



# Electric Vehicle Charging & Utility Pricing Structures

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*An Analysis by Ryan Wolber*

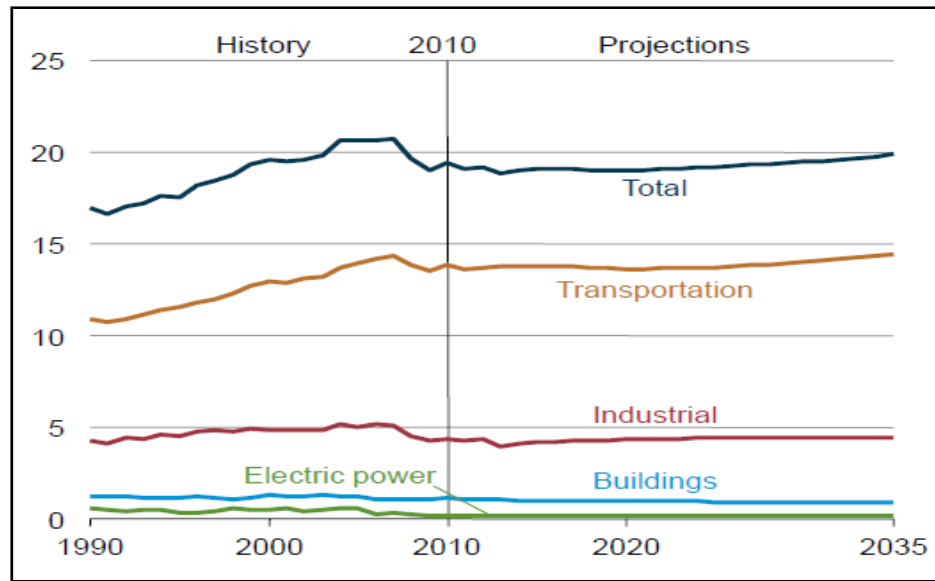
The purpose of this research is to find an economically efficient pricing scheme for residential electrical services that accomplishes two goals. First, provide electricity at a rate that will make electric vehicles more economically viable when compared to gasoline vehicles. Secondly, encourage electric vehicle owners to charge their vehicles during off-peak hours in a manner that is cost efficient for utility companies and does not result in additional investment in utility infrastructure to handle the increased electrical demand.

## **I. Introduction**

### *A) Topic Overview:*

Rising energy costs along with concerns on planetary climate change have created a unique situation for our country, and the way we meet our increasing energy demands. For over the last century we have been heavily reliant on traditional fossil fuels; oil; coal; and natural gas, for our main sources of energy, and that reliance continues to this day. According to the U.S. Energy Information Administration (U.S. EIA) these three fossil fuels make up 83% of the energy that is used to power our country<sup>1</sup>. While traditional fossil fuels have played a major role in our country's rise in military, diplomatic and economic dominance, these sources of energy are unsustainable and will eventually become economically inefficient. The realization that our current energy supplies are limited has led to technological advances in and increased usage of alternative forms of energy; an example of such is switching from a petroleum based transit system, to an electric one. This reality is more pertinent now than it has ever been with the sheer number of passenger vehicles being driven on our roads. According to the US Bureau of Transportation Statistics, there were 250,272,812 registered passenger vehicles on the road in the United States during the year 2010<sup>2</sup>.

What is more concerning than the sheer number of vehicles on road today, is the projected number of vehicles that will be on the road, burning more unsustainable fossil fuels in the near future. According to a study conducted by the Center for Automotive Research, by the year 2025 there will be an estimated 284 million light vehicles, operating and driving across the United States<sup>3</sup>. This is an estimated increase of over 30 million vehicles within a fifteen year time period. Additionally, according to the Department of Energy, the transportation sector is the leading consumer of petroleum/gasoline in the United States. Below is a graphic from the DOE showing this data and the projection of future gasoline use by the transportation sector<sup>4</sup>.



This visual clearly supports the claim from the Center for Automotive Research that there is a projected increase in the number of vehicles being driven on U.S. roads for the next twenty-five years. Converting our transportation sector from consuming greenhouse gas emitting oil, to electricity would reduce emissions that are tied to planetary climate change. We need to seriously look into an alternative to using gasoline to power our expanding passenger vehicle fleet, and the one alternative that my research and this paper will discuss is electric charged vehicles and the economics behind supplying the necessary electricity to power a cleaner, more environmentally friendly automotive market.

*B) Organizational Composition of this Paper:*

This paper will shed light on how utility provider’s can structure rates so as to make electric vehicle charging more economically viable than gasoline. More specifically the goal of my research will be to analyze cost effective market pricing structures for residential electric vehicle charging stations and how they compare to current and forecasted prices for standard unleaded and premium grade fuel. The research area that I will focus my efforts on analyzing will be the greater Bloomington-Normal. The main utility provider in Bloomington-Normal is Ameren IL,

and all utility rates will be based off of their information. In order to find an efficient rate I will to compare local utility rates for electricity, specifically during off-peak times, to local gasoline prices. Once I have these statistics I will conduct an efficiency conversion and analysis to determine the specific costs for traditional gasoline and electric vehicle users. In the following section I will go over the history of electric vehicles, along with the technical aspects of electric charging vehicles. We will then move onto section three where I will present the different ways companies can structure pricing options, and if they can do so in a manner that allows the company to use the current infrastructure and still handle the increased load demand. Section four will analyze the economic impact of electric vehicle charging on utility companies, while section five will perform an economic analysis and cost comparison for consumers. The last two sections will briefly look into any possible environmental benefits that a growth in the electric vehicle market may produce, along with my policy recommendations and concluding remarks.

