the rule. The requirements include a phase-in period for the installation of VDECS on certain heavier in-use vehicles that began January 1, 2012 with the replacement of older vehicles starting January 1, 2015. By January 1, 2023, nearly all vehicles must have engines certified to the 2010 engine standard or equivalent. A drayage/port truck rule (http://www.arb.ca.gov/msprog/onroad/porttruck/porttruck.htm) regulates heavy-duty diesel-fueled vehicles that transport cargo to and from California's ports and intermodal rail facilities. The rule requires that certain drayage trucks be equipped with VDECS and that all applicable vehicles have engines certified to the 2007 emissions standards by January 1, 2014. A public transit agency fleet rule (http://www.arb.ca.gov/msprog/bus/bus.htm) regulates public transit fleets and sets emissions reduction standards for new transit vehicles. A solid waste collection vehicle rule (http://www.arb.ca.gov/msprog/swcv/swcv.htm) regulates solid waste collection vehicles with a gross vehicle weight rating of 14,000 pounds or more that operate on diesel fuel, have 1960 through 2006 engine models, and collect waste for a fee. The fleet rule for public agencies and utilities (http://www.arb.ca.gov/msprog/publicfleets/publicfleets.htm) requires fleets to install VDECS on vehicles or purchase vehicles that run on alternative fuels or use advanced technologies to achieve emissions requirements by specified implementation dates.

A summary of the requirements for diesel truck and equipment owners can be found in the ARB Multi-Rule Summary (http://www.arb.ca.gov/msprog/onrdiesel/documents/multirule.pdf) fact sheet. (Reference California Code of Regulations (http://www.oal.ca.gov/) Title 13, 2021-2027)

***Point of Contact***
Diesel Hotline
California Air Resources Board
Phone: (866) 6DIESEL (634-3735)
8666diesel@arb.ca.gov (mailto:8666diesel@arb.ca.gov)

**Alternative Fuel and Plug-in Hybrid Electric Vehicle Retrofit Regulations**
Converting a vehicle to operate on an alternative fuel in lieu of the original gasoline or diesel fuel is prohibited unless the California Air Resources Board (ARB) has evaluated and certified the retrofit system. ARB will issue certification to the manufacturer of the system in the form of an Executive Order once the manufacturer demonstrates compliance with the emissions, warranty, and durability requirements. A manufacturer is defined as a person or company who manufactures or assembles an alternative fuel retrofit system for sale in California; this definition does not include individuals wishing to convert vehicles for personal use. Individuals interested in converting their vehicles to operate on an alternative fuel must ensure that the alternative fuel retrofit systems used for their vehicles have been ARB certified. For more information, see the ARB Alternative Fuel Retrofit System (http://www.arb.ca.gov/msprog/aftermkt/altfuel/altfuel.htm) website.

A hybrid electric vehicle that is Model Year 2000 or newer and is a passenger car, light-duty truck, or medium-duty vehicle may be converted to incorporate off-vehicle charging capability if the manufacturer demonstrates compliance with emissions, warranty, and durability requirements. ARB issues certification to the manufacturer and the vehicle must meet California emissions standards for the model year of the original vehicle.

ARB is considering amendments to the alternative fuel certification procedures for new and in-use vehicles and engines. For more information, see the Proposed Amendments (http://www.arb.ca.gov/msprog/onroad/altfuelconv/altfuelconv.htm) website. (Reference California Code of Regulations (http://www.oal.ca.gov/) Title 13, Section 2030-2032, and California Vehicle Code (http://www.oal.ca.gov/) 27156)

**Alternative Fuel and Vehicle Policy Development**
The California Energy Commission (CEC) must prepare and submit an Integrated Energy Policy Report (IEPR) to the governor on a biannual basis. The IEPR provides an overview of major energy trends and issues facing the state, including those related to transportation fuels, technologies, and infrastructure. The IEPR also examines potential effects of alternative fuels use, vehicle efficiency improvements, and shifts in transportation modes on public health and safety, the economy, resources, the environment, and energy security. The IEPR's primary purpose is to develop energy policies that conserve resources, protect the environment, ensure energy reliability, enhance the state's economy, and protect public health and safety. For the current IEPR, see the CEC California's Energy Policy (http://www.energy.ca.gov/energypolicy/)

