STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS
PUBLIC UTILITIES COMMISSION

Petition of The Narragansett Electric Company d/b/a National Grid for Approval of its Proposed Power Sector Transformation Vision and Implementation Plan.	R.I.P.U.C. No. 4780

Direct Testimony of
Douglas B. Jester

On Behalf Of
Conservation Law Foundation, Sierra Club, Natural Resources Defense Council and People's Power & Light

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I. INTRODUCTION

Q. Please state for the record your name, position, and business address.

A. My name is Douglas B. Jester. I am a Partner of 5 Lakes Energy LLC, a Michigan limited liability corporation, located at Suite 710, 115 W Allegan Street, Lansing, Michigan 48933.

Q. On whose behalf is this testimony being offered?

A. Conservation Law Foundation, Sierra Club, Natural Resources Defense Council, and People's Power & Light.

Q. Please summarize your experience in the field of electric utility regulation.

A. I have worked for more than 20 years in the field of electric industry regulation and related fields. My work experience is summarized in my resume, attached as Exhibit CLF-SC-NRDC-PP&L-A.

Q. Have you testified before this Commission?

A. No.

I have testified before the Michigan Public Service Commission in:

- Case U-17473 (Consumers Energy Plant Retirement Securitization);
- Case U-17096-R (Indiana Michigan 2013 PSCR Reconciliation);

- Case U-17301 (Consumers Energy Renewable Energy Plan 2013 Biennial Review);
- Case U-17302 (DTE Energy Renewable Energy Plan 2013 Biennial Review);
- Case U-17317 (Consumers Energy 2014 PSCR Plan);
- Case U-17319 (DTE Electric 2014 PSCR Plan);
- Case U-17671-R (UPPCO 2015 PSCR Reconciliation);
- Case U-17674 (WEPCO 2015 PSCR Plan);
- Case U-17674-R (WEPCO 2015 PSCR Reconciliation);
- Case U-17679 (Indiana-Michigan 2015 PSCR Plan);
- Case U-17688 (Consumers Energy Cost of Service and Rate Design);
- Case U-17689 (DTE Electric Cost of Service and Rate Design);
- Case U-17698 (Indiana-Michigan Cost of Service and Rate Design);
- Case U-17735 (Consumers Energy General Rates);
- Case U-17752 (Consumers Energy Community Solar);
- Case U-17762 (DTE Electric Energy Optimization Plan);
- Case U-17767 (DTE General Rates);
- Case U-17792 (Consumers Energy Renewable Energy Plan Revision);
- Case U-17895 (UPPCO General Rates);
- Case U-17911 (UPPCO 2016 PSCR Plan);

- Case U-17911-R (UPPCO 2016 PSCR Reconciliation);
- Case U-17990 (Consumers Energy General Rates);
- Case U-18014 (DTE General Rates);
- Case U-18089 (Alpena Power PURPA Avoided Costs);
- Case U-18090 (Consumers Energy PURPA Avoided Costs);
- Case U-17911-R (UPPCO 2016 PSCR Reconciliation);
- Case U-18091 (DTE PURPA Avoided Costs);
- Case U-18092 (Indiana Michigan Power Company PURPA Avoided Costs);
- Case U-18093 (Northern States Power PURPA Avoided Costs);
- Case U-18094 (Upper Peninsula Power Company PURPA Avoided Costs);
- Case U-18095 (Wisconsin Public Service Company PURPA Avoided Costs);
- Case U-18096 (Wisconsin Electric Power Company PURPA Avoided Costs);
- Case U-18224 (UMERC Certificate of Necessity);
- Case U-18255 (DTE Electric General Rates);
- Case U-18322 (Consumers Energy General Rates);
- Case U-18406 (UPPCO 2018 PSCR Plan);
- Case U-18408 (UMERC 2018 PSCR Plan); and
- Case U-18419 (DTE Certificate of Necessity).

I testified as an expert witness before the Public Utilities Commission of Nevada in case 16-07001 concerning the 2017-2036 integrated resource plan of NV Energy. I testified before the Missouri Public Service Commission in cases ER-2016-0179, ER-2016-0285, and ET-2016-0246 concerning residential rate design and electric vehicle (EV) policy, revenue requirements, cost of service, and rate design. I also filed testimony before the Kentucky Public Service Commission in case 2016-00370 concerning municipal street lighting rates and technologies, and the Massachusetts Department of Public Utilities in Case Nos. DPU 17-05 and DPU 17-13 concerning EV charging infrastructure program design and cost recovery.

In the past, I have also testified as an expert witness on behalf of the State of Michigan before the Federal Energy Regulatory Commission in cases relating to the relicensing of hydro-electric generation. I also have been listed as a witness on behalf of the State of Michigan, prepared case files and submissions, and been deposed in cases before the United States District Court for the Western District of Michigan and the Ingham County Circuit Court of the State of Michigan concerning electricity generation matters in which the cases were settled before trial.

Q. What is the purpose of your testimony?

A. National Grid is seeking the following approvals and findings from the Rhode Island PUC in this case:

(1) Approval of the proposed Power Sector Transformation Provision, R.I.P.U.C. No. 2205, for Narragansett Electric and Power Sector Transformation Plan, RIPUC NG-GAS No. 101, Section 3, Distribution Adjustment Charge, Schedule A, Sheets 1-6, Ninth Revision, for Narragansett Gas (collectively, the Tariff Provisions), which include, but are not limited to:

(a) the methodology for calculating Power Sector Transformation Factors and Power Sector Transformation Reconciliation Factors;

(b) the methodology for recovering Power Sector Transformation-related Performance Incentives through a Performance Incentive Factor; and

(c) the process for submitting annual plans to the PUC by December 1 for Fiscal Year 2020 and January 1 annually thereafter, for PUC approval by April 1;

(2) Approval of $2 million in funding for Fiscal Year 2019 to begin design work on the Company's proposed advanced metering functionality (AMF) investments;

(3) Approval of new performance incentive mechanisms in three categories: (1) System Efficiency, (2) Distributed Energy Resources, and (3) Network Support Services, including approval of the individual metrics, measurement methodologies, targets and associated basis points of earning opportunity; and

(4) Findings regarding whether each proposed category of PST Plan investment and the proposed PST incentive mechanism are consistent with Rhode Island law, the PUC's Docket 4600 Guidance Document, and state regulatory policy, and therefore, appropriate for inclusion in annual PST Plans to implement the Company's overall PST Plan over time.

The purpose of my testimony is to discuss the appropriateness of these requests with respect to advanced metering functionality (AMF) and National Grid's Electric Transportation Initiative. With respect to advanced metering functionality, I will

(1) discuss the importance of advanced metering in Power Sector Transformation;

(2) discuss the appropriateness of National Grid's approach to deploying advanced metering functionality; and

(3) offer recommendations to improve the net benefits of National Grid's proposed deployment of advanced metering functionality.

With respect to the Company's proposed Electric Transportation Initiative, I will

(1) discuss the importance of accelerated EV deployment for meeting Rhode Island's greenhouse gas (GHG) emission reduction requirements and achieving other public policy goals and objectives;

(2) discuss the appropriate role for utility engagement in promoting electric vehicles;

(3) describe and evaluate the positive and negative features of the Electric Transportation Initiative proposed by National Grid; and

(4) offer recommendations for improving upon shortcomings of National Grid's Electric Transportation Initiative.

Q. Do you have specific qualifications in relation to advanced metering?

A. From late 2007 through 2009, I reported in to the Office of the Chief Technology Officer at Verizon and led that Company's efforts to develop a smart grid product architecture. In that capacity, I represented Verizon in various working groups of the National Institute of Standards and Technology's Smart Grid Interoperability Panel with a particular emphasis on communications standards, security, metering, and customer engagement. I and my team also worked with most of the vendors of advanced meters and distribution system automation solutions to determine communications and security requirements and establish partnerships for product integration.

In 2010 and 2011, I served as an active member of the Michigan Public Service Commission's smart grid collaborative.

Since 2013, I have testified as an expert witness in numerous cases before the Michigan Public Service Commission in which I have evaluated utility advanced metering proposals, examined whether utilities were making good use of data derived from advanced metering to improve distribution system reliability and resilience, control voltage and VARs, reduce losses, and otherwise improve distribution system performance. I have also testified in ten cases before the Michigan Public Service Commission on cost of service studies and rate design in which I made extensive use of

hourly load data derived from advanced metering and made recommendations for time-varying rates that depend on advanced metering functionality. Further, I have used interval load data derived from advanced metering to develop improved methods to target energy efficiency programs and identify incremental energy efficiency measures to be included in utility energy efficiency programs.

I also currently serve as a Commissioner of the Lansing Board of Water and Light, a large municipal utility, which is currently deploying advanced metering functionality.

Q. Do you have specific qualifications in relation to electric vehicle charging infrastructure?

A. In 2010, I served as an active member of the Michigan Public Service Commission's electric vehicle charging collaborative.

In 2012, my colleagues at 5 Lakes Energy and I, on behalf of the Pew Charitable Trusts, engaged stakeholders in a number of states in roundtable discussions about the development of electric vehicle infrastructure and drafted a report about best practices, which informed Pew Charitable Trusts' subsequent work in this field.

More recently, my colleagues at 5 Lakes Energy and I produced integrated resource planning tools for least-cost compliance with the Clean Power Plan in ten states. These

tools incorporate means to model the potential effects of various levels of electric vehicle market penetration on the electricity system.

Most recently, my colleagues at 5 Lakes Energy and I are organized a national conference on the convergence of transportation electrification, vehicle autonomy, and transportation as a service, titled "Powering Mobility", held in Detroit on September 25, 2017.

Currently, my colleagues at 5 Lakes Energy and I are convening a series of six day-long workshops of all Michigan stakeholders in order to develop a consensus on electric transportation policy. Participants include automobile manufacturers, electric vehicle service equipment suppliers, utilities, government officials, and others. Topics include integration of utility programs and Volkswagen settlement mitigation funding, customer communications and adoption experience, long-dwell charging, fast charging, and fleet charging.

Q. How is your testimony structured?

A. My testimony is structured as follows:

- Section I: Introduction;
- Section II: Importance of Advanced Metering in Power Sector Transformation
- Section III: Appropriateness of National Grid's Approach to Advanced Metering

- Section IV: Recommendations Regarding National Grid's Advanced Metering Proposal
- Section V: Importance of Electric Vehicle Adoption in Massachusetts;
- Section VI: Appropriate Utility Engagement in Promoting Electric Vehicles;
- Section VII: Evaluation of National Grid's Electric Transportation Initiative; and
- Section VIII: Recommendations Regarding National Grid's Electric Transportation Initiative.

Q. Are you sponsoring any exhibits?

A. Yes. I have attached the following exhibits for review:

- Exhibit CLF-SC-NRDC-PP&L-A: Resume of Douglas B. Jester
- Exhibit CLF-SC-NRDC-PP&L-B: Citizens Utility Board, The ABCs of EVs: A Guide for Policy Makers and Consumer Advocates (2017).

II. IMPORTANCE OF ADVANCED METERING IN POWER SECTOR TRANSFORMATION

Q. National Grid proposes to implement advanced metering functionality as a foundational element of power sector transformation. Do you agree that this is an essential step?

A. I do. Power Sector Transformation as envisioned by this Commission requires two things that are provided by advanced metering functionality. Power Sector Transformation

requires more flexible power demand that can adjust to power supply conditions; advanced metering functionality is required for both the time-varying prices and customer engagement that are necessary to achieve flexible demand.

Power Sector Transformation also requires that control of power flows in the grid be enhanced so as to maintain sufficient reliability and power quality even as power flows vary more than they have historically. Advanced metering is an important source of data for such controls, particularly since metering is ubiquitous on the grid and is the location to measure reliability and power quality provided to each customer.

III. APPROPRIATENESS OF NATIONAL GRID'S APPROACH TO ADVANCED METERING

Q. What materials did you review to support your testimony about National Grid's approach to advanced metering?

A. I focused primarily on Chapter 4 of National Grid's Power Sector Transformation Plan and the associated workpapers filed by National Grid in this case.

Q. What is your overall opinion of National Grid's approach to advanced metering?

A. Overall, it is one of the best plans that I have seen for deployment of advanced metering. I note particularly that the plan calls for rapid deployment once initiated, focuses on customer enablement through both the services to be provided by National Grid and

through support for third-party services, and for prompt and comprehensive adaptation of rate design based on the capabilities provided by advanced metering. These aspects of the plan provide reasonable assurance that National Grid will take the steps that ensure customers benefits from advanced metering and that those benefits accrue roughly consonant with when customers experience the costs of adopting advanced metering.

Q. Why do you consider rapid deployment to be important?

A. Many utilities have deployed advanced metering in their service territories over periods of three to five years, while they and their regulators have held back from providing services or changing rate design based on advanced metering until all customers have advanced metering and access to associated services and rate treatment. This leads to customers paying for advanced metering without receiving benefits and a significant deterioration of the net benefits of advanced metering.

Q. Why do you consider a primary focus on customer enablement to be important?

A. Although utility operations can benefit from advanced metering, every careful analysis of net metering that I have reviewed shows that most of the benefits of net metering accrue because customers are able to use metering data to either reduce their energy cost or increase its value or because customer responses to pricing and other signals based on

advanced metering enable the utility to reduce costs, improve reliability, or reduce pollution emissions. Without customer enablement, most of these benefits do not accrue.

Q. Why do you consider that prompt and comprehensive adaptation of rate design is important?

A. National Grid proposes to implement time-varying rates to all customers on an opt-out basis soon after deployment of advanced metering functionality is complete. There are four reasons that this aspect of National Grid's plan is important. First, while customer enablement is essential for most of the benefits of advanced metering, it is rate design that gains customer attention. Few people are "energy nerds" who want to pay attention to their electricity usage. Time-varying rate design provides customers an interest in managing electricity usage in ways that are in their own interest and in society's interest and also provides an unambiguous signal about when and what behavior or investment is beneficial.

Second, it activates markets in goods and services that utility customers can use to respond to rate design. If only a few customers are engaged with experimental rate designs, the suppliers of building services, electrical equipment, and automation services will not find it profitable to supply or advertise those services.

Third, time-varying rates will aid in customer adoption of technologies that advance beneficial electrification. For example, if electric vehicle charging can be done at lower-cost times under a time-varying rate design, this lowers the total cost of ownership of an electric vehicle and increases the value of electric vehicles to the grid. Aside from electric vehicles, time-varying rates are supportive of PV deployment and shifting other electricity uses from on-peak to off-peak periods.

Fourth, time-varying rates will more accurately charge customers their own cost of service, eliminating intra-class subsidies and providing fairer rates. In recent testimony before the Michigan Public Service Commission in general rate cases for both DTE Electric and Consumers Energy, I was able to use 8760-hour load profiles of a random sample of customers to compare cost-of-service of individual residential customers based on the utility's cost of service study to annual bills for those same customers based on these utilities "traditional" rate designs.[1] In both cases, I found that intraclass cross-subsidies were approximately 20% of total class required revenue and that this intraclass cross-subsidy could be substantially mitigated by use of fairly simple time-of-use rates.

In the Consumers Energy case, I was also able to obtain 8760-hour load profiles of a random sample of income-eligible customers enrolled in the Company's Residential

[1] Direct testimony of Douglas B Jester in Michigan Public Service Commission cases U-18255 and U-18322.

Income Assistance program. My analysis showed that the average income-eligible customer of this utility is paying approximately 15.6% more than their cost of service, that the income-eligible bill credit only offset about 6.1% of the average income-eligible customer's bill leaving about 9.1% excess billing to low-income customers.[2] Of course, low-income customers who are not enrolled in the bill assistance program pay the full amount of this subsidy to higher-income customers. Michigan income-eligible customers must work about 1.8 hours per month at minimum wage to subsidize the electricity usage of better-off residential customers. Theses excessive bills to income-eligible customers would be eliminated by time-varying rates reflecting cost of service.

A recent analysis[3] by Illinois Citizens Utility Board and Environmental Defense Fund using a large sample of anonymous residential electricity customers in Illinois showed that approximately 97% of those customers would have a reduced annual bill under real-time pricing compared to flat pricing per kWh without changing their load profile. While this finding partly reflects that Illinois is a restructured state with generation operating in

[2] Surrebuttal testimony of Douglas B Jester in Michigan Public Service Commission case U-18322.
[3] Zethmayr, J. and D, Kolata. 2017. The Costs and Benefits of Real-Time Pricing: An empirical investigation into consumer bills using hourly energy data and prices. The Citizens Utility Board of Illinois and Environmental Defense Fund. Available at https://citizensutilityboard.org/wp-content/uploads/2017/11/FinalRealTimePricingWhitepaper.pdf.

retail competition, it is nonetheless instructive that time-varying rates can be broadly beneficial to residential customers.

Q. Do you support National Grid's proposal to implement time-varying rates on an opt-out basis?

A. I do. Giving customers the opportunity to opt out of a change in rate schedule provides them as much free choice as requiring them to opt in to a rate schedule. A customer who prefers a rate schedule different from the default rather than accepting one proposed by the utility can still make that choice.

However, default decisions are commonly accepted by customers, whether or not they are actually preferred by those customers, because of the demands on their time, attention, and faculties to make and act on an informed decision. For example, Lawrence Berkeley National Laboratory reported4 that when presented utility rate program options on an opt-in basis less than 20% of customers made the choice to switch while on an opt-out basis approximately 80% accepted the switch. Further, in one experiment in which identical program options were offered and customers were randomly assigned to opt-in or opt-out offers, only 11% of those offered the new rate design through opt-in accepted

[4] Todd, A., P. Cappers, and C. Goldman. 2013. Residential Customer Enrollment in Time-Based Rate and Enabling Technology Programs. LBNL Report 7247E. Available at https://emp.lbl.gov/sites/all/files/lbnl-6247e.pdf.

the offer while 84% of those offered on an opt-out basis accepted the new rate design. Brandon Hofmeister, in an excellent article in the Southeastern Environmental Law Journal discussed barriers to the adoption of cost-effective energy efficiency measures but some of his observations are equally applicable to customer rate selection: Transaction Costs and Insufficient Information (p. 16), Status Quo Bias (p 21), Certainty Effect (p 23), Saliency and the Affect Heuristic (p. 28) are the most obvious of these.5 In essence, there are important psychological and decision-making barriers to customer opt-in that bias against a change from the status quo.

Consequently, public policy should assume that the most socially beneficial tariff is what a utility customer prefers unless the customer explicitly chooses otherwise.

Q. Do you find National Grid's benefit-cost analysis for advanced metering functionality to be reasonable?

A. I do. I carefully reviewed both the methods and estimates provided in Appendix 4.1 and Appendix 4.2 of National Grid's Power Sector Transformation Plan and found them to be appropriately prepared and reasonable, based on my experience.

Q. Do you have any concerns about National Grid's advanced metering functionality

[5] Hofmeister, B. 2010. Bridging the Gap: Using Social Psychology to Design Market Interventions to Overcome the Energy Efficiency Gap in Residential Energy Markets. 19 Se. Envtl. L. J. 1 2010-2011.

proposal?

A. Yes, but each can be readily addressed. My concerns are (1) that National Grid has not adequately addressed the opportunity provided by advanced metering to "groom" its distribution system, (2) that the Commission should review its policies with respect to collections-related disconnection, and (3) that National Grid and the Commission should timely engage stakeholders in designing time-varying rates and the plan for transition to those rates.

Q. Please explain the opportunity to "groom" National Grid's distribution system.

A. I applaud National Grid's plan to use advanced metering functionality to improve and expand Volt-VAR optimization. This is a genuine and important opportunity to improve the operation of the distribution grid to improve power quality, reduce energy and generation capacity consumption, and somewhat increase the reliability of the distribution system by reducing damage to equipment. Data supplied through advanced metering functionality presents at least two other opportunities to improve National Grid's distribution system, through a process which I label as "grooming." These are "phase balancing" and "transformer right-sizing."

Q. Please explain the best practices and expected benefits of distribution system phase balancing.

A. Primary distribution circuits are three-phase while most domestic and small commercial loads are single phase. Some loads, especially thermal end uses, of primary customers are single phase. As a result, the load on each phase of a three-phase distribution line can become unbalanced. Waveform changes due to inductance and capacitance of end-uses can also cause alternating current misalignments between the phases so that when superposed there is a loss of real power and efficiency.

When phases are unbalanced, one or two phases carry excessive current and one or two phases carry insufficient current. Those carrying excessive current experience higher line and transformer losses while those carrying insufficient current experience lower line and likely lower transformer losses. Because losses are proportional to the square of current, the imbalance causes greater overall losses than if the phases were balanced. The phases with higher load also experience greater voltage drop than the phases with lower load, affecting delivered voltage; phase balancing can thereby enable greater voltage control, using Volt-VAR optimization as proposed by National Grid. Three phase equipment also generally operates less efficiently and with greater wear when the phases are unbalanced. It is therefore beneficial to balance load between phases.

Basic load balancing can be accomplished by optimizing the assignment of load to fixed wiring but additional performance is possible through distribution automation using sectionalizing reclosers.

It has historically been difficult to identify phase imbalance and to determine best ways to rebalance loads between phases. However, with AMI it becomes relatively easy. The phase to which a single-phase load is attached can be determined by regressing voltage at each meter to reference voltage on each phase to find the best fit.6 Various algorithms are then available to optimally combine load profiles from advanced metering into phases.

Direct benefits of phase balancing are generally fairly small and mostly are reductions in losses. However, because the costs of phase balancing are also quite low, the cost-effectiveness of phase balancing is generally high. For instance, EPRI's Green Circuits project7 included detailed analysis of 66 distribution circuits and included an evaluation of phase rebalancing at the substation (additional benefits can be obtained by phase balancing using additional equipment further along the circuit). The following graph shows the results of that analysis

[6] T. A. Short, Advanced Metering for Phase Identification, Transformer Identification, and Secondary Modeling. IEEE Transactions on Smart Grid 4:651-658, 2013.
[7] EPRI. Green Circuit Distribution Efficiency Case Studies 2011 Technical Report, available at http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001023518&Mode=download.

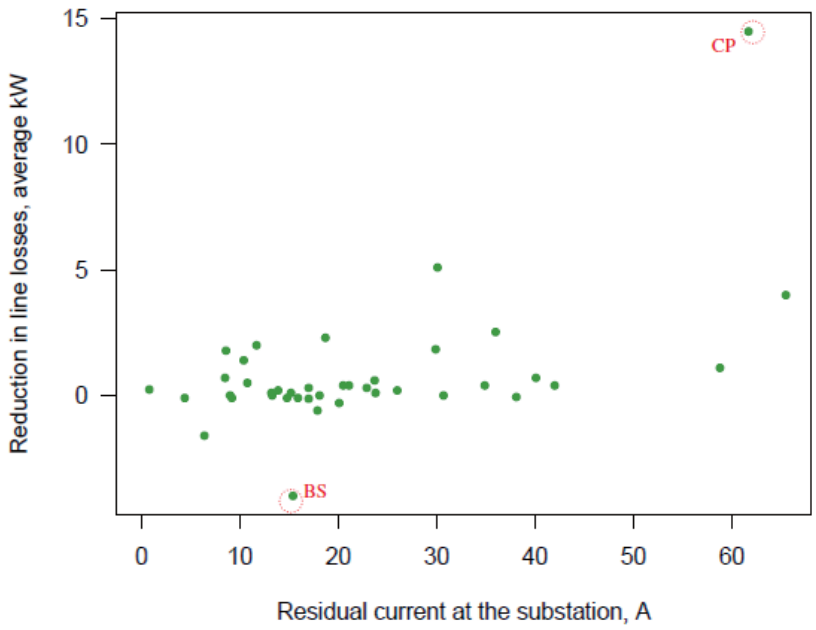

Figure 2-38
Reduction in Line Losses with Ideal Phase Balancing

This graph shows that for some circuits, rebalancing caused negative line loss reductions, which can be attributed to the EPRI analysis using phase balancing at peak load rather than a more advanced algorithm that takes account of the entire load profile. This limitation of method was likely detrimental to the positive results for other circuits. Nonetheless, 12 circuits showed definite beneficial results.