## **II. Electric Vehicle Charging**

### *a) History of Electric Vehicles:*

In 1976, Congress passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act. The intent of this legislation was to act as a catalyst for developing hybrid/electric vehicle technologies. It would encourage electric vehicle development by allocating \$160million in federal research across a five-year timeframe. Aside from federal funding, the legislation would require the government to purchase over 7,000 electric vehicles for agencies and government employees to use. This two-pronged approach would increase public exposure to electric vehicles along with enhanced efficiency through improved technology. Even though President Gerald R. Ford vetoed the bill, both Houses of Congress voted to override the President's veto and the legislation became law<sup>5</sup>. Under the Energy Policy

Act of 1992, the usage of electricity to power vehicles is officially referred to as an alternative fuel to gasoline. This analysis will focus specifically on electric vehicle charging that involves “plug-in” electric vehicles. A plug-in electric vehicle utilizes a rechargeable electric battery that then feeds electricity to an electric motor. Plug-in electric vehicles are charged through the use of vehicle charging stations. There are several different types of charging stations that designed for different voltages and power levels. Electric vehicle charging stations have been on the rise in recent years, and according to the United States Department of Energy, there are currently 4,364 of these public electric vehicle charging stations across the country. More specifically there are 175 public charging stations throughout Illinois and 8 public charging stations in the greater Bloomington-Normal area<sup>6</sup>. Unfortunately the information on electric vehicle charging stations tracked by the DOE does not relate to home charging stations.

*b) Electric Vehicle Charging Stations:*

There are currently two levels of electric vehicle charging that have become customary, level one and level two. In the case of level one charging the average full recharging time may take 8-20 hours with the charging taking place at 120V, and at a 1.8kW power level. Level two charging is an alternative rate of charging and has the capacity to fully recharge a vehicle in a time frame of 3-8 hours with its charging occurring at 240VAC, and at a 19kW power level. Another model of charging station is being speculated for large scale usage; a charging level at a DC-DC. It would only take a vehicle roughly 30minutes to become fully charged with the 50kW power level this charging station could provide. However, there are significant safety concerns due to the high level of electricity used in this technology<sup>7</sup>. Level one and level two charging stations are available for home charging stations, while DC-DC is not available for home charging.

Even though it would be ideal to use the DC-DC charging station model because of its quick recharging capability, the safety concerns surrounding it make it ineligible. Also, while a level one charging station would be a safe baseline model to use because of its lower electrical system requirements, it simply does not charge the vehicle in a time efficient manner. Therefore for the remainder of my research will discuss level two charging stations. My reasoning behind this selection is that level two charging takes an estimated seven hours per charge for an 80% charge. More specifically a level two charging station can roughly provide an electric car with 10-20 miles of driving range for each hour the car is charged<sup>8</sup>. A seven hour charging period synchronizes perfectly with the most common off-peak time frame, night time. This data will be vital in my analysis between gasoline and electric vehicle charging later in this paper.

Level two charging equipment requires a system with an electrical circuit in the range of 20-80 amps, and at a 19.2 kW power output level. However, most residential level two Electric Vehicle Supply Equipment (EVSE) will operate at lower power within this spectrum, but as long as the power level is in the 20-80amps range the charging time will be unaffected. The term EVSE has been defined as such in California Article 625 EVSE as follows, “*The conductors, including the ungrounded, grounded, and equipment grounding conductors, the electric vehicle connectors, attachment plugs, and all other fittings, devices, power outlets or apparatuses installed specifically for the purpose of delivering energy from the premises wiring to the electric vehicle*”<sup>9</sup>. Simply, EVSE technology assists in communicating with the electric vehicle to ensure that an appropriate and safe flow of electricity is supplied. EVSE technology is a key component of electric vehicle charging and along with the history of electric vehicles; it completes the background information behind electric vehicles and their charging stations.

### **III. Off & On Peak Load Pricing**

#### *a) What is On & Off Peak Electricity*

In order to address this issue we will pursue off/on peak pricing schemes, on/off peak electricity? On peak refers to a period of time that may be minutes, hours, or even days in which the demand for electricity is greater than the projected level of electricity demanded. The exact definition of peak-load pricing is the variation in electricity prices according to the time of use. This variation can be attributed to the fact that the marginal cost, or the additional cost incurred for one more unit of electricity, is greater during certain day time hours than it is at night<sup>10</sup>. Peak electricity hours can be attributed to when people are typically at home and consuming electricity for powering devices, or consuming electricity for heating/cooling. Off peak times are the exact opposite of on peak hours and typically have a lower demand for electricity. Subsequently, off peak hours are during the morning hours and late evening hours when families are either at school, work or sleeping. If there is a miscalculation in electrical generation and levels of demand, then the electricity demanded will be greater than the electricity supplied then the resulting difference can cause a power outage. Peak and off peak hours are also impacted by the local climate.

According to the Citizens Utility Board, electricity can be quite inexpensive throughout most of the year, but just a handful of steamy summer hours have a devastating impact on our electric bills<sup>11</sup>. Peak demand hours during summer months are between 4pm-8pm, while off peak hours are from 6am-4pm, and 8pm-6pm<sup>12</sup>. Compared to summer months, on and off peak hours for winter months differ quite substantially. Peak winter hours include 5pm-8pm and 6am-10am and the additional four hours a day of peak hours can be contributed to the colder weather that comes with winter and the extra electricity demanded to heat homes during cold winter nights.

One final note on peak/off peak times, for the duration of my analysis we will work off of the claim that weekend days are categorized as off peak. Weekends can be listed as off-peak because the overall demand for electricity is lower on the weekends, which is a direct result of families not being home and instead traveling and/or running errands.

b) *Load Pricing Concerns:*

The Pacific Northwest National Laboratory conducted an impact assessment that electric vehicles would have on the U.S. power grid and came to this finding, “*Without further infrastructure investments, the current electric power system would be heavily loaded for most hours of all days. The overall system reliability could be reduced in this high utilization scenario as less reserve capacity is available to the system operators for managing system emergencies*”<sup>13</sup>. To really drive the point home as to how much electrical demand an electric vehicle can add to local grid, one report claims that an electric vehicle, plugged into a socket, can draw as much power as a small house. While one house using an electric vehicle does not create too much concern, the theory behind electric vehicle clustering does raise alarm bells for utility providers. Electric vehicle clustering applies social/economic/political dynamics to assume that purchasing an electric vehicle can be attributed to other reasons than economics, and that people of like minds tend to live in close proximity to one another. Therefore, there is the strong likelihood of entire neighborhoods converting to electric vehicles creating an unexpected high demand for electrical service. Electric vehicle clusters are expected in neighborhoods where there are generous subsidies are offered by states and localities, or even in areas with milder weather. Since batteries tend to perform better in warmer climates, warmer weather may act as a catalyst for electric vehicle usage, and in high-income and environmentally conscious commuters neighborhood and towns<sup>15</sup>.



