World Electric Vehicle Journal

Article

Charge for Less: An Analysis of Hourly Electricity Pricing for Electric Vehicles

Jeff Zethmayr and David Kolata *

Citizens Utility Board, Chicago, IL 60606, USA; jzethmayr@citizensutilityboard.com
* Correspondence: dkolata@citizensutilityboard.com

Received: 19 October 2018; Accepted: 9 January 2019; Published: 17 January 2019

Abstract: By motivating Electric Vehicle (EV) owners to charge their vehicles when power supply exceeds demand, dynamic pricing can improve system load shape and capacity utilization, reduce consumer costs, and cut pollution. We compare what perfectly rational EV drivers would pay to charge their vehicle on ComEd's hourly pricing program with costs associated with the utility's flat-rate energy price. We find that ComEd's hourly pricing program would have saved EV owners significantly over its flat-rate tariff in both 2016 and 2017, with cost reductions from 52 percent to 59 percent. Using price signals to manage charging is almost certainly one of the best (and cheapest) strategies to implement in order to achieve the traditional regulatory goals of a safe, reliable, and affordable service while advancing system efficiency, enhancing environmental sustainability, and facilitating the integration of distributed energy resources.

Keywords: hourly pricing; charging; cost savings; dynamic pricing

1. Introduction

Once a subject of prophecy, electric vehicles (EVs) have arrived. While currently a small share of overall car purchases in most countries, they are becoming a familiar sight on roads—and industry analysts predict EV sales will grow at a robust clip in the next decade, as consumers become familiar with their technological advantages, and as anticipated cost reductions and extended driving ranges turn EVs into appealing alternatives to gasoline-burning cars. Bloomberg New Energy Finance, for example, predicts that by 2040, EVs will capture 55% of all new car sales and comprise 33% of the total vehicle fleet [1].

Transportation electrification presents both opportunities and challenges for utility consumers. According to the U.S. Department of Energy's National Renewable Resources Laboratory, millions of EVs on the road could increase overall U.S. electricity demand by 38 percent, or up to a sustained 80 terawatt hours per year [2]. If not managed appropriately, such an increase in usage could require costly expansion of the electric system's delivery and generation capacity. Yet the Rocky Mountain Institute shows that increased power usage associated with transportation electrification could be largely accommodated without additional power plants or grid expansion if EVs are charged at optimal times [3].

How can we make sure that EVs charge at the right times [4]? While multiple strategies may be required, time-variant rates are almost certainly the cheapest way to accomplish this aim [5]. By motivating EV owners to charge their vehicles when power supply exceeds demand, dynamic pricing can improve system load shape and capacity utilization, reduce consumer costs, and cut pollution [6–8]. Particularly in states that have deployed smart meters, implementing that simple policy option can make EVs a substantial source of system benefit, even for those who don't drive or own an EV [9].

Some utility EV programs to date have assumed that EVs will be price-responsive without necessarily putting into place measures that guarantee price-responsiveness. There are several reasons for this—including the fact that we are still in the early stages of EV deployment and thus may lack a perceived sense of urgency—but the biggest is likely that dynamic pricing remains little understood, largely because of the lack of robust analysis utilizing real data on the predicted impacts of new rate designs. While we disagree with some of her conclusions, dynamic pricing critic Barbara Alexander is correct when she says that it is "poor public policy to leap into (new methods of pricing) electricity service to residential customers without a careful analysis and access to factual information on the impacts of such proposals on customer bills" [10].

In this paper, we attempt to fill this information gap within the realm of EVs by comparing what customers of Illinois utility Commonwealth Edison would have paid in 2016 and 2017 to charge their vehicle under average rates compared to its hourly pricing program. We use three representative battery ranges and four representative daily driving amounts to do so, and determine the maximum achievable level of savings from an optimized charging schedule using the lowest priced hours of the day. While this is an idealized assumption, it shows the potential range of savings and we plan on updating future analyses with real-world travel patterns as those become available. We find that hourly prices would have yielded energy cost savings ranging between 52 and 59 percent, depending upon the circumstances, for drivers using a Level 2 charger. The savings are even greater for Level 3 DC fast chargers. Because Level 3 charging occurs during the daily hour with the lowest priced energy, every vehicle saves 59 percent over flat-rate energy pricing under all driving scenarios.

