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State Corporation Commission
of Kansas

**BEFORE THE STATE CORPORATION COMMISSION
OF THE STATE OF KANSAS**

DIRECT TESTIMONY OF

Daniel Bowermaster

ELECTRIC POWER RESEARCH INSTITUTE

IN THE MATTER OF THE APPLICATION OF KANSAS CITY POWER & LIGHT COMPANY FOR APPROVAL OF ITS CLEAN CHARGE NETWORK PROJECT AND ELECTRIC VEHICLE CHARGING STATION TARIFF

DOCKET NO. 16-KCPE-160-MIS

Q: Please state your name and business address.

A: My name is Daniel Bowermaster. My business address is 3420 Hillview Road, Palo Alto, California 94304.

Q: By whom and in what capacity are you employed?

A: I am employed by the Electric Power Research Institute ("EPRI") as Program Manager, Electric Transportation. EPRI is an independent non-profit center for public interest energy and environmental research.

Q: In what capacity are you testifying?

A: KCP&L requested EPRI perform an analysis of the economic, environmental and consumer impacts related to its deployment of its Clean Charge Network ("CCN") for electric vehicle ("EV") charging stations. I am presenting the results of that independent scoping study.

Q: What are your responsibilities?

A: I am responsible for managing EPRI's electric transportation research program.

The program's research focuses on the development, deployment, and analysis of plug-in electric vehicles and charging infrastructure and collaborates heavily with the automotive and technology industries. A sample of the team's research and demonstration projects includes electric vehicle infrastructure grid impact and integration, environmental impact of electric vehicles, plug-in truck demonstration, total cost of ownership, electric vehicle driver preference/behavior, electric forklift cost savings calculator, seaport electrification case studies, analysis of electric and natural gas options for fleet support, and plug-in electric vehicle readiness for utility customers.

Q: Please describe your education, experience and employment history.

A: Prior to joining EPRI in December 2011, I worked at Pacific Gas & Electric Company where I led PG&E's customer-facing Electric and Natural Gas Vehicles team. I joined PG&E in September 2008 as part of the MBA Leadership Program, working in PG&E's Engineering and Operations, Power Generation, and Corporate Strategy groups. From 1999 to 2006, I worked for medical device manufacturer Stryker Corporation in roles manufacturing engineering, quality engineering, and production management, working in six different factories in California, Texas, and Germany.

In May 2008, I completed the Wharton-Lauder dual graduate degree program, earning a master's in business administration from the Wharton School of Business and a master's in international studies from the University of Pennsylvania. In addition, I hold bachelor's degrees in mechanical engineering and in international relations from the University of California, Davis earned in 1999.

Q: Have you previously testified in a proceeding before the Kansas Corporation Commission ("Commission" or "KCC") or before any other utility regulatory agency?

A: No.

Q: What is the purpose of your testimony?

A: The purpose of my testimony is to present EPRI's study regarding the benefits of electric transportation vehicles and related charging infrastructure. EPRI's report on this study entitled, *Preliminary Scoping Analysis of the Effects of Transportation Electrification in the KCP&L Service Territory*, ("EPRI Study") is attached to my testimony as Schedule A-1.

Q: How is the EPRI Study organized?

A: The study is a scoping study that is intended to provide a preliminary look at the potential effects of increased infrastructure availability. It is organized into four main parts which describe the environmental, macroeconomic, and transformer-level impacts of increased transportation electrification and the potential ratepayer impacts of the proposed charging program.

Q: What are the primary conclusions of the EPRI Study?

A: The study finds that transportation electrification could provide environmental and economic benefits for the KCP&L service territory, with relatively low impacts on the existing distribution system. The ratepayer effects of infrastructure installation will depend on the number of plug-in electric vehicles sold within the service territory, but payback could be achieved with adoption levels that are reasonable to expect.

Q: Did EPRI review other studies regarding EV charging stations as part of its research for the EPRI Study?

A: EPRI conducts its own research of electric transportation. In addition, EPRI reviews studies on an ongoing basis, serving as peer reviewers of papers and studies as well as conducting independent reviews of specific studies of EV charging and related infrastructure.

Q: Will EPRI be conducting any follow-up research/study on KCP&L's EV CCN project following full implementation of the project?

A: The current scoping study established an initial estimate of potential value, and it is EPRI's understanding that KCP&L will direct further investigation of the various value elements in more detail. This will allow the initial results to be validated and made more specific to the final plan proposal.

Q: Does that conclude your testimony?

A: Yes, it does. Thank you.

BEFORE THE STATE CORPORATION COMMISSION
OF THE STATE OF KANSAS

In the Matter of the Application of Kansas City Power & Light Company For Approval of Its Clean Charge Network Project and Electric Vehicle Charging Station Tariff	))))	Docket No.: 16-KCPE-160-MIS

AFFIDAVIT OF DANIEL BOWERMASTER

STATE OF CALIFORNIA)
COUNTY OF SANTA CLARA)

Daniel Bowermaster, being first duly sworn on his oath, states:

1. My name is Daniel Bowermaster. I work at the non-profit Electric Power Research Institute (EPRI) in Palo Alto, California, and I am employed by EPRI as Program Manager, Electric Transportation. I have been retained to serve as an expert witness to provide testimony at the request of Kansas City Power & Light Company.

2. Attached hereto and made a part hereof for all purposes is my Direct Testimony prepared at the request of Kansas City Power & Light Company consisting of forty-nine (49) pages, having been prepared in written form for introduction into evidence in the above-captioned docket.

3. I have knowledge of the matters set forth therein. I hereby swear and affirm that my answers contained in the attached testimony to the questions therein propounded, including any attachments thereto, are true and accurate to the best of my knowledge, information and belief.

Daniel S. Bowermaster

Daniel Bowermaster

Subscribed and sworn before me this 16th day of February, 2016.

Sandra K. Tokunaga

Notary Public

My commission expires: October 12, 2017

SANDRA K. TOKUNAGA
Commission # 2051548
Notary Public - California
San Mateo County
My Comm. Expires Dec 12, 2017

CALIFORNIA ALL-PURPOSE ACKNOWLEDGMENT **CIVIL CODE § 1189**

A notary public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity of that document.

State of California)
County of Santa Clara)

On February 16, 2016 before me, Sandra K. Tokunaga, Notary Public,
Date *Here Insert Name and Title of the Officer*

personally appeared Daniel Bowermaster
Name(s) of Signer(s)

who proved to me on the basis of satisfactory evidence to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

SANDRA K. TOKUNAGA
Commission # 2051548
Notary Public - California
San Mateo County
My Comm. Expires Dec 12, 2017

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.

Signature [signature]
Signature of Notary Public

Place Notary Seal Above

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Schedule A-1

Preliminary Scoping Analysis of the Effects of Transportation Electrification in the KCP&L Service Territory

Electric Power Research Institute

February 16, 2016

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I. Executive Summary

Transportation has a large and significant role in the economy and livelihoods of Americans. A transition toward electric transportation will likely have far-reaching effects. It is widely expected that ownership of electric vehicles will increase substantially over the next decade. In order to understand the effects of transportation electrification in the Kansas City Power and Light Company (KCP&L) service territory, the Electric Power Research Institute (EPRI) performed an initial scoping analysis of such a transition. The analysis consists of four sections which describe the effects of transportation electrification on (1) the environment, (2) the existing KCP&L distribution system, (3) the regional economy, and (4) utility customers. The analysis used existing research and models incorporating KCP&L specific data to analyze each element. The results indicate that transportation electrification could provide significant benefit to KCP&L's stakeholders. Further analysis utilizing KCP&L data from the Clean Charge Network is planned to be performed later this year to confirm and expand upon these initial findings.

A summary of findings from the initial scoping analysis include:

(1) Environmental Effects

The environmental analysis using KCP&L's generation fleet mix confirms the findings in the Union of Concerned Scientists (USC) analysis (2015), a nationwide comparison that shows the fuel economy that a gasoline vehicle would have to achieve in order to have the same life cycle greenhouse gas emissions as most conventional vehicles throughout the country. Based on KCP&L's fleet mix, a plug-in electric vehicle (PEV) in the KCP&L service territory in 2015 had emissions equivalent to a conventional vehicle with a fuel economy of 36 MPG. The current average fuel economy of new conventional vehicles was 25.3 MPG in 2015.

The results of this analysis indicate that transportation electrification would result in modest but measurable improvements in air quality in the KCP&L area.

(2) Distribution System Effects

The analysis shows that KCP&L has more than enough capacity available to support a large fleet of PEVs in its service territory; however, the results are preliminary and do not include the effects on transformers which are already near their maximum load. Further analysis is needed to examine each transformer individually and to assess the current load in combination with projected PEV load. Past EPRI studies have shown that while PEV adoption may require some transformer upgrades over time, these costs can be minimized through the use of Time-of-Use (TOU) rates.

(3) Regional Economic Effects

EPRI analyzed the effects of a large-scale shift to electricity as a transportation fuel in the Kansas City metropolitan area and found that the direct and indirect benefits of transportation electrification might lead to large increases in economic activity in the region, and up to 4,000 additional jobs.

The level of achievable economic benefits are dependent on the volatility of gasoline prices. As gasoline prices rise, the benefits increase. The analysis provides a directional finding that there is a net economic benefit at the point gas prices are $1.82/gallon. With petroleum prices at or above $1.82/gallon, the positive shift in employment combined with increased economic activity would provide a regional buffer against the volatile gas prices with the relative stabilization of energy-equivalent electricity. A review of the past 10 years shows that gas prices have on average been approximately $3.00/gallon and have been above $1.82/gallon in all but four out of 120 months, and are currently at a 10-year low of $1.57/gallon.[1]

(4) Effect on KCP&L Customers

EPRI analyzed the effects of investments in public PEV charging infrastructure to both PEV drivers, the Total Resource Cost (TRC) test, and utility customers as a whole, the Ratepayer Impact Measure (RIM) test. This analysis simulated vehicle adoption and charger use. Chargers are used nominally at home, but with rate-based public charging infrastructure, added benefits can be obtained for both PEV drivers and utility customers. The key success factor is vehicle adoption.

EPRI tested three scenarios for vehicle adoption and found that under Scenario 3 (nominal public charger deployment costs and adoption of 29,700 EVs by 2025) the TRC and RIM tests are both positive. The increase in net benefit to all KCP&L customers is projected to be $6.3 million. Further comparison of the various scenarios tested shows that the 'break even' point for utility customers is a PEV adoption rate that would see between 20,000 and 36,000 PEV within the KCP&L service territory by 2025, depending on the actual program cost.

The following sections describe the current status of PEV sales, projections for sales within the KCP&L service territory, and the detailed results for each part of the analysis.

[1] Based on the Energy Information Agency price for Midwest regular gasoline: https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_r20_m.htm (accessed Feb. 15, 2016)

II. ELECTRIC VEHICLE ADOPTION

Recent Sales Trends for PEVs

Over the past five years, more than 400,000 PEVs have been sold in the U.S. This includes both plug-in hybrid electric vehicles (PHEVs) as well as fully electric battery electric vehicles (BEVs) with a wide range of prices and travel range. Looking ahead, the PEV market is expected to continue to expand and with it the demand for PEV charging options in a variety of locations: at home, in public, and at work locations.

National Trends

The cumulative number of PEVs sold in the U.S. as of November 2015 is shown in Figure 1. The cumulative breakdown of PEV models is shown in Figure 2.

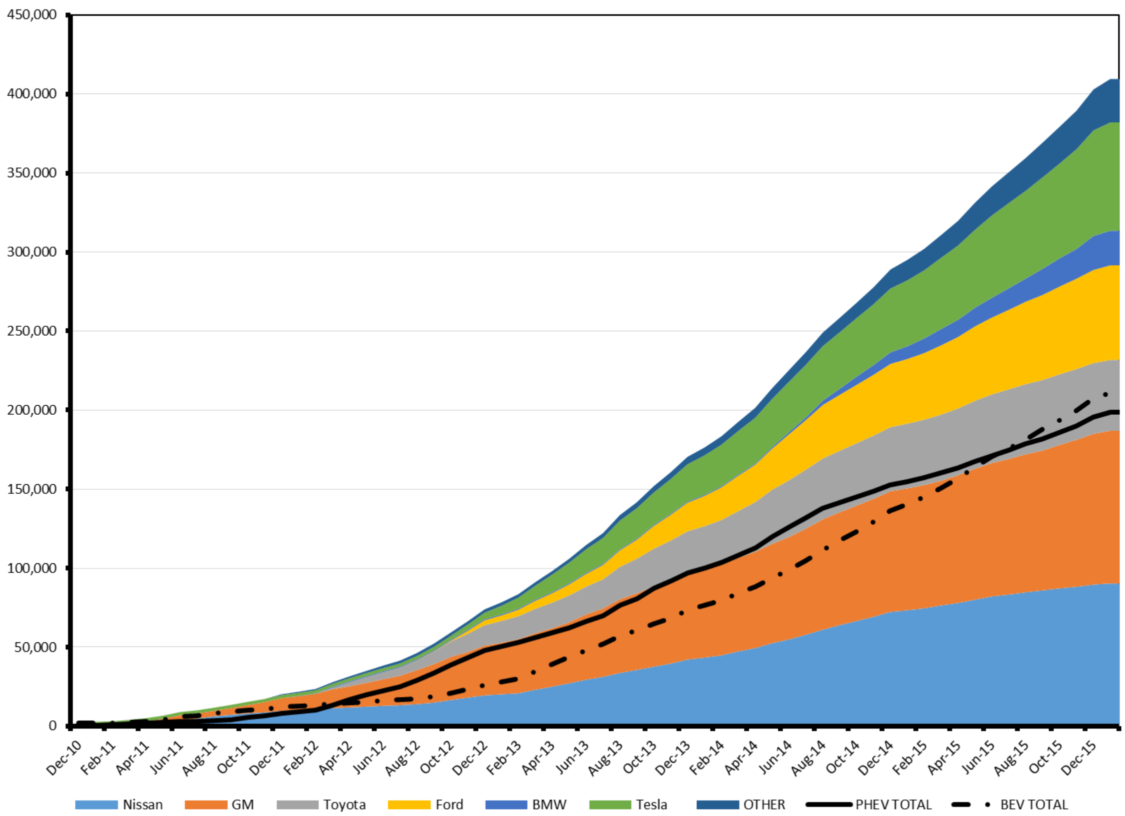

Figure 1
Cumulative PEV sales for the U.S. through January 2016

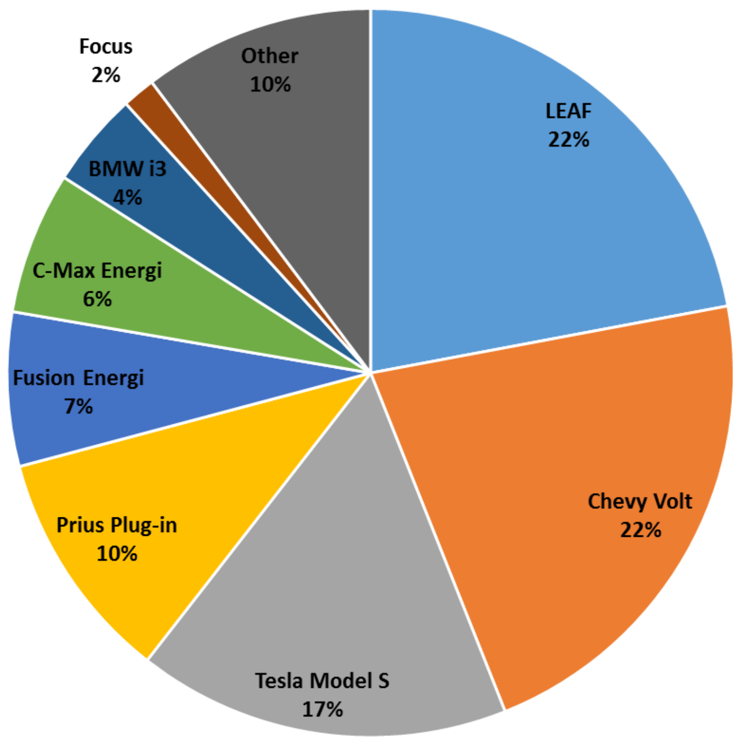

Figure 2
Nationwide Cumulative Sales broken down by vehicle type through January 2016

The largest PEV sales categories are the Nissan Leaf, Chevrolet Volt and Tesla Model S. Looking forward, it is expected that PEV sales will move toward larger battery models with longer ranges. It is also expected that the price of these longer range PEVs will be decreasing in the future.

KCP&L Trends

Unlike the national trends, in the KCP&L service territory, the PEV with the largest cumulative sales is the Volt with almost 50% of the total sales. The Tesla S, Nissan Leaf, Ford C Max Energi, and Ford Fusion Energi each share a similar proportion of the remaining sales numbers.

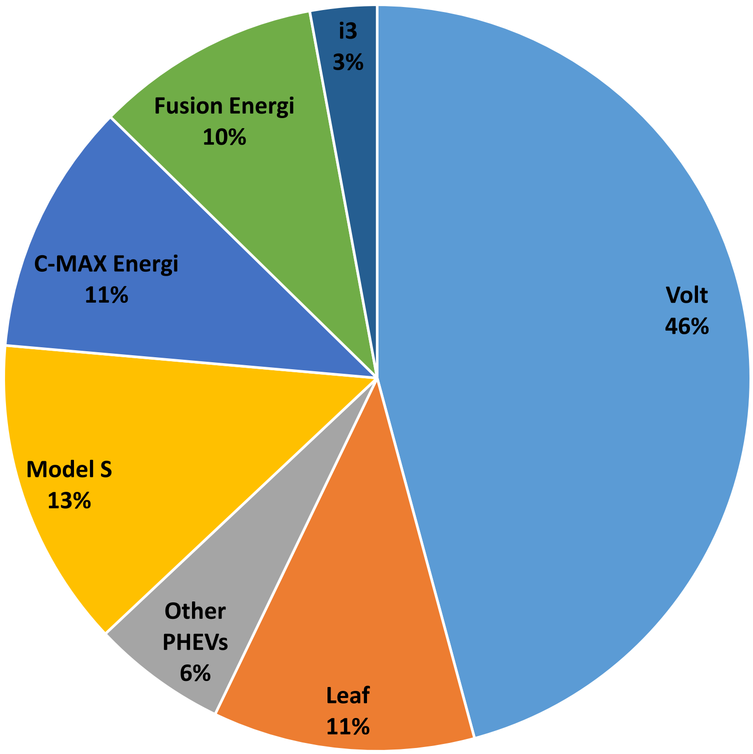

Figure 3
Cumulative Sales for the KCP&L territory broken down by vehicle type (as of November 1st, 2015)

Sales trends (Figure 4) show cumulative sales numbers from January 2011 through October 2015 with a total of 921 PEV sales. While the sales seem to be consistent over all PEVs, there was a large increase in Tesla S sales in the middle of 2015.

