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File No. ER-2016-0179

DIRECT TESTIMONY

OF

NOAH GARCIA

ON

BEHALF OF

NATURAL RESOURCES DEFENSE COUNCIL

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Introduction and Qualifications

Q. Please state your name and address.

A. My name is Noah Garcia and my business address is 20 North Wacker Drive, Chicago, Illinois 60606.

Q. What organization are you employed at and what is your position?

A. I work at the Natural Resources Defense Council (NRDC) as a Schneider Fellow. NRDC is a non-profit environmental organization with more than two million members and online activists. NRDC uses law, science, and the support of its members to ensure the rights of all people to clean air, clean water, and healthy communities. One of NRDC's top priorities is to reduce transportation sector air pollutants.

Q. Please describe your educational background and work experience.

A. My educational experience includes a Bachelor of Arts in International Relations with a concentration in economics from Stanford University and a Master of Arts in Public Policy from Stanford University with a concentration in energy and environmental policy.

During my time at Stanford, I was a research assistant at the Steyer-Taylor Center for Energy Policy and Finance and analyzed the role of policy and market drivers behind clean energy development. At NRDC, I have advocated and provided support for state-based clean energy policies in various legislative and regulatory environments in Illinois. I have also advocated for and collaborated with partners on utility-driven transportation electrification programs in several jurisdictions in the Midwest. In Missouri, I participated in the *Working Case Regarding Electric Vehicle Charging Facilities* (File No. EW-2016-0123), providing substantive comments and materials on the necessity of charging stations to the development of the plug-in electric vehicle (PEV) market and how utilities could beneficially engage in this space. As part of the docketed proceeding, I presented at the Missouri Public Service Commission's EV workshop on May 25, 2016; along with Sierra Club and the Electric Power Research Institute, we expanded on the environmental benefits of vehicle electrification and the need for strategic deployment of charging infrastructure to realize these benefits.

Purpose of Direct Testimony

Q. What is the purpose of your testimony?

A. The purpose of this testimony is to respond to the Commission order issued August 29th, 2016 soliciting more information on plug-in electric vehicle (PEV) rates that follow a time-of-use (TOU) rate structure and TOU rates more broadly.[1] In order to fully address the questions surrounding these rates, I expand on the following topics:

1) The relationship between electric vehicles and electric vehicle charging stations;
2) The public policy rationale for utility investments to accelerate transportation electrification;
3) Rates and rate structures that maximize the benefits of transportation electrification; and
4) The need for simple nudges to ensure PEV load does not strain, but supports the electrical grid and to ensure PEV drivers maximize their fuel savings relative to gasoline.

I recommend that Ameren Missouri consider how best to default PEV drivers onto time-varying rates that would maximize their fuel savings relative to gasoline and encourage charging that improves the utilization of the grid to the benefit of all utility customers.

The Relationship between Electric Vehicles and Electric Vehicle Charging Stations

Q. Please describe the current status of national transportation sector greenhouse gas and criteria pollutant emissions.

A. In the summer of 2016, the US Energy Information Administration found that for the first time since 1979, carbon emissions from the transportation sector surpassed those from the power

[1] "Order Directing Consideration of Certain Questions in Testimony," File No. ER-2016-0179, Issued August 29th, 2016

sector in the US and increased to 1,876 million metric tons (MMt).[2] Light-duty vehicles (LDVs) are responsible for over half of the carbon emissions associated with the transportation sector.[3] Moreover, these LDVs are responsible for elevated levels of harmful criteria pollutants in many urban areas. It is estimated over 50,000 Americans in the lower 48 states die prematurely from traffic pollution every year, which is over one-and-a-half times as many as die in traffic accidents.[4] Any comprehensive effort to beneficially reduce carbon emissions and criteria pollutant emissions pursuant to the Clean Air Act must consider how to effectively decarbonize the domestic vehicle fleet.

Q. Does transportation electrification play a significant role in achieving carbon dioxide reductions?

A. Numerous independent studies have come to the same conclusion: reducing greenhouse gas emissions to 80 percent below 1990 levels by 2050 will require a dramatic shift to electric-drive vehicles powered by zero-emitting energy sources.[5] Because just 15 to 17 million passenger vehicles are sold each year in the U.S., it will take decades to transform the existing U.S. stock of 250 million vehicles. To meet long-term global warming pollution reduction targets, studies have estimated that PEVs will need to account for 40 percent or more of new vehicle sales by 2030.[6]

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[2] Doug Vine, "Transportation Emissions Roll Over Power Sector Emissions," Center for Climate and Energy Solutions, http://www.c2es.org/blog/vined/transportation-emissions-roll-over-power-sector-emissions (accessed November 22, 2016)

[3] "Sources of Carbon Dioxide Emissions," U.S. Environmental Protection Agency (EPA), https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#transportation

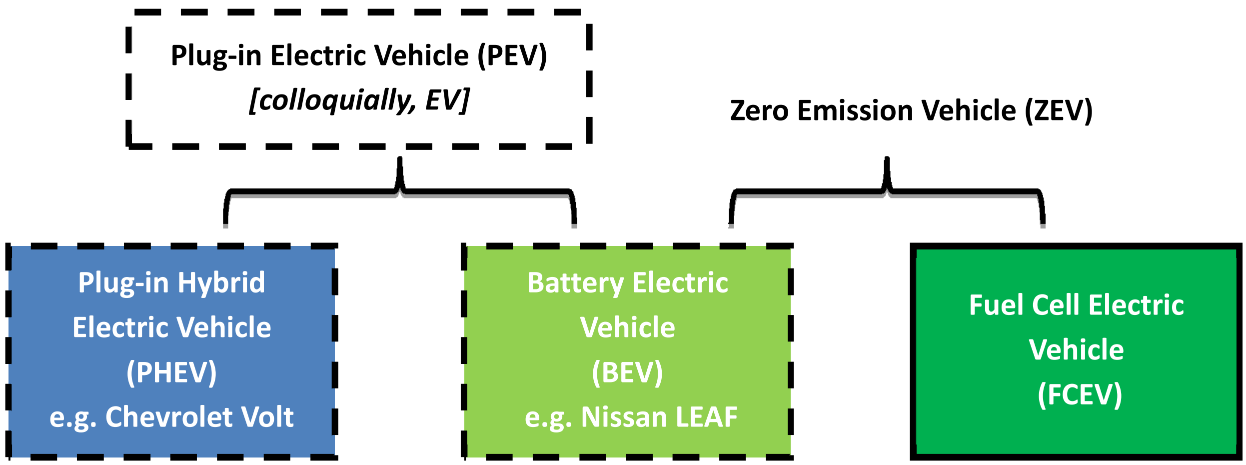
[4] Fabio Caiazzo et al., *Air pollution and early deaths in the United States*, Atmospheric Environment, 2013; National Highway Traffic Safety Administration, Fatality Analysis Reporting System (FARS) Encyclopedia.

[5] California Council on Science and Technology, *California's Energy Future*, May 2011; Williams et al., *The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity, Science*, January, 2012; Joshua Cunningham (Air Resources Board), *Achieving an 80% GHG Reduction by 2050 in California's Passenger Vehicle Fleet*, SAE International Journal of Passenger Cars, December, 2010; Max Wei et al., *Deep carbon reduction in California require electrification and integration across economic sectors*,. Environ. Res. Lett. 8, 2013; Melaina and Webster, *Role of fuel carbon intensity in achieving 2050 greenhouse gas reductions within the light-duty vehicle sector*, Environ. Sci. Technol. 45, 3865–3871, 2011; International Energy Agency, *Transport, Energy, and CO2: Moving Towards Sustainability*, OECD/IEA, 2009; National Research Council, *Transitions to Alternative Vehicles and Fuels*, The National Academies Press, 2013.

[6] California Air Resources Board, *Vision for Clean Air: A Framework for Air Quality and Climate Planning*, Public Review Draft, June 27, 2012; and National Research Council, *Transitions to Alternative Vehicles and Fuels*, National Academies of Science, 2013.

Regrettably, the transportation policy space rivals the traditional utility policy world in its use of acronyms. Figure 1 harmonizes the categories of vehicle technology described in sources used in these comments.