#### **IV. Economics of Electric Vehicles for Utilities**

##### *a) Utilities providers in central Illinois:*

From my preliminary research, utility companies try to have electric vehicle charging take place during off-peak times in an attempt to allow the current infrastructure to be able to handle to electric load caused from electric vehicle charging. Ameren Illinois is the utility provider for central Illinois. For this study I have focused on the activities of Ameren Illinois. Ameren Illinois provides electricity to a majority of the state, covering all of southern and central Illinois. The company breaks down the state rates into three rate zones. Bloomington-Normal is covered under rate zone three. Prior to this system, what is now known as zone three received electricity from Ameren IP. The zoning structure was a measure taken by Ameren Illinois to limit confusion for customers during the transition period. This is a very narrow research topic, the methodology and efficiency facts are transferable to alternative locations and utility providers. Future research could simply reapply the same process that has been completed for this analysis and input the case specific values for electricity rates and fuel expenses.

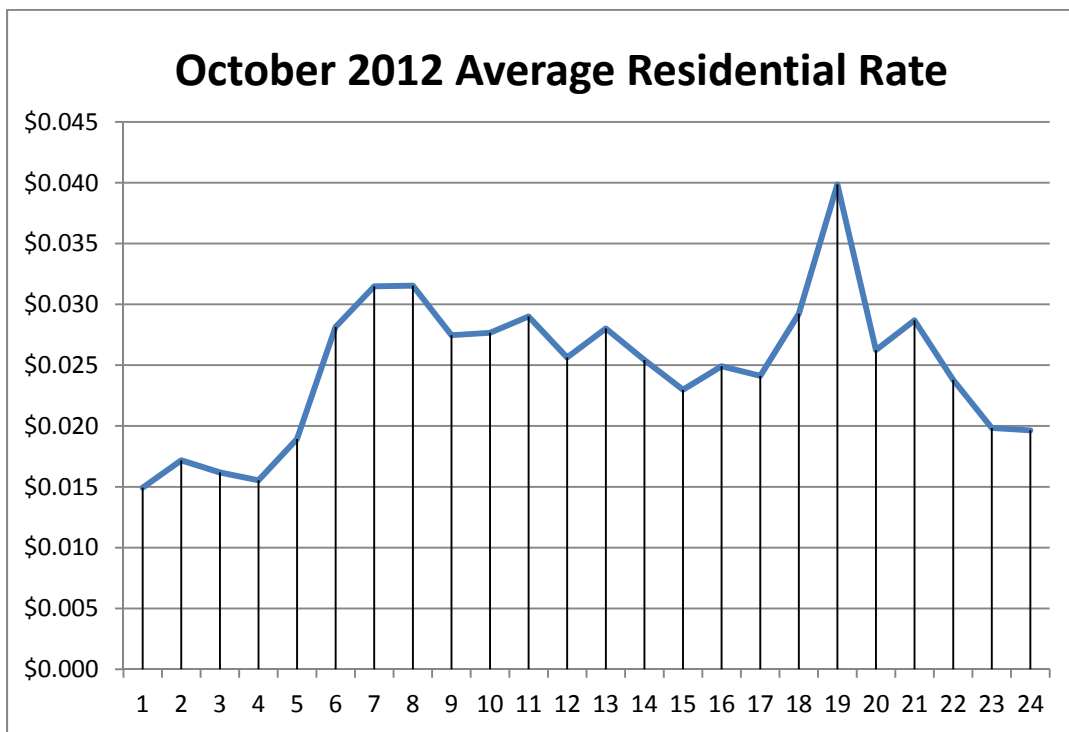
Ameren Illinois applies a monthly delivery charge at a rate of per kWh delivered to the customer. Ameren Illinois assigns load profile classifications not an account level, but at a point specific level of service. This means that if an account has multiple electric service points then each service point will be assigned its own load profile classification. Ameren offers sixteen different load profile classifications that are broken down into residential/commercial/industrial and are even broken down further by temperature/seasons and time of use. Each of these load profiles have a unique capacity and whichever category the consumer falls under decides this level. The standard Ameren pricing plan is the basic generation service. In this pricing plan the consumer pays for electric power at a predetermined rate that is agreed upon by both the

consumer and supplier. The standard pricing plan is the default plan and if consumer is apart of this pricing structure they cannot pursue other pricing options provided by Ameren, one of those alternatives is real time pricing. Ameren offers a real-time pricing option for its customers who wish to be able to take advantage of varying hourly prices. These prices represent direct figures for electricity provided per kWh and are the result of a fluctuating market supply and demand. Even though standard pricing structures are more commonly used, I will be applying real time pricing schemes to my analysis because the real time data categorized by Ameren will allow an analysis of on and off peak times. Real time pricing also has the potential to provide an incentive for consumers to charge their electric vehicles during times where the price per kWh is at its lowest.