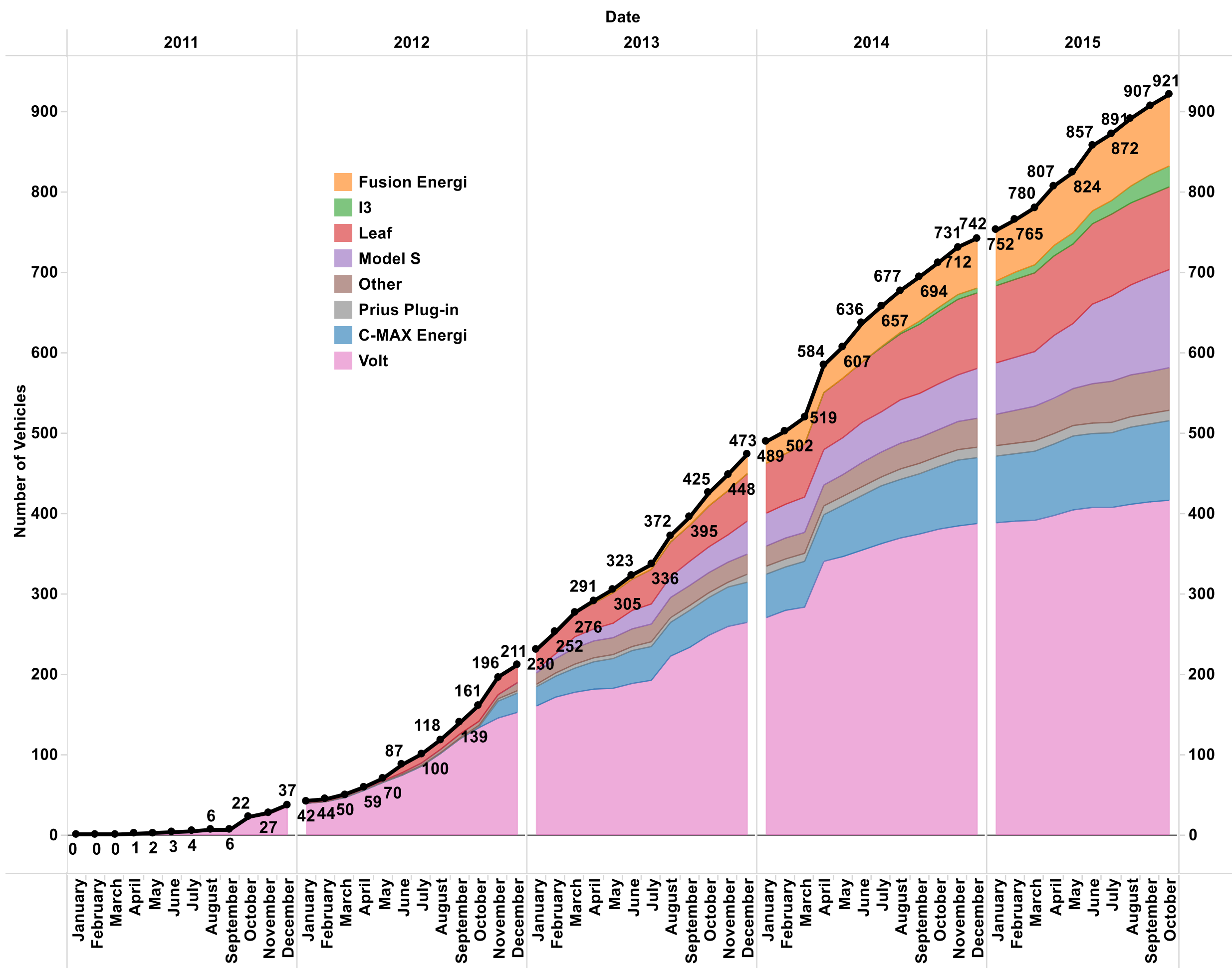

Figure 4
Cumulative Sales over time in KCP&L's service territory broken down by vehicle type (as of November 1st, 2015)

Projections of PEV Sales

PEV sales are expected to accelerate. This section presents EPRI's current projection for sales in the KCP&L service territory (a summary of EPRI's Electric Vehicle Projection tool is presented here; for more details on the projection methodology please see EPRI report 3002005949, *Plug-in Electric Vehicle Projections: Scenarios and Impacts*[2]).

EPRI's tool estimates sales for three levels: Low PEV adoption, Medium PEV adoption, and High PEV adoption. These scenarios help provide guidelines for what PEV penetration numbers may look like depending on different adoption rates. For each year of each scenario a slightly different percentage of each vehicle type was used. This was done to reflect a shift to larger battery vehicles in the future. In total, the tool generates projections of new vehicle sales, vehicle population, vehicle miles traveled (VMT), amount of electrified VMT, liquid fuel consumption (gasoline and diesel), electricity consumption, and greenhouse gas emissions.

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[2] https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002005949

The three vehicle adoption projection scenarios are defined below. They are based on three data sources: recent PEV registration data for 2010-2014 (which EPRI has at the county level), a near term national PEV sales estimate created by EPRI for 2015-2018, and other external publicly available forecasts. The data presented here is based on EPRI PEV projection analysis for KCP&L's service territory. The PEV sales numbers used in this analysis are based on new PEV registrations. The PEV adoption scenarios are as follows:

- ***Low Adoption:*** This scenario was based on the Energy Information Administration's (EIA's) Annual Energy Outlook (AEO) 2015[3]. The AEO uses a model and assumptions that are unfavorable to PEV adoption. For example, 2015 PEV sales are expected to be 75% higher than the AEO projections.
- ***Medium Adoption:*** This scenario was based on the National Research Council's (NRC's) *Transitions to Alternative Vehicles and Fuels* report[4] (the Midrange PEV Scenario) and the "Portfolio scenario" from the infrastructure Expansion report published by National Renewable Energy Laboratory (NREL) on behalf of the U.S. Department of Energy (DOE)[5].
- ***High Adoption:*** This scenario is an average of two scenarios that are highly favorable to PEV adoption. It utilizes the "Optimistic PEV" case in the NRC 2013 report[3] and the "Electrification" case of the DOE/NREL (2013) report[4].

Figure 5 shows the projected number of PEVs in KCP&L's service territory out to 2025. The three PEV adoption scenarios are shown (Low, Medium and High). There is a wide range between the Low and High adoption cases with the Low case showing approximately 5,500 PEVs in the service territory in 2025 and the High case reaching approximately 73,500 PEVs in 2025.

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[3] *Annual Energy Outlook 2015*. U.S. Energy Information Administration, Washington, DC: 2015. DOE/EIA-0383 (2015).

[4] *Transitions to Alternative Vehicles and Fuels*. National Research Council, Washington, DC: 2013.

[5] *Alternative Fuel Infrastructure Expansion: Costs, Resources, Production Capacity and Retail Availability for Low-Carbon Scenarios*. Prepared for the U.S. Department of Energy by National Renewable Energy Laboratory, Golden, CO: 2013. DOE/GO-102013-3710.

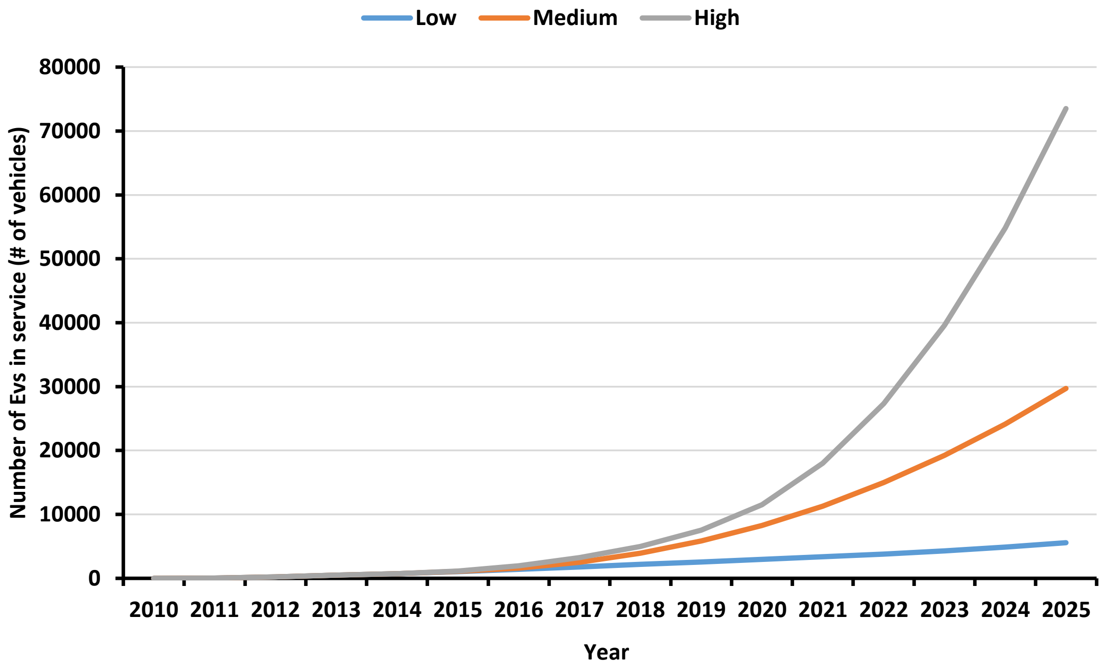

Figure 5
Simulated number of PEVs in the KCP&L's service territory out to 2025. Three adoption scenarios were shown: Low, Medium and High

Figure 6 shows the projected MWh/year that each projected scenario will need to support the projected PEV adoption rate. These range from around 16,000 MWh/year for the Low PEV adoption scenario to 225,000 MWh/year for the High adoption scenario.

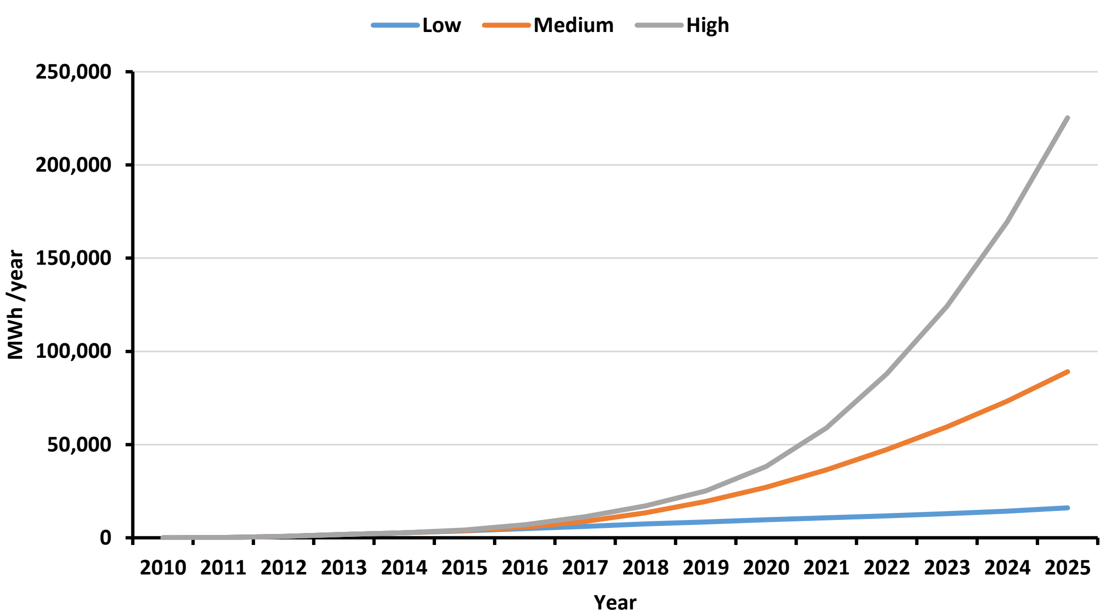

Figure 6
Simulated MWh/year based on different PEV adoption scenarios.

III. ENVIRONMENTAL ANALYSIS

Environmental Effects of Increased Transportation Electrification

Battery electric vehicles (BEVs) have almost no direct emissions and plug-in hybrid electric vehicles (PHEVs) can have much-reduced direct emissions if they are driven substantially on electricity. However, the generation of electricity to recharge vehicle batteries results in indirect emissions which will decrease the environmental benefits of transportation electrification. This section discusses the net environmental effects of transportation electrification within the KCP&L service territory, including the effects on greenhouse gas emissions and the effects on air quality.

Generation in KCP&L

KCP&L obtains electricity from a variety of sources, but as noted in Table 1 just over 70% of KCP&L's generation is from coal (with a small portion of natural gas) and about 30% of generation is from non-emitting sources, primarily nuclear and wind. Because coal generation nationally is the primary source of electricity-sector greenhouse gas emissions and a significant source of other pollutants it is important to understand how this generation affects the effect of transportation electrification.

Table 1
In-territory generation for KCP&L for 2015[6]

	CAPACITY (MW)	CAPACITY FRACTION	ESTIMATED ENERGY (MWH)	ENERGY GENERATION FRACTION
COAL	2,521	54%	14,653,906	71%
NUCLEAR	549	12%	3,950,426	19%
OIL	375	8%	1,069	0.005%
NAT. GAS	808	17%	230,579	1%
WIND	380	8%	1,345,929	7%
HYDRO	61.5	1%	377,155	2%
SOLAR	0.173	0.004%	140	0.001%
OVERALL	4,695	100%	20,559,204	100%

Net Greenhouse Gas Emissions for Transportation Electrification

When considering the effects of transportation electrification, it is important to compare the benefits of reducing gasoline or diesel consumption with increased electricity generation. Figure 7 shows a nationwide comparison performed by the Union of Concerned Scientists (UCS) (2015), which shows the fuel economy that a gasoline vehicle would have to achieve in order to have the same life cycle greenhouse gas emissions as a current plug-in electric vehicle (PEV). PEVs have lower life cycle greenhouse gas emissions than most conventional vehicles throughout the country, but benefits are lower in the more coal-intensive Midwest. In the Southwest Power Pool Regional Entity / North (SPNO) region that includes KCP&L, the UCS analysis finds that the emissions related to a PEV are equivalent to the emissions of a gasoline vehicle with a fuel economy of 35 MPG. This is lower than some gasoline vehicles,

[6] This data is derived from the 2015 KCP&L Integrated Resource Plan

but is significantly above the new vehicle average of 25.3 MPG in 2015.[7] The generation described in Table 1 results in the direct CO_2 emissions and life cycle greenhouse gas emissions described in Table 2, which indicates that KCP&L (the top portion of the table) has lower emissions than the SPNO results in the UCS analysis (last row in the table). The discussion below shows net emissions for KCP&L only.

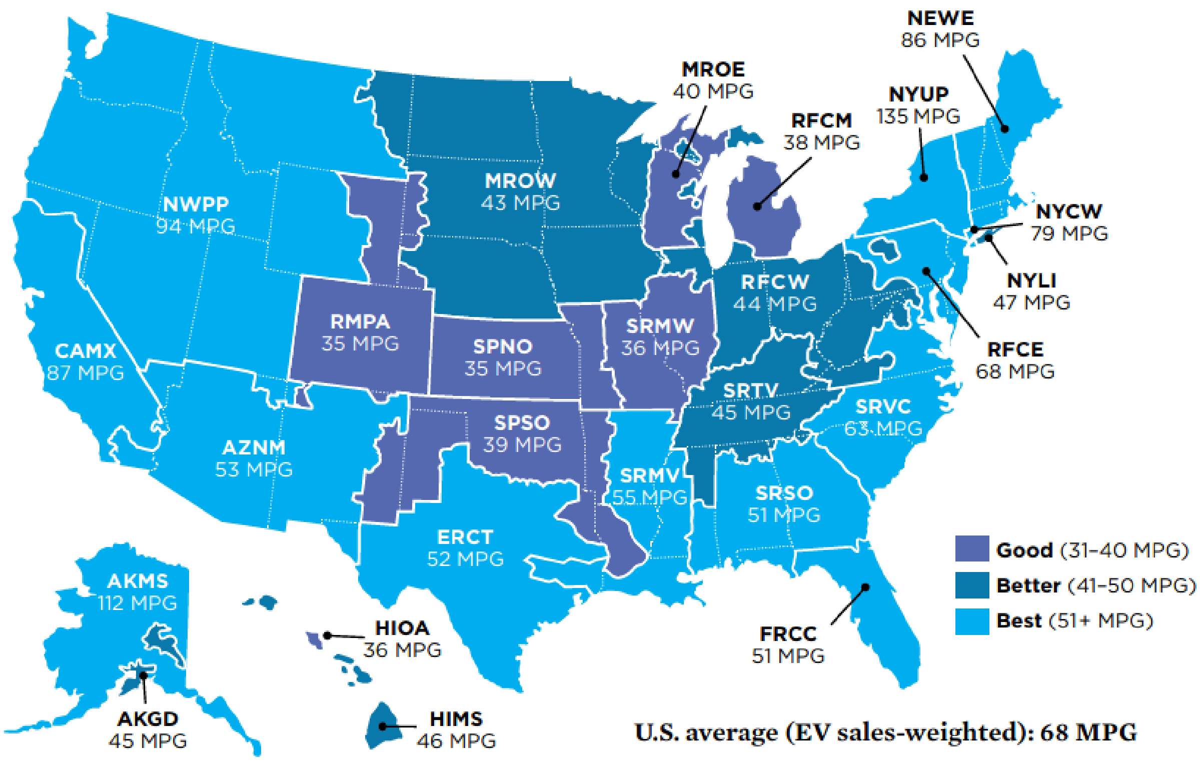

Figure 7
Equivalent fuel economy for a PEV in regions across the United States (from UCS, 2015[8])

[7] http://www.umich.edu/~umtriswt/EDI_sales-weighted-mpg.html; accessed Feb. 8. 2016

[8] http://www.ucsusa.org/sites/default/files/attach/2015/11/Cleaner-Cars-from-Cradle-to-Grave-full-report.pdf

Table 2
Greenhouse gas emissions for electricity generation for KCP&L in 2015 (emissions factors for individual generation technologies and KCP&L use the emissions factors in ANL (2015)[9]; emissions for SPNO are from UCS (2015))

	DIRECT CO_2 EMISSIONS (GCO_2/KWH)	LIFE CYCLE EMISSIONS (GCO_{2E}/KWH)
COAL	1017	1136
NUCLEAR	15	16
OIL	0	0
NATURAL GAS	540	621
WIND	0	0
HYDRO	0	0
SOLAR	0	0
KCP&L	**710**	**793**
SPNO FROM UCS (2015)	**785**	**923**

In *Environmental Assessment of a Full Electric Transportation Portfolio* (EPRI, 2015)[10], EPRI analyzed the net effects of a large scale shift to electric transportation. The study had a similar scope to the UCS analysis (2015) and included direct emissions, upstream fuel processing emissions, transmission and distribution losses, and battery manufacturing emissions. Figure 8 shows a comparison between the lifetime fuel cycle emissions of conventional vehicles in EPRI (2015) and a PEV with the emissions for KCP&L in Table 2. Although calculated using different reference vehicles, this comparison confirms the findings in the UCS analysis (2015), indicating that a PEV in the KCP&L service territory in 2015 had emissions equivalent to a conventional vehicle with a fuel economy of 36 MPG.

