BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of a Working Case Regarding	)	
Electric Vehicle Charging Facilities	)	Case No. EW-2016-0123

RESPONSE OF KANSAS CITY POWER & LIGHT COMPANY AND KCP&L GREATER MISSOURI OPERATIONS COMPANY TO COMMISSION QUESTIONS

Kansas City Power & Light Company ("KCP&L") and KCP&L Greater Missouri Operations Company ("GMO") (collectively, "KCP&L" or "the Company") hereby submits responses to the questions attached to the Missouri Public Service Commission's Notice Scheduling Workshop and Requesting Responses issued on January 20, 2016.

1. *What is the Missouri Public Service Commission's role in regulation of electricity from a charging station to an electric vehicle? Please provide the legal justification for your response.*

Response:

Section 386.020(43) RSMo. defines a "public utility" as any "electrical corporation" "owning, operating or controlling or managing any electric plant. . . "[1] KCP&L is an "electrical corporation,"[2] owning, operating, controlling and managing the electric vehicle ("EV") charging

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[1] Section 386.020(43) RSMo. states: "Public utility" includes every pipeline corporation, gas corporation, electrical corporation, telecommunications company, water corporation, heat or refrigerating corporation, and sewer corporation, as these terms are defined in this section, and each thereof is hereby declared to be a public utility and to be subject to the jurisdiction, control and regulation of the commission and to the provisions of this chapter." (emphasis added)

[2] Section 386.020(15) RSMo. defines electrical corporation as: "Electrical corporation" includes every corporation, company, association, joint stock company or association, partnership and person, their lessees, trustees or receivers appointed by any court whatsoever, other than a railroad, light rail or street railroad corporation generating electricity solely for railroad, light rail or street railroad purposes or for the use of its tenants and not for sale to others, owning, operating, controlling or managing any electric plant except where electricity is generated or distributed by the producer solely on or through private property for railroad, light rail or street railroad purposes or for its own use or the use of its tenants and not for sale to others. (emphasis added)

stations. The EV charging stations are "electric plant" under Section 386.020(14)[3] which facilitates the distribution, sale or furnishing of electricity for power.

Missouri case law has imposed the further requirement that such service must be offered "for public use." See State ex rel. Danciger and Co. v. Public Service Commission of Missouri, 275 Mo. 483, 205 S.W. 36 (1918). Relying on Danciger, the federal court in City of St. Louis v. Mississippi River Fuel Corporation, 97 F.2d 726 (8th Cir. 1938), stated that the public use of a service is the deciding factor in determining whether an operation is a "public utility" under Missouri law. It concluded that "under Missouri law the term 'for public use' . . . means the sale . . . to the public generally and indiscriminately, and not to particular persons upon special contract." Id. at 730. The City of St. Louis court cited with favor the following definition:

> To constitute a public use all persons must have an equal right to the use, and it must be in common, upon the same terms, however few the number who avail themselves of it. Id.

The Commission should conclude that KCP&L is providing electrical service through the EV charging stations as a public utility. The service will be available to any electrical vehicle driver that wishes to avail themselves of the electric service. The Commission should conclude that the EV charging stations are part of the Company's regulated local distribution network which is necessary to provide electricity to the EVs. As such, KCP&L's Clean Charge Network ("CCN") facilities should be treated as electric plant needed to provide electric service through EV charging stations to EV drivers as a public utility service.

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[3] Section 386.020(14) RSMo. states: "Electric plant" includes all real estate, fixtures and personal property operated, controlled, owned, used or to be used for or in connection with or to facilitate the generation, transmission, distribution, sale or furnishing of electricity for light, heat or power; and any conduits, ducts or other devices, materials, apparatus or property for containing, holding or carrying conductors used or to be used for the transmission of electricity for light, heat or power; (emphasis added)

2. *What is the Missouri Public Service Commission's role in regulation of electricity from a utility to a charging station? Please provide the legal justification for your response.*

<u>Response</u>:

The Company is and will be providing electricity service through the charging stations at the Company's tariffed rates. This is no different than any other part of its regulated distribution system which it provides as a regulated public utility. The EV charging stations are part of the Company's regulated local distribution network which is necessary to provide electricity to the EVs. The Company's CCN facilities should be treated as electric plant needed to provide electric service through EV charging stations to EV drivers as a public utility service.

3. *Are Investor Owned Utilities ("IOU") the only entities that can provide electricity to electric vehicles via a charging station? What other entity (ies) can provide electricity to electric vehicles via charging stations? Is the answer dependent on whether the entity (ies) charges for the electricity? Please provide the legal justification for your response.*

<u>Response</u>:

Yes. As explained in response to question 1 above, CCN is a public utility service under Missouri law. Therefore, only public utilities can provide the service for a fee in their certified territories. Section 393.170, RSMo. To the extent other entities are providing electricity to EV owners and operators through EV charging stations in KCP&L and GMO's service territory, this is permissible only if those other entities are not charging a fee. <u>See</u> <u>Danciger</u>; <u>City of St. Louis</u>.

   a. *Is there a legal restriction which would prevent any company other than the local IOU electric company from providing electricity to an EV charging station?*

Response:

Yes. The tariffs of both KCP&L and GMO prohibit the resale of electricity.

Rule 5.03 on Sheet No. 1.19 of KCP&L's tariff provides that except as provided in Rules 5.05, 5.06 and 5.07 the Company will not supply electrical service to a Customer for resale and redistribution by the Customer.

Rule 3.02(B) on Sheet No. R-24 of GMO's tariff provides that a customer shall not sell the electricity purchased from the Company to any other customer, company or person. Electricity provided is for the personal use of the customer. The customer shall not deliver the electricity purchased from the Company to any connection wherein such electricity is to be used off of the customer's premises or used by persons over whom customer has no control. Customers receiving electricity on retail rate tariffs may not submeter and resell electricity. For violations of the rule, the Company may remove its meter and discontinue service.

b. Is the local IOU electric company obligated by law to provide electricity to EV charging stations?

Response:

KCP&L and GMO have an obligation to serve in their certificated service territory in accordance with Commission-approved terms and conditions, rules and regulations. Part and parcel of a utility's obligation to serve is the responsibility to provide facilities that are safe and adequate. Section 393.130.1 RSMo. The adequacy of facilities provided by any utility is a question of fact, and it is reasonable to expect that standards regarding what constitutes "adequate" facilities may change over time.

This is one reason KCP&L and GMO proposed CCN as a pilot project. EVs are presently in their nascent stage with relatively low adoption rates resulting from a variety of factors, many of which are beyond the ability of KCP&L, GMO or the Commission to affect. But KCP&L, GMO and the Commission can affect one significant factor causing low EV adoption rates, what has been called "range anxiety"; that is, the driver's concern that the EV's battery will not be sufficient to propel the vehicle to the driver's intended destination and back home where the driver can re-charge.

Solving "range anxiety" presents a classic chicken/egg conundrum. Is increased EV usage possible without greater availability of EV charging stations? Conversely, is greater availability of EV charging stations possible without increased EV usage? In a recent study conducted by Cornell University, *The Market for Electric Vehicles: Indirect Network Effects and Policy Design*[4], they found the market for plug-in EVs exhibits indirect network effects in that there is interdependence between consumer decision of EV purchase and investor decision of charging station deployment. According to the study, a 10% increase in the number of public charging stations would increase EV sales by about 8%. The study also evaluated the effectiveness of the federal income tax credit that provides up to $7,500 for new EV purchases. The study further shows that if the $1.05 billion tax incentives were used to build charging stations instead of subsidizing EV purchases, the increase in EV sales would be three times as large.

The Company believes that increased EV usage offers customer and public benefit. The Company contracted with the Electric Power Research Institute ("EPRI") to perform a

[4] Li, Shanjun and Tong, Lang and Xing, Jianwei and Zhou, Yiyi, "The Market for Electric Vehicles: Indirect Network Effects and Policy Design" (June 2015), pp. 1-3. Available at SSRN: http://ssrn.com/abstract=2515037 or http://dx.doi.org/10.2139/ssrn.2515037

preliminary analysis[5] (attached hereto as Schedule 1) of the benefits related to its deployment of the CCN. The Company believes customer and public benefits from increased EV usage are provided in five distinct areas, namely:

1. Beneficial Electrification: As opposed to EV charging stations owned and operated by multiple entities other than the serving electric utility, installation and operation of EV charging stations as part of the utility's electric distribution system should facilitate efficient use of the electrical grid through increased sales during off-peak times, spreading the cost of operating and maintaining the grid over more kilowatt-hours without causing increased generation investment. The EPRI study indicated that under the nominal EV adoption scenario, the net benefit to all KCP&L customers is projected to be $6.3 million.
2. Environmental Benefits: Increased EV usage would displace fossil fuel vehicle usage, thereby reducing tailpipe emissions – including particulate matter and ozone emissions in addition to others. According to a study conducted by EPRI, with KCP&L's fleet mix, EV's are equivalent to a 36 MPG conventional vehicle. The average fuel economy of new conventional vehicles in 2015 was 25.3 MPG. This further confirms the findings in the Union of Concerned Scientists (USC) analysis (2015)[6] which demonstrated a nationwide comparison of the fuel economy a gasoline vehicle would have to achieve in order to have the same life cycle greenhouse gas emissions as conventional vehicles throughout the country.

[5] EPRI, "Preliminary Scoping Analysis of the Effects of Transportation Electrification in the KCP&L Service Territory," (2016)

[6] http://www.ucsusa.org/clean-vehicles/electric-vehicles/life-cycle-ev-emissions#.VtBx6JiFN9N

3. Economic Development: Increased EV usage should spur regional economic development by attracting auto industry, EV industry and charging station companies to the Company's service territory; it should also assist in local job creation resulting from increased household spending on local goods and services rather than gas at the pump; regional recruitment in competitive job categories such as STEM (science, technology, engineering and math) may also see a boost with increased EV usage in the Company's service territory. The EPRI analysis found that direct and indirect benefits of transportation electrification could lead to large increases in economic activity 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[7].

4. Customer Programs: As opposed to EV charging stations owned and operated by multiple entities other than the serving utility, installation and operation of EV charging stations as part of the utility's electric distribution system should enable

[7] 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).

customer programs for cost-effective demand side management, time-of-use rates and vehicle to grid battery storage and discharge.

5. Cost and Efficiency Benefits: As opposed to EV charging stations owned and operated by multiple entities other than the serving utility, installation and operation of EV charging stations as part of the utility's electric distribution system should reduce the cost of equipment and installation while use of the utility as a standard payment platform should also reduce cost; such efficiencies should ease expansion of the system if deemed appropriate.

In light of the potential benefits resulting from increased EV usage, KCP&L and GMO proposed CCN as a pilot project to assess whether and to what extent greater availability of EV charging stations results in increased EV usage.

Must EV charging stations be provided by electric utilities in Missouri in order to meet the statutory standard of "adequate" facilities? Given the current state of EV adoption in Missouri, the answer to that question may well be "no" today. But that answer is likely to change with the passage of time, and KCP&L and GMO believe it is wiser to take steps which anticipate and seek to mold this evolving market rather than to simply wait and react to market changes. The CCN pilot provides an opportunity for the Commission, KCP&L, GMO and other interested stakeholders to do just that.

The courts have long held that the Commission has broad discretion to approve experimental rates for the purpose of acquiring the data necessary to fix just and reasonable rates. See Union Electric Co. v. Public Service Commission, 136 S.W.3d 146, 149, 152 (Mo. App. WD 2004; In the Matter of the Investigation Into All Issues Concerning the Provision of Extended Area Service (EAS) in the State of Missouri under Commission Rule 4 CSR 240-30.030, 29 Mo.

P.S.C. (N.S.) 75, 106 (1987), citing, State ex rel. Watts Engineering Company v. Missouri Public Service Commission, 191 S.W. 412 (Mo. banc 1917); State ex rel. Washington University v. Missouri Public Service Commission, 272 S.W. 971 (Mo. banc 1925); State ex rel. City of St. Louis v. Missouri Public Service Commission, 296 S.W. 790 (Mo. banc 1927); State ex rel. Campbell Iron Company v. Missouri Public Service Commission, 296 S.W. 998 (Mo. banc 1927); State ex rel. McKittrick v. Missouri Public Service Commission, 175 S.W. 2d 857 (Mo. banc 1943); and State ex rel. Laclede Gas Company v. Missouri Public Service Commission, 535 S.W. 2d 561 (Mo.App. K.C.D. 1976). In light of advances in EV technology, greater receptivity in the marketplace to EVs generally and the potential benefits to KCP&L and GMO customers from increased EV usage, the Company requests that the Commission exercise its broad authority regarding experimental rates to authorize the CCN as a pilot program.

c. *What impact do the responses provided above in sub-bullets a and b have on EV charging stations that are installed and operations as of this date?*

Response:

From KCP&L and GMO's perspective, its responses to questions 3.a, and 3.b above provide guidance for ongoing operation of EV charging stations.

4. *Is each charging station a distinct electric utility?*

Response:

No. Pursuant to Section 386.020(14) – EV charging stations are "electric plant" which facilitates the distribution, sale or furnishing of electricity for power by an electrical corporation such as KCP&L.

5. *How will there be accessibility to electric vehicles for low-income ratepayers? At what point in time would accessibility to electric vehicles for low-income ratepayers occur?*

Response:

For EVs to become accessible to low income ratepayers two main obstacles must be overcome; cost and access to charging infrastructure. The following linked article illustrates how California has adopted incentives designed to make EVs more affordable to low income drivers. http://www.plugincars.com/california-make-electric-cars-affordable-low-income-buyers-130133.html.

Most EVs have typically been more expensive than their internal combustion engine ("ICE") powered counterparts. But, costs are coming down and EVs cost less to operate than ICE equivalents. Green Car Reports.com lists six 2016 model year EVs with list prices under $30,000 with the Mitsubishi i-MiEV having the lowest list price of $23,845. In addition to the EV cost, lower income buyers often have additional obstacles in the new vehicle market. They tend to not benefit from federal tax credits, due to a low tax burden, and often are not able to qualify for leasing, which could otherwise allow the tax credit to mitigate up-front costs.

EVs have been in the market long enough that a variety of used EVs are available on the used car market and the prices of these used vehicles reflects initial costs minus the tax credit. Costs for used EVs can still be higher than other used vehicle options, but they are increasingly within reach of lower income customers, especially when fuel and maintenance savings are included. A check of several used car marketplaces on February 22, 2016 found multiple used EVs for sale in the Kansas City market. For example, we found 2013 Chevy Volts starting at $14,000 on both CraigsList.com and AutoTrader.com and Nissan Leafs starting at $8,200 (2012) on CraigsList.com and $9,899 (2013) on AutoTrader.com.

To illustrate the lower operational cost of EVs, consider the following. Assuming that an EV travels 3.3 miles for each kWh of energy consumed, the cost to charge an EV at $0.15 per kWh would equate to filling up an ICE vehicle rated at 33 MPG with gas priced at $1.50 per gallon. Comparing to an ICE vehicle rated at 25.3 MPG, the average fuel economy of new conventional vehicles in 2015, would equate to gasoline priced at $1.15 per gallon. The website, InsideEVs.com[8], provides a comparison of the lower maintenance requirements of EVs compared to gasoline powered equivalents. Their comparison shows that while tire wear is common to both classes of vehicles, EVs do not require changes to engine or transmission oil, coolant, spark plugs, muffler and tailpipes, and due to regenerative breaks only half of the brake jobs will be required. An EPRI[9] analysis estimated that the cumulative lifetime maintenance cost saving of an EV over a conventional vehicle could range between $2,500 and $4,000 (2012). The other significant obstacle to ownership of EVs by lower income rate payers is access to EV charging infrastructure. Many drivers with garaged EVs and minimal driving needs can utilize Level 1 (110v) charging, but those with greater charging demands may not be able to afford the installation of, or landlords will not provide, a L2 (240v) charge station in the garage. Other potential EV drivers that rely on un-garaged parking, either on-street or outdoor multi-dwelling unit ("MDU") parking, will have to rely exclusively on the availability of EV charge station infrastructure installed at their workplace, MDU, or other driving destinations. Accessibility to adequate EV charging infrastructure will continue to be a significant impediment to adoption of EVs by lower income drivers.

KCP&L and GMO believe that utility installed public charging infrastructure pilot program such as the CCN, where benefits flow to all customer and are recovered through rates paid by all customers, can provide a portion of the EV charging infrastructure needed to support the adoption of EVs by lower income drivers.

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[8] http://insideevs.com/ev-vs-ice-maintenance-the-first-100000-miles/

[9] EPRI, "Total Cost of Ownership Model of Current Plug-in Electric Vehicles", Appendix B, (2012).

6. *How many EV charging stations are there in your company's service territory?*

a. *Who owns the charging station(s)?*

b. *Who operates the charging stations(s)?*

c. *Does the EV owner pay for the electricity used to charge the vehicle?*

Response:

The U.S. Department of Energy's ("DOE") Alternative Fuels Data Center ("AFDC") tracks the deployment of publically accessible EV charging stations and makes this data available on their web site, www.afdc.energy.gov/locator/stations/. While this site listing may not be all inclusive, it is the most authoritative source for public EV charge stations available. The DOE AFDC data set does not report the number of EV charging stations, but instead provides the number of EV charging ports available by location.

Within the combined KCP&L/GMO service territory across both Kansas and Missouri, the DOE AFDC data set identified 200 EV charging locations with a total of 848 EV Charging ports available as of January 31, 2016. Of these, 145 locations (740 ports) were KCP&L/GMO locations. KCP&L/GMO actually had 395 EV charge stations with 769 ports available illustrating that the DOE data is remarkably current. The remaining 55 locations (108 ports) were predominately auto dealerships with some public entities and other private business. Other than KCP&L/GMO, Sprint and Walgreens have the largest number of locations.

Ownership of the charge stations at the 55 non-KCP&L/GMO locations cannot be ascertained from the DOE AFDC data, but these EV charge stations are typically owned by the location host entity. The majority of the EV charge stations are networked and operate on one of three EV networks; ChargePoint Network, SEMA Charge Network, or Tesla.

Currently the EV drivers do not pay for the electricity used to charge the vehicle at any of the EV charge stations in the KCP&L/GMO service territory. At most locations the EV charging is entirely free. It does appear that at some locations the EV drivers may be charged an hourly session fee for the use of the charge station, typically $1.00 - $2.00 per hour. However, this could not be established with certainty as several of the public EV driver web portals provided conflicting cost information.

7. *What are other states doing to fund the development and installation of EV charging stations? Is cost recovery allowed through a utility's rate? Please include a reference to any legal authority that explicitly authorizes the method of funding or cost recovery.*

Response:

Utility regulatory authorities in several states have allowed, or are considering allowing, utilities to install, own, operate and maintain EV charging stations and a number of states have passed legislation that allows for utilities to rate base EV charging station costs:

In California, the California's Public Utilities Commission ("CPUC") Decision 14-12-079 rescinded the blanket prohibition against electric utility ownership of plug-in EV charging infrastructure adopted in Decision 11-07-029, and replaced it with a case-specific approach. Subsequent to this order Southern California Edison ("SCE"), San Diego Gas & Electric ("SDG&E") and Pacific Gas & Electric ("PG&E") each filed applications (A.14-10-014, A.14-04-014 & A.15-02-009 respectively) with the CPUC for EV charging infrastructure deployment programs. While the program specifics of each application vary, each includes the utility ownership of some portion of the EV charging infrastructure with the costs socialized across all customer rate classes.

In Decision 16-01-023, the CPUC approved a SCE ‘Charge Ready Program’ pilot with 1,500 EV charge stations. Under this pilot SCE will own, rate base and socialize the EV charging infrastructure. SCE will expense EV charging station rebates that it pays to the host who will own and operate the charging station. The host is the SCE customer of record and EV charge rates will be set by the host.

In a more recent Decision 16-01-045, the CPUC approved a SDG&E Vehicle Grid Integration (VGI) Pilot Program consisting of 3,500 EV charging stations installed specifically at workplace and multi-dwelling unit host locations. SDG&E will own the EV charging infrastructure including the charge stations. Under the program, SDG&E will bill the SDG&E customer, EV driver or host on a real-time pricing EV rate through SDG&E’s customer information system (CIS). Charge station usage by EV drivers that are not SDG&E customers will be billed to the host under the EV rate.

The proceeding for the PG&E application is ongoing. In the application, PG&E proposes to own the EV charging infrastructure including the charge stations. PG&E also proposes to contract with 3rd parties to operate their charge station network. The 3rd parties become the PG&E customer of record and set the EV charge rates.

In Indiana, Proceeding 44478 granted approval from the Indiana Utility Regulatory Commission to Indianapolis Power & Light’s for rate recovery related to distribution extensions and service lines to Blue Indy owned EV charging stations. They did not allow recovery of installation costs for Blue Indy owned charging locations and equipment.

In Washington, SHB 1571 provides that the Washington Utilities and Transportation Commission shall not regulate charging facilities provided by entities not regulated as utilities while at the same time indicating that utilities may offer EV charging as a regulated service. Additionally, in 2015, SHB 1853 provided clear policy directive and financial incentives to utilities for EV infrastructure build-out. This included the allowance of utilities to rate base EV charging station infrastructure when provided as a regulated service and established an incentive rate of return for EV charging station infrastructure at 2% above the utilities allowable ROE on other investments.

Oregon's Public Utilities Commission opened up Investigative Docket UM1461 that led to addressing non-utility ownership of EV supply equipment and utility ownership of EV supply equipment with and without rate recovery. This led to the order 12-013 that allowed non-utility resale of electricity as a motor fuel; allowed utility ownership of EV charging station as a non-regulated, non-rate based venture; and permits utility operation as a regulated service. As a regulated service, rate base recovery is allowed, a separate rate EV rate class must be established and other need and benefit analysis is required.

The Arizona Public Service Company applied for approval of a proposed EV readiness demonstration project in proceeding E-01345A-10-0123. This was approved and allowed for approximately 50 EV charging stations and a public sale rate that included an infrastructure charge to cover costs. The approval also allowed for the demonstration infrastructure costs to be recovered through normal rate making if the pilot was discontinued.

Most recently, in pending Case #2015-00355 with the Kentucky Public Service Commission, Kentucky Utilities Company and Louisville Gas and Electric Company made application to install, own, operate and maintain EV Charging Stations. The application requested that rates be established for EV charging stations provided by the utility to host managed site locations. The station site host will have the option of assessing a fee to station users. The application also asks that a rate be adopted for EV charging services provided to directly to EV drivers at utility managed locations. As proposed, the full cost of charging stations, including maintenance, installation, and energy usage, will be borne by those who request the stations or who use the charging service and will be recovered through the proposed rate schedules.

8. *Based on the current generation mix of your utility, will carbon emissions, NOx, or Sox increase or decrease if electric vehicle adoption increases? Please explain.*

Response:

When considering the effects of transportation electrification, it is important to compare the reduction in greenhouse gas emission and other pollutants from avoided gasoline or diesel consumption with those resulting from increased electricity production. KCP&L contracted with the Electric Power Research Institute (EPRI) to perform a preliminary analysis of the economic, environmental, distribution system, and consumer impacts related to its deployment of the CCN. Included in their report[10], EPRI's environmental analysis using KCP&L's generation mix confirms the finding in the Union of Concerned Scientists (USC) analysis[11], (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 EV 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.

Vehicle emissions will be reduced as more drivers adopt EVs. Environmental and health benefits through reducing tailpipe emissions – in particular help the Kansas City region attain

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[10] EPRI, "Preliminary Scoping Analysis of the Effects of Transportation Electrification in the KCP&L Service Territory," (2016).

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

EPA regional ozone emissions compliance, carbon dioxide reduction as part of state compliance with the Clean Power Plan, and reductions in other EPA categorized pollutants.

9. *Who should pay for the equipment, installation and maintenance for the EV charging station networks?*

<u>Response</u>:

As a modestly-scaled pilot project implemented to assess whether KCP&L and GMO's deployment of EV charging stations increases EV usage and whether such increase is accompanied by other potential benefits that would be realized by all customers, KCP&L and GMO believe that it is fair and reasonable to recover costs associated with CCN through rates paid by all customers.

To date, KCP&L and GMO customers have not borne any costs in rates directly related to implementation of CCN because neither rate base nor operations and maintenance ("O&M") expenses in connection with CCN have been included in either KCP&L or GMO's revenue requirement and rates. It is also true, however, that electricity provided by KCP&L and GMO to the CCN charging stations and used to charge EVs has been paid for by the owners of the host sites (in the case of slower charging stations) and by a grant from Nissan (in the case of faster charging stations). It is expected that these funding sources will cease upon the conclusion of the first two years of the CCN pilot in December of 2016

While KCP&L and GMO believe it is fair and reasonable to recover costs associated with the CCN pilot through rates paid by all customers, KCP&L and GMO also believe that drivers of EVs who use the CCN should bear some of the cost their CCN-related electricity usage upon cessation of the two existing funding sources (owners of the host sites in the case of slow-fill stations, and Nissan in the case of fast-fill stations). This does not mean, however, that KCP&L

and GMO believe it would be fair and reasonable to immediately begin recovering all CCN-related costs from CCN users.

To date, CCN-related rate base and O&M costs have been borne by KCP&L and GMO shareholders while tariffed charges for the electricity consumed by drivers of EVs using CCN have been paid for either by the host site owners or by the Nissan grant. Expressed more specifically, KCP&L and GMO believe that CCN-related costs should be recovered through rates paid by all customers as well as rates paid by drivers of EVs who make use of the CCN network. It is also possible that some host site owners may desire to continue funding the use of EV charging stations located on their property, and KCP&L and GMO believe that reasonable tariff provisions can be developed to meet this potential desire on the part of host site owners. Initially, the majority of CCN-related costs would be borne by rates paid by all customers, and this is fair because the CCN is a pilot designed to assess whether it can produce benefits for all KCP&L and GMO customers as discussed above in response to question 3.b., above. If the CCN proves successful and results in increased adoption of EV usage, the proportion of CCN-related costs recovered through rates paid by drivers of EVs who use the CCN network should increase along with increased usage of CCN.

Data shows that from January 2015, the beginning of the CCN implementation, to January 2016, we have seen the following increases: Number of charging sessions increased from 513 to 3,337 – a 550% increase; kWh usage from charging stations increased from 4,029 to 20,335 – a 405% increase; Number of unique EV drivers increased from 88 to 548 – a 523% increase. Once we are closer to fully deployed and have 18 months to evaluate the CCN's impact, we will develop a more sophisticated model to estimate EV adoption and the impact of the CCN.

It would not be reasonable to expect that all CCN-related costs would immediately be recovered through rates paid by drivers of EVs for their use of CCN for two good reasons:

- Because EV adoption rates are at relatively low levels currently, CCN usage will also be relatively low, and recovering all CCN-related costs over so few kWh would lead to prohibitively high rates for CCN use. As a result, recovering 100% of CCN-related costs through CCN usage by EV drivers would simply add another barrier to EV adoption.
- To the extent that CCN increases EV usage in KCP&L and GMO's service territory, the associated increase in electricity usage will occur not only through CCN charging stations, but also through EV charging done at the driver's "home base" (whether a residence or a business). CCN should get at least some "credit" for the revenues produced by this increased electricity consumption at the driver's "home base". A recent study by the Idaho National Laboratory[12] examined the charging patterns of 8,300 EVs over three years from 2011 to 2013. EV owners participating in the study were provided a Level 2 charger at their residence. The study determined that for these 'garaged' EVs 84-87% of the charging occurred at home and nearly half of the participants charged almost exclusively at home. As EV adoption increases, 'un-garaged' EVs will rely more heavily on workplace and public EV charging infrastructure. Because of this, analysis of public charging infrastructure, like the CA TEA Phase 2: Grid Impacts[13] study, typically assume that 75-80% of charging will occur at home.

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[12] Idaho National Laboratory. "Plugged In: How Americans Charge Their Electric Vehicles" (2015). http://avt.inl.gov/pdf/arra/SummaryReport.pdf

[13] Energy+Environmental Economics, Inc. "California Transportation Electrification Assessment Phase 2: Grid Impacts", (2014), pg. 31, http://www.caletc.com/wp-content/uploads/2014/10/CalETC_TEA_Phase_2_Final_10-23-14.pdf

Nor would it be reasonable to expect KCP&L and GMO shareholders to continue absorbing all CCN-related rate base and O&M costs indefinitely into the future. This would have a chilling effect on the willingness and ability of utilities to take steps to stay ahead of markets in anticipation of customer needs and, ultimately, would inevitably lead to a state of stasis in which the status quo prevails until customers rebel and demand change. There must be a better way than that.