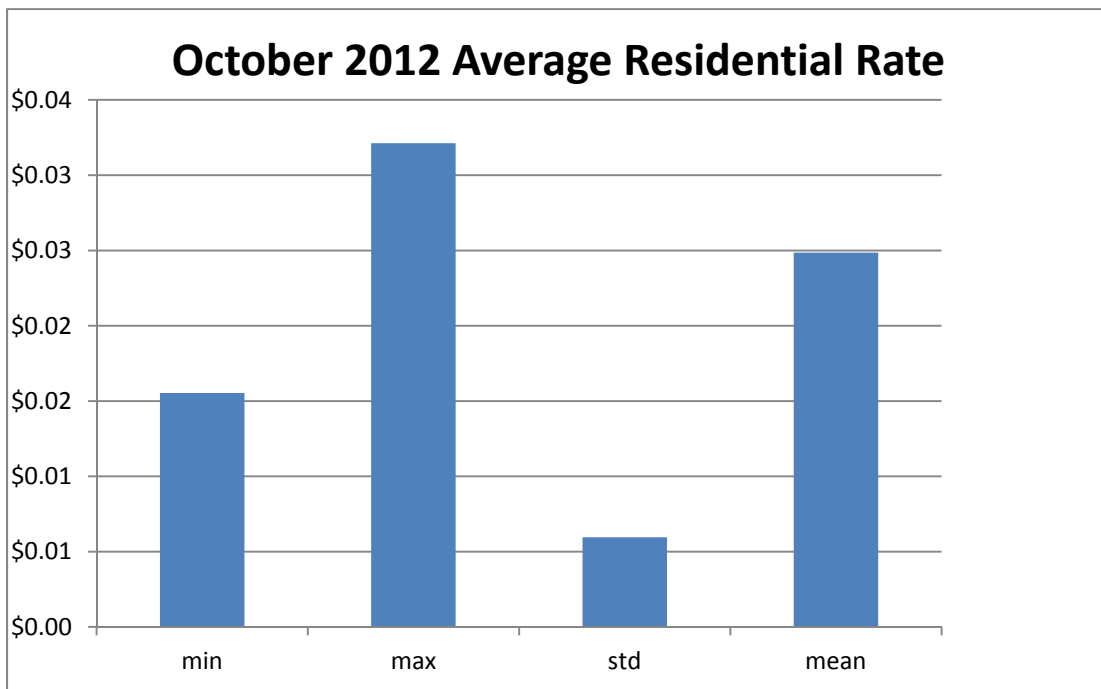
*b) Real Time Pricing*

Ameren Illinois offers two real time pricing options for their residential customers, power smart pricing and standard real time pricing. Customers who wish to be a part of the power smart pricing plan must take the initiative to sign up for these services through Ameren. The key difference between power smart pricing and real time pricing from the consumer viewpoint is that the power smart pricing is administered through an outside organization, CNT Energy and this program requires the consumer to contract with this rate pricing structure for at one fiscal year. Standard real time pricing schemes allow customers to use pricing signals that are made available through Ameren to take advantage of peak and off peak time frames. I will be utilizing Ameren standard real time pricing schemes for my research due to the convenience of this system for consumers, which is relatively much simpler to use than power smart pricing. According to historical data kept on pricing for rate zone three, as of Oct 19, 2012 the average monthly meter charge per electric service account was \$4.46. Utilizing the historical database

from Ameren Illinois, I was able to collect data on real time prices in \$/kWh for rate zone three for the entire month for July and October 2012. I selected these months because they are recent months in this past calendar year and will vary in weather and temperature which has been stated to have a difference in electricity pricing. The real time residential rates kept by Ameren organized the usage for each \$/kWh into individual hour throughout the month. Originally there were 744 separate values for real time prices per kWh for each hour of each day throughout the month of October but after analyzing the data it into its present and condensed form for this report, we have values for an entire twenty-four day. Microsoft excel will not allow a user to graph several hundred individual lines of data so I took the average cost of each kWh delivered for each hour of in each day. Using excel I categorized these prices according to the hour that they occurred so that the resulting data should each hours average real time price for a “standard” day in the test month.

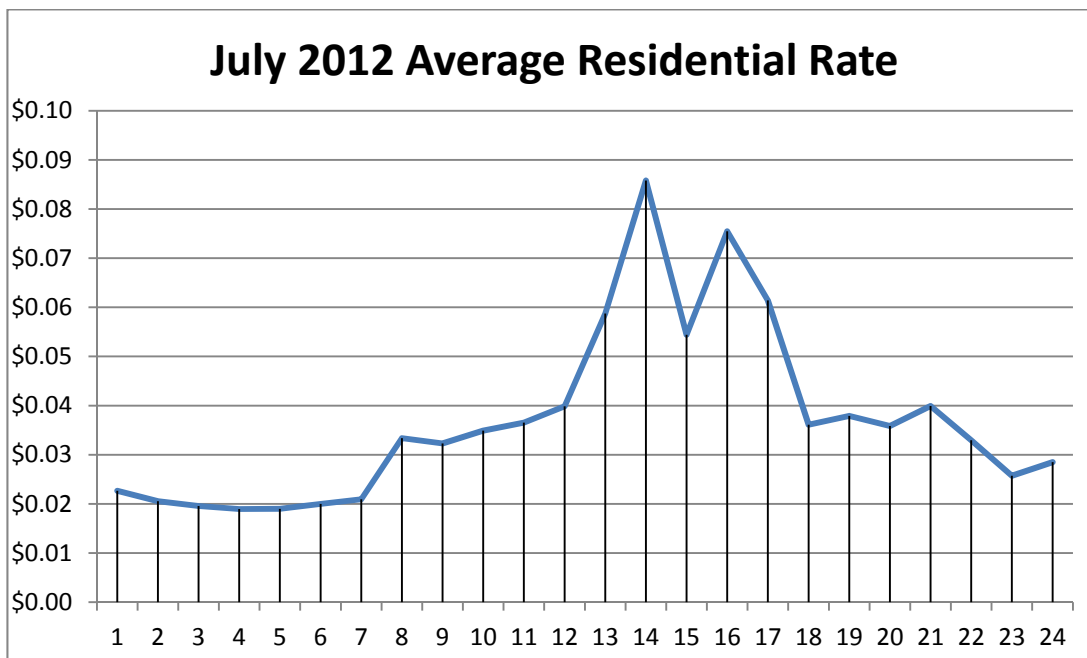


The x-axis on the graph shows the price per kWh of distributed electricity for each hour in an average day for the month of October. The y-axis shows the hours in a day, starting at one for 1am and going all the way to twenty-four for midnight. But after analyzing this data and summing the price per kWh distributed between 10pm-6am, I found that the average off-peak price per kWh of electricity distributed in Ameren IL rate zone three is \$.0187/kWh. I found this value by adding each average \$/kWh between 10pm-6pm and finding the average of those combined values. I selected this time frame because it fits into the predetermined off-peak times for both summer and winter months. Finally, I broke down the data from the month of October to include mean, min/max, and standard deviation to give a more comprehensive view of the data.