Figure 1: Vehicle Types



This testimony focuses on plug-in electric vehicles (PEVs), commonly referred to as "electric vehicles" or "EVs," which can be charged with electricity from the electric grid. This includes both Battery Electric Vehicles (BEVs) that rely entirely upon electricity and Plug-in Hybrid Electric Vehicles (PHEVs) that rely upon electricity for daily driving needs, but use gasoline for longer trips. While PHEVs can be driven primarily on electricity, because they have tailpipe emissions when operating on gasoline, they are not referred to as Zero Emission Vehicles (ZEVs).

Q. Is a lack of charging infrastructure a barrier to the acceleration of EV adoption?

A. Yes, a dearth of strategically located charging infrastructure presents a significant barrier to transportation electrification and this phenomenon is recognized and well-documented by the National Academies of Science.[7] Achieving significant PEV penetration levels requires the development of an extensive, well-planned charging station network that provides value to drivers.

[7] Kassakian, John G., David Bodde, and Jeff Doyle. "Overcoming Barriers to Deployment of Plug-in Electric Vehicles." The National Academies Press. 2015.

Q. Please identify the target market segments where charging infrastructure will have the greatest impact in accelerating vehicle electrification.

A. NRDC finds that standard charging at home and at workplaces and other long dwell time locations, and fast charging at public locations such as highway corridors are critical to accelerate PEV adoption. The use and value of charging stations will vary depending on where they are sited, but these market segments present a significant opportunity to advance transportation electrification.

The majority of PEV charging takes place at the home, and this is the most crucial segment to spur PEV adoption. In a recent report of the National Research Council of the National Academies of Science (commissioned by the Department of Energy at the direction of the U.S. Congress) entitled, "Overcoming Barriers to the Deployment of Plug-in Electric Vehicles," the authors characterize home charging as follows:

> *First, home charging is a virtual necessity for all EV classes given that the vehicle is typically parked at a residence for the longest portion of the day. Accordingly, the home is (and will likely remain) the most important location for charging infrastructure, and homeowners who own EVs have a clear incentive to install home charging. Residences that do not have access to a dedicated parking spot or one with access to electricity clearly have challenges to overcome to make EV ownership practical for them.*

Following this argument, drivers are very unlikely to purchase plug-in vehicles if they cannot plug in at home, where cars are typically parked for 12 hours out of the day.[8] Unfortunately, less than half of U.S. vehicles have reliable access to a dedicated off-street parking space at an owned residence where charging infrastructure could be installed.[9] To date, almost 90 percent of PEV drivers live in single-family detached homes.[10] As the National Research Council notes: "Lack of

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[8] Adam Langton and Noel Crisotomo, *Vehicle-Grid Integration*, California Public Utilities Commission, October, 2013, p. 5; *see also* Marcus Alexander, *Transportation Statistics Analysis for Electric Transportation*, Electric Power Research Institute, December, 2011.

[9] Traut et al., *US Residential Charging Potential for Electric Vehicles*, *(Transportation Research Part D)*, November, 2013.

[10] Center for Sustainable Energy, *California Plug-in Electric Vehicle Owner Survey Dashboard*.

access to charging infrastructure at home will constitute a significant barrier to PEV deployment for households without a dedicated parking spot or for whom the parking location is far from access to electricity."[11] It is essential for the PEV market to move beyond single family detached homes to scale up to achieve the benefits described in the most recent Missouri Comprehensive State Energy Plan.[12] Installing charging stations at apartment buildings and other multi-unit dwellings could unlock the potential for a broader, younger, and more diverse market for PEVs. This targeted approach to charging station deployment at multi-unit dwellings has been adopted by San Diego Gas and Electric, Southern California Edison, Pacific Gas & Electric and Avista Utilities in their respective approved PEV infrastructure programs.[13]

The range-extending function and visibility of charging stations in the social context of a workplace can also spur additional vehicle sales. Nissan credits a workplace charging initiative with a five-fold increase in monthly PEV purchases by employees at Cisco Systems, Coca Cola, Google, Microsoft, and Oracle.[14] Likewise, the Department of Energy recently concluded that employees of companies who participated in its "Workplace Charging Challenge" were 20 times more likely to drive a PEV than the average worker.[15] Workplace charging can effectively double the electric miles driven on a daily basis by PEVs. This is especially important for plug-in PHEVs that can operate on both electricity derived from the grid or gasoline, which have shorter all-electric ranges than BEVs.[16] Workplace charging can also improve the utility of BEVs and help alleviate "range anxiety" for drivers who want to make the occasional longer trip after work.

In brief, workplace charging can drive the adoption of both BEVs and PHEVs, as summarized by the National Research Council:

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[11] National Research Council of the National Academies of Sciences, *Overcoming Barriers to the Deployment of Plug-in Electric Vehicles*, the National Academies Press, 2015, p. 116.

[12] Department of Economic Development – Division of Energy, *Missouri Comprehensive State Energy Plan*, October 2015, p. 104 available at: https://energy.mo.gov/energy/docs/MCSEP.pdf

[13] Herman K. Trabish, "If you build it, will they charge? Utilities cautious in plans to spur electric vehicle adoption," August 10, 2016, available at http://www.utilitydive.com/news/if-you-build-it-will-they-charge-utilities-cautious-in-plans-to-spur-elec/423982/

[14] Brandon White, Senior Manager of EV Sales Operations, Nissan North America, at EPRI Plug-in 2014, "Taking the 'Work' Out of Workplace Charging."

[15] U.S. Department of Energy, *Workplace Charging Challenge – Progress Update 2014: Employers Take Charge*.

[16] California New Car Dealers Association, *California Auto Outlook*, February, 2015.

> *Charging at workplaces provides an important opportunity to encourage the adoption of PEVs and increase [electric vehicle miles traveled]. BEV drivers could potentially double their daily range as long as their vehicles could be fully charged both at work and at home, and PHEV drivers could potentially double their all-electric miles. Extending the electric range of PHEVs with workplace charging improves the value proposition for PHEV drivers because electric fueling is less expensive than gasoline. For BEVs and PHEVs, workplace charging could expand the number of people whose needs could be served by a PEV, thereby expanding the market for PEVs. Workplace charging might also allow households that lack access to residential charging the opportunity to commute with a PEV.*[17]

Workplace charging is also essential to allow the Commission to leverage the growing customer investment in PEVs to support the integration of variable renewable generation. Missouri PEV drivers have already purchased batteries that collectively represent about 40 megawatt-hours of advanced chemical energy storage that could be used to address this new load shape by absorbing afternoon solar generation and overnight wind generation.[18] The Commission should take advantage of that growing sunk investment to benefit all utility customers. Combining both workplace and residential charging will provide maximum availability to help cost-effectively integrate renewables. Workplace and home charging are needed to make this possible; PEVs that are not connected to the grid cannot support the grid.

A robust network of charging stations along highway corridors is also needed to accelerate the electric vehicle market. In particular, the development of direct current (DC) Fast Charging stations – which charge at a significantly faster rate than traditional AC charging stations – will be critical for this particular segment.[19] They enable long-distance, all-electric travel without

[17] National Research Council of the National Academies of Sciences*, Overcoming Barriers to the Deployment of Plug-in Electric Vehicles*, the National Academies Press, 2015, p. 117.
[18] Assuming sales-weighted average battery size of 24.6 kWh, based on sales data from the Department of Energy's Alternative Fuels Data Center and the Missouri Department of Economic Development's estimate of 1,600 PEVs in the state.
[19] While AC Level 2 charging is able to deliver 10-20 miles of range per hour of charging, DC fast charging can deliver 150-210 miles of range per hour of charging. See Alterrative Fuels Data Center, "Developing Infrastructure

significantly altering the time it takes to reach a particular destination. Electric Power Research Institute's analysis reveals that one in ten weekdays a vehicle is driven, it is driven in excess of 70 miles, which approaches the point at which many drivers of the pure battery electric vehicles would begin to suffer from range anxiety.[20] The fear of being stranded is not just a source of anxiety for those who have already purchased BEVs, but a significant barrier to a mass market for BEVs. Although most PEV charging will occur at home, consumer research shows the lack of "robust DC fast charging infrastructure is seriously inhibiting the value, utility and sales potential" of BEVs.[21] Advances in battery technology that enable affordable longer range all-electric vehicles, such as the Chevrolet Bolt, will not reduce, but increase the need for DC fast charging stations. As more automakers introduce vehicles that can complete the occasional longer trip while re-fueling during stops that would likely be made regardless to eat meals or use restrooms, demand for DC fast charging stations will increase significantly. Overall, developing the highway corridor fast charging market will be critical for the acceleration of the electric vehicle market.