Beginning November 1, 2015, and every four years thereafter, the CEC must also include in the IEPR strategies to maximize the benefits of natural gas in various sectors. This includes the use of natural gas as a transportation fuel. (Reference California Public Resources Code (http://www.oal.ca.gov/) 25302 and 25303.5)

**Vehicle Acquisition and Petroleum Reduction Requirements**
The California Department of General Services (DGS) is responsible for maintaining specifications and standards for passenger cars and light-duty trucks that are purchased or leased for state office, agency, and department use. These specifications include minimum vehicle emissions standards and encourage the purchase or lease of fuel-efficient and alternative fuel vehicles (AFVs). On an annual basis, DGS must compile information including, but not limited to, the number of AFVs and hybrid electric vehicles acquired, the locations of the alternative fuel pumps available for those vehicles, and the total amount of alternative fuels used.

Vehicles the state owns or leases that are capable of operating on alternative fuel must operate on that fuel unless the alternative fuel is not available. Additionally, the California State and Consumer Services Agency, in consultation with DGS and other appropriate state agencies, must develop, implement, and submit to the California Legislature and governor a plan to increase the state fleet's use of alternative fuels, synthetic lubricants, and fuel-efficient vehicles. This must be done by reducing or displacing the fleet's consumption of petroleum products by 20% by January 1, 2020, as compared to the 2003 consumption level. DGS must also:

- Take steps to transfer vehicles between agencies and departments to ensure that the most fuel-efficient vehicles are used and to eliminate the least fuel-efficient vehicles from the state's motor vehicle fleet;
- Submit annual progress reports to the California Department of Finance, related legislative committees, and the general public via the DGS website;
- Encourage other agencies to operate AFVs on the alternative fuel for which they are designed, to the extent feasible;
- Encourage the development of commercial fueling infrastructure at or near state vehicle fueling or parking sites;
- Work with other agencies to incentivize and promote state employee use of AFVs through preferential or reduced-cost parking, access to electric vehicle charging, or other means, to the extent feasible; and
- Establish a more stringent fuel economy standard than the 2007 standard.

(Reference Senate Bill (http://leginfo.legislature.ca.gov/faces/billSearchClient.xhtml) 1304 and 1265, 2014, Executive Order (http://www.documents.dgs.ca.gov/ofa/eos-14-09.pdf) S-14-09, 2009 and California Public Resources Code (http://www.oal.ca.gov/) 25722.5 - 25722.9)

## State Incentives

**Alternative Fuel Vehicle (AFV) and Fueling Infrastructure Grants**
The Motor Vehicle Registration Fee Program (Program) provides funding for projects that reduce air pollution from on- and off-road vehicles. Eligible projects include purchasing AFVs and developing alternative fueling infrastructure. Contact local air districts (http://www.arb.ca.gov/capcoa/roster.htm) for more information about available grant funding and distribution from the Program. Also see the Program (http://www.arb.ca.gov/planning/tsaq/mvrfp/mvrfp.htm) website. (Reference California Health and Safety Code (http://www.oal.ca.gov/) 44220 (b))

**Low Emission Vehicle Incentives and Technical Training - San Joaquin Valley**
The San Joaquin Valley Air Pollution Control District (SJVAPCD) administers the REMOVE II program, which provides incentives for cost-effective projects that result in motor vehicle emissions reductions and long-term impacts on air pollution in the San Joaquin Valley. REMOVE II is providing funding for vanpool agencies that reduce or replace single occupant vehicle commutes in the San Joaquin Valley. To participate, vanpool agencies must submit an application to SJVAPCD and sign a contract to become a Vanpool Voucher Incentive Program partner. REMOVE II also includes an Alternative Fuel Vehicle (AFV) Mechanic Training Component that provides incentives to educate personnel on the mechanics, operation safety, and maintenance of AFVs, fueling stations, and tools involved in the implementation of alternative fuel technologies. For more information, see the REMOVE II (http://www.valleyair.org/Grant_Programs/GrantPrograms.htm) website, the Vanpool Voucher Incentive Program (http://valleyair.org/grants/vanpoolvoucher.htm) and the AFV Mechanic Training Component (http://valleyair.org/grants/mechanictraining.htm) website.