[9] https://greet.es.anl.gov/main

[10] http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=3002006881

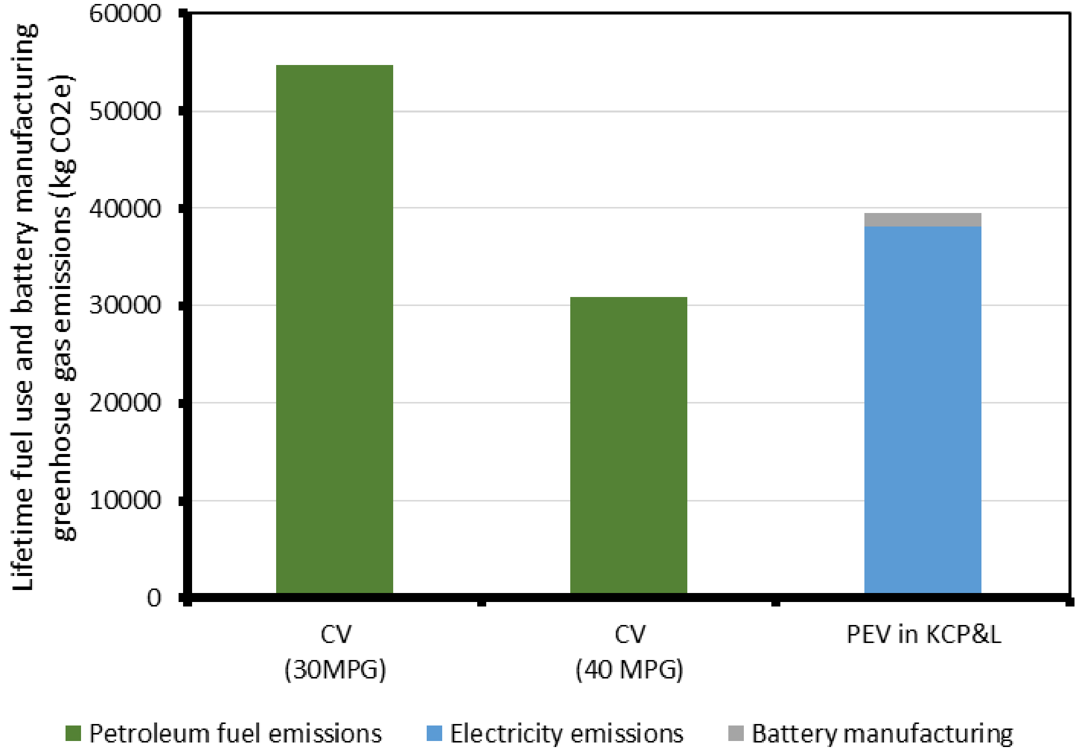

Figure 8
Comparison between emissions of conventional vehicles with fuel economies of 30 MPG and 40 MPG and plug-in electric vehicles with KCP&L's generation mix

EPRI (2015) also contains projections for grid emissions, which help to show how emissions are likely to change over time. Figure 9 shows the trajectory of national grid emissions and emissions for the Northwest Central region that encompasses KCP&L along with current emissions for KCP&L from Table 2.[11] These projections indicate that CO_2 emissions for KCP&L will continue to decrease over time, so transportation electrification will provide a continuing greenhouse gas benefit relative to conventional vehicles.[12]

[11] The definitions of electricity regions used in EPRI (2015) differ from those in UCS (2015), so emissions for KCP&L are slightly higher than the enclosing region in EPRI (2015) rather than lower as shown in Table 2.

[12] This data is derived from the 2015 KCP&L Integrated Resource Plan

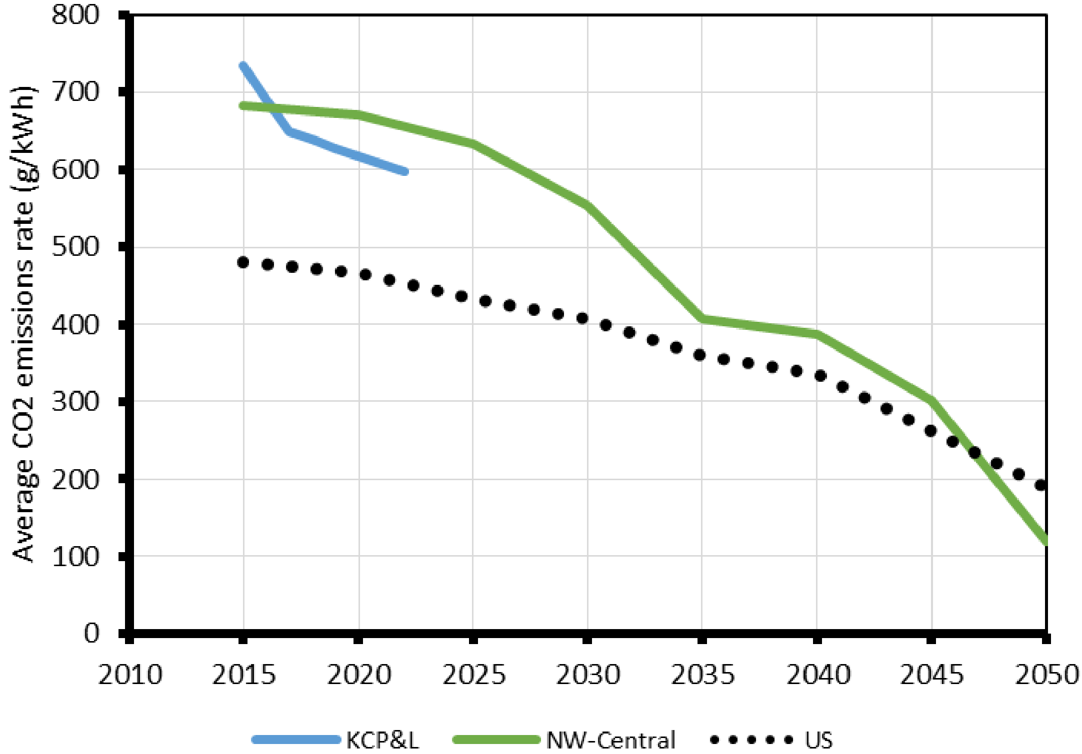

Figure 9
Emissions trajectory for the region enclosing KCP&L in EPRI (2015)

Air Quality Effects of Transportation Electrification

The effects of transportation electrification on air quality are difficult to analyze since they depend on the precise timing, location, and speciation of emissions. In *Environmental Assessment of a Full Electric Transportation Portfolio* (EPRI report 3002006880)[13], EPRI analyzed the effects of a large scale shift toward electric transportation on a number of different air quality indicators. In this analysis, a 'large scale' shift was represented as 17% of light-duty and medium-duty miles being electrified, which is consistent with the "High" projection described above (in this projection 15% of miles would be electrified by 2030). The analysis additionally includes significant electrification of non-road devices like forklifts and lawn and garden equipment. As shown in Figure 10 for ozone levels and Figure 11 for $PM_{2.5}$ levels, the results indicate that transportation electrification would result in modest but measurable improvements in air quality in the KCP&L area.

[13] https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002006880

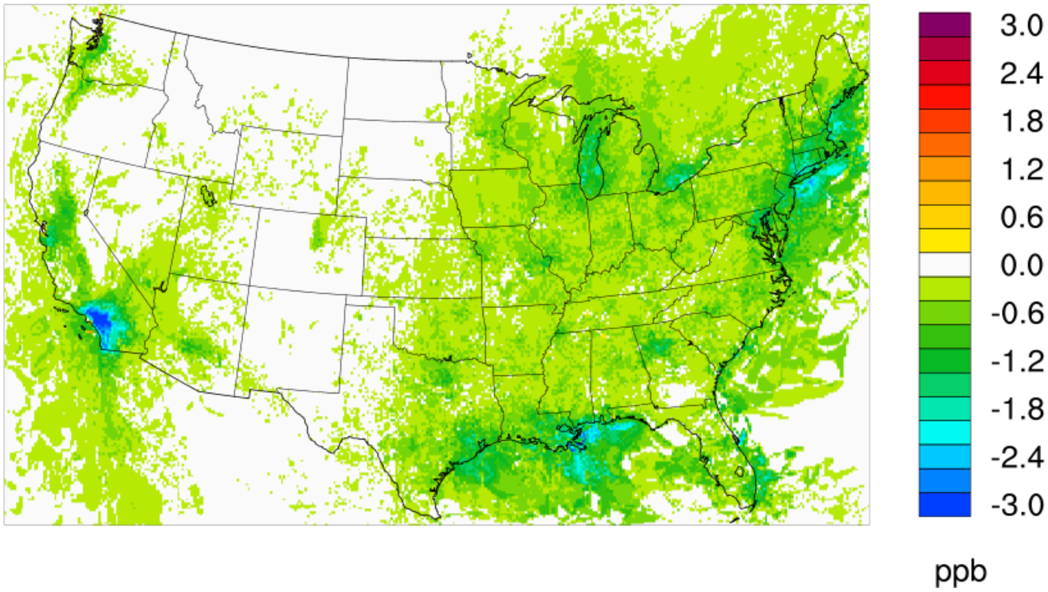

Figure 10
Change in projected 2030 ozone levels due to transportation electrification[14]

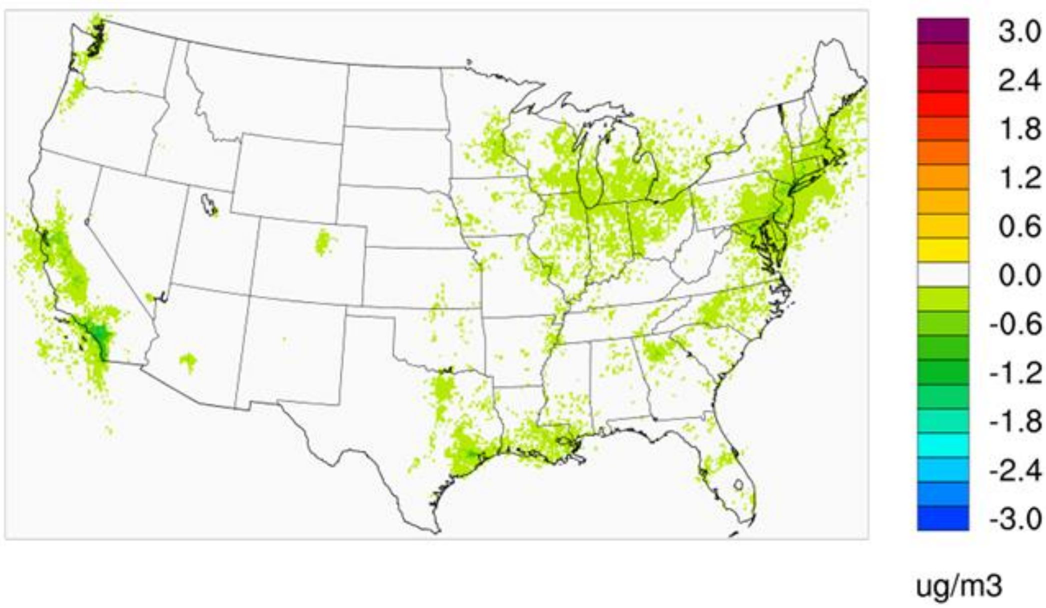

Figure 11
Change in projected 2030 PM2.5 levels due to transportation electrification[15]

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[14] The change is in terms of annual 4th highest 8-hour-ozone levels for each cell

[15] The change is in terms of annual 8th highest 24-hour average concentrations (µg m^{-3}) of $PM_{2.5}$

IV. EFFECTS ON KCP&L'S DISTRIBUTION SYSTEM

Effects of Increased Transportation Electrification on KCP&L's Distribution System

EPRI performed an initial estimate of the effects of increasing transportation electrification on KCP&L's distribution system.

This analysis aims to address the question: How much would PEVs affect KCP&L's commercial grid through public charging infrastructure use? To do this, information from monthly commercial peak load curves, total yearly commercial MWh, and projected MWh due to PEV adoption was collected. This was combined with an estimation of hourly loads generated from KCP&L's currently deployed public charging stations.

The analysis shows that there is more than enough capacity available to support a large fleet of PEVs; however, the results are preliminary and do not include the effects on those transformers that are already near their maximum load. Further analysis is needed to examine each transformer individually and assess the current load in combination with projected PEV load.

Previous studies using EPRI's Hotspotter tool, have shown that while PEV adoption does require some transformer upgrades over time, these costs can be minimized through the use of TOU rates and by switching low load, high kVA transformers with high load, low kVA transformers. One analysis revealed that altering a TOU rate from starting at 8 PM to starting at 10 PM to avoid residential peak loads between 6 and 9 PM avoided many upgrade costs over time.

KCP&L infrastructure Summary

The KCP&L territory consists of just over 200,000 transformers. These transformers are classified as serving commercial (GS), residential (RS) and 'mixed' loads (a combination of both commercial and residential). Of the 200,000 transformers, 31,734 are commercial transformers. In this report both commercial and residential transformer data are shown; however, the commercial transformer data is most pertinent to the public PEV charging infrastructure. Figure 12 shows KCP&L's service territory and the locations of commercial transformers. The commercial transformers cover a wide expanse of area and are therefore capable of supporting a wide-ranging PEV fleet.

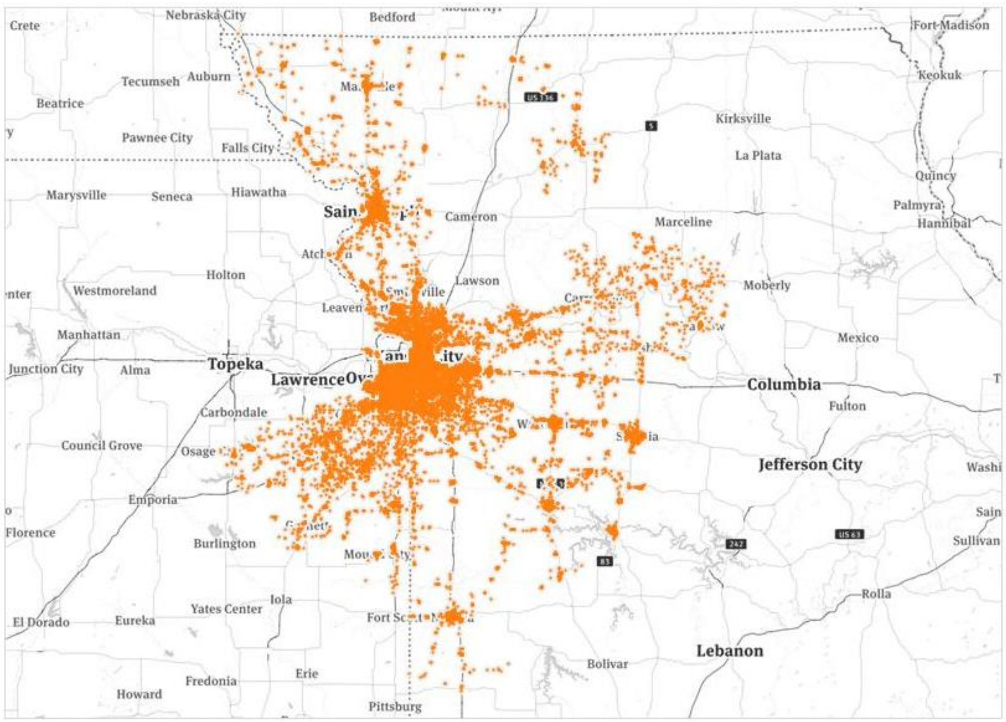

Figure 12
Location of commercial transformers in KCP&L's territory

Figure 13 shows how many accounts are located on each transformer. A majority of the transformers have 0-4 accounts and about 45,000 transformers serve 5-9 accounts. The majority of the 'high account' transformers are residential. This information is significant as load problems can occur by charging at home when multiple vehicles are located on a single residential transformer creating significant increase in transformer loading. In the case of commercial transformers, the additional load created by several EVs charging is a much smaller percentage of the commercial load and will create less of an overload issue. Individual transformer analysis will be performed in the next phase of analysis to determine which of these 'high account' transformers may be at risk for overloading.

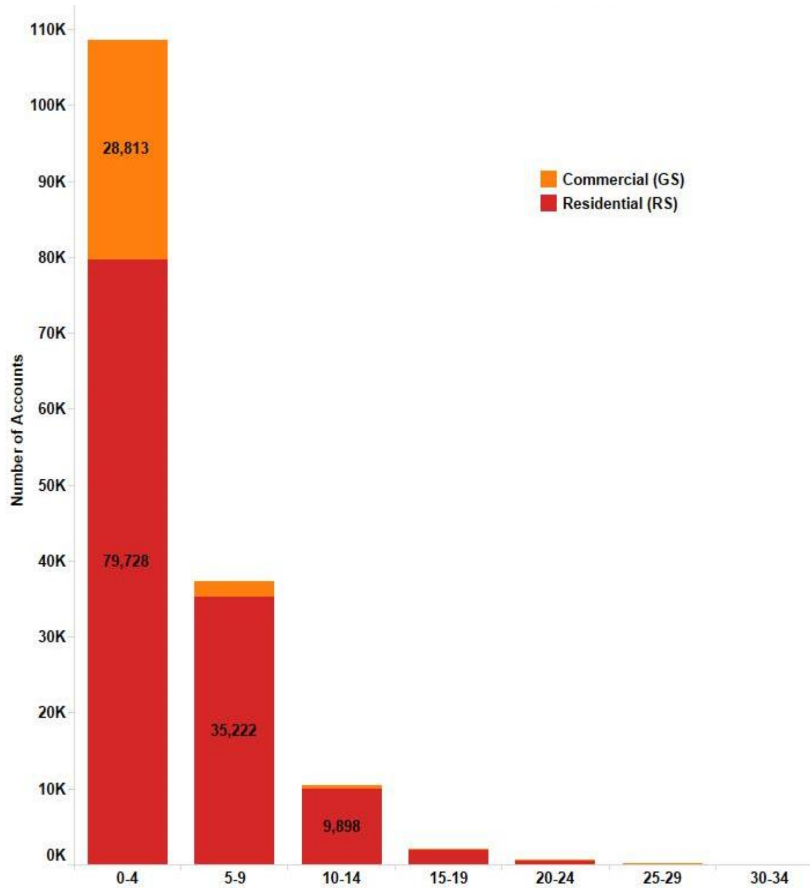

Figure 13
Histogram of the number of accounts on each transformer

Figure 14 shows the total kW capacity broken down by transformer type as well as whether a transformer is underground or overhead. This is pertinent because in the event that a transformer needs to be upgraded, it is more expensive to upgrade an underground transformer than an overhead transformer. Approximately 75% of KCP&L's commercial transformers are underground.