The Public Policy Rationale for Vehicle Electrification

Q. What is the public policy rationale for vehicle electrification and increased charging station deployment?

A. The prudent development of charging station networks increases PEV adoption. This not only benefits utility customers who drive electric vehicles or who are considering purchasing one; it delivers important benefits to utility customers as a whole.

First, widespread and intelligently integrated vehicle charging could lower electric rates for all utility customers. As described in Natural Resources Defense Council's *Driving Out Pollution*: *How Utilities Can Accelerate the Market for Electric Vehicles:*

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to Charge Plug-In Electric Vehicles," U.S. Department of Energy available at: http://www.afdc.energy.gov/fuels/electricity_infrastructure.html

[20] Marcus Alexander, *Transportation Statistics Analysis for Electric Transportation*, Electric Power Research Institute, December, 2011.

[21] Norman Hajjar, *New Survey Data: BEV Drivers and the Desire for DC Fast Charging*, California Plug-in Electric Vehicle Collaborative, March 11, 2014.

> *Charging electric vehicles predominantly during off-peak electricity hours (when the electric grid is underutilized and there is plenty of spare capacity in the generation, transmission, and distribution system) allows utilities to avoid new capital investments while capturing additional revenues, lowering the average electricity cost for all their customers. This effect is the opposite of the utility "death spiral," whereby increasing costs borne by a decreasing pool of customers causes rate increases that drive away more customers, leaving those who cannot afford distributed generation or home energy storage to pay for an aging grid.*[22]

This increased electric load from PEVs exerts downward pressure on rates by spreading the utility's fixed costs over a greater amount of kilowatt-hour (kWh) sales. As described above, utility customers and the utility have the potential to benefit from increased load without commensurate increases in costs to serve that incremental load.

This downward pressure on rates as a result of increased electric vehicle load is consistent with the findings of researchers at the Pacific Northwest National Laboratory. They conclude there is sufficient spare generation capacity in the nation's electric grid to power virtually the entire light-duty passenger vehicle fleet without necessitating the construction of any new power plants, if vehicle charging load is integrated during off-peak hours and at lower power levels.[23] The same researchers also modelled impacts on the marginal price of electricity associated with transformative transportation electrification on two utilities, Cincinnati Gas & Electric and San Diego Gas &Electric (SDG&E). The results of a 100 percent PEV penetration scenario (1.1 million plug-in electric vehicles) in SDG&E territory are illustrated in Figure 2.[24]

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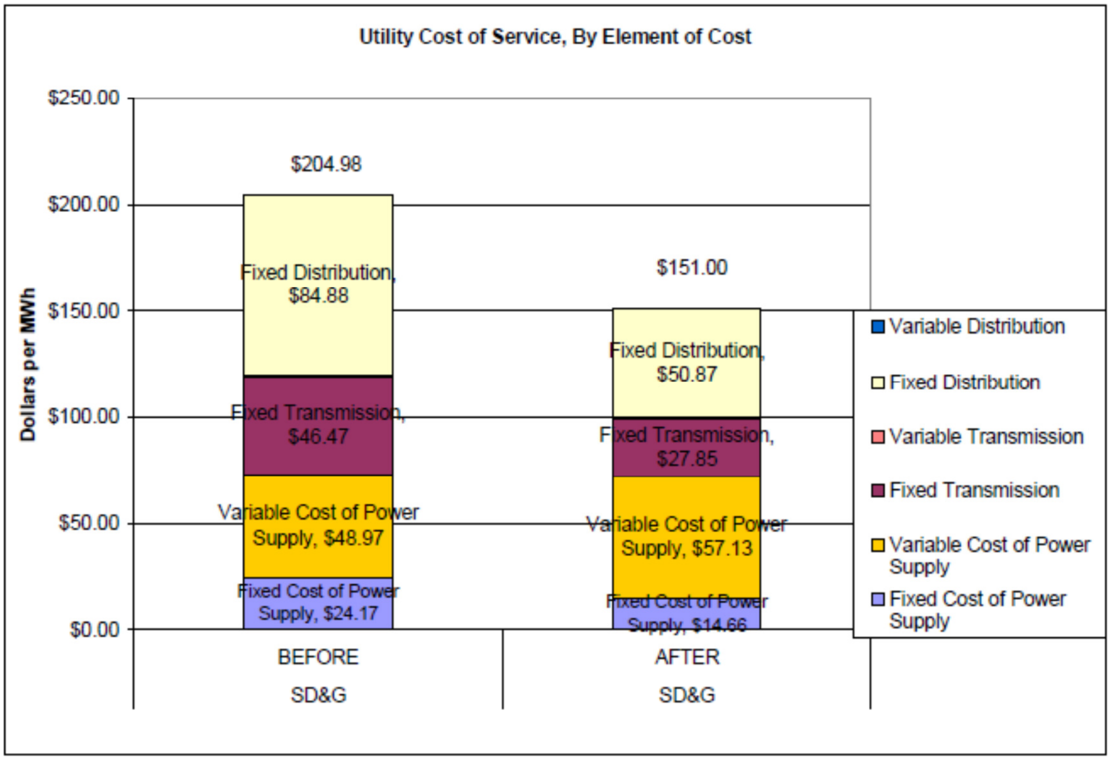
[22] Max Baumhefner, Roland Hwang, Pierre Bull, *Driving Out Pollution: How Utilities Can Accelerate the Market for Electric Vehicles*, Natural Resources Defense Council, June 2016.

[23] Michael Kintner-Meyer Kevin Schneider Robert Pratt, *IMPACTS ASSESSMENT OF PLUG-IN HYBRID VEHICLES ON ELECTRIC UTILITIES AND REGIONAL U.S. POWER GRIDS: PART 2: ECONOMIC ASSESSMENT*, November, 2007. p. 11 available at: https://www.ferc.gov/about/com-mem/5-24-07-technical-analy-wellinghoff.pdf

[24] It is important to note that the analysis assumes that charging occurs during the "valley-filling" period between 10 pm and 6 am. Establishing residential rate structures that generally encourage off-peak charging are crucial to ensuring widespread vehicle electrification delivers system-wide net benefits in the long run.

Figure 2: Short Run Impact of Electric Vehicle Off-Peak Charging on Components of System Cost for San Diego Gas & Electric



Source: *Pacific Northwest National Laboratory*

These results should not be construed as a forecast, but the directional shift (approximately 25 percent reduction in the cost of electricity) is significant. Non-PEV customers would benefit from such efficient transportation electrification in the form of lower electricity bills. No utility service area in Missouri is expected to reach this level of PEV adoption in the near-term, but increased charging station deployment could play a critical role in accelerating adoption early in the market. In sum, greater electric vehicle load can help flatten load curves, improve the efficiency and utilization of fixed distribution assets, and achieve cost savings for the body of utility customers.

Vehicle electrification also provides benefits to utility customers as a whole by cutting harmful greenhouse gas emissions relative to gasoline powered vehicles, reducing the state's dependence on oil imported both domestically and internationally, and potentially facilitating renewable energy integration necessary to reach other public policy goals – such as the Renewable Portfolio Standard.

Rates and Rate Structures to Complement Vehicle Electrification

Q. Will rate design impact the economics of transportation electrification?

A. Yes. A survey of over 16,000 PEV drivers reveals that "saving money on fuel costs" is the single most important decision factor driving PEV purchases.[25] Therefore, to ensure that charging station deployment achieves its goal of developing the electric vehicle market, it is crucial that PEV drivers generally realize fuel cost savings when switching from gasoline to electric fuel. Charging for electricity in excess of equivalent gasoline costs at certain stations would dilute the incentive to purchase a PEV, jeopardizing the use and usefulness of the charging stations in question as well as the overall success of a network. For these reasons, appropriate and transparent tariffs that give drivers who charge in a manner that is consistent with grid conditions the potential to achieve fuel cost savings relative to gasoline are an essential element of a comprehensive charging network.

Q. Can rate design help ensure transportation electrification benefits the body of utility customers?

A. Yes. Consistent with the findings in Staff's report from *A Working Case Regarding Electric Vehicle Charging Facilities* (File No. EW-2016-0123) and the Missouri Comprehensive State Energy Plan, NRDC generally finds a time-of-use rate to be effective in managing residential PEV load and augmenting the benefits of vehicle electrification.[26] Transportation electrification done at a scale necessary to meet air quality and climate goals will have significant implications for the electrical grid. If it is done poorly, the costs will be substantial and could undermine the

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[25] Center for Sustainable Energy (2016). California Air Resources Board Clean Vehicle Rebate Project, EV Consumer Survey Dashboard. Retrieved [date retrieved] from http://cleanvehiclerebate.org/survey-dashboard/EV.