We then supplement these empirical findings with a normative recommendation: Policymakers should implement "opt-out" dynamic rates for EV charging and charging infrastructure, as none of the relevant conditions typically invoked to support flat-rate pricing are present in the case of EVs. With the aid of the sophisticated sensor and data-analysis capabilities prevalent in vehicle charging technology, utilities could isolate EV-related consumption, making a separate opt-out policy feasible should policymakers decide to preserve the consumer's prerogative to opt-in to hourly pricing for other forms of household usage.

We conclude by outlining why hourly pricing has several key advantages over time-of-use rates if the goal is (as it should be) to "charge for less", in both the economic and environmental sense of the term.

2. Materials and Methods

In this paper, we used actual 2016 and 2017 locational marginal prices (LMP) from PJM Interconnection (PJM), the Regional Transmission Organization that serves ComEd, to compare what perfectly rational EV drivers would pay to charge their vehicle on ComEd's hourly pricing program with costs associated with the utility's flat-rate energy price for both Level 2 and Level 3 DC fast charging. Illinois is the only US state that offers comprehensive, opt-in hourly pricing—where electricity rates vary by the hour, according to wholesale electricity markets—and ComEd participates in the large PJM wholesale electricity market, making it a good test case for the potential benefits of dynamic pricing. This analysis was performed using a model built in MS Excel. This model calculates the daily energy cost to recharge the EV battery for a given daily average mileage, using both ComEd's flat-rate energy price and the Hourly Pricing Program, for each day in 2016 and 2017. The maximum achievable savings through optimized charging was then calculated as the total difference between these two charging costs over the two-year span.

We started by choosing three representative electric vehicles: The 2018 Toyota Prius Prime, the 2018 Chevy Bolt, and the Tesla 3 Long-Range. These vehicles offer a range of battery sizes, power efficiencies, and maximum A/C charging rates, and serve as good examples of products currently on the market, as shown in Table 1.

Table 1. Three representative electric vehicles studied.

Vehicle Model	Drive Type	Battery Size (kWh)	Max L2 A/C Charge Rate (kW)	Efficiency (kWh/100 mi)	Range (mi)
Prius Prime [11]	PHEV	8.8	3.3	25.9 EV/1.38 Hybrid	30 EV/640 Hybrid
Bolt [12]	EV	60	7.7	28	230
Tesla [13]	EV	75	11.5	26	310

PHEV: plug-in hybrid electric vehicle.

In the next step, we chose off-the-shelf representative Level 2 and Level 3 chargers to estimate the maximum achievable charge rate (Table 2).

Table 2. Summarized specifications for the two selected products from ChargePoint.

Product	Charge Rate (kW/hour)
ChargePoint CT4000 L2 [14]	7.2
ChargePoint Express 200 L3 DC [15]	50

Next, while the model was constructed to allow testing of any driving level, we picked four typical daily driving amounts to simplify presentation—15 miles (light driver); 30 miles (average driver); 50 miles (heavy driver); and 100 miles (Lyft/Uber driver) [16,17]. In the end, then, we ran the model quantifying the results for twelve overall cells, shown in Table 3.

Table 3. Recharge consumption for the twelve vehicle/driver profile scenarios (kWh).

Vehicle	Light (15 mi)	Average (30 mi)	Heavy (50 mi)	Lyft/Uber (100 mi)
Prius	3.9	7.8	8.8	8.8
Bolt	4.2	8.4	14	28
Tesla	3.9	7.8	13	26

With these assumptions in place, we calculated what EV drivers would pay to charge their car on ComEd's flat-rate energy tariff to meet their daily driving needs. Because this tariff includes recovery of capacity costs and certain administrative costs, it was necessary to isolate the energy-supply only component of the flat-rate charge to allow for an accurate comparison with hourly pricing.