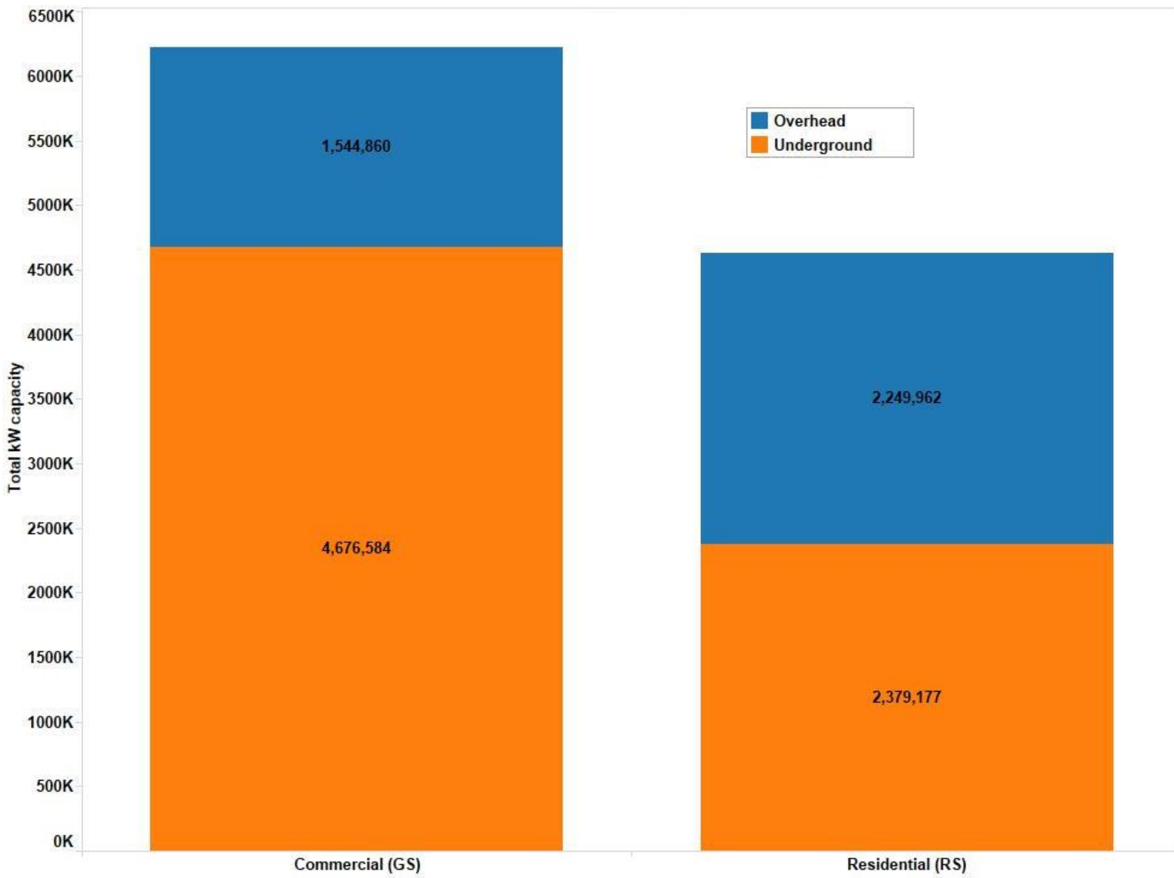

Figure 14
Total kW capacity broken down by transformer type and whether it is underground or overhead

Figure 15 compares the annual kWh with potential kWh by transformer type. The potential kWh are calculated by assuming that each transformer is working at its nameplate rating throughout the year. While this shows that there is a lot of extra capacity on the grid, these figures do not take into account variances in hourly loading. Even with high levels of additional capacity, if there is a large increase in demand during certain hours, there still may not be enough capacity during those couple hours. Table 3 shows the same numbers as Figure 15; however, it also shows what percent of the total potential capacity is currently being used. In general, 20% of KCP&L's grid capacity is being used.

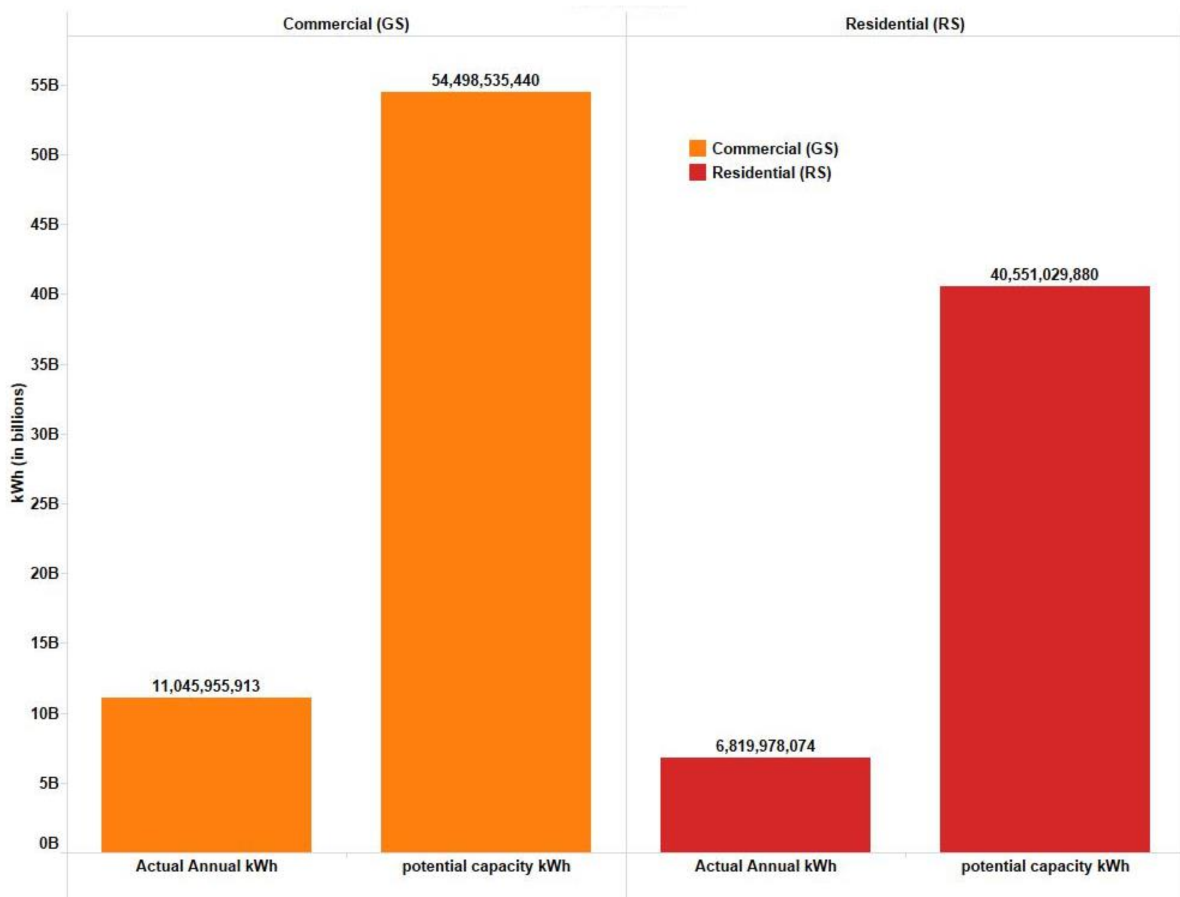

Figure 15
Comparison of actual annual kWh with potential kWh based on transformer nameplate rating

Table 3
Comparison of actual annual MWh with potential MWh

	COMMERCIAL (GS)	RESIDENTIAL (RS)
TOTAL MWH	11,045,956	6,819,978
MWH POTENTIAL (BASED ON NAME PLATE RATING)	54,498,535	40,551,030
% CURRENTLY USED	20.27%	16.82%

Using peak monthly meter data from KCP&L as well as PEV load estimated from existing Clean Charge Network (CCN) public charging stations, peak load times for both the commercial grid as well as public charging can be estimated. Figure 16 shows the normalized distribution of an average commercial daily load (blue) as well as a normalized vehicle distribution load on public chargers (orange). It shows that while the two different demand curves peak at different times, there is some coincident peaking from 1-2 PM and between 5 and 9 PM. Therefore, it is important to look critically at those hours to see if there is enough capacity for the potential demand.

While it is impossible to generate aggregate load curves without more detailed analysis, if it is assumed that each day throughout the year uses the same total kWh, then yearly kWh totals together with the demand curves (both commercial load and PEV load) can be used to estimate the kW demand each hour for a sample day. In reality each day carries a slightly different load, and different times of the year will also carry more load than others; however, this can be used as an approximation.

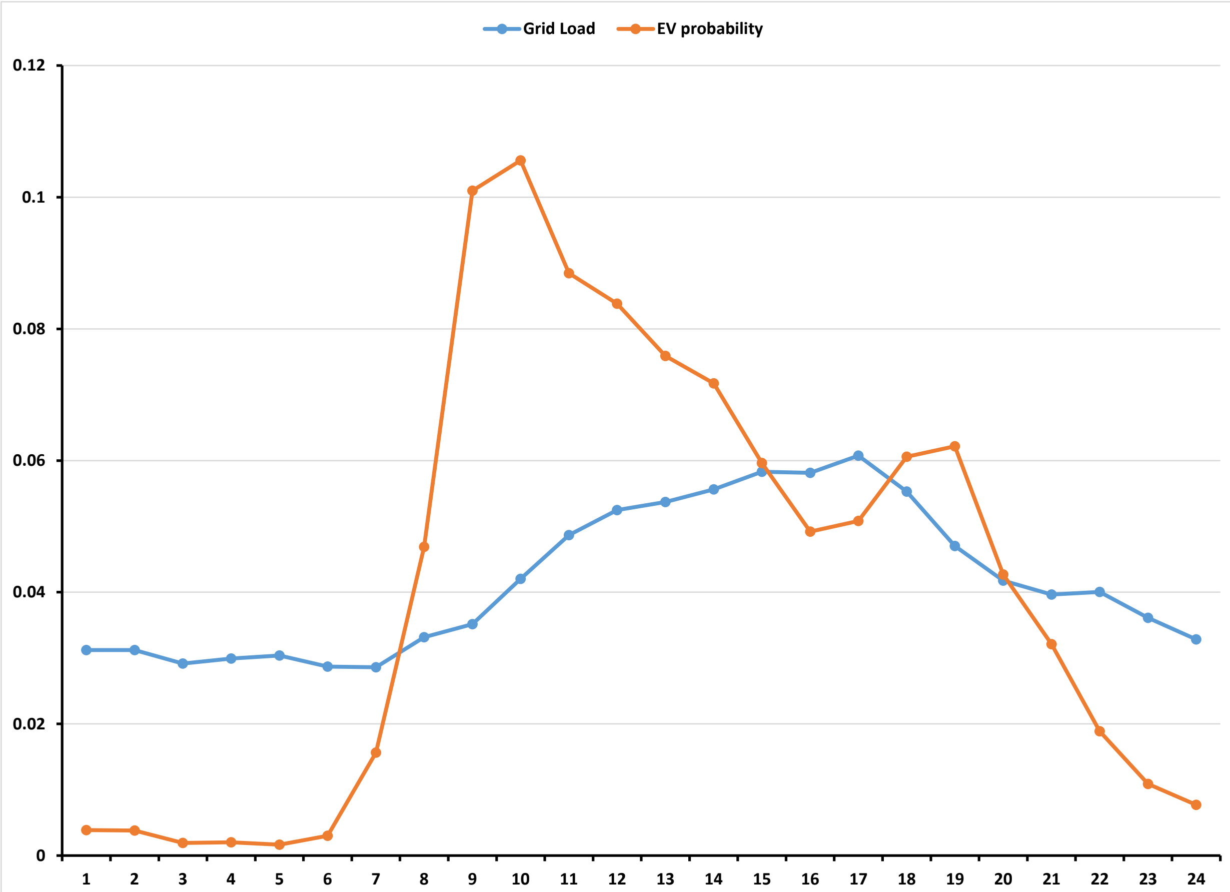

Figure 16
Probability of PEV load (from public charging stations) and normalized commercial (peak) load profile, both from KCP&L data

The load curves shown in Figure 16 can be used to distribute the kWh needed by the projected PEV fleets resulting in hourly demand. To test the most extreme case first, the MWh needed by 'High PEV adoption' scenario was used first. Because this preliminary analysis showed that the commercial grid could support this High adoption case, the 'Medium' and 'Low' cases were not used. In the more detailed KCP&L individual transformer analysis that is planned for later this year, the upgrade costs and potential transformer overloading for each PEV adoption case will be considered.

Figure 17 shows the grid capacity, current load, and available load on all commercial transformers as well as the predicted PEV load (High adoption case) for public charging in 2025. Note that the axis for the general grid values and the PEV values are different.

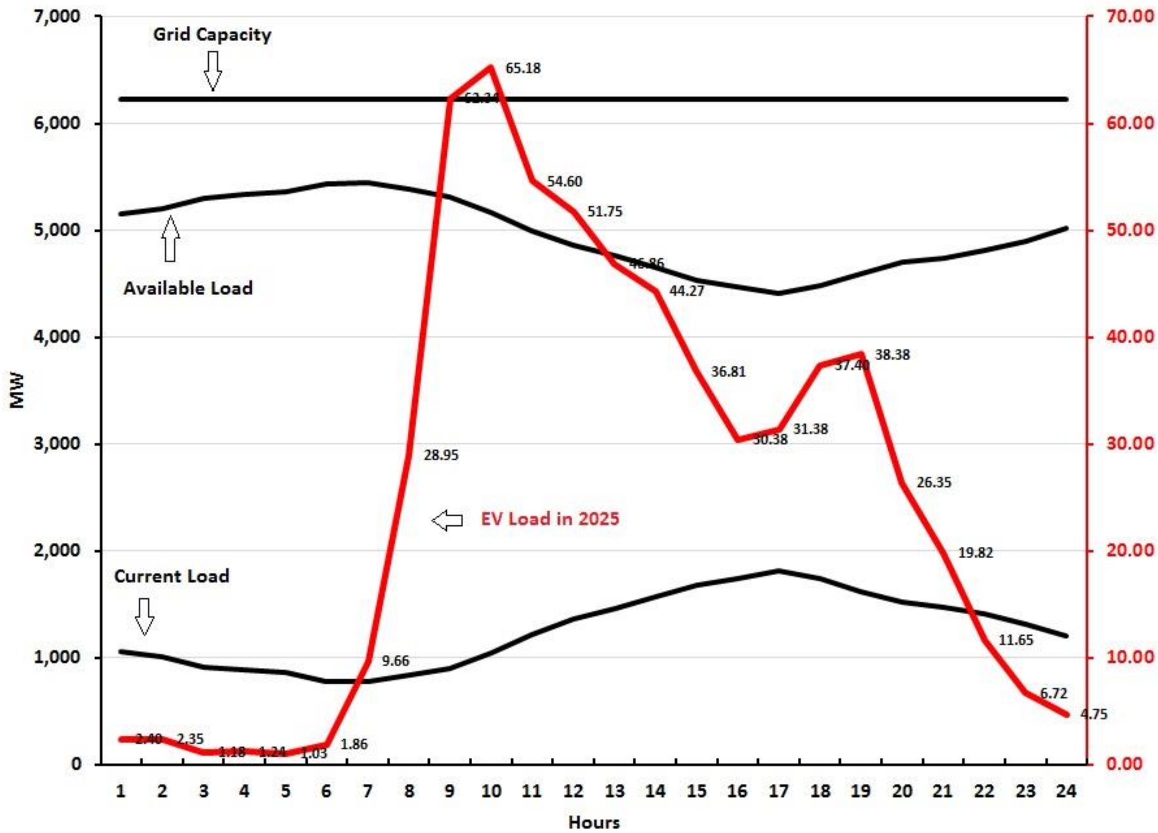

Figure 17
Daily MW estimates (black lines) for the general grid as well as for PEV demand (red line) for the High adoption scenario in 2025. Note that the two vertical axes have different scale; however, both are MW. The black lines are estimates for the 'current', 'available' and 'potential' loads currently on the system. The red line is for a future (2025) commercial PEV load.

Figure 17 highlights that while there is coincident peak loading between the commercial grid and projected 2025 PEV public charging levels, there is more than enough capacity to support the growing PEV fleet with public charging. As an example, during the peak PEV demand hour (10AM), 65 MW are needed and the current commercial grid would have approximately 5000 MW available for use at that time. The PEV load shown in Figure 17 assumes that all PEV charging is done publicly. In reality, studies show that people generally charge 80% at home and 20% at work. Therefore the kW demand for PEVs would decrease by 80% as only 20% of the charging would be done on commercial charging infrastructure. So while a majority of the commercial transformers are underground and could potentially be costly to upgrade, this initial analysis shows that the commercial transformer upgrades could be at a minimum. Future transformer analysis will address how the future PEV load will affect residential transformers.

The analysis shows that there is more than enough capacity available to support a large fleet of PEVs; however, the numbers provided are all average values and will not capture specific transformers/areas that are currently overloaded or highly utilized. These locations would not appear in this analysis because they are countered by locations with an abundance of extra capacity. Transformer overloads can occur due to high PEV concentrations over just a few transformers with low kVA ratings. Further analysis is needed to examine each transformer individually and assess the current load in combination with projected PEV load.