[26] Department of Economic Development – Division of Energy, *Missouri Comprehensive State Energy Plan*, October 2015, p. 101 available at: https://energy.mo.gov/energy/docs/MCSEP.pdf; Missouri Public Service Commission Staff Report, File No. EW-2016-0123, Filed August 5, 2016

viability of a strategy that is critical to meet mid- and long-term goals. However, with the right policies and programs in place, the electrification of the transportation sector could be cost-effective and maximize benefits for all utility customers.

In California – which now has over 250,000 PEVs – there have been virtually no electric system upgrades driven by increased electric vehicle load: approximately 0.1 percent of PEV sales have resulted in service line or distribution system upgrades.[27] According to the Missouri Comprehensive State Energy Plan, there are approximately 1,600 PEVs in Missouri.[28] Real world data from the Department of Energy's "EV Project" demonstrate that, in jurisdictions without active utility PEV programs where time-of-use (TOU) tariffs are either not available or not widely adopted, PEV customers will plug in and charge immediately upon returning home from work, exacerbating evening system-wide peak demand, but that in jurisdictions with effective utility education and outreach and time-variant price signals, the vast majority of PEV charging occurs during off-peak hours.[29] This is shown in Figures 3 and 4. In other words, without a clear price signal or other mechanisms designed to influence charging behavior at home, real world experience demonstrates that PEV load will generally increase evening system peak load. Active utility programs, time-variant rates, and effective customer education and outreach will be needed to ensure that efficient transportation electrification benefits all utility customers in the long-term. Thankfully, Figure 4 demonstrates that a simple TOU rate that encourages PEV drivers to take advantage of their vehicles' ability to be programmed to begin charging at a specified hour or to complete charging by a specified hour can be sufficient to ensure that upwards of 80 percent of residential PEV charging occurs during the "super-off-peak" period between midnight and 5:00AM, when there is excess capacity on the grid.

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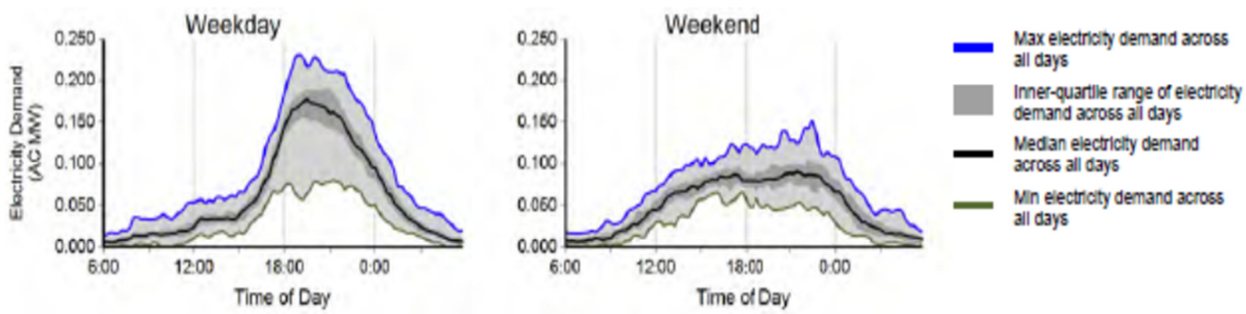
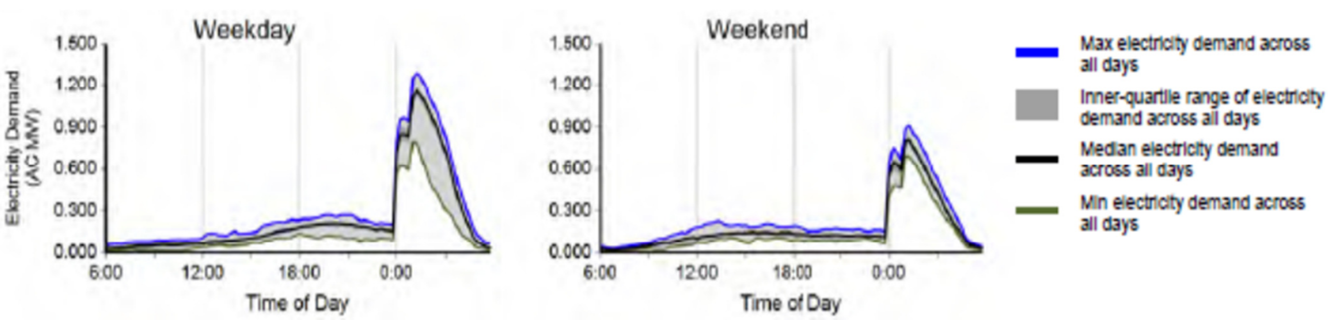
[27] *See* California Auto Outlook, February, 2016; Pacific Gas & Electric, San Diego Gas & Electric, Southern California Edison, *Joint IOU Electric Vehicle Load Research Report 4th Report*, Filed on December 24, 2015.
[28] Department of Economic Development – Division of Energy, *Missouri Comprehensive State Energy Plan*, October 2015, p. 106 available at: https://energy.mo.gov/energy/docs/MCSEP.pdf
[29] *Idaho National Laboratory, 2013 EV Project Electric Vehicle Charging Infrastructure Summary Report,* January 2013 through December 2013.

Figure 3: Dallas/Fort Worth Electric Utility PEV Load Profile



Source: *The EV Project, U.S. Department of Energy*

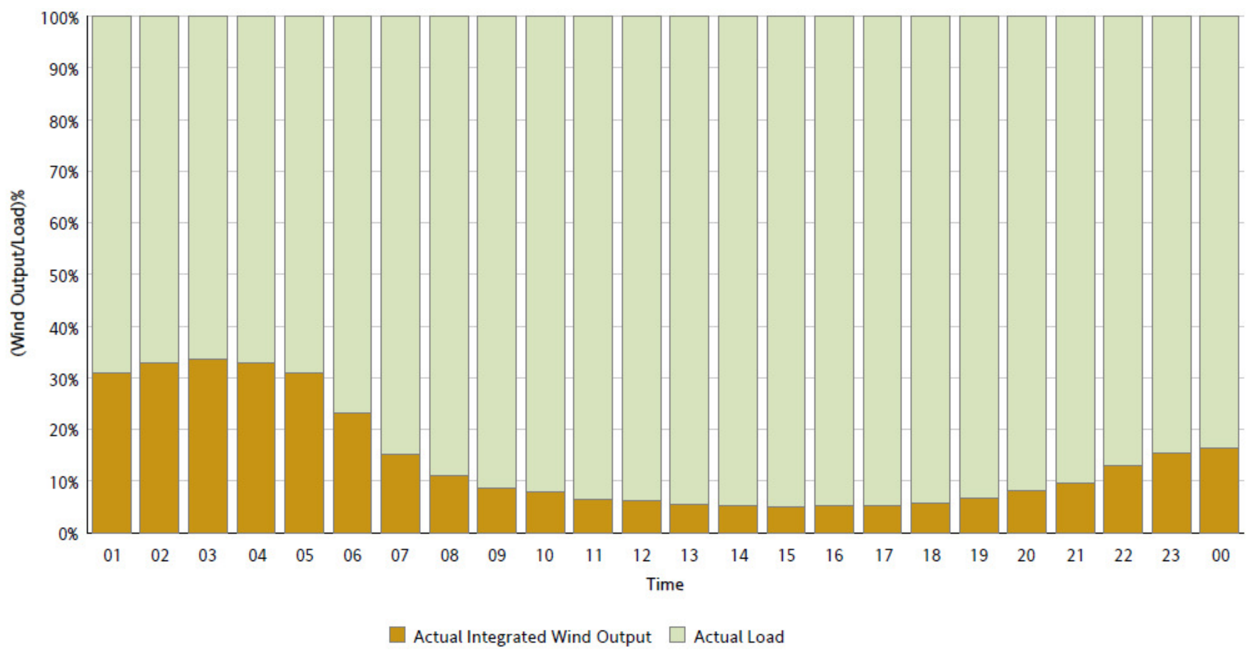
Figure 4: San Diego Electric Utility Load PEV Profile



Source: *The EV Project, U.S. Department of Energy*

The PEV charging that occurs between midnight and 5:00 AM in San Diego also demonstrates that PEV load can be a cost-effective tool to absorb wind generation that generally peaks during hours when most people are sleeping, as shown Figure 5, which illustrates wind output in Texas.