These Purchased Electricity Charges (PECs) were calculated by combining Illinois Power Agency (IPA) procurement results for the study delivery years, and taking the seasonal weighted average price of energy for each month [18]. Daily flat-rate charges were determined by multiplying the total energy required for battery recharge by the prevailing PEC for that month.

Consumers on ComEd's hourly pricing program are charged PJM's real-time ComEd Zonal Residual LMP for their hourly volumes [19]. To calculate the costs of charging vehicles on hourly pricing, we took the hourly prices for each day in 2016 and 2017 from PJM, and placed them in ascending rank order [20]. Tables 4a and 4b summarize the process for the week of 10–16 July 2017.

Table 4a. Week of 10–16 July 2017. Unranked LMPs by hour, $/MWh.

Hour	10 July	11 July	12 July	13 July	14 July	15 July	16 July
12 AM	$16.75	$19.76	$22.55	$21.77	$22.04	$20.66	$19.32
1 AM	$15.17	$20.09	$20.54	$21.96	$20.13	$20.88	$20.64
2 AM	$14.51	$19.08	$18.64	$20.93	$20.89	$18.51	$17.13
3 AM	$13.93	$18.53	$18.18	$19.65	$19.42	$18.00	$17.24
4 AM	$14.52	$18.61	$18.77	$19.61	$20.17	$17.63	$17.26
5 AM	$17.52	$20.14	$20.48	$20.96	$21.43	$17.78	$11.30
6 AM	$16.90	$20.98	$22.08	$22.02	$22.19	$16.54	$5.45
7 AM	$19.09	$23.11	$21.91	$23.76	$23.86	$17.45	$15.92
8 AM	$19.66	$25.62	$22.90	$25.62	$25.31	$20.63	$19.22
9 AM	$23.54	$26.45	$25.26	$28.76	$26.94	$21.55	$20.84
10 AM	$25.60	$27.62	$28.16	$30.26	$31.96	$23.68	$21.64
11 AM	$26.45	$30.97	$27.57	$37.74	$33.69	$26.51	$24.24
12 PM	$28.29	$33.98	$28.16	$31.08	$52.03	$27.79	$26.77
1 PM	$30.24	$32.58	$28.89	$35.56	$39.26	$28.95	$30.89
2 PM	$28.43	$46.54	$31.20	$46.05	$38.38	$28.20	$34.06
3 PM	$48.84	$48.71	$29.28	$36.94	$61.59	$30.59	$38.85
4 PM	$48.18	$40.93	$31.47	$38.85	$29.50	$30.22	$38.66
5 PM	$115.04	$35.96	$32.46	$36.21	$29.27	$60.58	$50.75
6 PM	$55.53	$37.48	$31.94	$37.78	$32.22	$30.77	$28.48
7 PM	$36.70	$31.70	$34.95	$40.42	$26.69	$29.72	$35.05
8 PM	$37.28	$30.25	$37.64	$35.15	$26.07	$26.25	$27.38
9 PM	$30.19	$31.06	$39.31	$30.50	$26.00	$26.31	$27.82
10 PM	$25.96	$25.99	$28.46	$26.17	$23.85	$23.57	$24.37
11 PM	$22.56	$24.31	$24.75	$23.46	$19.81	$20.57	$20.43

Table 4b. Week of 10–16 July 2017. Ranked LMPs, $/MWh.