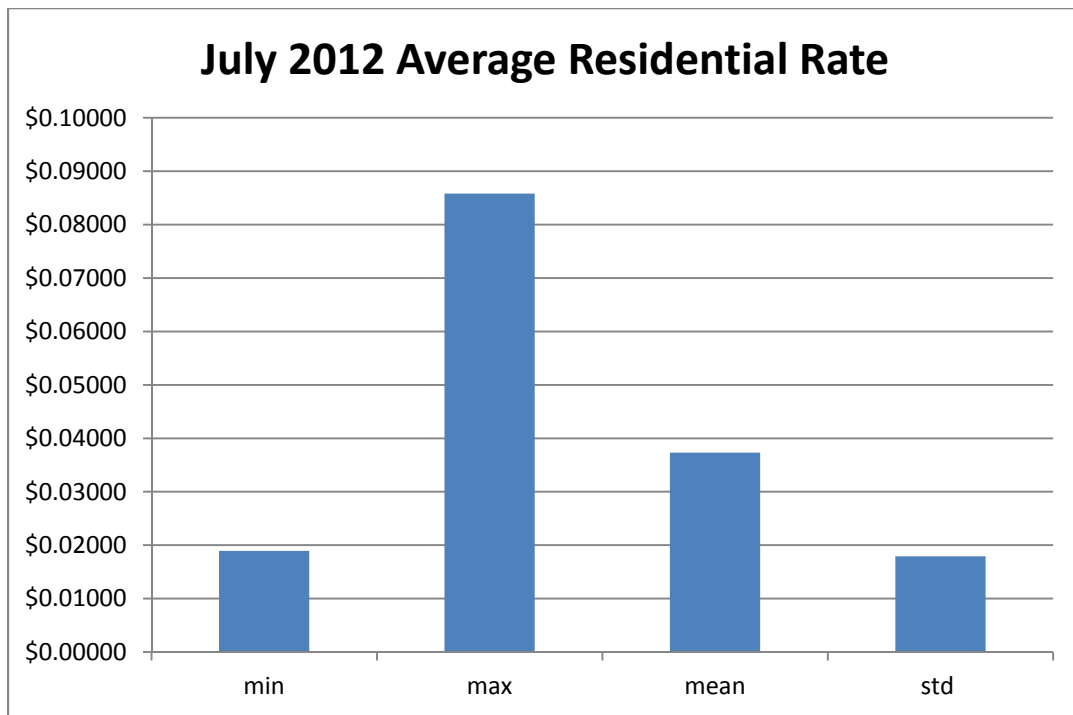
The minimum rate is \$.01554/kWh (midnight-1am) for the entire month, the maximum value is \$.03212/kWh (7pm-8pm), the standard deviation is \$.00595, and the mean for the month of October is \$.02485/kWh.

Earlier in this paper I stated that peak load pricing differs in the hottest months during the year, including July. I wanted to see if this statement were true for Ameren IL rate zone three and if the off peak prices were different during hot summer months as well. I performed the same data analysis and conversion process for the month of July that I conducted for the month of October. On the following page there is a similar graph that was constructed for October. The x-axis is the same for the July graph, with it representing the price paid by the consumer for each kWh of electricity. Additionally, the y-axis is the same with it showing the hours in a day, starting at one for 1am and going all the way to twenty-four for midnight.



Unlike the October graph, from month of July 2012 has significantly higher peak prices with prices spiking to nearly \$.09/kWh during peak load hours. Compare this rate to the peak load hours during October 2012 which only peak around \$.04/kWh, there is an increase of over 100% in peak load pricing per kWh between these months. While there is a significant difference of more than double peak load prices, there is no such difference for off peak pricing between the two months. After summing the average hourly rates for the time frame of 10pm-6am for the

month of July and finding the average of those values, the average hourly rate for off-peak pricing is \$.0215/kWh, which is \$0.0028 more expensive than the off-peak rate for the October. This difference can be attributed to an increased demand of electricity because of the hot weather during summer months, like July. Finally, I broke down the data from the month of July just like performed for the month of October to include mean, min/max, and standard deviation to give a more comprehensive view of the data.



The minimum rate is \$.01894/kWh (midnight-1am) for the entire month, the maximum value is \$.08579/kWh (7pm-8pm), the standard deviation is \$.0179/kWh, and the mean for the month of July is \$.03733/kWh. Even though the monthly average is higher than the off-peak rate, we are using the off-peak average since that is the period of time that the electric vehicle consumer will be charging his/her vehicle.

Part of my research was to determine efficient pricing schemes for both customers and suppliers (utility companies) during peak and off peak load times. By accessing Ameren's

database on historical real time prices, I have done just that. The prices that I found were the direct product of economic market principles in action. We now have specific real prices that were applied to the utilities market for a sample summer month and a sample later autumn month. The next step in this economic analysis is to apply these off-peak prices to charging electric vehicles to local gasoline prices and projected fuel prices to determine the cost competitiveness between the two technologies.

## **V. Economics of Electric Vehicle for Consumers**

### *a) Selecting a Baseline Model*

While it is incredibly important to find an economically efficient manner to construct off peak pricing for the utility provider, it is equally important to determine if these costs and rates are cost-effective for consumers. For this analysis I only took into consideration the purchase price of the one pre-selected electric vehicle model, while focusing my analysis a payback period for the consumer purchasing the electric vehicle and comparing fueling costs between gasoline and electric. The electric vehicle market has countless models and manufacturers, so in order to simplify my analysis I have selected the Nissan Leaf to be my case subject electric vehicle for this analysis because it is widely popular with an annual global production of 500,000 units and has market presence on four continents (Asia, Australia, Europe and North America).

The Nissan Leaf has a 24kWh lithium-ion battery with an advertised all electric range of 100miles per fully charged battery, but a 73mile all electric range according to the Environmental Protection Agency. I selected the conservative mileage range designated by the Environmental Protection Agency, 73miles per charged battery. Additionally, before any tax breaks, the Nissan Leaf costs \$33,720<sup>15</sup>. An additional reason for selecting the Nissan Leaf for my test vehicle is that it falls under the definition of a light duty vehicle. A light duty vehicle has

been defined as a vehicle with a gross vehicle weight rating of 6,000 pounds or less, as determined under section 216(7) of the Clean Air Act (42 U.S.C. § 7550(7)CLEAN AIR<sup>16</sup>. This category of vehicle covers most electric vehicles, especially the one highlighted in this report as the benchmarking tool, the Nissan Leaf and its 24kWh battery. According to the Research and Innovative Technology Administration, which is a part of the Bureau of Transportation, the average fuel efficiency in 2009 for a U.S. light duty vehicle was 23.8mpg<sup>17</sup>. With a baseline average for miles per gallon for traditional gasoline light duty vehicles, it is now vital to determine current oil and projected oil prices.