Figure 5: Actual Wind Output as a Percentage of ERCOT Load



Q. Are there other examples where TOU rates offered by a utility have proven effective at influencing charging behavior?

A. Yes. TOU rates have already proven to be remarkably effective at managing and encouraging PEV load during hours considered "off-peak" by the utility implementing the rate. The California Public Utility Commission ordered the state's three investor owned utilities to report on PEVs and their interaction with the grid in each utility's respective service area via annual Joint IOU Load Research Reports.[30] In general, all three utilities have found that PEV drivers take advantage off-peak or super-off peak periods when rates are lowest.[31]

Here, I describe the PEV load impact in Southern California Edison (SCE), a utility that serves approximately 5 million commercial, industrial, and residential customers. The utility has two

[30] The three California investor owned utilities are Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric. The majority of PEVs in the state are driven by customers that reside in these utilities' service areas. The fourth and most recent Load Research Report was published December 24, 2015.
Pacific Gas & Electric, San Diego Gas & Electric, Southern California Edison, *Joint IOU Electric Vehicle Load Research Report 4th Report*, Filed on December 24, 2015.

[31] Pacific Gas & Electric, San Diego Gas & Electric, Southern California Edison, *Joint IOU Electric Vehicle Load Research Report 4th Report* p.2, Filed on December 24, 2015.

separate categories of TOU rates: a single meter (i.e. whole-house) rate category and a PEV meter rate category (i.e. PEV-only meter). The single meter rates and PEV rate are shown below in Figures 6 and 7, respectively.

Figure 6: Southern California Edison Single Meter TOU Rate: TOU-D-A/B ($/kWh)

	Option A				Option B			
Clock Hour Ending	Winter		Summer		Winter		Summer	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
1	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
2	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
3	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
4	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
5	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
6	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
7	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
8	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
9	0.26	0.26	0.30	0.30	0.14	0.14	0.18	0.18
10	0.26	0.26	0.30	0.30	0.14	0.14	0.18	0.18
11	0.26	0.26	0.30	0.30	0.14	0.14	0.18	0.18
12	0.26	0.26	0.30	0.30	0.14	0.14	0.18	0.18
13	0.26	0.26	0.30	0.30	0.14	0.14	0.18	0.18
14	0.26	0.26	0.30	0.30	0.14	0.14	0.18	0.18
15	0.36	0.26	0.46	0.30	0.25	0.14	0.35	0.18
16	0.36	0.26	0.46	0.30	0.25	0.14	0.35	0.18
17	0.36	0.26	0.46	0.30	0.25	0.14	0.35	0.18
18	0.36	0.26	0.46	0.30	0.25	0.14	0.35	0.18
19	0.36	0.26	0.46	0.30	0.25	0.14	0.35	0.18
20	0.36	0.26	0.46	0.30	0.25	0.14	0.35	0.18
21	0.26	0.26	0.30	0.30	0.14	0.14	0.18	0.18
22	0.26	0.26	0.30	0.30	0.14	0.14	0.18	0.18
23	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
24	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11

Option A: 0.10 Baseline Credit, 0.03 SF or 0.02 MDU meter/day Basic Charge
Option B: 0.54 meter/day Basic Charge

Source: *Southern California Edison*

Figure 7: Southern California Edison PEV Meter TOU Rate: TOU-EV-1 ($/kWh)

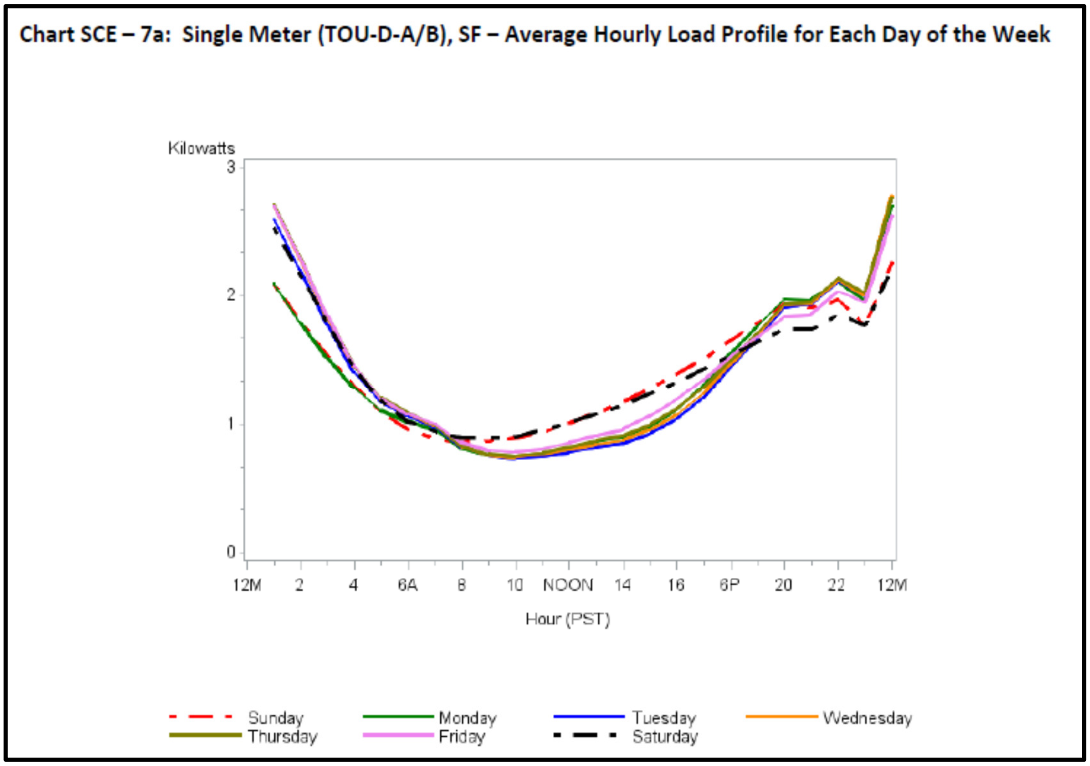
Clock Hour Ending	Winter Weekday	Winter Weekend	Summer Weekday	Summer Weekend
1	0.11	0.11	0.12	0.12
2	0.11	0.11	0.12	0.12
3	0.11	0.11	0.12	0.12
4	0.11	0.11	0.12	0.12
5	0.11	0.11	0.12	0.12
6	0.11	0.11	0.12	0.12
7	0.11	0.11	0.12	0.12
8	0.11	0.11	0.12	0.12
9	0.11	0.11	0.12	0.12
10	0.11	0.11	0.12	0.12
11	0.11	0.11	0.12	0.12
12	0.11	0.11	0.12	0.12
13	0.23	0.11	0.36	0.12
14	0.23	0.11	0.36	0.12
15	0.23	0.11	0.36	0.12
16	0.23	0.11	0.36	0.12
17	0.23	0.11	0.36	0.12
18	0.23	0.11	0.36	0.12
19	0.23	0.11	0.36	0.12
20	0.23	0.11	0.36	0.12
21	0.23	0.11	0.36	0.12
22	0.11	0.11	0.12	0.12
23	0.11	0.11	0.12	0.12
24	0.11	0.11	0.12	0.12

Source: *Southern California Edison*

There were approximately 6500 SCE customers who owned PEVs on the single meter (TOU-D-A/B) rates and approximately 650 on the separate meter rate in August, 2016 – the most recent month that data was collected.