**High Occupancy Vehicle (HOV) and High Occupancy Toll (HOT) Lane Exemption**
Compressed natural gas (CNG), hydrogen, electric, and plug-in hybrid electric vehicles (PHEVs) meeting specified California and federal emissions standards and affixed with a California Department of Motor Vehicles Clean Air Vehicle sticker may use HOV lanes regardless of the number of occupants in the vehicle. White Clean Air Vehicle Stickers are available to an unlimited number of qualifying CNG, hydrogen, and electric vehicles. Green Clean Air Vehicle Stickers are available for the first 70,000 applicants that purchase or lease a qualified PHEV. Both stickers will expire January 1, 2019, or until federal authorization for HOV lane access expires. These vehicles are also exempt from toll charges imposed on HOT lanes, unless prohibited by federal law. For more information, including a list of qualifying vehicles, see the California Air Resources Board Carpool Lane Use Stickers (http://www.arb.ca.gov/msprog/carpool/carpool.htm) website. (Reference Assembly Bills (http://www.legislature.ca.gov/) 1721 and 2013, 2014, and California Vehicle Code (http://www.oal.ca.gov/) 5205.5 and 21655.9)

**Plug-In Hybrid and Zero Emission Light-Duty Public Fleet Vehicle Fleet Rebates**
The Public Fleet Pilot Project (PFPP) offers rebates to eligible state and local public entities for the purchase of qualified light-duty fleet vehicles located in disadvantaged communities. The rebates are for up to $5,250 for plug-in hybrid electric vehicles, $10,000 for battery electric vehicles, and $15,000 for fuel-cell electric vehicles the California Air Resources Board (ARB) has certified. Rebates are available on a first-come, first-served basis. Manufacturers must apply to ARB to have their vehicles included in the PFPP. Each entity may receive up to 30 rebates annually and cannot receive California Vehicle Rebate Project incentives for the same vehicle. For more information, including a list of eligible vehicles, locations, and entities, see the PFPP (https://energycenter.org/public-fleet-project) website. (Reference Assembly Bill (http://www.legislature.ca.gov/) 8 and Senate Bill (http://www.legislature.ca.gov/) 862, 2014, and California Health and Safety Code (http://www.oal.ca.gov/) 44274 and 44258)

**Residential Electric Vehicle Supply Equipment (EVSE) Financing Program**
Property-Assessed Clean Energy (PACE) financing allows property owners to borrow funds to pay for energy improvements, including purchasing and installing EVSE. The borrower repays over a defined period of time through a special assessment on the property. Local governments in California are authorized to establish PACE programs. Property owners must agree to a contractual assessment on the property tax bill, have a clean property title, and be current on property taxes and mortgages. Financing limits are 15% of the first $700,000 of the property value and 10% of the remaining property value. For more information, see the California Alternative Energy and Advanced Transportation Financing Authority PACE (http://www.treasurer.ca.gov/caeatfa/pace/index.asp) website. (Reference Assembly Bill (http://www.legislature.ca.gov/) 2597, 2014, and California Public Resources Code (http://www.oal.ca.gov/) 26050-26082)

**Low Emissions School Bus Grants**
The Lower-Emission School Bus Program (Program) provides grant funding for the replacement of older school buses and for the purchase of air pollution control equipment for in-use buses. The California Air Resources Board must verify that the air pollution control devices reduce particulate matter emissions by at least 85% for each retrofitted school bus. Public school districts in California that own their buses are eligible to receive funding. Private school transportation providers that contract with public school districts in California to provide transportation services are also eligible to receive funding for the retrofit of in-use buses. New buses purchased to replace older buses may be fueled with diesel or an alternative fuel, provided that the required emissions standards specified in the current guidelines for the Program are met. Funds are also available for replacing on-board natural gas tanks on older school buses and for updating deteriorating natural gas fueling infrastructure. Commercially available hybrid electric school buses may be eligible for partial funding. For more information, see the Program (http://www.arb.ca.gov/msprog/schoolbus/schoolbus.htm) website and contact local air districts to confirm funding availability. (Reference California Health and Safety Code (http://www.oal.ca.gov/) 41081 and 44099)