10. How are other countries promoting public use of EV charging stations?

Response:

In a recent report issued by The International Council on Clean Transportation (ICCT) entitled "Transition to a Global Zero-Emission Vehicle Fleet: A Collaborative Agenda For Governments"[14] (attached hereto as Schedule 2), the ICCT summarizes the global adoption trends and national targets, as well as major EV promotion policies (e.g., consumer incentives and charging infrastructure support) for select markets; China, Europe, Japan, and the United States. Additionally, the report summarizes research on the effectiveness of various EV promotions and presents emerging best practices on EV policy. Based on this report's findings, the ICCT drew the following conclusions:

> **Policy action by leading governments is spurring electric vehicle deployment.** The most comprehensive electric vehicle promotion actions globally are in Norway, the Netherlands, and California, and these actions are resulting in electric vehicle deployment that is more than 10 times the average international electric vehicle uptake. More broadly, the actions of the governments of China, France, Germany, Japan, the Netherlands, Norway, the United Kingdom, and the United States are leading with policy incentives and infrastructure investments, and these countries make up over 90% of the world's electric vehicle market.

[14] Lutsey, Nic, (September, 2015), *Transition to a Global Zero-Emission Vehicle Fleet: A Collaborative Agenda For Governments*, The International Council on Clean Transportation, http://www.theicct.org/sites/default/files/publications/ICCT_GlobalZEVAlliance_201509.pdf

> **Best practices in electric vehicle promotion policies are emerging**. From the early electric vehicle promotion activity, best practices to accelerate electric vehicle deployment are beginning to emerge. Increasingly stringent efficiency standards, electric vehicle research and development support, and national electric vehicle planning appear to be necessary but insufficient actions to grow the electric vehicle market. Consumer incentives that reduce the cost of ownership are important to improve the consumer proposition on the new advanced electric technologies. Increasing the availability of home, workplace, and public electric charging infrastructure is also of high importance, (emphasis added) and several leading automobile markets (e.g., Japan, Norway, and parts of the United States) have far more extensive charging infrastructure per capita than others. It is becoming increasingly clear that a comprehensive portfolio of national, state, and local actions is critical for the increased deployment and use of electric vehicles.
>
> **Greater international collaboration could better leverage existing efforts to promote zero-emission vehicles**. This assessment points to several possible ways that governments can better collaborate and coordinate. The establishment of a zero-emission vehicle deployment target (e.g., 35% of automobile sales being zero-emission vehicles and 30 million annual global zero-emission vehicle sales) and an electric mobility target (e.g., at least 15% of vehicle use being electric) for 2035 would help in establishing a common long-term global electric-drive vision. Such goals would send clear signals about the pace of development and amount of resources that will be needed. Further coordinated research on policy effectiveness would help prioritize government actions that are most important in increasing zero-emission vehicle uptake and use.

Section 2 of the ICCT report outlines the major EV promotion policies of China, Japan, several European countries, and the United States. Table 2 lists twenty two (22) promotional practices in the areas of vehicle manufacturer, consumer purchase, consumer use, fuel provider/infrastructure, and consumer awareness by country.

WHEREFORE, the Company respectfully requests that the Commission consider the foregoing responses.

Respectfully submitted,

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Dated: March 1, 2016

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

Electric Power Research Institute

February 16, 2016

Contents

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.

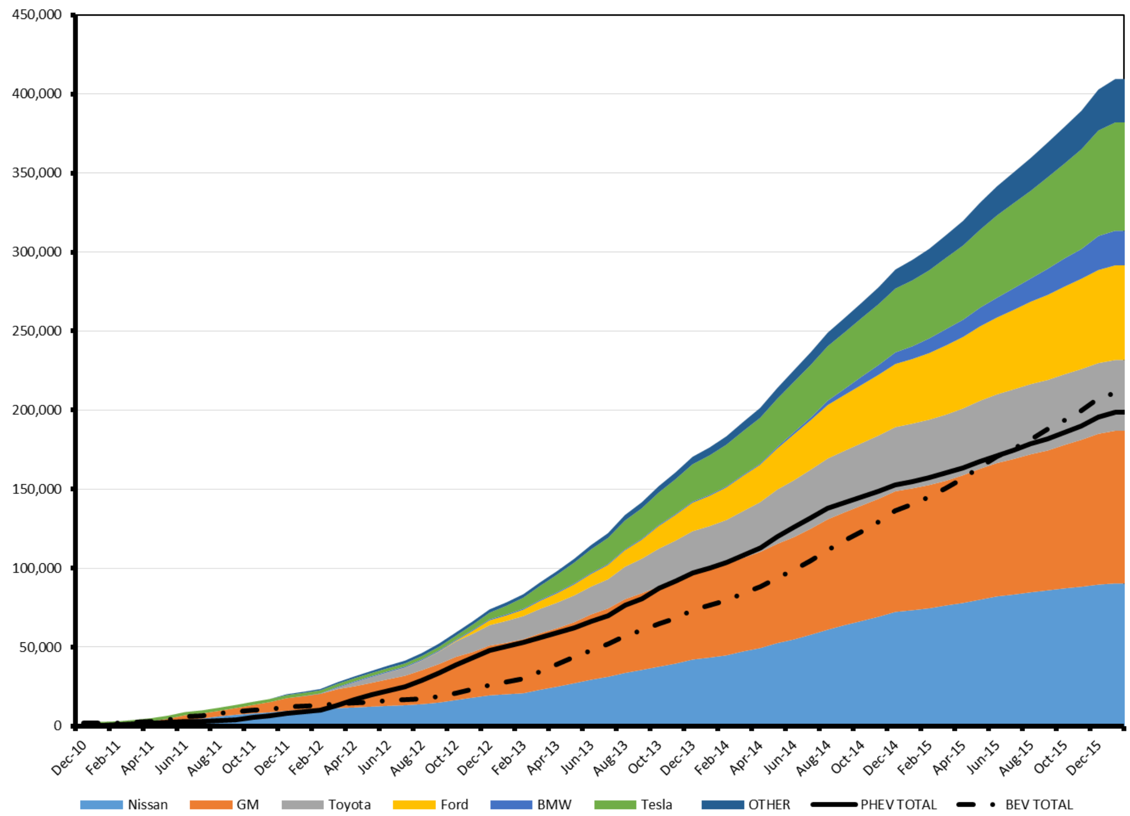

Figure 1
Cumulative PEV sales for the U.S. through January 2016

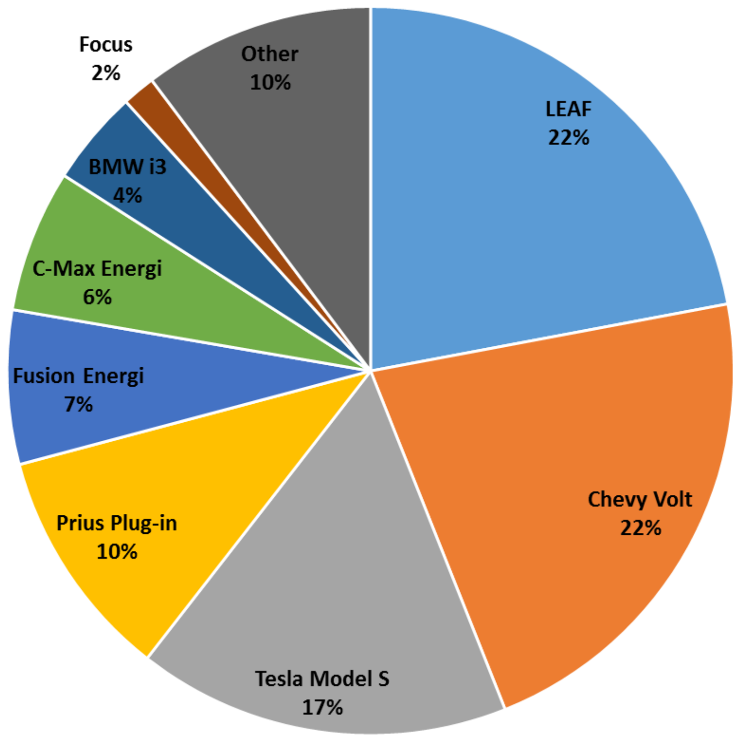

Figure 2
Nationwide Cumulative Sales broken down by vehicle type through January 2016

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.

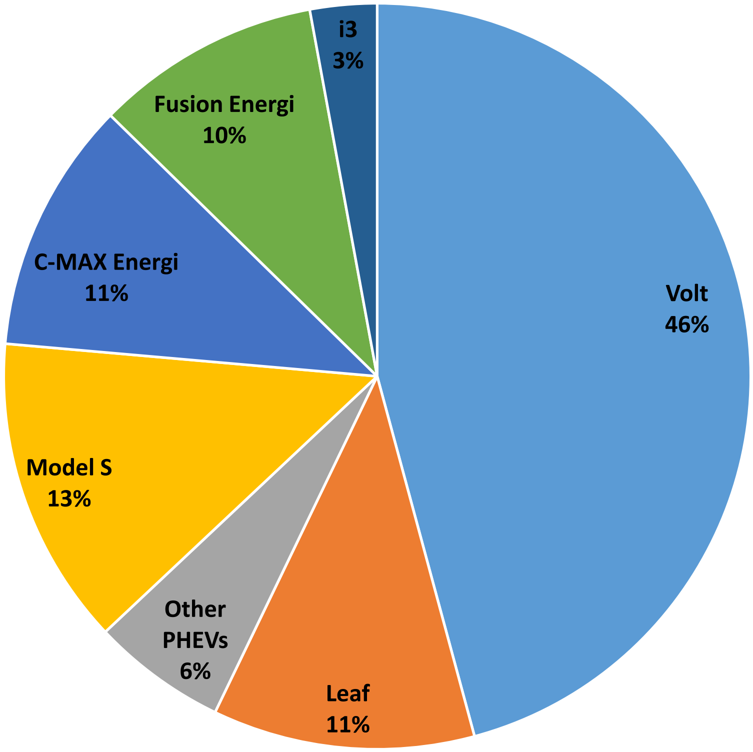

Figure 3
Cumulative Sales for the KCP&L territory broken down by vehicle type (as of November 1st, 2015)

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.

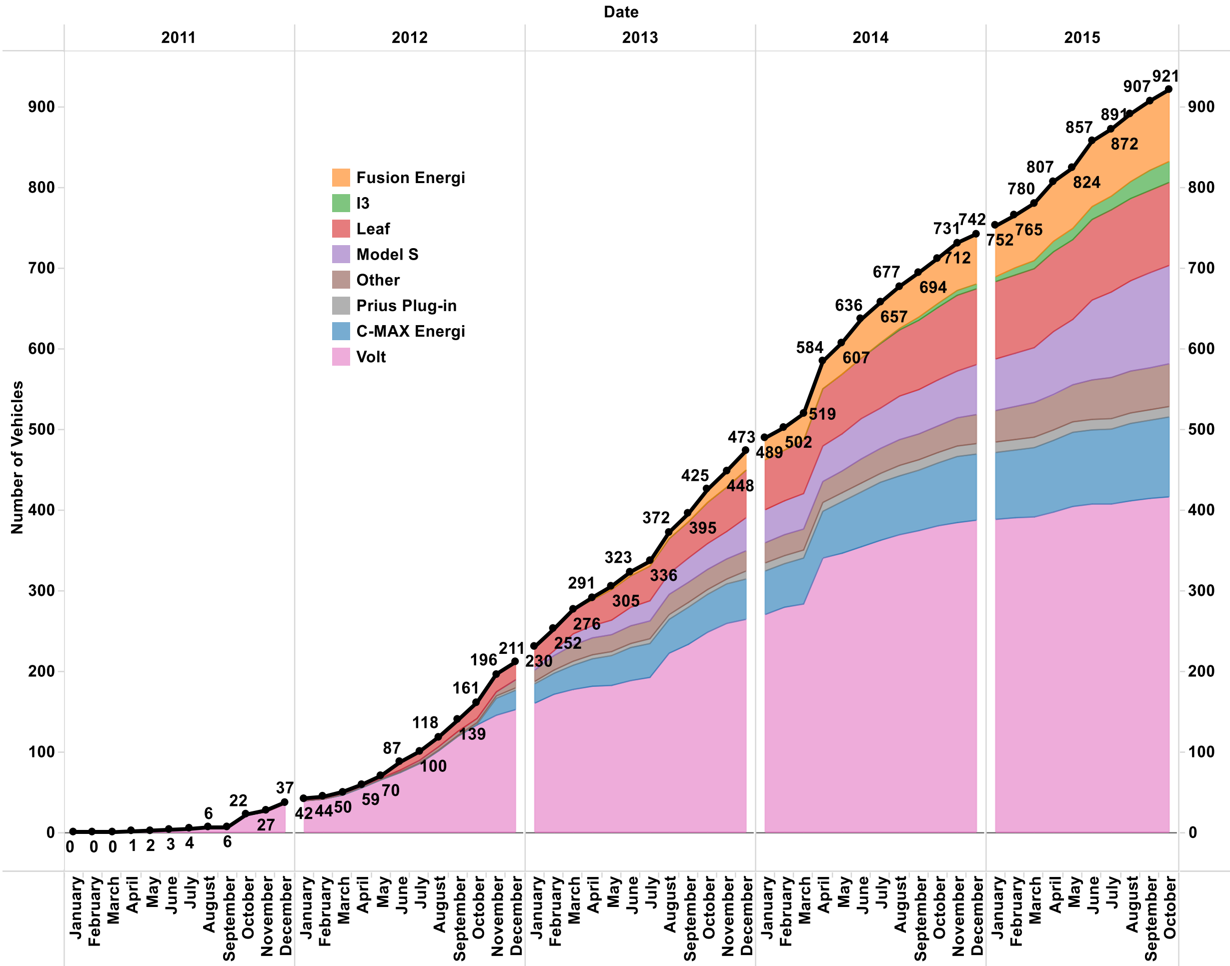

Figure 4
Cumulative Sales over time in KCP&L's service territory broken down by vehicle type (as of November 1st, 2015)

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.

[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.

[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.

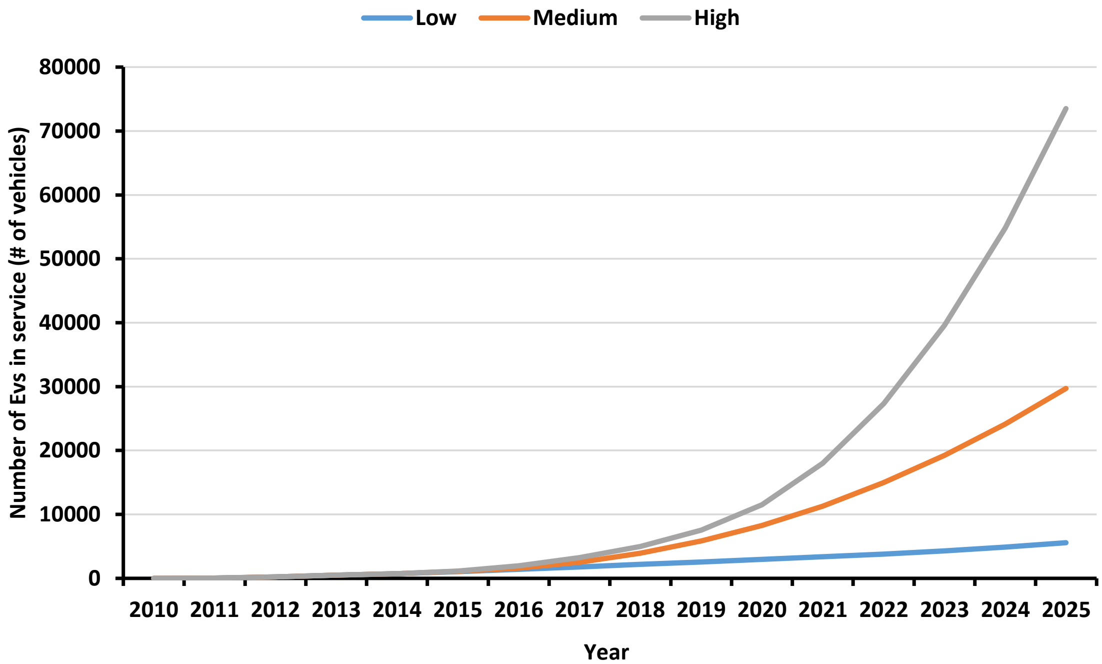

Figure 5
Simulated number of PEVs in the KCP&L's service territory out to 2025. Three adoption scenarios were shown: Low, Medium and High

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.

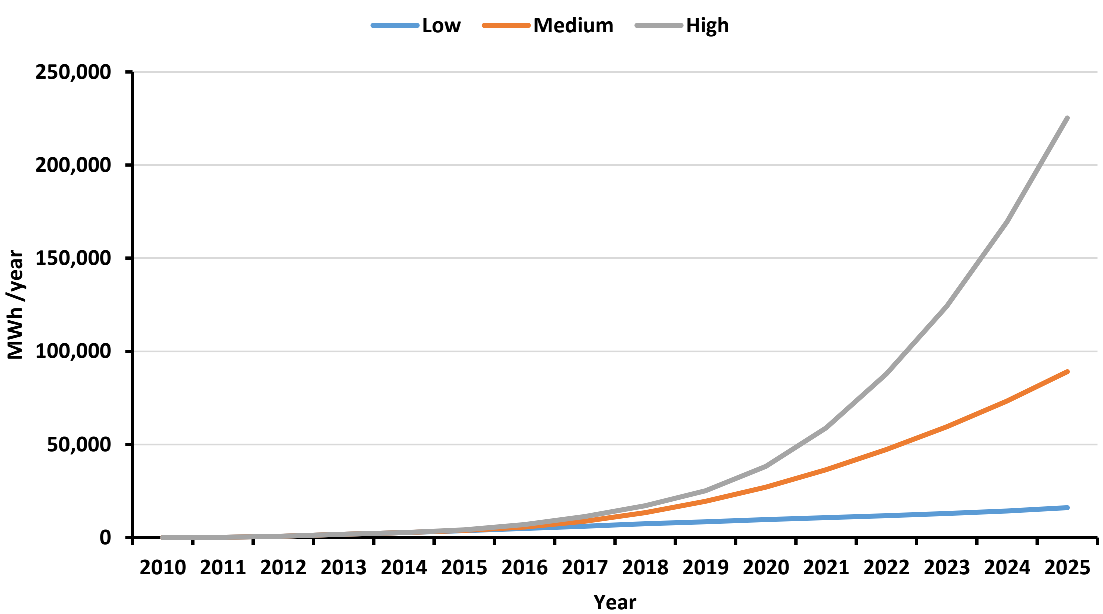

Figure 6
Simulated MWh/year based on different PEV adoption scenarios.

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.

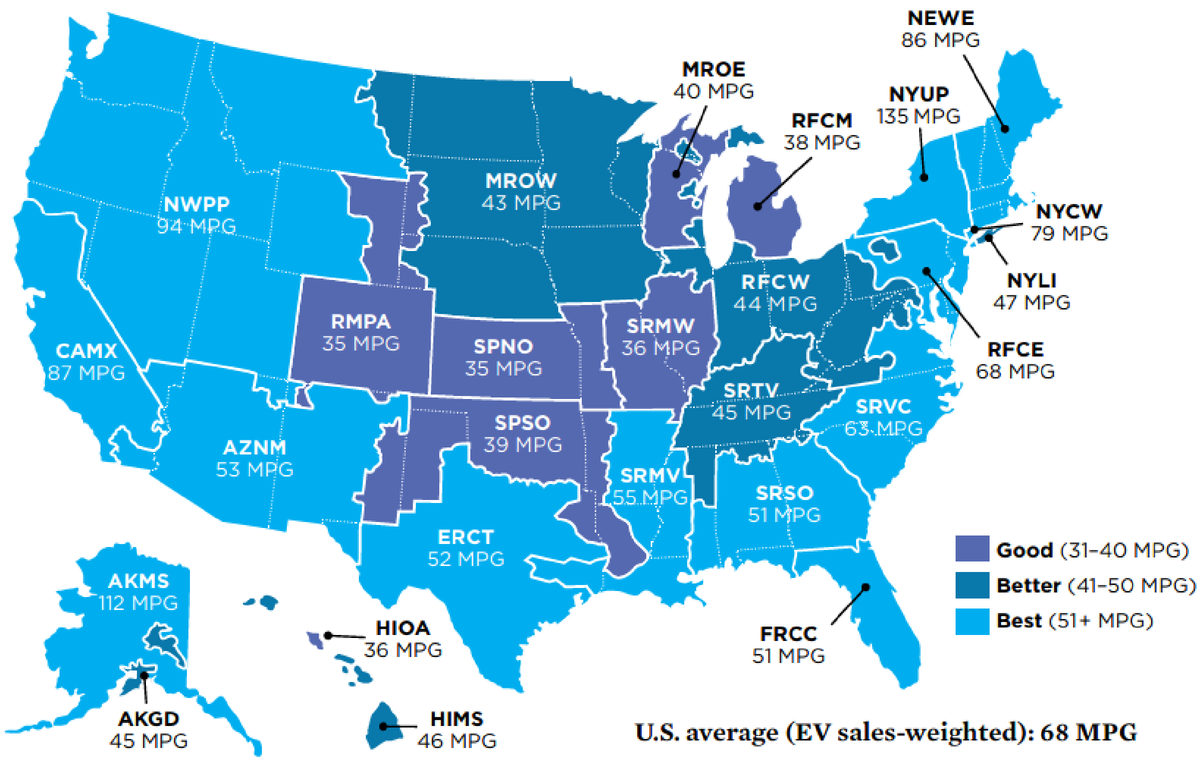

Figure 7
Equivalent fuel economy for a PEV in regions across the United States (from UCS, 2015[8])

[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

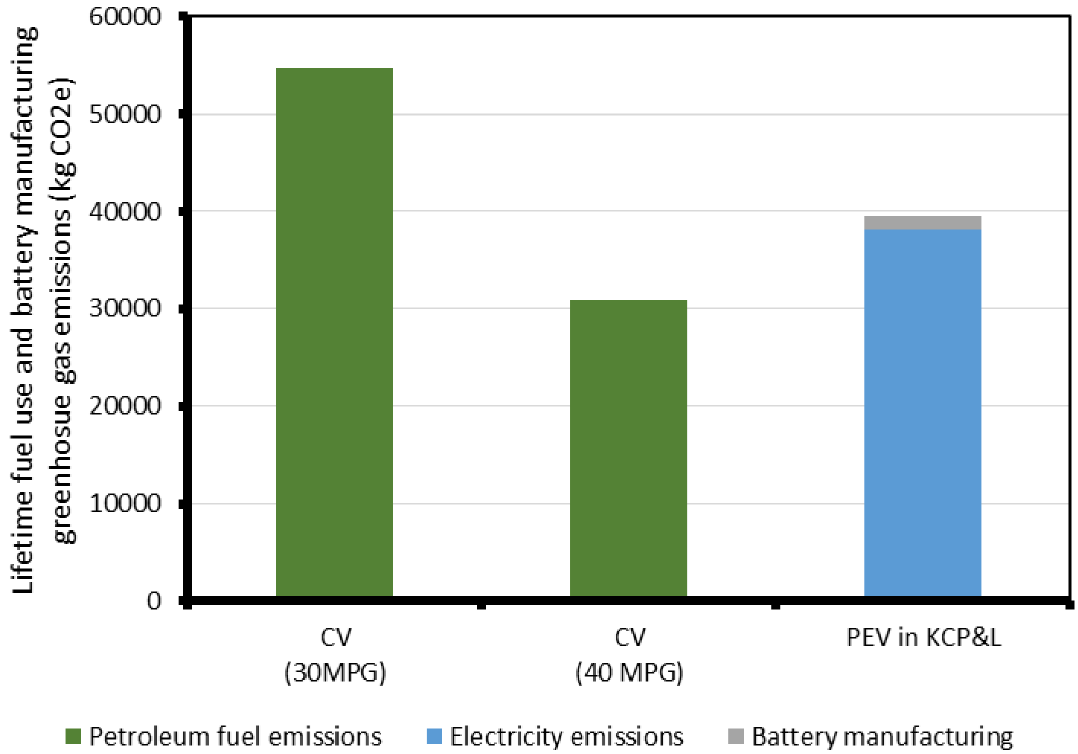

Figure 8
Comparison between emissions of conventional vehicles with fuel economies of 30 MPG and 40 MPG and plug-in electric vehicles with KCP&L's generation mix

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

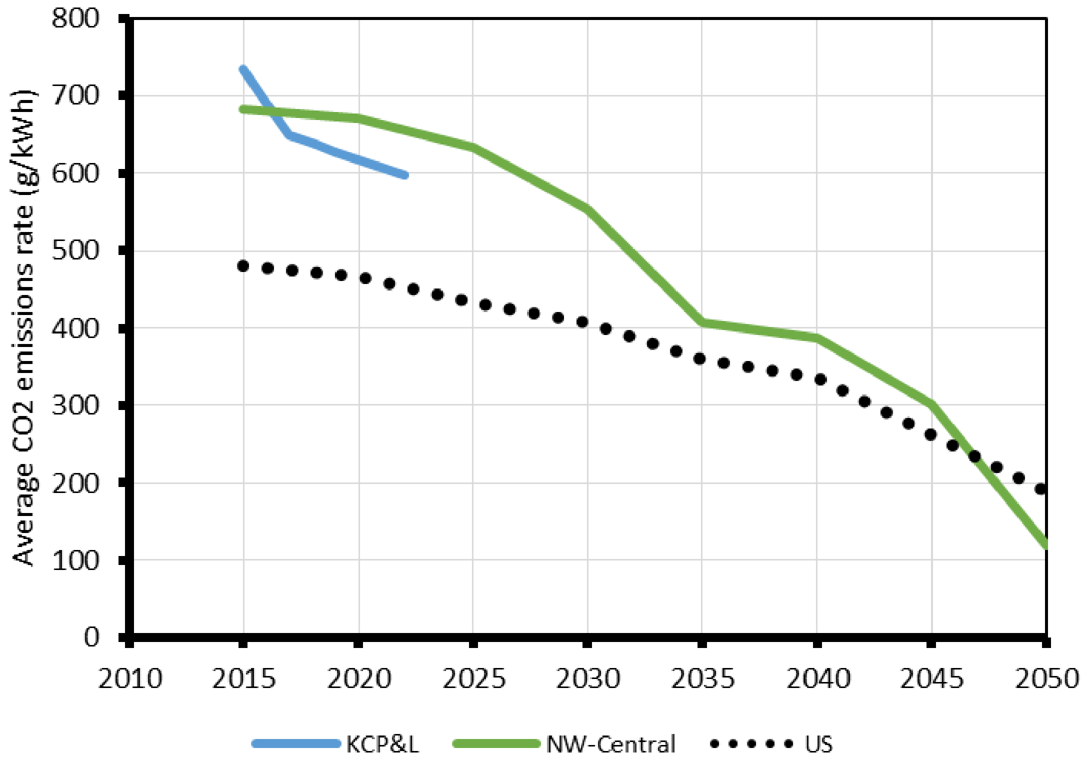

Figure 9
Emissions trajectory for the region enclosing KCP&L in EPRI (2015)

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

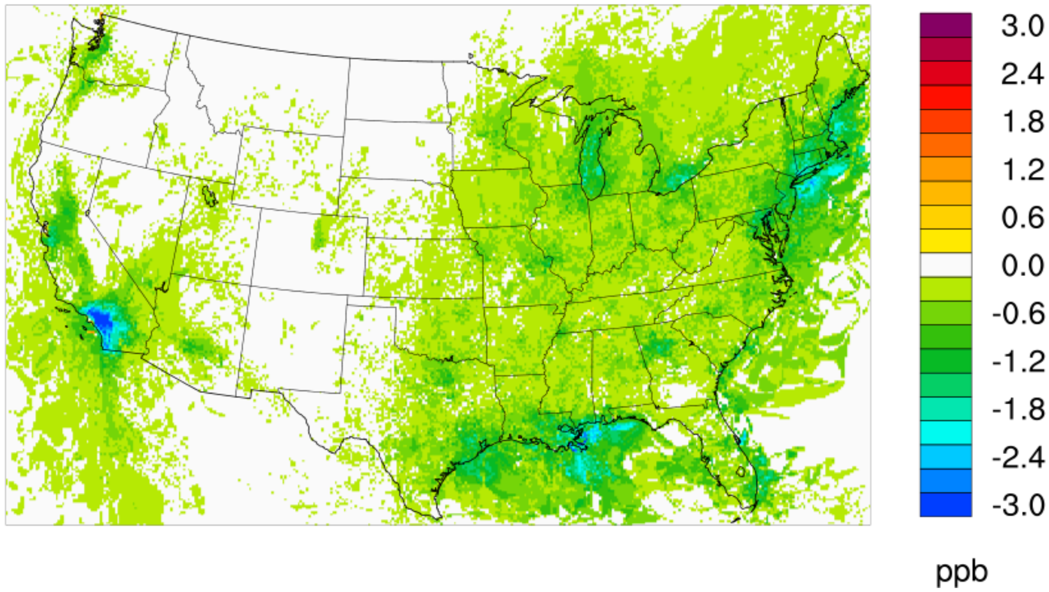

Figure 10
Change in projected 2030 ozone levels due to transportation electrification[14]

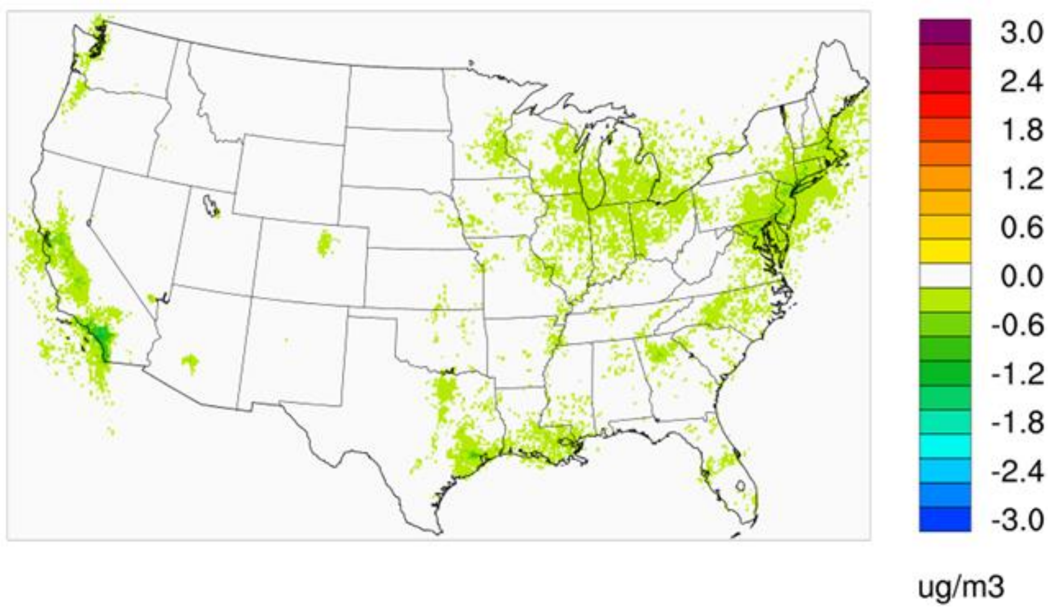

Figure 11
Change in projected 2030 PM2.5 levels due to transportation electrification[15]

[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 ($\mu g\ m^{-3}$) 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.