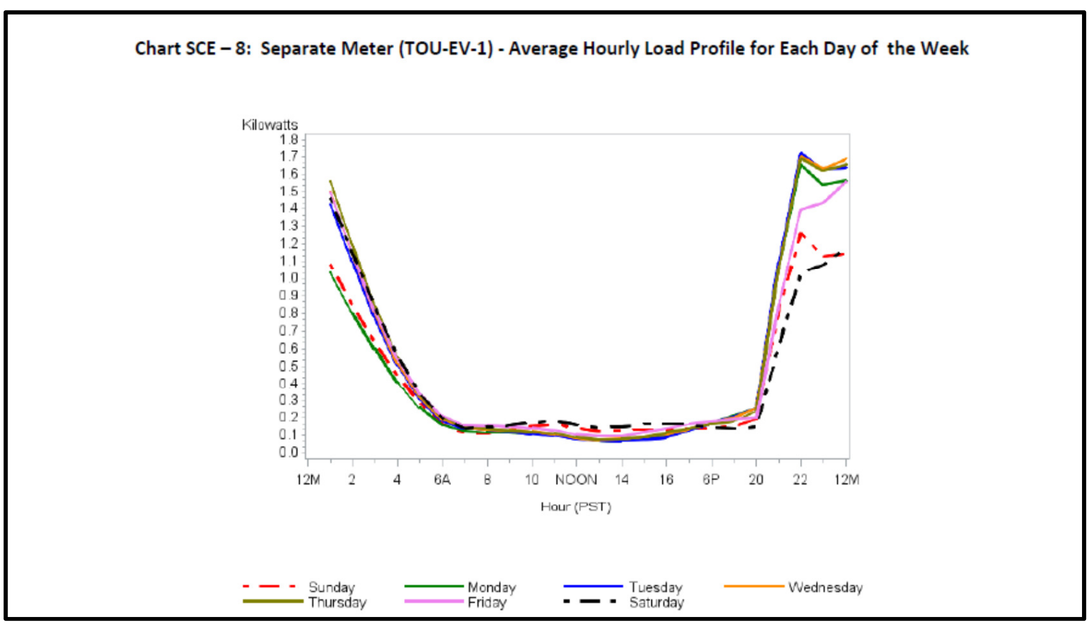
To illustrate the effect TOU rates have on its customers' electricity use, SCE developed average load profiles that reveal how usage changes by time of day and day of the week. Shown below are the average load profiles for single family EV customers on the single meter (TOU-D-A/B) rate and all customers on the PEV meter (TOU-EV-1) rate.

Figure 8: Average Hourly Load Profile of Single Family EV Drivers on TOU-D-A/B



Source: *Southern California Edison*

Figure 9: Average Hourly Load Profile of EV Drivers on TOU-EV-1



Source: *Southern California Edison*

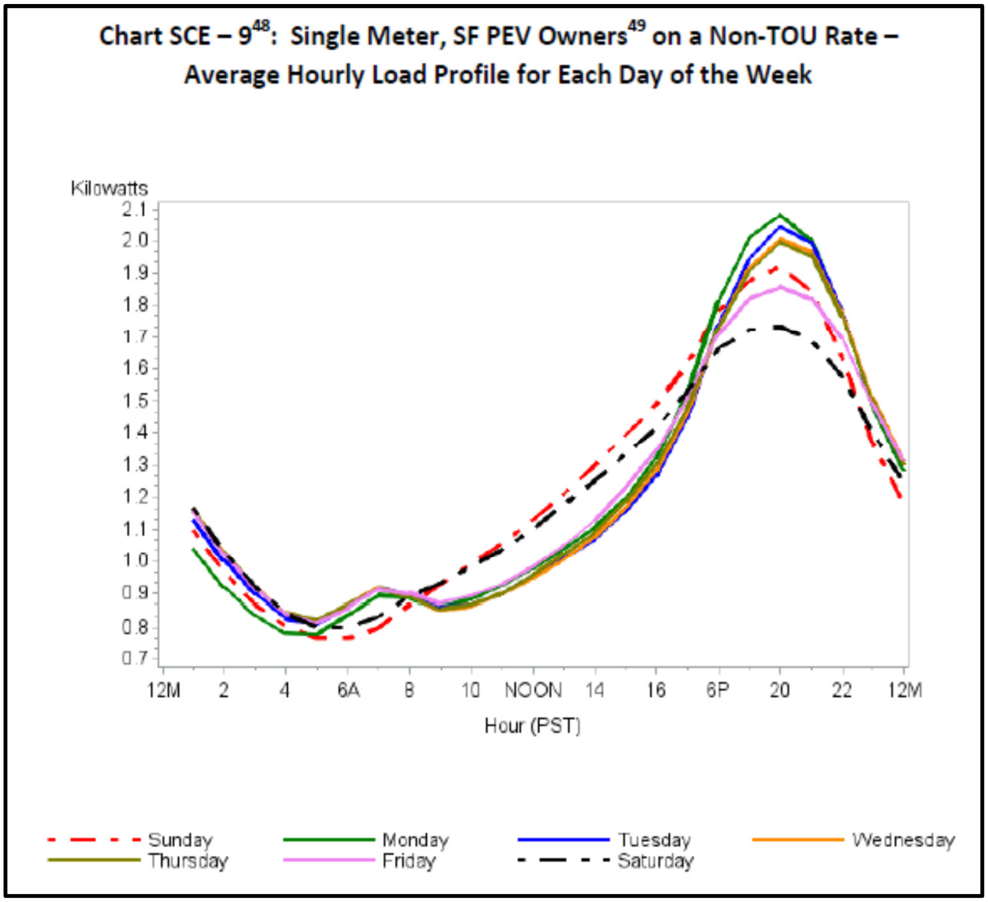
Although we cannot parse out single meter customers' PEV load with absolute certainty, it is clear that the TOU rate likely had an effect on charging behavior. While residential customers without EVs may traditionally see their load peak in the early evening, the PEV drivers on the TOU-D-A/B rate see their load increase begin to increase after 10 p.m. – the start of the tariff's off-peak period – and peak around midnight before declining again. It is important to note that SCE found that customers in multi-unit dwellings on the TOU-D-A/B tariff generally mirrored the average load profiles of their single family counterparts, but typically had lower loads in the late morning and early afternoons.[32]

Under the PEV-only TOU rate, it is apparent that customers had a robust response to the tariff. PEV load remains low and flat through the late morning, afternoon, and early evening periods. However, once the tariff moves from the on-peak to off-peak period, EV charging increases significantly and begins to ramp down through the early morning.

It is evident from these load profiles that PEV drivers on TOU rates respond to the price signals of the tariff they are on, but what is the *effect* of being on time of use rates relative to the status quo? In other words, do PEV drivers that are on flat rates already display similar charging behavior to drivers that are on TOU rates? To answer this question, SCE also developed an average load profile of single meter residential customers that were known to have PEVs but were *not* on a TOU rate. This load profile is shown below:

[32] Pacific Gas & Electric, San Diego Gas & Electric, Southern California Edison, *Joint IOU Electric Vehicle Load Research Report 4th Report* p. 63, Filed on December 24, 2015.

Figure 10: Average Hourly Load Profile of EV Drivers not on TOU Rates



Source: *Southern California Edison*

It is unmistakable that EV drivers on non-TOU rates exhibit a different load profile from single meter single family customers on TOU-D-A/B in Figure 6. Load hits a trough in the early morning hours, rapidly begins increasing in the late afternoon, and peaks around 8 p.m. Without a structured price signal that encourages off-peak electricity consumption, EV drivers will likely plug in their vehicles upon returning home in the evening, potentially exacerbating residential peak loads and increasing costs to serve that load.

In sum, I have made two related observations based on these SCE load profile data. First, TOU rates *do* have an effect on EV drivers' charging behavior relative to flat rate structures. This effect can be beneficial to the utility and all utility customers by shifting flexible PEV charging loads to off-peak periods when there is spare capacity on the grid. Second, once on TOU rates, PEV drivers respond in a predictable manner by charging during designated off-peak periods. For these interrelated reasons, TOU rates are an effective load management strategy for residential PEV charging.

Q. What issues must be considered in the implementation residential TOU rates for PEVs?

A. Currently, the two main paths to implementing a residential TOU rate for electric vehicles generally follow the options illustrated in the SCE case: customers can either switch onto a whole-house time of use rate or install a separate meter with TOU capability specifically for EV charging. Ameren Missouri currently offers an optional, or opt-in, residential whole-house TOU tariff, but it is unclear how many residential customers are on this tariff.[33]

If customers are unwilling to migrate to a whole-house TOU rate, it may be possible to circumvent the need for a separate utility service meter through advanced metering infrastructure (AMI) and other technologies that can accurately meter EV load on a time-varying basis, such as the use of sub-meters embedded in PEVs, charging stations, or even in circuit breakers.