***Point of Contact***

Lisa Jennings
Air Pollution Specialist, Lower-Emission School Bus Program
California Air Resources Board
Phone: (916) 322-6913
Fax: (916) 322-3923
lisa.jennings@arb.ca.gov (mailto:lisa.jennings@arb.ca.gov)
http://www.arb.ca.gov/msprog/schoolbus/schoolbus.htm (http://www.arb.ca.gov/msprog/schoolbus/schoolbus.htm)

**Hybrid and Zero Emission Truck and Bus Vouchers - San Joaquin Valley**
The San Joaquin Valley Air Pollution Control District (SJVAPCD) contributed funds to the California Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) for eligible vehicles used in the eight-county San Joaquin Valley Air Basin. These "plus-up" vouchers range from $12,000 to $30,000, depending on the vehicle, and are in addition to California Air Resources Board voucher amounts. Vehicles must be domiciled in the air basin 100% of the time for at least three years. For more information, see the San Joaquin Valley Plus-Up (http://www.californiahvip.org/san-joaquin-valley-plus-up) website.

**Alternative Fuel and Advanced Vehicle Rebate - San Joaquin Valley**
The San Joaquin Valley Air Pollution Control District (SJVAPCD) administers the Drive Clean! Rebate Program, which provides rebates for the purchase or lease of eligible new vehicles, including qualified natural gas, hydrogen fuel cell, propane, zero-emission motorcycles, battery electric, neighborhood electric, and plug-in electric vehicles. The program offers rebates of up to $3,000, which are available on a first-come, first-served basis for residents and businesses located in the SJVAPCD. For more information, including a list of eligible vehicles and other requirements, see the SJVAPCD Drive Clean! Rebate Program (http://valleyair.org/grants/driveclean.htm) website.

**Technology Advancement Funding - South Coast**
The South Coast Air Quality Management District's (SCAQMD) Clean Fuels Program provides funding for research, development, demonstration, and deployment projects that are expected to help accelerate the commercialization of advanced low emission transportation technologies. Eligible projects include powertrains and energy storage/conversion devices (e.g., fuel cells and batteries), and implementation of clean fuels (e.g., natural gas, propane, and hydrogen), including the necessary infrastructure. Projects are selected via specific requests for proposals on an as-needed basis or through unsolicited proposals. Approximately $10 million in funding is available annually with expected cost-share from other project partners and stakeholders. For more information, see the SCAQMD Research, Development, and Demonstration (http://www.aqmd.gov/home/library/technology-research/research-development-and-demontration) website.

**Alternative Fuel and Vehicle Incentives**
The California Energy Commission (CEC) administers the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP) to provide financial incentives for businesses, vehicle and technology manufacturers, workforce training partners, fleet owners, consumers, and academic institutions with the goal of developing and deploying alternative and renewable fuels and advanced transportation technologies. The CEC must prepare and adopt an annual Investment Plan (http://www.energy.ca.gov/2013publications/CEC-600-2013-003/CEC-600-2013-003-CMF.pdf) for the ARFVTP to establish funding priorities and opportunities that reflect program goals and to describe how program funding will complement other public and private investments. Funded projects include:

- Commercial alternative fuel vehicle (AFV) demonstrations and deployment;
- Alternative and renewable fuel production;
- Research and development of alternative and renewable fuels and innovative technologies;
- AFV manufacturing;
- Workforce training; and
- Public education, outreach, and promotion.

The program will be available until January 1, 2024. For more information, see the ARFVTP (http://www.energy.ca.gov/drive/) website. (Reference Assembly Bill (http://www.legislature.ca.gov/) 8, 2013; California Vehicle Code (http://www.oal.ca.gov/) 5205.5; California Health and Safety Code (http://www.oal.ca.gov/) 44270-44274.7; and California Code of Regulations (http://www.oal.ca.gov/), Title 13, Chapter 8.1)

**Advanced Transportation Tax Exclusion**
The California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA) provides a sales and use tax exclusion for qualified manufacturers of advanced transportation products, components, or systems that reduce pollution and energy use and promote economic development. Incentives are not available after June 30, 2016. For more information, including application materials, see the CAEATFA Sales and Use Tax Exclusion Program (http://www.treasurer.ca.gov/caeatfa/ste/index.asp) website. (Reference California Public Resources Code (http://www.oal.ca.gov/) 26000-26017)