Rank	10 July	11 July	12 July	13 July	14 July	15 July	16 July
1	$13.93	$18.53	$18.18	$19.61	$19.42	$16.54	$5.45
2	$14.51	$18.61	$18.64	$19.65	$19.81	$17.45	$11.30
3	$14.52	$19.08	$18.77	$20.93	$20.13	$17.63	$15.92
4	$15.17	$19.76	$20.48	$20.96	$20.17	$17.78	$17.13
5	$16.75	$20.09	$20.54	$21.77	$20.89	$18.00	$17.24
6	$16.90	$20.14	$21.91	$21.96	$21.43	$18.51	$17.26
7	$17.52	$20.98	$22.08	$22.02	$22.04	$20.57	$19.22
8	$19.09	$23.11	$22.55	$23.46	$22.19	$20.63	$19.32
9	$19.66	$24.31	$22.90	$23.76	$23.85	$20.66	$20.43
10	$22.56	$25.62	$24.75	$25.62	$23.86	$20.88	$20.64
11	$23.54	$25.99	$25.26	$26.17	$25.31	$21.55	$20.84
12	$25.60	$26.45	$27.57	$28.76	$26.00	$23.57	$21.64
13	$25.96	$27.62	$28.16	$30.26	$26.07	$23.68	$24.24
14	$26.45	$30.25	$28.16	$30.50	$26.69	$26.25	$24.37
15	$28.29	$30.97	$28.46	$31.08	$26.94	$26.31	$26.77
16	$28.43	$31.06	$28.89	$35.15	$29.27	$26.51	$27.38
17	$30.19	$31.70	$29.28	$35.56	$29.50	$27.79	$27.82
18	$30.24	$32.58	$31.20	$36.21	$31.96	$28.20	$28.48
19	$36.70	$33.98	$31.47	$36.94	$32.22	$28.95	$30.89
20	$37.28	$35.96	$31.94	$37.74	$33.69	$29.72	$34.06
21	$48.18	$37.48	$32.46	$37.78	$38.38	$30.22	$35.05
22	$48.84	$40.93	$34.95	$38.85	$39.26	$30.59	$38.66
23	$55.53	$46.54	$37.64	$40.42	$52.03	$30.77	$38.85
24	$115.04	$48.71	$39.31	$46.05	$61.59	$60.58	$50.75

The required daily recharge consumption is determined by each vehicle's kWh/mile drive efficiency, multiplied by the number of miles in a given driving scenario. As a plug-in hybrid electric vehicle (PHEV), the Prius Prime has a significantly smaller battery—for daily driving amounts above the electric only range it was assumed the battery was fully depleted.

For Level 2 charging, the hourly recharge consumption is equal to the vehicle's maximum A/C charge rate, and the number of charge hours per day equals the required daily recharge consumption divided by the hourly charging rate. For Level 3 charging, the recharge rate depends on the charger's rating, rather than the vehicles; in this case, the cars recharged at 50 kW per hour, for less than an hour, in all scenarios.

From this, an optimal daily charging amount was calculated as the sum of the minimal amount of charging consumption needed to meet daily driving needs multiplied by LMP during the required number of charging hours, starting with the lowest priced LMP hour and moving to the next rank-ordered LMP hour if necessary. More specifically, the respective vehicle's kW charging rate was multiplied by the LMP for each day's lowest-ranking LMP hours up to the total number of required charging hours less one, with the final hour being assessed the remaining kWh required.

$$DHC = LMP_T * (CHR - (T-1) * VCR) \; + \sum_{n=1}^{T-1} VCR * LMP_n$$
$$T = \lceil CHR/VCR \rceil$$

- *DHC*: Daily Hourly Charges ($): the dollar value of electric supply charges resulting from battery recharge under scenario and vehicle conditions using optimized hourly charging.
- *VCR*: Vehicle Charge Rate (kW): the maximum hourly charging rate for test vehicle.
- *T*: Charging Hours (H): the total number of hours required to recharge battery under test conditions, rounded to the next whole hour.
- *CHR*: Charge Required (kWh): the total amount of energy required to recharge battery under test conditions.
- LMP_n: LMP during *n*th lowest ranked hour of day ($/kWh)

Once optimized hourly and flat-rate charging costs were calculated, we finally compared the total charging costs for each car and driving scenario by summing the daily costs for both rate options in 2016 and 2017 and then calculating the difference between the two total cost summations.