V. ECONOMIC ANALYSIS

Regional Economic Effects of Increased Electrification in the KCP&L Service Territory

Transportation electrification can improve regional economic performance by shifting fuel use from externally-sourced petroleum products to locally sourced, inexpensive electricity. Shifting to local fuel generation keeps more money within the region and lower costs leave customers with more money to spend on other products within the region. EPRI analyzed the effects of a large-scale shift to electricity as a transportation fuel in the Kansas City metropolitan area, which would result in 20% of light-duty miles being electrified by 2030 (this about 1/3 higher than the "High" case described above, which would have an electrification level of 15% of miles by 2030). The analysis found that the direct and indirect benefits of transportation electrification would lead to large increases in economic activity in the region, and up to 4000 additional jobs. The large range in forecasted effects is due to the uncertainty concerning the future price of petroleum products, with the greatest benefit of $853 million occurring at a gasoline price of $3.79/gallon and the lowest benefit of $174 million occurring at a gasoline price of $2.08/gallon. This effect also decreases the sensitivity of regional economic performance to variation in the price of oil. The following section describes the background, methodology, and detailed results for this analysis. The full results are described in EPRI report 1013781, *Plug-in Hybrid Electric Vehicles and Petroleum Displacement: A Regional Economic Impact Assessment*, which includes a detailed analysis of Kansas City.[16]

Background for Economic Effects of Electrification

Relative to petroleum products, electricity has a diverse set of locally-sourced fuel inputs that result in lower, stable prices. Figure 18 shows a comparison between gasoline and energy-equivalent electricity prices which shows that electricity prices have generally been stable and low relative to gasoline prices.[17] Throughout this section, electricity prices are expressed on a 'gallon-equivalent' basis, which adjusts kWh of electricity to more familiar units on a per-mile basis for equivalent-sized electric and gasoline vehicles (an electric vehicle that achieves 3.3 kWh/mile and a conventional vehicle that achieves 30 miles per gallon of gasoline). Customers who use electric vehicles would spend less on petroleum products and have more to spend on other products, increasing economic activity. Expenditures on electricity would also increase the fraction of fuel spending that stays within the region; according to the analysis in the report 72% of Kansas City's power generation is met by local industry, while only 1.3% of household petroleum demand is met with local resources.

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[16] https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001013781

[17] This comparison uses the Energy Information Agency's (EIA) grade-averaged gasoline prices in Kansas before 2011 and prices for the Midwest Petroleum Administration for Defense District afterwards (the EIA discontinued state-level series in 2011), and the EIA residential price for electricity in Kansas. Monthly data is available for gasoline prices from 1983-today and for electricity prices from 2001-today. National data indicate the annual variation in electricity prices before 2001 was likely similar to the variation from 2001 onwards. The comparison uses an energy-equivalent electricity price calculated assuming a plug-in electric vehicle with an efficiency of 3.3 kWh/mi is 'equivalent' to a conventional vehicle with a fuel economy of 30 miles per gallon. Both figures are representative of averages for current passenger cars.

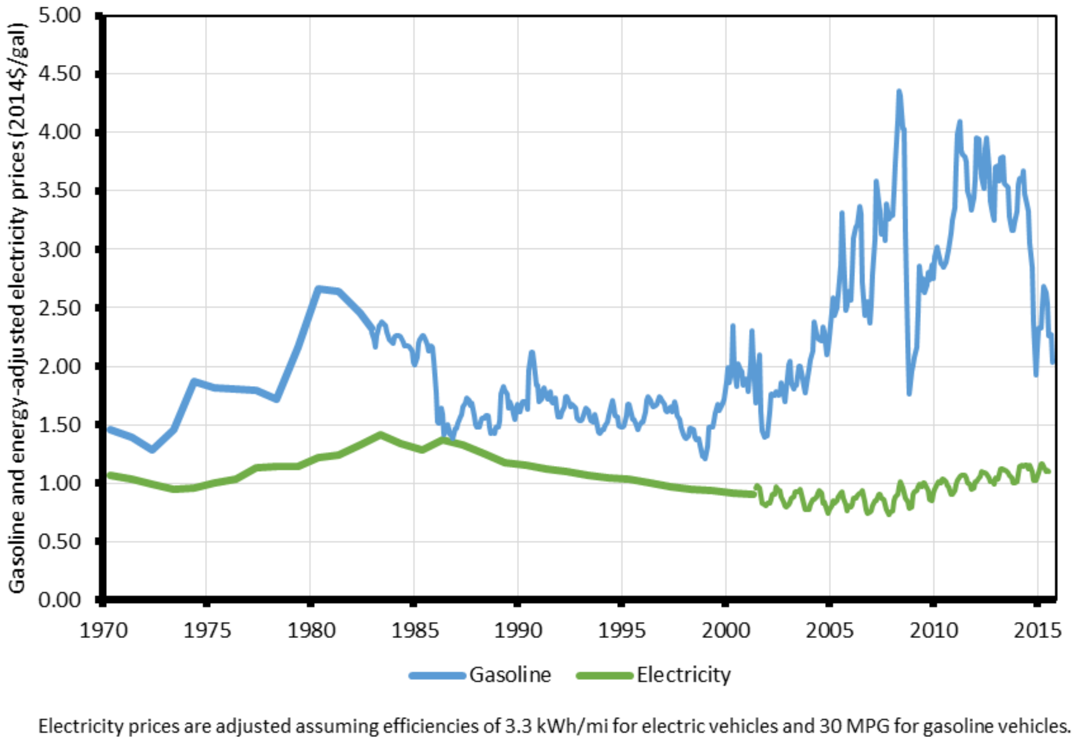


Figure 18
Long-term variation in gasoline and electricity prices in Kansas

Methodology in the Analysis

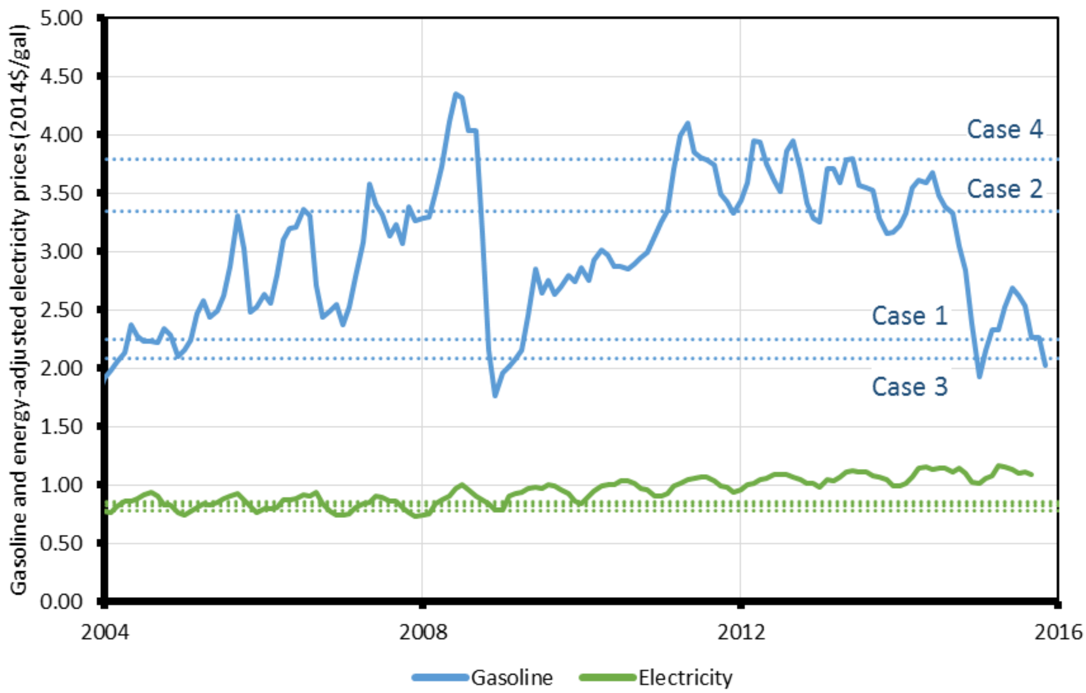
The analysis of regional economic effects was performed in 2007 assuming that by the future year 2030 increasing sales of PHEVs would result in the electrification of 20% of light-duty vehicle miles traveled. Although much has changed since 2007, the structure of the regional economy is expected to be quite similar, so the results provide an indication of the effects of increased electrification today. This shift in energy use provides a direct savings in fuel expenditures, but also leads to indirect effects due to the allocation of spending. In the analysis, three economic shifts occurred due to increasing electrification: (1) an increase in electricity demand; (2) a decrease in demand for petroleum; and, (3) reduced fuel expenditures by households, the savings from which are spent in other sectors of the economy. For each of these categories, we quantify the total (direct, indirect, and induced) output and employment effects associated with each shift. The net effects of all shifts demonstrate the expected overall economic effect of large-scale transportation electrification.

The analysis uses a "regional input-output" (RIO) approach to analyze the economic effects of transportation electrification. RIO analysis is one of the most extensively employed techniques in studying the macro-level effects due to shifts in expenditures within a regional economy. RIO analysis tracks the economic effects from shifts in economic activity within a regional economy. RIO is valuable not only because it captures the direct effects of such shifts (for example, a shift of household spending from gasoline to electricity), but because it also captures the indirect and induced effects of these direct effects. For example, the production of electricity involves fuel purchases, equipment purchases, labor, and maintenance services. RIO analysis allows one to capture the changes in demand for all these production inputs due to a change in demand for the final product.

A key assumption in the analysis is the relative price for the two fuels. The study included four cases with varying energy prices, shown in Table 4 (electricity prices are displayed in terms of $/kWh and $/gallon-equivalent based on the conversion described above). Figure 19 shows the comparison between these analyzed prices and recent historical trends. Gasoline prices have varied since the time of the study, but have mostly stayed within the analyzed bounds. Electricity prices are currently higher than the analyzed prices, so the analysis will slightly overstate the benefits due to transportation electrification.

Table 4
Assumed energy prices in the four cases analyzed (2014$)

	DESCRIPTION	GASOLINE ($/GAL)	ELECTRICITY ($/KWH)	ELECTRICITY ($/GAL-E)
CASE 1	2004 prices	2.24	0.091	0.82
CASE 2	2008 prices	3.35	0.086	0.78
CASE 3	"Low" 2030 prices from AEO2007	2.08	0.093	0.85
CASE 4	"High" 2030 prices from AEO2007	3.79	0.094	0.86



Electricity prices are adjusted assuming efficiencies of 3.3 kWh/mi for electric vehicles and 30 MPG for gasoline vehicles.

Figure 19
Analyzed energy prices compared to recent historical trends in Kansas

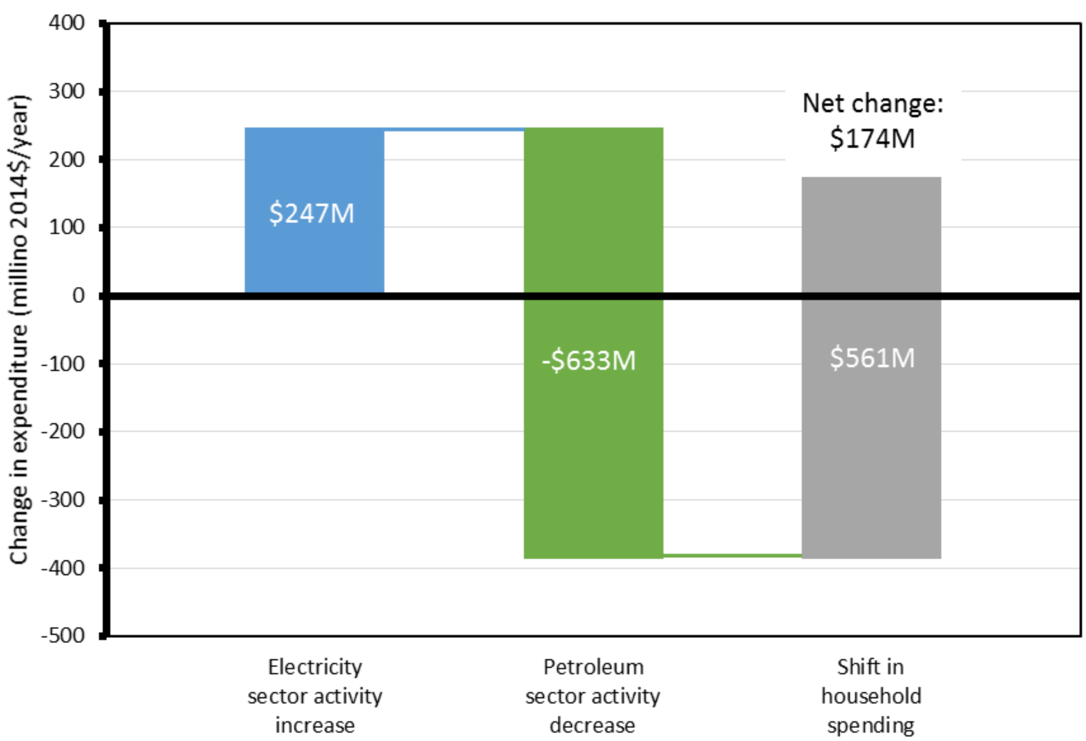
The RIO analysis shows the regional economic effects of the following two key parameters:

- Output, which is measured in $/year and represents the value of economic activity in the region (by sector and in total).
- Employment, which is measured in jobs/year. Employment includes wage and salary employees, and self-employed jobs.

The next section describes these results for the analyzed cases.

Results for Economic Effects of Transportation Electrification

As described above, the shift from gasoline to electricity as a transportation fuel has the following effects: (1) an increase in expenditures and activity in the electricity sector; (2) a reduction in expenditures and activity in the petroleum sector; and (3) an increase in household savings, much of which is returned to the economy as expenditures for other goods and services. Figure 20 shows the impact of these effects on total economic activity in Case 3, which has energy prices closest to today's lower values. The increased demand for electricity increases expenditures on electricity. The decreased demand for petroleum lowers expenditures on petroleum, and due to the higher cost per gallon-equivalent of gasoline, expenditures on petroleum decrease by a higher amount than the increase in electricity expenditures. These two factors alone would decrease regional economic activity (blue and green bar alone), but the change in fuel prices also results in increased household savings (grey bar), which allows customers to purchase other items. Since an increased fraction of total spending circulates within the regional economy compared to the base case, the change results in a net economic benefit of \$174M/year.[18] This change occurs at a gasoline price of \$2.08/gallon; other scenarios with higher prices have greater benefits. Although these results cannot be readily linearized, the trends in Figure 21 indicate net costs would occur if the difference between gasoline and electricity costs was approximately \$0.75/gallon, which at current electricity prices occur at a gasoline cost of \$1.82/gallon.



[18] The results presented in this analysis are from Scenario B in the referenced study. This scenario assumes that refining activity within the region is constant. Since most finished petroleum products used within the Kansas City region are imported, the change in petroleum refining is likely to come from changes in imports rather than changes in in-region refining.

Figure 20
Changes in economic activity due to transportation electrification in Case 3

Table 5 shows the change in economic activity and change in employment for each case. In all modeled cases increased electrification of transportation results in a net economic benefit to the Kansas City region. In Case 3, the case with the lowest petroleum prices ($2.08/gallon), the change in employment was slightly negative since household savings were lowest (other sectors employ fewer people per dollar of activity than retail gasoline sales, so the shift of expenditures toward other sectors reduced employment slightly). This trend would continue with lower gasoline prices. However, with higher petroleum prices the positive shift in employment is much higher and combined with the increased economic activity would provide a regional 'buffer' against the difference between the prices of gasoline and energy-equivalent electricity.

Table 5
Economic changes due to transportation electrification

	CASE 1	CASE 2	CASE 3	CASE 4
NET CHANGE IN ECONOMIC ACTIVITY (2014 DOLLARS/YEAR)	$273M	$659M	$174M	$853M
NET CHANGE IN EMPLOYMENT (JOBS/YEAR)	505	2879	-103	4078

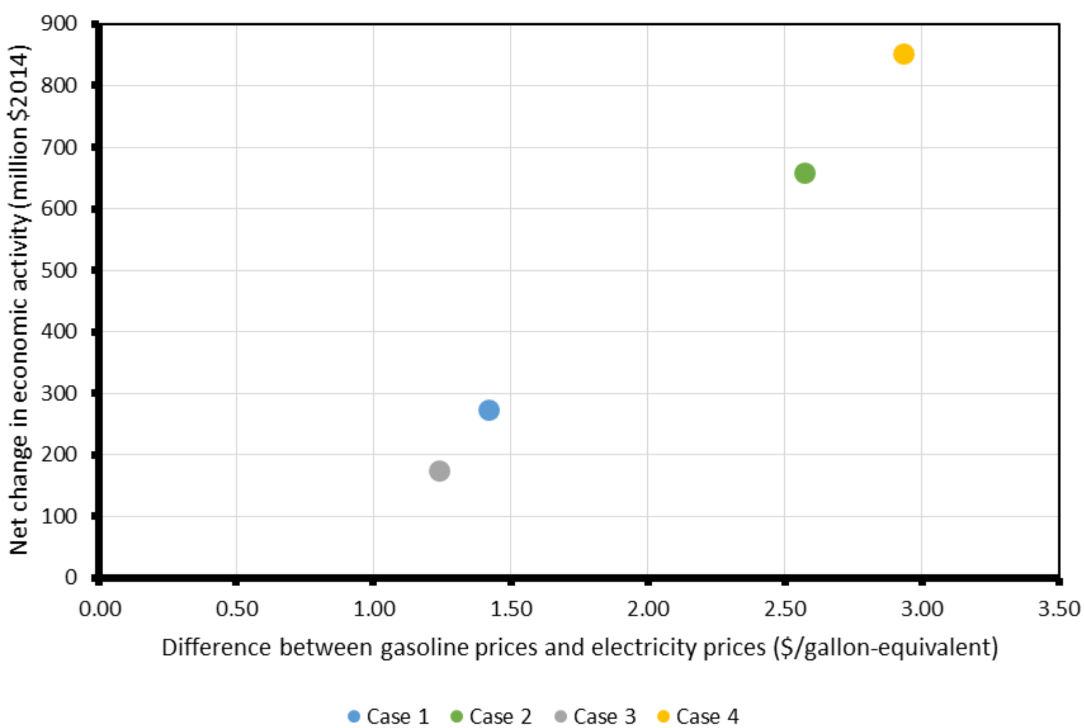


Figure 21
Change in economic activity compared to the price difference between gasoline and electricity

VI. EFFECT ON KCP&L'S CUSTOMERS

This section describes the results of simulations of vehicle adoption and charger use. Chargers are used nominally at home, but with rate-based public charging infrastructure, added benefits can be obtained for both ratepayers and investors. The key success factor is vehicle adoption. We tested three scenarios for vehicle adoption and found that the nominal forecast is close to "break-even" for a $21.6 million public charging infrastructure program.

Methodology for Evaluating Customer and Ratepayer Effects

The period of active vehicle adoption and charging infrastructure construction is from 2016 to 2025, and given that these additions are assumed to have lifetimes of 10 years, the horizon extends to 2035 in order to represent retirements.