Broader Applications of Time-Varying Rate Structures

Q. Can TOU rates provide benefits to residential customers regardless of whether they are EV drivers or not?

A. Yes. Up to this point, I have explained how TOU rates can benefit both EV drivers and the body of utility customers as a whole in the acceleration of the electric vehicle market. But if designed correctly, TOU rates can provide additional customer benefits that go beyond the transportation electrification process.

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[33] See https://www.ameren.com/-/media/missouri-site/Files/Rates/UECSheet54Rate1MRES.pdf

Even despite the increased deployment of AMI that makes TOU tariffs possible, 98 percent of U.S. residential customers currently pay for electricity on flat or inclining block rates.[34] Part of the explanation behind this statistic may be that TOU rates are offered primarily as a pilot or on an opt-in basis to these customers.

In a rare opportunity to perform a utility customer experiment with randomized control trial and randomized encouragement design elements, Lawrence Berkeley National Laboratory (LBNL) and the University of California at Berkeley (UCB) ran a study examining the effects of TOU rates on residential customer load behavior and welfare in the Sacramento Utility Municipal District (SMUD).[35] In setting up the experiment, researches established experimental subpopulations in the following manner: they made a subset of customers take a TOU rate as the default, they offered a subset of customers a TOU rate that they could voluntarily sign up for, and they did not engage a subset of customers (i.e. the control group). Note that customers that were defaulted onto the TOU were free to defect and switch back to their previous rate. The result of this experimental design was the creation of three distinct customer subsets explained here:

• ***Never takers****: the set of customers that would not actively opt-in to voluntary TOU rate offers, and would actively opt-out when TOU rates are the default;*

• ***Always takers****: the set of customers that would actively opt-in to voluntary TOU rate offers and would not actively opt-out when TOU rates are the default; and*

• ***Complacents****: the set of customers who would not actively opt-in to voluntary TOU rate offers, but would not actively opt-out when TOU rates are the default.*[36]

The relative size of these groups is shown below:

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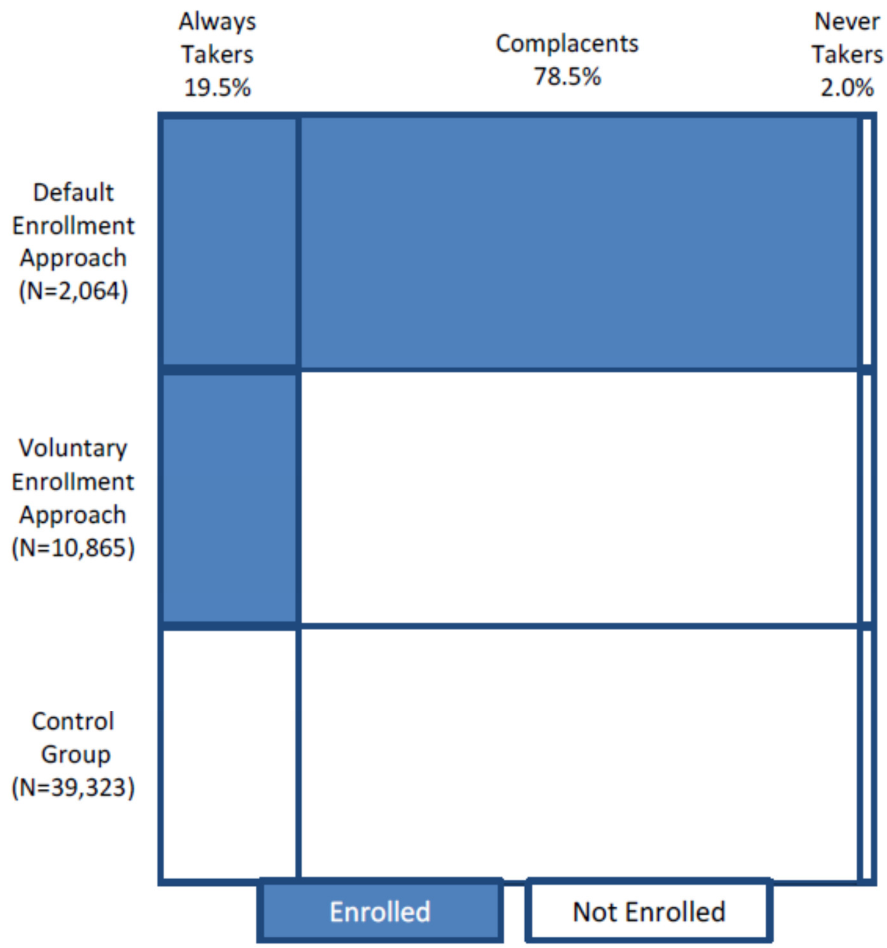
[34] Peter Cappers, C. Anna Spurlock, Annika Todd, *Time-of-Use as a Default Rate for Residential Customers: Issues and Insights* p. xvi, Lawrence Berkeley National Laboratory and University of California at Berkeley, June 2016 available at: https://eetd.lbl.gov/sites/all/files/lbnl-1005704_0.pdf

[35] Randomized encouragement design is a study in which participants are randomly assigned into treatment and control groups to observe the particular effect of a treatment. If the participant is assigned to the treatment group, they are offered the treatment, but they do not have to accept it. For the purposes of the experiment, customers that reject the offer are still part of the treatment group.

[36] Peter Cappers, C. Anna Spurlock, Annika Todd, *Time-of-Use as a Default Rate for Residential Customers: Issues and Insights* p. xviii, Lawrence Berkeley National Laboratory and University of California at Berkeley, June 2016 available at: https://eetd.lbl.gov/sites/all/files/lbnl-1005704_0.pdf ; Note that these three customer subsets are estimates based upon voluntary enrollment rates and default drop-out rates and additional proxy tests.

Figure 11: Distribution of SMUD Customer Subpopulations



Source: *Lawrence Berkeley National Laboratory and University of California at Berkeley*

The experiment, which took place in 2012 and 2013, revealed several important findings. The first is that defaults are powerful: validating the well-known "status quo bias" phenomenon, only two percent of customers that were assigned to take the TOU rate actively opted-out at the beginning. Additionally, TOU drop-out rates of both voluntary enrollees and customers that were defaulted onto the rate were relatively low: 4.4 percent and 3.9 percent, respectively.

Second, there was no noticeable evidence of "dramatically higher levels of dissatisfaction" from customers that were defaulted onto the TOU rate in comparison to those who voluntarily opted in or between Always Takers and Complacents.[37] In some cases, greater understanding and exposure to TOU rates actually increased satisfaction levels.[38] However, for the most part, the Complacents were relatively less informed and attentive than the Always Takers and Never Takers. Considering the size of the Complacent subpopulation, there may be value in defaulting PEV drivers to TOU rates, while providing adequate education and outreach to ensure they maximize the potential to realize lower utility bills on such rates and the opportunity to opt-out.

Moreover, as was expected, peak period demand reductions were greater for the Always Takers than for the Complacents: 16.7 percent and 3.1 percent, respectively. This may likely be the case because residential customers that always enroll in a TOU rate may generally be more interested in managing their energy use to better take advantage of the rate. However, the demand reduction results for *both* Always Takers and Complacents were statistically significant, meaning that the TOU rate had a clear effect on Complacents' behavior relative to the control group. Total aggregate peak demand reductions reached 5.7 percent.

Finally, it was estimated that defaulting all SMUD residential customers onto a TOU rate would generate $34 million in net benefits on a net present value basis over 10 years. However, due to higher recruitment costs and lower overall demand reductions, a voluntary enrollment approach to TOU rates for all customers would generate $5.5 million in net losses over the same period.[39]

In sum, while there are undoubtedly some challenges to achieving full residential customer adoption of TOU rates, these tariffs provide an opportunity for customers to lower their monthly bills and improve the reliability and efficiency of the grid, and the Commission should consider the benefits that would result from defaulting PEV drivers onto rates that would reduce their utility bills and encourage charging that improves the utilization of the grid.

[37] Peter Cappers, C. Anna Spurlock, Annika Todd, *Time-of-Use as a Default Rate for Residential Customers: Issues and Insights* p. xx, Lawrence Berkeley National Laboratory and University of California at Berkeley, June 2016 available at: https://eetd.lbl.gov/sites/all/files/lbnl-1005704_0.pdf

[38] Peter Cappers, C. Anna Spurlock, Annika Todd, *Time-of-Use as a Default Rate for Residential Customers: Issues and Insights* p. 21, Lawrence Berkeley National Laboratory and University of California at Berkeley, June 2016 available at: https://eetd.lbl.gov/sites/all/files/lbnl-1005704_0.pdf

[39] Under the voluntary enrollment approach, recruitment costs were estimated to be approximately $60 per enrollee. Under the default approach, recruitment costs were $4 per enrollee.