*b) Current & Forecasted Oil Prices:*

Earlier in this paper I briefly mentioned how our current energy sources, specifically fossil fuels, are unsustainable and will eventually become economically inefficient. One of those fossil fuels in particular, oil, will have a major impact on the future of the automobile sector in the United States. According to the CNN Money data on the commodities trading, as of Oct 2012 Oil (light crude) was being traded at \$91.86 per barrel. Comparing this data with forecasted models on the price of oil per barrel from 2015-2035, we can see that it is projected that oil prices per barrel will increase. One main problem with using forecasted models for an economic analysis is the accuracy of the forecast, and the validity and level of bias that may be present during the calculations. There is also the issue of completely unforeseen economic or natural disasters that may take place. The United States Federal Reserve Board had this to say on oil price forecasting, *“There is reason to be skeptical of the seeming forecasting success of many nonlinear models during the recent financial crisis”*<sup>18</sup>. It was clear that selecting a valid source for my forecasted oil pricing would be crucial to the validity of my own study so taking all of this into consideration; I have decided to reference the Energy Information Administration on



future oil prices per barrel in order to find data on possible future prices of oil in this country.

One of the main concerns with electric vehicles on the consumer side of this topic is the high upfront costs of this technology when compared to traditional gasoline powered vehicles<sup>19</sup>.

While current fuel costs are significantly higher than the days of \$1.90/gallon, if we are to see usage of electric vehicles expand even further then they will have higher fuel costs to make electric vehicles even more economically viable than they currently are. After gathering data from seven separate projections on oil price futures and compiling an average of those future prices at the bottom of the graphic, there is a uniform trend of an increasing average price of oil per barrel from 2015-2035.

Price of oil per barrel 2015-2035 (at 2010 dollars per barrel)

Projection	2015	2020	2025	2030	2035
AEO 2012 (reference case)	116.91	126.68	132.56	138.49	144.98
EVA	82.24	84.75	89.07	94.78	102.11
International Energy Agency	106.3	118.1	127.3	134.5	140
INFORUM	91.78	105.84	113.35	117.83	116.76
IHSGI	99.16	72.89	87.19	95.65	98.08
Purvin & Gertz	98.75	103.77	106.47	107.37	107.37
SEER	94.2	101.57	107.13	111.26	121.94
<b>Average</b>	<b>98.1</b>	<b>102.83</b>	<b>110.2</b>	<b>115.51</b>	<b>119.66</b>

These projections were compiled by the Energy Information Administration and I took those figures and averaged those values together to gather a holistic view on future oil prices. It should be noted that these projections are in present day nominal dollars and do not take inflation

into account. The average price of oil per barrel is currently being traded at \$91.86 per barrel, but this figure is estimated to increase continuously from present day to 2035. But within 23yrs there is an estimated increase of \$27.80 per barrel of oil, which is a 30.26% increase in price from its original value in 2012. All of this data gives clarity to the fact that oil and gasoline prices are expected to rise over the next twenty years. This fact will play a role in the upcoming cost comparison, but first we must find specific fuel cost in my research location, central IL.

*c) Fuel costs in central Illinois:*

The state of Illinois keeps a database on gasoline prices, and after accessing this database I found that the statewide averages for September 2012 were \$4.10/gallon for mid-grade, and \$4.22/gallon for premium grade fuel<sup>20</sup>. By breaking it down even further and analyzing the gas prices for the 61761 zip code area, which includes Bloomington-Normal, the averages for September 2012 were \$3.80/gallon for mid-grade, and \$4.02/gallon for premium grade fuel. This database tracks current gasoline prices by state, by county and even by the service station in the area selected. Additionally, this database condenses pricing information to show trends in gasoline prices and whether they are increasing, decreasing, or remaining static.

It is extremely important to properly define charging costs when making the cost comparison between standard gasoline and electric charging. When compared to traditionally vehicles, the most important factor for calculating fuel cost of driving an electric vehicle depends on the cost of electricity per kilowatt-hour and the energy efficiency of the vehicle. For my upcoming analysis the charging costs will only include the physical electrical charging expenses consumers pay to run their electric vehicles.

*d) Electric v. Gasoline Cost Comparison:*

Before going into my analysis on fuel cost comparisons, I analyzed the costs differences between a Nissan Leaf electric vehicle and a standard light duty vehicle. First, I did not take any government incentives for purchasing an electric vehicle into consideration for this assessment. Secondly, the cost of the electric charging station has been calculated into the initial cost of the electric vehicle. A level two electric charging station costs between \$1,000-\$7,000 and this price variance depends on the efficiency of electric charging station. For my analysis I took the median value of this range and assumed that the charging station was priced at \$4,000 <sup>21</sup>.

I have already set the efficiency of the vehicle by going off of the Nissan Leafs 24kWh hour that has an EPA estimated electric range of 73 miles per full charge<sup>22</sup>. The testing range will be 73 miles per day for both the electric vehicle Nissan Leaf, and the U.S. average light duty vehicle. In order to find the costs for running a Nissan Leaf getting an average 73miles per fully charged battery, I had to make several assumptions on the infrastructure of the electric system in the home charging station. First, since the ampere range needed to run a level two charging station is between 20-80amps, I have selected the median amp value, 50amps. Next I had to determine how many miles/kWh the Nisan Leaf can get going off of the 73miles per charge determined by the EPA. This was a simple mathematical operation including dividing the estimated fuel economy by its battery capacity (73miles/24kWh), which led me to find the miles/kWh in a Nissan Leaf is 3.04miles/kWh. At a rate of \$.02/kWh, the cost per mile is only \$.00067, and even at a rate of \$.11/kWh, the cost per mile is only \$.036 per mile. Going off of the historic real time prices of \$.02/kWh during the eight time frame between 10pm-8pm, the total cost for fully charging a Nissan Leaf would only be \$.48. Running your electric vehicle at these prices and efficiency for one month (30 days) would only cost \$14.40, and for one year

(365 days) it would only cost \$175.20. These costs are incredibly low and to show just how inexpensive they are when compared to gasoline costs, I have attached my costs estimation for the same miles traveled for a traditionally powered gasoline vehicle. The costs below are calculated for driving a gasoline powered U.S. average light duty vehicle for one day, one month and one year.