3. Results

ComEd's hourly pricing program would have saved EV owners significantly over its flat-rate tariff in both 2016 and 2017, with cost reductions from 52 percent to 59 percent, equaling as much as $389 over the two-year study period. Table 5 summarizes the results for the twelve scenarios in the case of Level 2 charging.

Table 5. Summarized results for the 12 scenarios in the case of Level 2 charging.

Driver Profile	Vehicle	Hourly	Flat Rate	% Savings Hourly	$ Savings Hourly
Light Driver	Prius	$38	$91	58%	$54
	Bolt	$40	$98	59%	$58
	Tesla	$37	$91	59%	$54
Average Driver	Prius	$82	$181	55%	$99
	Bolt	$81	$196	59%	$115
	Tesla	$74	$182	59%	$108
Heavy Driver	Prius	$94	$205	54%	$111
	Bolt	$143	$327	56%	$184
	Tesla	$132	$303	57%	$172
Lyft/Uber	Prius	$94	$205	54%	$111
	Bolt	$315	$654	52%	$339
	Tesla	$289	$607	52%	$318

Given the daily driving amounts tested and the 50 KW charge rate, every vehicle saves 59 percent with hourly pricing over flat-rate pricing using Level 3 DC charging. Because this analysis assumes a perfectly rational consumer who only charges in the cheapest hour(s) needed to meet their driving needs, by definition Level 3 charging occurs during the hour with the lowest-priced energy, and thus every vehicle and driving scenario has the same percentage savings. Total two-year cost savings ranged from $54 to $389 depending upon the type of vehicle and driving profile. Figure 1 summarizes the recharging cost results of the overall analysis.

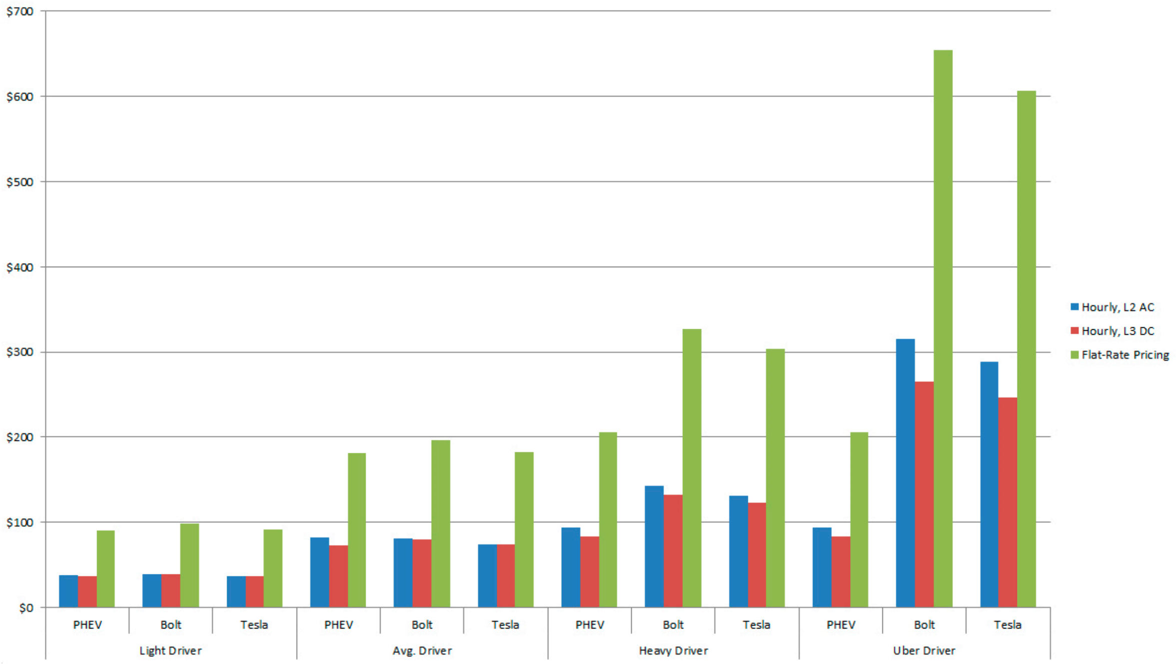

Figure 1. Charging cost comparison over two years.