Q. Are there other examples that demonstrate the value of time-varying rates to residential customers?

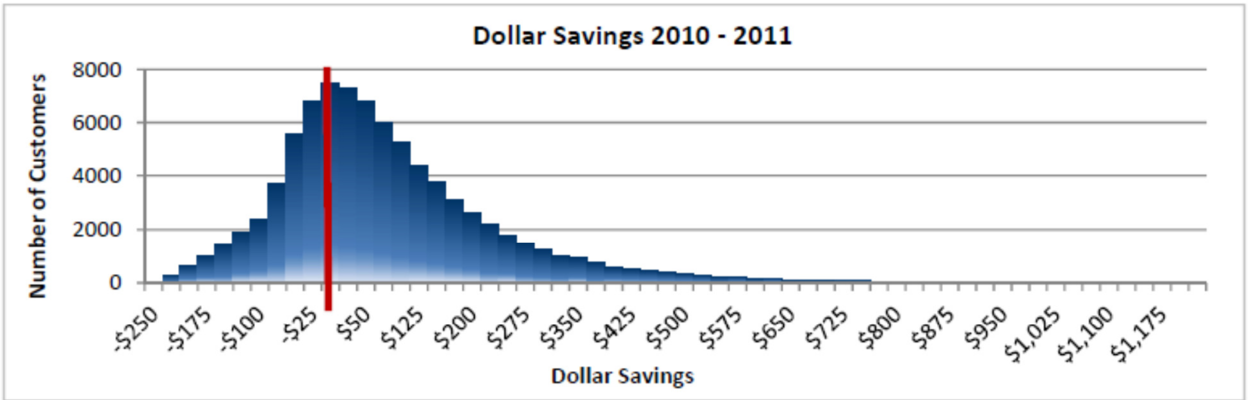
A. Yes. In Illinois, Commonwealth Edison (ComEd) – the utility serving the northern portion of the state – has begun the mass deployment of AMI, or smart meters, in its service area. The utility plans to complete the installation of four million smart meters by 2018.[40] ComEd also offers residential customers a time-varying rate through its Hourly Pricing Program (HPP).[41] In this tariff, ComEd essentially passes through the wholesale hourly energy price, along with standard distribution and capacity charges, to the residential customer. Although the tariff differs from a traditional TOU in that it does not establish fixed blocks of time that dictates how much customers are charged, the rate still provides a time-based price signal that allows customers to enjoy greater savings for using electricity during off-peak times. In short, HPP is a finer instrument than a TOU rate, but they both aim to achieve the same goal.

With the development of AMI deployment and HPP offering, Elevate Energy – the administrator of ComEd's HPP – was able to conduct a study over several years that observes AMI-equipped residential customers on a flat rate and compares what their bills *would have been* had they adopted the HPP tariff. Elevate Energy analyzed the energy use data of over 80,000 residential customers between 2010-2011 and completed additional studies for 2011-2012, 2012-2013, and 2013-2014.[42]

In the 2010-2011 study, 67.4 percent of customers in the study would have been better off economically by switching to the hourly price tariff. Of those that benefitted, the median savings would have been $50.45 per year. The distribution of customer savings is shown below:

[40] "ComEd's AMI programme saves US$400 000 in consumer bills," Metering and Smart Energy International, November 18, 2015 available at: https://www.metering.com/comeds-ami-programme-saves-us400-000-in-consumer-bills/
[41] See https://hourlypricing.comed.com/
[42] "ComEd Residential Real-Time Pricing Performance vs. Fixed-Price Rate 2010 – 2012," Elevate Energy, 2014; "ComEd Residential Real-Time Pricing Performance vs. Fixed-Price Rate During 2013," Elevate Energy, 2015; "ComEd Residential Real-Time Pricing Performance vs. Fixed-Price Rate During 2014," Elevate Energy, 2016

Figure 12: Distribution of Customer Savings from Hourly Pricing Tariff



Source: *Elevate Energy*

In the 2011-2012 study, 85 percent of the nearly 98,000 residential customers observed would have benefitted from the hourly pricing rate. Of those that would have seen bill savings, the average annual amount saved was $178.76. Of those that would not have seen bill savings, the average annual amount lost was $30.16. In the 2012-2013 study, over 108,000 AMI-equipped households on flat rates were observed. Over this period, 97 percent of those households, including 99 percent of customers enrolled in the Low-Income Home Energy Assistance Program (LIHEAP) or Percentage of Income Payment Plan (PIPP), would have economically benefitted from the hourly rate relative to their flat rate.[43] The mean annual savings for those that would have benefitted from the program were $123.52 and the mean annual losses would have been $6.29.[44]

One important observation to highlight from these studies is that the majority of customers would have achieved savings *even without altering their behavior under an hourly pricing tariff.* If these customers were aware of the tariff and educated on how to take advantage of it, they would very likely be no worse off economically. In fact, they would likely achieve even greater

[43] Over 8,000 LIHEAP and PIPP accounts were included in the study.

[44] While these savings are significant, the hourly pricing scheme can also have disadvantages. The 2014 polar vortex caused wholesale energy and capacity prices to increase dramatically. In a 2014 version of the study that observed only 10,000 customers, only 23 percent would have seen savings by switching to the HPP. Understandably, because flat rate customers do not face a price signal that encourages them to save during times when the grid is stressed, they did not shift their energy use. However, it is important to note that customers that actually were on the HPP responded by shifting and reducing use, and approximately broke even relative to being on the flat rate.

savings; even those that would not have benefitted under the tariff could potentially see net savings through targeted outreach and education. Although it would be misguided to assume that Ameren Missouri customers would realize the exact same benefits as ComEd customers, there is value in further exploration of time-varying rate structures.

It is also important to note that PEV drivers stand to benefit more than the general population from time-varying rates, as PEVs are a very flexible “smart” load and because they are parked for the vast majority of the day, allowing for charging that supports the grid and maximizes fuel savings without compromising travel needs.

Conclusion

Q. What have you illustrated in this testimony?

A. I have demonstrated that charging infrastructure, particularly across diverse residential settings, is a critical component for accelerating the vehicle electrification process. Flexible electric vehicle charging can provide significant benefits to all utility customers, but this load should be managed in order to ensure that these utility customer benefits become manifest. Because the overwhelming majority of PEV charging takes place at the home, residential charging is a natural fit for load management applications. I have illustrated that TOU rates do have a discernable effect on EV charging behavior and that customers on these rates respond in a predictable manner by generally charging during off-peak periods. This benefits PEV drivers by generating greater fuel cost savings relative to gasoline and benefits utility customers as a whole by ensuring that charging occurs in a manner that puts downward pressure on electric rates. However, TOU rates are not only useful for PEV charging applications. I demonstrate that the majority of customers in multiple utility services areas can benefit from time-varying rates and deployment of AMI.

Ameren Missouri should consider how to best default PEV customers onto time-varying rates that would maximize their fuel savings relative to gasoline and encourage charging that improves the utilization of the grid. In sum, without a nudge, PEV charging will exacerbate evening peak demand, but with a simple nudge and appropriate education and outreach, PEV charging can take advantage of spare capacity on the system and lower the cost of integrating variable wind generation that generally peaks overnight. Thankfully, this can be done with readily available technology, taking advantage of the simple timers and other functionality already embedded in PEVs.

Q. Does this conclude your testimony?

A. Yes, it does.

BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of Union Electric	)	
Company d/b/a Ameren Missouri's	)	File No. ER-2016-0179
Tariffs to Increase Its Revenues for	)	
Electric Service	)	

County of Cook)
State of Illinois)

AFFIDAVIT OF NOAH GARCIA

Noah Garcia, of lawful age, on his oath states: that he has participated in the preparation of this direct testimony in question and answer form to be presented in the above case; that the answers in this direct testimony were given by him; that he has knowledge of the matters set forth in such answers; and that such answers are true to the best of his knowledge and belief.

Noah Garcia

In witness whereof I have hereunto subscribed my name and affixed my official seal this 21st day of December, 2016.

OFFICIAL SEAL
JENNIFER R DALY
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:06/28/17