Average Light Duty vehicle Fuel Economy = 23.8mpg	3.07 gallons needed for an average LDV to travel 73 miles (one days worth of traveling)
Bloomington-Normal Mid Grade = \$3.80/gallon	1 day = <b>\$11.67</b> for 3.07 gallons of fuel 1 month = ( $\$11.67 * 30$ ) = <b>\$350.10</b> 1 year = ( $\$11.67 * 365$ ) = <b>\$4,249.55</b>
Bloomington-Normal Premium Grade = \$4.02/gallon	1 day = <b>\$12.34</b> for 3.07 gallons of fuel 1 month = ( $\$12.34 * 30$ ) = <b>\$370.20</b> 1 year = ( $\$12.34 * 365$ ) = <b>\$4504.10</b>

Working off of the 73miles of travel per day and the 23.8mpg average fuel economy, an average light duty vehicle would require 3.07gallons of gasoline to travel those 73miles. At a rate of \$3.80/gallon for mid grade fuel, one day of traveling would cost \$11.67. Subsequently one month would cost \$350.10 and one year would cost \$4,249.55 in mid grade fueling costs. Applying the same mathematical process to premium grade fuel, at a rate of \$4.02/gallon, one day of traveling would cost \$12.34, one month would cost \$370.20 and one year would cost \$4,504.10 for premium grade fueling.

After finding costs for both types of vehicles it is clear that electric vehicles have significantly lower fueling costs. The Nissan Leaf only has a fueling cost of \$175. 20 for an

entire year while medium grade gasoline would cost \$4, 249.55 and premium grade gasoline fueling cost would total \$4,504.10 for an entire year. Even if the Nissan Leaf were to be charged at the national average residential rate of \$.12/kWh, it would only cost \$2.88 for an entire charge and day's worth of driving<sup>23</sup>. Continuing the application of average residential rate of \$.12/kWh, it would only cost \$86.40 and even more impressive is that it would only cost \$1,051.20 to charge your electric car and drive it every day for an entire year. Originally I researched the average price for a US Standard Light Duty Vehicle, but I was unable to find such a value. Furthermore, since my fuel cost analysis compared the Nissan Leaf to the US Standard Light Duty Vehicle, comparing costs of the Nissan Leaf to a specific vehicle or different type would make these analyses inconsistent with one another. Next I will perform a payback analysis for the Nissan Leaf, based off of the potential fuel savings from switching from gasoline fuel to electricity.

The Nissan Leaf has an upfront purchasing cost of \$33,720 before any tax breaks the consumer may benefit from. This analysis will take the conservative approach and shall not take into consideration any economic incentives from government tax incentives. By combining the upfront purchasing cost of \$33,720 for the vehicle, with the median purchasing and installation cost for the residential charging station of \$4,000, we have an initial investment of \$37,720 for an electric vehicle. The fuel savings each year from driving the electric vehicle would repay the initial investment of the electric vehicle and charging station in 9.256 years when compared to mid grade fuel, and 8.713 years for premium grade fuel.

The savings between these two vehicles is clear and impossible to ignore. If electricity is priced at off peak real time pricing, the car owner is looking at an annual fuel savings of \$4,074.35 when compared to mid-grade fuel and a savings of \$4,328.90 when compared to

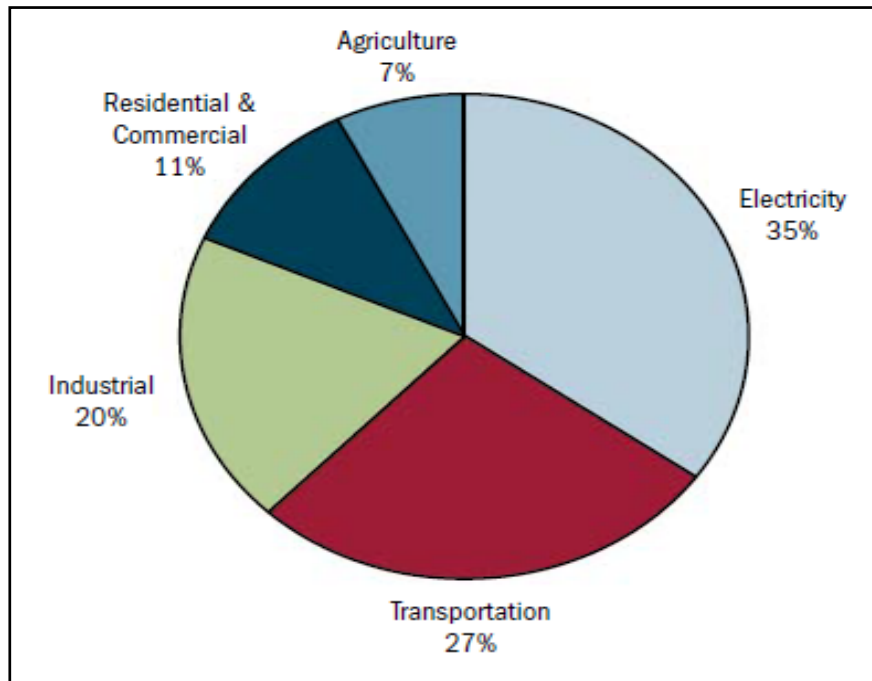
premium grade fuel. Even if electricity is priced at the average residential rate which would include peak load pricing, the electric vehicle owner would still see savings of \$3,198.35 when compared to mid grade and a savings of \$3,452.90 when compared to premium grade fuel. The economics behind electric vehicle charging create a clear case for drivers to invest in electric vehicles. Even if electric companies do not choose to rate electricity at real time prices, the electric vehicle owner would save money when compared to gasoline powered U.S. light duty vehicles. One concern electric vehicle users face is the lack of experience maintenance providers have in providing inexpensive and efficient maintenance for electric vehicles. However, as this technology because more widely used, it is expected that efficient and inexpensive service will be developed to provide for the new electric vehicle market.

The economics behind electric vehicle charging for both the utility supplier and the consumer are clear in saying that it is economically feasible to have electric car charging during off peak times for both parties. One final issue this paper will briefly investigate is the environmental aspects of electric vehicle charging.