The EPRI project looked in more detail at 6 circuits, intended to represent the variety of relevant conditions in the larger sample. The following table shows the benefit-cost ratio of each of the strategies they analyzed for each of the circuits.

Table 3-8
Benefit-to-Cost Ratio for the Best Option in each Category

	Circuit					
	A	B	C	D	E	F
Base voltage feedback	8.1	17.6	3.5	1.8	3.6	29.9
Phase balancing	9.8	17.0	3.9	2.3	3.4	25.2
Var optimization	9.5	17.2	3.3	4.1	3.1	29.0
Reconductoring	4.7	2.4	0.2	0.4	0.7	15.6
Voltage regulators					3.1	22.4
Combinations	11.3	10.8	3.8	4.7	2.1	5.3

Phase balancing shows consistently good benefit-to-cost ratios across these example circuits. The analysts also observed that phase balancing was most cost effective when applied to circuits with high load density (load per length of circuit), which could be used as a basis for prioritizing phase balancing analysis of National Grid's distribution system. EPRI did not produce a table showing detailed phase balancing results across these 6 circuits, but did show detailed results for two circuits. These were not chosen based on the phase balancing results so may or may not be representative. They do indicate that examination of phase balancing by National Grid is warranted. I prepared the following table of the best phase balancing solution for each circuit based on their presentation, where each entry is a percentage of that circuit's base load or demand.

Circuit	Annual Consumption Saved	Annual Losses Saved	Peak Demand Saved	Peak Losses Saved	Annual Energy Saved	Total Peak Reduction	Levelized Cost $/kWh Saved
A	3.1%	2.3%	0.1%	0.1%	3.1%	0.1%	$0.009
F	2.4%	2.5%	0.1%	0.2%	2.4%	0.1%	$0.004

Q. Please explain the best practices and expected benefits of transformer load balancing.

A. Distribution transformers account for 26% of typical utility transmission and distribution system losses and 41% of distribution and subtransmission losses.[8] Transformers lose energy through two primary mechanisms. Resistive losses in the windings of the transformer are proportional to the square of current and electromagnetic field losses related to energizing the transformer core are more or less proportional to voltage. As a result, power losses in a transformer as a percent of load are dependent upon load as is shown in the following graph[9] where the various lines represent various load profiles used in European standards:

[8] T. A. Short, Electric Power Distribution Equipment and Systems. Boca Raton, FL, USA: CRC/Taylor & Francis, 2006.
[9] From *The Scope for Energy Savings in the EU Through the Use of Energy-Efficient Electricity Distribution Transformers by Hans De Keulenaer et al, available at http://www.cired.net/publications/cired2001/4_27.pdf.*

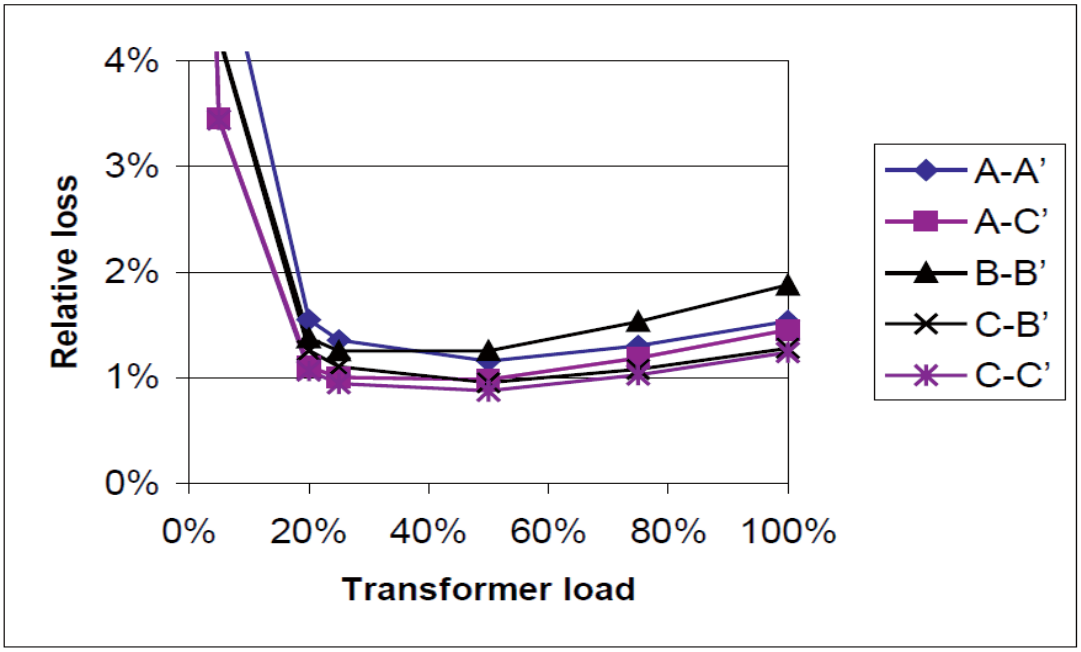

FIGURE 1 - Variation of relative loss (% of energy transformed, as a function of load) - 400 kVA transformer

This illustrates why common engineering practice is to size transformers for average load around 50% of nominal capacity. In practice, many above-ground transformers are overloaded for some hours of the year since they do not fail when rated capacity is exceeded; rather they suffer greater losses (following the square of load) as heat which accelerates transformer aging but with a reasonable economic tradeoff. It should also be noted that when represented as actual loss rather than relative loss, losses at high loads are much higher than losses at low loads. Thus transformer load balancing has potential to reduce overall energy loss factors through reducing both overload and underload

conditions, but particularly to reduce energy and capacity requirements associated with peak loads.

When transformers are consistently underloaded, this causes excessive losses as a percentage of load. When transformers are consistently overloaded, this causes excessive losses as a percentage of load (and in absolute amounts) and accelerated aging of the transformer. Aged transformers are most likely to fail during a period of high load and in such circumstances are likely to spill cooling oil, requiring environmental remediation.

With the deployment of advanced meters, it is now possible to empirically examine transformer loading. The basic strategy is to add up the hourly (or more granular) loads served by a particular transformer and compare this to the transformer's rating. Transformer loading problems can then be addressed by reassigning load to a different transformer, moving transformers around wihtin the distribution system to better match transformer ratings to loads, or by taking steps to reduce high loads through targeted efficiency, demand response, distributed generation, or storage. Such analyses can be done using database queries and spreadsheets or by using commercially-available software developed for this purpose.

As an illustration of the benefits of transformer load balancing that might be achieved by National Grid, I draw the Commission's attention to the testimony of Karen R Lefkowitz on behalf of Potomac Electric Power Company (PEPCO) before the Maryland Public

Service Commission in Case No. 9418. For context, PEPCO, with approximately 550,000 customers, is similar in size to National Grid in Rhode Island. In this testimony Lefkowitz describes that during 2014 and 2015, PEPCO analyzed over 9,500 transformers serving over 74,000 customers located on its 2014 and 2015 Priority Feeders. This study identified 420 overloaded transformers that could impact nearly 4,000 customers. The overloading determination was based on occurrence of overloads of more than five hours in length that equaled or exceeded 160% of transformer nameplate capacity for overhead transformers. For underground transformers, the overloading determination was made based on overloads of more than five hours in length and a loading magnitude of 100% of transformer nameplate capacity. (The delineation in criteria between overhead and underground transformers is attributable to the ability of overhead transformers to dissipate heat into the outdoor air.) By methods outlined in pages 40 through 44 of her testimony, Lefkowitz estimates net present value net benefits of about $13,480,000 from instituting this practice, dominated by reliability benefits. This estimate did not include benefits from power quality improvements or line loss reductions, as these were not quantified.

There is no a priori reason that National Grid's transformers are better or worse matched to load than PEPCO's. A calculation of potential energy and capacity savings through transformer load balancing is necessarily speculative absent specific studies by National

Grid, but can be approximated based on PEPCO's experience. While the potential benefits described above are speculative, they justify an effort by National Grid to evaluate and, as appropriate, implement the practice of using AMI data to balance load with transformer capacity.

Q. Why do you recommend that the Commission review its policies with respect to collections-related disconnection?

A. National Grid discusses remote connect and disconnect capabilities of advanced meters on page 20 of Appendix 4.1 of its Power Sector Transformation Plan. They specifically state

> With respect to collections related disconnects, the Company will comply with all requirements per Title 39 of the State of Rhode Island General Law and the Rules and Regulations promulgated by the PUC and the Rhode Island Division of Public Utilities and Carriers regarding termination of service, including visits to the customer premises. Avoided meter visits will reduce labor and vehicle costs.

I take this representation at face value and to be in good faith. However, I have observed on multiple occasions that utilities and their regulators are surprised to find unexpected issues with remote disconnection. These surprises have been the result of unstated assumptions related to the disconnection process that are no longer true with remote disconnection. On that basis, while I am not recommending against all use of remote disconnection nor questioning National Grid's estimates of the benefits of remote disconnection, I am recommending that, out of an abundance of caution, the Commission

afford consumer advocates an opportunity to review this matter in detail with National Grid and the Commission.

Q. Why are you concerned that National Grid and the Commission should timely engage stakeholders in designing time-varying rates and the plan for transition to those rates?

A. The power of time-varying rates is primarily in their ability to influence customer behavior and investments. As I discussed above, I view time-varying rates as good policy with multiple benefits. However, since they are intended to modify customer behavior and investments and will have effects on bills and customer budgets, it is particularly important that the Commission give these matters careful consideration in preparation for and through the process of significant change in rate design.

For this reason, I and a number of colleagues submitted a letter to NARUC in 2016 describing our consensus on certain principles concerning "good process" for developing good rate design.[10] We emphasize the importance of assessment and analysis, collaboration, data-driven discussion, testing, special attention to low income/vulnerable population impact, and consumer education.

[10] Available at http://blogs.edf.org/energyexchange/files/2016/06/Good-Rate-Design-Process-Letter-to-NARUC.pdf.

I have a favorable impression of the Commission's process to date regarding Power Sector Transformation. I also am personally persuaded that time-varying rates with fairly strong price differentials from one time to another are strongly beneficial to most utility customers and to society. However, the transition from current rate design to such time-varying rate design is an important one that should be worked through with stakeholders. Whatever consensus the Commission feels that it has amongst stakeholders regarding Power Sector Transformation may mask significantly differing expectations regarding the rate designs that will be implemented.

Good process takes time and National Grid's proposed timeline for implementing advanced metering functionality is fairly rapid (which I view as a positive feature of their plan). I therefore recommend that the Commission initiate a collaborative process immediately after the conclusion of this case in which National Grid and other stakeholders can work toward a consensus regarding concrete rate design and implementation of time-varying rates and schedule that process to be completed timely for National Grid to file its time-varying rate proposals for implementation soon after the scheduled complete deployment of advanced metering functionality.

IV. RECOMMENDATIONS REGARDING NATIONAL GRID'S ADVANCED METERING PROPOSAL

Q. Do you recommend that the Commission approve $2 million in funding for Fiscal

Year 2019 to begin design work on the Company's proposed advanced metering functionality (AMF) investments?

A. I do. Advanced metering functionality is an important foundation for a modern grid and for power sector transformation. National Grid's plan for deployment of advanced metering functionality is better than that of most utilities and its estimated costs are reasonable. Provided that National Grid and the Commission proceed as planned to timely obtain the benefits of advanced metering functionality, the benefit cost ratio should be distinctly positive.

Q. Do you recommend that the Commission find that PST Plan investment in advanced metering functionality and the proposed PST incentive mechanism are consistent with Rhode Island law, the PUC's Docket 4600 Guidance Document, and state regulatory policy, and therefore, appropriate for inclusion in annual PST Plans to implement the Company's overall PST Plan over time?

A. I recommend that the Commission find the proposed PST Plan investment in advanced metering functionality is in the public interest.

Q. Do you recommend that the Commission undertake any other action in relation to National Grid's proposals with respect to advanced metering functionality?

A. Yes. As explained earlier in my testimony, I recommend that the Commission:

1) Direct the Company to evaluate the potential benefits of distribution system grooming as an early effort following the implementation of advanced metering functionality;

2) At the appropriate time, establish a process by which consumer advocates and other stakeholders can review for the Commission whether existing provisions of law and regulations are appropriate when connection and disconnection are performed remotely;

3) Immediately after the completion of this proceeding, establish a collaborative process for the timely development of time-varying rates to be implemented when advanced metering functionality has been deployed by National Grid.

V. IMPORTANCE OF ELECTRIC VEHICLE ADOPTION IN RHODE ISLAND

Q. Does transportation electrification produce benefits for Rhode Island?

A. Yes. Transportation electrification produces a number of general societal benefits, including mitigation of climate change, reductions in air pollution that benefit public health, improvements in energy security, and increases in macroeconomic stability. Furthermore, as detailed in Section IV, accelerating electric vehicle adoption in Rhode Island will provide substantial benefits to the electrical grid and all electric utility customers, regardless whether they own electric vehicles, especially if tariffs guide

electric vehicle drivers to charge their vehicles at off-peak times. Drivers of electric vehicles will experience reduced fueling and vehicle maintenance costs.[11] A more fulsome discussion of the benefits of transportation electrification can be found in Vermont Energy Investment Corporation's report "Fully Charged: How Utilities Can Realize Benefits of Electric Vehicles in the Northeast."[12]

Q. How does transportation electrification mitigate climate change?

A. The National Research Council has determined that stabilization of climate requires at least an 80-percent reduction in carbon dioxide (CO_2) emissions.[13] Combusting fossil fuels in vehicles produces carbon dioxide. The U.S. Environmental Protection Agency (EPA) found that 26.3 percent of greenhouse gas emissions in the United States in 2014 were from transportation fuels.[14] Rhode Island's own greenhouse gas emissions are even

[11] Union of Concerned Scientists. 2017. Going from Pump to Plug: Adding up the Savings from Electric Vehicles. Available at https://www.ucsusa.org/sites/default/files/attach/2017/11/cv-report-ev-savings.pdf.
[12] Vermont Energy Investment Corporation. 2016. Fully Charged: How Utilities Can Realize Benefits of Electric Vehicles in the Northeast. Available at https://www.veic.org/documents/default-source/resources/reports/veic-report-fully-charged-2016-09-06.pdf?sfvrsn=2.
[13] National Research Council. 2011. Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia. Washington D. National Academies Press. Available at www.nap.edu.
[14] EPA. 2016. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014. Available at https://www.epa.gov/sites/production/files/2016-04/documents/us-ghg-inventory-2016-main-text.pdf.

more heavily from transportation sources, with 40 percent of Rhode Island's greenhouse gas emissions from transportation sources in 2015.[15]

Analyses of strategies to mitigate climate change broadly conclude that substantial reduction of greenhouse gas emissions from vehicles is a necessary step,[16] and that the most likely path to do so is transportation electrification[17] in combination with reductions in the carbon intensity of electric power production.[18] Moreover, multiple studies have shown that transportation electrification reduces greenhouse gas emissions even with current generation portfolios. For example, a recent blog post[19] by the Union of Concerned Scientists, updating their earlier report[20] illustrates in the following map (Figure CLF-SC-NRDC-PP&L-1) that electric vehicles charged in Rhode Island produce greenhouse gases equivalent to those from a gasoline vehicle that averages 102 miles per

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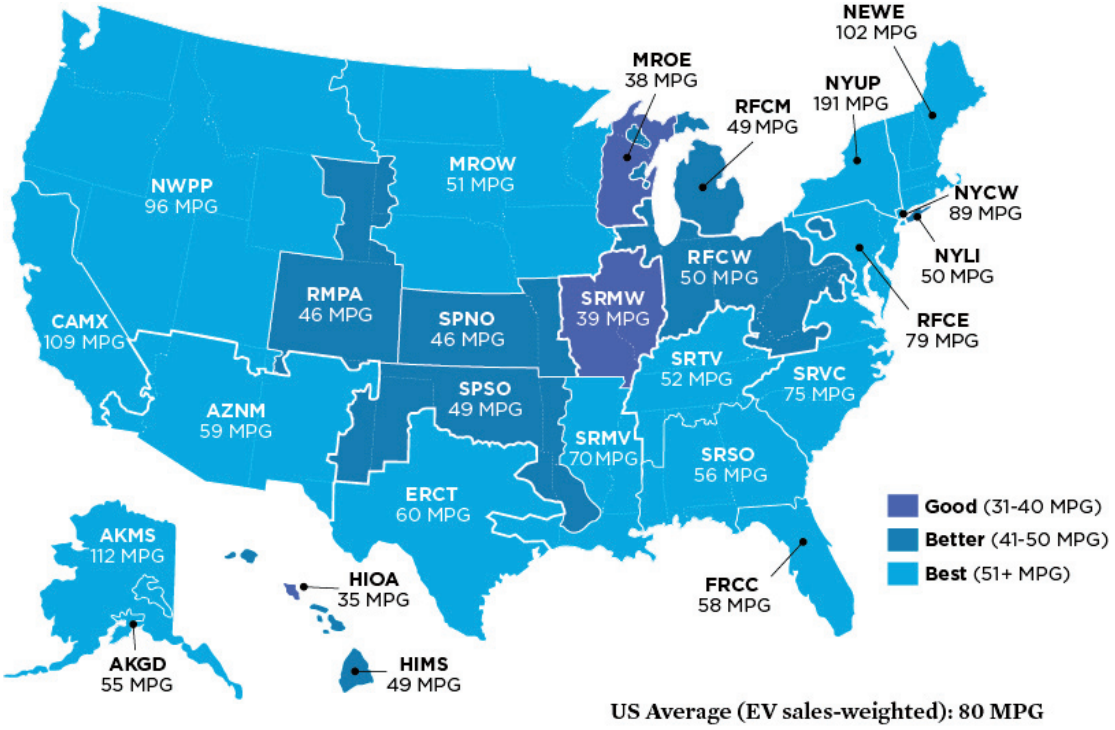
[15] *See* Rhode Island Executive Climate Change Coordinating Council. 2016. Rhode Island Greenhouse Gas Reduction Plan. Available at http://climatechange.ri.gov/documents/ec4-ghg-emissions-reduction-plan-final-draft-2016-12-29-clean.pdf.
[16] *See, e.g.*, Williams, J.H. et al. The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity. *Science*. 2012. 335: 6064, pp 53-59.
[17] On-board energy storage can be in the form of voltaic energy in batteries or hydrogen for use in fuel cells, either of which would be charged using electric power.
[18] *See, e.g.*, Williams, J.H. et al. 2014. Pathways to Deep Decarbonization in the United States. Available at http://unsdsn.org/wp-content/uploads/2014/09/US-Deep-Decarbonization-Report.pdf (concluding that, in concert with other power sector trends, 80-95 percent of all passenger vehicle miles traveled must come from vehicles that use primarily electricity in order to achieve deep decarbonization).
[19] Union of Concerned Scientists. 2018. New Data Show Electric Vehicles Continue to Get Cleaner. Available at https://blog.ucsusa.org/dave-reichmuth/new-data-show-electric-vehicles-continue-to-get-cleaner.
[20] Union of Concerned Scientists. 2015. Cleaner Cars from Cradle to Grave. Available at http://www.ucsusa.org/clean-vehicles/electric-vehicles/life-cycle-ev-emissions#.V4vXAI-cFJ8.

gallon, which is higher than the mileage of any gasoline-powered vehicles rated by EPA.[21]

Figure CLF-SC-NRDC-PP&L-1

Electric Vehicle Emissions in Gasoline Vehicle Mileage Equivalents[22]



Note: The MPG (miles per gallon) value listed for each region is the combined city/highway fuel economy rating of a gasoline vehicle that would have global warming emissions equivalent to driving an EV. Regional global warming emissions ratings are based on 2016 power plant data in the EPA's eGRID 2016 database (the most recent version). Comparisons include gasoline and electricity fuel production emissions estimates using Argonne National Laboratory's GREET 2017 model. The 80 MPG US average is a sales-weighted average based on where EVs were sold in 2011-2017.

[21] The highest mileage gasoline-fueled passenger car in EPA's mileage ratings is the 2017 Toyota Prius Eco with average mileage of 56 miles per gallon. *See* http://www.fueleconomy.gov/.
[22] Union of Concerned Scientists. 2015. Cleaner Cars from Cradle to Grave. Available at http://www.ucsusa.org/clean-vehicles/electric-vehicles/life-cycle-ev-emissions#.V4vXAI-cFJ8.

The U.S. Department of Energy also has a calculator[23] that compares emissions from powering an electric vehicle to emissions from a comparable internal combustion vehicle. For Massachusetts, this calculator shows that EVs emit about 64 percent less CO_2 than the average gasoline-fueled automobile, accounting for the emissions associated with electricity generation. The climate benefits of EVs will improve over time as the portion of the electricity consumed in Rhode Island that is generated by renewable energy resources grows under existing state and regional clean energy policies such as the Regional Greenhouse Gas Initiative, Rhode Island Renewable Energy Growth Program and similar efforts.

Q: How quickly must transportation electrification proceed in order to mitigate climate change consistent with Rhode Island's climate goals?

A. Because only 15 to 17 million passenger vehicles are sold each year nationally, it will take about 15 years of exclusively electric vehicle purchases to largely replace the U.S. fleet with electric vehicles. Ramping electric vehicle penetration of new sales to 100 percent by 2035 will require that the annual increment of electric vehicle share of sales average almost 5 percent per year beginning immediately. In 2017, electric vehicles constituted 1.2 percent of national vehicle sales and 0.92 percent of Rhode Island vehicle

[23] *See* http://www.afdc.energy.gov/vehicles/electric_emissions.php.

sales.[24] Thus, if transportation electrification is necessary for mitigating climate change, then near-term acceleration of electric vehicle adoption is essential.

Q. Does Rhode Island have a state policy designed to mitigate climate change?

A. Rhode Island's Resilient Rhode Island Act of 2014 establishes targets for greenhouse gas emissions reductions including:

(A) Ten percent (10%) below 1990 levels by 2020;

(B) Forty-five percent (45%) below 1990 levels by 2035;

(C) Eighty percent (80%) below 1990 levels by 2050.

In recognition of the need to accelerate electric vehicle adoption to mitigate climate change, Rhode Island joined California, Connecticut, Maryland, Massachusetts. New York, Oregon, Rhode Island, and Vermont in a memorandum of understanding committing to coordinated action to ensure successful implementation of their state zero-emission vehicle (ZEV) programs.[25] That commitment includes that "[b]y 2025, about 15 percent of new vehicles sold in the participating states will be required to be ZEVs."

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[24] *See* https://autoalliance.org/energy-environment/zev-sales-dashboard/.[25] State Zero-Emission Vehicle Programs Memorandum of Understanding. 2013. Available at http://www.nescaum.org/documents/zev-mou-8-governors-signed-20131024.pdf/. *See also* ZEV Program Implementation Task Force. 2014. Multi-State ZEV Action Plan. Available at http://www.nescaum.org/documents/multi-state-zev-action-plan.pdf/.

[25] State Zero-Emission Vehicle Programs Memorandum of Understanding. 2013. Available at http://www.nescaum.org/documents/zev-mou-8-governors-signed-20131024.pdf/. *See also* ZEV Program Implementation Task Force. 2014. Multi-State ZEV Action Plan. Available at http://www.nescaum.org/documents/multi-state-zev-action-plan.pdf/.

Thus, the near-term objective implied by Rhode Island's commitment to the ZEV memorandum of understanding is to accelerate zero-emissions vehicle sales by about 2 sales-share percentages per year through 2025.

As discussed by National Grid in its Power Sector Transformation Plan filed in this case, the Rhode Island Zero Emission Vehicle Draft Plan calls for increasing EV adoption to 43,000 by 2025. Although the Zero Emission Vehicle Draft Plan does not constitute policy itself, it points Rhode Island in that direction.