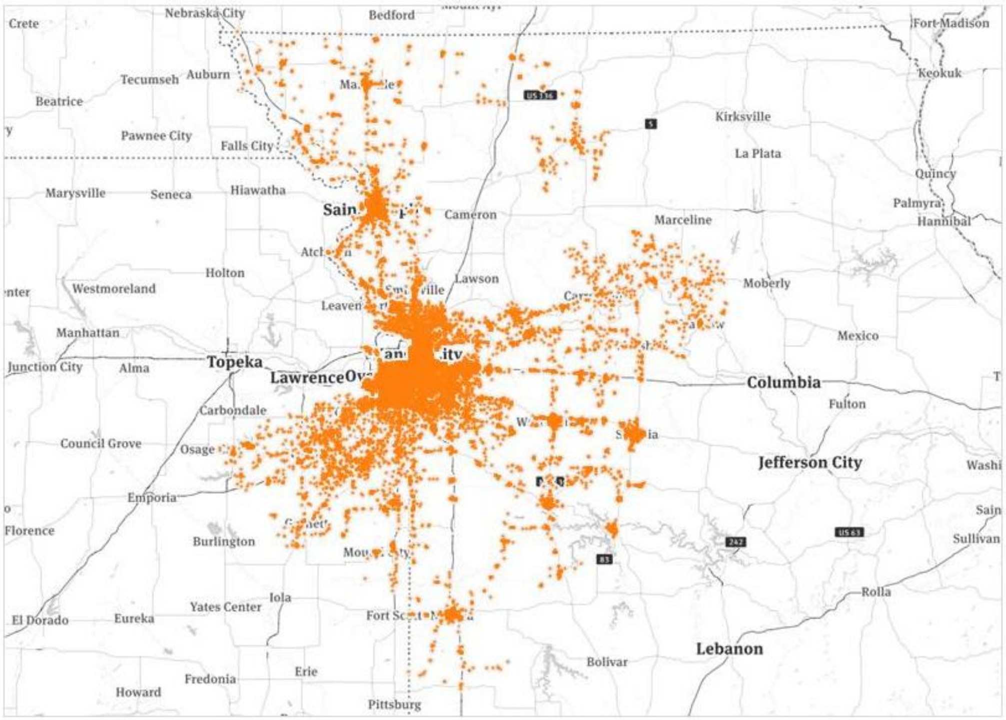

Figure 12
Location of commercial transformers in KCP&L's territory

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.

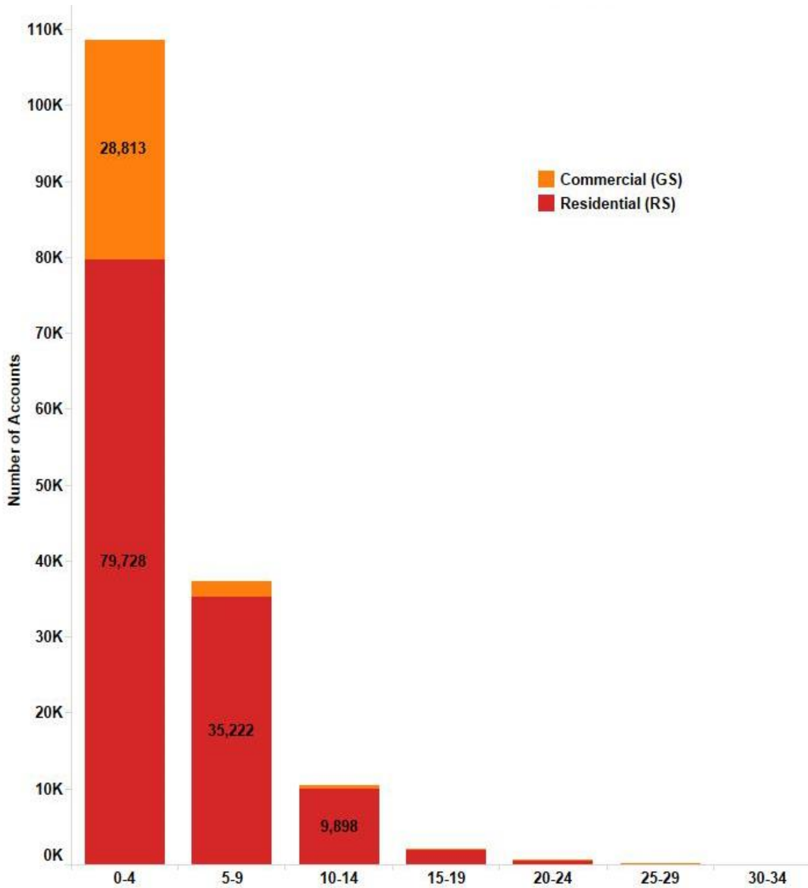

Figure 13
Histogram of the number of accounts on each transformer

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.

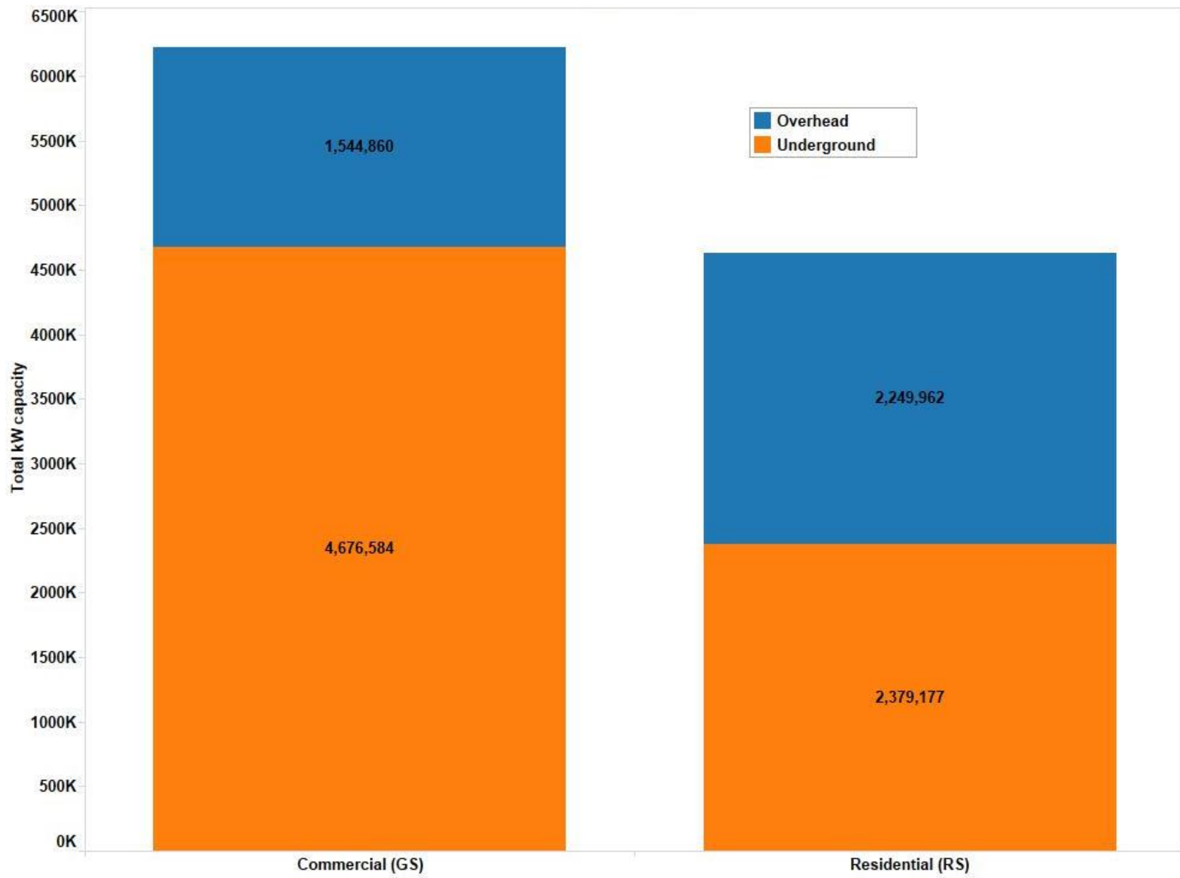

Figure 14
Total kW capacity broken down by transformer type and whether it is underground or overhead

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.

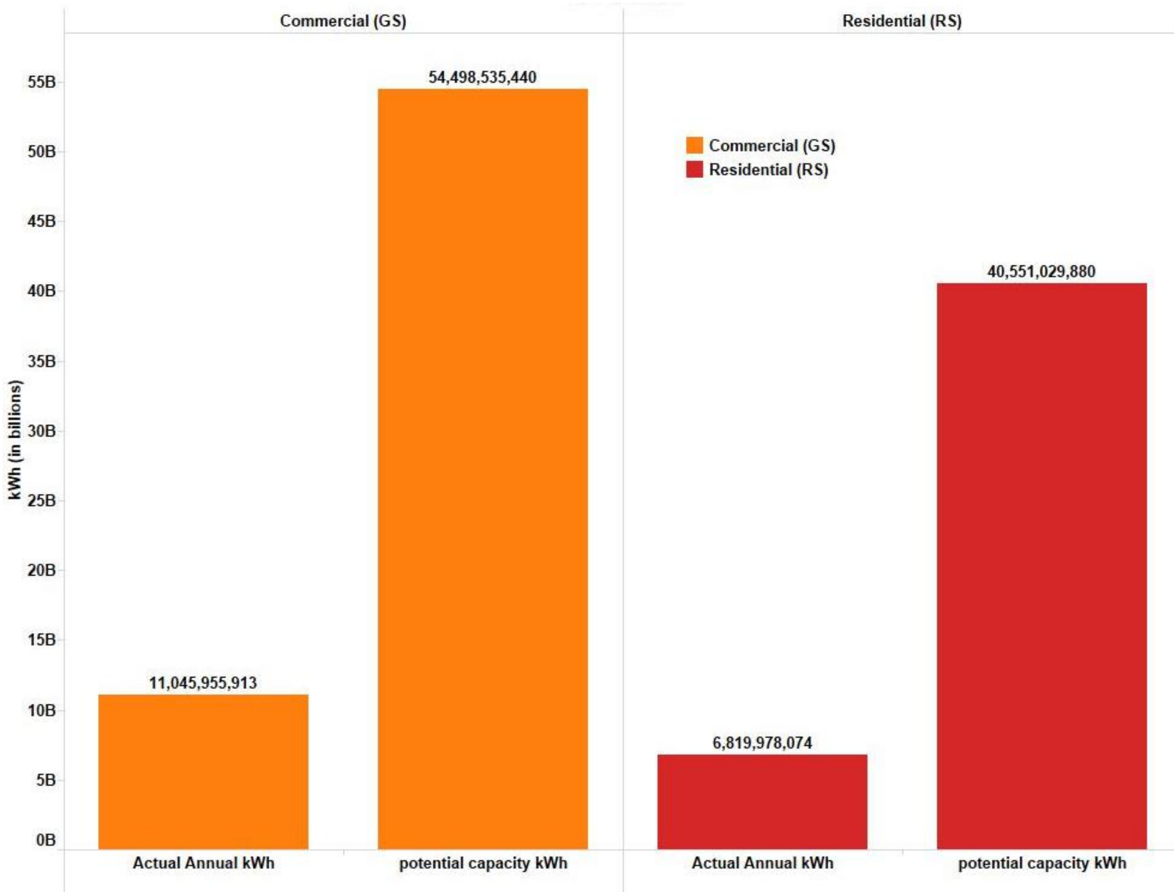

Figure 15
Comparison of actual annual kWh with potential kWh based on transformer nameplate rating

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.

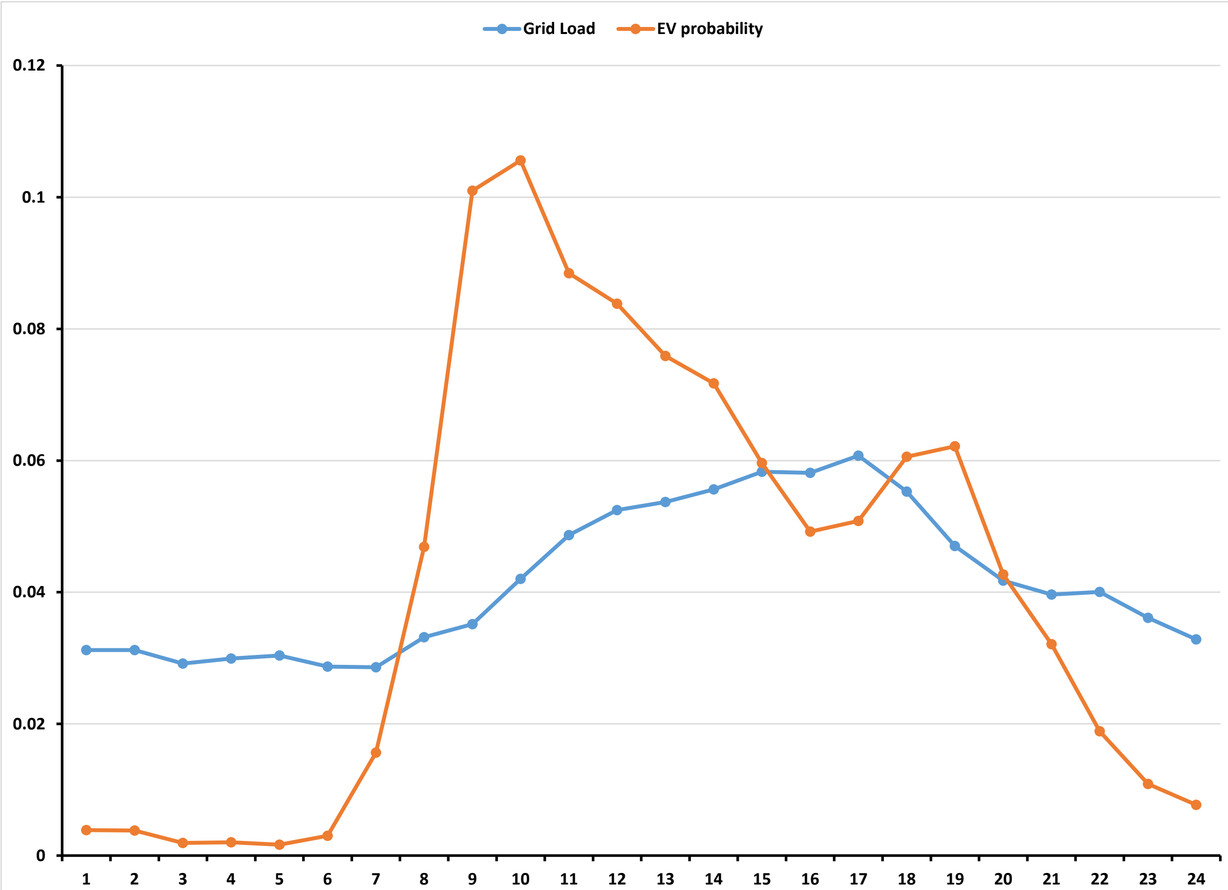

Figure 16
Probability of PEV load (from public charging stations) and normalized commercial (peak) load profile, both from KCP&L data

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.

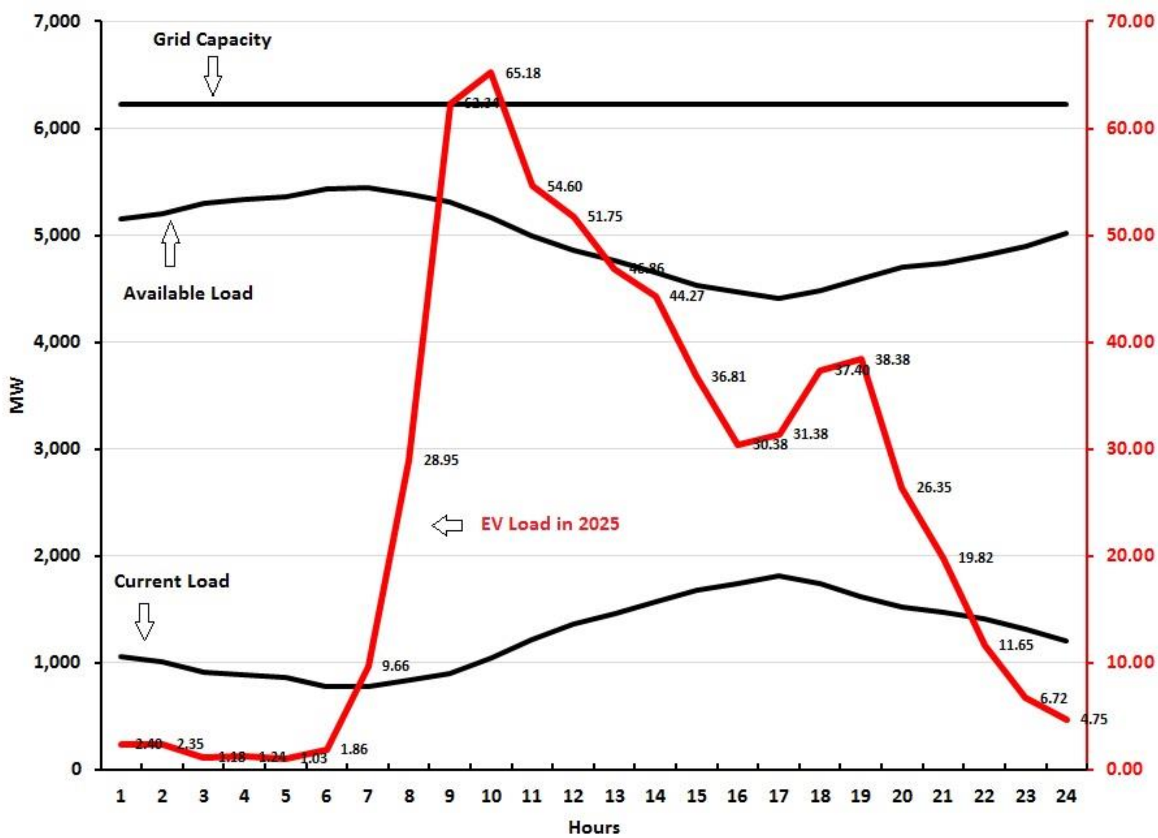

Figure 17
Daily MW estimates (black lines) for the general grid as well as for PEV demand (red line) for the High adoption scenario in 2025. Note that the two vertical axes have different scale; however, both are MW. The black lines are estimates for the 'current', 'available' and 'potential' loads currently 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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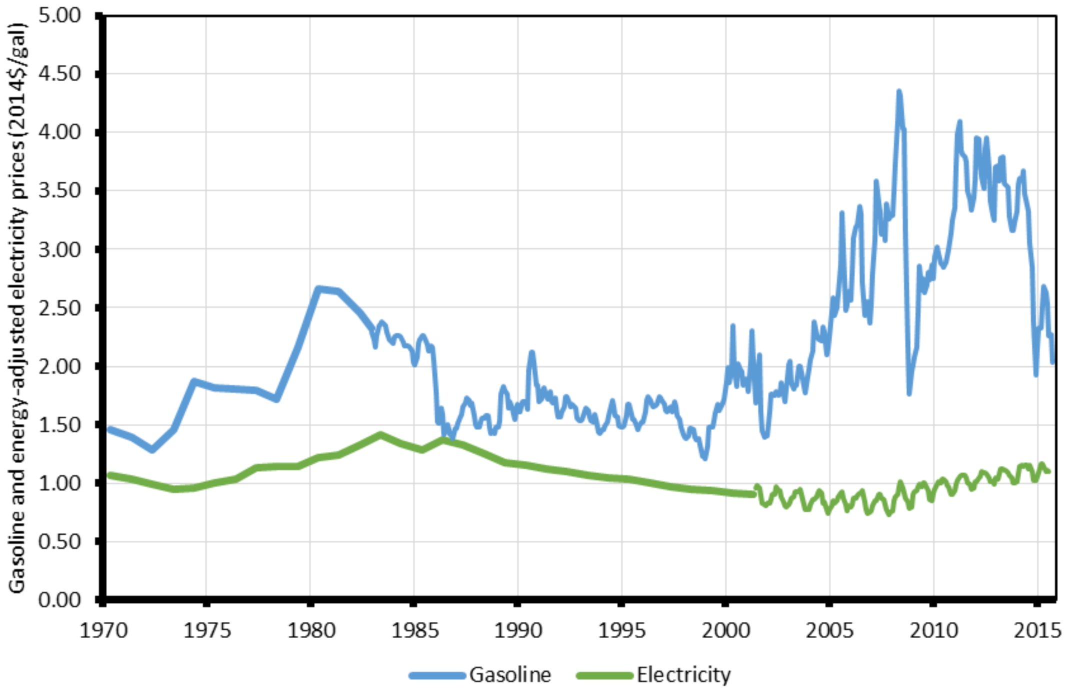
[16] https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001013781

[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.



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

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

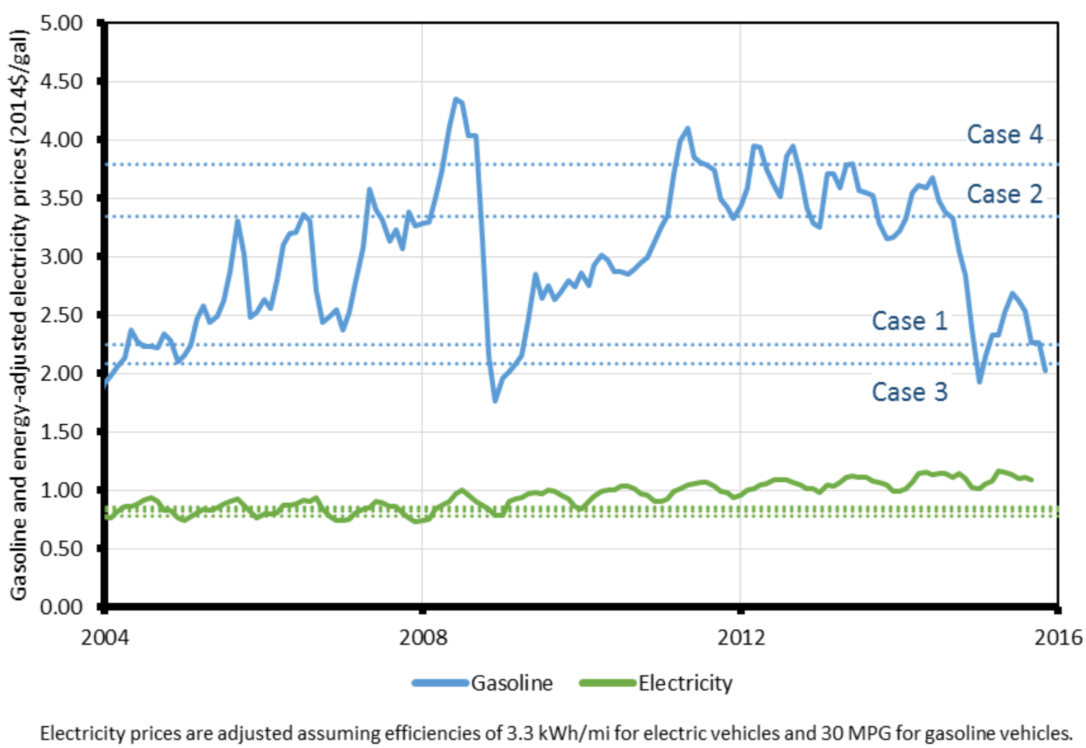


Figure 19
Analyzed energy prices compared to recent historical trends in Kansas

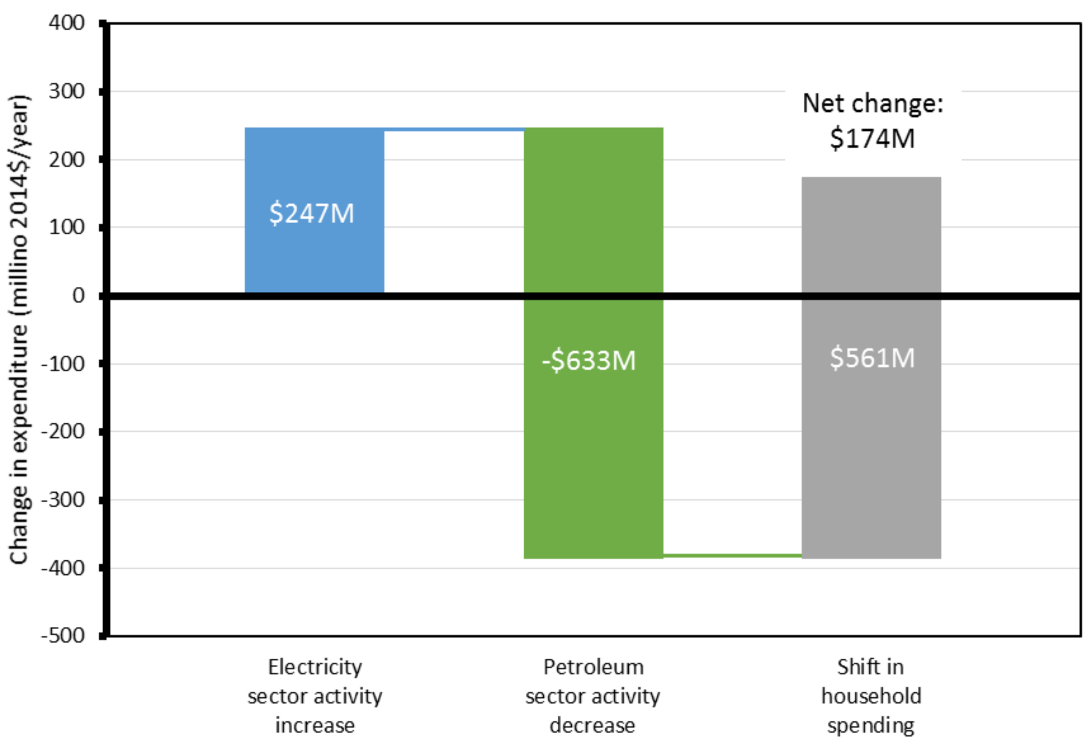
The RIO analysis shows the regional economic effects of the following two key parameters:

- 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

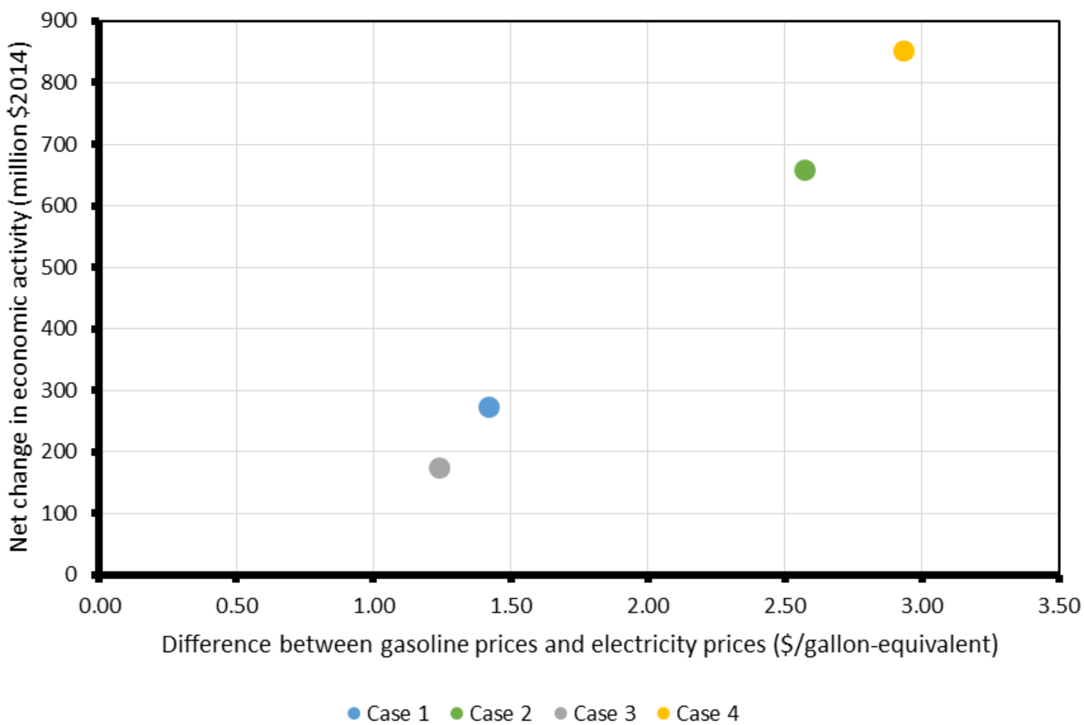


Figure 21
Change in economic activity compared to the price difference between gasoline and electricity

Schedule 1

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.