A few notes are in order. First, this is an energy-only analysis and thus does not include the costs of electric distribution, transmission, capacity, taxes, surcharges, and fees. This approach has no material impact on the comparison between charging costs on hourly-and flat-rate energy pricing, but it does mean that it would not be "apples to apples" to compare the fuel costs above with the gasoline cost needed to power a traditional internal combustion vehicle.

Second, as stated previously, our model is an optimization analysis that assumes a perfectly rational charging strategy, where EVs are charged only the minimum number of hours needed to meet daily driving needs and are charged at the lowest-cost times. This is an idealized assumption, and a difficult strategy to implement flawlessly even in a world with increased automation. In the real world, a driver may be driving the vehicle during the lowest-priced hours of the day, or may prefer to charge during adjacent hours even if the price rises. Nevertheless, the data reveals an ample opportunity for savings even under sub-optimal conditions. Over 81 percent of the hours in 2016 and 2017 combined were below ComEd's flat-rate energy price, and 23 percent of the total hours were less than 2 cents/kWh.

Finally, while the total dollar amount of savings through hourly pricing (max. $389 with Level 3) is small in comparison to the fuel-cost savings achieved simply by switching from an internal combustion engine vehicle to an EV, this analysis does not take into account the substantial grid and environmental benefits inherent in price-responsive demand when targeted at reducing peaks and improving load shape.

The fact that optimized hourly pricing cut EV charging bills at least in half in the two study years without consideration of these additional benefits strongly indicates that dynamic pricing can play a key role in maximizing social welfare.

4. Discussion

Transportation electrification presents a rare opportunity for all stakeholders affected by electricity regulatory policy to benefit. The right set of policies can help achieve the traditional regulatory goals a of safe, reliable, and affordable service while advancing system efficiency, enhancing environmental sustainability, and facilitating the integration of distributed energy resources. But to achieve these aims, we need to make sure that EVs charge when it is best for the grid.

Time-based rates are effective at motivating EV owners to charge their vehicles when they will not burden the utility system [21]. And as the analysis in this paper shows, they also provide a route for EV drivers to unlock savings at the same time. For these reasons, we recommend that policymakers implement opt-out dynamic pricing for EV charging. One rate structure is usually applied to all usage in a home, but it need not be in the case of electric vehicles as the chargers (and/or cars) have sophisticated sensor and data-analysis capabilities.

Although we generally believe that the risks of dynamic pricing—and the concomitant benefits of average rates—are overstated, separately calculating EV charging costs can be a boon to adoption by customers who may fear having all their household usage priced under time-variant rates [22]. The need to get out ahead of transportation electrification to maximize consumer and environmental value is strong, and we do not want to see opt-out dynamic rates for EV charging stalled because of controversies surrounding opt-out whole-home dynamic pricing.

Will EV-only, opt-out time-variant rates also prove controversial? Perhaps. But it is worth noting that none of the arguments typically made against dynamic pricing really apply in the case of electric vehicles. Consider, for example, the claim that dynamic pricing is problematic because not all consumers can respond to price signals (e.g., on a hot summer day when they are home and simply need the air conditioner to run). EVs are simply different than other appliances because: They have batteries; that battery capacity means even heavy drivers do not need to charge very often; the charging process itself can be easily scheduled through automation; and EV operating costs can be reduced significantly by charging in low-cost hours. Electric vehicles have the perfect type of load and load shape for dynamic pricing from both an individual owner and a societal welfare point of view, so that kind of rate design should be utilized.