Q. Does transportation electrification contribute to compliance with the Resilient Rhode Island Act of 2014?

A. Yes. Rhode Island's principal plan for compliance, the Rhode Island Greenhouse Gas Emissions Reduction Plan[26] published in December 2016, reports that "Scenario modeling results indicate that achieving the Resilient Rhode Island GHG targets could likely require ~75% of on-road VMT to be served by electric vehicles by 2050, along with ~97% of rail transport."[27]

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[26] Available at http://climatechange.ri.gov/documents/ec4-ghg-emissions-reduction-plan-final-draft-2016-12-29-clean.pdf.
[27] *Id.* at 20.

A 2016 report by Synapse Energy Economics[28] also shows that electric vehicles are one of the least-cost strategies to meet the emissions reductions goals of Rhode Island and other states in the Regional Greenhouse Gas Initiative (RGGI).

Q. How does transportation electrification reduce air pollution and benefit public health?

A. EPA estimates that mobile sources (principally on-road vehicles) are the source of more than 84 percent of anthropogenic carbon monoxide emissions,[29] over 50 percent of nitrogen oxide emissions, over 30 percent of volatile organic compounds, and over 20 percent of fine particulate matter ($PM_{2.5}$) emissions in the United States.[30] Carbon monoxide interferes with oxygen uptake and transport in all animals, including humans, and can impair vision, motor function, mental acuity, and work performance. Nitrogen oxides are a primary precursor of ozone—also known as smog—which causes respiratory distress including asthma exacerbations, may cause structural alteration of lungs, and is increasingly understood to cause premature death.[31] Fine particulate matter aggravates

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[28] See Stanton, E. A. et al. 2016. The RGGI Opportunity 2.0: RGGI as the Electric Sector Compliance Tool to Achieve 2030 State Climate Targets, p iii ("The least-cost strategies modeled by Synapse to achieve an all-sector 40 percent emission reductions in the RGGI region by 2030 include converting one-third of gasoline-powered light-duty vehicles to electric vehicles . . . .").
[29] *See* https://cfpub.epa.gov/roe/indicator.cfm?i=10#1
[30] *See* https://www.epa.gov/air-pollution-transportation/smog-soot-and-local-air-pollution
[31] EPA. 2013. Integrated Science Assessment for Ozone and Related Photochemical Oxidants. Ch. 6. Available at https://www.epa.gov/isa/integrated-science-assessment-isa-ozone.

respiratory and cardiovascular problems and has been implicated in heart disease, lung disease, and miscarriages. Numerous studies have documented associations between long-term exposure to $PM_{2.5}$ and increased mortality in urban populations,[32, 33, 34] especially due to cardiovascular disease.[35, 36]

- In 2010, the American Heart Association concluded on the basis of new scientific research that short-term exposure to $PM_{2.5}$ can cause cardiovascular disease-related events and mortality, while longer term exposure increases the risk of cardiovascular mortality to an even greater extent.[37]

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[32] Brook, R. D.; Rajopalan, S.; Pope, C. A.; Brook, J. R.; Bhatnagar, A.; Diez-Roux, A. V.; Holguin, F.; Hong, Y.; Luepker, R. V.; Mittleman, M. A.; Peters, A.; Siscovick, D.; Smith, S. C., Jr.; Whitsel, L.; Kaufman, J. D., Particulate Matter Air Pollution and Cardiovascular Disease: An Update to the Scientific Statement From the American Heart Association. *Circulation.* 2010. *121*, 2331-2378. Available at http://circ.ahajournals.org/content/121/21/2331.

[33] Dockery, D. W.; Pope, C. A. I.; Xu, X.; Spengler, J. D.; Ware, J. H.; Fay, M. E.; Ferris, B. G. J.; Speizer, F. E., An Association Between Air Pollution and Mortality in Six U.S. Cities. *The New England Journal of Medicine.* 1993. *329* (24), 1753-1759.

[34] Pope, C. A. I.; Thun, M. J.; Namboodiri, M. M.; Dockery, D. W.; Evans, J. S.; Speizer, F. E.; Heath, C. W. J., Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. *American Journal of Respiratory and Critical Care Medicine.* 1995. *151*, 669-674.

[35] Pope, C. A. I.; Burnett, R. T.; Thurston, G. D.; Thun, M. J.; Calle, E. E.; Krewski, D., Cardiovascular mortality and long-term expsoures to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. *Circulation.* 2004. *109*, 71-77.

[36] Thurston, G. D.; Burnett, R. T.; TUrner, M. C.; Shi, Y.; Krewski, D.; Lall, R.; Ito, K.; Jerrett, M.; Gapstur, S. M.; Diver, W. R.; Pope, C. A. I., Ischemic Heart Disease Mortality and Long-term Exposure to Source-Related Components of U.S. Fine Particle Air Pollution. *Environmental Health Perspectives.* 2016. *124* (6), 785-794. Available at https://ehp.niehs.nih.gov/wp-content/uploads/124/6/ehp.1509777.alt.pdf.

[37] Brook, R. D.; Rajopalan, S.; Pope, C. A.; Brook, J. R.; Bhatnagar, A.; Diez-Roux, A. V.; Holguin, F.; Hong, Y.; Luepker, R. V.; Mittleman, M. A.; Peters, A.; Siscovick, D.; Smith, S. C., Jr.; Whitsel, L.; Kaufman, J. D., Particulate Matter Air Pollution and Cardiovascular Disease: An Update to the Scientific Statement From the American Heart Association. *Circulation.* 2010. *121*, 2331-2378. http://circ.ahajournals.org/content/121/21/2331.

- More recent research has found that nearly one in five deaths due to cardiovascular disease in the United States is associated with $PM_{2.5}$ exposure.[38]
- In 2016, a study of the American Cancer Society's Cancer Prevention Study-II cohort found that adults were at five times higher risk for mortality caused by cardiovascular disease (e.g., fatal heart attacks) due to exposure to $PM_{2.5}$ released during coal combustion. Particles released by diesel trucks were also associated with increased mortality. In contrast, $PM_{2.5}$ released during biomass combustion and blowing of soil particles was not associated with increased cardiovascular mortality.[39]
- Premature deaths due to vehicle emissions likely exceed those due to vehicle crashes by more than 50 percent.[40] Caiazzo et al.[41] specifically estimate that Rhode Island annually suffers 178 premature deaths due to $PM_{2.5}$ from vehicles.

Transportation electrification along with cleaner electricity generation can reduce these emissions and their health effects.[42] The American Lung Association estimates that

[38] Fann, N.; Lamson, A.; Wesson, K.; Anenberg, S.; Risley, D.; Hubbell, B., Estimating the national public health burden associated with exposure to ambient PM2.5 and ozone. *Risk Analysis.* 2012. *32* (1), 81-95. Available at https://www.ncbi.nlm.nih.gov/pubmed/21627672.
[39] Thurston, G. D.; Burnett, R. T.; TUrner, M. C.; Shi, Y.; Krewski, D.; Lall, R.; Ito, K.; Jerrett, M.; Gapstur, S. M.; Diver, W. R.; Pope, C. A. I., Ischemic Heart Disease Mortality and Long-term Exposure to Source-Related Components of U.S. Fine Particle Air Pollution. *Environmental Health Perspectives.* 2016. *124* (6), 785-794. https://ehp.niehs.nih.gov/wp-content/uploads/124/6/ehp.1509777.alt.pdf.
[40] *See* Caiazzo, Fabio et al. 2013. Air Pollution and Early Deaths in the United States. *Atmospheric Environment* 79: 198-208.
[41] *Id.* at tbl. 5.

annual health and climate benefits from zero-emission vehicles in 2050 will be approximately (2016) $1,045 per household in Rhode Island and other states.[43]

Nitrogen oxides and small particulates produced by vehicles are concentrated near roadways and this is especially acute near high-volume roadways. More than 19% of the United States population lives near a high-volume roadway and minority and low-income households are overrepresented in that population.[44] Consequently, transportation electrification is one of the more important strategies for providing greater environmental justice.

Q. How does transportation electrification improve energy security?

A. Despite the effects of fuel efficiency standards and recent increases in U.S. oil production, the United States still imports approximately 20 percent of its oil consumption and is not currently projected to ever reach oil self-sufficiency except in circumstances where world oil prices are high.[45] Because of the potential disruption to the U.S. economy due to international oil supply interruptions, the United States invests

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[42] Holmes-Gen, B. and W. Barrett, American Lung Association. 2016. Clean Air Future: Health and Climate Benefits of Zero Emissions Vehicles. Available at http://www.lung.org/local-content/california/documents/2016zeroemissions.pdf.
[43] *Id.* at 14.
[44] Gregory M. Rowangould, *A Census of the US Near-Roadway Population: Public Health and Environmental Justice Considerations* (2013), http://www.sciencedirect.com/science/article/pii/S1361920913001107.
[45] U.S. Energy Information Administration [EIA]. 2018. Annual Energy Outlook 2018. Available at http://www.eia.gov/forecasts/aeo/.

substantially in a strategic oil reserve and large military presence in oil-producing regions.[46, 47]

Since electricity can be produced using a wide variety of technologies and fuels, and in practice all of these are largely domestic, transportation electrification will reduce the United States' exposure to oil-related risks. Accordingly, the U.S. Department of Energy (DOE) found that "reliance on oil is the greatest immediate threat to U.S. economic and national security. . . . Vehicle efficiency has the greatest short- to mid-term impact on oil consumption. Electrification will play a growing role in both efficiency and fuel diversification."[48]

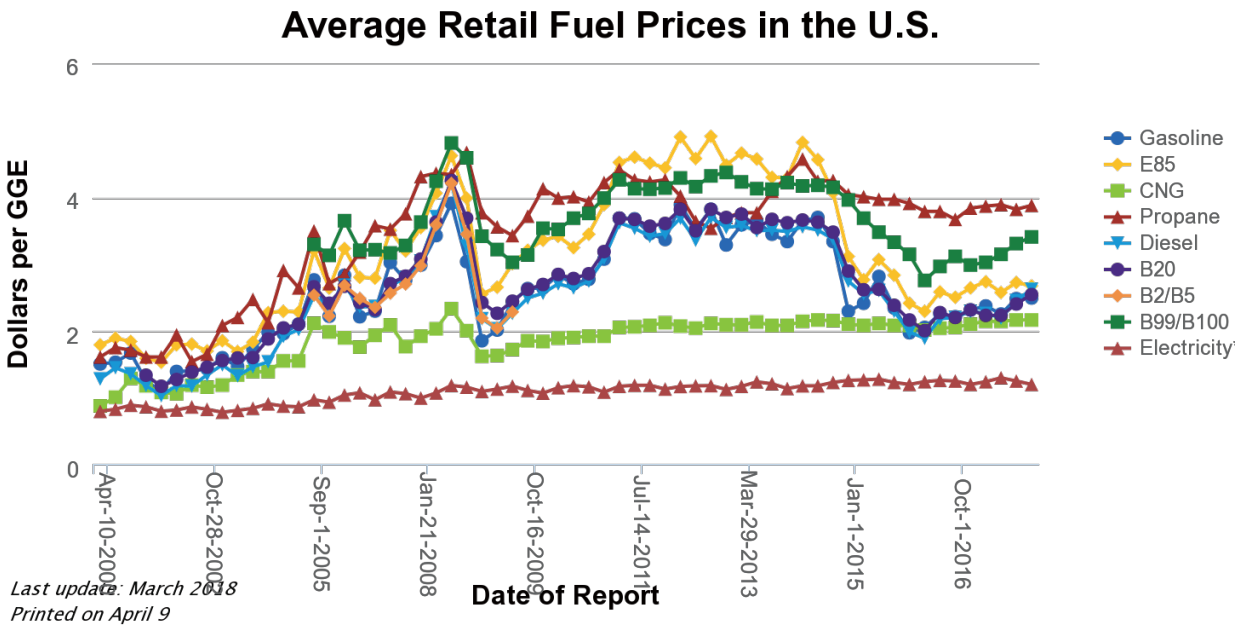
Q. How does transportation electrification positively increase macroeconomic stability?

A. Oil prices are significantly more volatile than electricity prices, so transportation electrification serves to stabilize the cost of living and economic activity. The US

[46] U.S. Department of Defense. 2014. 2014 Quadrennial Defense Review. Available at http://archive.defense.gov/pubs/2014_Quadrennial_Defense_Review.pdf .
[47] Liska, A.J. & Perrin, R.K. 2010. The Hidden Cost of Oil Securing Foreign Oil: A Case for Including Military Operations in the Climate Change Impact of Fuels. Available at http://ethanolrfa.3cdn.net/d34e75ae062493e49b_ugm6vqudb.pdf.
[48] DOE. 2011. Report on the First Quadrennial Technology Review. Available at https://energy.gov/sites/prod/files/QTR_report.pdf.

Department of Energy Alternative Fuels Data Center provides a comparison of fuel prices since 2000, which I reproduce below in Figure CLF-SC-NRDC-PP&L-2.[49]

Figure CLF-SC-NRDC-PP&L-2



Oil price and supply shocks have been a significant contributing factor to economic recessions. "All but one of the 11 postwar recessions were associated with an increase in the price of oil, the single exception being the recession of 1960. Likewise, all but one of the 12 [identified] oil price episodes . . . were accompanied by US recessions, the single

[49] Available at https://www.afdc.energy.gov/fuels/prices.html.

exception being the 2003 oil price increase associated with the Venezuelan unrest and second Persian Gulf War."50 Further, these episodes have particularly acute effects on the automobile industry as is suggested by the following Table CLF-SC-NRDC-PP&L-1 of real gross domestic product (GDP) growth (annual rate) and contribution of autos to the overall GDP growth rate in five historical oil shock episodes.[51]

Table CLF-SC-NRDC-PP&L-1

Real GDP growth (annual rate) and contribution of autos to the overall GDP growth rate in five historical episodes.

Period	GDP growth rate	Contribution of autos
1974:Q1-1975:Q1	-2.5%	-0.5%
1979:Q2-1980:Q2	-0.4%	-0.8%
1981:Q2-1982:Q2	-1.5%	-0.2%
1990:Q3-1991:Q3	-0.1%	-0.3%
2007:Q4-2008:Q4	-0.7%	-0.7%

Since the auto industry has accounted for 2.8 to 4.5 percent of GDP during this period,[52] contributions to GDP change by the auto industry of the magnitudes shown in Table CLF-SC-NRDC-PP&L-1 illustrate substantial auto industry recessions. In some cases,

[50] Hamilton, J. 2013. Historical Oil Shocks. In Parker, R. E..and R. Whaples, 2013. Handbook of Major Events in Economic History. Preprint available at http://econweb.ucsd.edu/~jhamilton/oil_history.pdf.
[51] *Ibid*.
[52] Bureau of Economic Analysis. 2017. Gross-Domestic-Product-(GDP)-by-Industry Data. Available at http://bea.gov/industry/gdpbyind_data.htm.

the recession was entirely in the auto industry while the rest of the economy grew, as indicated in Table CLF-SC-NRDC-PP&L-1 by an auto industry contribution to the recession that is larger than the size of the recession itself.

The principal mechanisms by which oil shocks cause recessions are large shifts in balance of payments for oil imports and large shifts in automobile product mix demand, caused by oil price changes, that cannot be satisfied with existing model-specific capacity.[53] Transportation electrification will contribute to reduced oil imports, weakening the transmission of oil shocks to aggregate demand. Electricity prices are more stable than oil prices, so transportation electrification will reduce or eliminate the effects of oil prices on product demand shifts. Thus, transportation electrification will increase macroeconomic stability for the United States and for Rhode Island.

Q. How does transportation electrification positively impact Rhode Island's local and regional economies?

A. Transportation uses about 30 percent of all energy consumed in Rhode Island and about 33 percent of all energy expenditures.[54] Annual spending on transportation fuels in

[53] Hamilton, J. 2013. Historical Oil Shocks. In Parker, R. E..and R. Whaples, 2013. Handbook of Major Events in Economic History. Preprint available at http://econweb.ucsd.edu/~jhamilton/oil_history.pdf.
[54] Energy Information Administration State Energy Data System. Rhode Island data available at https://www.eia.gov/state/data.php?sid=RI#EnergyIndicators.

Rhode Island is about $1.191 billion.[55] As such, transportation fuels play a significant role in Rhode Island's economy.[56] According to the U.S. Energy Information Administration, more than 80 percent of the cost of gasoline immediately leaves the local economy.[57] Using electricity, which can be locally or regionally sourced, as fuel can reverse this trend.

In addition, numerous studies indicate that electric vehicles are cheaper to operate and maintain than gasoline-powered vehicles, due to their greater efficiency and smaller number of moving parts. The fuel savings and maintenance cost savings associated with driving an electric vehicle translate into real and local economic benefits.[58, 59] A recent analysis[60] of electric vehicle costs and benefits in the neighboring Commonwealth of Massachusetts by M.J. Bradley and Associates based on methods described in a

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[55] *id*
[56] *See* EIA's Rhode Island's energy profile at https://www.eia.gov/state/?sid=RI#tabs-2.
[57] EIA. *Gasoline and Diesel Fuel Update*. www.eia.gov/petroleum/gasdiesel/ (68 percent of the cost of gasoline is for crude oil and refining, and a portion of taxes are federal, leaving about 20 percent consisting of local taxes, distribution, and marketing).
[58] Todd, J. et al. 2013. Creating the Clean Energy Economy: Analysis of Electric Vehicle Industry.
[59] California Electric Transportation Coalition. 2012. Plug in Electric Vehicle Development in California: An Economic Jobs Assessment.
[60] Lowell, D., B. Jones, and D. Seamonds. 2016. Plug-in Electric Vehicle Cost-Benefit Analysis: Massachusetts. M.J. Bradley and Associates. Available at http://mjbradley.com/sites/default/files/MA_PEV_CB_Analysis_FINAL_17nov16.pdf.

subsequent report[61] examined the aggregate effects of vehicle operations savings, electricity system cost dilution, and health benefits and found that:

> if Massachusetts meets its short term (2025) goals for [plug-in electric vehicle (PEV)] penetration and the increase in percent PEV penetration then continues at the same annual rate in later years, the net present value of cumulative net benefits from greater PEV use in Massachusetts will exceed $5.4 billion state-wide by 2050. Of these total net benefits:
>
> - 56 percent ($3.6 billion) will accrue directly to PEV owners in the form of reduced annual vehicle operating costs
> - 21 percent ($1.4 billion) will accrue to electric utility customers in the form of reduced electric bills, and
> - 23 percent ($1.5 billion) will accrue to society at large, as the value of reduced GHG emissions….
>
> [I]f the state meets its long-term goals to reduce light duty fleet GHG emissions by 80 percent from 1990 levels by 2050, which requires even greater PEV penetration, the net present value of cumulative net benefits from greater PEV use in Massachusetts could exceed $32 billion state-wide by 2050. Of these total net benefits:
>
> - 51 percent ($16.8 billion) will accrue directly to PEV owners in the form of reduced annual vehicle operating costs
> - 24 percent ($7.8 billion) will accrue to electric utility customers in the form of reduced electric bills, and
> - 25 percent ($8.0 billion) will accrue to society at large, as the value of reduced GHG emissions.

Benefits in Rhode Island should be similar but scaled to the population of Rhode Island.

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[61] Lowell, D., B. Jones, and D. Seamonds. 2016. Mid-Atlantic and Northeast Plug-in Electric Vehicle Cost-Benefit Analysis: Methodology & Assumptions. M. J. Bradley and Associates. Available at http://mjbradley.com/sites/default/files/NE_PEV_CB_Analysis_Methodology.pdf.

Q. Should public policy accelerate electric vehicle adoption?

A. Yes. Given the benefits outlined above, such policy is justified.

VI. UTILITY ENGAGEMENT IN ELECTRIFYING TRANSPORTATION

Q. Is electric vehicle charging infrastructure important to the adoption of electric vehicles?

A. Yes. Reliable access to electric vehicle charging infrastructure is critical to the growth of the electric vehicle market, including medium- and heavy-duty vehicles.[62] Electric vehicle adoption and electric vehicle charging infrastructure suffer a "chicken-or-egg" market coordination problem. The market coordination problem can be described as follows. In general, a driver is reluctant to purchase an electric vehicle unless vehicle charging infrastructure is generally available, since the driver perceives that the absence of charging infrastructure limits the uses of an electric vehicle and hence reduces its value to the driver. On the other hand, businesses cannot see a business case for providing electric vehicle charging infrastructure if there are not enough electric vehicles in use to

[62] National Research Council. 2015. Overcoming Barriers to Deployment of Plug-In Electric Vehicles. Available at http://www.nap.edu/catalog/21725/overcoming-barriers-to-deployment-of-plug-in-electric-vehicles.

provide sufficient use and revenue to repay the investment.[63] This problem is common in network industries and has been studied in contexts including but not limited to information technology hardware, software, telecommunications, broadcasting, markets for information, banks and automated teller machines (ATMs), and airlines.[64] The universal effect of these coordination problems is that the market for the good or service grows or changes more slowly than the market optimum, sometimes to the point that it never develops.

The particular form of this coordination problem present in the case of electric vehicle charging is called "indirect network effects." Indirect network effects arise because a decision by one driver to buy an electric vehicle increases the demand for vehicle charging infrastructure, the forthcoming or resultant supply of which attracts electric vehicle purchases by other drivers; thus one purchase indirectly increases other purchases. In the case of electric vehicle charging, there are indirect network effects on both sides of the market.

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[63] This phenomenon may be particularly acute for Direct Current Fast Charging (DCFC) infrastructure where value to (prospective) EV drivers is high but utilization may be relatively low compared to long-dwell time Level 2 stations.
[64] *See* Shy, Oz. 2001. The Economics of Network Industries. Cambridge University Press.

Indirect network effects are compounded by the importance of word-of-mouth and direct observation of products. Although formal studies apparently have not been done, there is every indication that electric vehicle adoption is "contagious" in the sense that people are more likely to purchase one if there are others already in use in their neighborhood.

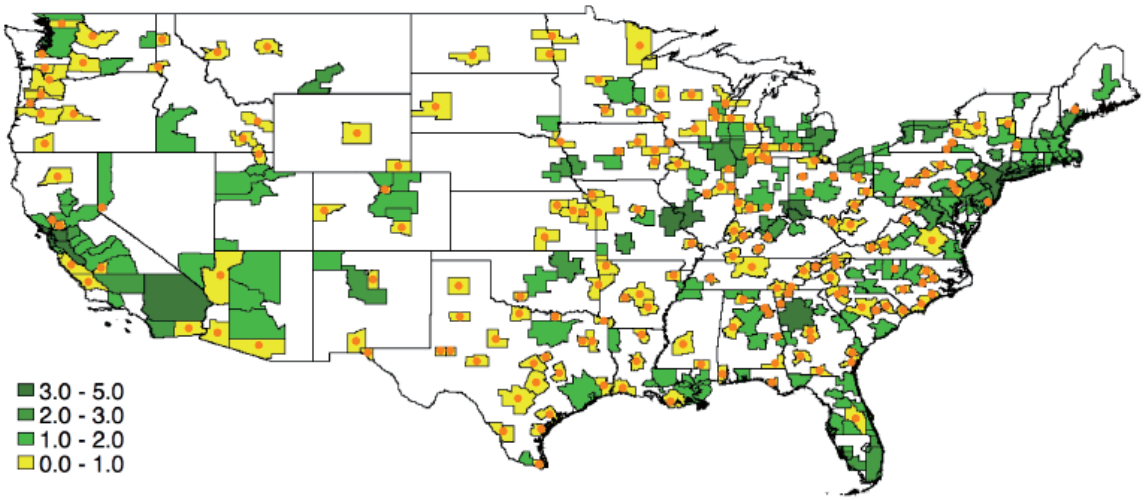
The Market for Electric Vehicles: Indirect Network Effects and Policy Design[65] specifically estimates the quantitative elements of the market coordination problem. The authors estimate that a 10-percent increase in the number of non-residential charging stations will increase EV sales by 8 percent, and that a 10-percent increase in the number of EVs will increase non-residential charging station deployment by 6 percent. Thus, any non-market "shock" to the supply of either electric vehicles or charging stations will produce a "virtuous cycle" of feedback between the two markets that will significantly accelerate electric vehicle adoption. The authors further show, based on their parameter estimates, that increases in EV sales attributable to financial support for EV infrastructure are more than double the sales increases associated with equivalent financial incentives offered for EV purchases.