**Employer Invested Emissions Reduction Funding - South Coast**
The South Coast Air Quality Management District (SCAQMD) administers the Air Quality Investment Program (AQIP). AQIP provides funding to allow employers within SCAQMD's jurisdiction to make annual investments into an administered fund to meet employers' emissions reduction targets. The revenues collected are used to fund alternative mobile source emissions/trip reduction programs, including alternative fuel vehicle projects, on an on-going basis. Programs such as low emission, alternative fuel, or zero emission vehicle procurement, and old vehicle scrapping may be considered for funding. For more information, including current requests for proposals and funding opportunities, see the AQIP (http://www.aqmd.gov/home/programs/business/business-detail?title=air-quality-investment-program) website.

***Point of Contact***
Shashi Singeetham
Air Quality Specialist
South Coast Air Quality Management District
Phone: (909) 396-3298
Fax: (909) 396-3608
ssingeetham@aqmd.gov (mailto:ssingeetham@aqmd.gov)
http://www.aqmd.gov/home/programs/business/business-detail?title=air-quality-investment-program (http://www.aqmd.gov/home/programs/business/business-detail?title=air-quality-investment-program)

**Alternative Fuel Vehicle (AFV) Incentives - San Joaquin Valley**
The San Joaquin Valley Air Pollution Control District administers the Public Benefit Grant Program, which provides funding to cities, counties, special districts (such as water districts and irrigation districts), and public educational institutions for the purchase of new AFVs, including electric, natural gas, and propane vehicles, as well as hybrid electric vehicles. The maximum grant amount allowed per vehicle is $20,000, with a limit of $100,000 per agency per year. Projects are considered on a first-come, first-serve basis. For more information, see the Public Benefit Grant Program (http://valleyair.org/grants/content/publicbenefit.html) website.

**Plug-In Hybrid and Zero Emission Light-Duty Vehicle Rebates**
The Clean Vehicle Rebate Project (CVRP) offers rebates for the purchase or lease of qualified vehicles. The rebates are for up to $5,000 for zero emission and plug-in hybrid light-duty vehicles that the California Air Resources Board (ARB) has approved or certified. The rebates are available on a first-come, first-served basis to individuals, business owners, and government entities in California that purchase or lease new eligible vehicles. Manufacturers must apply to ARB to have their vehicles included in CVRP. ARB determines annual funding amounts for CVRP, which is expected to be effective through 2023. No later than June 30, 2015, ARB and the State Energy Resources Conservation and Development Commission may adopt revisions to the criteria and requirements for CVRP such as a phase down of the rebate based on cumulative sales levels, eligibility limitations based on income, or other revisions to increase participation rates. For more information, including a list of eligible vehicles and other requirements, see the CVRP (http://energycenter.org/clean-vehicle-rebate-project) website. (Reference Senate Bill (http://www.legislature.ca.gov/%3EAssembly Bill%3C/a%3E 8 and %3Ca href=) 1275, 2014, and California Health and Safety Code (http://www.oal.ca.gov/) 44274 and 44258)

## Utility/Private Incentives

**Plug-In Electric Vehicle (PEV) and Natural Gas Infrastructure Charging Rate Reduction - SDG&E**
San Diego Gas & Electric (SDG&E) offers lower rates to customers for electricity used to charge PEVs. SDG&E's PEV Time-of-Use rates are available in two variations: EV-TOU-2 bills home and vehicle electricity use on a single meter; and EV-TOU bills vehicle electricity use separately, requiring the installation of a second meter. Lower rates are also available to customers who own a natural gas vehicle and use a qualified compressed natural gas fueling appliance at home. For more information about PEV Time-of-Use rates, see the SDG&E EV Rates (http://sdge.com/clean-energy/electric-vehicles/ev-rates) and NGV Rates (http://regarchive.sdge.com/tm2/pdf/GAS_GAS-SCHEDS_G-NGV.pdf) website.