Automated charging has the potential to further expand the base of customers who could realize these benefits when combined with machine learning. Moving from the retrospective optimization model, which relies on perfect pricing information, to a model that employs pricing algorithms to make charging decisions would allow EV owners to put this strategy into practice using a “set it and forget it” approach. This would make the potential of realizing the full cost-savings accessible to all customers. Further research into optimized charging models should incorporate pricing models with the option to utilize strategies such as inter-day price arbitrage, skipping a day of charging, or even selling energy power as behind-the-meter generation, should a particular day’s LMPs exceed expected levels.

This discussion raises the questions of whether a time-of-use or hourly-pricing rate structure is preferable. Our view is that either can work and that the main issue is getting as many EVs as possible on time-variant rates aimed at ensuring charging occurs when it is best for consumers, the grid, and the environment [23]. That having been said, as transportation electrifies and there are millions of electric vehicles on the road, hourly pricing may prove the better alternative.

To maximize the public interest, we will want to incorporate distribution systems and environmental attributes in price signals and also be able to respond rapidly when (and if) the peak starts to change. Charging at night in Illinois because of wind—or during the day in California because of the duck curve—is an easy rule-of-thumb now, but that may change as EV deployment scales. The inherent flexibility of hourly pricing provides an advantage over administratively set TOU rates, and thus we recommend that it be offered as an alternative for all EV drivers, even in places where policymakers choose an opt-out TOU structure.

Transportation electrification is in its infancy, but the wheels are beginning to pick up speed and are unlikely to stop. Keeping up with this evolving market and ensuring it delivers system benefits requires proactive regulatory policies, and opt-out dynamic pricing should be one of those tools. We encourage all states to open proceedings as soon as possible to start moving in this direction, as there are many logistical and strategic implementation questions to answer.

Should third parties like a pharmacy or shopping center, for example, be able to offer charging rates that differ from the dynamic rate? We think the answer is likely yes, provided that the third party (or an entity it has a business relationship with) pays the actual time variant-price, but there are complicated questions involved here and it's important that they be thought through carefully in a stakeholder process. It's also possible that states will need to reconsider "meter grade" billing requirements and other potential regulatory hurdles.