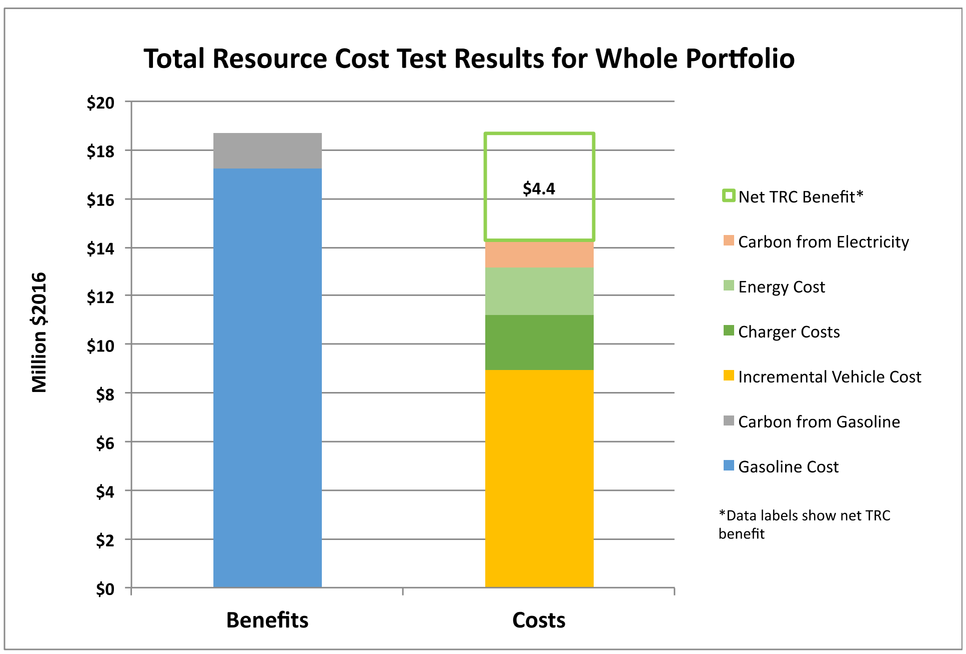


Figure 22
Case 0 Total Resource Cost Test Results (Million 2016$)

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.

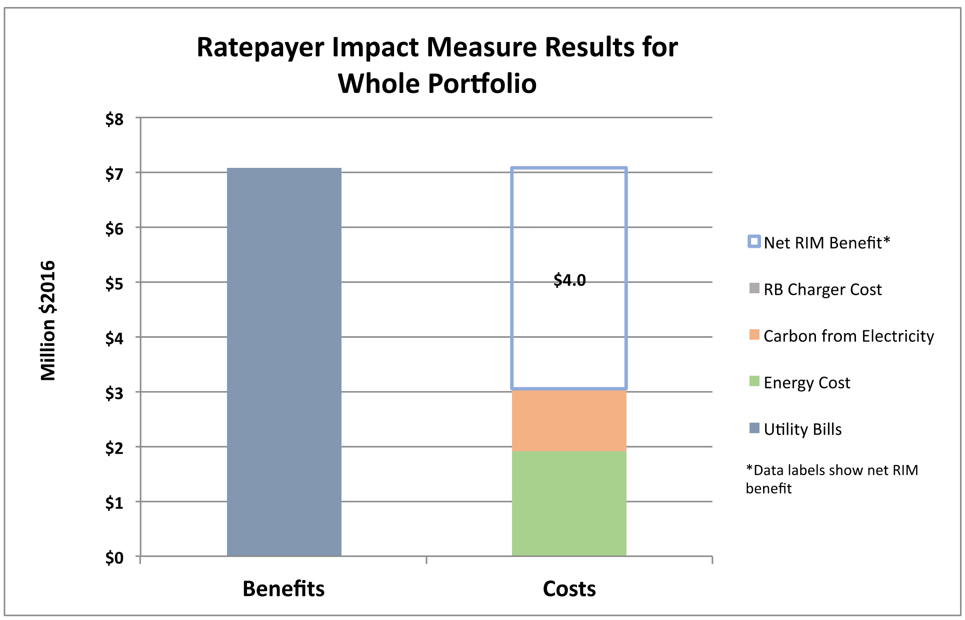


Figure 23
Case 0 Ratepayer Impact Measure Test Results (Million 2016$)

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.

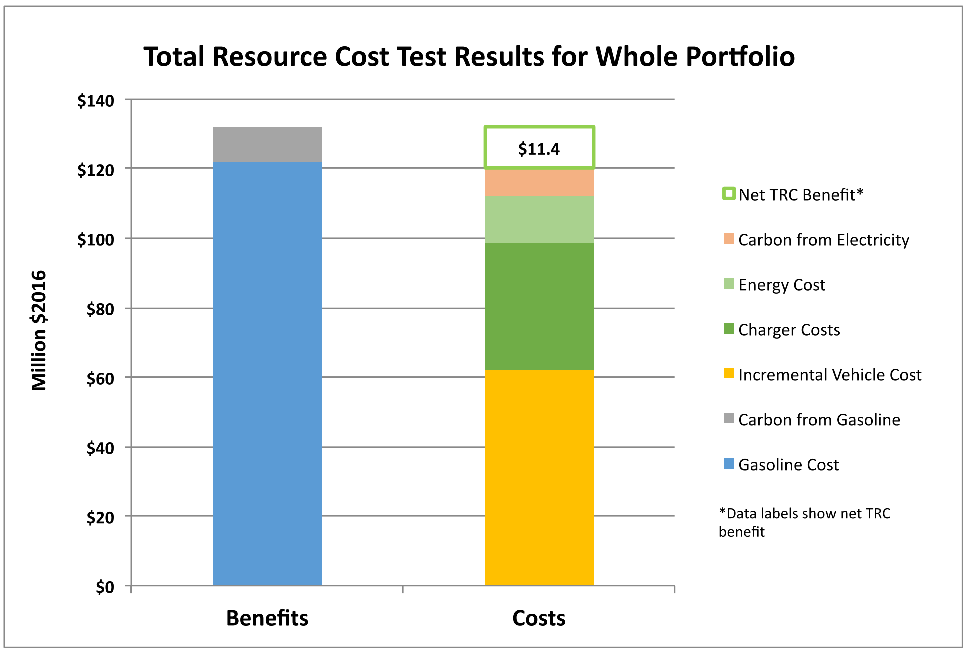


Figure 24
Case 2 Total Resource Cost Test Results (Million 2016$)

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.

Schedule 1

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.

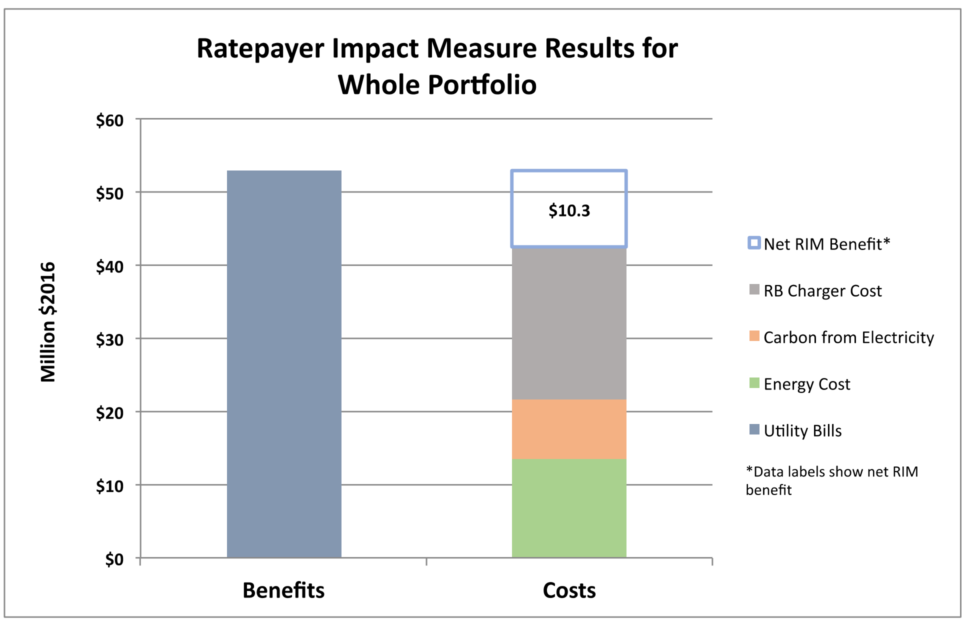


Figure 25
Case 2 Ratepayer Impact Measure Test Results (Million 2016$)

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.

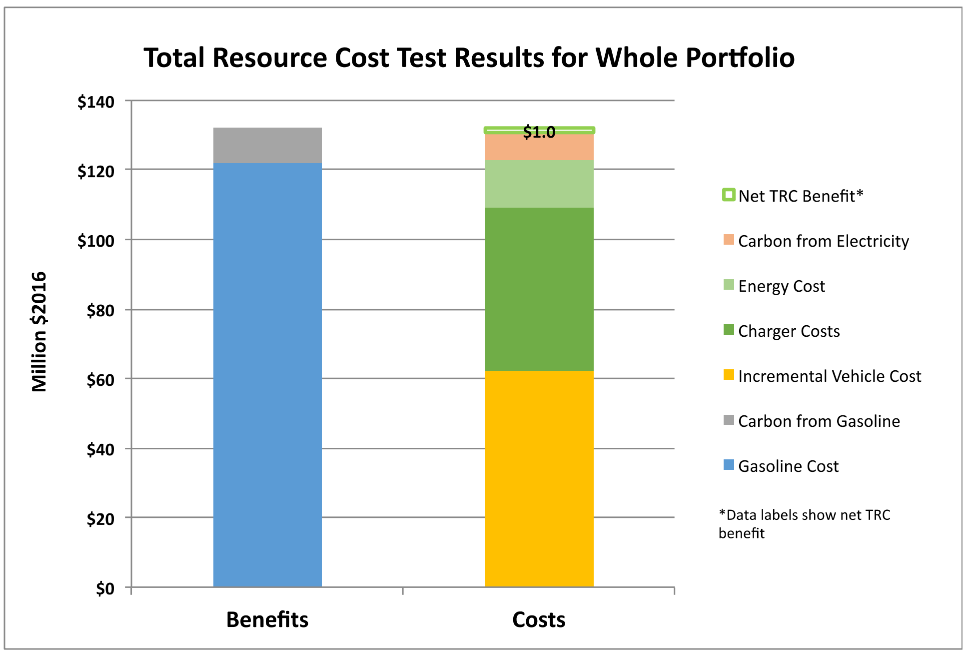


Figure 26
Case 5 Total Resource Cost Test Results (Million 2016$)

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.

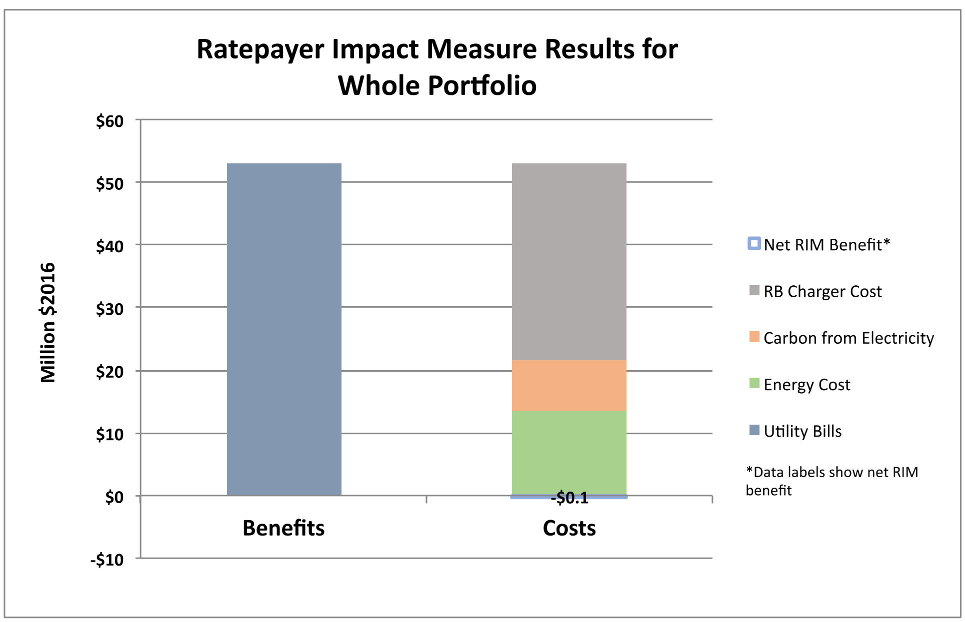


Figure 27
Case 5 Ratepayer Impact Measure Test Results (Million 2016$)

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.

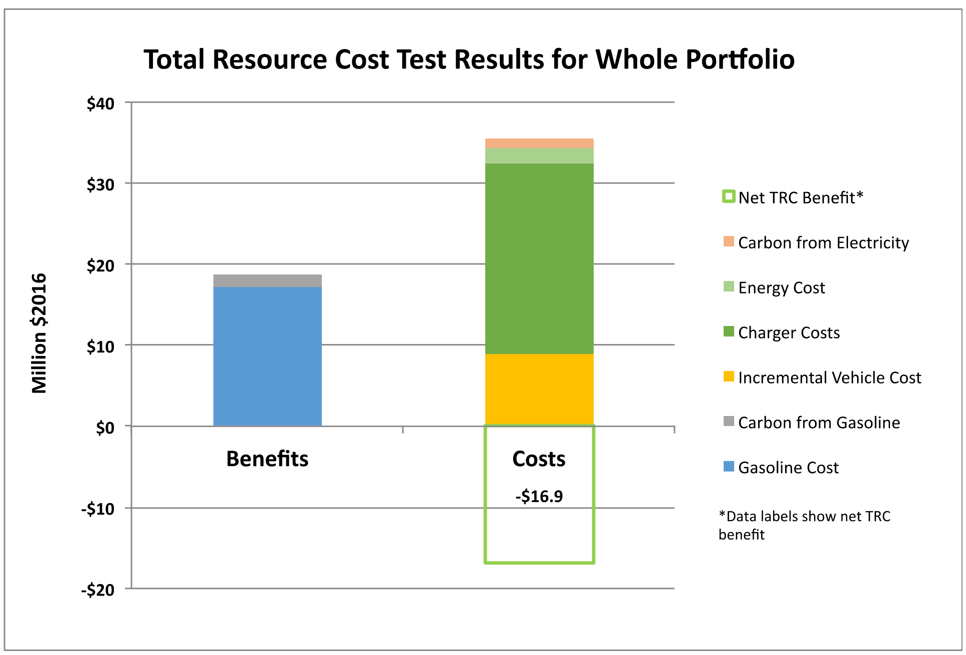


Figure 28
Case 1 Total Resource Cost Test Results (Million 2016$)

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.

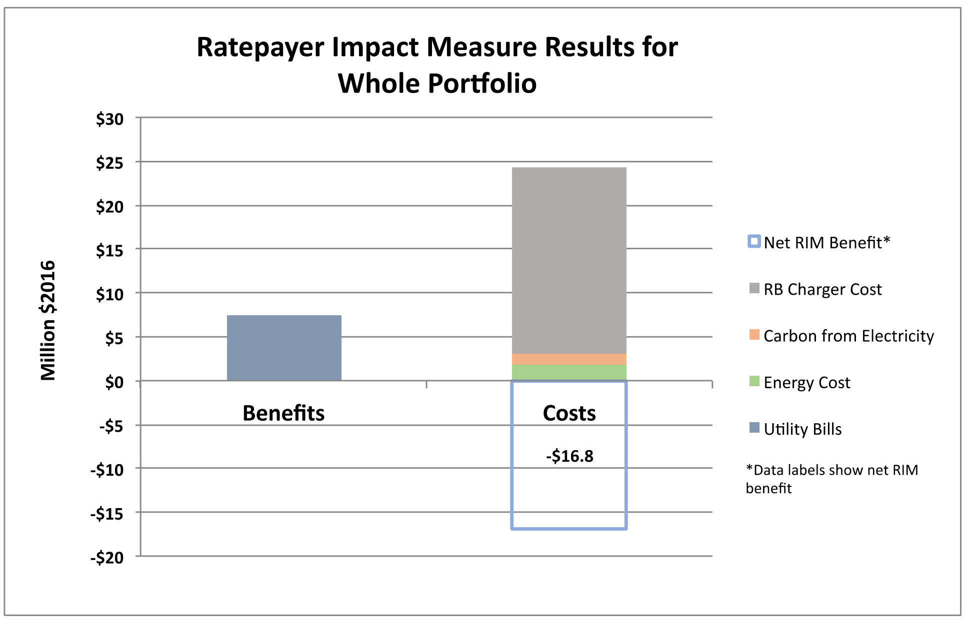


Figure 29
Case 1 Ratepayer Impact Measure Test Results (Million 2016$)

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.

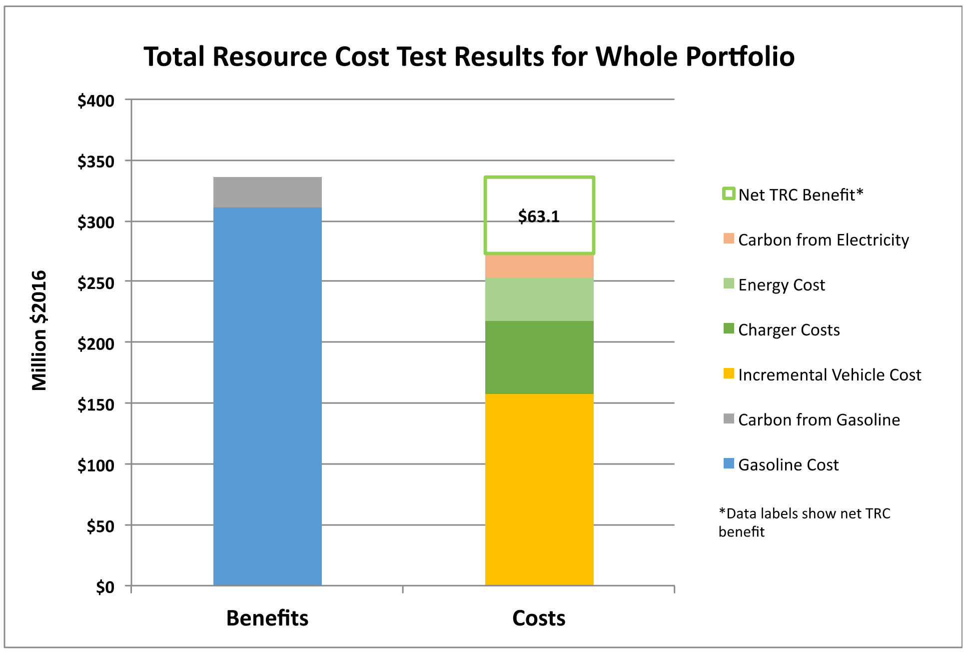


Figure 30
Case 3 Total Resource Cost Test Results (Million 2016$)

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

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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.

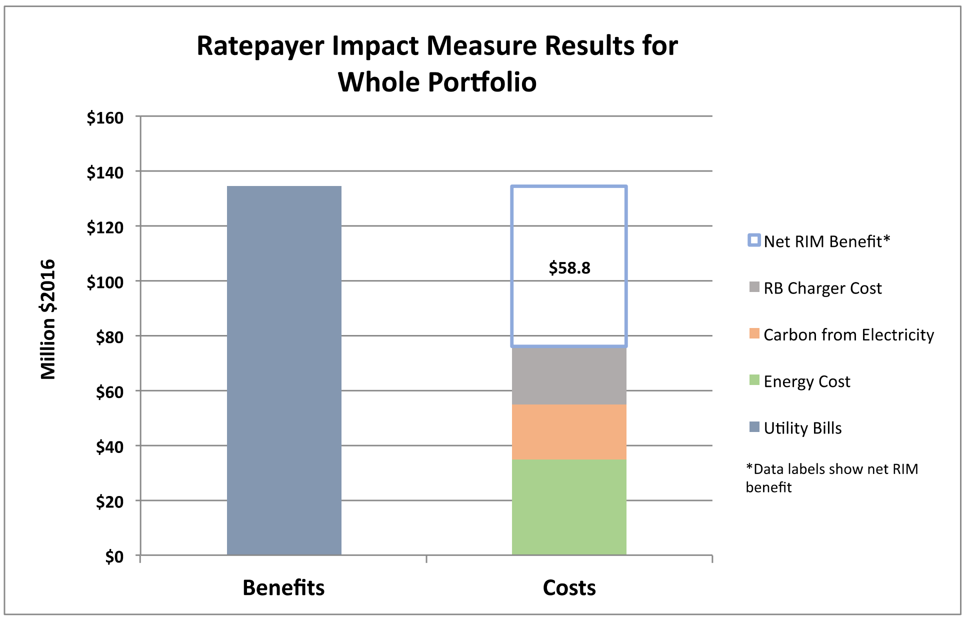

Figure 31
Case 3 Ratepayer Impact Measure Test Results (Million 2016$)

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.

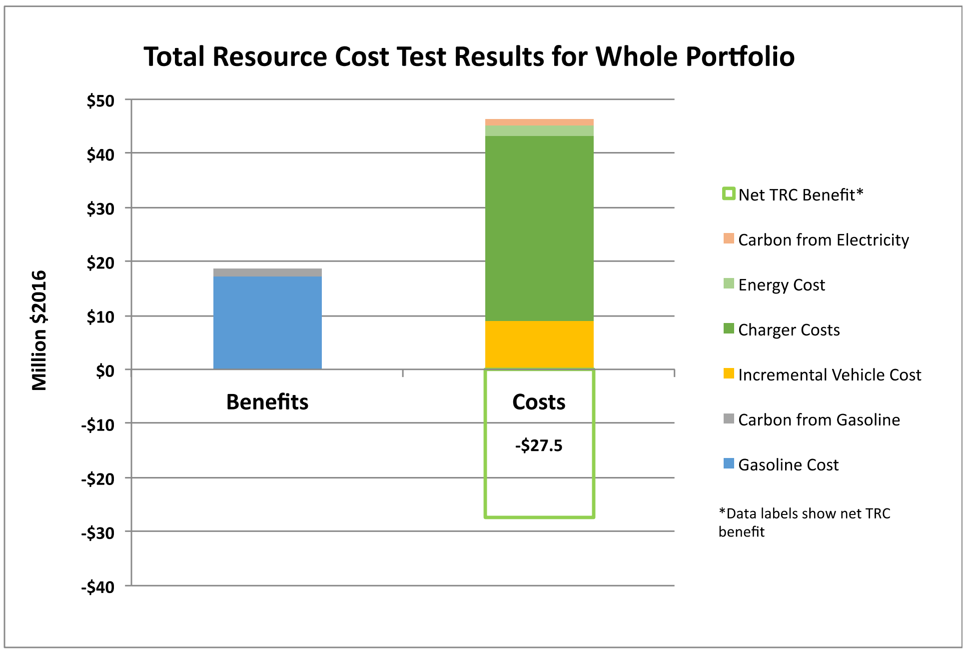

Figure 32
Case 4 Total Resource Cost Test Results (Million 2016$)

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.

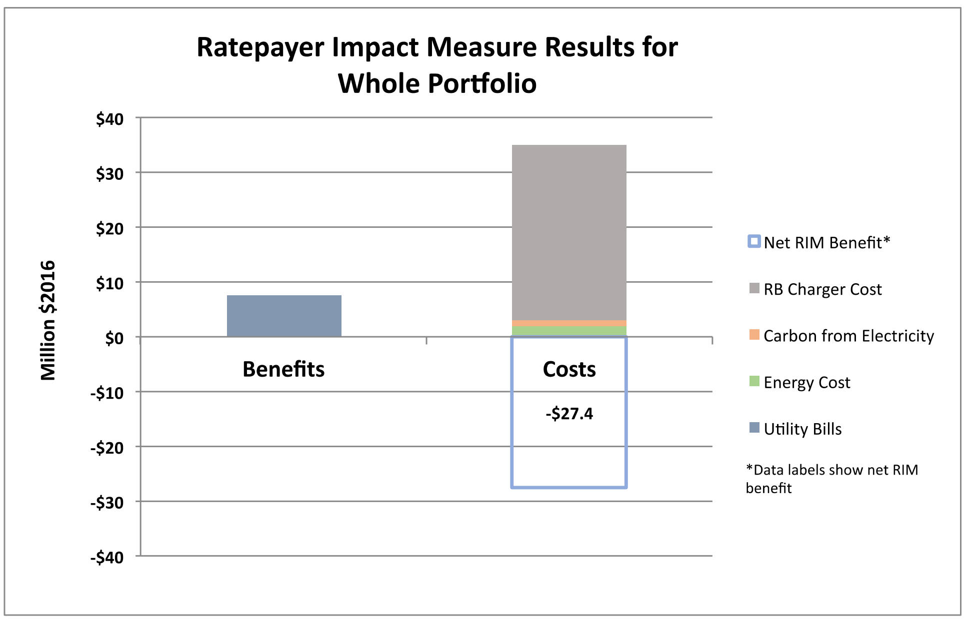

Figure 33
Case 4 Ratepayer Impact Measure Test Results (Million 2016$)

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.