**Plug-In Electric Vehicle (PEV) Charging Rate Reduction - SMUD**
The Sacramento Municipal Utility District (SMUD) offers two discounted pricing plans to residential customers who charge PEVs. Options include whole house and dedicated meter plans. For more information, see the SMUD PEV Pricing Plans (https://www.smud.org/en/residential/environment/plug-in-electric-vehicles/PEV-Rates/) website.

**Clean Vehicle Electricity and Natural Gas Rate Reduction - PG&E**
Pacific Gas & Electric (PG&E) offers a discounted Residential Time-of-Use rate for electricity used for plug-in electric vehicle charging and natural gas vehicle (NGV) home fueling appliances. Special rates are also available for natural gas that residential customers compress using home fueling appliances. For more information, see the PG&E EV Rate Options (http://www.pge.com/myhome/environment/whatyoucando/electricdrivevehicles/rateoptions/) and NGV Rates (http://www.pge.com/myhome/environment/pge/cleanair/naturalgasvehicles/rates/) websites.

**Electric Vehicle Supply Equipment Rebate - GWP**
Glendale Water and Power (GWP) offers a $200 rebate to the first 100 single-family residential customers that are electric vehicle owners and install a Level 2 240V charging station with a Safety Socket Meter Panel. For more information, see the Vehicle Home Charge Rebate Application (http://www.glendalewaterandpower.com/utility_modernization/electric_vehicle_rebate.aspx).

**Plug-In Electric Vehicle (PEV) Charging Rate Reduction - LADWP**
The Los Angeles Department of Water and Power (LADWP) offers a $0.025 per kilowatt discount for electricity used to charge PEVs during off-peak times. Residential customers who install a separate time-of-use meter panel will also receive a $250 credit. For more information, see the LADWP Electric Vehicle Incentives (https://www.ladwp.com/ladwp/faces/wcnav_externalId/r-gg-EVincentives?_adf.ctrl-state=il6iu2y7z_34&_afrLoop=203033140060675&_afrWindowMode=0&_afrWindowId=kfolzdw9d_1#%40%3F_afrWindowId%3Dkfolzdw9d_1%26_afrLoop%3D203033140060675%26_afrWindowMode%3D0%26_adf.ctrl-state%3Dkfolzdw9d_25) website.

**Alternative Fuel Vehicle (AFV) and Hybrid Electric Vehicle (HEV) Insurance Discount**
Farmers Insurance provides a discount of up to 10% on all major insurance coverage for HEV and AFV owners. To qualify, the automobile must be a dedicated AFV using ethanol, compressed natural gas, propane, or electricity, or be a HEV. A complete vehicle identification number is required to validate vehicle eligibility. For more information, see the Farmers California Insurance Discounts (http://www.farmers.com/california_insurance_discounts.html) website.

**Plug-In Electric Vehicle (PEV) Charging Rate Reduction - SCE**

**Plug-In Electric Vehicle (PEV) Charging Rate Reduction - SCE**
Southern California Edison (SCE) offers a discounted rate to customers for electricity used to charge PEVs. Two rate schedules are available for PEV charging during on- and off-peak hours, the Home & Electric Vehicle Plan and the Electric Vehicle Plan. For more information, see the SCE Electric Vehicle Residential Rates (http://www.sce.com/residential/rates/electric-vehicles.htm) website.

**Electric Vehicle Supply Equipment (EVSE) Rebate - LADWP**
The Los Angeles Department of Water and Power (LADWP) provides rebates to commercial and residential customers toward the purchase of Level 2 or DC fast charge EVSE. Commercial customers who purchase and install EVSE for employee and public use can receive $750, $1,000, or $15,000, depending on the charger type. Residential customers who purchase or lease qualifying plug-in electric vehicles can receive $750. EVSE must be installed within the LADWP service area; rebates do not cover the cost of installation. Rebates are available to the first 2,000 approved customers. The program will be in effect through June 30, 2015, or until funds are exhausted, whichever occurs first. For program guidelines and application materials, see the Charge Up L.A.! (https://www.ladwp.com/ladwp/faces/ladwp/residential/r-gogreen/r-gg-driveelectric?_adf.ctrl-state=1d4357epvd_4&_afrLoop=472125629767806) website.

California ▾ GO

**More Laws and Incentives**
To find laws and incentives for other alternative fuels and advanced vehicles, search all laws and incentives (/laws/).