The significant base assumptions are that there is assumed to be no Federal Tax Credit, because most of the vehicle adoption is occurring after 2020, the assumed sunset year for the credit[19]. The gasoline costs begin relatively low at $2/gallon and rise to the Annual Energy Outlook (AEO) 2015 values by 2025.

There are no added generation or transmission capacity costs, because we assume that the added load from PEV charging is managed by demand response technology to avoid these added costs. Also, the traditional system peak is between 4:00 pm and 6:00 pm, which is not coincident with peak public charging periods, which is in the early morning and early afternoon. Further information on this subject is found in the Transformer analysis section.

Electricity energy costs are based on publicly available forecasts. Carbon costs for electricity are based on utility resource mix forecasts. Avoided future NO_x and SO_x benefits are not accounted.

The incremental vehicle cost is using a default, declining trajectory.

Scenario Definitions

We will have three scenario variables, which will help evaluate changes in:

- Vehicle Adoption,
- Public Charging Deployment, and
- Charging Behavior.

Vehicle Adoption

These values come from EPRI research. We consider benefits from vehicles that are sold from 2016 through 2025. They retire over the years 2026 through 2035, because we assume they have a 10-year lifetime. See Section II for more information on the adoption levels.

Low	5,559 vehicles in 2025
Medium	29,733 vehicles in 2025
High	73,533 vehicles in 2025

[19] By default the model assumes a steeply escalating introduction rate which pushes most benefits to later years. If introduction occurs more rapidly, the benefits will be discounted less and should pay off the fixed costs earlier.

Public Charging Deployment

None	No public (work) charging infrastructure is added. No cost for commercial chargers.
Nominal	This includes 1,000 L2 dual-head chargers at a cost of $20M and 15 Direct Current Fast Chargers at a cost of $1.6M.
High Cost	This includes 1,000 L2 dual-head chargers at a cost of $30M and 15 Direct Current Fast Chargers at a cost of $2.4M.

This analysis does not include an estimated $250k/year O&M cost for the program. The Net Present Value (NPV) of this cost for 10 years is $2.2 million, based on 3% escalation and 6.34% discount. This is about 10% of the capital costs and will likely increase the breakeven vehicle adoption by as much.

Charging Behavior

None	Little to no new public charging is installed. Everyone is assumed to charge at home.
Nominal	The utility installs public charging equipment, which is used by PEV owners and may contribute to increased vehicle sales.

Case Study Setup

The focus of the Case Study is to identify costs and benefits and then the break-even point for introducing public infrastructure. Table 6 describes all of the cases in terms of the scenario definitions for vehicle adoption, public charging deployment, and charging behavior.

Table 6
Case Definitions

CASE	VEHICLE ADOPTION	PUBLIC CHARGING DEPLOYMENT	CHARGING BEHAVIOR
0	Low	None	None
1	Low	Nominal	Nominal
2	Medium	Nominal	Nominal
3	High	Nominal	Nominal
4	Low	High Cost	Nominal
5	Medium	High Cost	Nominal
6	High	High Cost	Nominal

The following are descriptions of how the cases will be used individually and together.

- *Case 0* – Base Case having no new public infrastructure, which is to be used for cost comparisons.
- *Case 2* – Introduction of public infrastructure with nominal cost and nominal sales.
- *Case 5* – Introduction of public infrastructure with high cost and nominal sales.

- *Case 1 and Case 3* – Help determine break-even point of benefits to cover costs of public infrastructure having nominal cost.
- *Case 4 and Case 6* – Help determine break-even point of benefits to cover costs of public infrastructure having high cost.

Results

This section presents and explains the results of running the Transportation Electrification model in terms of two performance tests that show the marginal effects of the public charging program, which is very small relative to the full utility financial portfolio. They are not indicative of the full portfolio. For more information, please see the *California Standard Practice Manual*[20], which says the following:

- "The *Total Resource Cost (TRC) Test* measures the net costs of a demand-side management program as a resource option based on the total costs of the program, including both the participants' and the utility's costs."
- *"*The *Ratepayer Impact Measure (RIM) Test* measures what happens to customer bills or rates due to changes in utility revenues and operating costs caused by the program. Rates will go down if the change in revenues from the program is greater than the change in utility costs. Conversely, rates or bills will go up if revenues collected after program implementation are less than the total costs incurred by the utility in implementing the program. This test indicates the direction and magnitude of the expected change in customer bills or rate levels."

These TRC test depends on the following components:

- *Carbon from Electricity* – Added costs of carbon emissions from electricity for vehicle charging.
- *Energy Cost* – Added cost of electricity to charge vehicles.
- *Charger Costs* – Cost to install home and public charging infrastructure.
- *Incremental Vehicle Cost* – Added cost of a plug-in vehicle over a conventional vehicle.
- *Carbon from Gasoline* – Avoided cost of carbon emissions from avoided use of gasoline.
- *Gasoline Cost* – Avoided cost of gasoline not used.

Net TRC Benefit = Gasoline Cost + Carbon from Gasoline
– Incremental Vehicle Cost – Charger Costs
– Energy Cost – Carbon from Electricity

The RIM test depends on the some of the above costs and the following two components:

- *Utility Bills* – A measure of ratepayer benefit from electricity use.
- *RB (Rate-Based) Charger Cost* – Portion of vehicle charger costs covered in the rate base.

Net RIM Benefit = Utility Bills – RB Charger Cost
– Carbon from Electricity – Charger Costs
– Energy Cost

[20] CPUC (2001). California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects, California Public Utility Commission Report, October 2001.
http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=7741

In the subsections below, Base Case (Case 0) results are presented first, then Case 2 and Case 5 are presented as variations on Case 0 that add public charging infrastructure. Case 2 results show the effects of increased infrastructure investment and increased sales, and Case 5 shows the effects on Case 2 results if infrastructure installation costs are higher than expected (in this case by 50%).

Finally, four additional sensitivity cases are presented. Case 1 shows the effects of investing in infrastructure but achieving no additional sales, and Case 3 shows the beneficial support of vehicle adoptions that exceed those in Case for these same investments.

Cases 4 and 6 show how many additional PEV sales would be required to overcome additional costs if costs are 50% higher than expected.

Note that all dollar figures will be reported in millions of 2016 dollars (million 2016$).

Case 0 – Base Case Results

The base case results represent the value of the installed base and a low forecast for vehicle adoption. They establish a point of comparison for assessing the impacts of introducing public charging infrastructure. The following figures present the results of the base case and indicate significant nominal benefits in the given area. The TRC test reveals that there are $4.4 million in net benefits from the nominal increase from 1,596 PEVs in 2016 to 5,559 PEVs in 2025. This increase is due to 'organic' sales unrelated to the proposed infrastructure program.

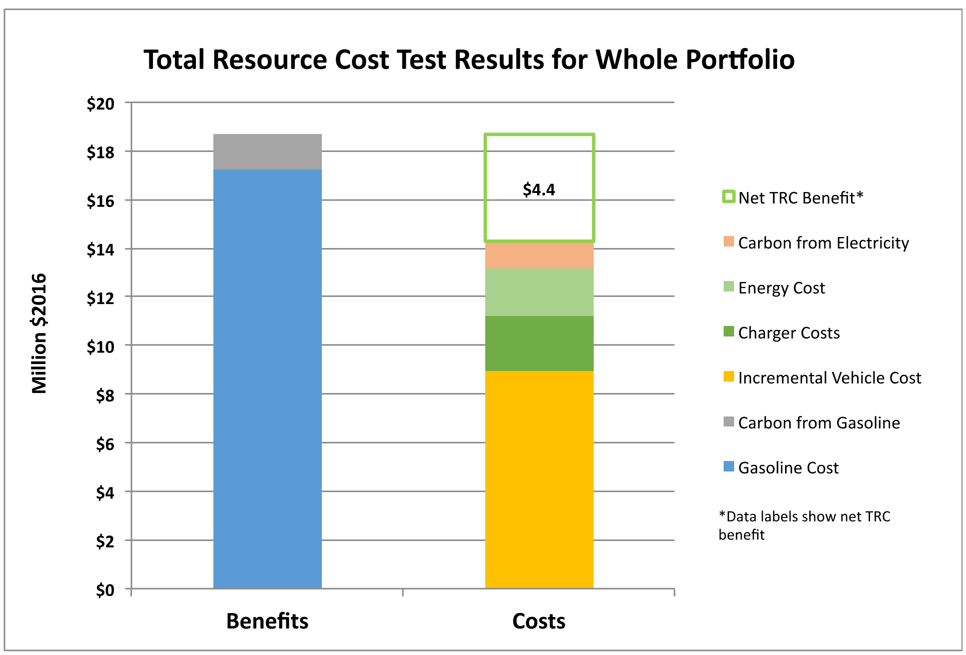


Figure 22
Case 0 Total Resource Cost Test Results (Million 2016$)

The indication is that the Net TRC Benefit is $4.4 million, deriving mainly from avoided Gasoline Cost ($17.2 million) and Carbon from Gasoline ($1.4 million), despite significant Energy, Charger, Incremental Vehicle, and Carbon from Electricity Costs ($14.3 million). Recall that the Federal Tax Credit is assumed to be zero in all cases, because most vehicles are being purchased in the latter part of the horizon.

Following are the detailed values for components of the TRC test.

Table 7
Case 0 Total Resource Cost Test Results (Million 2016$)

COST COMPONENT	CASE 0 BENEFITS	CASE 0 COSTS
GASOLINE COST	$17.2	$0.0
CARBON FROM GASOLINE	$1.4	$0.0
INCREMENTAL VEHICLE COST	$0.0	$9.0
CHARGER COSTS	$0.0	$2.3
ENERGY COST	$0.0	$1.9
CARBON FROM ELECTRICITY	$0.0	$1.1
NET TRC BENEFIT	***$4.4***	–

Note that Case 0 has charger costs of $2.3 million to accommodate home charging for the additional plug-in vehicles rising from 1596 in 2016 to 5559 in 2025.

Following is a high-level comparison of benefits and costs for the RIM test.

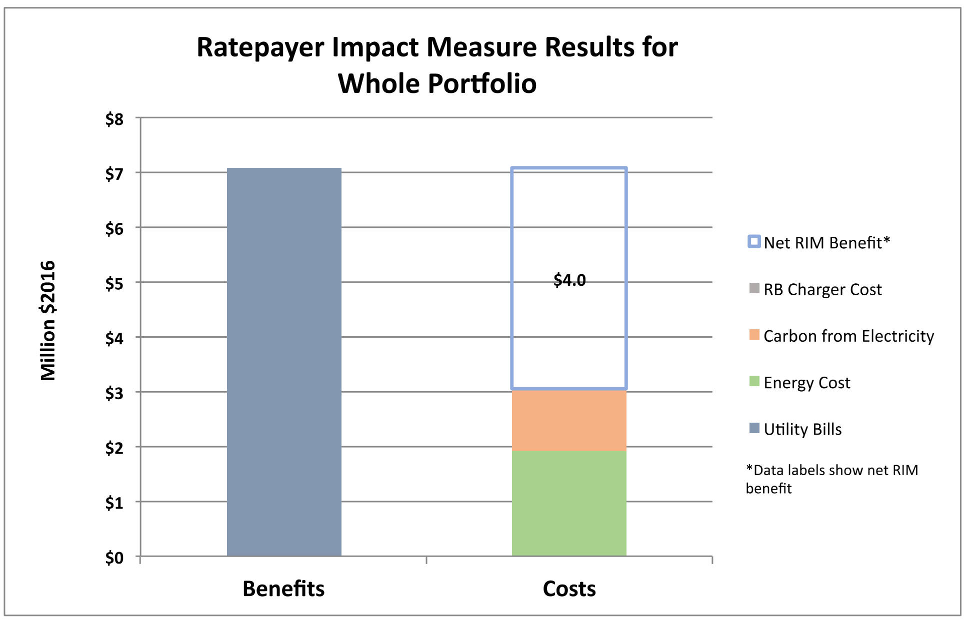


Figure 23
Case 0 Ratepayer Impact Measure Test Results (Million 2016$)

The RIM test for Case 0 indicates that all ratepayers are deriving net benefits of $4.0 million as a result of a small portion investing privately in electric vehicles and charging infrastructure.

Following is detailed figures for the components of the RIM test.

Table 8
Case 0 Ratepayer Impact Measure Test Results (Million 2016$)

COST COMPONENT	CASE 0 BENEFITS	CASE 0 COSTS
UTILITY BILLS	$7.1	$0.0
ENERGY COST	$0.0	$1.9
CARBON FROM ELECTRICITY	$0.0	$1.1
RB CHARGER COST	$0.0	$0.0
NET RIM BENEFIT	***$4.0***	–

The major cost components that subtract from the ratepayer benefits, are Energy Cost ($1.9 million) for incremental wholesale energy supply, and Carbon from Electricity ($1.1 million).

Case 2 – Nominal Public Infrastructure Cost

This case introduces to Case 0 a $21.6 million public charging infrastructure project that is supported 100% by the rate base. The following figures and tables will show the absolute costs and benefits of this case, as well as the incremental changes that this impact has when compared to Case 0.

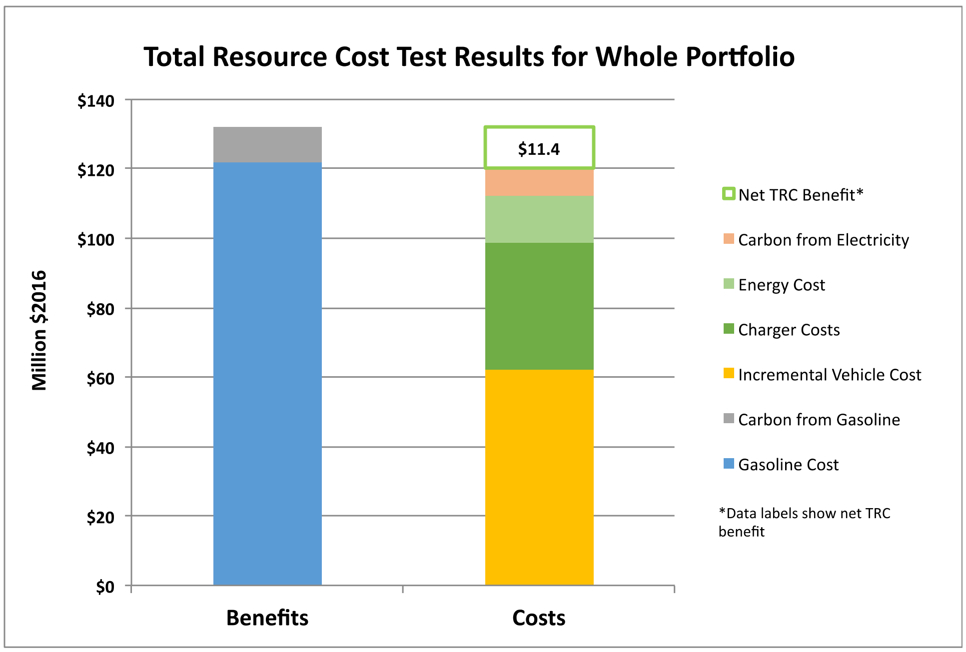


Figure 24
Case 2 Total Resource Cost Test Results (Million 2016$)

The TRC has risen to $11.4 million from Case 0 due to the addition of the public infrastructure.

Following are the detailed values for components of the TRC test.

Table 9
Case 2 Total Resource Cost Test Results and Incremental over Case 0 (Million 2016$)

COST COMPONENT	CASE 2 BENEFITS	CASE 2 COSTS	INCREMENTAL BENEFITS	INCREMENTAL COSTS
GASOLINE COST	$121.8	$0.0	$104.6	$0.0
CARBON FROM GASOLINE	$10.0	$0.0	$8.6	$0.0
INCREMENTAL VEHICLE COST	$0.0	$62.1	$0.0	$53.1
CHARGER COSTS	$0.0	$36.7	$0.0	$34.4
ENERGY COST	$0.0	$13.6	$0.0	$11.7
CARBON FROM ELECTRICITY	$0.0	$8.0	$0.0	$6.9
NET TRC BENEFIT	***$11.4***	–	***$7.1***	–

The indication is the Net TRC Benefit has an additional $7.1 million in net benefits that derive mainly from avoided Gasoline Cost and Carbon from Gasoline ($131.8 million), despite significant Incremental Vehicle, Charger, Energy, and Carbon from Electricity Costs ($120.4 million).

Note that there are $34.4 million in incremental Charger Costs and that the additional cost of Carbon from Electricity ($8.0 million) is on the order of the wholesale Energy Cost ($13.6) and is exceeded by the benefits of avoided Carbon from Gasoline ($10.0 million).

Following is a high-level comparison of benefits and costs for the RIM test.

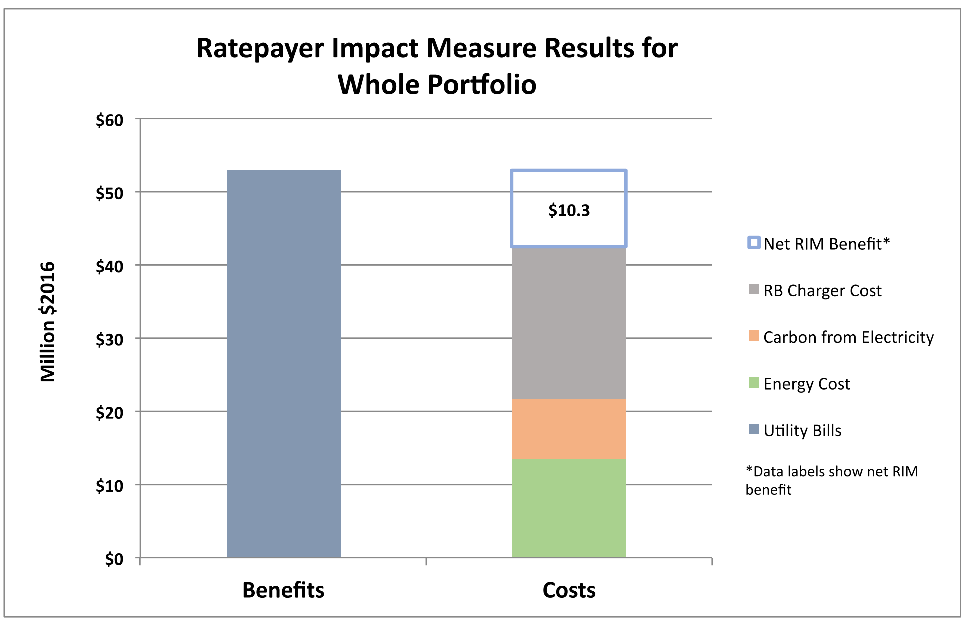


Figure 25
Case 2 Ratepayer Impact Measure Test Results (Million 2016$)

The Net RIM Benefit has risen to $10.3 million compared to Case 0, because of the added electricity sales growing to $52.8 million, even though there is additional Energy Cost, Carbon from Electricity Cost, and Rate-Based (RB) Charger Cost.