[65] Li, Shanjun et al. The Market for Electric Vehicles: Indirect Network Effects and Policy Design. *Journal of the Association of Environmental and Resource Economists.* 2017. 4:1, pp 89-133.

The authors also apply their model to each Standard Metropolitan Statistical Area defined by the U.S. Census to determine whether, given current numbers of electric vehicles and non-residential charging stations, investment in charging stations or electric vehicles should lead the development of the local market. Their map is reproduced as Figure CLF-SC-NRDC-PP&L-2 below.

Figure CLF-SC-NRDC-PP&L-2

Figure 7: Heterogeneous Policy Effectiveness (Policy2/Policy1)



Note. -Policy 1 gives new EV buyers a tax credit of of $2,500-$7,500 based on different models as the current income tax credit policy for EVs. Policy 2 builds charging stations in all MSAs with the same budgetary cost as policy 1 assuming the investment cost per station being $27,000. The figure plots the ratio of the EV increases due to the two subsidy policies. The policy effectiveness of policy 2 varies across locations due to the heterogeneous impacts of public charging stations on the EV demand. The regions with the dots are locations where policy 1 is more effective.

For Rhode Island, Figure CLF-SC-NRDC-PP&L-2 shows that accelerated investment in charging infrastructure is the better leading investment. Some Rhode Island drivers are purchasing electric vehicles, as evidenced by a 2017 market share of 0.92 percent of Rhode Island vehicle sales,[66,67] but the analysis of indirect network effects in the electric vehicle market discussed above suggests significant acceleration is possible by addressing the market coordination problem between electric vehicle sales and electric vehicle charging.

Although charging infrastructure is the more important investment to make, Rhode Island's state zero-emissions vehicle and climate goals for electric vehicle adoption by 2025 may require both infrastructure deployment and electric vehicle incentives. Vehicle incentives are effective, as has been demonstrated by both sales increases in response to new rebates[68] and sales declines in response to termination of rebate programs.[69]

Q. What effect does the indirect network coordination problem have on potential electric vehicle drivers?

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[66] *See* https://autoalliance.org/energy-environment/zev-sales-dashboard/ .
[67] Rhode Island ended a rebate program on June 30, 2017 with effects that are currently not known.
[68] See https://www.nyserda.ny.gov/About/Newsroom/2018-Announcements/2018-03-22-Governor-Cuomo-Announces-5750-Electric-Car-Rebates-Approved
[69] http://www.politifact.com/georgia/statements/2015/nov/02/don-francis/electric-car-sales-hit-brakes-tax-credit-axed-and-/

A. This is just the other side of the market coordination problem faced by a potential provider of vehicle charging services that cannot profitably invest until there are enough electric vehicles to make the investment worthwhile. A potential driver of an electric vehicle cannot afford that investment, even though it might be worthwhile on the basis of cost of ownership (due to savings on electricity compared to gasoline, reduced maintenance costs, etc.) if the electric vehicle cannot meet most of the driver's vehicle transportation needs. If the absence of charging infrastructure means that even a modest share of the driver's trips cannot be made in the electric vehicle, then the value of the electric vehicle is greatly diminished and the driver likely won't invest in an electric vehicle.

Q. Is electric utility engagement in electric vehicle promotion important to addressing this market coordination problem and accelerating the adoption of electric vehicles?

A. Yes. Utilities, which are well positioned to deploy charging infrastructure in partnership with third party providers, have an important role in accelerating transportation electrification to meet state goals and customer needs. When carefully framed and limited, utilities can play this role without interfering with the development of a competitive market in the provision of electric vehicle charging equipment and services.

The principal reasons that utilities are well positioned to aid in scaling up electric vehicle charging infrastructure are utilities' ability to benefit from network effects and deploy

patient capital. After examining the case for various entities to provide electric vehicle charging infrastructure in various settings, the National Research Council Committee on Overcoming Barriers to Electric Vehicle Deployment concluded with respect to electric utilities that:

> Electric utility companies could emerge as a willing source of capital for public charging stations. That conclusion reflects the prospect that a network of public charging stations would induce more utility customers to purchase PEVs, which would lead not only to electricity consumption at the public chargers, but also to much greater consumption of electricity at residences served by the utilities. If public charging infrastructure drives greater [electric vehicles miles traveled] and greater deployment of vehicles, capital and variable costs for public infrastructure might be covered by the incremental revenue from additional electricity that PEV drivers consume at home, where roughly 80 percent of PEV charging takes place.[70]

In addition to residential charging infrastructure, utilities can deploy public charging infrastructure that drives incremental EV adoption, encourages greater home charging, and begets grid benefits. Thus, utility investments in public charging infrastructure should be thought of as investments in load growth similar to line extensions, even though a portion of the incremental revenue from investments in public charging accrues from home charging. This is especially so in settings where additional market failures

[70] National Research Council. 2015. Overcoming Barriers to Deployment of Plug-In Electric Vehicles. Available at http://www.nap.edu/catalog/21725/overcoming-barriers-to-deployment-of-plug-in-electric-vehicles.

prevail (which I discuss below). It is therefore uniquely possible for a utility – in partnership with third party providers – to strategically scale and equitably locate charging infrastructure during early development of the electric vehicle market. It is logical that one of the best strategies to accelerate adoption of electric vehicles in Rhode Island is to support utility investment in electric vehicle charging infrastructure.

In addition to the utility's ability to derive revenue to support public charging through network effects with home charging, utilities can also overcome certain other market barriers that occur in specific market segments. An electric vehicle owner who has a private garage or other dedicated parking can potentially acquire charging equipment to meet their private needs. An electric vehicle owner who lives in multi-family housing without designated parking cannot make the investment in charging infrastructure because they will be unable to ensure that it is available for their use rather than being occupied by someone else. An electric vehicle owner who must use shared or public parking because they don't have on-site parking at home and must park on the street will not be able to invest in or rely upon charging at home and must use public charging.[71] Low-income communities are likely to be slowest to adopt electric vehicles to a sufficient degree that privately owned charging infrastructure can be profitable as a private

[71] WXY. 2015. Accommodating Garage Orphans in Boston, Cambridge, and Somerville. v 2.1.

investment. It is therefore appropriate that electric utilities make specific investments within a charging network to ensure equitable access to electrified transportation.

Further, because the utility already has established connections to its relatively large customer base, it is also well positioned to provide brand-neutral education and outreach on the benefits of transportation electrification.[72] The benefits to the grid and other customers of increased electricity sales from electric vehicle load, which I describe in greater detail below, justify the utility leveraging its existing customer relationships to meaningfully engage potential EV drivers and EV charging infrastructure site hosts. Importantly, electric vehicle charging can also benefit utility customers who do not drive electric vehicles or host EV charging infrastructure, which I explain below.

Q. How does accelerating electric vehicle adoption potentially benefit electric utility customers who do not drive electric vehicles?

A. As indicated above, the deployment of additional public charging infrastructure drives electric vehicle adoption, which not only produces incremental electricity sales at the public charging stations but also induces additional electricity sales for charging at home. Increases in electricity sales for electric vehicle charging, if well integrated into the

[72] Max Baumhefner et al., Natural Resources Defense Council, Driving Out Pollution: How Utilities Can Accelerate the Market for Electric Vehicles (June 2016).

electric power system, can dilute the fixed costs of transmission and distribution and lower electricity rates for all utility customers.

An electric vehicle "can be recharged while its owner is sleeping, eating, working, or doing anything other than driving."[73] Consequently, if electric vehicle charging is well-integrated into the near-future electric power system, it can "fill valleys" in load without proportionally increasing overall capacity requirements; this can reduce the average cost of power for all utility customers. As variable renewable resources like wind and solar generation gain larger shares of electric power generation, flexible electric vehicle charging can add value to the electric power system by facilitating the integration of these resources and balancing electricity generation with demand; this can stabilize power flows and reduce the average cost of electricity.

Q. How much will transportation electrification contribute to utility sales?

A. According to EPA fuel economy labels for electric vehicles, current model electric vehicles use between 28 kilowatt-hours (kWh) and 54 kWh per 100 miles, with most models that have significant sales using between 35 kWh and 42 kWh per 100 miles.[74] I assume, conservatively, for this illustrative calculation that future vehicles will average

[73] *Id*. at 6.
[74] EPA's fuel economy labels can be viewed at fueleconomy.gov.

30 kWh per 100 miles. According to the Federal Highway Administration, vehicle miles traveled in Rhode Island in 2016 totaled 7,927 million.[75] If this amount of vehicle travel had been fully electrified, electric vehicles would have consumed about 2.378 terrawatt-hours (TWh). This would have resulted in a 31.8-percent increase in 2017 electricity sales in Rhode Island.

Of course, full electrification of all vehicle travel in the Rhode Island will take time. Electricity sales associated with vehicle fueling will scale with electric vehicle adoption. If Rhode Island achieves its 2025 zero-emissions vehicle goal of 43,000 vehicles and these are driven the same amount as the average Rhode Island vehicle, then these vehicles will be used for approximately 385 million annual vehicles miles traveled. This level of electric vehicle use would require about 115.5 GWh per year, or about 1.55-percent increase over 2017 electricity sales in Rhode Island.

Q. How much would transportation electrification dilute fixed costs of transmission and distribution?

A. Many details are important to such a calculation. However, for a rough approximation, I reviewed the annual reports of New England utilities and determined that approximately

[75] Available at the Federal Highway Administration at http://www.fhwa.dot.gov/policyinformation/statistics/2016/vm2.cfm. Averaged across all vehicles registered in Rhode Island, this is an average of 8,951 miles per vehicle-year.

60 percent of electric utility revenue is to recover generation costs and about 40 percent is for transmission, distribution, customer service, and administration. If non-generation costs could remain unchanged and generation costs per kWh were unchanged as a result of adding load to fully electrify vehicle travel in Rhode Island, then average rates would be reduced by about 9 percent.[76] In the alternative, rates could be held constant if generation costs per kWh were unchanged and the costs of transmission and distribution increased by as much as 31.8 percent. While it is likely that some additions to distribution system costs would be required if electric vehicles become ubiquitous, it is highly likely that the net effect of transportation electrification will be significant dilution of fixed costs of transmission and distribution over enlarged electricity sales and a consequent reduction in rates. In short, the increased utility revenue that will be paid for electric vehicle charging, mostly at home, will more than offset the incremental costs of providing that electricity.

M.J. Bradley's analysis[77] of the costs and benefits of transportation electrification in Massachusetts, using more modest assumptions about electric vehicle adoption and allowing for some generation capacity, transmission, and distribution system costs

[76] This is calculated by multiplying the generation share of costs by the percentage increase in load, adding unchanged transmission and distribution costs, and dividing the result by the increased load.
[77] M.J. Bradley & Associates, Plug-in Electric Vehicle Cost-Benefit Analysis: Massachusetts (Nov. 2016).

associated with electric vehicle charging, projected that about 25 percent of revenue from electric vehicle charging would accrue to the benefit of ratepayers generally and about 75 percent would be required to cover costs of electric vehicle charging in a baseline scenario where EV charging is unmanaged. In the case where the majority of EV charging is encouraged or shifted to off-peak periods, the share of revenue and benefits that accrue to all utility customers increases to roughly 33 percent. These results are generally consistent with my calculations above.

It is likely that electric vehicle adoption for the next several years will not require significant investment.[78] As I calculated above, achieving Rhode Island's zero emissions vehicle goal of 43,000 vehicles by 2025 will only increase annual electricity sales by about 1.5%. If incented to occur mostly off-peak, through rate design, this level of charging should not require incremental investments in distribution system capacity or generation capacity. Assuming that fuel and other variable costs of marginal off-peak generation are about 35% of retail rates, then about 65% of revenue from electric vehicle charging will be available for either investments in electric vehicle infrastructure or to dilute rates paid by other customers of National Grid.

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[78] Allison, A and M Whited. 2017. Electric Vehicles Are Not Crashing the Grid: Lessons from California. Synapse Energy Economics. Available at http://www.synapse-energy.com/sites/default/files/EVs-Not-Crashing-Grid-17-025_0.pdf.

Q. Does transportation electrification cancel the benefits of Demand-Side Management programs?

A. No. Transportation electrification will increase electricity sales while efficiency programs reduce electricity sales, but this does not diminish the value to customers of greater energy efficiency in their businesses and residences. Transportation electrification, while adding back sales reduced by demand-side management, creates new value for customers and society as described earlier in my testimony. Further, because electric vehicles are more energy efficient on a full fuel-cycle basis than vehicles powered by internal combustion engines, transportation electrification can be viewed as an energy efficiency program.[79] Transportation electrification should become an important part of a fully integrated demand-side management program.

However, it is important that vehicle charging be well integrated into load patterns so as to minimize its impact on power supply costs.

Q. How much can "valley-filling" by electric vehicle charging reduce the average cost of power?

A. "Valley-filling" refers to the potential that electric vehicle charging can be done at times when loads for other uses of electricity are low, leveling the load overall. Pacific

[79] See https://www.nrdc.org/experts/max-baumhefner/are-efficiency-and-electrification-policies-conflict

Northwest National Laboratory found that nationally there is sufficient generation capacity to charge almost all passenger vehicles through "valley-filling."[80] ISO New England currently has total generation capacity of about 33.2 GW, providing approximately 140.6 TWh per year[81] for a load factor of about 48 percent. Rhode Island's share of this load is about 6.6 percent,[82] so for purposes of a reasonable approximation, we can consider that Rhode Island's "share" of ISO New England's capacity is about 2.01 GW. If transportation electrification added 2.378 TWh[83] electricity consumption per year and this load was accommodated by "valley-filling," then the load factor for Rhode Island's "share" of ISO New England's generation capacity would rise to more than 60 percent. A 60-percent load factor is somewhat high for most utilities but not unreasonable with the load-scheduling flexibility of electric vehicles. Assuming, consistent with the current generation portfolio, that generation capacity represents an average of 25 percent of total utility costs, and that fuel and other variable costs represent an average of about 35 percent of total utility costs, then a revision[84] of the calculation I made above concerning the dilution of fixed costs suggests that vehicle charging would increase

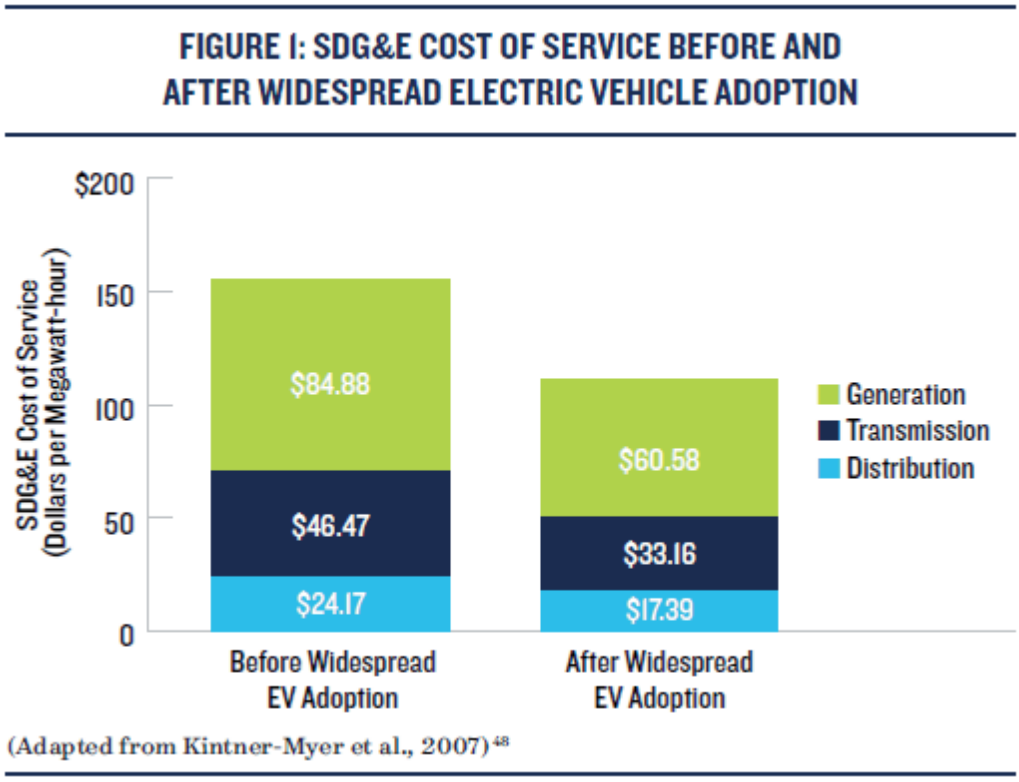
[80] Kintner-Meyer, M., K. Schneider, and R. Pratt. 2007. Impacts Assessment of Plug-in Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids, Pacific Northwest National Laboratory. Available at energyenvironment.pnnl.gov/ei/pdf/PHEV_Feasibility_Analysis_Part1.pdf.
[81] *See* https://www.iso-ne.com/about/key-stats/electricity-use.
[82] *See* https://www.iso-ne.com/system-planning/system-plans-studies/rsp.
[83] *See* my earlier calculation of electricity load to fully electrify Rhode Island's vehicle miles traveled.
[84] In this case, I multiplied only the variable costs of generation by the increased load, added the unchanged costs of distribution, transmission, and generation capacity, then divided the result by the increased load.

utility sales by 31.8 percent but only increase utility costs by about 11.1 percent. Consequently, rates would be reduced by 15.6 percent. In the alternative, rates could be held constant if the incremental costs of transmission, distribution, and generation capacity to support electric vehicle charging were as much as 20.625 percent of the current costs of transmission, distribution, and generation capacity.

In *Driving Out Pollution*, a report by the Natural Resources Defense Council,[85] the authors present the following graph (reproduced below as Figure CLF-SC-NRDC-PP&L-3) illustrating a similar but more detailed analysis for San Diego Gas and Electric, consistent with my results.

[85] Max Baumhefner et al., Natural Resources Defense Council [NRDC]. 2016. Driving Out Pollution: How Utilities Can Accelerate the Market for Electric Vehicles. Available at https://www.nrdc.org/sites/default/files/driving-out-pollution-report.pdf.

Figure CLF-SC-NRDC-PP&L-3



A 2015 report to the New York State Energy Research and Development Authority[86] provides a detailed analysis of the costs and emissions in New York State under various

[86] M.J. Bradley and Associates. 2015. Electricity Pricing Strategies to Reduce Grid Impacts from Plug-in Electric Vehicle Charging in New York State. NYSERDA Report 15-17. Available at https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Transportation/EV-Pricing.pdf.

electric vehicle penetration and charging scenarios. The following table illustrates the importance of controlling charging versus baseline charging behavior.

Figure CLF-SC-NRDC-PP&L- 4[87]

Table 23. 2030 Summer Peak Hour PEV Charging Loads (MW) under Baseline and Controlled Charging Scenarios (High Penetration)

Source: MJB&A PEV Modeling Analysis

NYCA LOAD Zone	BASELINE				CONTROLLED CHARGE				*REDUCTION FROM BASELINE (mW)*
	14:00	15:00	16:00	AVG	14:00	15:00	16:00	AVG	
A	53.65	61.02	71.38	62.02	35.89	41.71	47.72	41.77	*20.24*
B	15.02	17.08	19.98	17.36	10.05	11.68	13.36	11.70	*5.66*
C	31.03	35.34	41.38	35.92	20.68	24.03	27.49	24.07	*11.85*
D	1.64	1.87	2.20	1.90	1.08	1.26	1.44	1.26	*0.64*
E	20.47	23.33	27.33	23.71	13.60	15.81	18.09	15.83	*7.88*
F	28.79	32.79	38.38	33.32	19.19	22.30	25.51	22.33	*10.98*
G	33.53	38.17	44.66	38.79	22.39	26.02	29.77	26.06	*12.73*
H	4.34	4.93	5.76	5.01	2.91	3.38	3.87	3.39	*1.62*
I	29.72	33.77	39.48	34.32	19.93	23.16	26.49	23.19	*11.13*
J	87.82	99.79	116.66	101.42	58.89	68.44	78.29	68.54	*32.88*
K	98.16	111.54	130.40	113.37	65.83	76.50	87.52	76.61	*36.75*
TOTAL	**404.17**	**459.63**	**537.61**	**467.14**	**270.44**	**314.29**	**359.56**	**314.76**	***152.37***

[87] *Id.* at 82.

In short, the combination of fixed cost dilution and load "valley-filling" through electric vehicle charging can significantly reduce electric rates for all electricity customers, whether or not those customers directly use electric vehicles.

Q. To what extent can electric vehicle charging buffer the variability of wind and solar generation?

A. Two strategies for integrating electric vehicle charging with generation from renewables have been the subject of recent studies. One strategy focuses on integration at a utility customer site, usually combining solar generation with building loads and electric vehicle charging.[88] The other strategy, more relevant here, focuses on integration at utility scale. *Electric vehicles and the electric grid: A review of modeling approaches, impacts, and renewable energy integration* summarizes some of the work associated with utility-scale integration and concludes that "[t]he existing literature is fairly unanimous and conclusive in its assessment that EVs can increase the amount of renewable energy that can be brought online while reducing the negative consequences for the grid."[89] This conclusion is based in part on review of a number of studies that look at regional- and

[88] *See, e.g.*, Van Roy, J. et al. 2014. Electric Vehicle Charging in an Office Building Microgrid with Distributed Energy Resources. *IEEE Transactions on Sustainable Energy*, 5 (40), pp 1389-1396; Kamankesh, H. et al. 2016. Optimal scheduling of renewable micro-grids considering plug-in hybrid electric vehicle charging demand. *Energy*. 100 (1), pp 285-297.
[89] Richardson, D. Electric vehicles and the electric grid: A review of modeling approaches, impacts, and renewable energy integration. *Renewable and Sustainable Energy Reviews*. 2013. 19, pp 247-254.

national-scale balancing and show that smart[90] electric vehicle charging allows significantly greater increases in renewable generation than the amount of vehicle charging load. With 50 percent of U.S. electricity generation from wind, the required regulation services can be provided by electrification of just 3.2 percent of the vehicle fleet and operating reserves can be provided by electrification of 38 percent of the vehicle fleet.[91] In short, transportation electrification is a key enabler of very high penetration of renewable generation and is nearly sufficient for that purpose, without requiring the use of fossil-fueled plants or of grid-attached storage for regulation services.

Although the New England system can still increase the level of variable renewable generation before electric vehicle charging or other new storage options are necessary for renewable resource integration to the grid, the New England states have adopted goals or requirements to increase their use of renewables to a level requiring electric vehicle charging or other new storage options *within the life cycle of vehicles that will be purchased in the next few years*. Therefore, it is prudent to prepare for the strategic integration of electric vehicles and variable renewable energy resources. Overall, the

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[90] Richardson explains that "The idea behind smart charging is to charge the vehicle when it is most beneficial, which could be when electricity is at its lowest price, demand is lowest, when there is excess capacity, or based on some other metric. The rate of charge can be varied within certain limits set by the driver; the most basic limit being that the vehicle must be fully charged by morning." *Id.*

[91] Kempton, W. and J. Tomic. Vehicle-to-grid power implementation: from stabilizing the grid to supporting large-scale renewable energy. *Journal of Power Sources*. 2005. 144: pp 280-294.

Commission should be mindful of this long-run benefit; but since electric vehicle integration is not presently required for renewable integration, the Commission can initially focus on the rate reduction that electric vehicles offer through dilution of fixed costs and load "valley-filling."