Author Contributions: Methodology, J.Z.; Formal Analysis, J.Z. and D.K.; writing—original draft preparation, J.Z. and D.K.; writing—review and editing, J.Z. and D.K.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Bloomberg NEF, Electric Vehicle Outlook 2018. Available online: https://about.bnef.com/electric-vehicle-outlook/ (accessed on 17 October 2018).
2. Mai, T.; Jadun, P.; Logan, J.; McMillan, C.; Muratori, M.; Steinberg, D.; Vimmerstedt, L.; Jones, R.; Haley, B.; Nelson, B. *Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States*; NREL/TP-6A20-71500; National Renewable Energy Laboratory: Golden, CO, USA, 2008. Available online: https://www.nrel.gov/docs/fy18osti/71500.pdf (accessed on 17 October 2018).
3. Fitzgerald, G.; Nelder, C. From Gas to Grid: Building Charging Infrastructure to Power Electric Vehicle Demand. Rocky Mountain Institute. Available online: https://www.rmi.org/insight/from_gas_to_grid/ (accessed on 17 October 2018).
4. Bradley, M.J.; Associates LLC. Regulatory Assistance Project and International Council on Clean Transportation. "Electric Vehicle Integration in the U.S., Europe, and China: Challenges and Choices for Electricity and Transportation Policy". 1 July 2013. Available online: https://www.theicct.org/sites/default/files/publications/EVpolicies_final_July11.pdf (accessed on 17 October 2018).
5. Cohen, M. The ABCs of EVs: A Guide for Policy Makers and Consumer Advocates. Citizens Utility Board, 2017. Available online: https://citizensutilityboard.org/wp-content/uploads/2017/04/2017_The-ABCs-of-EVs-Report.pdf (accessed on 17 October 2018).
6. Bin Humayd, A.; Bhattacharya, K. Design of Optimal Incentives for Smart Charging Considering Utility-Customer Interactions and Distribution Systems Impact. *IEEE Trans. Smart Grid* **2017**. [CrossRef]
7. Luo, C.; Huang, Y.-F.; Gupta, V. Stochastic Dynamic Pricing for EV Charging Stations with Renewable Integration and Energy Storage. *IEEE Trans. Smart Grid* **2018**, *9*, 1494–1505. [CrossRef]
8. Liu, P.; Yu, J.; Mohammed, E. Decentralised PEV Charging Coordination to Absorb Surplus Wind Energy via Stochastically Staggered Dual-Tariff Schemes Considering Feeder- Level Regulations. *IET Gener. Transm. Distrib.* **2018**, *12*, 3655–3665. [CrossRef]
9. Dallinger, D.; Wietschel, M.; Santini, D.J. Effect of demand response on the marginal electricity used by plug-in electric vehicles. *World Electr. Veh. J.* **2012**, *5*, 730–738. [CrossRef]
10. Alexander, B. *Smart Meters, Real Time Pricing, and Demand Response Programs: Implications for Low-Income Electric Customers*; Purchase Order No. 4000049807; Oak Ridge National Laboratory UT-Battelle, LLC: Oak Ridge, TN, USA, 2007.
11. 2018 Toyota Prius Prime Plug-In Hybrid. Available online: https://www.toyota.com/priusprime/ (accessed on 17 October 2018).
12. 2018 Chevrolet Bolt EV Features, Specs, Trims and Dimensions. Available online: https://www.gmfleet.com/chevrolet/bolt-ev-electric-vehicle/features-specs-trims-dimensions (accessed on 17 October 2018).
13. Tesla Model 3. Available online: https://www.tesla.com/model3 (accessed on 11 January 2019).
14. CT4000 Level 2 Commercial Charging Station Specifications and Ordering Information. Available online: https://www.chargepoint.com/files/datasheets/ds-ct4000.pdf (accessed on 17 October 2018).

15. Express 200 DC Commercial Charging Stations Specifications and Ordering Information. Available online: https://www.chargepoint.com/files/datasheets/ds-cpe200.pdf (accessed on 17 October 2018).
16. Plotz, P.; Jakobsson, N.; Sprei, F. On the distribution of individual daily driving distances. *Transp. Res. Part B* **2017**, *101*, 213–227. Available online: https://doi.org/10.1016/j.trb.2017.04.008 (accessed on 17 October 2018). [CrossRef]
17. New Study Reveals When, Where and How Much Motorists Drive. AAA. Available online: https://newsroom.aaa.com/2015/04/new-study-reveals-much-motorists-drive/ (accessed on 17 October 2018).
18. Illinois Power Agency. Electricy Procurement Plan: 2018 Final Plan. 6 April 2017. Available online: https://www2.illinois.gov/sites/ipa/Documents/2018ProcurementPlan/2018-IPA-Procurement-Plan-20180406.pdf (accessed on 11 January 2019).
19. ComEd's Hourly Pricing Program. Available online: https://hourlypricing.comed.com/ (accessed on 17 October 2018).
20. PJM Daily Real-Time LMP. Available online: http://www.pjm.com/markets-and-operations/energy/real-time/lmp.aspx (accessed on 17 October 2018).
21. Walton, R. How Pepco Is Finding Ways to Shift Demand through Maryland EV Pilot Program. Utility Dive. 18 January 2017. Available online: http://www.utilitydive.com/news/how-pepco-is-finding-ways-to-shift-demand-through-maryland-ev-pilot-program/434156 (accessed on 17 October 2018).
22. Zethmayr, J.; Kolata, D. The costs and benefits of real-time pricing: An empirical investigation into consumer bills using hourly energy data and pricing. *Electr. J.* **2018**, *31*, 50–57. [CrossRef]
23. Zhang, J.; Markel, T. Charge Management Optimization for Future TOU Rates. *World Electr. Veh. J.* **2016**, *8*, 521. [CrossRef]