Following is detailed figures for the components of the RIM test.

Table 10
Case 2 Absolute Ratepayer Impact Measure Test Results and Incremental over Case 0 (Million 2016$)

COST COMPONENT	CASE 2 BENEFITS	CASE 2 COSTS	INCREMENTAL BENEFITS	INCREMENTAL COSTS
UTILITY BILLS	$52.8	$0.0	$45.8	$0.0
ENERGY COST	$0.0	$13.6	$0.0	$11.7
CARBON FROM ELECTRICITY	$0.0	$8.0	$0.0	$6.9
RB CHARGER COST	$0.0	$20.9	$0.0	$20.9
NET RIM BENEFIT	***$10.3***	–	***$6.3***	–

The incremental RIM test results indicate that all ratepayers derive significant absolute benefits ($10.3 million) from the new public charging infrastructure, and that those benefits have increased by $6.3 million with respect to Case 0.

Case 5 – High Public Infrastructure Cost

This case introduces to Case 0 a $32.4 million public charging infrastructure project that is supported 100% by the rate base. This case assumes the same number of chargers and additional vehicles as Case 2, but assumes that public infrastructure costs are 50% higher than the $21.6 million that is currently planned. The following tables show absolute results and the incremental changes that this impact has when compared to Case 0.

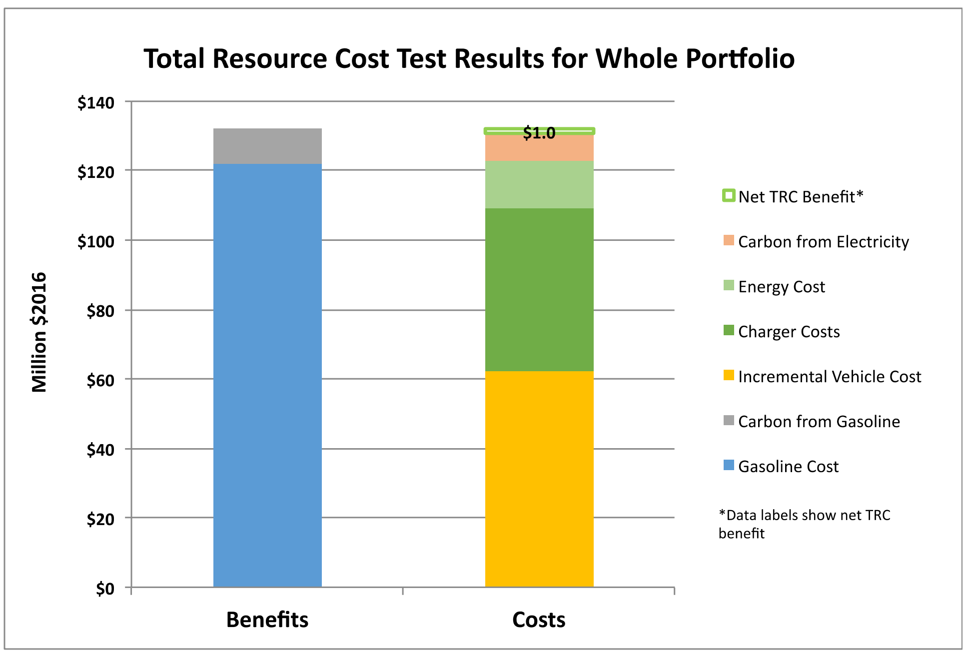


Figure 26
Case 5 Total Resource Cost Test Results (Million 2016$)

Following are the detailed values for components of the TRC test.

Table 11
Case 5 Total Resource Cost Test Results and Incremental over Case 0 (Million 2016$)

COST COMPONENT	CASE 5 BENEFITS	CASE 5 COSTS	INCREMENTAL BENEFITS	INCREMENTAL COSTS
GASOLINE COST	$121.8	$0.0	$104.6	$0.0
CARBON FROM GASOLINE	$10.0	$0.0	$8.6	$0.0
INCREMENTAL VEHICLE COST	$0.0	$62.1	$0.0	$53.1
CHARGER COSTS	$0.0	$47.2	$0.0	$44.9
ENERGY COST	$0.0	$13.6	$0.0	$11.7
CARBON FROM ELECTRICITY	$0.0	$8.0	$0.0	$6.9
NET TRC BENEFIT	***$1.0***	–	***-$3.4***	–

Note that there are $53.1 million in incremental Charger Costs over Case 0, when both home chargers and public infrastructure costs are included.

The indication is that Net TRC Benefit is positive ($1.0 million), but there is an incremental Net TRC *Cost* of $3.4 million, when compared to Case 0. The major components of the incremental net benefits are avoided Gasoline Cost and Carbon from Electricity ($131.8 million), which is not enough to overcome the significant total costs ($130.9 million).

The main observations about the TRC analysis from this case are:

- High Infrastructure Cost has positive Net TRC Benefits for the nominal vehicle adoption forecast, but there is an incremental cost when compared to Case 0.
- The vehicle adoption target for Case 5 is close to level needed to support the TRC test.

The following figure has a high-level comparison of benefits and costs for the RIM test.

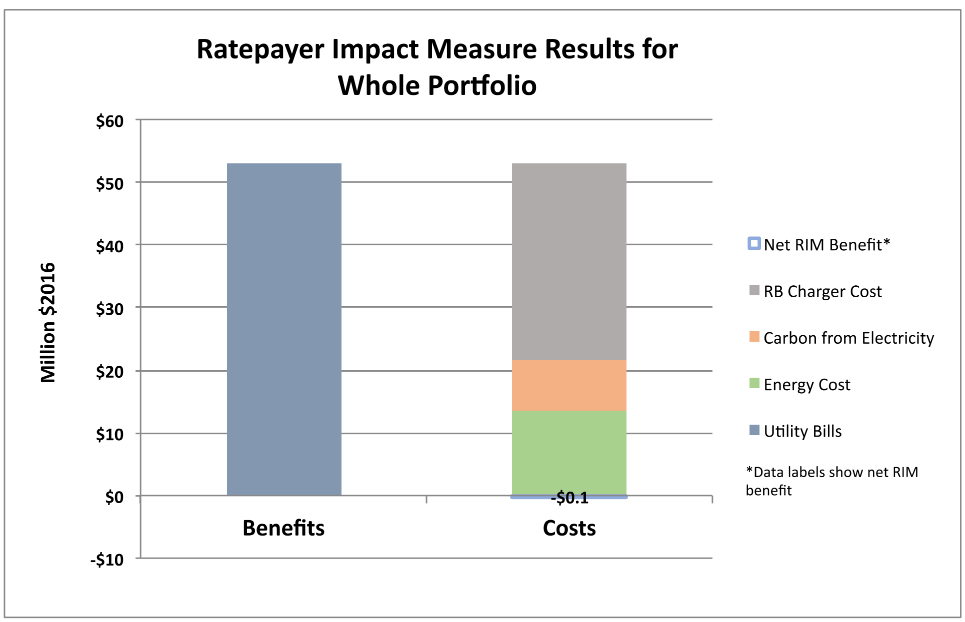


Figure 27
Case 5 Ratepayer Impact Measure Test Results (Million 2016$)

Following is detailed figures for the components of the RIM test.

Table 12
Case 5 Ratepayer Impact Measure Test Results and Incremental over Case 0 (Million 2016$)

COST COMPONENT	CASE 5 BENEFITS	CASE 5 COSTS	INCREMENTAL BENEFITS	INCREMENTAL COSTS
UTILITY BILLS	$52.8	$0.0	$45.8	$0.0
ENERGY COST	$0.0	$13.6	$0.0	$11.7
CARBON FROM ELECTRICITY	$0.0	$8.0	$0.0	$6.9
RB CHARGER COST	$0.0	$31.4	$0.0	$31.4
NET RIM BENEFIT	***-$0.1***	–	***-$4.2***	–

The Net RIM Benefit results indicate that all ratepayers derive marginal *costs* ($0.1 million) from the new public charging infrastructure, and there is an incremental Net RIM *Cost* of $4.2 million when compared to Case 0.

The main observations about the RIM analysis from this case are:

- High Infrastructure Cost is detrimental to the nominal forecast for Net RIM Benefits.
- The vehicle adoption target for Case 5 is close to level needed to support the RIM test.

Case 1 – Nominal Infrastructure Cost, Low Vehicle Adoption

Because Case 2 passes all tests, Case 1 with low vehicle penetration, is necessary for determining the crossover point of the amount of vehicle adoption that can support the new public infrastructure.

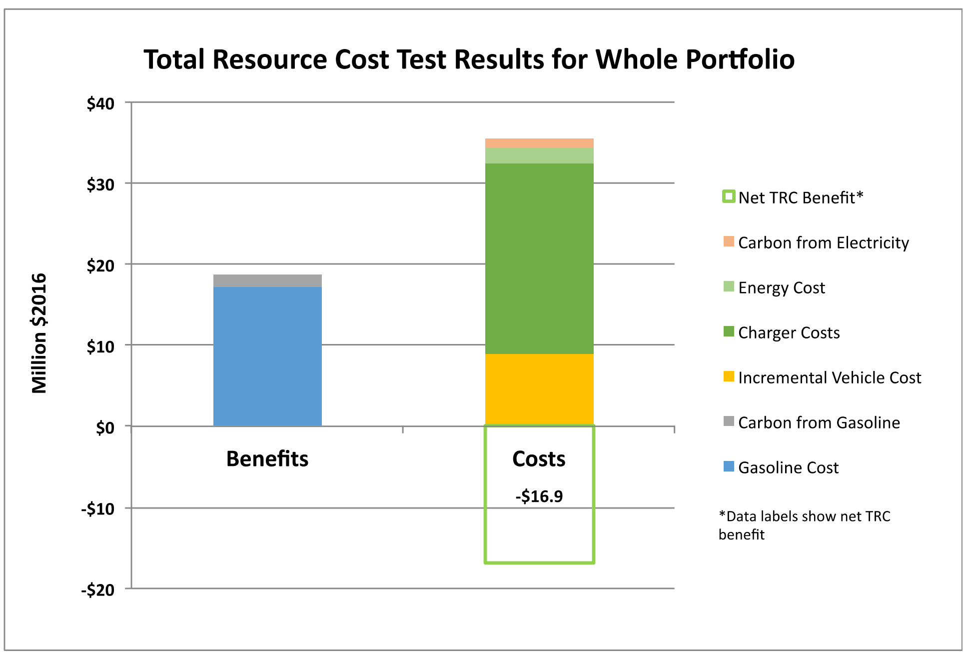


Figure 28
Case 1 Total Resource Cost Test Results (Million 2016$)

Following are the detailed values for components of the TRC test.

Table 13
Case 1 Total Resource Cost Test Results and Incremental over Case 0 (Million 2016$)

COST COMPONENT	CASE 1 BENEFITS	CASE 1 COSTS	INCREMENTAL BENEFITS	INCREMENTAL COSTS
GASOLINE COST	$17.2	$0.0	$0.0	$0.0
CARBON FROM GASOLINE	$1.4	$0.0	$0.0	$0.0
INCREMENTAL VEHICLE COST	$0.0	$9.0	$0.0	$0.0
CHARGER COSTS	$0.0	$23.5	$0.0	$21.3
ENERGY COST	$0.0	$1.9	$0.0	$0.0
CARBON FROM ELECTRICITY	$0.0	$1.1	$0.0	$0.0
NET TRC BENEFIT	**-**	***-$16.9***	***-$21.3***	**–**

The only change between Case 0 and Case 1 is regarding increased cost of the public infrastructure, and this shows up as a $21.3 million dollar difference in Charger Costs (this differs from the $21.6 million assumed program cost due to rounding of the inputs).

The following figure has a high-level comparison of benefits and costs for the RIM test.

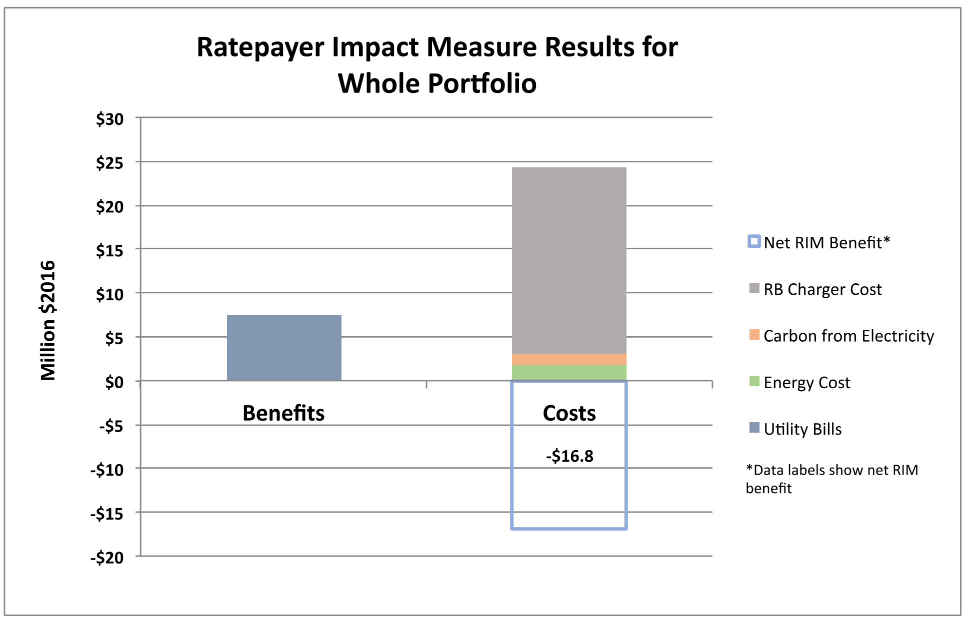


Figure 29
Case 1 Ratepayer Impact Measure Test Results (Million 2016$)

Following is detailed figures for the components of the RIM test.

Table 14
Case 1 Ratepayer Impact Measure Test Results and Incremental over Case 0 (Million 2016$)

COST COMPONENT	CASE 1 BENEFITS	CASE 1 COSTS	INCREMENTAL BENEFITS	INCREMENTAL COSTS
UTILITY BILLS	$7.5	$0.0	$0.4	$0.0
ENERGY COST	$0.0	$1.9	$0.0	$0.0
CARBON FROM ELECTRICITY	$0.0	$1.1	$0.0	$0.0
RB CHARGER COST	$0.0	$21.3	$0.0	$21.3
NET RIM BENEFIT*	***-$16.8***	**–**	***-$20.8***	**–**

It also shows that the only difference from Case 0 is in Rate Base (RB) Charger Cost.

Case 3 – Nominal Infrastructure Cost, High Vehicle Adoption

Because Case 2 passes all tests, Case 3 with high vehicle penetration, is not necessary for determining the crossover point, but it is included to show how the value of the public charging infrastructure changes as even more vehicles are adopted over Case 0.

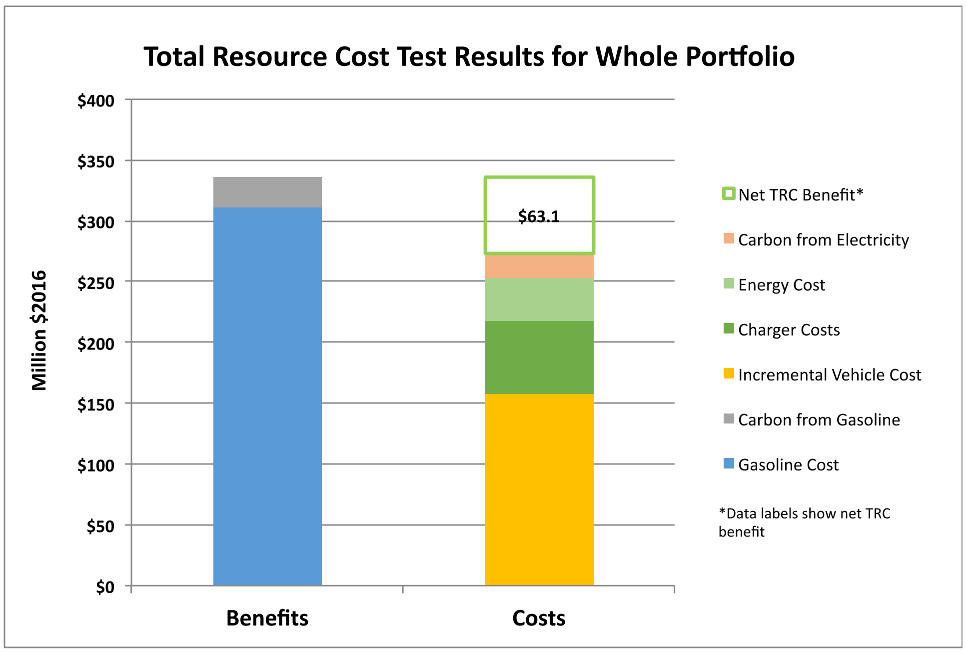


Figure 30
Case 3 Total Resource Cost Test Results (Million 2016$)

Following are the detailed values for components of the TRC test.

Table 15
Case 3 Total Resource Cost Test Results and Incremental over Case 0 (Million 2016$)

COST COMPONENT	CASE 3 BENEFITS	CASE 3 COSTS	INCREMENTAL BENEFITS	INCREMENTAL COSTS
GASOLINE COST	$310.8	$0.0	$293.6	$0.0
CARBON FROM GASOLINE	$25.6	$0.0	$24.2	$0.0
INCREMENTAL VEHICLE COST	$0.0	$157.4	$0.0	$148.4
CHARGER COSTS	$0.0	$60.9	$0.0	$58.6
ENERGY COST	$0.0	$34.7	$0.0	$32.8
CARBON FROM ELECTRICITY	$0.0	$20.4	$0.0	$19.3
NET TRC BENEFIT	***$63.1***		***$58.7***	–

The main difference between Case 0 and Case 3 is the cost of the public charging infrastructure, and this shows up as an additional $58.6 million over Case 0, which is more than the expected program cost of $21.6 million because the high vehicle adoption also leads to more need for home charging. The increases in the Incremental Vehicle Cost ($148.4 million), Energy Cost ($32.8 million), and Carbon from Electricity ($19.3 million) are also from the extra vehicles.

The following figure has a high-level comparison of benefits and costs for the RIM test.