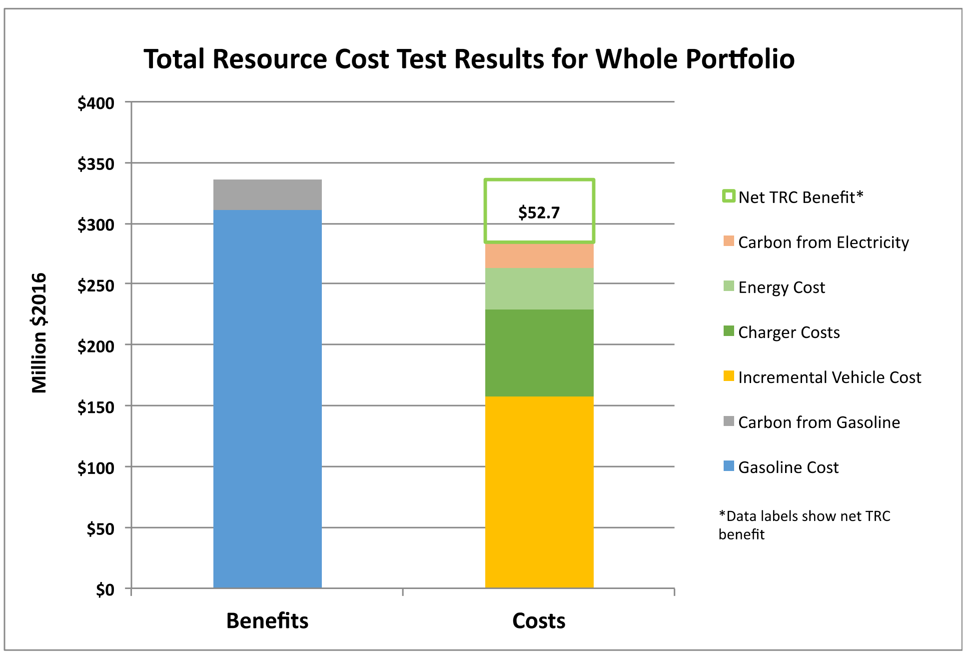

Figure 34
Case 6 Total Resource Cost Test Results (Million 2016$)

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.

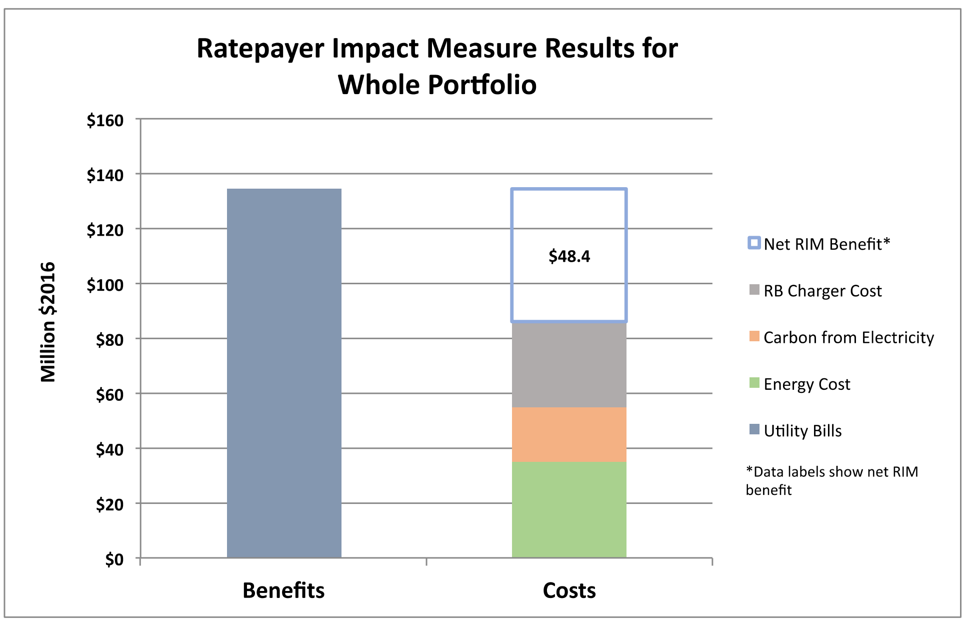

Figure 35
Case 6 Ratepayer Impact Measure Test Results (Million 2016$)

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.

WHITE PAPER

SEPTEMBER 2015

TRANSITION TO A GLOBAL ZERO-EMISSION VEHICLE FLEET: A COLLABORATIVE AGENDA FOR GOVERNMENTS

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Schedule 2

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EXECUTIVE SUMMARY

Governments around the world are implementing policies to promote electric vehicles to reduce oil consumption, climate-related emissions, and local air pollution and to stake out an industrial leadership position in the new advanced technology. Electric vehicle promotion efforts across the world are increasingly diverse, with many governments, automakers, and advocates pushing to promote awareness and sales of advanced electric-drive vehicles, as well as the necessary regulatory, charging infrastructure, and financial support. Yet there are key questions about which policy actions are working well, about how the various efforts around the world compare, and about whether best policy practices to promote electric vehicles are emerging.

This report synthesizes recent information on global electric vehicle activity to help scope out an agenda for increased collaboration among governments around the world to promote the transition to a zero-emission vehicle fleet. Although the report emphasizes plug-in electric vehicles, the transition to a zero-emission vehicle fleet will also include hydrogen fuel cell electric vehicles. The report summarizes global adoption trends and national targets, as well as major electric vehicle promotion policies (e.g., consumer incentives and charging infrastructure support) for select markets around the world. In addition, the report summarizes research to date on the effectiveness of various electric vehicle promotions to investigate emerging best practices on electric vehicle policy. Building from these areas, and intergovernmental efforts to date, the report points toward an agenda for increased international cooperation and joint research to accelerate electric vehicle deployment.

Global electric vehicle sales are increasing, especially in particular regions. Figure ES-1 summarizes electric vehicle sales by major automobile market. Global annual electric vehicle sales reached approximately 100,000 in 2012, 200,000 in 2013, and 300,000 in 2014. As indicated in the figure, the electric vehicle sales growth in the United States was greater in 2012 and 2013, whereas sales growth in China and Europe was greater in 2014. Within Europe, the leading markets by sales volume are France, Germany, the Netherlands, Norway, and the United Kingdom. Based on this assessment, these regions — China, Europe, Japan, and the United States — differ in the electric vehicle promotion actions they implement, their policy incentives and infrastructure, and the electric vehicle deployment patterns they see.

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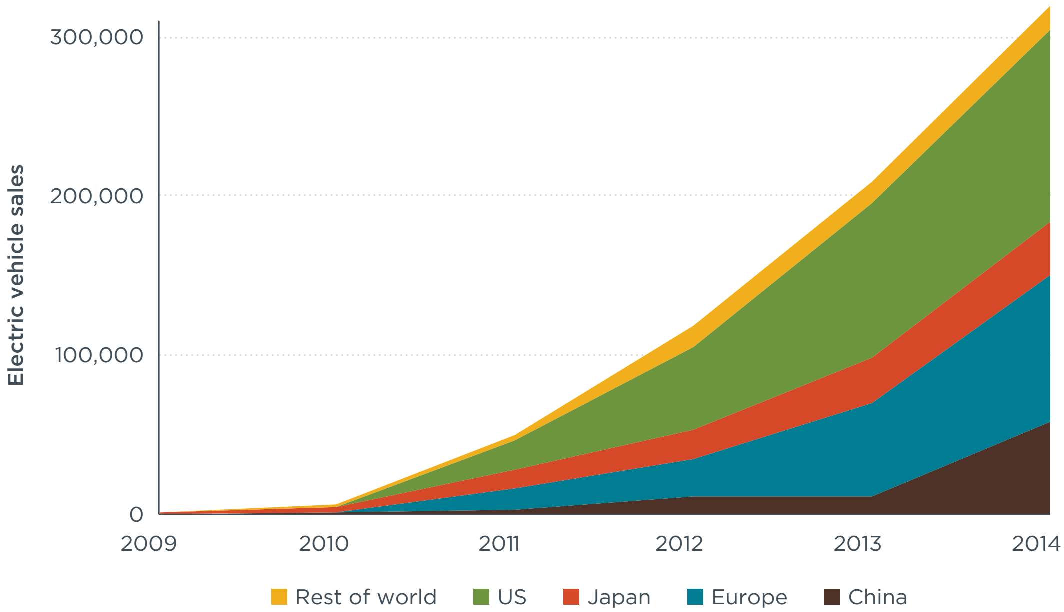

Figure ES-1. Annual global electric vehicle sales

Based on this report's findings, we draw the following three conclusions:

Policy action by leading governments is spurring electric vehicle deployment. The most comprehensive electric vehicle promotion actions globally are in Norway, the Netherlands, and California, and these actions are resulting in electric vehicle deployment that is more than 10 times the average international electric vehicle uptake. More broadly, the actions of the governments of China, France, Germany, Japan, the Netherlands, Norway, the United Kingdom, and the United States are leading with policy incentives and infrastructure investments, and these countries make up over 90% of the world's electric vehicle market.

Best practices in electric vehicle promotion policies are emerging. From the early electric vehicle promotion activity, best practices to accelerate electric vehicle deployment are beginning to emerge. Increasingly stringent efficiency standards, electric vehicle research and development support, and national electric vehicle planning appear to be necessary but insufficient actions to grow the electric vehicle market. Consumer incentives that reduce the cost of ownership are important to improve the consumer proposition on the new advanced electric technologies. Increasing the availability of home, workplace, and public electric charging infrastructure is also of high importance, and several leading automobile markets (e.g., Japan, Norway, and parts of the United States) have far more extensive charging infrastructure per capita than others. It is becoming increasingly clear that a comprehensive portfolio of national, state, and local actions is critical for the increased deployment and use of electric vehicles.

Greater international collaboration could better leverage existing efforts to promote zero-emission vehicles. This assessment points to several possible ways that governments can better collaborate and coordinate. The establishment of a zero-emission vehicle deployment target (e.g., 35% of automobile sales being zero-emission vehicles and 30 million annual global zero-emission vehicle sales) and an electric mobility target (e.g., at least 15% of vehicle use being electric) for

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2035 would help in establishing a common long-term global electric-drive vision. Such goals would send clear signals about the pace of development and amount of resources that will be needed. Further coordinated research on policy effectiveness would help prioritize government actions that are most important in increasing zero-emission vehicle uptake and use.

The transition of the automobile sector to electric drive will require not only sustained policy incentives but also increased communications about progress and policy learning. In these early years in the transition, there is much to learn from every region's experience in the rollout of zero-emission vehicles. Developing the new zero-emission vehicle market will require global scale, in the tens of millions of vehicles, to achieve lower cost and long-term success. Automakers are learning from their first- and second-generation electric vehicles and increasingly developing global electric vehicle platforms and launching them in multiple markets. Similarly, governments ideally will have to continue to learn from initial policy experiences and embrace common international best policy practices in many markets across the globe. International collaboration will be a critical step toward greater volume and a long-term market transformation to a zero-emission vehicle fleet.

Schedule 2

I. INTRODUCTION

Governments around the world are implementing policies to promote electric vehicles to reduce oil consumption, reduce climate-related emissions, reduce local air pollution, and stake out an industrial leadership position in the new advanced technology. Efforts across the world are increasingly diverse, with many governments, automakers, and advocates pushing to promote awareness and sales of advanced electric-drive vehicles, as well as the necessary regulatory, charging infrastructure, and financial support. From the early electric vehicle promotion policy actions, best practices to accelerate electric vehicle deployment are beginning to emerge.

Many nations are looking to become the leading markets for electric-drive technology. Based on several vehicle market statistics, illustrated in Figure 1, electric-drive technology might be most likely to develop in several particular regions. Just five regions, China, Europe, Japan, South Korea, and the United States, dominate the world automobile market, making up 75% of world vehicle sales and 76% of world vehicle manufacturing (OICA, 2015a, b). Further, these five vehicle markets are the epicenter of most research and development, engineering, design, and investment decisions related to the launch of new vehicle technologies. Of the 50 largest vehicle manufacturers, 43 manufacturers that represent 97% of global vehicle sales are headquartered in these five regions (OICA, 2014). Looking to both make and sell the new technologies, these five regions have the greatest interest and opportunity in developing and growing the electric vehicle market.

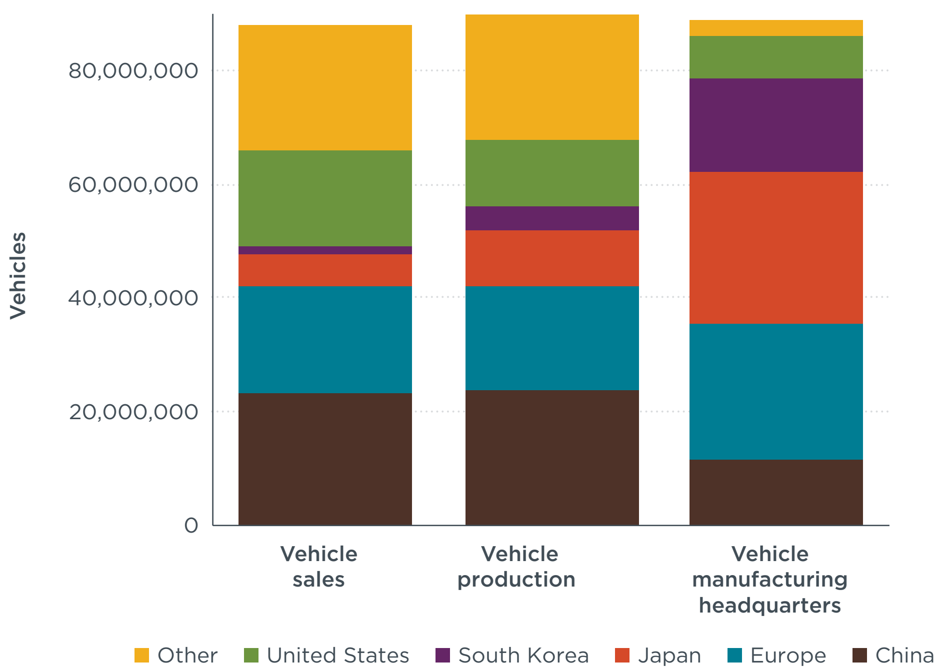

Figure 1. World vehicle sales, production, and manufacturing headquarters in 2014 by major region

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However, it is too early to tell which markets will lead in a shift to an electric vehicle fleet. The electric vehicle market, in 2015, is in its nascent stage. Electric vehicle sales in 2014 amounted to more than 300,000 vehicles, less than 0.5% of the annual global sales of approximately 68 million passenger cars (and 88 million total vehicles) per year (OICA, 2015b). However, there are pockets within the five major automobile markets, and several vehicle manufacturing companies, that are demonstrating electric vehicle leadership. Every major automaker is launching new plug-in electric vehicle models annually, electric vehicle sales continue to increase, and several companies in particular are beginning to show early leadership. Moreover, the markets of Norway, the Netherlands, and California are illustrating how policy leadership can increase electric vehicle sales shares by an order of magnitude higher than the global average adoption rate even while the technology has limitations in terms of its relatively high cost, low consumer awareness, limited public charging infrastructure, and only modest model availability.

The primary objective of this report is to help scope out an agenda for improved global collaboration among leading governments that are seeking to accelerate the shift to zero-emission vehicles. This report builds on previous regional and national work to synthesize the existing body of knowledge on government cooperation, results to date, and potential gaps in the interest of furthering the understanding and growth of a global electric vehicle industry. The report is organized as follows.

» **Section I** summarizes global adoption trends, targets, future projections, benefits, and barriers for electric vehicles.

» **Section II** summarizes major electric vehicle promotion policies around the world.

» **Section III** reports on research findings to date on the effectiveness of various electric vehicle promotion policies and distills a research agenda for international cooperation and research to promote electric vehicle deployment.

» **Section IV** provides a final summary discussion related to global goals and collaboration to promote the transition to a global fleet of zero-emission vehicles.

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ELECTRIC VEHICLE ADOPTION, PROJECTIONS, AND GOALS

Since 2009, the early electric vehicle market has shown steady growth globally. Figure 2 depicts approximate electric vehicle sales growth from 2009 through 2014, highlighting four major regions' electric vehicle sales based on Mock & Yang (2014) and EV Sales (2015). This increasing global trend for electric vehicles represents more than a 90% annual average sales growth over the 2011-2014 period.

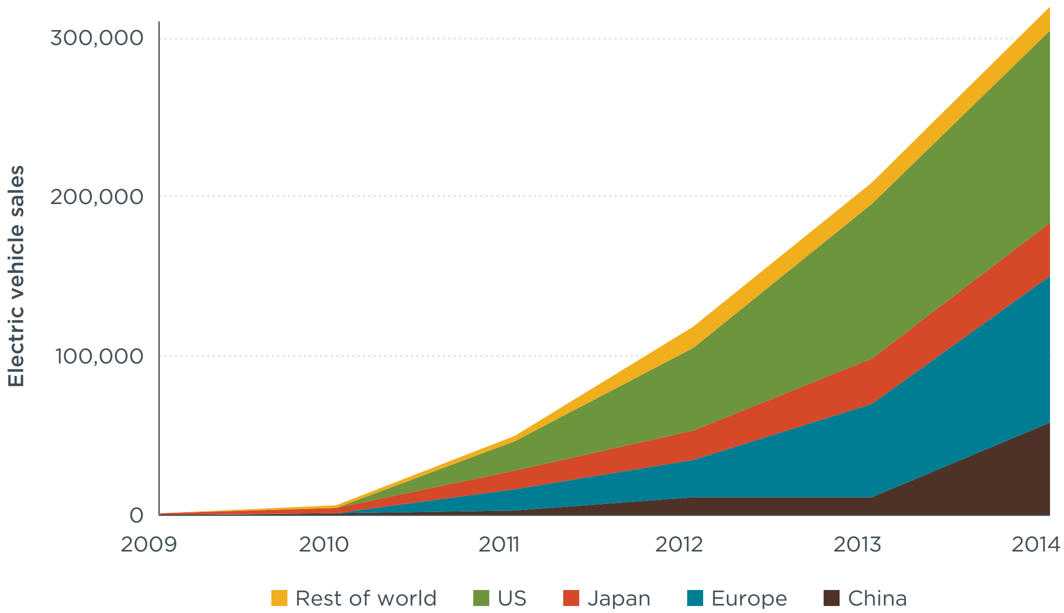

Figure 2. Annual global electric vehicle sales

Overall, this trend has resulted in global cumulative electric vehicle sales of 50,000 in 2011, more than 150,000 in 2012, more than 350,000 in 2013, and more than 700,000 in 2014. As shown in the figure, the 2014 electric vehicle sales are dominated by four major regions, with approximately 17% in China, 29% in Europe, 10% in Japan, and 37% in the United States. The figure also shows that electric vehicle sales growth in the United States was greater in 2012 and 2013, whereas sales growth in China and Europe was greater in 2014.

For further background on the current state of the industry, the global sales of electric vehicles by manufacturer are depicted in Figure 3. The figure shows the 15 highest selling electric vehicle manufacturers and their sales in the four major regions. Based on best available data (EV Sales, 2015; Hybridcars, 2015; evobsession.com, 2015), these 15 companies represent 96% of global electric vehicle sales, and each sold at least 2,000 electric vehicles in 2014. In particular, companies like Renault-Nissan (26% of world 2014 electric vehicle market), Mitsubishi (12%), and Tesla (10%) are especially showing market development, each with plug-in electric vehicle sales of more than 30,000 per year and launches in multiple regions (EV Sales, 2015). General Motors, Ford, and Toyota are next, with 6%-8% each of global electric vehicle sales, mostly from sales of plug-in hybrid electric vehicles (PHEV) in the U.S. market. After the top six, five of the next eight companies, led by BYD, are focused almost exclusively on the China market. Not shown in the figure are 10 major companies that are top-20 overall global auto manufacturers — Hyundai, Fiat-Chrysler, Honda, Suzuki, Peugeot Citroën, SAIC, Mazda, Dongfeng, Changan, and Tata — each of which had fewer than 2,000 global electric vehicle sales in 2014.

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Although the electric vehicle growth is small in comparison to the overall automobile market that is dominated by gasoline and diesel vehicles, there are many reasons that governments will persist in what could be a decades-long transition to a predominantly electric-drive vehicle fleet. Any rigorous transportation planning exercise leads to the basic finding that climate change stabilization goals (e.g., 450-ppm, 2°C increase) will require a large-scale shift from the internal combustion of petroleum fuels to electric-drive (e.g., see IEA, 2012; Deetman et al., 2013; Greenblatt, 2015; Williams et al., 2011). Studies imply that electric-drive vehicles powered by ultra-low carbon electricity or hydrogen will be needed, as efficiency standards and attempts at curbing transport activity and availability of sustainable low-carbon biofuels will likely not be sufficient if the transportation sector is to meet its global carbon reduction goals.

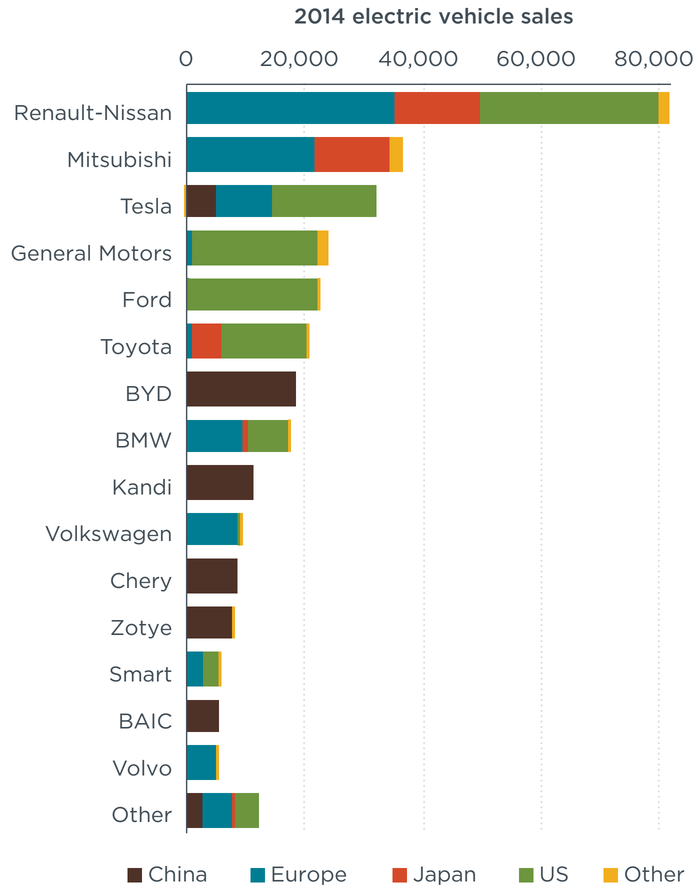

Figure 3. Highest-selling electric vehicle manufacturers and regions where electric vehicles were sold

Many studies have, in turn, sought to model and project the deployment of electric vehicle sales under various market and policy conditions. The projections, forecasts, and scenario analyses on future electric vehicle deployment are too numerous to discuss. Figure 3**.** shows there were more than 300,000 electric vehicle sales in 2014, or about 0.3% of overall global vehicle sales, and about 0.5% of global car sales, excluding commercial heavy-duty vehicles. From the many analyses and projections, the potential increase in electric vehicle sales could vary greatly, depending on region as well as policy drivers, technology progress, market conditions, and other factors.

Figure 4 summarizes projections from numerous studies that analyzed future electric vehicle deployment[1]. In the figure, as well as throughout this report, electric vehicles or "zero-emission vehicles" include the three major technology types — plug-in hybrid, full-battery electric, and hydrogen fuel cell. Several studies (e.g., NRC, 2013b) indicate that fuel cell electric vehicle technology might have greater potential in the long term 2050 contest. However, most of the recent trends and data on electric vehicles are more exclusively focused on plug-in electric vehicles, due to their increased availability, marketing, and sales in recent years. Generally studies that assumed greater technical

1 BCG, 2011; Berhart, Kleimann & Hoffmann, 2011; Bharat Book, 2014; CARB, 2011; Dunne, 2013; Element Energy, 2013; ETS Insights, 2014; Greene et al., 2013, 2014 ; IEA, 2011; IEA, 2013b; Malins et al., 2015; McKinsey, 2014; Navigant, 2013, 2014; NRC, 2013.

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advancement, such as in battery technology, and increased policy support in areas such as R&D, infrastructure, and regulation, found 20% to more than 50% electric vehicle shares were possible in leading electric vehicle markets in the 2025-2030 time frame. However, studies that considered lesser policy support and lesser technical advancement generally found that the electric vehicle market, in various countries and globally, could remain as low as 5%-10% in the 2025-2030 time frame.

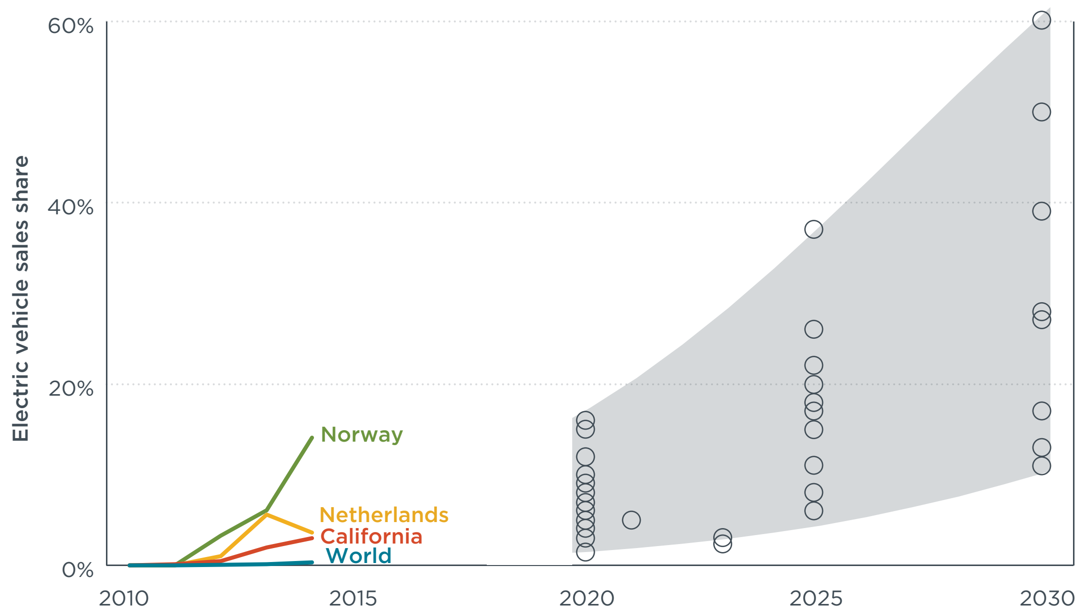

Figure 4. Electric vehicle 2010-2014 sales share for selected regions and 2020-2030 sales share projections for U.S., EU, China, Japan, and the world from various studies

To be on a trajectory toward long-term climate goals, many governments have established interim targets, incentives, and long-term policy to accelerate the electric-drive vehicle market share. Table 1 shows national goals several countries have used as milestones for electric vehicle deployment. Generally the national governments have set and announced these goals in terms of a cumulative stock (e.g., 1 million vehicles by a given date). Together these goals, if simply summed, amount to at least 15 million electric vehicles globally by 2020, and more than 25 million vehicles in the 2025-2030 time frame.

Many of these countries have also indicated their aspirations for nearly all new vehicles to be electric-drive or have near-zero emissions in the 2035-2050 time frame. Leading countries and companies are providing R&D funding for battery development to spur innovation, decrease battery costs, and increase manufacturing economies of scale to help achieve these goals. Many countries are offering attractive fiscal and other incentives for prospective electric vehicle consumers and users (Mock &Yang, 2014; Jin et al., 2014). Leading research (e.g., see Greene et al., 2014a, b) indicates that sustaining such policy and technology improvements will be necessary to facilitate the decades-long transition to electric-drive fleets. The goals and underlying policies are discussed in more detail in the sections that follow.