## **VI. Environmental Impacts**

While the focus of this paper has been on the economic structuring of electric car charging stations, one of the main selling points of an electric car infrastructure are its positive environmental benefits and such a key characteristic warrants further investigation. I mentioned earlier in my paper that the unique energy situation our country faces comes from a two pronged approach of increasing energy costs and planetary climate change from the burning of fossil fuels. One of the main claims used to support the advancement of electric vehicle usage in the United States is that current fuel for automobiles releases green house gases, mostly carbon dioxide from gasoline. The chart below by the Pew Center on Global Climate, Transportation

Emissions illustrates the different sectors and the amount of climate change inducing green house gases they emit as of 2008<sup>24</sup>.



Even though the transportation sector is single handedly accounting for over a quarter of the green house gases emitted, the greatest single producer of green house gases is from electricity generation. Unfortunately I have been unable to find specific data on green house gas emissions from electrical generation that is specifically used to power electric vehicles. However, according to the Energy Information Administration, the second leading producer for electricity generation in Illinois is from coal-fired power plants which are responsible for generating 8,104 GWh of electricity per year, just behind nuclear power which contributes 8,175GWh of electricity per year. The carbon footprint that is associated with producing electricity from nuclear is entirely insignificant, but the footprint from coal powered electricity is significant. What type of feedstock that is used to produce electricity plays a critical role in determining how environmentally friendly an electric vehicle is when compared to gasoline vehicles.

Electric vehicles do not release any direct emissions from actually driving the vehicle; there is the possibility for significant emissions from the production of the electricity used to charge the vehicle. Depending on the source of electrical generation, there can be costly emissions produced from electrical generation. You must take into account the carbon released from extracting the oil that is converted into gasoline, and the amount of carbon that is released from extracting and processing coal that is used to create electricity for electric vehicles. A study performed by the Union of Concerned Scientists analyzed the differences in green house gas emissions between petroleum based vehicles and electric vehicles and came up with a unit of measurement to determine which option is less damaging to the atmosphere. *This unit of measurement evaluates the global warming emissions that would result at the power plant from charging a vehicle with a specific amount of electricity by converting the standard miles-per-gallon (MPG) into a gasoline mile-per-gallon equivalent—designated  $MPG_{ghg}$ , where “ghg” stands for greenhouse gases. If an electric vehicle has an  $MPG_{ghg}$  value equal to the mpg of a gasoline-powered vehicle, both vehicles will emit the same amounts of global warming pollutants for every mile they travel<sup>25</sup>.*

This study went onto break down portions of the United States according to the electrical generation to then determine the necessary fuel economy a gasoline vehicle would need to be equally “carbon clean” as an electric vehicle. Bloomington-Normal fell under the grid section of SERC Midwest, which has a score of 37. This number was figured from electrical generation by source in the area and then converted into  $MPG_{ghg}$ . A score of 37 means that a gasoline powered vehicle would have to have a fuel economy of 37mpg to be as environmentally friendly as an electric vehicle. Going off of the national average fuel economy of 23.8mpg, it my claim that electric vehicles, even those charged with coal in Illinois, do not produce as many direct/indirect green house gas emissions as gasoline powered vehicles<sup>26</sup>. This is proof that electric vehicles in



Illinois are both economically beneficial, and a more environmentally friendly transportation option when compared to gasoline vehicles.

## VII. Concluding Remarks

### *a) Electric Vehicle Economic findings:*

From the cost comparison that I performed during my research it is clear that when compared to the current fuel economy of an average gasoline powered U.S. light duty vehicle, electric vehicles have a significantly smaller fueling cost at off-peak electricity rates. Not only are fueling costs less in today's current market, but the projected fuel costs create a scenario for an even better cost savings for electric vehicle drivers when compared to traditional gasoline powered vehicles. With average prices per barrel of oil expected to rise 30.6% by 2035, electric vehicle charging will only become more economically viable than it already is. It should be noted that this analysis only looked into costing for one specific test vehicle, the Nissan Leaf and that there are various models of electric vehicles with a less efficient fuel economy. While I did perform a payback analysis on the economic savings compared to the high upfront costs, future research into this topic could include an expansion on my analysis and include a specific make and model of a gasoline vehicle to determine which is more cost competitive, gasoline or electric.

### *b) Rate Structuring Tools:*

My findings on the cost comparisons and costs savings for electric vehicle consumers is positive news for that share of the market, but what does this mean for utility providers. One of the key assumptions my analysis worked with was electricity service being priced at a real time price structure. While real time pricing is favorable for utility companies because it allows its consumers to monitor their own electrical consumption according to costs, resulting in a

decreasing demand during high cost/high peak demand times, real time pricing also results in zero profit for the provider. Ameren Illinois clearly states on the corporations informational section on real time pricing that “Ameren Illinois does not profit from electric supply charges, including those for real-time pricing. We pass along the price we pay for electricity to our customers, dollar for dollar”. Even though enacting policies and initiatives that will encourage consumers to utilize real time pricing structures would decrease the strain on the electrical system, is that a sacrifice corporations are willing to pay for losing out on profits?

My recommendation to remediate this issue would be to install a time of use rate structuring model for all residential customers. This price structuring model would charge a standard fee for all hours of the day, except for pre-determined hours that would be agreed upon by both parties. Time of use tariffs are currently used in electrical markets, one company taking advantage of this pricing option is Pacific Gas & Electric. By offering lower rates to their customers during off-peak hours the company can attempt to entice electric vehicle owners to charge their vehicles during times when the electrical system can handle the additional demand. The ideal result of this system is that electric vehicle owners are able to charge their vehicles at lower prices, while at the same time efficiently maximizing the potential of utility power plants<sup>27</sup>.

Ameren Illinois could adopt a similar time of use system and apply their own historic real time prices during off-peak hours where they sell electricity at \$.02/kWh during 10pm-6am, regardless of seasonal changes. For remaining times throughout the day they could charge the standard residential rate that it already employs. This mixed pricing tariff would benefit electric vehicle owners and utility providers alike by providing very inexpensive electricity for people to charge their vehicles with, while incentivizing and encouraging off-peak electric vehicle charging and therefore avoiding system overload during peak hours.

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