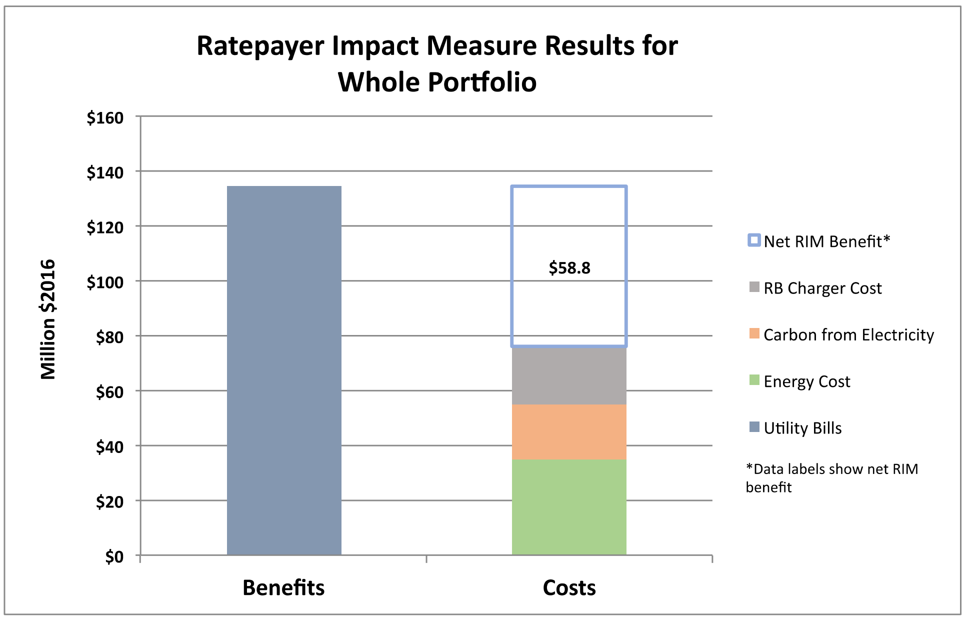


Figure 31
Case 3 Ratepayer Impact Measure Test Results (Million 2016$)

Following is detailed figures for the components of the RIM test.

Table 16
Case 3 Ratepayer Impact Measure Test Results and Incremental over Case 0 (Million 2016$)

COST COMPONENT	CASE 3 BENEFITS	CASE 3 COSTS	INCREMENTAL BENEFITS	INCREMENTAL COSTS
UTILITY BILLS	$134.7	$0.0	$127.6	$0.0
ENERGY COST	$0.0	$34.7	$0.0	$32.8
CARBON FROM ELECTRICITY	$0.0	$20.4	$0.0	$19.3
RB CHARGER COST	$0.0	$20.8	$0.0	$20.8
NET RIM BENEFIT*	***$58.8***	**–**	***$54.7***	**–**

These show increases in costs, but also increases in sales that represent higher Utility Bills as Ratepayer Benefits ($134.7 million), which is $127.6 million higher than Case 0.

Case 4 – High Infrastructure Cost, Low Vehicle Adoption

Since Case 5 results barely changes the TRC and RIM tests, it is necessary to investigate Case 4, which has lower vehicle adoption, in order to determine the marginal effect of lower vehicle adoption.

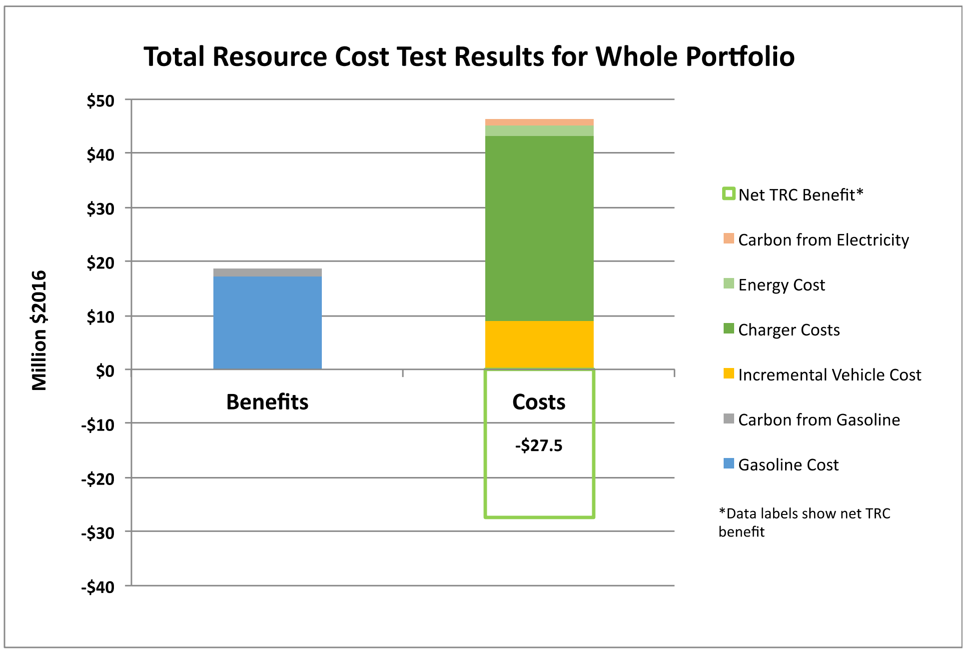


Figure 32
Case 4 Total Resource Cost Test Results (Million 2016$)

Following are the detailed values for components of the TRC test.

Table 17
Case 4 Total Resource Cost Test Results and Incremental over Case 0 (Million 2016$)

COST COMPONENT	CASE 4 BENEFITS	CASE 4 COSTS	INCREMENTAL BENEFITS	INCREMENTAL COSTS
GASOLINE COST	$17.2	$0.0	$0.0	$0.0
CARBON FROM GASOLINE	$1.4	$0.0	$0.0	$0.0
INCREMENTAL VEHICLE COST	$0.0	$9.0	$0.0	$0.0
CHARGER COSTS	$0.0	$34.1	$0.0	$31.9
ENERGY COST	$0.0	$1.9	$0.0	$0.0
CARBON FROM ELECTRICITY	$0.0	$1.1	$0.0	$0.0
NET TRC BENEFIT	***-$27.5***	**–**	***-$31.9***	**–**

The only change between Case 0 and Case 1 is regarding an increased cost of the public infrastructure, and this shows up as a $31.9 million dollar difference in Charger Costs.

The main observation about the TRC analysis from this case is:

- Low vehicle adoption is detrimental to high charger costs, with an absolute TRC loss of $31.9 million.

The following figure has a high-level comparison of benefits and costs for the RIM test.

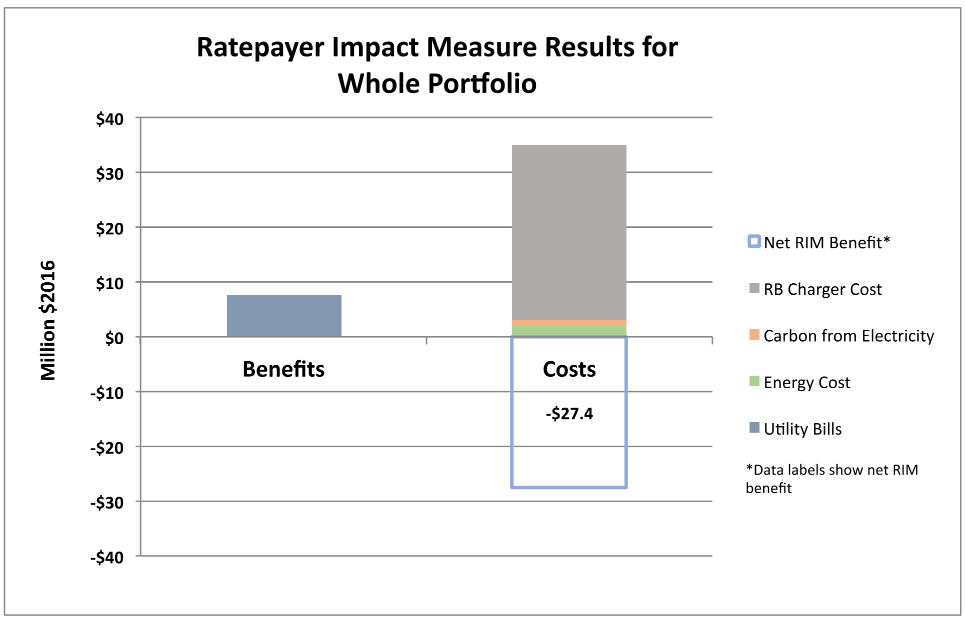


Figure 33
Case 4 Ratepayer Impact Measure Test Results (Million 2016$)

Following is detailed figures for the components of the RIM test.

Table 18
Case 4 Ratepayer Impact Measure Test Results and Incremental over Case 0 (Million 2016$)

COST COMPONENT	CASE 4 BENEFITS	CASE 4 COSTS	INCREMENTAL BENEFITS	INCREMENTAL COSTS
UTILITY BILLS	$7.5	$0.0	$0.4	$0.0
ENERGY COST	$0.0	$1.9	$0.0	$0.0
CARBON FROM ELECTRICITY	$0.0	$1.1	$0.0	$0.0
RB CHARGER COST	$0.0	$31.9	$0.0	$31.9
NET RIM BENEFIT*	***-$27.4***	**–**	***-$31.5***	**–**

The RIM test value for Case 4 is ($27.4 million), which is $31.5 million lower than Case 0. The RB Charger Cost is $31.9 million, with a little extra benefit to ratepayers ($0.4 million) when compared to Case 0.

The main observation about the RIM analysis from this case is:

- Low vehicle adoption is detrimental to high charger costs, with a RIM loss of $27.4 million.

Case 6 – High Infrastructure Cost, High Vehicle Adoption

Case 6 has higher infrastructure cost, like Case 5, but it also has higher vehicle adoption to support that cost. In fact, it passes the TRC and RIM tests and can serve as a means to estimate the marginal effect of increased vehicle adoption.

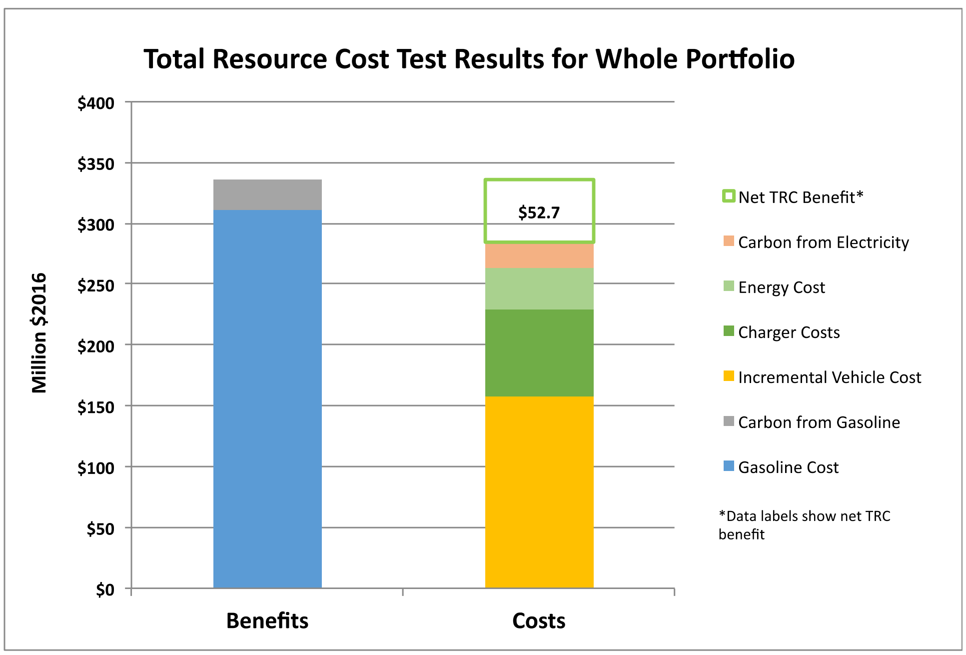


Figure 34
Case 6 Total Resource Cost Test Results (Million 2016$)

Following are the detailed values for components of the TRC test.

Table 19
Case 6 Total Resource Cost Test Results and Incremental over Case 0 (Million 2016$)

COST COMPONENT	CASE 6 BENEFITS	CASE 6 COSTS	INCREMENTAL BENEFITS	INCREMENTAL COSTS
GASOLINE COST	$310.8	$0.0	$293.6	$0.0
CARBON FROM GASOLINE	$25.6	$0.0	$24.2	$0.0
INCREMENTAL VEHICLE COST	$0.0	$157.4	$0.0	$148.4
CHARGER COSTS	$0.0	$71.3	$0.0	$69.0
ENERGY COST	$0.0	$34.7	$0.0	$32.8
CARBON FROM ELECTRICITY	$0.0	$20.4	$0.0	$19.3
NET TRC BENEFIT	***$52.7***	**–**	***$48.3***	**–**

The changes between Case 0 and Case 6 are regarding increased cost of the public charging infrastructure, and this shows up as an additional $69.0 million over Case 0, because the additional vehicle adoption also leads to more need for home charging. The increases in the Incremental Vehicle Cost ($148.4 million), Energy Cost ($32.8 million), and Carbon from Electricity ($19.3 million) are also from the extra vehicles.

The main observation about the TRC analysis from this case is:

- High vehicle adoption is beneficial to high charger costs, with a TRC gain of $52.7 million over Case 0.

The following figure has a high-level comparison of benefits and costs for the RIM test.

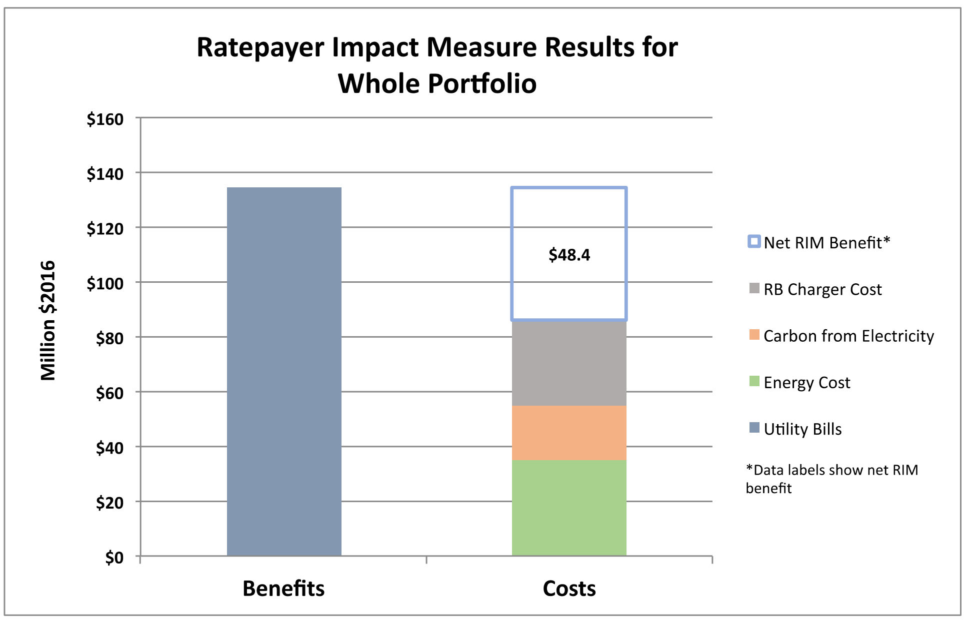


Figure 35
Case 6 Ratepayer Impact Measure Test Results (Million 2016$)

Following is detailed figures for the components of the RIM test.

Table 20
Case 6 Absolute Ratepayer Impact Measure Test Results and Incremental over Case 0 (Million 2016$)

COST COMPONENT	CASE 6 BENEFITS	CASE 6 COSTS	INCREMENTAL BENEFITS	INCREMENTAL COSTS
UTILITY BILLS	$134.7	$0.0	$127.6	$0.0
ENERGY COST	$0.0	$34.7	$0.0	$28.9
CARBON FROM ELECTRICITY	$0.0	$20.4	$0.0	$19.3
RB CHARGER COST	$0.0	$31.2	$0.0	$31.2
NET RIM BENEFIT*	***$48.4***	–	***$44.3***	–

These show increases in costs, but also increases in sales that represent higher Utility Bills as Ratepayer Benefits ($134.7 million), which is $127.6 million higher than Case 0.

- High vehicle adoption is beneficial to high charger costs, with a RIM benefit of $48.4 million, $44.3 million more than Case 0.

Summary

This section collects the TRC and RIM test results in one place and explains how the RIM test Benefits switch from negative to positive for the Nominal and High Cost public charging deployments when vehicle adoption reaches a break-even point.

The following table summarizes the TRC and RIM test results across all cases and allows for comparisons across the Vehicle Adoption scenarios in order to estimate the break-even adoption rates needed to support the Nominal and High Cost public charging deployments.

Table 21
Case Summary of Net TRC and RIM Benefits (Million 2016$)

CASE	VEHICLE ADOPTION	PUBLIC CHARGING DEPLOYMENT	CHARGING BEHAVIOR	TRC TEST BENEFITS	RIM TEST BENEFITS
0	Low (5,559)	None	None	$4.4	$4.0
1	Low (5,559)	Nominal	Nominal	($16.9) ($21.3)*	($16.8) ($20.8)*
2	Medium (29,733)	Nominal	Nominal	$11.4 $7.1*	$10.3 $6.3*
3	High (73,533)	Nominal	Nominal	$63.1 $58.7*	$58.8 $54.7
4	Low (5,559)	High Cost	Nominal	($27.5) ($31.9)*	($27.4) ($31.5)*
5	Medium (29,733)	High Cost	Nominal	$1.0 ($3.4)*	($0.1) ($4.2)*
6	High (73,533)	High Cost	Nominal	$52.7 $48.3*	$48.4 $44.3*

* Incremental net benefits over Base Case 0.

At the budgeted nominal Public Charger Deployment costs and medium vehicle adoption (Case 2) the Incremental Net Ratepayer Benefit is $6.3 million, when compared to the Case 0, which represents business as usual.

Break-Even Points

A straight-line approximation between Cases 1 and 2 vehicle adoption and RIM test results is used to estimate the break-even point for ratepayers in the Nominal public charging infrastructure scenario. It uses the incremental RIM benefits over Case 0 in order to isolate the effects of the added infrastructure from other effects due to the initial conditions. Likewise, Cases 5 and 6 are used to estimate the break-even point for the High nominal public charging infrastructure.

- The break-even point for vehicle adoption for the $21.6 million public charger program is near 20,600 vehicles.

At the high Public Charger Deployment cost (150% of nominal cost), Case 5 shows that with the medium adoption rate, the ratepayers do not reach the break-even point, because the incremental net RIM benefits over Case 0 is ($4.2 million).

The break-even point for vehicle adoption for the $32.4 million public charger program is near 33,700 vehicles.