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Table 1. Selection of national electric vehicle sales goals for 2020-2030

Region	Electric vehicle cumulative sales target by 2020 (or before, as specified)	Electric vehicle cumulative sales target for post 2020
Canada (Ontario)	0.3 million[a]	
China	3 million[a]	14 million (2025)
Denmark	0.2 million	
France	1-2 million	
Germany	1 million	6 million (2030)
India	6-7 million[b]	
Japan	0.6 million[a]	1 million (2030)[a]
Netherlands	0.2 million	1 million (2025)
Norway	0.05 million (2018)	
South Korea	0.2 million	
Spain	1 million (2014)	
Sweden	0.6 million	
United Kingdom	0.5 million[a]	
United States	1 million (2015)	
United States (eight states)[c,d]		3.3 million (2025)
United States (California)[c]	0.5 million[a]	1.5 million (2025)

Based on ADEME, 2010; BMUB, 2014; Governor's Interagency Working Group on Zero-emission Vehicles, 2013; CARB, 2011; CEM, 2015b; IEA, 2011; METI, 2010; MIIT, 2015; NESCAUM, 2014; OLEV, 2013; Ontario, 2009; U.S. DOE, 2011
[a] Approximate, based on sales or sales share target
[b] Includes two-wheel and hybrid vehicles
[c] California, Massachusetts, Connecticut, Oregon, Maryland, Rhode Island, New York and Vermont
[d] Includes plug-in and hydrogen fuel cell electric vehicles

The various countries' electric vehicle targets in Table 1 have differing applicability by technology. Several of the targets include hybrid and plug-in electric vehicles, and many of the targets and their associated government planning documents predominantly refer to plug-in electric vehicles. Fuel cell electric vehicle targets often are included in government dialogue and analytical scenarios about future electric vehicle deployment, but no countries have specific hydrogen fuel cell electric vehicle targets. With nearly every global automaker selling at least one plug-in electric model, and with more than 300,000 plug-in electric vehicles sold in 2014, much of the global electric vehicle deployment and policy action is currently centered on passenger plug-in electric vehicles. However, Japan, Germany, the United Kingdom, the Netherlands, California, and others also have strong initiatives to advance hydrogen infrastructure as fuel cell electric vehicles come to market — with more than 18,000 such fuel cell vehicles projected in California alone through 2020.

Because plug-in electric automobiles make up the vast majority of the electric vehicle market today, the scope of this report is more focused on passenger plug-in electric vehicles. It is acknowledged, though, that to meet long-term climate goals, zero-emission electric-drive technology will likely include widespread diffusion of plug-in electric technology into heavy-duty vehicles as well as hydrogen fuel cell electric vehicle technology following the more near-term plug-in electric passenger vehicle deployment.

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BENEFITS OF INCREASED ELECTRIC VEHICLE DEPLOYMENT

Governments around the world are attempting to surmount the prevailing barriers and accelerate the electric vehicle market for various reasons. The anticipated benefits and the common barriers that stand in the way of the emerging electric vehicle market are summarized to provide further background for the report.

Compared to conventional vehicles, electric vehicles have two fundamentally superior technical features: greater on-vehicle efficiency and greater upstream energy source flexibility. Figure 5 illustrates the efficiency advantage of electric-drive technology versus a conventional petroleum-driven vehicle based on U.S. EPA (2012, 2014) and Lutsey (2013). Electric vehicle use, defined as the percentage of energy delivered to the vehicle that is ultimately used to overcome the vehicle road load, is about 4 times more efficient than conventional internal combustion gasoline engine efficiency, which is about 10%-20% (Lutsey, 2013). Conventional gasoline and diesel vehicles have greater thermodynamic energy losses, friction losses, fuel pumping losses, accessory loads, and transmission losses. The use of other alternative fuels, such as biofuels, can offer low-carbon energy sources but has supply limitations and is subject to the same combustion inefficiency disadvantage. On the other hand, electric-drive vehicles avoid most of these losses on the vehicle by using highly efficient electric powertrains, in addition to allowing for reduced upstream fossil energy use. As shown, moving from mostly fossil to 50% renewable energy sources for electricity further reduces the primary fossil-based energy requirements of electric vehicles.

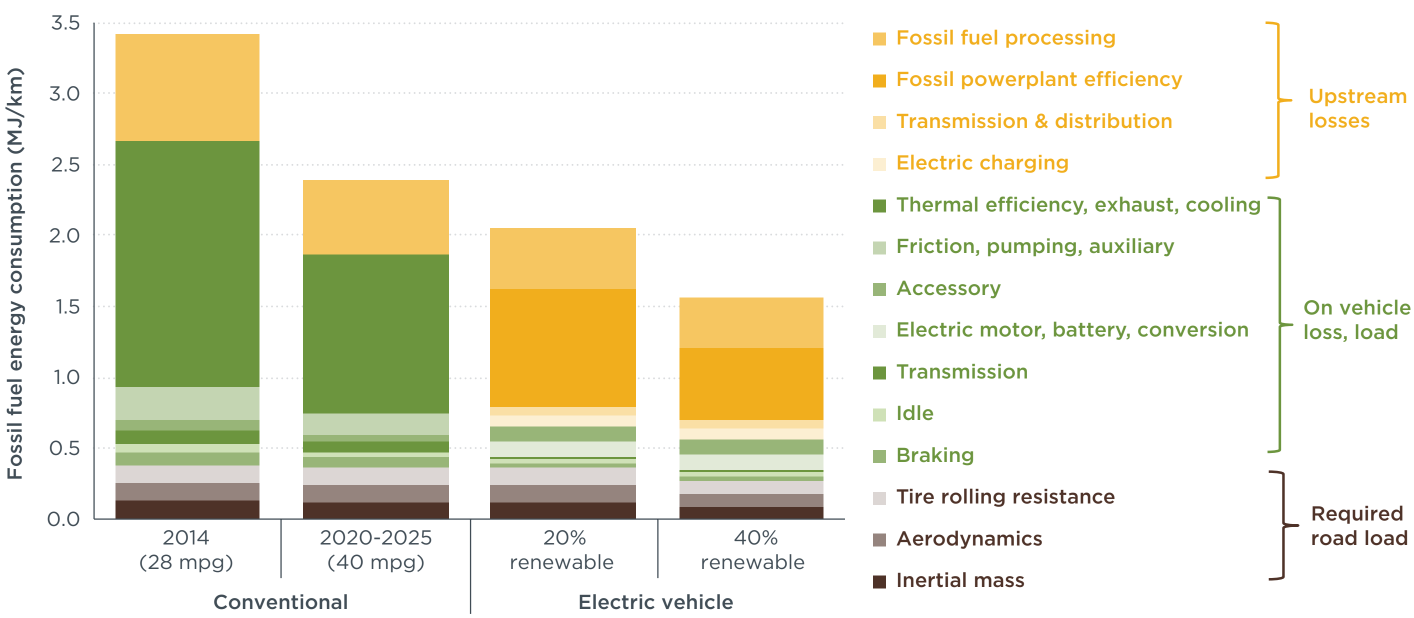

Figure 5. Life cycle energy losses and loads in converting primary fossil fuel energy to conventional internal combustion and battery electric vehicles

Electric vehicles, beyond consuming less energy, enable greater use of low-carbon and renewable energy sources than are available from conventional petroleum-based fuels. These technical advantages lead to the potential for greatly reducing petroleum use, air pollution, and carbon emissions.

Figure 6 provides a U.S.-based snapshot of primary energy sources and greenhouse gas emissions for the average conventional new U.S. car, an average electric vehicle

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on the average U.S. grid, and the same electric vehicle on the lower-carbon California grid in 2012 (Based on U.S. EPA, 2013, 2014). Although, not shown, fuel cell electric vehicles have well-to-wheel fossil energy use that is similar to plug-in electric vehicles as hydrogen is similarly increasingly produced from renewable sources. Similar dynamics are seen elsewhere around the world. Figure 6 shows the average model year 2014 U.S. passenger car at 28 miles per gallon on the adjusted on-road EPA fuel economy label values resulting in 320 gCO_2/mile in tailpipe emissions, and 400 gCO_2/mile in tailpipe-plus-fuel production emissions. This compares with a 0.34 kilowatt-hour (kWh)/mile all electric Nissan Leaf, which results in 42% (average U.S. grid) and 74% (average California grid) lower greenhouse gas emissions. The electric vehicle assumptions include 7% transmission and distribution losses and 10% charging losses. Also for comparison, the 2014 hybrid Toyota Prius achieves 50 miles per gallon on the adjusted on-road EPA test cycle and results in 222 gCO_2/mile in tailpipe-plus-fuel production emissions.

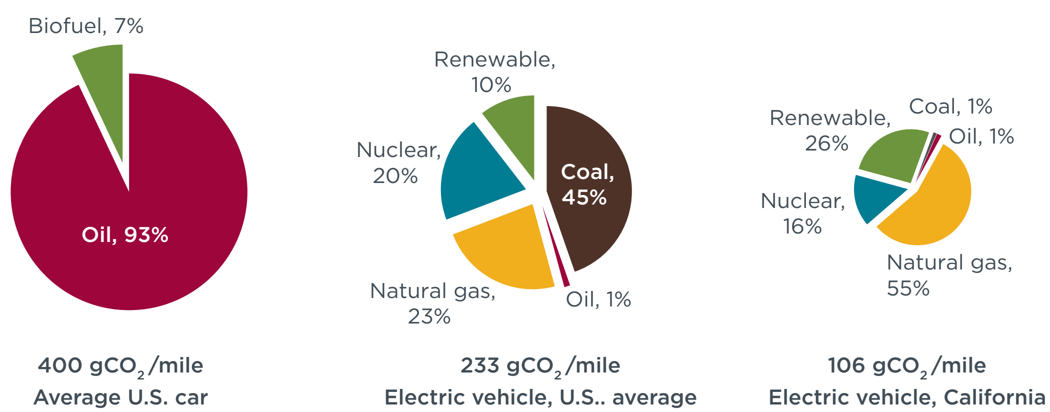

Figure 6. Energy sources and life cycle greenhouse gas emissions in 2014 for conventional and electric vehicles on average U.S. and California electricity grids

Figure 6 illustrates the multiple benefits of shifting vehicular travel from conventional petroleum sources to more highly efficient vehicles and more diversified and low-carbon energy sources. The dynamic shown in the figure is similar to elsewhere around the world, where average electricity use is primarily fossil fuel-based, but particular regions and adopted policies are moving the electric grid toward lower-carbon primary energy sources.

In global terms, electricity generation is powered by approximately 67% fossil sources (coal, oil, natural gas), 13% nuclear, and 20% renewable, based on IEA (2012) figures. Although most electricity is currently from fossil sources, hydrogen has the potential to displace fossil energy sources in the future with low carbon emitting nuclear, wind, solar photovoltaic, biomass, and hydroelectric power. Most countries have separate, parallel power sector initiatives to decarbonize their electric grids, and some also have related projects to integrate renewable hydrogen production into these energy initiatives.

BARRIERS TO INCREASED ELECTRIC VEHICLE DEPLOYMENT

Despite the potential fuel saving and climate mitigation benefits of new electric vehicle technology, major studies point to clear and present barriers to its widespread adoption. These barriers range from technical vehicle issues and adequate charging infrastructure to broader consumer and economic questions. The potential barriers for

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prospective electric vehicle consumers include vehicle cost, range, charge time, battery life uncertainty, vehicle model choices and availability, charging infrastructure, and awareness and understanding of the technology (e.g., NRC, 2013a; 2015).

Of the several technology barriers to the increased deployment of electric vehicles, one key barrier is the elevated incremental upfront vehicle cost compared to conventional vehicles. Among the most substantial incremental cost components are those for electric vehicle battery packs. Incremental technology costs for battery electric and plug-in hybrids have been estimated to be about $8,000-$16,000 greater than for conventional vehicles, based on battery pack costs above $500/kWh; however, estimated battery pack costs for the 2015-2020 time frame have decreased considerably (CARB, 2011; NRC, 2013b). Notably, Nissan and Tesla have committed to higher volumes and already have suggested they are in the $240-$375/kWh range (Abuelsamid, 2010; Cole, 2013).

Figure 7 illustrates the estimated optimistic and mid-range electric vehicle technology costs in the 2015-2025 time frame (NRC, 2013b). The underlying battery cost estimate for high-energy battery electric vehicles (BEV) moves from $550-$650/kWh in 2010 to $240-$350 in 2025 based on Nelson et al. (2011). The NRC analysis also projects that electric motor prices would decline by about half, from $12/kW to $6/kW, in that time frame. A key assumption in such estimates is that competitive high-volume production (i.e., over 100,000 units per year) is achieved to reduce per-unit costs. Recent analysis indicates market-leading companies in 2014 are manufacturing battery packs at $300/kWh (Nykvist & Nilsson, 2015). This latest analysis indicates that battery pack costs are falling faster than the optimistic projections shown in the figure, with technology leaders essentially achieving projected 2020 costs in 2015.

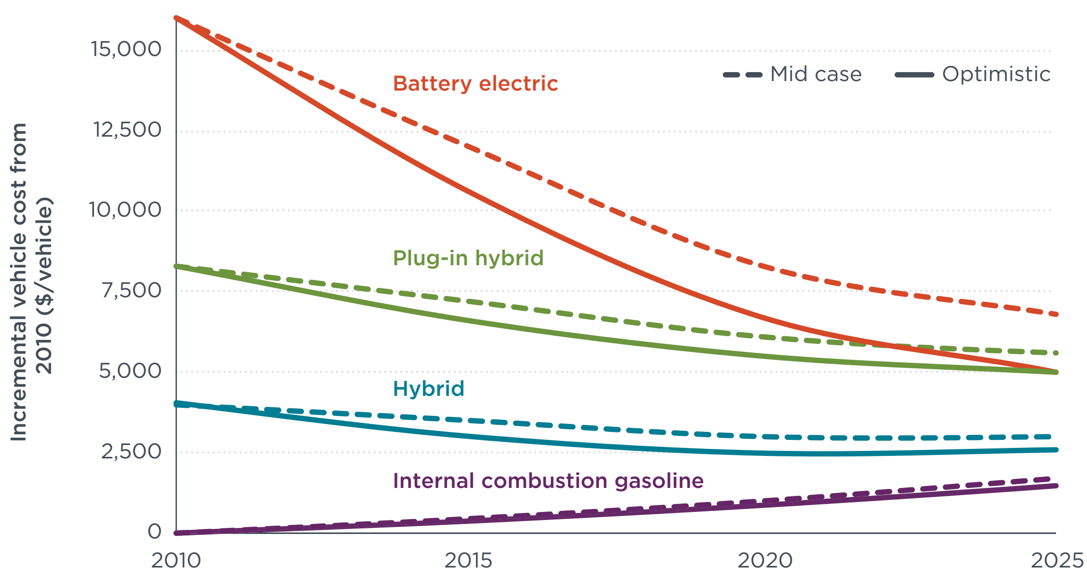

Figure 7. Incremental technology cost of electric and conventional vehicles through 2025

The question of electric vehicles' incremental cost is interrelated with vehicle range, as they both relate fundamentally to the battery pack capacity. Most early battery electric vehicle models, including the Nissan Leaf and BMW i3, have real-world average electric ranges of approximately 75 to 100 miles, and the Tesla Model S offers a range of more

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than 200 miles (U.S. EPA, 2015a). Two next-generation General Motors models give an indication of improvements on the way. The all-electric Chevrolet Bolt has an announced range of 200 miles and plug-in hybrid Chevrolet Volt will see an increased range to about 50 miles (Colias, 2015). These represent more than double the current all-electric 2015 Chevrolet Spark range of 82 miles and at least a 30% increase from the 2015 Chevrolet Volt range of 38 miles (U.S. EPA, 2015a, b). This indicates a combination of continued cost and range improvements can be expected with the next wave of electric vehicles.

Along with cost and range, electric vehicles' charging availability and recharge time present additional barriers to widespread adoption. The time it takes to recharge battery electric vehicles ranges from 4-8 hours for Level 2 charging (i.e., 240 volt, generally 3-10 kW) to 25-40 minutes for direct current quick charging (i.e., 480 volt, generally 40-90 kW) for most all-electric vehicles. Increased battery capacity and vehicle range will offer some ability to reduce the demand for public fast charging and workplace charging availability. Increased charging availability will further increase the functional daily range of vehicles and also increase driver confidence in using the expanded vehicle range. Through public financing and workplace charging initiatives, various vehicle markets around the world are seeing greatly expanded charging infrastructure networks. Based on several recent studies, consumer awareness, understanding, and responsiveness connect to the above questions about electric vehicle technical issues and infrastructure, but present additional questions. The recent research in this area is discussed in Section III.

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II. INTERNATIONAL ACTIONS TO PROMOTE ELECTRIC VEHICLES

This section briefly summarizes only select high-level policies in China, Europe, Japan, and the U.S., although it is important to acknowledge there are significant local efforts in these regions and other major national efforts elsewhere as well. It builds on the background presented in preceding sections concerning zero-emission vehicle adoption, targets, projections, benefits, and barriers to discuss various regional policies for accelerating the adoption of zero-emission vehicles. This section draws from the recent literature on financial and non-financial incentives for electric vehicles (e.g., Mock & Yang, 2014; Jin et al., 2014; OECD, 2015). The financing and construction of electric vehicle charging infrastructure, as well as other electric vehicle promotion actions, are summarized from various government and research literature sources.

CHINA

China's efforts to grow the electric vehicle market include research and development, regulatory incentives, public vehicle procurement, vehicle production subsidies, consumer incentives, and public charging investments. Since the 2000s, China has spent more than $1 billion per year at the national level in R&D loans and grants, plus an additional $1 billion from local governments and industry (OECD, 2015). From 2009, China shifted toward a focus on incentives for manufacturer production, public procurement (e.g., fleets, taxis), and private consumer subsidies for electric vehicles, first in 10 particular cities and later 25 (Howell et al., 2014; OECD, 2015). The incentives generally have not been available to foreign-manufactured electric vehicles. Of the leading electric vehicle models in China in 2014, 15 of the top 16 are domestically produced (EV Sales, 2015). China's electric vehicle growth was slow from 2010-2013, but growth in 2014 brought China's electric passenger vehicle sales to more than 50,000 per year, behind only the United States in total national annual sales.

China's national *12th Five-Year Plan* calls for 500,000 cumulative plug-in electric vehicles on China's roads by 2015. The 2015 "Made in China 2025" plan includes goals to increase annual plug-in electric vehicle sales to more than 1 million in 2020 and more than 3 million in 2025 (MIIT, 2015). The plan also includes direction for increased fuel cell research and development, pilot fuel cell electric vehicle deployment in 2020, and expanded hydrogen infrastructure. The electric vehicle promotion activities include passenger car purchasing incentives up to 35,000-60,000 yuan ($6,000-$10,000) per vehicle, which have been extended through 2015. China has recently proposed to offer incentives of 32,000-55,000 yuan per passenger car for 2016-2020 (MOF, 2014). The plan also involves the construction of up to 400,000 charge points over 2011-2015 (Li, 2014). By the end of 2014, there were approximately 28,000 charge points and about 700 charging stations in China (IEA, 2015a), and many local governments are working on partnerships with local providers to increase the charging infrastructure. The government has placed further focus on pilot areas of Beijing, Shanghai, Shenzhen, Hangzhou, Hefei, Changchun, and Chongqing. These regional pilot efforts include substantial additional direct consumer incentives, sometimes doubling the national incentives; innovative partnerships with particular vehicle and battery companies; and charging infrastructure plans (Marquis et al., 2013; Howell et al., 2014).

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EUROPE

There is a great diversity of electric vehicle promotion activity across Europe. Common to the European Union member states, vehicles are all promoted by the increasingly stringent carbon dioxide emission standards that aim to achieve a 95 gCO_2/km new vehicle fleet in 2021, and these regulations provide further promotion for electric vehicles with "supercredits" and the omission of upstream emissions (Mock, 2014). European countries have installed various levels of electric vehicle charging equipment in order to improve the value proposition, electric range, and range confidence of electric vehicle users. The EU-wide Clean Power for Transport directive provides targets for each member state regarding the increased deployment of plug-in charging and hydrogen refueling infrastructure (European Commission, 2014). Some European countries have also established bold targets, offered large fiscal incentives to consumers, installed vehicle charging networks, and implemented other support policies to promote electric vehicle deployment. Also, each of the European countries has had higher gasoline and diesel prices of about 1.50-1.80 euros per liter in 2013-2014 that inherently have provided greater fuel savings and a stronger relative motivation for alternative fuel vehicles (Mock & Yang, 2014).

Figure 8 provides context for the current status of the electric vehicle sales, share of new vehicles, and electric vehicle charging equipment across selected European countries (based on data from Chargemap.com, 2015; Kraus, 2015; CEM, 2015a). Norway, the Netherlands, France, the United Kingdom, and Germany lead in electric vehicles, with sales between 12,000 and 20,000 per year. The figure also shows the mix between BEVs and PHEVs. Norway's 14% electric vehicle sales share is far higher than the rest, and Norway and the Netherlands have deployed the highest electric vehicle charging infrastructure per capita (i.e., in charge points per million population). The brief sections below provide summaries of electric vehicle promotion actions that are in play in several of the countries.

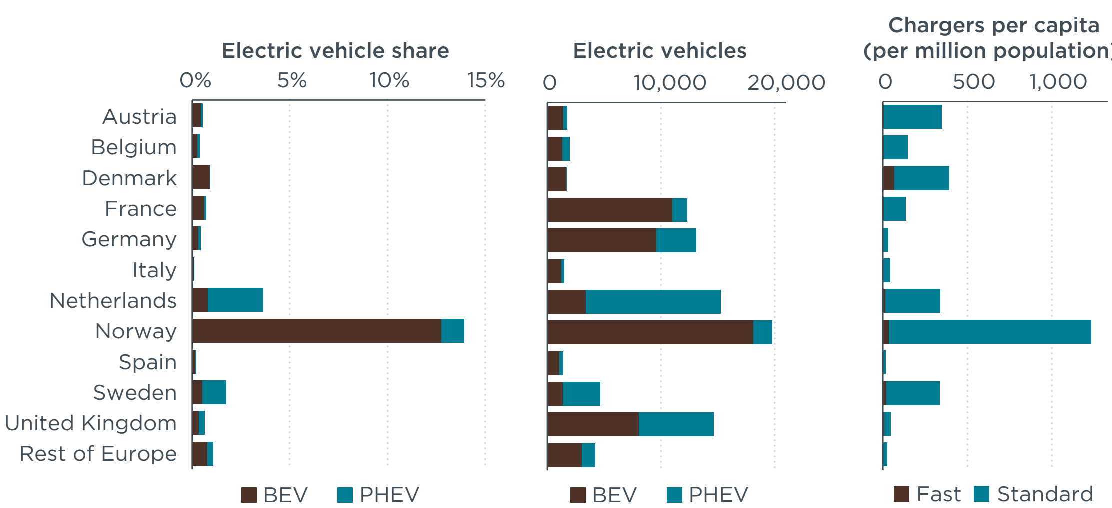

Figure 8. Electric vehicle sales share, new registrations, and charging in 2014 in Europe

Norway. As a percentage of new vehicle sales, Norway has the highest electric vehicle share, and the country also has had some of the strongest electric vehicle incentives globally. Norway already, in April 2015, had met its 2018 goal of 50,000 cumulative electric vehicles. The exemption from the normal value-added tax (VAT) and the one-time registration fee around the time of the electric vehicle purchase, as well as high fuel savings, make a battery electric vehicle less expensive to own and operate than its conventional gasoline

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counterpart. Norway's electric vehicle policy framework includes free toll roads, access to bus lanes, free parking, extensive charging network, and free charging, which are also important motivating factors for electric vehicle users (Haugneland & Kvisle, 2013). In addition, Norway's relatively high gasoline and diesel prices improve the fuel-saving proposition for electric vehicle users. Norway's electric vehicle charging network is also among the most extensive in the world, on a per capita basis.

Netherlands. The Netherlands has been among the leaders in electric vehicle deployment and electric vehicle shares, and has among the more extensive national charging networks in Europe. The country has cumulative electric vehicle goals of 200,000 by 2020 and 1 million by 2025. As part of the incentive policy framework to incentivize electric vehicles, the Netherlands excludes both BEVs and PHEVs from registration and ownership taxes. Compared to comparable non-electric vehicles, the Netherlands offers per-vehicle incentives that are greater for PHEVs than for BEVs and for company (i.e., non-private) cars (Mock & Yang, 2014). The Netherlands' relatively high gasoline and diesel prices improve the fuel-saving proposition for electric vehicle users. The Netherlands also has set specific targets for the increased deployment of up to 15,000 fuel cell vehicles and 80 public hydrogen stations by 2025.

France. France is among the electric vehicle sales leaders in Europe, and seeks to put 1-2 million electric vehicles on its roads by 2020 (ADEME, 2010). France offers extensive electric vehicle incentives of generally 4,000 euros for PHEVs and 6,300 euros for BEVs through its Bonus/Malus feebate scheme, and relatively high gasoline and diesel prices further improve the fuel-saving proposition for electric vehicle users. Policies have been adopted to increase France's public charging points to 16,000 across the country over the next several years, and to seven million charging points by 2030. In addition, France offers tax incentives for private charging equipment installation (IEA, 2015a).

United Kingdom. The United Kingdom is also among the electric vehicle sales leaders in Europe in 2014, and has a strategic goal to grow electric vehicle market share up to approximately 5% of the new automobile market by 2020 (OLEV, 2013). The government is now implementing a 500 million pound 2015-2020 plan, in addition to 400 million pounds previously, that includes research, consumer incentives, charging infrastructure, and local support elements (OLEV, 2014). The government planning and policy are technology-neutral, supporting plug-in and fuel cell electric vehicles and hydrogen fueling infrastructure, with a roadmap for 65 hydrogen fueling stations to launch the market (UK H2 Mobility, 2013). The United Kingdom plan for a network of rapid electric vehicle charging infrastructure includes growing the network to 500 rapid electric charge points by the end of 2015. Customer purchasing incentives, including a one-time incentive of up to 5,000 pounds or 25% of the car price, are applicable for new electric vehicles with less than 75 gCO_2/km, and greater tax incentives are available for company cars. Relatively high gasoline and diesel prices also improve the fuel savings for prospective electric vehicle users.

Germany. Germany was among the higher electric vehicle sales volume markets in 2014, and has previously stated goals for 1 million cumulative electric vehicles by 2020, and 5 million by 2030 (BMUB, 2014). The country has placed more focus on R&D and public-private partnerships, for example with its National Electric Mobility Platform (NPE, 2014), and less on per-vehicle consumer incentives, compared to the preceding countries. Although Germany has not used consumer purchasing tax credits or rebates to reduce the initial vehicle costs, the country has offered an exemption from the annual vehicle circulation tax, and relatively high fuel prices provide an incentive for electric vehicle

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purchase and use. A 2015 law allows municipalities to offer free or dedicated parking, use of bus lanes, and access to restricted areas for electric vehicles. Germany also has four showcase regions for targeted support, visibility, and stakeholder collaboration with vehicle demonstrations, charging infrastructure, and car-sharing programs (BMVI, 2011; IEA, 2015a). Germany is also on track to achieve its goal of 50 hydrogen stations by the end of 2015, expanding to 100 by 2017 and 400 by 2023 with additional industry commitments (NOW, 2013, 2014; Daimler, 2014)

Beyond the five European countries mentioned, many similar national actions are taking place in other countries across Europe. In terms of electric charging infrastructure, for example, Estonia stands out with more than 150 quick-chargers (ABB, 2013), which is among the largest network of quick-charging stations per capita in the world. A number of cities and regions in Europe (e.g., Amsterdam, London, Oslo, and Paris) are implementing diverse and innovative local actions to promote EVs (Urban Foresight, 2014).