Q. How can electric utilities play a constructive, complementary role in the deployment of EV charging infrastructure?

A. A small, but growing market exists for EV charging equipment and services. But on its own, this market faces several notable barriers and likely will not be able to deploy the charging infrastructure necessary to accelerate transportation electrification in a manner consistent with the state's goals. Without high utilization rates, it is difficult for EV charging service providers to realize a return on investment in the time frame required for most private enterprises. In order to accelerate electric vehicle adoption, charging infrastructure must be conveniently available in enough locations that a driver can reliably complete trips and recharge on a regular basis. Until significant electric vehicle adoption occurs, high utilization of a sufficiently ubiquitous charging infrastructure cannot be achieved. Thus, the entities involved in deploying public charging infrastructure face the "chicken or egg" market coordination problem discussed earlier in this testimony. Because the utility can redirect current and expected net revenue from

providing power to private parking locations, such as homes, the utility can help solve this problem.

This problem may be acute for investments in DC fast charging. DC fast charging requires a larger investment per site than slower-throughput charging stations. To enable highway travel in electric vehicles, DC fast charging is needed at reasonable intervals along the entire route so the number of sites during early development of the electric vehicle market will be driven by distance requirements rather than sales volume. As a result, the network coordination problem is more acute for DC fast charging than for other charging services. Automakers generally do not see themselves as the appropriate actor to make significant charging station investments. While Tesla has successfully built and operated a DC fast charging station network, I do not expect charging station deployment to become a core business of automakers, which did not enter the service station business to sell gasoline to gasoline-powered vehicles. Indeed, open access networks that can serve all vehicle types will provide lower cost and better service to drivers than a series of overlapping proprietary networks by vehicle brand. Utility engagement in DC fast charging to enable electric vehicle ownership by using current and expected revenue from home charging is thus among the most acute needs for utility engagement.

Once the electric vehicle charging market develops so that utilization rates of public charging stations are sufficiently high, there will be little reason for utility engagement in providing electric vehicle charging equipment or hosting charging sites. Rather, in the long run electric utilities should be primarily distributors of power for electric vehicle charging and suppliers of power when customers are not served by a competitive power supplier or distributed generation.

VII. EVALUATION OF NATIONAL GRID'S ELECTRIC TRANSPORTATION INITIATIVE

Q. What materials did you review to support your testimony about National Grid's approach to electric transportation?

A. I focused primarily on Chapter 5 of National Grid's Power Sector Transformation Plan and the associated workpapers filed by National Grid in this case.

Q. Please summarize National Grid's electric transportation proposal in this case.

A. National Grid proposes an Electric Transportation Initiative, consisting of six components:

1. Off-peak Charging Rebate Pilot
2. Charging Station Demonstration Program
3. Discount Pilot for Direct Current Fast Charging Station Accounts
4. Transportation Education and Outreach

5. Company Fleet Expansion

6. Initiative Evaluation

The Off-Peak Charging Rebate will provide customers a rebate of 6 cents per kWh in summer months and 4 cents per kWh in all other months for charging after 9pm and before 1pm each day. "This Pilot will serve as a demonstration of program design, rate design, and marketing strategies in anticipation of the subsequent broad implementation of advanced metering functionality and time-varying rates."[92]

The Charging Station Demonstration Program to develop charging infrastructure for use by the general public and operators of dedicated fleets at locations and of types shown in Table 5-2 of the Company's Power Sector Transformation Plan. Some of these sites will be "make-ready" and others will be Company-owned. Whether make-ready or Company-owned, site hosts will participate financially. Charging Rates at Company-owned sites will be set by formula in a tariff to be filed before program launch, which will be intended to be affordable but to encourage drivers to avoid charging during peak hours.

The Discount Pilot for Direct Current Fast Charging Station Accounts will offer a time-limited discount for dedicated DC Fast Charging stations established during an initial

[92] National Grid Power Sector Transformation Plan, Chapter 5, Section 2.1 in RIPUC Docket No 4770, Schedule PST-1.

period of EV market growth. This discount is intended to mitigate the effect of demand-based delivery charges on charging costs per kWh when utilization is low during early EV market growth.

The Transportation Education and Outreach component will leverage National Grid's customer communications to "educate customers on the benefits of EVs, the decreasing costs to purchase and maintain and EV, advances made in driving range, continued increases in charging station availability, and newer charging technologies that greatly reduce EV charging time."[93]

The Company Fleet Expansion component provides for the Company to acquire and use in various roles 12 new electrified heavy-duty trucks.

The Initiative Evaluation component is an effort by the Company to evaluate each electric transportation market development strategy and share these learnings with Rhode Island stakeholders and industry participants.

[93] National Grid Power Sector Transformation Plan, Chapter 5, Section 2.4 in RIPUC Docket No 4770, Schedule PST-1.

Q. What is your overall evaluation of National Grid's proposal?

A. National Grid's Electric Transportation Initiative is very well framed as a demonstration project anticipating further development of electric vehicle charging infrastructure and the electric vehicle market. The scope reflects an appropriate role for the utility in development of this market. Emphasis on prompt use of time-varying rates for vehicle charging addresses the most important grid integration issue.

In the Company's Charging Station Demonstration Program, the ability for the site host to choose from multiple deployment models – including a "make-ready" model and turnkey ownership model – demonstrates an understanding that one size does not, in fact, fit all and that multiple approaches to charging infrastructure deployment may be necessary to accommodate varying customer needs at this nascent stage of the EV charging services market. In particular, a utility ownership model may be a practical option for site hosts in difficult-to-reach market segments that may not otherwise be able to handle or manage charging station assets while the make-ready model is likely to work well for employment-related parking, destination charging, and similar circumstances where a site host may prefer the services of a third-party equipment and service provider. Regardless of the model used to deploy charging infrastructure, the utility has the opportunity to enable competition for EV charging services where it otherwise would not have existed and to foster a stronger charging services market in Rhode Island.

The Discount Pilot for Direct Current Fast Charging (DCFC) Stations is another commendable feature of National Grid's Electric Transportation Initiative. Consumer research shows the lack of "robust DC fast charging infrastructure is seriously inhibiting the value, utility and sales potential" of all-electric vehicles.[94] However, demand charges have especially challenged the economics of operating DCFC equipment, given that these stations frequently have high throughput (>50 kW) and at current levels of EV adoption, they also have low, unpredictable usage rates. Indeed, DCFC equipment does not operate much like the commercial and industrial facilities for which demand charges were originally designed and may dissuade site hosts from operating stations at locations that benefit traveling drivers.[95] The Discount Pilot for Direct Current Fast Charging Stations attempts to address the "chicken or egg" problem by leading with a finite incentive to spur the DCFC market as EV adoption increases, station utilization grows, and the economics of operating DCFC stations with private capital improves. To ensure the pilot has the intended effect of increasing the limited quantity of DCFC charging in the state, we recommend that National Grid extend the pilot beyond three years or develop a plan to gradually sunset the incentive based on market needs.

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[94] Norman Hajjar, New Survey Data: BEV Drivers and the Desire for DC Fast Charging, California Plug-in Electric Vehicle Collaborative, March 11, 2014
[95] Rocky Mountain Institute. 2017. EVgo Fleet and Tariff Analysis. Available at: https://www.rmi.org/wp-content/uploads/2017/04/eLab_EVgo_Fleet_and_Tariff_Analysis_2017.pdf

The income-eligible carve-out and some of the fleet options could address equity concerns. Addressing the needs of low-income communities through fleet electrification and charging station deployment should be a central element of the Electric Transportation Initiative. In particular, transit bus fleet electrification can reduce harmful diesel pollutant emissions from conventional buses and demonstrate that the scope of transportation electrification extends beyond light-duty personal vehicles.

The plan leverages the Company's customer relationships to educate its customers about electric transportation. Customer education and outreach is critical to expanding awareness of EVs and associated benefits. Company efforts should leverage experience and expertise of local groups engaged in EV outreach.

The evaluation effort is iterative and includes stakeholder engagement. Given the growing interest and need to address transportation electrification topics at the regulatory level, an in-depth publicly available evaluation of National Grid's program is essential. This evaluation will allow for the Commission and other stakeholders to assess how the program is performing, enable National Grid to make course-corrections if necessary to improve the program, and inform future transportation electrification efforts in the state and the region.

Q. Do you have any concerns about National Grid's proposal?

A. Citizens Utility Board of Illinois, which is a consumer advocate in utility regulatory proceedings, recently published a useful guide (Exhibit CLF-SC-NRDC-PP&L-B)[96] to electric vehicle policy for policy makers and consumer advocates. The guide includes a list of principles[97] that may be useful to the Commission in evaluating National Grid's proposal and may provide a useful context for my concerns about that proposal. Citizens Utility Board's principles may be summarized as:

> 1. Optimize charging patterns to improve system load shape, reduce local load pockets, and maximize utilization of renewable generation; . . .
> 2. Ensure any utility customer-funded programs provide demonstrable system benefits; . . .
> 3. Allow EV chargers to be grid-connected efficiently, quickly, and safely; . . .
> 4. Facilitate aggregation of EV demand for dispatch as a Distributed Energy Resource (DER); . . .
> 5. Benefit underserved/disadvantaged communities; . . .
> 6. Promote interoperability, common standards and open networks; . . .
> 7. Support competition to accelerate market development, encourage private investment, promote innovation and bring down prices; . . .
> 8. Deploy utility resources where needed to address public needs; . . .
> 9. Foster coordinated regional planning for systems and infrastructure to accommodate and integrate expanding EV loads; . . .
> 10. Manage EV loads to reduce energy costs . . . .

[96] Citizens Utility Board. 2017. ABCs of EVs: A Guide for Policy Makers and Consumer Advocates.
[97] *Id.* at 5.

National Grid's proposal in this case satisfies most of the principles recommended by the Citizens Utility Board of Illinois. The proposal could be improved through attention to principles 4, 5, and 6.

Q. What is your concern about the aggregation of EV demand for dispatch as a Distributed Energy Resource?

A. By including prompt use of time-varying rates in its advanced metering functionality proposal, National Grid has addressed the most important grid integration issue, which is to incent charging at the most propitious times. National Grid also proposes to acquire experience with time-based rates using off-peak charging rebate program in the interim.

However, there is significant value in also providing demand response and load management capability in electric vehicle charging infrastructure. Demand response and load management are technical means by which a utility requests load to adjust (usually downward but sometimes upward) in order to better balance load and generation. Because most level 2 vehicle charging sessions are part of a longer parking session, electric vehicles, like electric water heaters, are a prime opportunity to apply load management to a specific end-use.

Demand response and load management are important tools for reducing the cost of electricity by avoiding the costs of rarely used generation, transmission, and distribution

capacity. A number of utilities have incorporated or piloted level 2 electric vehicle charging into load management programs. I therefore recommend that National Grid require or incent demand response capabilities in the level 2 charging stations installed through its Electric Transportation Initiative.

Q. How can the proposal better serve underserved and disadvantaged communities?

A. I take it as a general standard for public policy that it should be inclusive. In this instance, National Grid is proposing some investments in electric transportation that will be funded in general rates, hence partly by low-income and disadvantaged communities. However, National Grid has proposed only a limited effort to provide transportation electrification in disadvantaged communities. Further, National Grid's investments will be partly funded by people who live in multi-family housing or live in areas without private-on-site parking. These market segments may or may not be in economically disadvantaged communities. National Grid has not given sufficient emphasis to program designs and goals to serve these markets.

Despite the fact many new EV models are already priced below the average upfront cost of a new vehicle even before accounting for fuel and maintenance savings, it may be unlikely that many will be purchased by members of disadvantaged communities in the near term. However, this does not mean that electric transportation is inaccessible to

disadvantaged communities. There are at least four options that warrant consideration by National Grid and the Commission. First, used electric vehicles are generally attractively priced (the average price of a used Nissan LEAF is around $11,000[98]) and may be a viable option for a low-income household and more used EVs will be coming onto the market in the next three years reflecting historical growth of new electric vehicle sales. Second, electric vehicles may be viable as shared vehicles hosted by a neighborhood institution or cooperative. Third, medium- and heavy-duty public transportation vehicles that serve disadvantaged communities can be electrified and provide improvement in local environments through reductions in harmful diesel vehicle emissions. Fourth, there has been a very large increase in the availability of electrified cycles and neighborhood vehicles that may have significant utility in disadvantaged communities.

I recommend that the Commission direct National Grid to consult with disadvantaged communities and craft a pilot project to be included in the Electric Transportation Initiative that addresses the needs of disadvantaged communities in Rhode Island. It is likely that such consultation will suggest that National Grid go beyond a limited commitment to provide Level 2 public charging stations in disadvantaged communities and will include DC fast charging to serve people without private parking in fixed

[98] https://insideevs.com/six-fastest-selling-used-plug-electric-cars/

parking places as well as electrification of public transportation and commercial delivery fleets in order to reduce pollution and noise.

In addition to ensuring that economically disadvantaged communities receive equitable investment in charging infrastructure, National Grid's programs should give particular emphasis to those market segments that experience specific market failures because of misalignments of incentives due to ownership and charging station control issues. Multi-family dwellings with shared parking lots are the most prominent example of this problem.

While it is laudable that National Grid has dedicated charging station deployment in multi-family settings, I recommend that National Grid significantly increase the number of stations set aside for this market segment. Multifamily dwellings with share parking lots are a particularly challenging segment due to generally higher station deployment costs and misaligned incentives between tenants and property managers to install stations. These dynamics make multifamily dwellings with shared parking a particularly worthy area for increased utility engagement, and increasing charging access in this segment will allow for a broader, more diverse electric vehicle market to grow. For these reasons, I recommend increasing the required number of multi-family stations deployed in the Electric Transportation Initiative to 100 stations, with an aspirational goal of 200 stations.

Q. What is your concern about interoperability, common standards, and open networks?

A. Interoperability, common standards, and open networks are the foundations for vibrant competition in a future electric vehicle charging market. As such, they are in the public interest and should be an element of National Grid's plans. Nothing in National Grid's Power Sector Transformation Plan indicates that an intent to be anything but interoperable, use common standards, and use open networks but the Plan also does not declare a commitment to these principles. The Commission should direct National Grid to follow these principles in its procurement of electric vehicle charging equipment.

Q. Do you have any other recommendations regarding National Grid's Electric Transportation Initiative?

A. Yes. National Grid should undertake to integrate the proposed battery storage investments in its Energy Storage System Initiative paired with DC fast charging station(s) in its Electric Transportation Initiative. Storage that can be charged more or less continually or during low-load times can mitigate the effects of DC fast charging on both local distribution capacity and on system peak load. It can also reduce electricity losses

associated with high power draw.[99] There are also likely to be some useful infrastructure savings from collocating storage with DC Fast Charging. Thereby, it dovetails with several Power Sector Transformation goals articulated in docket 4600 by leveraging distributed energy resources to provide value to utility customers and the grid.

VIII. RECOMMENDATIONS REGARDING NATIONAL GRID'S ELECTRIC TRANSPORTATION INITIATIVE

Q. Do you recommend that the Commission find that the Electric Transportation Initiative is consistent with Rhode Island law, the PUC's Docket 4600 Guidance Document, and state regulatory policy, and therefore, appropriate for inclusion in annual PST Plans to implement the Company's overall PST Plan over time?

A. I recommend that the Commission find the proposed PST Plan investment in electric transportation is in the public interest.

I also recommend that the Commission find that the proposed Electric Transportation Initiative is consistent with the Commission's "Rhode Island Power Sector

[99] Christen, D., F. Jauch, and J. Biel. 2015. Ultra-fast charging station for electric vehicles with integrated split storage. In 17th European Conference on Power Electronics and Applications.

Transformation: Beneficial Electrification Principles and Recommendations."[100] I have testified above at some length demonstrating that transportation electrification will:

- Provide reliable, safe, clean and affordable energy to Rhode Island customers over the long term (this applies to all energy use, not just regulated fuels);
- Strengthen the Rhode Island economy, support economic competitiveness, retain and create jobs by optimizing the benefits of a modern grid and attaining appropriate rate design structures;
- Address the challenge of climate change and other forms of pollution;
- Align distribution utility, customer, and policy objectives and interests through the regulatory framework, including rate design, cost recovery, and incentives.
- Prioritize and facilitate increasing customer investment in their facilities (efficiency, distributed generation, storage, responsive demand, and the electrification of vehicles and heating) where that investment provides recognizable net benefits;

…

- Appropriately charge customers for the cost they impose on the grid; and
- Appropriately compensate the distribution utility for the services it provides.

[100] Available at http://www.ripuc.org//utilityinfo/electric/PST_BE_draft.pdf

I also testified above that National Grid's proposal describes an appropriate role for the utility in the provision of electric vehicle charging services, that aggregate utility revenues from electric vehicle charging at all locations dilutes the rates of other customers and justifies reasonable utility investment in electric vehicle charging infrastructure.

Q. Do you recommend that the Commission undertake any other action in relation to National Grid's proposals with respect to the Electric Transportation Initiative?

A. I recommend that the program be approved subject to certain conditions that will assure that it meets the public interest. Those conditions should:

1. require National Grid to include demand response or load management capabilities in its electric vehicle charging program;
2. increase the number of charging stations targeted for MUDs from 24 to 100, with an aspirational goal of 200 stations;
3. require National Grid to adopt interoperability, common standards, and open networks in its procurement of electric vehicle charging equipment; and
4. request that National Grid work with disadvantaged communities to develop a pilot project for appropriate electric transportation to serve such communities in Rhode Island; and

5. request that National Grid integrate its proposed work on grid-integrated battery storage with one or more DC Fast Charging sites.

Q. Does that complete your testimony?

A. Yes.

Tab A

Douglas B. Jester

Personal Information

Contact Information:
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Professional experience

January 2011 – present 5 Lakes Energy

Partner

Co-owner of a consulting firm working to advance the clean energy economy in Michigan and beyond. Consulting engagements with foundations, startups, and large mature businesses have included work on public policy, business strategy, market development, technology collaboration, project finance, and export development concerning energy efficiency, smart grid, renewable generation, electric vehicle infrastructure, and utility regulation and rate design. Policy director for renewable energy ballot initiative and Michigan energy legislation advocacy. Supported startup of the Energy Innovation Business Council, a trade association of clean energy businesses. Expert witness in utility regulation cases. Developed integrated resource planning models for use in ten states' compliance with the Clean Power Plan.

February 2010 - December 2010 Michigan Department of Energy, Labor and Economic Growth

Senior Energy Policy Advisor

Advisor to the Chief Energy Officer of the State of Michigan with primary focus on institutionalizing energy efficiency and renewable energy strategies and policies and developing clean energy businesses in Michigan. Provided several policy analyses concerning utility regulation, grid-integrated storage, performance contracting, feed-in tariffs, and low-income energy efficiency and assistance. Participated in Pluggable Electric Vehicle Task Force, Smart Grid Collaborative, Michigan Prosperity Initiative, and Green Partnership Team. Managed development of social-media-based community for energy practitioners. Organized conference on Biomass Waste to Energy.

August 2008 - February 2010 Rose International

Business Development Consultant - Smart Grid

- Employed by Verizon Business' exclusive external staffing agency for the purpose of providing business and solution development consultation services to Verizon Business in the areas of Smart Grid services and transportation management services.

December 2007 - March 2010 Efficient Printers Inc

President/Co-Owner

- Co-founder and co-owner with Keith Carlson of a corporation formed for the purpose of acquiring J A Thomas Company, a sole proprietorship owned by Keith Carlson. Recognized as Sacramento County (California) 2008 Supplier of the Year and Washoe County (Nevada) Association for Retarded Citizens 2008 Employer of the Year. Business operations discontinued by asset sale to focus on associated printing software services of IT Services Corporation.

August 2007 - present IT Services Corporation

President/Owner

- Founder, co-owner, and President of a startup business intended to provide advanced IT consulting services and to acquire or develop managed services in selected niches, currently focused on developing e-commerce solutions for commercial printing with software-as-a-service.

2004 – August 2007 Automated License Systems

Chief Technology Officer

- Member of four-person executive team and member of board of directors of a privately-held corporation specializing in automated systems for the sale of hunting and fishing licenses, park campground reservations, and in automated background check systems. Executive responsible for project management, network and data center operations, software and product development. Brought company through mezzanine financing and sold it to Active Networks.

2000 - 2004 WorldCom/MCI

Director, Government Application Solutions

- Executive responsible in various combinations for line of business sales, state and local government product marketing, project management, network and data center operations, software and product development, and contact center operations for specialized government process outsourcing business. Principal lines of business were vehicle emissions testing, firearm background checks, automated hunting and fishing license systems, automated appointment scheduling, and managed application hosting services. Also responsible for managing order entry, tracking, and service support systems for numerous large federal telecommunications contracts such as the US Post Office, Federal Aviation Administration, and Navy-Marine Corps Intranet.
- Increased annual line-of-business revenue from $64 million to $93 million, improved EBITDA from approximately 2% to 27%, and retained all customers, in context of corporate scandal and bankruptcy.
- Repeatedly evaluated in top 10% of company executive management on annual performance evaluations.

1999-2000 Compuware Corporation

Senior Project Manager

- Senior project manager, on customer site with five project managers and team of approximately 80, to migrate a major dental insurer from a mainframe environment to internet-enabled client-server environment.

1995 - 1999 City of East Lansing, Michigan

Mayor and Councilmember

- Elected chief executive of the City of East Lansing, a sophisticated city of 52,000 residents with a council-manager government employing about 350 staff and with an annual budget of about $47 million. Major accomplishments included incorporation of public asset depreciation into budgets with consequent improvements in public facilities and services, complete rewrite and modernization of city charter, greatly intensified cooperation between the City of East Lansing and the East Lansing Public Schools, significant increases in recreational facilities and services, major revisions to housing code, initiation of revision of the City Master Plan, facilitation of the merger of the Capital Area Transportation Authority and Michigan State University bus systems, initiation of a major downtown redevelopment project, City government efficiency improvements, and numerous other policy initiatives. Member of Michigan Municipal League policy committee on Transportation and Environment and principal writer of league policy on these subjects (still substantially unchanged as of 2009).

1995-1999 Michigan Department of Natural Resources

Chief Information Officer

- Executive responsibility for end-user computing, data center operations, wide area network, local area network, telephony, public safety radio, videoconferencing, application development and support, Y2K readiness for Departments of Natural Resources and Environmental Quality. Directed staff of about 110. Member of MERIT Affiliates Board and of the Great Lakes Commission's Great Lakes Information Network (GLIN) Board.

1990-1995 Michigan Department of Natural Resources

Senior Fisheries Manager

- Responsible for coordinating management of Michigan's Great Lakes fisheries worth about $4 billion per year including fish stocking and sport and commercial fishing regulation decisions, fishery monitoring and research programs, information systems development, market and economic analyses, litigation, legislative analysis and negotiation. University relations. Extensive involvement in regulation of steam electric and hydroelectric power plants.
- Served as agency expert on natural resource damage assessment, for all resources and causes.
- Considerable involvement with Great Lakes Fishery Commission, including:
  - Co-chair of Strategic Great Lakes Fishery Management Plan working group

- Member of Lake Erie and Lake St. Clair Committees
- Chair, Council of Lake Committees
- Member, Sea Lamprey Control Advisory Committee
- St Clair and Detroit River Areas of Concern Planning Committees

1989-1990 American Fisheries Society

Editor, North American Journal of Fisheries Management

- Full responsibility for publication of one of the premier academic journals in natural resource management.

1984 - 1989 Michigan Department of Natural Resources

Fisheries Administrator

- Assistant to Chief of Fisheries, responsible for strategic planning, budgets, personnel management, public relations, market and economic analysis, and information systems. Department of Natural Resources representative to Governor's Cabinet Council on Economic Development. Extensive involvement in regulation of steam electric and hydroelectric power plants.

1983-present Michigan State University

Adjunct Instructor

- Irregular lecturer in various undergraduate and graduate fisheries and wildlife courses and informal graduate student research advisor in fisheries and wildlife and in parks and recreation marketing.