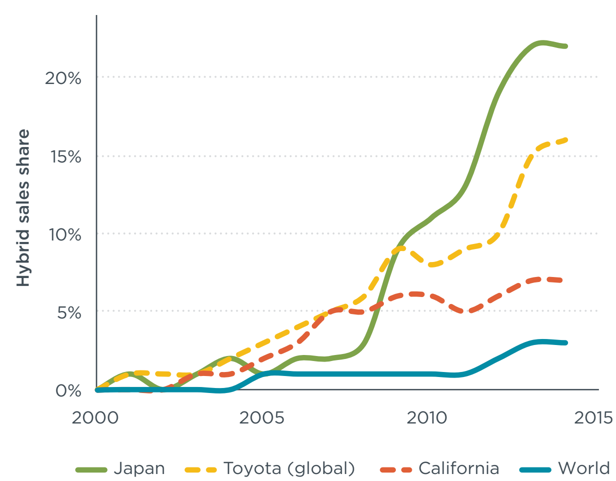
JAPAN

Japan is among the leaders in early electric vehicle growth with more than 30,000 sales in 2014. Japan has goals for plug-in electric vehicles to make up 20%-30%, and fuel cell electric vehicles 3%, of total vehicle sales by 2030 (METI, 2010). Japan's share of hybrid electric vehicles is far higher than other countries around the world; this hybrid success could provide an example of how comprehensive support policies (e.g., R&D, efficiency standards, consumer fiscal incentives) can help support the development of a market for advanced technology (see sidebar).

As part of its electric vehicle promotion efforts, Japan also has several consumer incentives and substantial electric vehicle charging infrastructure in place. Incentive programs allow for a one-time subsidy and purchasing tax exemptions for EVs and other qualified fuel-efficient vehicles since 2009. The subsidies are based on the price difference between an EV and a comparable gasoline car, with a maximum of 850,000 yen (about

JAPAN, TOYOTA, AND DEVELOPING THE HYBRID MARKET

The hybrid market in Japan provides a case study on the development of a new market for a more expensive, advanced technology. Since the late 1990s introductions of the first hybrid models, the Japan market has gone well beyond purchases by early adopters, greatly surpassing market shares elsewhere. This occurred for many reasons. Among them, Japan has had among the most aggressive efficiency standards and maintained consumer and manufacturer incentives for hybrid deployment, and Toyota in particular has made a multi-billion-dollar global bet on hybrids. The result is that, in 2014, Japan's new car market was more than 20% hybrids. In addition, Toyota is now selling more than 30 hybrid models in more than 80 countries, sells more than 1 million hybrids per year, and has reached approximately 7 million total hybrid sales. Similar hybrid support policies have pushed the share of hybrids in California to 7%. Globally, nearly every automaker has numerous hybrid models, hybrid sales are roughly 2 million per year, and the hybrid market continues to move beyond early adopters.



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6,300 euros) (see CEV, 2015; Mock & Yang, 2014). These incentives generally amount to about 3,000-5,000 euros for typical BEVs and PHEVs. Japan also has reductions and exemptions for BEV and PHEV acquisition and annual tonnage taxes that can nearly double those upfront incentives for the first vehicle owner (Mock & Yang, 2014).

Japan has an extensive electric vehicle charging infrastructure plan, especially for rapid charging equipment. More than 10,000 public stations, including 3,000 fast-charge stations, have been installed in Japan (CHAdeMO, 2015; IEA, 2015a). Cities throughout Japan are exploring innovative ideas like integrated electric vehicle mobility networks and ensuring electric vehicle-ready buildings (Urban Foresight, 2014). Japan has made hydrogen a central part of its strategic energy plan, with a goal of 100 hydrogen stations in four major urban areas and corridor highways to meet the increasing deployment of fuel cell electric vehicles and a plan to showcase hydrogen and fuel cells at the 2020 Olympics (Tanaka, 2015; METI, 2014).

UNITED STATES

With more than 100,000 sales in 2014, the U.S. had the highest electric vehicle sales of any country. The U.S. set a goal of 1 million cumulative electric vehicles by 2015 and is about a third of the way to that goal. National policies to promote electric vehicles include consumer subsidies and infrastructure investments. A federal income tax credit grants from $2,500 per PHEV (for about 10-15 mile range) up to $7,500 for longer-range PHEV (at 16 kWh battery, or about 40-mile PHEV) and BEVs. Federal funding for an expansive national public electric vehicle charging network has helped in the rollout of more than 20,000 charge outlets at 8,000 stations (U.S. DOE, 2015). The U.S. also has a growing workplace charging network that includes more than 100 employers, 250 workplaces, and more than 4,000 chargers (U.S. DOE, 2014a,b).

California and other leading electric vehicle states. The state of California, with its Zero Emission Vehicle (ZEV) regulation, fiscal incentives (up to $2,500 for plug-in electric and $5,000 per fuel cell vehicles), non-monetary incentives (e.g., carpool lane access), and extensive charging infrastructure, has among the more comprehensive electric vehicle support plans (Governor's Interagency Working Group on Zero-emission Vehicles, 2013). The ZEV program is unique globally in mandating electric-drive technology with enforceable fines. Figure 9 shows electric vehicle sales, electric vehicle share of new vehicles, and chargers per million people in selected U.S. states (based on data from IHS Automotive, 2014; US DOE, 2015). California has dedicated funding through 2023 to deploy at least 100 hydrogen stations to support fuel cell electric vehicles (CARB, 2014). California, with about 11% of the U.S. car sales, makes up about 50% of overall U.S. electric vehicle sales. Other states within the U.S. provide additional extensive electric vehicle support and have greater electric vehicle shares and electric vehicle charging infrastructure in place. In particular, Washington, Oregon, Georgia, and Hawaii are providing combinations of consumer, charging, and local policy support that are driving their electric vehicle shares considerably higher than the national average (Jin et al., 2014).

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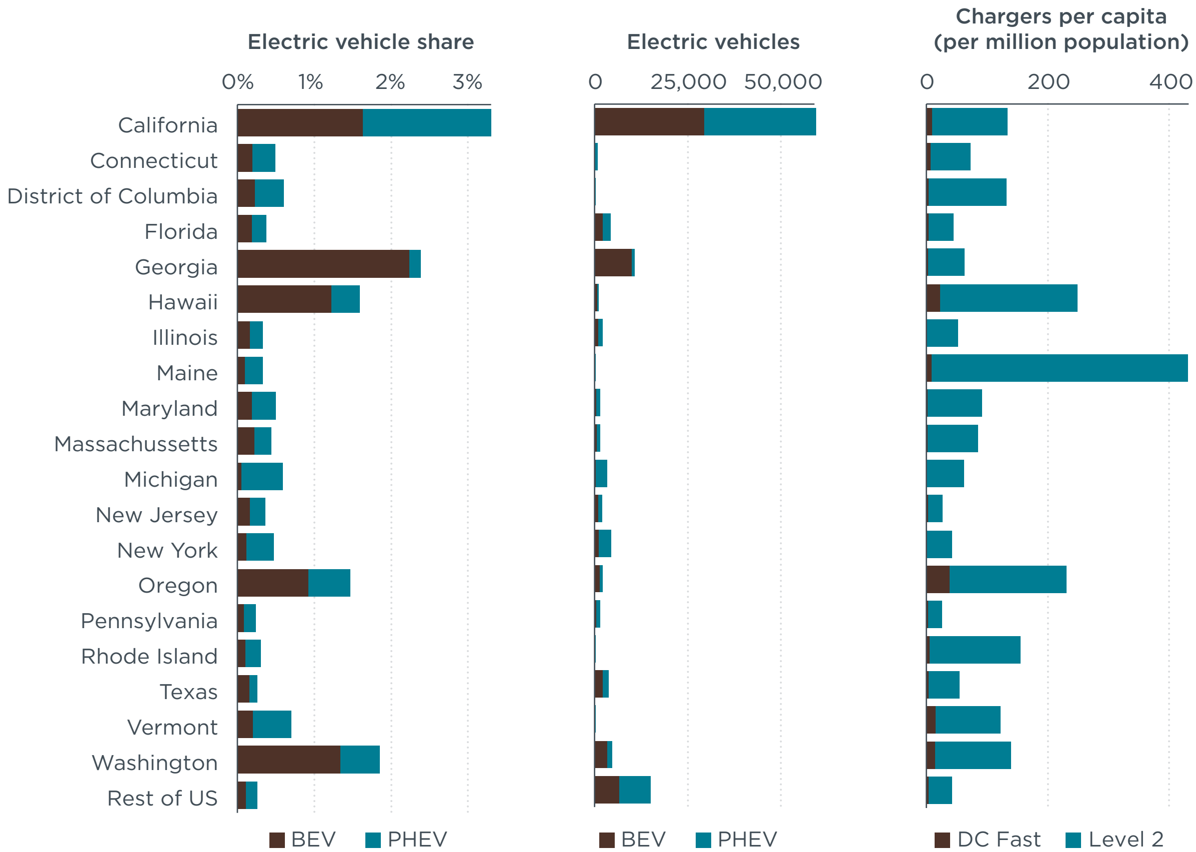

Figure 9. Electric vehicle share, new registrations, and public charging infrastructure in 2014 in various U.S. states

OVERVIEW OF ACTIONS

Table 2 summarizes which electric vehicle promotion actions are in place in several major automobile markets. The table highlights the breadth of activity that is underway in many of the leading governments seeking to promote electric vehicles, including vehicle manufacturing, consumer purchasing incentives, and infrastructure-focused actions. Along the top two rows in the table, the various regions' vehicle sales and production of all passenger vehicles are shown to provide context of the scale of the market in each place. The markets in the table represent more than 90% of global electric vehicle sales in 2014. As shown, some of the electric vehicle promotion actions (e.g., efficiency standards, investment in charging infrastructure, and public outreach activity) are in place in many of the jurisdictions. However, other actions are only adopted in several places. It is noted that although all the jurisdictions are seeing electric vehicle charging infrastructure rollout, there is great variation in the charging infrastructure per capita (e.g., see Figure 8 and 9). Although most governments have adopted many of the listed electric vehicle promotion activities, more promotion actions are in place in Norway, the Netherlands, and California than in the other areas. The table is, of course, not comprehensive of the full span of activities underway in the various areas and also does not convey the varying levels of the activity (e.g., the amount of consumer incentives and infrastructure).

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Table 2. Summary of government electric vehicle promotion actions in selected areas

Area	Action	China	France	Germany	Japan	Netherlands	Norway	United Kingdom	United States (excl. California)	California
Global market share	Vehicle sales in 2014 (million vehicles)	22	2.2	3.3	4	0.5	0.2	2.6	14	1.7
	Vehicle manufacturing in 2014 (million vehicles)	22	1.7	5.7	10	<0.1	<0.1	1.6	11	<0.1
	Percent of 2014 global electric vehicle sales	17%	4%	4%	10%	5%	6%	5%	19%	19%
Vehicle manufacturer	Research and development support	X	X	X	X	X	X	X	X	X
	Long-term efficiency standards	X	X	X	X	X	X	X	X	X
	Incentive provisions within efficiency regulations	X	X	X		X	X	X	X	
	Cumulative sales goal	X	X	X		X	X	X	X	X
	Vehicle deployment requirements									X
	Vehicle production subsidy	X								
Consumer purchase	Vehicle purchase subsidy (tax credit)								X	
	Vehicle purchase subsidy (rebate)	X			X			X		X
	Vehicle purchase tax exemption					X	X		/	
	Vehicle fee-bate scheme		X					X		
	Government fleet vehicle purchasing preferences		X		X			X	X	X
	High fuel price and greater fuel savings		X	X		X	X	X		
Consumer use	Annual vehicle fee exemption			X	X	X	X	/	/	
	Discounted/free electric charging				X	X	X	/	/	X
	Preferential lane (e.g., bus, HOV lane) access			/		X	X		/	X
	Reduced roadway tax or tolls			X	X	X	X	X		
	Preferential parking access		/	/		/	/	/	/	/
Fuel provider, infrastructure	Carbon pricing scheme	X	X	X	X	X	X	X	/	X
	Low carbon fuel incentive for electricity providers							/		X
	Public charging network funding	X	X	X	X	X	X	X	X	X
	Home charging equipment tax incentives		X						/	/
Consumer awareness	Public outreach activities to educate on consumer benefits	X	X	X	X	X	X	X	X	X

Based on IEA, 2015a; Jin et al., 2014; Mock & Yang, 2014; NRC, 2015; OECD, 2015; OICA, 2015a,b;
"X" denotes national program; "/" signifies smaller local or regional program

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INTERGOVERNMENTAL ELECTRIC VEHICLE INITIATIVES

Beyond national, state, and local actions, many government agencies in various areas are forging collaborations with agencies in other countries to leverage their efforts to promote electric vehicles. Among the international activities is the Clean Energy Ministerial's Electric Vehicle Initiative (EVI), which involves 17 member countries. The EVI seeks to facilitate the global deployment of 20 million EVs by 2020 by encouraging national goals and best practices; leading the sharing of city experiences; sharing information; engaging private-sector stakeholders to better align expectations; discussing the respective roles of industry and government; and focusing on the benefits of continued investment in EV technology innovation and EV procurement for fleets (CEM, 2015b).

Another international initiative is the International Energy Agency Hybrid and Electric Vehicle Implementing Agreement, which consists of 18 member countries and includes working groups collaborating on various electric vehicle technology questions (IEA, 2015b). Another initiative, the Urban Electric Mobility Initiative (UEMI), involving UN-Habitat, cities, industry, and development banks, seeks to increase the global market share of electric vehicles in cities to at least 30% in 2030 (UN-Habitat, 2015). The United Nations Economic Commission for Europe's Electric Vehicle and the Environment (EVE) working group exchanges information on, and seeks to minimize differences in, electric vehicle regulations across countries (UN ECE, 2014). Finally, the C40 Cities Climate Leadership Group's Low Emission Vehicle Network coordinates city-level actions by facilitating knowledge sharing on topics like electric vehicle charging and fleet projects among the 24 participating cities (C40 Cities, 2014).

There are many high profile bilateral international electric vehicle initiatives; two prominent ones involve China and Germany and China with the U.S. Under the Sino-German Electric Vehicle Strategic Partnership Framework, China and Germany signed various ministry-level memoranda of understanding between the ministries in the two countries on electric vehicles, leading to collaboration in many areas (China, 2014). The activities include research into the technology and market development of EVs, pilot demonstration programs, charging infrastructure and regulations, policies, and standardization. Another initiative includes three pairs of collaborative cities and includes the investigation of new business models and innovative transportation solutions (such as electric car sharing); non-fiscal incentives such as parking policies and dedicated lanes, battery safety, testing, EV application to certain logistics fleets; and some hydrogen research. Other components include in-depth collaboration between German and Chinese universities on energy storage, electric drive and electric systems research and development, and environmental impacts of electric vehicles. Finally, another collaboration led to a July 2014 agreement between China and Germany to harmonize charging interface protocols for electric vehicles in the two countries.

Two China-U.S. collaborations focus on similar areas related to electric vehicles. First, the U.S.-China Clean Energy Research Center was established in 2009, and, in 2014, President Obama and President Xi renewed the commitment to the center. One of the four main components of the Center is the Clean Energy Vehicle Consortium, which has included more than $50 million in funding for research on advanced batteries, vehicle electrification research, and vehicle-grid integration (Peng & Minggao, 2013). The Center also has hosted joint conferences, technical meetings, and collaborative meetings; authored technical journal and conference papers; and filed international

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patents. The second, more recent, collaboration is the China-U.S. ZEV Policy Lab, which involves collaboration on policy activity to increase the use of zero-emission vehicles (UC Davis, 2014).

Within North America, a number of prominent initiatives help support the deployment of electric vehicles. Ten states have adopted the California Zero Emission Vehicle program. Eight U.S. states, representing more than half the U.S. electric vehicle market, have signed a memorandum of understanding to support the associated deployment of electric vehicles and collaborated on a Multi-State ZEV Action Plan to prioritize and enact many complementary actions to support electric vehicle deployment and use (NESCAUM, 2013, 2014). Four Pacific Coast Collaborative jurisdictions are coordinating to support electric vehicles by implementing low carbon fuel standards, supporting fleet electric vehicle deployment, and investing in infrastructure (PCC, 2014). Collaboration between Québec and California includes a working group to work together on zero-emission vehicle promotion activities, policies, and incentives (Quebec, 2015). Also, the U.S. DOE Clean Cities program helps coordinate 80 major U.S. metropolitan areas' efforts to reduce their fleets' petroleum use by establishing local public-private coalitions, identifying funding opportunities, facilitating information sharing, and providing technical assistance regarding the deployment of alternative fuel vehicles (U.S. DOE, 2015b).

A brief summary of such intergovernmental electric vehicle initiatives is provided in Table 3. The initiatives summarized above, taken as a whole, have resulted in far greater coordination, exchange of research information, and sharing of policy experience than would have occurred otherwise. In particular, the IEA Implementing Agreement and the CEM EVI have resulted in the convening of many ministry staff officials to exchange notes several times a year, and have produced a number of reports that have synthesized information from multiple jurisdictions (e.g., see CEM, 2015b; IEA, 2013a). The other initiatives have brought more targeted collaborations in particular research areas.

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Table 3. Summary of intergovernmental electric vehicle initiatives

Initiative	Participants	Elements
Clean Energy Ministerial Electric Vehicle Initiative	17 countries: Canada, China, Denmark, Finland, Germany, India, Italy, Japan, Netherlands, Norway, Portugal, South Africa, South Korea, Spain, Sweden, UK, U.S.	• Convene twice a year • Share information, experiences • Conduct several projects per year (e.g., EV Outlook, City EV Casebook)
International Energy Agency Hybrid and Electric Vehicle Implementing Agreement	18 countries: Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal, South Korea, Spain, Sweden, Switzerland, Turkey, U.K., U.S.	• Convene twice a year • Share information, experiences • Working groups on various technical research areas
Urban Electric Mobility Initiative (UEMI)	UN-Habitat, Mahindra Reva, BYD, Wuppertal Institute, Michelin, Siemens, CEM EVI, IEA	• Commitments from cities, industry for 30% electric vehicle share in 2030 • Provide forum for knowledge transfer
United Nations Economic Commission for Europe (UN ECE) Electric Vehicle and the Environment (EVE) working group	Led by Canada, China, Japan, and U.S., with participation from many countries, battery and vehicle manufacturers, non-governmental organizations	• Exchange information on, and seek to minimize differences in, regulatory requirements for electric vehicles • Develop electric vehicle regulatory reference guide
C40 City Leadership Low Emission Vehicle	More than 20 major world cities, including Bogota, London, Los Angeles, Madrid, Mexico City, San Francisco, Santiago de Chile, Warsaw, Yokohama	• Share information and best practices in implementing vehicle charging, car-sharing, fleet, taxi projects
Sino-German Electric Vehicle Strategic Partnership Framework	China (Ministry of Industry and Information Technology [MIIT], Ministry of Science and Technology [MoST], National Development and Reform Commission [NDRC], China Automotive Technology & Research Center [CATARC]); Germany (Federal Ministry of Economic Affairs and Energy [BMWi]; Ministry of Transport and Digital Infrastructure [BMVI]; Ministry of Education and Science [BMBF]; Federal Ministry of Environment Protection [BMU]; Federal Enterprise for International Cooperation [GIZ])	• Technology and market development, pilot demonstration programs, charging infrastructure and regulations, policies and standardization • Study electric car sharing, non-fiscal incentives, and other local electric vehicle support policies in three pairs of cities • Research collaboration on battery research and environmental impact of EVs • Harmonization of charging interface protocols
U.S.-China Clean Energy Research Center	China (Ministry of Science and Technology [MoST], National Bureau of Energy, research groups [including China Academy of Science, Tsinghua University, Beijing Institute of Technology]); United States (U.S. Department of Energy, research [including University of Michigan, Massachusetts Institute of Technology, Oak Ridge National Laboratory], industry [including vehicle, oil, and battery companies])	• $50 million in funding for Clean Energy Vehicle Consortium, including focus on advanced battery, vehicle electrification research, vehicle-grid integration • Host joint conferences, technical meetings, collaborative meetings • File international patents
China-U.S. Zero Emission Vehicle Policy Lab	China (National Development and Reform Commission [NDRC]; China Automotive Technology and Research Center [CATARC]); California (Air Resources Board; UC-Davis)	• Collaborate on policy activity to increase the usage of zero-emission vehicles
Green eMotion	42 partners including European Union, Bosch, IBM, SAP, Siemens, BMW, Daimler, City of Copenhagen, City of Rome, research organizations, TÜV Nord	• Define EU-wide standards for electric mobility • Showcase 12 regions to demonstrate technical and business solutions for electric vehicles (ended in February 2015)
Governors eight U.S. states' Memorandum of Understanding	California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont	• Coordinate on Multi-State ZEV Action Plan to support deployment of 3.3 million electric vehicles by 2025
Zero Emission Vehicle program	Ten U.S. states: California, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont	• Adopt and co-implement the California zero-emission vehicle requirement for new vehicles through 2025
Pacific Coast Collaborative	Three U.S. states: California, Oregon, Washington One Canadian province: British Columbia	• Coordinate on fuel standards, fleet procurement, and infrastructure investment for electric vehicles
Québec-California collaboration	California (Environmental Protection Agency), Québec (Ministry of Sustainable Development)	• Working group to collaborate on zero-emission vehicle promotion, policies, and incentives
U.S. DOE Clean Cities Coalition	84 major U.S. metropolitan areas	• Establish local coalitions, identify funding, facilitate info sharing on alternative fuel vehicles

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III. ELECTRIC VEHICLE POLICY EFFECTIVENESS

RESEARCH TO DATE

Research into electric vehicle policies and electric vehicle deployment continues to examine various government policies' relative effectiveness. Assessments that have been conducted on particular U.S., European, China, and international bases are each providing early insights into the relative importance of various types of policies, public and private investments, and other non-policy electric vehicle promotion actions.

Table 4 summarizes recent studies that have investigated the importance of various electric vehicle promotion policies. Generally, these studies are clearly indicating that many different actions by governments at various levels (national, regional, state) and by industry stakeholders (vehicle manufacturers, charging infrastructure providers) will be necessary over the 2015-2025 time frame to grow the electric vehicle market.

Although regulatory standards for vehicle efficiency are found to be important to promote electric vehicle deployment, they are shown to be insufficient to drive the electric vehicle technology into the marketplace without complementary policies and incentives. This has led to additional regulatory incentives in the U.S., the EU, China, and elsewhere within the efficiency standards for 2020-2025 new vehicles. The consensus from the emerging studies clearly indicates the importance of consumer electric vehicle purchasing incentives and electric vehicle charging infrastructure, as well as education and awareness actions in driving electric vehicle purchasing and use; however, the studies appear to put additional importance on various types of measures.

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Table 4. Summary of major findings related to electric vehicle policy effectiveness

Finding	Study
• Consumer incentives, the presence of local manufacturing, and especially charging infrastructure are significantly connected to increased electric vehicle adoption • Consumer incentives and charging infrastructure do not ensure high electric vehicle adoption	Sierzchula et al., 2014
• Fiscal incentives are reducing electric vehicles' total cost of ownership in line with conventional vehicles and helping spur electric vehicle sales, e.g., the Netherlands, Norway, California • The relative importance of non-fiscal, local, and infrastructure actions warrants further study	Mock & Yang, 2014
• Electric vehicle promotion policies vary greatly by type and by magnitude across all OECD countries	OECD, 2015
• Standardization and increased deployment of charging infrastructure, fleet deployment, and other local measures are most important to stimulate electric vehicle mobility in cities	Bakker & Trip, 2013
• Vehicle efficiency and CO_2 standards through 2020 in the EU can be met with gasoline and diesel technologies and are therefore insufficient to drive electric vehicles into the market	Meszler et al., 2013
• Free toll roads, vehicle sales tax exemption, fuel savings, access to bus lanes, free parking are most important electric vehicle incentives for Norwegian consumers	Haugeland & Kvisle, 2013
• Fiscal incentives, preferential access (lanes, parking) are important drivers of electric vehicle sales • States with consumer incentives (California, Georgia, Hawaii, Oregon, Washington) have 2-4 times greater than average electric vehicle uptake	Jin et al., 2014
• Consumer subsidies, infrastructure, and local policies are critical in driving electric vehicle uptake, and are causing large variation in electric vehicle uptake across 25 major U.S. cities • Cities with greater consumer incentives, charging infrastructure have 2-5 times greater electric vehicle uptake	Lutsey et al., 2015
• Vehicle efficiency and CO_2 standards through 2025 in the U.S. would only require that approximately 2% of new 2025 vehicles are electric	U.S. EPA and NHTSA, 2012
• Regulatory incentives within vehicle efficiency standards (e.g., 0 g/mile accounting, super credits) make the deployment of electric vehicles cost effective as compliance approach	Lutsey & Sperling, 2012
• Consumers tend to underestimate fuel savings from electric vehicles • Consumers are generally unaware of state and local incentives for electric vehicles	Krause et al., 2013
• Public announcements and marketing that raise awareness about the available consumer incentives and fuel savings are especially important	Krupa et al., 2013
• Charging and incentives are both important, infrastructure may be more important	Li et al., 2015
• Compared with workplace and public recharging, home recharging infrastructure improvements appear to have a greater impact on BEV-PHEV sales. • The impact of improved charging infrastructure is amplified by a faster reduction in battery cost	Lin & Greene, 2011
• Plug-in electric vehicles put greater demands on, and may require new approaches from, vehicle dealers to market and sell them	Cahill et al., 2014
• Regional weather differences can increase annual energy use by 15% • Differing marginal electricity sources can double the carbon emissions of electric vehicles	Yuksei & Michalek, 2015
• Long-term policies (e.g., ZEV program, incentives) are essential in the transition to electric drive fleet • Hydrogen refuelling infrastructure deployment must precede fuel cell electric vehicle market launch • Plug-in electric and fuel cell vehicles will both be important in the long term • Transition to an electric fleet will take decades and benefits are likely to be at least 10 times greater than the costs (technology, incentives, infrastructure)	Greene et al., 2014a, b
• Difficult to overcome electric vehicle price premiums by fuel savings alone • State and local electric vehicle purchasing incentives, preferential access would be important to encourage electric vehicle ownership and use	NRC, 2013a
• Lower operating costs (reduced fuel and maintenance costs) reduce the total cost of operating plug-in electric vehicles to make it lower than conventional vehicles	Davis et al., 2013
• Electric vehicle charging is predominately at home at 75%-80% across 16 US cities and regions • Plug-in hybrid electric vehicles with 38-mile range are accruing approximately similar annual electric miles as 84-mile range all-electric vehicles	INEL, 2014
• Public charging infrastructure, environmentalism, fuel price, electricity price, education, VMT per capita, HOV lane access, and incentives significantly correlated with electric vehicle sales	Vergis & Chen, 2014
• Market formation incentives, legitimation from sales targets, and positive externalities may be contributing to higher shares of PEV market shares	Vergis et al., 2014
• Home charger access could be more important than public charging infrastructure for electric vehicle interest	Bailie et al., 2015

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EMERGING BEST-PRACTICE PRINCIPLES

Based on the results of various government actions promoting electric vehicles and recent research on effective policies, some basic principles are emerging regarding electric vehicle policy. The policies would ideally be targeted at helping overcome known potential barriers to prospective electric vehicle users, including incremental vehicle cost, vehicle range, vehicle recharge time, and consumer awareness regarding electric vehicle ownership benefits. Many countries are seeking to overcome these barriers and promote electric vehicle technology, mobility, and sales.

Several basic design principles appear important in policy implementation. To promote vehicle sales to consumers, it appears to be important to make purchasing incentives significant in magnitude (e.g., above 15% of the purchase price) and available at the initial point of vehicle sale. Among the various forms of incentives, the use of vehicle purchasing tax exemptions and making the rebates applicable at the point of sale can be especially attractive. These forms of incentives ensure that consumers are not dissuaded by the delay in receiving the tax benefit or the uncertainly about its applicability due to their tax liability. Making the incentives applicable for vehicle leasing also helps mitigate consumer uncertainty about battery life and resale value. Another important factor involves committing to consumer purchasing incentives for a relatively long-term period (e.g., through 2020, not only renewed one year at a time) to send a clear signal to automakers to invest in and deploy the technology.

In addition, non-fiscal incentives of various types are also important for many consumers. For example, preferential parking access, preferential highway access, and free toll road access can be monetized and have the effective value to average consumers of well over $1,000 per vehicle in particular urban conditions, specifically when parking is relatively scarce and when driving is relatively congested. However, a key consideration is that such benefits must be well analyzed in advance to avoid over-use and minimize any potential public resistance.