1977 – 1984 Michigan Department of Natural Resources

Fisheries Research Biologist

- Simulation modeling & policy analysis of Great Lakes ecosystems. Development of problem-oriented management records system and "epidemiological" approaches to managing inland fisheries.
- Modeling and valuation of impacts power plants on natural resources and recreation.

Education

1991-1995 Michigan State University

PhD Candidate, Environmental Economics

Coursework completed, dissertation not pursued due to decision to pursue different career direction.

1980-1981 University of British Columbia

Non-degree Program, Institute of Animal Resource Ecology

1974-1977 Virginia Polytechnic Institute & State University

MS Fisheries and Wildlife Sciences

MS Statistics and Operations Research

1971-1974 New Mexico State University

BIS Mathematics, Biology, and Fine Arts

Citizenship and Community Involvement	Youth Soccer Coach, East Lansing Soccer League, 1987-89
	Co-organizer, East Lansing Community Unity, 1992-1993
	Bailey Community Association Board, 1993-1995
	East Lansing Commission on the Environment, 1993-1995
	East Lansing Street Lighting Advisory Committee, 1994
	Councilmember, City of East Lansing, 1995-1999
	Mayor, City of East Lansing, 1995-1997
	East Lansing Downtown Development Authority Board Member, 1995-1999
	East Lansing Transportation Commission, 1999-2004
	East Lansing Non-Profit Housing and Neighborhood Services Corporation Board Member, 2001-2004
	Lansing – East Lansing Smart Zone Board of Directors, 2007-present
	Council on Labor and Economic Growth, State of Michigan, by appointment of the Governor, May 2009 – May 2012
	East Lansing Downtown Development Authority Board Member and Vice-Chair, 2010 – present.
	East Lansing Brownfield Authority Board Member and Vice-Chair, 2010 – present.
	East Lansing Downtown Management Board and Chair, 2010 – 2016
	East Lansing City Center Condominium Association Board Member, 2015 – present.

Douglas Jester
Specific Energy-Related Accomplishments

Unrelated to Employment

- Member of Michigan SAVES initial Advisory Board. Michigan SAVES is a financing program for building energy efficiency measures initiated by the State of Michigan Public Service Commission and administered under contract by Public Sector Consultants. Program launched in 2010.
- Member of Michigan Green Jobs Initiative, representing the Council for Labor and Economic Growth.
- Participated in Lansing Board of Water and Light Integrated Resource Planning, leading to their recent completion of a combined cycle natural gas power plant that also provides district heating to downtown Lansing.
- In graduate school, participated in development of database and algorithms for optimal routing of major transmission lines for Virginia Electric Power Company (now part of Dominion Resources).
- Commissioner of the Lansing Board of Water and Light, representing East Lansing. December 2017 – present.

For 5 Lakes Energy

- Participant by invitation in the Michigan Public Service Commission Smart Grid Collaborative, authoring recommendations on data access, application priorities, and electric vehicle integration to the grid.
- Participant by invitation in the Michigan Public Service Commission Energy Optimization Collaborative, a regular meeting and action collaborative of parties involved in the Energy Optimization programs required of utilities by Michigan law enacted in 2008.
- Participant by invitation in Michigan Public Service Commission Solar Work Group, including presentations and written comments on value of solar, including energy, capacity, avoided health and environmental damages, hedge value, and ancillary services.
- Participant by invitation in Michigan Senate Energy and Technology Committee stakeholder work group preliminary to introduction of a comprehensive legislative package.
- Participant by invitation in Michigan Public Service Commission PURPA Avoided Cost Technical Advisory Committee.
- Participant by invitation in Michigan Public Service Commission Standby Rate Working Group.
- Participant by invitation in Michigan Public Service Commission Street Lighting Collaborative.
- Participant by invitation in State of Michigan Agency for Energy Technical Advisory Committee on Clean Power Plan implementation.
- Conceived, obtained funding, and developed open access integrated resource planning tools (State Tool for Electricity Emissions Reduction aka STEER) for State compliance with the Clean Power Plan:
    - For Energy Foundation - Michigan and Iowa
    - For Advanced Energy Economy Institute – Arkansas, Florida, Illinois, Ohio, Pennsylvania, Virginia
    - For The Solar Foundation - Georgia and North Carolina
- Presentations to Michigan Agency for Energy and the Institute for Public Utilities Michigan Forum on Strategies for Michigan to Comply with the Clean Power Plan.
- Participant in Midcontinent Independent Systems Operator stakeholder processes on behalf of Michigan Citizens Against Rate Excess and the MISO Consumer Representatives Sector, including Resource Adequacy Committee, Loss of Load Expectation Working Group, Transmission Expansion Working Group, Demand Response Working Group, Independent Load Forecasting Working Group, and Clean Power Plan Working Group.
- Expert witness before the Michigan Public Service Commission in various cases, including:

- Case U-17473 (Consumers Energy Plant Retirement Securitization)
- Case U-17096-R (Indiana Michigan 2013 PSCR Reconciliation)
- Case U-17301 (Consumers Energy Renewable Energy Plan 2013 Biennial Review);
- Case U-17302 (DTE Energy Renewable Energy Plan 2013 Biennial Review);
- Case U-17317 (Consumers Energy 2014 PSCR Plan);
- Case U-17319 (DTE Electric 2014 PSCR Plan);
- Case U-17674 (WEPCO 2015 PSCR Plan);
- Case U-17679 (Indiana-Michigan 2015 PSCR Plan);
- Case U-17689 (DTE Electric Cost of Service and Rate Design);
- Case U-17688 (Consumers Energy Cost of Service and Rate Design);
- Case U-17698 (Indiana-Michigan Cost of Service and Rate Design);
- Case U-17762 (DTE Electric Energy Optimization Plan);
- Case U-17752 (Consumers Energy Community Solar);
- Case U-17735 (Consumers Energy General Rates);
- Case U-17767 (DTE General Rates);
- Case U-17792 (Consumers Energy Renewable Energy Plan Revision);
- Case U-17895 (UPPCO General Rates);
- Case U-17911 (UPPCO 2016 PSCR Plan);
- Case U-17990 (Consumers Energy General Rates); and
- Case U-18014 (DTE General Rates);
- Case U-17611-R (UPPCO 2015 PSCR Reconciliation);
- Case U-18089 (Alpena Power PURPA Avoided Costs);
- Case U-18090 (Consumers Energy PURPA Avoided Costs);
- Case U-18091 (DTE PURPA Avoided Costs);
- Case U-18092 (Indiana Michigan Electric Power PURPA Avoided Costs);
- Case U-18093 (Northern States Power PURPA Avoided Costs);
- Case U-18094 (Upper Peninsula Power Company PURPA Avoided Costs);
- Case U-18095 (UMERC PURPA Avoided Costs);
- Case U-18224 (UMERC Certificate of Necessity);
- Case U-18255 (DTE General Rate Case);
- Case U-18322 (Consumers Energy General Rate Case).

- Expert witness before the Public Utilities Commission of Nevada in
  - Case 16-07001 (NV Energy 2017-2036 Sierra Pacific Integrated Resource Plan)
- Expert witness before the Missouri Public Service Commission in
  - Case ER-2016-0179 (Ameren Missouri General Rate Case)
  - Case ER-2016-0285 (KCP&L General Rate Case)
  - Case ET-2016-0246 (Ameren Missouri EV Policy)
- Expert witness before the Kentucky Public Service Commission
  - Case 2016-00370 (Kentucky Utilities General Rate Case)
- Expert witness before the Massachusetts Department of Public Utilities in
  - Case 17-05 (Eversource General Rate Case)
  - Case 17-13 (National Grid General Rate Case)
- Coauthored “Charge without a Cause: Assessing Utility Demand Charges on Small Customers”
- Currently under contract to the Michigan Agency for Energy to develop a Roadmap for CHP Market Development in Michigan, including evaluation of various CHP technologies and applications using STEER Michigan as an integrated resource planning tool.
- Under contract to NextEnergy, authored “Alternative Energy and Distributed Generation” chapter of Smart Grid Economic Development Opportunities report to Michigan Economic Development Corporation and assisted authors of chapters on “Demand Response” and “Automated Energy Management Systems”.
- Developed presentation on “Whole System Perspective on Energy Optimization Strategy” for Michigan Energy Optimization Collaborative.
- Under contract to NextEnergy, assisted in development of industrial energy efficiency technology development strategy.

- Under contract to a multinational solar photovoltaics company, developed market strategy recommendations.
- For an automobile OEM, developed analyses of economic benefits of demand response in vehicle charging and vehicle-to-grid electricity storage solutions.
- Under contract to Pew Charitable Trusts, assisted in development of a report of best practices for electric vehicle charging infrastructure.
- Under contract to a national foundation, developed renewable energy business case for Michigan including estimates of rate impacts, employment and income effects, health effects, and greenhouse gas emissions effects.
- Assisted in Michigan market development for a solar panel manufacturer, clean energy finance company, and industrial energy management systems company.
- Under contract to Institute for Energy Innovation, organized legislative learning sessions covering a synopsis of Michigan's energy uses and supply, energy efficiency, and economic impacts of clean energy.

For Department of Energy Labor and Economic Growth

- Participant in the Michigan Public Service Commission Energy Optimization Collaborative, a regular meeting and action collaborative of parties involved in the Energy Optimization programs required of utilities by Michigan law enacted in 2008.
- Lead development of a social-media-based community for energy practitioners in Michigan at www.MichEEN.org.
- Drafted analysis and policy paper concerning customer and third-party access to utility meter data.
- Analyzed hourly electric utility load demonstrating relationship amongst time of day, daylight, and temperature on loads of residential, commercial, industrial, and public lighting customers. Analysis demonstrated the importance of heating for residential electrical loads and the effects of various energy efficiency measures on load-duration curves.
- Analyzed relationship of marginal locational prices to load, demonstrating that traditional assumptions of Integrated Resource Planning are invalid and that there are substantial current opportunities for cost-effective grid-integrated storage for the purpose of price arbitrage as opposed to traditionally considered load arbitrage.
- Developed analyses and recommendations concerning the use of feed-in tariffs in Michigan.
- Participated in Pluggable Electric Vehicle Task Force and initiated changes in State building code to accommodate installation of vehicle charging equipment.
- Organized December 2010 conference on Biomass Waste to Energy technologies and market opportunities.
- Participated in and provided support for teams working on developing Michigan businesses involved in renewable energy, storage, and smart grid supply chains.
- Developed analyses and recommendations concerning low-income energy assistance coordination with low-income energy efficiency programs and utility payment collection programs.
- Drafted State of Michigan response to a US Department of Energy request for information on offshore wind energy technology development opportunities.
- Assisted in development of draft performance contracting enabling legislation, since adopted by the State of Michigan.

For Verizon Business

- Analyzed several potential new lines of business for potential entry by Verizon's Global Services Systems Integration business unit and recommended entry to the "Smart Grid" market. This recommendation was adopted and became a major corporate initiative.
- Provided market analysis and participation in various conferences to aid in positioning Verizon in the "Smart Grid" market. Recommendations are proprietary to Verizon.

- Led a task force to identify potential converged solutions for the “Smart Grid” market by integrating Verizon’s current products and selected partners. Established five key partnerships that are the basis for Verizon’s current “Smart Grid” product offerings.
- Participated in the “Smart Grid” architecture team sponsored by the corporate Chief Technology Officer with sub-team lead responsibilities in the areas of Software and System Integration and Network and Systems Management. This team established a reference architecture for the company’s “Smart Grid” offerings, identified necessary changes in networks and product offerings, and recommended public policy positions concerning spectrum allocation by the FCC, security standards being developed by the North American Reliability Council, and interoperability standards being developed by the National Institute of Standards and Technology.
- Developed product proposals and requirements in the areas of residential energy management, commercial building energy management, advanced metering infrastructure, power distribution monitoring and control, power outage detection and restoration, energy market integration and trading platforms, utility customer portals and notification services, utility contact center voice application enablement, and critical infrastructure physical security.
- Lead solution architecture and proposal development for six utilities with solutions encompassing customer portal, advanced metering, outage management, security assessment, distribution automation, and comprehensive “Smart Grid” implementation.
- Presented Verizon’s “Smart Grid” capabilities to seventeen utilities.
- Presented “Role of Telecommunications Carriers in Smart Grid Implementation” to 2009 Mid-America Regulatory Conference.
- Presented “Smart Grid: Transforming the Electricity Supply Chain” to the 2009 World Energy Engineering Conference.
- Participant in NASPInet work groups of the North American Energy Reliability Corporation (NERC), developing specifications for a wide-area situational awareness network to facilitate the sharing and analysis of synchrophasor data amongst utilities in order to increase transmission reliability.
- Provided technical advice to account team concerning successful proposal to provide network services and information systems support for the California ISO, which coordinates power dispatch and intercompany power sales transactions for the California market.

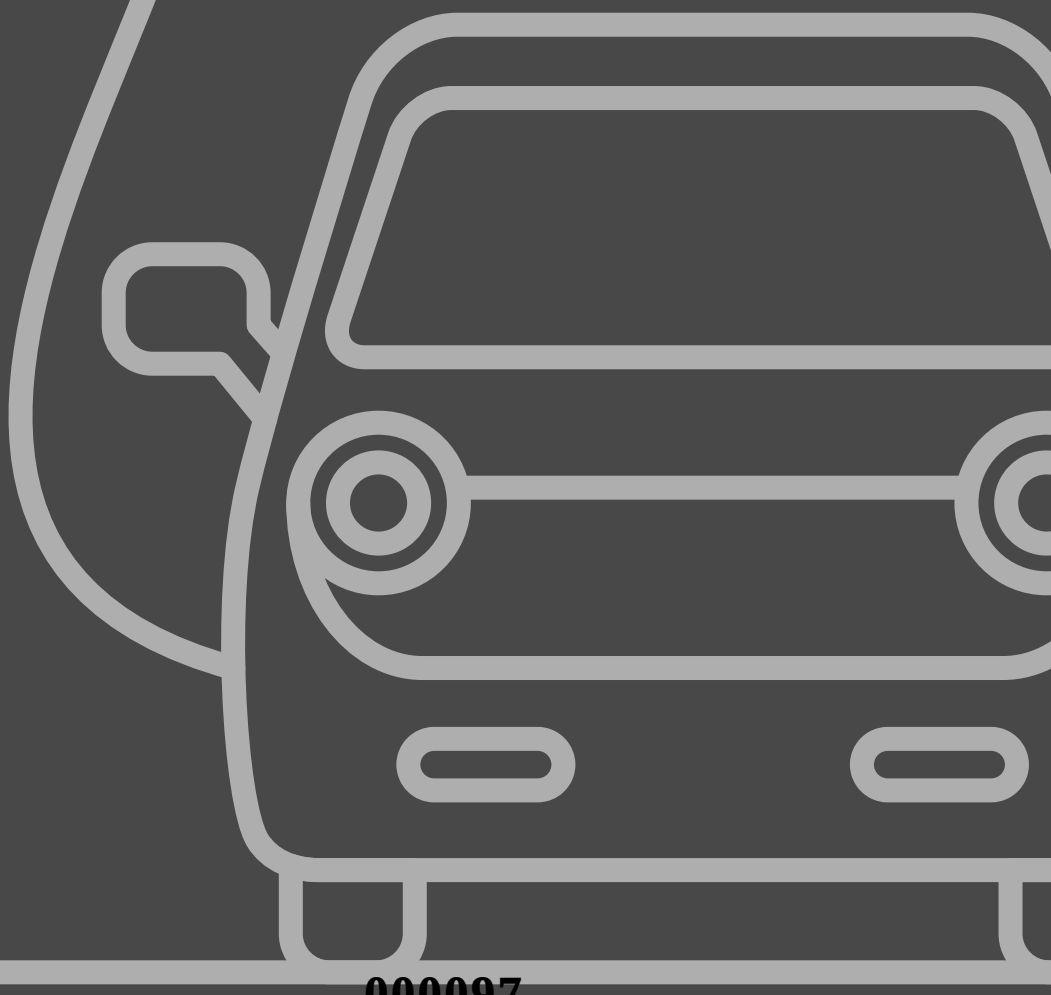
For Michigan Department of Natural Resources

- Determined permit requirements under Section 316 of the Clean Water Act for all steam electric plants currently operating in the State of Michigan.
- Case manager and key witness for the State of Michigan in FERC, State court, and Federal court cases concerning economics and environmental impacts of the Ludington Pumped Storage Plant, which is the world’s largest pumped storage plant. A lead negotiator for the State in the ultimate settlement of this issue. The settlement was valued at $127 million in 1995 and included considerations of environmental mitigation, changes in power system dispatch rules, and damages compensation.
- Managed FERC license application reviews for the State of Michigan for all hydroelectric projects in Michigan as these came up for reissuance in 1970s and 1980s.
- Testified on behalf of the State of Michigan in contested cases before the Federal Energy Regulatory Commission concerning benefit-cost analyses and regulatory issues for four different hydroelectric dams in Michigan.
- Reviewed (as regulator) the environmental impacts and benefit-cost analyses of all major steam electric and most hydroelectric plants in the State of Michigan.
- Executive responsibility for development, maintenance, and operations of the State of Michigan’s information system for mineral (includes oil and gas) rights leasing, unitization and apportionment, and royalty collection.
- In cooperative project with Ontario Ministry of Natural Resources, participated in development of a simulation model of oil field development logistics and environmental impact on Canada’s Arctic slope for Tesoro Oil.

Tab B

THE ABCs OF EVs

A GUIDE FOR POLICY MAKERS AND CONSUMER ADVOCATES



THE ABCs OF EVs

A GUIDE FOR POLICY MAKERS AND CONSUMER ADVOCATES

EXECUTIVE SUMMARY

Once a subject of prophecy, electric vehicles (EVs) have now arrived. While still a small share of car purchases, they are becoming a familiar sight on American roads—and industry analysts predict EV sales will grow at a robust clip in the next decade, as consumers become familiar with the advantages of their technology, and anticipated cost reductions and extended driving ranges turn EVs into appealing alternatives to gasoline-burning cars.

Why should policymakers and consumer advocates concern themselves with EVs? After all, we don't typically focus on end-use electricity—there aren't regulatory proceedings about refrigerators or coffee-makers. However, EVs are different from other appliances in ways that have profound implications for the electricity system.

An EV in the garage could increase the electricity consumption of an average household by 40%—and millions of them could require costly expansion of electric system delivery and generation capacity. But if EVs and EV infrastructure are managed as distributed energy resources, the rise of transportation electrification can lead to lower—not higher—electric rates for all consumers.

This report is intended to help policymakers forge local and regional strategies designed to capture the potential of EV growth to contribute to system optimization. We identify factors favoring EV market penetration; assess its ramifications for the electric grid and the consumers who depend on it; advance a set of principles to protect the interests of electricity customers; describe proceedings and initiatives underway in a number of jurisdictions; and lay out options for state regulatory action.

We conclude that proactive regulatory efforts to set the direction of state policies are crucial at this nascent stage of EV market development. While regulatory outcomes will reflect differences in law, market structure, supply technologies, load dynamics, social goals and other factors, effective EV policy initiatives will have common elements across jurisdictions. They will:

- Benefit from collaboration among the diverse community of EV stakeholders;
- Maximize consumer and social value by employing smart EV dispatch to optimize system load shapes;
- Adopt optional dynamic and time-based rates to incentivize system-beneficial charging behaviors;
- Promote interoperability, common standards, and open networks for EV infrastructure;
- Ensure that EV policies benefit underserved/disadvantaged communities;
- Subject proposed utility investments to cost-benefit tests, performance standards, and compatibility with comprehensive strategic plans designed to maximize grid value and customer benefit;
- Maintain regulatory oversight of any customer-funded or public investment in EV infrastructure.

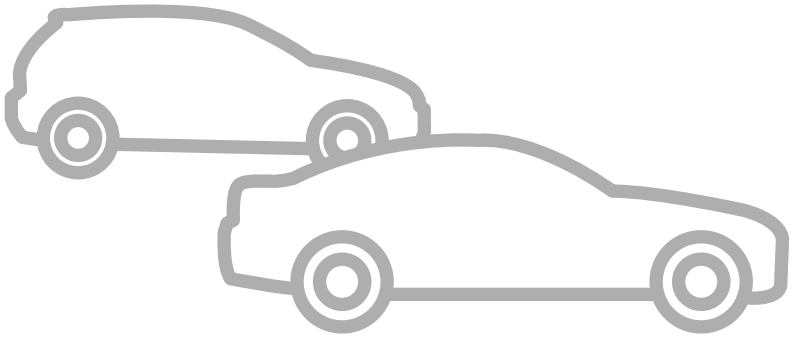
To craft viable policies, lawmakers and regulators will first need to consider threshold questions about the scope of state regulatory authority and its applicability to a range of issues related to the pace of EV market penetration and its effects in a jurisdiction. The lengthy list of issues to be examined in an EV evaluation process include:

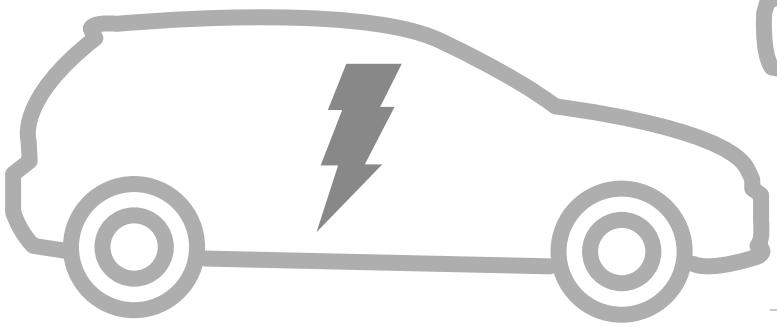
- Implications of EV growth for load shapes, rates and rate designs;
- Available metering, charging, and load management technologies;
- Options for administration, location and support of charging infrastructure;
- Consumer protection rules;
- Consumer education and information;
- Geographic and demographic disparities in EV adoption;
- Allocation and recovery of EV-related costs and investments;
- Value, scale and design of pilot programs;
- Opportunities and obstacles to regional cooperation;
- The roles of public utilities, private vendors, EV owners and other actors.

EV issues are complex, and there won't be a one-size-fits-all solution. But if consumer value and system optimization are the central priorities shaping formation of EV policy, public benefit will be the result. This guide is intended to help lay the groundwork for achieving that goal.

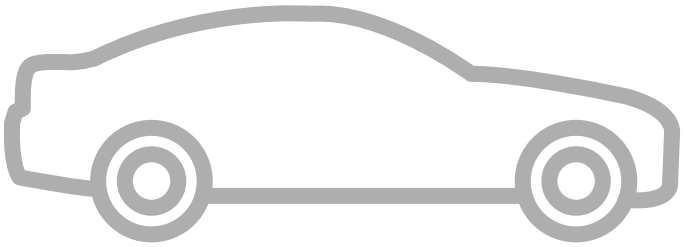
Electric Vehicles Are Emerging into the Mass Market

Driven by market dynamics, consumer preferences, advances in technology, and public policy, electrification of the global vehicle fleet has begun. While EVs remain a small fraction of the 17.5 million light vehicles sold annually in the U.S. today, EV sales rose by 37% in 2016 and have more than tripled in four years.[1] With 570,187 EVs on the road at the end of 2016, the U.S. ranks third, behind China and Europe, in cumulative sales.[2] Assuming 12,000 electricity powered miles per year and average consumption of 34 kWh to travel 100 miles, EVs are already using more than 2.3 million megawatt-hours of electricity annually, equivalent to the total usage of about 216,000 average households.





With the impending introduction in 2017 of a new generation of EVs with higher range and lower costs, the electrification trend is accelerating and a tipping point toward mass market acceptance may be reached this decade.[3] Market analysts agree that EVs are here to stay, though they offer widely varying forecasts of the pace of adoption. UBS sees EV penetration of the U.S. car market reaching 3% in 2025, a four-fold increase from today but still a fraction of the 22% EV share predicted by Goldman Sachs.[4] Bloomberg predicts EVs will capture 35% of the car market by 2040, with EV unit sales 80 times greater than today.[5] These wide-ranging forecasts reflect different assumptions about EV life-cycle costs, gasoline prices, charging availability, technological advances, environmental policies and consumer behavior. But even at the low end of projections, EV growth will have a substantial positive impact on society. Transportation Electrification (TE) is seen as a key driver of cleaner air, reduced carbon emissions, lower transportation costs, and greater energy independence. This paper focuses primarily on a different goal: How the right set of public policies can use TE to create a more efficient and lower cost electric system.



1 Rising from 52,607 in 2012 to 159,139 in 2016; see http://insideevs.com/monthly-plug-in-sales-scorecard/

2 Data from U.S. Energy Information Administration

3 As used in this paper, EV refers to a car or light truck that plugs in and can drive on electricity only, including Battery Electric Vehicles (BEV) and Plug-in Hybrid Vehicles (PHEV)

4 http://www.goldmansachs.com/our-thinking/technology-driving-innovation/cars-2025/ and http://www.goldmansachs.com/our-thinking/pages/new-energy-landscape-folder/report-the-low-carbon-economy/report.pdf

5 https://about.bnef.com/blog/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040/

EVs Pose Unique Opportunities and Challenges for the Electricity System

Because anybody can buy an EV, bring it home and plug it in, an electric car may appear to be just like any other electrical appliance. But EVs are different from rolling refrigerators because they store electricity and have controllable demand. With large intermittent loads and manageable charging schedules, EVs are an entirely new form of electrical device, with unprecedented potential for consumer and system benefits.

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The physics of electricity—the need to have supply and demand balanced at every moment for the power grid to function—and the limits of 20th century technology dictated the construction of an inefficient electric system. Generation, transmission and distribution were sized to serve peak electricity demands, leaving tremendous excess capacity most of the time. Advanced technology deployed under careful regulatory policy can use EV loads to optimize tomorrow's electric system. Analyses by the Rocky Mountain Institute show that if the entire U.S. fleet of cars and light trucks were converted to electricity, overall demand for power would go up by about 25%, but could be largely accommodated without additional power plants or grid expansion if EVs were charged at optimal times.[6]

Instead of higher costs for generation and delivery capacity that would otherwise be required to serve EV demand, lower costs will be the result if surplus capacity is the primary resource for EV charging. When new utility revenue from EV charging exceeds incremental costs, average costs per unit of energy

decline, which translates into lower electricity rates for all customers. Using EVs as grid-supporting demand response resources could fill gaps in system load shape and reduce utility costs. And in states with significant variable renewable generation, syncing EV charging peaks with solar and wind output could add a further level of system optimization.

Yet high EV penetration could pose challenges to a system that is unprepared for it. For example, early EV adoption appears to be clustering in certain neighborhoods—those where residents can afford to

6 http://www.rmi.org/Content/Files/RMI_Electric_Vehicles_as_DERs_Final_V2.pdf and http://www.rmi.org/RFGraph-US_projected_electric_vehicle_stocks

buy them, and have a garage or parking space with a power source—which has the potential to strain circuits and necessitate distribution capacity upgrades, the costs of which are generally socialized as ratebase expenditures. In vertically integrated electricity systems, the costs of new generators, if needed to serve EV loads, are also borne across the customer base.

EV policy can enhance grid reliability, advance sustainability, and reduce energy costs for everybody, whether or not they have an EV. But these achievements won't happen automatically and there isn't one clear path for every state.

The right mix of policies and programs—reflecting the market structure, supply mix, load dynamics, social goals and other characteristics in a jurisdiction—can make EVs a substantial source of system benefit, but the wrong one (or none at all) could mean higher costs and cross-subsidies.

EV policies concern many stakeholders operating beyond the usual scope of state regulation. Players on the EV field whose actions and interactions influence EV integration include not just utilities, consumer advocates, and regulatory commissions, but charge station providers, car makers and dealers, transportation service companies, electricity generators, regional grid operators, commercial property and charging site owners, community and civic groups, municipal governments, labor unions, demand response aggregators, and other hardware, software and service providers. All of these stakeholders will want to be heard and will have something to add to EV policy consideration. EV regulatory proceedings would benefit from a process to engage interested stakeholders at the outset—not in an adversarial docket but in a collaborative effort that develops a shared base of information and allows a free exchange of ideas and views. In turn, the regulatory outcome could then benefit from a commonly understood set of policy priorities for EV integration, shared criteria for evaluating the success of those priorities and ultimately, a clearly stated common goal.

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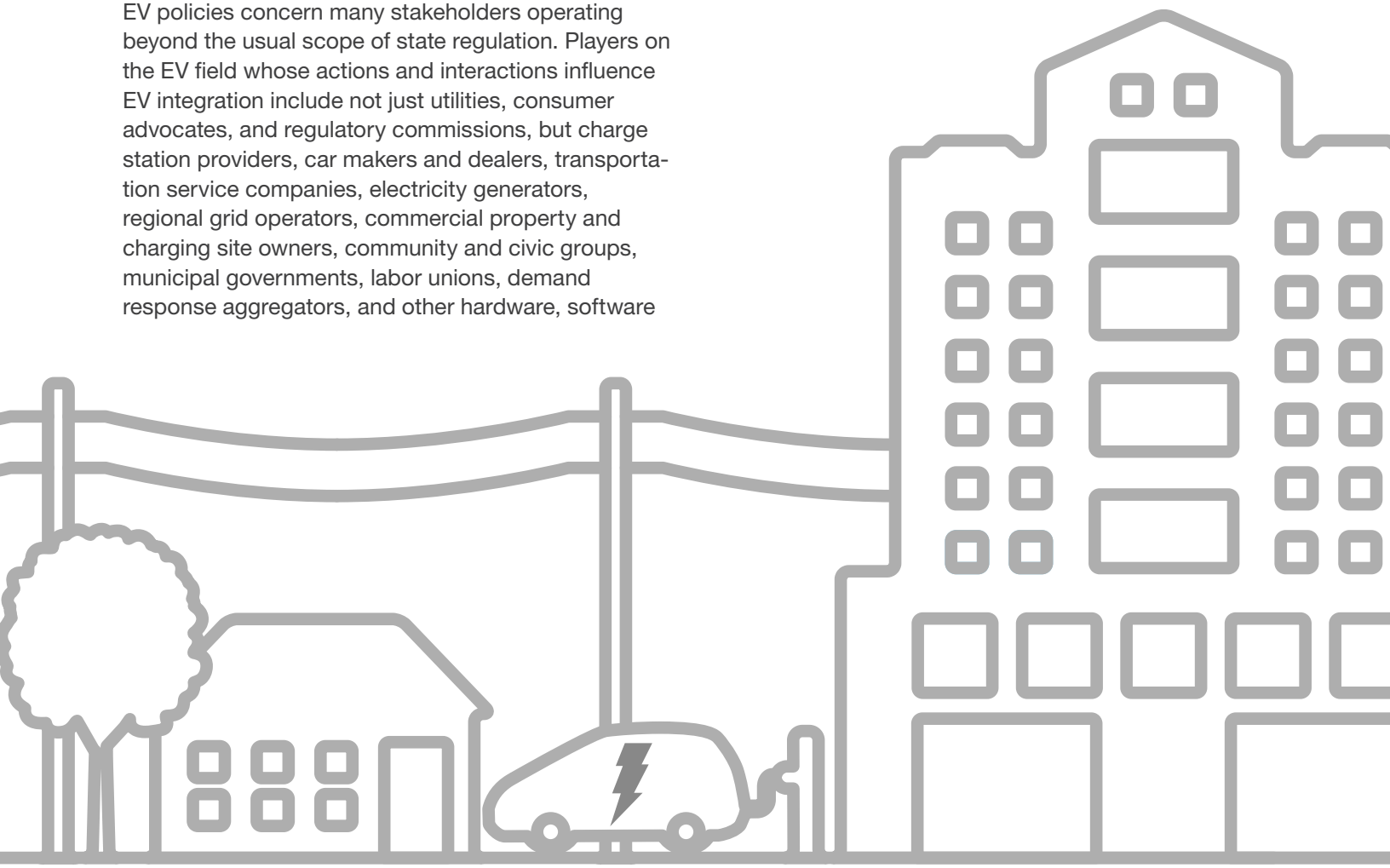

Effective Public Policy Starts with Customer-Focused Principles

Advancing consumer interests and achieving public benefits are the central goals of sound public utility regulation. Toward those ends, we propose the following core principles to guide public policy discussions:

1. **Optimize charging patterns to improve system load shape, reduce local load pockets, and maximize utilization of renewable generation;**
   Using a combination of time-based rates, smart charging, financial incentives and other innovative applications, EV loads should be managed in the interest of all electricity customers.
2. **Ensure any utility customer-funded programs provide demonstrable system benefits;**
   Cost-benefit analytical frameworks should be developed to project the effects of proposed EV policies and to evaluate ongoing performance of implemented programs. Customer funding of charging infrastructure should include smart dispatch requirements, mechanisms and policies. These can iterate over time as new options become available, but should be part of initial plans.
3. **Allow EV chargers to be grid-connected efficiently, quickly, and safely;**
   Administrative process should be minimized and permitting should be expedited so that customers and service providers face minimal impediments and delays.
4. **Facilitate aggregation of EV demand for dispatch as a Distributed Energy Resource (DER);**
   The opportunity to participate in Demand Response programs should be made available to all EV chargers, and public policy should make it as seamless as possible to participate.
5. **Benefit underserved/disadvantaged communities;**
   A portfolio of EV programs and policies should be designed to benefit all geo-demographic customer segments in a service territory. Efforts to bring EVs to low-income areas could include subsidized EV car-sharing services or EV transit, rather than installation of charging stations in neighborhoods where EVs may be unaffordable or impractical for residents to own.
6. **Promote interoperability, common standards and open networks;**
   Any utility investments and subsidies should support deployment of technologies that accommodate all EV makes and models, allow seamless flows of data, and accommodate all EV drivers. Utilities could play an important coordinating role in promoting interoperable, open networks.
7. **Support competition to accelerate market development, encourage private investment, promote innovation and bring down prices;**
   Competitors should not be restricted from entering markets for EV-related goods and services. Investments paid for by utility customers require regulatory oversight to protect consumers.
8. **Deploy utility resources where needed to address public needs;**
   Where private investment in needed EV infrastructure does not emerge, utility support should be provided to the extent necessary to produce public benefits for its service territory. Putting grid optimization at the center of EV planning is key to reaching this objective.
9. **Foster coordinated regional planning for systems and infrastructure to accommodate and integrate expanding EV loads;**
   EV demand is part of complex system dynamics, with potential efficiencies from multi-utility and multi-state coordination.
10. **Manage EV loads to reduce energy costs.**
    Increased energy sales to fuel EVs allow utility fixed costs to be spread over a larger number of kilowatt-hours, benefiting all customers when policies and programs are designed to make sure incremental revenue from EV loads exceeds the incremental cost to serve it. EV management can also change load shapes, leading to reductions in peak demand and cost savings from avoided capacity costs.

How these principles can be realized through innovative policies and programs is the central subject of this paper.

EV Policy Makers Face Fundamental Regulatory Questions

Each jurisdiction considering EV policy will face a range of questions regarding legal authority, policy framework, and jurisdiction-specific facts. At the outset a commission considering proactive steps must consider threshold questions about its regulatory scope and authority under state law, including:

- **What is the statutory role of public utility regulation in addressing uncertain EV growth?** *Improving reliability and quality of service is at the core of state regulatory responsibility. However, public policy goals and the role of regulators in advancing them vary widely. Some states have explicitly tasked regulators with supporting EVs through policy initiatives and programs. In others, proactive regulatory policies may be authorized by general public interest statutory language.*

- **Does the commission have authority to account for externalities such as environmental effects of energy usage in setting regulatory policy?** *Public utility commissions are generally not charged with environmental regulation, though their oversight of utilities has significant environmental impact. But sustainable energy has become a key goal of many states, often reflected in renewable resource and energy efficiency standards, integrated resource planning, and now in EV support initiatives. Even without explicit environmental goals, if regulatory policies focus on managing EV charging patterns to make the system more efficient, reliable and less costly, the result would include ancillary environmental benefits.*

- **How should EV issues be addressed in long-term planning? Does the commission have authority to include transportation in its scope?** *As technology advances and policies in different energy sectors increasingly overlap and converge toward goals of sustainability and cost reduction, some states are beginning to take an integrated approach to long-term energy planning. EV growth may be a significant new factor, complementary to renewable resource development and delivery system efficiency goals.*

- **Should regulators tackle chicken/egg, cart/horse issues to promote EV expansion?** *"Build it and they will come," is not a traditional basis for regulatory policy, but utilities have always used growth projections for system planning. Any regulatory efforts to stimulate EV markets should be accompanied by policies and programs focused on achieving system benefits.*

- **Does the commission have authority to target regulatory policy at a particular electricity end use such as EVs?** *Regulation has not focused on end uses and generally recovers costs of electricity service through rate designs based largely on energy volumes, demand, time of use, and seasonality; however, the large and intermittent loads of EVs may warrant EV-specific options and incentives for optimized charge management.*

- **Does the commission have authority (and would it be advisable) to require EVs to be on particular rates and/or participate in demand response programs?**
  Customer choice is generally preferable to regulatory mandates, but incentives for participation by EV owners in programs benefiting all customers might include both carrots and sticks. Optimizing grid value will require policies that impact load shape.

- **Does the owner/operator of an EV charging station fit the definition of a public utility under current law? Is a charge service provider a reseller or retailer of electricity, or otherwise subject to regulatory jurisdiction?**
  The nascent EV charge industry asserts that EV charge stations are akin to cell phone charge stations in airports and should not be deemed a regulated provision of electricity. However, statutory language may be interpreted otherwise, or the regulatory category may depend on the pricing mechanisms employed by charge providers. In any case, state regulatory laws were not written with EV charging in mind and will likely need reconsideration to accommodate it. Smart dispatch optimized to reduce peak load and energy prices should be required if utilities build and/or subsidize charging infrastructure.

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- **Does the commission have jurisdiction and authority to create and enforce standards and consumer protections for non-utility charge station operation?**
  Competition among EV charge providers may not be sufficient to induce open access and interoperability, or to protect consumers from misleading marketing and price predation. Any public subsidies and utility support for independent charge station operators should be conditioned on their acceptance of regulatory guidelines.

- **Is installation of EV Supply Equipment (EVSE) subject to permitting, regulation or standards under current law?**
  Some states have enacted statutory standards requiring licensing of installers by public utility commissions.[7] Others have left EVSE unregulated or under the jurisdiction of local building codes.

Within its statutory authority and policy objectives, a regulatory commission will face questions about how to make EV policy decisions, including:

- **What factors should be included in a cost-benefit projection for EV-related infrastructure or programs?**
  Cost-benefit analysis is often used to evaluate utility programs but can raise contentious issues. These may include whether to include social and environmental benefits beyond the traditional scope of commission concern and how to quantify them, as well as projected adoption rates and the time horizon for the analysis.

- **How should any program or investment costs be allocated among customers and classes?**
  Cost allocation is a zero-sum game in the short term, and subject to cost of service studies. Whether program costs are allocated across-the-board hinges on the nature and scope of their projected benefits.

- **What type of evidence is needed for regulators to make EV policy decisions?**
  Elements of EV policy may be speculative at this early stage but identifying and addressing prospective issues should be a central focus of regulatory inquiry.

- **How might proposed policies and programs be tested through scalable pilot programs?**
  Given the uncertainties about EV market evolution, demand for services, and utilization of infrastructure, pilots to gauge the efficacy of different approaches may be warranted (and are underway in several states, as will be discussed later in this paper).

Another set of questions surrounding EV regulatory policy relates to characteristics specific to the jurisdiction—the local attributes of energy supply, delivery capacity, system loads and other key factors that affect policy options. These include:

7 See charge installer regulations in Illinois for example: http://www.ilga.gov/commission/jcar/admincode/083/08300469sections.html

- **What is the electricity market structure? Vertically integrated? Restructured? How are energy and capacity procured?**
  In a restructured market (where utilities do not own generating plants and power and energy are procured competitively) the regulated cost of service is generally limited to delivery and customer service. The distinction from a vertically integrated market (where the utility builds, owns and operates power plants as well as the wires system) affects policy considerations. For example, in a vertically integrated system, the embedded costs of power plant investment generally must be recovered in rates even if demand shrinks, and higher demand may precipitate construction of new power plants. In organized wholesale power markets, the output of different generation types is generally reflected in real-time market prices, which would be the basis for smart charging dispatch.

- **What is the local generation mix, including the marginal generator type during peak periods?**
  The generation mix and the shape of power output is a key factor in designing EV policies. For example, a state like California, with high solar capacity, may find that the optimal time to charge EVs is generally at mid-day when the sun is shining, whereas a state like Texas, with high wind capacity, may find the optimal charging time is generally overnight. As we will discuss, smart charging can accommodate generation fluctuations in real time for optimized efficiency based on local conditions—including a cloudy day or a windless night.

- **What is the system load shape and seasonal variation? What are the drivers of demand and supply fluctuations?**
  The shape of demand is the other side of the always-balanced energy equation. While many systems reach peak annual demand on hot summer days, others may see maximum usage on cold winter nights. Some systems are dominated by commercial/industrial demand and others by residential usage. In all cases, managed EV charging can help fill the gaps and flatten the load shape to make the system more efficient, complementing other demand management programs.

- **What metering technology is in place and planned? What rate options are available or could be introduced with existing meters?**

  Advanced Metering Infrastructure (AMI), otherwise known as "smart meters"—now installed at more than half of U.S. homes, capture near real-time data on energy consumption, demand, voltage and other end-use characteristic and allow two-way communication with the utility through a digital network. Many other meters use Automatic Meter Reading (AMR), which may be able to store interval usage data for occasional one-way transmission to the utility. Even in places with conventional watt-hour meters, time-based rate options and smart charging may be feasible with installation of additional equipment.

- **What utility systems (software, billing, hardware, etc.) would need modification to accommodate EV solutions, and at what cost and benefit?**
  A weak link in the chain of innovative options is often legacy utility software and billing systems. Many jurisdictions are looking at what upgrades would be needed to accommodate advanced technology or whether moving to flexible cloud-based solutions would be optimal. Integration of distributed energy resources (DER), including EVs, will be a primary focus for discussions on how distribution utilities could and should evolve.

Why Focus on EVs?

If EVs remain a tiny fraction of the car market, there's little reason to consider changes in regulatory policy to accommodate them. But most signs point to a big increase in EV adoption across the country. Stock market investors are particularly bullish on the prospects for Tesla. Although GM sold 125 times more cars in 2016, Tesla has surpassed its market capitalization and become the most valuable U.S. car company—because investors think Tesla will produce more profits in the long run. Rising market penetration of EVs is propelled by a confluence of potent factors including:

CONSUMER PREFERENCES

EVs are becoming popular because not only are they healthier for the environment and cheaper to operate, but their performance characteristics are superior to Internal Combustion Engine (ICE) vehicles. With immediate torque, quicker acceleration, low maintenance, smoother ride and lower noise levels (not to mention no exhaust fumes), EVs have been the highest ranked cars in recent consumer satisfaction surveys.[8] Charging at home instead of making a trip to the gas station is an unfamiliar consumer convenience—now made even easier by the introduction of plug-free automatic wireless charging—and the potential to power your car from solar panels on the roof of your home is alluring for customers in sunny climes. Early enthusiasm for EVs was powerfully demonstrated when Tesla announced its upcoming Model 3 and 373,000 customers—more than the annual sales of any other American car—put down a deposit, without having seen or driven it and not knowing the final price nor when they might take delivery.

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"Range Anxiety"—the concern that my EV might run out of juice and strand me somewhere I can't plug in, or leave me waiting for many hours while my battery charges—is believed to be a key barrier to broader market acceptance. A 2016 survey conducted for the National Renewable Energy Laboratory (NREL) found that although half of respondents believed EVs are just as good or better than conventional gasoline-powered cars, most people said they would not buy one unless the range on a single charge were at least 300 miles.[9]

However prevalent range anxiety may be, academic research on the issue shows the concern to be largely unfounded for local driving. A 2016 study by MIT and the Santa Fe Institute found that 87% of cars on the road today could complete their daily trips without exceeding the typical 80 mile range of most first-generation EVs.[10] Manufacturers are well aware that range is a barrier for a large segment of car buyers and are quickly adding battery capacity, with high-end Teslas already having crossed the 300-mile threshold and some less expensive cars expected to join them by 2018.[11] But larger capacity batteries are still costly, keeping these EVs out of reach for many potential customers. Cars with more limited range—and lower prices—may succeed in the market when buyers understand that these vehicles will meet their local driving needs. EV road trips are another matter—in a battery-only EV (BEV), they require a network of fast-charging stations. Until fast charge stations are ubiquitous on highways, BEVs will be primarily urban/suburban vehicles.

For many drivers the ideal car may be a plug-in hybrid vehicle (PHEV). PHEVs operate on electricity for a limited range—about 10 to 55 miles, depending on model—before switching to an auxiliary gasoline

8 See Consumer Reports: http://www.consumerreports.org/cars/the-most-satisfying-cars-for-commuting/ Tesla's Model S received the highest performance rating ever given for a car by Consumer Reports. But Tesla's reliability rankings recently have been below average.

9 http://www.afdc.energy.gov/uploads/publication/consumer_views_pev_benchmark.pdf

10 http://www.santafe.edu/news/item/new-model-electric-vehicles-could-meet-driving-needs-across-diverse-us-cities/, http://news.mit.edu/2016/electric-vehicles-make-dent-climate-change-0815

11 http://en.yibada.com/articles/152860/20160819/volkswagen-announce-300-mile-electric-car-paris-motor-show.htm

engine when the battery runs down.[12] They are not zero-emission vehicles (ZEV) but General Motors estimates that 90% of the miles driven in PHEV Chevy Volts are powered by electricity only, although its electric range is just 53 miles. At the current cost of batteries, it's cheaper to have an extra engine in a car than a huge battery pack, and the Volt sells for about $4,000 less than the battery-only Bolt. As battery costs drop, the differential may disappear, but PHEVs have the advantage of eliminating range anxiety, which is why Goldman Sachs forecasts that 80% of EVs on the road a decade from now will be PHEVs, not BEVs.

AUTOMOBILE INDUSTRY INVESTMENT

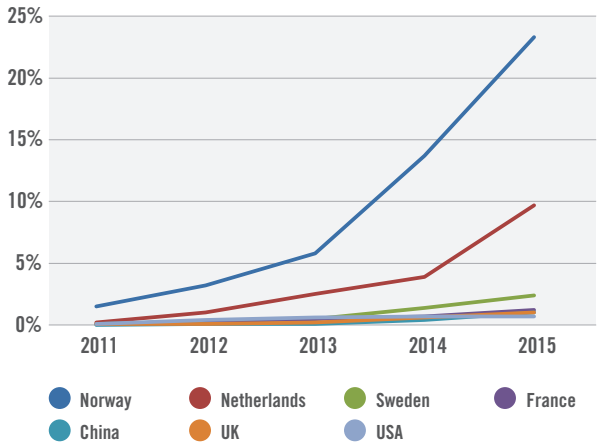
Car companies across the globe are making huge investments in EV development and manufacturing. More than two dozen plug-in vehicles are available in the 2017 U.S. market, including pure electric cars such as the Nissan Leaf, Chevy Bolt and the Tesla models, as well as PHEVs such as the Chevy Volt and the Ford Fusion Energi. Federal loan guarantees and grants supporting EV research and development in the U.S. are subject to potential curtailment, but intensifying global competition will continue to drive EV innovation. Manufacturers recently adding to the stream of new EV model announcements include BMW, Audi, Subaru, Fiat Chrysler, GM, Honda, Hyundai, Jaguar, Kia, Mercedes, Nissan, Renault, Tesla, Toyota, Volkswagen, Volvo, and a raft of Chinese companies led by BYD, the world's largest volume EV manufacturer. Seven countries reported EV market share exceeding 1% in 2015: Norway, the Netherlands, Sweden, Denmark, France, China and the United Kingdom. Norway led by a wide margin, with EVs totaling 23% of new car sales (increasing to 30% in the first half of 2016 and more than 50% in early 2017).[13] In pollution-plagued China, which has every incentive to electrify its fleet, government subsidies may soon bring the cost of an EV below $8,000, and Chinese EV sales have surpassed the U.S.[14]

FEDERAL AND STATE POLICIES

Crucial to initial EV sales have been federal tax credits of up to $7,500 per vehicle, plus a range of state incentives and policies.[15] Colorado has the highest state tax credit of up to $5,160, bringing the available financial incentives to as much as $12,660.[16] The importance of tax credits in stimulating demand was demonstrated in Georgia—which had been home to the second highest number of EVs—where elimination of the $5,000 state credit, and its replacement with a $200 annual fee, resulted in an 80% drop in EV registrations.[17] Federal tax credits are embedded in the tax code and subject to Congressional oversight.[18] Under current law, federal credits begin to phase out when EV sales volume for a manufacturer reaches 200,000 vehicles, so in any case EVs will

12 Some PHEVS, such as the Toyota Prius, plug-in operate on a system that uses both motors simultaneously, with the ICE kicking in for acceleration and higher speeds. Technologies vary, and the latest Volt has two electric motors as well as the gasoline engine.