Fully engaging electric power utilities with policies that encourage their active participation in promoting electric vehicles has only been partially explored, but is likely to be an important area in leading electric vehicle markets. Allowing and encouraging electricity providers to set preferential lower electricity rates for home, workplace, and public electric vehicle charging can be an important principle, and having "time-of-use" electric utility rates that link vehicle charging to off-peak rates tends to have advantages for both power utilities and consumers. Other beneficial policies, for example related to power utilities' role in public charging infrastructure, vehicle-to-grid activities, and low carbon fuel policies' ability to help finance charging infrastructure, are also emerging.

There are a number of policy design principles that would help overcome the barrier of electric vehicles' limited range. Deploying a more extensive public and workplace charging network, including strategic coverage for early adoption communities and high-traffic corridors, is a key focus area for many jurisdictions. These growing networks expand the effective range of electric vehicles, as well as increase the confidence of electric vehicle users. As previously illustrated in Figure 8 and 9, various markets are seeing greatly varying electric vehicle charging equipment (e.g., an order of magnitude difference in public chargers, and quick chargers, per capita). In addition to increasing the availability of public chargers, more widespread use of workplace charging is an area of emphasis that can effectively double the daily range for prospective electric vehicle

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commuters. Governments that are offering incentives for employers to install workplace charging infrastructure, as well as directly installing charging equipment for their own employees, are helping to mitigate electric vehicle range limitations.

Another way to mitigate the range limitation is the increased placement of electric vehicles in car-sharing fleets; this increases the use of electric vehicle activity, but allows consumers the option to select electric or non-electric vehicles depending on the necessary trip length. Another potential way to adjust policy design to better motivate increased vehicle range is to shift government consumer purchasing incentives to longer-range electric vehicles (e.g., greater subsidy for electric vehicle range of 200 or 250 kilometers). Making all consumer incentives that apply to plug-in electric vehicles equally applicable for hydrogen fuel cell vehicles, which tend to have significantly longer driving range, would also help avoid this potential barrier.

Several potential policy design principles could help overcome the barrier of electric vehicles' slow recharge time, compared with the refueling time of gasoline or diesel vehicles. Increased deployment of public fast charging is clearly in evidence in some jurisdictions (e.g., Norway, Oregon, and Japan), and this provides greater opportunities for 15-40 minutes of charging to work within more prospective electric vehicle users' average travel patterns. Governments can encourage such rapid charging stations with tax incentives for workplace or third party installations, or by directly funding or directly deploying the infrastructure through federal, state, or city government agencies. Implementing incentive policies that are inclusive of hydrogen fuel cell vehicles ensures that this technology, which does not have the charging time limitation, is also promoted.

There are several other potential government actions that could help overcome the barrier of prospective consumers' knowledge and awareness about electric vehicles. It is evident from the research that most prospective consumers are not well informed about the existing policy incentives or the potential fuel savings from replacing their conventional vehicles with electric vehicles. Education and awareness activities would ideally involve state and local governments, as well as utilities, providing information about relevant purchasing and charging incentives at dealerships, on websites, and through advertising campaigns.

Providing information to prospective electric vehicle consumers on vehicle ownership fuel-saving benefits on websites and consumer labels is an important basic step. Public events (e.g., ride-and-drive with public officials) and increased placement of electric vehicles in government fleets increase awareness regarding the new technology. Finally, the placement of vehicles in company, rental, and car-sharing fleets can also help to overcome the basic foundational lack of awareness and comfort regarding available electric vehicle models.

Table 5 summarizes actions to overcome potential barriers to greater electric vehicle uptake and use. The actions would aim to increase awareness among consumers about electric vehicles, reduce the effective electric vehicle ownership and operational cost, and help support increased vehicle range and reduced recharging times. Example areas where such policy actions are in place are listed in the final column.

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Table 5. Electric vehicle adoption barriers and policy actions

Potential barrier	Potential actions to help overcome barrier	Examples of regions with action
Vehicle ownership cost	Provide **fiscal incentives** to defray incremental upfront cost	France, Norway, Netherlands, U.K., U.S.
	Extend electric vehicle **fiscal incentives to 2020** or later	California, China
	Offer **non-fiscal incentives** (e.g., preferential road, parking, lane access) to provide effective monetary benefits to vehicle users	California, China, Norway
Vehicle range	Deploy **extensive plug-in vehicle charging network**, including strategic coverage for early adoption communities and high-traffic corridors	Japan, Norway, U.K.
	Deploy **extensive hydrogen refuelling network**, including strategic coverage for early adoption communities and high-traffic corridors	California, Germany, Japan, Netherlands, U.K.
	Encourage and create incentives for **workplace charging** infrastructure	U.S.
	Placement of vehicles in car-sharing **fleets**	France, Germany
	Introduce **minimum range requirements** to shift public fiscal and non-fiscal incentives to greater incentivize longer-range electric vehicles	
Vehicle recharge time	Provide **charging infrastructure incentives** for private deployment of more and faster at-home, workplace, public charging stations	
	Deploy extensive **public quick charging network**	Japan, Norway
Consumer knowledge and awareness	Provide information regarding state, local, and utility incentives widely, at dealerships, on websites, through advertising in **broad awareness campaign**	California, U.K.
	Provide **cost evaluation tools and information** to prospective electric vehicle consumers on vehicle ownership fuel-saving benefits (websites, consumer labels)	
	Conduct **public events** (e.g., ride-and-drive with public officials) to increase awareness and encourage first electric vehicle experiences	
	Place electric vehicles in government, company, and car-sharing **fleets**	China, Québec

RECOMMENDED RESEARCH

There are of many missing pieces in the movement to better understand what it will take to accelerate the deployment of electric vehicles in the marketplace in the decades ahead. The research summarized above, as well as the prevailing policy questions in each of the major automobile markets, hint at many of the areas that warrant deeper investigation including fiscal, regulatory, technical, and infrastructure aspects of electric vehicles.

Among the potential questions of high interest for electric vehicle policy are the following:

» *Getting the right mix of incentives and promotion actions*: With all the competing new research on electric vehicle promotion actions, are best-practice recommendations for governments emerging? For example, research could continue to inform whether vehicle purchasing subsidies of particular types, charging infrastructure rollout of a particular type or distribution, particular local policies, and particular awareness activities are proving to be most effective in influencing electric vehicle uptake. A rigorous review of the literature, including

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the studies listed in Table 4, could help distill lessons about critical and non-critical policy actions.

» *Matching future purchasing incentives with technology improvement*: How long might electric vehicle consumer purchasing incentives be needed? How might electric vehicle consumer purchasing incentives be incrementally reduced over time? In particular, a related question is whether electric vehicle incentives can be reduced, corresponding to technology improvements in the 2015-2025 time frame, while sustaining market growth. For example, if the next-generation PHEV and BEV technologies see reduced battery costs by given amounts (e.g., to less than $250/kWh), then subsidies might be reduced by a given amount. As a result, research into how the given cost-per-kilowatt reductions could allow some combination of greater range, less expensive cars, and a tapering off of incentives might help give policymakers and automaker perspective on the public investment for the subsidies. In addition, subsidies could evolve to provide greater incentives for second-generation technology. For example, electric vehicle subsidies could evolve to be applicable only to next-generation vehicles with greater range (e.g., only 200+ mile electric vehicles), which therefore better meet more widespread consumer constraints.

» *Focusing on the ideal types of consumer incentives*: What are the ideal types of subsidies to motivate prospective electric vehicle consumers? Variations include the mechanism (e.g., rebate, sales tax exemptions, annual tax exemptions), the timing of the incentive for consumers (e.g., point of sale), the applicable technologies (e.g., inclusion of plug-in hybrids, threshold battery capacity), and the time frame of the incentives (e.g., through 2020). A study of the rationale and effectiveness of subsidy types would also help inform how best to evolve existing subsidies as the next-generation of electric vehicles are commercialized and how they could best meet a broader customer base, from early adopters, to first followers, to mainstream consumers. An analysis that includes different national, regional, and local incentives, and how they affect the market would help in informing which types of incentives are most important.

» *The role of utilities in accelerating electric vehicle deployment*: How could electric power utilities gain from increased deployment of electric vehicles, and how might utilities provide direct incentives to electric vehicle owners to encourage greater use, lower carbon emissions, and reduced operating costs? At the same time, what are the issues for utilities regarding electric vehicles that must be solved? It is increasingly clear that there are synergies with lower-cost electricity for consumers and benefits for utilities and other fuel providers supplying the electricity (e.g., Ryan & Lavin, 2015). There also might be a great opportunity to capture and store renewable electricity generation that is otherwise not well matched to electricity demand, in electric vehicles. Distilling which governments around the world have had important lessons learned, have found particular problems, and are aligning utility and consumer interest could be helpful in prioritizing future policy.

» *Deploying charging infrastructure with increased electric vehicle sales*: Is there an ideal amount, type, and rate of electric vehicle charging infrastructure (home, workplace, public fast charging per capita) that best encourages electric vehicle purchasing and use? The electric vehicle charging equipment across cities, states, and countries varies greatly and is a key factor for the range and utility of electric vehicles. Improved tracking and analysis about the use of public and workplace charging would help direct future policy and infrastructure investments. Linking

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various types of charging equipment (per capita or per vehicle) with increased electric vehicle deployment in future years could help increase the attractiveness and use of electric vehicles. With more rigorous analyses of the diversity of charging deployment to date, it is plausible that some clear lessons could emerge that might be generally applicable for future government investments between consumer subsidies and charging infrastructure.

- *Electric vehicle model availability*: What is the role of the number of electric vehicle models available in given markets in the sale of the vehicles? As nearly every major automaker introduces electric vehicle models into the marketplace, electric vehicle awareness and sales continue to increase. However, some countries are seeing far more models and far more extensive attempts by companies to sell the models across various regions. Most electric vehicle models are sold in just a few automobile markets, and within those markets sales are greatly concentrated in just several areas. Some markets with relatively high consumer incentives appear not to have much electric vehicle uptake, with one plausible explanation being that these markets are not among the early focus areas for automaker launches of the new models. On the other hand, there are markets where relatively few electric vehicle models are available, but early sales uptake has been relatively high. A study that analyzed electric vehicle availability would help inform on the importance of electric vehicle model availability in driving the early electric vehicle market.
- *Long-term synergy between electric and autonomous vehicles*: With the recent excitement over autonomous or self-driving vehicles, are there potential synergies between the two technologies in the 2020-2030 time frame that might offer greater potential benefits in electric vehicle deployment and environmental benefits? Conversely, perhaps there could be issues or risks of the technologies simultaneously entering the market. For example, automobile companies' technology budgets or unique company strategies could slow the rollout of either autonomous or electric technologies. Or the two technologies could put different or increasing demands on infrastructure, consumers, energy use, and emissions.
- *Importance of green supply chains*: Electric vehicles continue to be subject to some amount of skepticism and backlash from both a consumer and political perspective due to questions about how clean the upstream power source is. In some cases this is related to legitimate questions about environmental benefits but often is related to misinformation in reporting of various life cycle emissions analyses. What are the full life cycle emissions of electric vehicles across the major auto markets? How important are the life cycle carbon and energy footprint to potential consumers? A synthesis of existing research into the impact of the primary electricity energy sources, vehicle manufacturing emissions, and these impacts' trends in the future could help elucidate when, where, and how electric vehicles are most beneficial to climate. Such a study could also report on findings related to best practice policies, utility practices, and information programs.

New analysis, and synthesis of existing experiences among leading electric vehicle stakeholders, namely government and industry, could help answer these questions. As introduced above, a number of studies have begun to answer these questions, but only in isolated circumstances, with limited 2011-2014 data, and generally looking within just one major automobile market. Now, as data on differing policy approaches proliferate across different markets, far deeper analyses are possible and could be helpful in charting out more informed electric vehicle policy in the 2015-2016 time frame.

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IV. SUMMARY FINDINGS REGARDING GLOBAL COLLABORATION

This section summarizes several key findings on the 2014 state of the global electric vehicle market, postulates several potential zero-emission vehicle targets that could help set policy to drive electric vehicle promotion policies in leading governments, and provides summary thoughts on the potential importance of increased global collaboration.

IMPLICATIONS FOR FUTURE ZERO-EMISSION VEHICLE GOALS

The findings of this report indicate that global electric vehicle sales are increasing, especially in several particular automobile markets. Figure 2 summarizes electric vehicle sales by the major regions of China, Europe, Japan, and the U.S. Global annual electric vehicle sales reached approximately 100,000 in 2012, 200,000 in 2013, and 300,000 in 2014. In 2014, Europe and China in particular saw greater increases in electric vehicle sales. Leading markets in sales volume within Europe are the Netherlands, France, Norway, and the UK. Based on this assessment, these regions are all implementing diverse electric vehicle promotion actions, but their policy incentives and infrastructure differ considerably, and they are seeing varying electric vehicle deployment shares.

Looking forward to the future market penetration of zero-emission vehicles, research studies have led to greatly divergent future projections. Analyses of particular markets, under varying assumptions for technical advancement and increased policy support (e.g., R&D, infrastructure, regulation) found 20% to more than 50% electric vehicle shares, including plug-in and fuel cell electric, were possible in leading electric-drive vehicle markets in the 2025-2030 time frame; however, lesser technology and policy assumptions generally pointed toward 5%-10% electric vehicle share in the same time frame. These analytical scenarios provide potential bounds for possible electric vehicle deployment in leading electric vehicle markets around the world.

A number of governments have sought to put forward particular electric vehicle deployment goals to provide milestones and aspirational visions for how far and how fast they would like to see the market grow. Such targets are shown in Table 1. The various national goals, if simply summed, amount to at least 15 million cumulative electric vehicle sales globally by 2020, and more than 25 million electric vehicles in the 2025-2030 time frame. In compiling these targets in 2013, the Clean Energy Ministerial indicated that the nations' targets would result in approximately 6 million electric vehicle sales per year in 2020 and include 20 million cumulative electric vehicles by 2020.

Some governments have acknowledged that the original electric vehicle goals are not likely to be met (e.g., Shephardson, 2015). Because 2010-2014 sales have been modest compared to the original goals (i.e., 300,000 global sales per year in 2014), global growth in electric vehicles sales would have to increase rapidly to reach those goals. Global electric vehicle annual sales growth would need to average greater than 65% per year to get back on track for the 6 million per year sales goal, and 75% per year to be on track for 20 million cumulative global electric vehicle goal by 2020. Another way to put the international 20-milllion-electric-vehicle goal in perspective is to compare it to the hybrid vehicle growth by the leading hybrid manufacturer. Toyota went from about 300,000 annual global hybrid sales in 2006 to roughly 1.4 million per year in 2014, selling more than 6 million hybrids in that period. To achieve 20 million electric vehicles by 2020, three companies would have to simultaneously accomplish the same growth

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in electric vehicle sales from 2014-2020 that Toyota demonstrated in hybrid sales from 2006-2014.

As various leading countries expand their electric vehicle activities and contemplate longer-term transportation, energy, and climate policy, new electric vehicle deployment goals for 2025-2035 could be considered. Now, in 2015, governments have a far better understanding of electric vehicle deployment constraints, have begun adopting more comprehensive promotion policies, and are more focused on long-term climate targets. Based on plausible electric-drive market growth trajectories, as well as putting the transport sector on a path toward long-term climate stabilization goals, new mid-term targets are postulated here.

Table 6 summarizes potential metrics for zero-emission vehicle goals, citing examples of such goals that have been announced in various circumstances and postulating several potential plausible goals for zero-emission vehicles in the 2025-2035 time frame. Such goals could provide approximate extensions to previously announced goals, and they could do so with levels of deployment that are plausible and ambitious for interested governments to help guide future zero-emission vehicle policy. The potential targets and their relative merits are discussed below.

Table 6. Metrics, examples, and potential zero-emission vehicle goals for leading governments

Target metric	Existing examples	Potential 2025-2035 targets
Cumulative sales target	• At least 3.3 million cumulative electric vehicle sales by 2025 *(U.S. eight-state agreement)* • At least 20 million cumulative electric vehicle sales by 2020 *(Clean Energy Ministerial EVI goal)* • At least 5 million hybrid and plug-in electric vehicles *(China New Energy Vehicle goal)*	• At least 30 million cumulative zero-emission vehicles are sold by 2025 • At least 90 million cumulative zero-emission vehicles are sold by 2030
Annual sales	• At least 6 million electric vehicle sales per year by 2020 *(Clean Energy Ministerial EVI goal)*	• At least 30 million zero-emission vehicle sales per year by 2035
Sales share	• At least 10% of new sales are battery electric vehicles by 2020 • *(Renault-Nissan CEO Carlos Ghosn)* • At least 20% of new sales are plug-in hybrid and battery electric vehicles by 2020 *(Mitsubishi)* • At least 15%-22% of new vehicle sales are plug-in and fuel cell electric vehicles by 2025 *(California Zero Emission Vehicle program)*	• At least 20%-30% of new vehicle sales are zero-emission vehicles by 2030 • At least 35% of new vehicle sales are zero-emission vehicles by 2035
Electric mobility share	• At least 30% of passenger vehicle activity is via electric vehicles by 2030 *(UN-Habitat Urban Electric Mobility Initiative)*	• At least 15% of national passenger vehicle activity is via zero-emission vehicles by 2035

The four example goals in the right-most column in Table 6 reflect future year sales, cumulative deployment, sales share, and zero-emission vehicle deployment that are approximately consistent with one another, depending on assumptions for relative vehicle sales growth across the countries. These goals relate to the leading 2015 electric vehicle markets (i.e., China, Europe, Japan, and the U.S.) seeing an average compounded annual increase in zero-emission vehicle sales of approximately 25% for 2015-2035 (greater in earlier years, lower in the later years). For this illustrative assessment of future goals, the remainder of the world vehicle market is assumed to lag the four major leading markets in zero-emission vehicle sales share by five years. The numbers presented here assume that Europe, Japan, and the U.S. experience

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overall vehicle market growth of 1% per year, and China and other nations experience annual overall vehicle market growth of 4% per year through 2035. To provide a sense of the relative optimism of this global electric drive scenario, it requires that the leading markets of Europe, China, Japan, and the U.S. (as a whole) lag the California market's ZEV requirements by about three years (i.e., 15% in 2028 compared to California's 2025). The rest of the world is assumed to lag the California ZEV program timeline by about 10 years.

Several considerations, assumptions, and relative merits related to the various zero-emission vehicle goals are postulated in Table 6. The top two example metrics listed in the table, for cumulative sales (90 million by 2030) and annual sales (30 million zero-emission vehicle sales per year by 2035) both relate to overall global goals. Any such long-term cumulative or annual sales goals could provide milestones on the path toward long-term electrification and give a benchmark related to the industry's movement toward larger economies of scale. Global vehicle sales could greatly increase from 2014 to 2030, and a fixed zero-emission vehicle sales target in 2030 could mean a far higher or lower zero-emission vehicle sales share. Depending on how quickly the overall automobile market grows — for example, up to 100 million or 150 million vehicles per year — then 30 million annual zero-emission sales could amount to 20% up to 30% of the total sales share. A volume-based global sales target could potentially function better as broader group target (e.g., for China, Europe, Japan, and the U.S.) because it takes out country-to-country fluctuations and collectively commits countries to a common global goal.

The two share-based zero-emission vehicle deployment goals, the bottom two rows in Table 6, also have relative merits and considerations. Contrary to volume-based zero-emission vehicle deployment goals, share-based goals could have greater meaning on an individual country basis. Zero-emission vehicle share and electric mobility goals might provide clearer links to long-term transportation climate stabilization goals, namely because governments could be interested in demonstrating progress toward near 100% zero-emission vehicle deployment in the 2040-2050 time frame. In addition, share-based goals allow each country to track the increase in its zero-emission vehicle share toward a future goal (e.g., 35% zero-emission vehicle share by 2035), as well as compare against other markets around the world. As a result, a percent-vehicle-share, more so than a cumulative-million-vehicle, goal provides a direct indication of the shift from conventional to electricity- or hydrogen-based energy sources. The electric mobility, or electric vehicle usage, share goal would similarly allow each country to better track its progress in electrifying the transport sector. However, zero-emission vehicle usage goals would have an associated difficulty in being able to track the actual vehicle activity over time, and such a goal is also more uncertain based on vehicle retirement assumptions.

Figure 10 illustrates a trajectory of zero-emission vehicle deployment that approximately matches the four goals postulated in Table 6. To summarize the key assumptions, this level of zero-emission vehicle deployment assumes an average 25% compounded global annual zero-emission vehicle sales growth from 2015-2030. This includes faster growth in the earlier years in China, Europe, Japan, and the U.S., and zero-emission vehicle shares in the rest of the world experience a five-year delay from those leading markets. The trajectory shown in the figure results in more than 30 million zero-emission vehicles sales in the four leading markets in 2035 (more than 35 million including the rest of the world), more than 90 million cumulative zero-emission vehicle sales by 2030, and 35% zero-emission vehicle sales share globally in 2035. These goals would roughly translate

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to 15% of national automobile usage being from zero-emission vehicles in the four leading zero-emission vehicle markets by 2035.

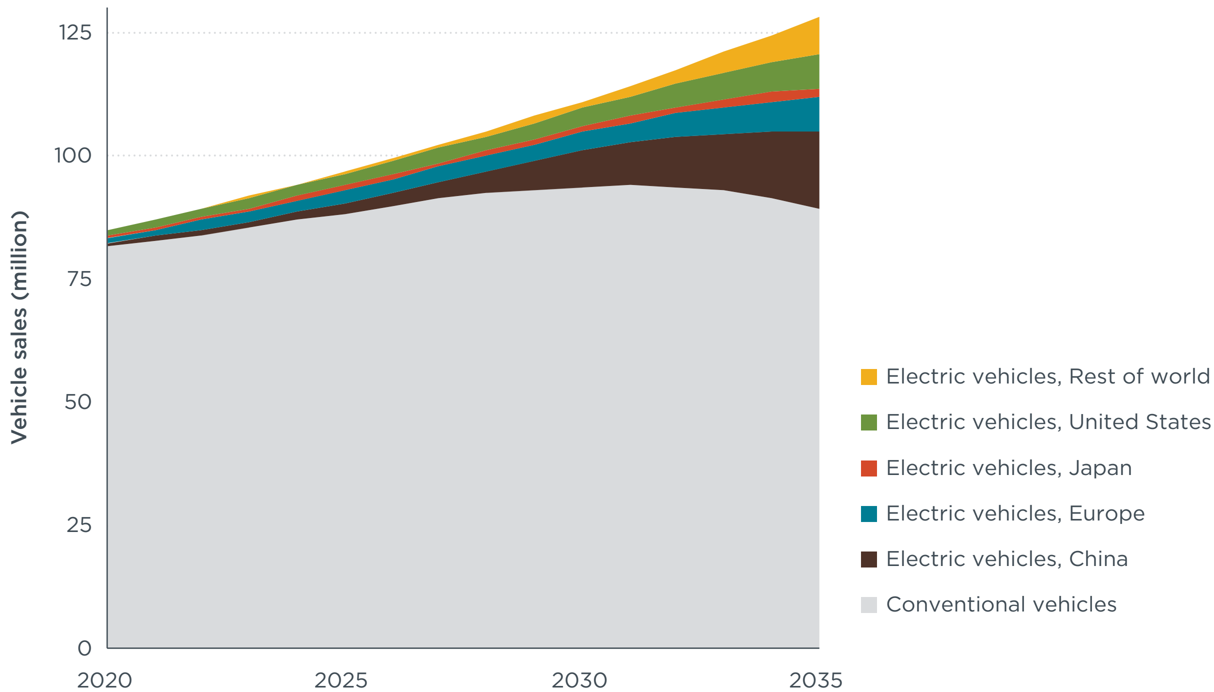

Figure 10. Illustrative scenario for increased 2020-2035 zero-emission vehicle deployment goals

CONCLUDING DISCUSSION

A key objective of this report is to investigate current and potential future government actions that can be taken to help drive the next-generation electric-drive technologies into the marketplace. Indirectly, then, the goal is to help accelerate zero-emission vehicle sales to drive up economies of scale, and thus help bring forward lower cost electric-drive technologies as much as possible in the 2015-2035 time frame. In the context of this report, the goal is broader than surmounting the individual market barriers; it is creating sustainable markets for automakers to make larger investments to roll out global electric vehicle platforms and launch new models in multiple markets. Simultaneously using public policy to help scale up supply chains, charging infrastructure, and consumer awareness about electric vehicles will be critical in building the full electric-drive ecosystem.

With this goal in mind, Table 5 provides example actions, and a template, for governments to continue to adopt similar such policies. Looking beyond the immediate time frame, the more successful each individual market is, the more it could lead to greater global success in commercializing electric vehicles.

Spurring automobile manufacturing companies toward higher-volume deployment of zero-emission vehicle technology is a global challenge. The policies described above, if more fully adopted, could help provide durable and consistent incentives, for manufacturers and consumers alike, across leading auto markets globally. Vehicle manufacturing companies choose the early launch regions where models are made available and where the first tens and hundreds of thousands of vehicles are being

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deployed. They also dictate how extensive and widespread their efforts are with dealer training, company sales incentives, and marketing. Examples of the sort of electric vehicle deployment approaches that result from increased global policy activity are seen in recent announcements by Renault-Nissan, General Motors, and Tesla. These companies are proceeding to roll out electric vehicle models with increased vehicle range, reduced cost, and higher volume in their second- and third-generation electric vehicle models. Global multiple-market launches for greater economies of scale at higher manufacturing volume are likely to be even more important for electric vehicles than conventional vehicles. Systematic policy promotion of electric vehicles by leading governments around the world facilitates more of these big moves by automakers to be made more quickly.

Overtaking the incumbent internal combustion technology will require global battery and fuel cell technology improvements, global manufacturing scale, cost reduction, and global electric vehicle platforms. The decades-long transition to an electric-drive fleet will also require global cooperation on what policies, incentives, infrastructure, and support activities create the right recipe to sustain growth in the new technology. Based on the findings, we draw the following three conclusions:

Policy action by leading governments is spurring electric vehicle deployment. The most comprehensive electric vehicle promotion actions globally are in Norway, the Netherlands, and California, and these actions are resulting in electric vehicle deployment that is more than 10 times the international electric vehicle uptake. More broadly, the actions of the governments of China, France, Germany, Japan, the Netherlands, Norway, the U.K., and the U.S. are leading with policy incentives and infrastructure investments, and these countries make up more than 90% of the world's electric vehicle market.

Best practices in electric vehicle promotion policies are emerging. From the early electric vehicle promotion activity, best practices to accelerate electric vehicle deployment are beginning to emerge. Increasingly stringent efficiency standards, electric vehicle research and development support, and national electric vehicle planning appear to be necessary but insufficient actions to grow the electric vehicle market. Consumer incentives that reduce the cost of ownership are important to improve the consumer proposition on the new advanced electric technologies. Increasing the availability of home, workplace, and public electric charging infrastructure is also of high importance, and several leading automobile markets (e.g., Japan, Norway, and parts of the U.S.) have far more extensive charging infrastructure per capita than others. It is increasingly becoming clear that a comprehensive portfolio of national, state, and local actions is critical for the increased deployment and use of electric vehicles.

Greater international collaboration could better leverage existing efforts to promote zero-emission vehicles. This assessment points to several possible ways that governments can better collaborate and coordinate. The establishment of a zero-emission vehicle deployment target (e.g., 35% of automobile sales being zero-emission vehicles and 30 million annual global zero-emission vehicle sales) and an electric mobility target (e.g., at least 15% of vehicle use being electric) for 2035 would help in establishing a common long-term global electric-drive vision. Such goals would send clear signals about the pace of development and amount of resources that will be needed. Further coordinated research on policy effectiveness

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would further help prioritize government actions that are most important in increasing zero-emission vehicle uptake and use.

The transition of the automobile sector to electric drive will require not only sustained policy incentives but also increased communications about progress and policy learning. In these early years in the transition, there is much to learn from every region's experience in the rollout of zero-emission vehicles. Developing the new zero-emission vehicle market will require global scale, in the tens of millions of vehicles, to achieve lower cost and long-term success. Automakers are learning from their first- and second-generation electric vehicles and increasingly developing global electric-drive vehicle platforms and launching them in multiple markets. Meeting long-term climate goals will also likely include diffusion of hydrogen fuel cell vehicle technology into the fleet, as well as electric-drive technologies into heavy-duty vehicles, so the technology and policy advancement into these areas will also be important over time. Similarly, governments ideally will have to continue to learn from initial policy experiences and embrace common international best policy practices in many markets across the globe. International collaboration will be a critical step toward greater volume and a long-term market transformation to a zero-emission vehicle fleet.

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