Figure 1: International EV Market Penetration



Source: International Energy Association's 'Global EV Outlook' for 2016

13 https://www.iea.org/publications/freepublications/publication/Global_EV_Outlook_2016.pdf; and http://www.greencarreports.com/news/1109339_half-of-norways-new-car-sales-are-now-hybrids-or-electrics

14 http://www.autoblog.com/2016/11/06/cheap-electric-vehicles-china-carlos-ghosn/

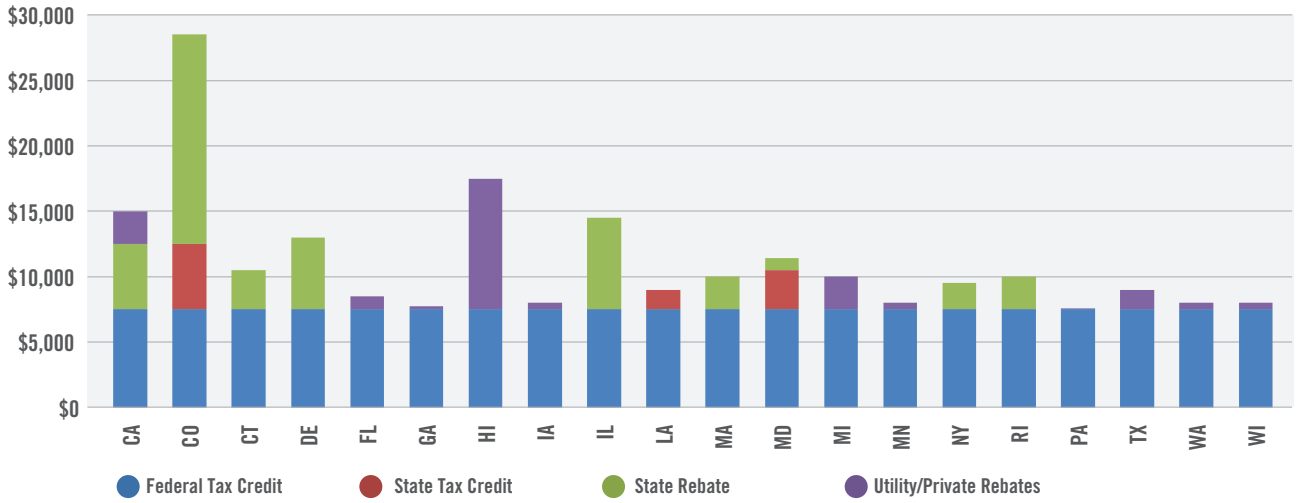
15 The U.S. Department of Energy maintains a database of all state and federal EV-related laws and incentives: http://www.afdc.energy.gov/laws/. Also the National Conference of State Legislatures maintains a state-by-state listing of policies and programs: http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx#il

16 State rebate is assignable to the car dealer, allowing a reduction in cost at point of sale regardless of buyer's tax status. 11 states have state tax credits, tax waivers or rebates.

17 See http://www.myajc.com/news/state-regional-govt-politics/here-why-electric-car-sales-are-plummeting-georgia/INGjfnDMALGkv2iUzwwXIO/

18 The EV federal tax credit varies based on the size of the battery. For a small capacity PHEV like a Prius, the credit is $2500 and reaches $7500 for an all-electric vehicle or longer range PHEV like the Chevrolet Volt. The tax credit is provided to the buyer of the car or to the leasing agent, which allows people who do not owe enough in taxes to take advantage of the credit to derive its benefit.

Figure 2: Combined Maximum State and Federal Tax Credits and Rebates towards EV/EVSE Purchase Price



Source: U.S. Department of Energy's database of State EV Incentives

have to compete without federal subsidies to achieve high market penetration.[19]

Combined Average Fuel Economy (CAFÉ) standards for cars and small trucks are slated to rise about 5% per year, reaching 54.5 mpg in 2025 under current federal policies. Even assuming continued advances in ICE vehicle efficiency, EV market share would have to reach 11% — 900,000 cars and trucks produced for the U.S. market in 2020—to meet the standards, according to a study by the World Energy Council.[20] While CAFE standards are subject to changes in federal policy, EV support at the state level remains high. California— where half of EVs in the U.S. are currently sold—and many other states can be expected to continue their policies favoring zero-emission vehicles (ZEV), regardless of federal policy.

California—where half of EVs in the U.S. are currently sold—and many other states can be expected to continue their policies favoring zero-emission vehicles (ZEV), regardless of federal policy.

Ten states require carmakers to offer ZEVs, and eight states comprising 27% of the U.S. auto market signed an agreement to put 3.3 million ZEVs on their roads by 2025 and to coordinate actions to build a robust EV market.[21] Tesla intends to produce 100,000 Model 3s in its first year, rising to an extremely ambitious 500,000 annual vehicles by the end of 2018. But GM has scaled back first year production of the Chevy Bolt to about 30,000 units. More than two dozen EV models are on the market but many are not yet available outside California and very little marketing has been done by car companies.[22]

ZEVs also include vehicles powered by fuel cells which convert hydrogen into electricity (FCVs) and emit only plain water as a byproduct. Toyota, Honda and Hyundai already have a small number of FCVs on the road in California. With a full tank of compressed hydrogen an FCV is capable of a range equal to a conventional gasoline powered car. However, fuel cell vehicles are a long way from widespread adoption due to high costs, relatively low performance, and lack of readily available fuel. EVs start with a big advantage because their basic fueling infrastruc-

19 For state-by-state incentives details see http://www.plugincars.com/federal-and-local-incentives-plug-hybrids-and-electric-cars.html
20 http://www.worldenergy.org/news-and-media/news/growth-in-electric-vehicles-sales-central-to-closing-emissions-gap/
21 https://www.oregon.gov/ODOT/HWY/OIPP/docs/Multi-State_ZEV_ActionPlan.pdf
22 http://www.ucsusa.org/clean-vehicles/electric-vehicles/ev-availability#.WFrIuvkrKUm

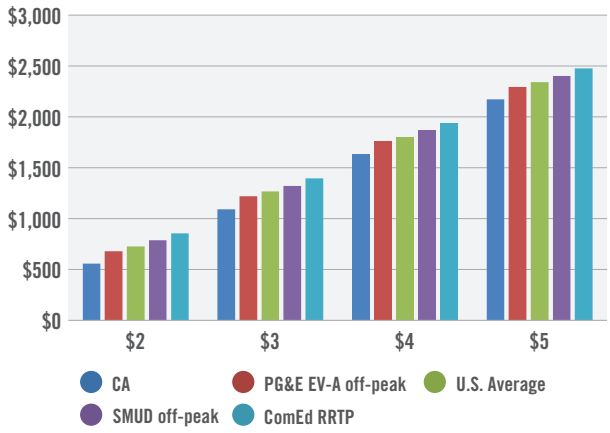
EVs cost less to operate than ICE vehicles, a comparative advantage that will grow as battery and motor technology continues to improve, and EV charging is optimized to reduce electricity outlays.

ture—the electricity grid—already exists.

VEHICLE ECONOMICS

While EVs are becoming a familiar sight on American roads, there remain significant barriers to mass market acceptance, most prominent of which is today's relatively high purchase price—a gap that is beginning to shrink. EVs cost less to operate than ICE vehicles, a comparative advantage that will grow as battery and motor technology continue to improve, and EV charging is optimized to reduce electricity outlays. Today's EV fuel costs are already substantially lower than comparable ICE vehicles. For example, the 2017 Chevy Bolt has a 60 kWh battery with an EPA-estimated range of 238 miles.[23] At the average residential electric rate of 12.63 cents/kWh, it will cost $7.38 to "fill the tank," compared to $23.80 for gasoline to drive a 25-mpg ICE car the same distance (at $2.50/gallon). Using the national average of 11,244 miles driven per year, that equates to annual fuel costs of $1,125 for the gasoline-powered car and $350 for the EV—a difference of $775, which rises with increased driving. At 18,000 miles, the yearly EV fuel cost advantage reaches $1,450, enough to finance about $8,000 of the additional cost to purchase the Bolt, which at $30,000 after the federal tax credit remains a relatively expensive car for its size. Fuel savings can be higher in locations with off-peak electric rate discounts, but are offset by $200-300 in higher annual costs for EV insurance. For some drivers, EVs are already an economical choice.

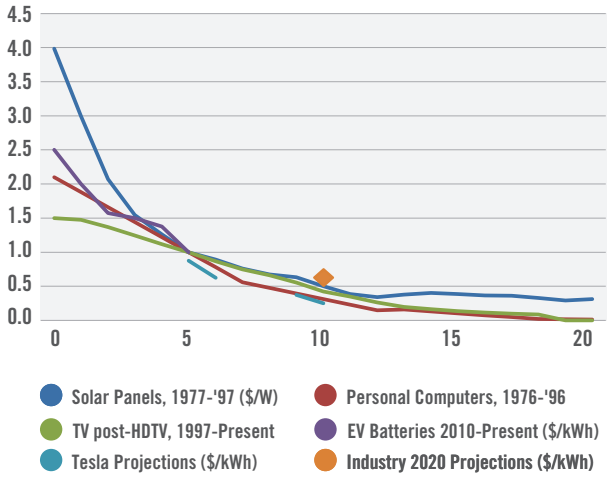
Figure 3: Annual Fuel Savings of Chevy Bolt vs. 25 MPG ICEV at Varying Gasoline Prices



Source: CUB calculations, based on rates available on utility websites

23 A reported Bolt road test found the actual range to be higher than 238 miles, however under normal driving conditions and using heat or AC, the anticipated range would be shorter. http://gmauthority.com/blog/2016/10/2017-chevrolet-bolt-ev-goes-240-miles-with-range-to-spare/

Figure 4: Unit Price Reductions after Major Product Introduction Indexed to Year 5



Sources:
PV Panels: Bloomberg New Energy Finance
PCs: 'Price and Quality of Desktop and Mobile Personal Computers', American Economic Review
TVs: Consumer Price Index, BLS
Batteries: 'Here's How Electric Cars Will Cause the Next Oil Crisis', BNEF; Cars 2025, Vol. 2, Goldman Sachs Equity Research

EVs also have non-fuel cost advantages over conventional cars. With few moving parts in the motor, simple transmissions, and no oil changes or engine tune-ups, EVs are anticipated to have far lower maintenance costs than ICE vehicles. And electric motors can be expected to last far longer than combustion engines.[24] Chevy's recommended maintenance schedule for the Bolt includes only tire rotation and new brake fluid every five years.[25]

In some locations, the life cycle outlays to own and operate an EV is dropping close to the average cost of similar ICE vehicles, but the differential must disappear for EVs to have maximum appeal. This now appears feasible. Battery costs—which can make up as much as half the cost of an EV—have fallen 50% in recent years and are anticipated to continue their decline. With manufacturing capacity expected to triple, Goldman Sachs forecasts another 62% drop in battery costs by around 2020, as well as technology improvements to cut their weight in half.[26] As EV manufacturing costs drop with higher production, battery technology continues to improve, and innovative rate designs and smart technologies bring down charging expenditures, the cost of owning and operating an EV is projected to become lower than a comparable ICE vehicle. A McKinsey report for Bloomberg New Energy Finance concludes that this inflection point will be reached by the mid-2020s.[27]

24 The useful lifetime of EV batteries is not yet known. While expensive to replace, they are warrantied for 80,000 to 100,000 miles by most manufacturers. EV batteries also have "second life" value for potential home use and grid support when no longer suitable for powering vehicles; however, these applications are not addressed in this paper.

25 Close to zero maintenance makes car dealers reluctant to push EV sales because servicing vehicles is a core part of their business model. Car dealers' lack of enthusiasm may be one reason why most maintain little EV inventory and manufacturers are not widely advertising EV models: https://chargedevs.com/newswire/data-shows-what-we-all-knew-the-auto-industry-isnt-advertising-its-evs/

26 http://pg.jrj.com.cn/acc/Res/CN_RES/INVEST/2015/8/5/2c24a0d8-eda6-4e79-93fb-4c49139f6614.pdf

27 https://www.bbhub.io/bnef/sites/4/2016/10/BNEF_McKinsey_The-Future-of-Mobility_11-10-16.pdf

The EV Market Is Rapidly Evolving

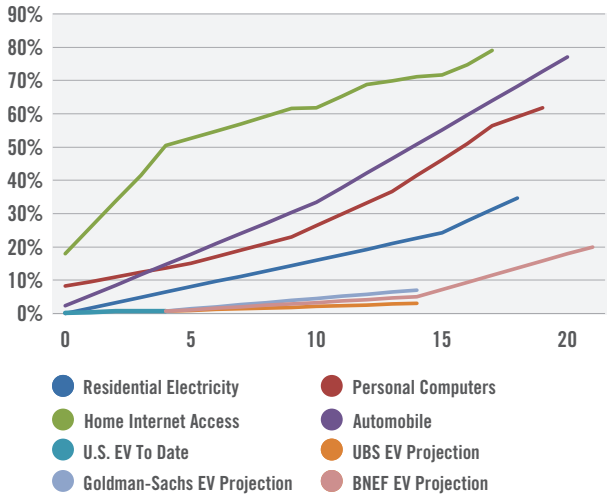
Early adopters in the residential market are beginning to acquire EVs, but broader acceptance will be accelerated by commercial fleets, shared vehicle services, and taxis and livery services, which can take advantage of the scale economies of centrally housed and charged vehicles. As EV range increases and charging time shrinks, drivers for mobility providers like Uber and Lyft may find it economical to use EVs because fuel and other EV operating savings increase with miles driven.

Heavy-duty trucks and buses are also prime candidates for electrification. Like other fleet applications, they can benefit from economies of scale through centralized housing and charging. Their enormous energy consumption and miles driven provide unique opportunities for fuel cost reductions, and their conventional diesel engines are heavy polluters. Giant trucks need giant batteries and a network of fast charging stations on interstate highways, but major truck manufacturers including Mack, Daimler, and Chinese company BYD are investing in electric truck development. The "California Sustainable Freight Action Plan" calls for 100,000 low or zero emission trucks, trains, and other heavy duty vehicles to be in service by 2030.[28]

Local bus transit electrification is feasible now and being piloted around the world. Many manufacturers are developing E-buses, with the most advanced model to date introduced by Proterra in 2016. It claims a range of 200-350 miles on a charge (depending on driving, load, and other conditions), enough for any local route. And it can be fast charged with high voltage in as little as 10 minutes, though most charging would be expected to take place over several overnight hours. They presently cost about twice as much as a typical diesel bus, but battery-electric buses have the same quiet, high performance and low maintenance characteristics of electric cars, and their higher costs can be offset more quickly through greater fuel savings. With more than 70,000 intra-city buses on the road and a replacement rate of about 8% per year, the introduction of cost-effective battery-electric bus transit could rapidly transform the industry. Electric buses can also be used to develop and demonstrate smart (and fast) charging systems and prepare for mass aggregation of smaller EV loads.

To be sure, there are factors that may inhibit EV growth. In addition to the uncertainty of national policies to reduce carbon emissions, these include persistently low gasoline prices, the relatively high cost to purchase EVs (which might not decline as quickly as forecast), the lack of public charging opportunities in many areas, and concerns about degraded battery performance over time. These issues may slow the pace of EV market penetration but, as technology and markets evolve, they are unlikely to stop it.

Figure 5: Market Penetration of Major Technologies over Time



Sources:
Electrification: Historical Statistics of the United States, Colonial Times to 1970, US Census Bureau
PCs, Internet: Current Population Study Appendix Table A: Computer and Internet Use, 1984-2009
Automobiles: State Motor Vehicle Registrations, 1900-1995, US DOT
EVs: Global EV Outlook 2016, IEA; The Low Carbon Economy, Goldman Sachs Equity Research, 2015; 'Electric Vehicles to be 35% of Global New Car Sales by 2040', BNEF, 2016

28 http://www.dot.ca.gov/casustainablefreight/

In this early stage it is not known whether EVs have potential for explosive growth similar to personal computers in 1984, the Internet in 1995, cellphones in 2000 or HDTV in 2005. All of these quickly became ubiquitous, supplanting earlier technologies seemingly overnight. EV market penetration may not follow those trajectories, not just because of their higher initial cost but due to a unique barrier to ubiquity: half of American households do not have a place to park a car with an electrical outlet nearby.[29] And those who do, and want a faster Level 2 charge, will have to equip their parking space with higher voltage electrical equipment (at a cost of about $800-$1,000), making an EV purchase a longer term commitment. EVs are similar in this way to rooftop solar panels, which currently are uneconomic for a significant segment of consumers and have an extended payback period. Like distributed photovoltaics, EVs have potential to produce system benefits without dominating the market, and as a result will prompt changes in utility systems and public policy. But already, EVs are sparking improvements in another key area: battery-charging technology.

Charging Technology Continues to Advance

A typical EV today uses about 30 kWh to travel 100 miles. To get that amount of electricity out of a 120 volt standard wall socket capable of handling 16 amps of current (a high Level 1 charge rate) takes about 15 hours.[30] A Level 1 charge can deliver a maximum of about six miles of travel per hour of charge and many chargers deliver about half that amount. Quicker charges require installation of "Electric Vehicle Supply Equipment" (EVSE), to connect to higher voltage and amperage. Level 2 EVSE uses a 240 V circuit (like an electric oven or clothes drier) and cuts charging time by as much as 75%, depending on the capacity of the circuit and charger. Tesla advertises that its level 2 connector adds 58 miles of range per hour when the car is equipped with optional dual chargers. GM says that the Chevy Bolt will charge from fully depleted to its 238 mile range in about 9 hours using its optional level 2 charger, a delivery of about 26 miles of travel per charging hour.[31] [Note: The charger itself is actually in the car, not in the EVSE. The EVSE just delivers electricity to the charger, which converts AC to DC and sends current to the battery.] The next step up in charging speed is the DC Fast Charger (DCFC), also known as Level 3 or DC Quick Charger (DCQC). Converting alternating current into direct current at 440-480 volts or above, DC Fast Chargers bypass the onboard charger in the vehicle and feed current directly into the battery through a separate connector (which few cars today have as standard equipment and many do not offer as an option). Operating at 30-150 kW, DCFC can deliver up to 250 miles of

29 As reported in a survey by the National Renewable Energy Laboratory: http://www.afdc.energy.gov/uploads/publication/consumer_views_pev_benchmark.pdf

30 The last 20% of a charge takes longer, as the charging rate slows as the battery gets closer to full charge.

31 An option anticipated to cost about $750

COMING SOON TO URBAN AMERICA: THE SELF-DRIVING CAR

Autonomous vehicles (AVs)—aka "self-driving cars"—are not yet embryonic as a commercial force, but remaining technological obstacles may soon be overcome, as a host of leading tech companies including Apple, Intel, and Google, as well as car manufacturers are racing to solve them. The social and political barriers to AVs are another matter, and it will take time before people are comfortable with the idea of driverless cars on the road. But Tesla has announced that all its cars will soon be AV-capable, Uber has begun operating an AV pilot in Pittsburgh, and General Motors is road testing AVs in its home state of Michigan. Eventually the 100-year-old paradigm of car ownership may be upended because when a car doesn't need the driver, the driver no longer needs a car. This entails a social shift that may seem far-fetched in a culture steeped in car ownership, however "Mobility as a Service" (MaaS) may come to dominate urban transportation markets—and because of cost advantages and fleet scale economies, autonomous vehicles are almost certain to be electric.

range in an hour, though existing stations are not yet capable of that speed and most cars today can't accept such a powerful charge. The Bolt's owner's manual says it can add 90 miles of range in 30 minutes on DCFC, about the same as a Nissan Leaf.

Tesla has installed more than 5,300 of what it calls DCFC "superchargers" at an expanding proprietary network of about 800 stations (about half of which are in the U.S.). The company claims eventually it will be able to deliver a full charge in five to ten minutes (though its current vehicles could not accommodate it).

Improvement in battery technology is the focus of an unending stream of announcements. For example, Samsung says it has developed a battery capable of adding 300 miles of range in 20 minutes—but it will not be in production until 2021.[32] And the co-inventor of the lithium-ion battery that powers most EVs has come up with a solid state battery that holds three times the energy, lasts far longer and can be charged much more quickly. It may be many years from commercialization but is being scaled up for further testing and development.[33]

Volkswagen's Porsche division has demonstrated a fast charger operating on 800 volts, and the technology to fill a battery with electricity almost as quickly as a gas pump can fill the tank is technologically feasible.[34] Such high voltage/high amperage DCFC will certainly be expensive to maintain, as it requires delivery cables to be cooled. Oak Ridge National Laboratory is testing wireless fast-charge equipment that could use electrified roadways and eliminate the need for highway charge stations altogether.[35] But it is not known if or when a path will be found from technical feasibility to mass deployment of ultra-fast charging, and many potential EV drivers simply await greater access to convenient public charging stations.

32 http://electronics360.globalspec.com/article/7983/samsung-develops-electric-car-battery-allowing-a-300-mile-range-on-a-20-minute-charge
33 https://www.sciencedaily.com/releases/2017/02/170228131144.htm
34 https://chargedevs.com/newswire/porsches-new-fast-charger-could-work-with-other-brands-including-tesla/
35 See: https://www.ornl.gov/news/ornl-surges-forward-20-kilowatt-wireless-charging-vehicles and http://thesai.org/Downloads/Volume6No6/Paper_34-Dynamic_wireless_charging_of_electric_vehicles.pdf

ELECTRICITY 101

Electricity is the lifeblood of modern life, but even physicists don't know quite how to describe it. It has elements of waves, charged particles and magnetic fields, but electricity remains a mysterious force. We do know that when an electric charge moves through a wire it can be harnessed to create energy that can be used to do work, like running a motor or lighting a bulb. Or it can be stored in a battery for later use.

The power of electricity is quantified through the simplified equation of Volts x Amps = Watts. One way to think about these terms is to imagine electricity as if it were water flowing through a hose.

Voltage is equivalent to the size of the hose. Wattage is the pressure in the hose. Amperage is the amount flowing through it. Finally, Watt-hours measure the volume that pours out when you open the faucet.*

For example, at 120 Volts, it takes less than 1 Amp of current (.8333) to power a 100 Watt lightbulb, which in ten hours will consume 1,000 watt-hours of electricity (or one kilowatt-hour (kWh)).

*Please note that this metaphor is not perfectly accurate but close enough for a general understanding.

Away-from-Home Charging Opportunities Are Expanding

The average U.S. daily round trip commute of 30 miles could be fully fueled by connection to a standard 120 V wall socket during the work day, and many employers are beginning to provide on-site charging as a benefit to employees. Some jurisdictions are deciding that social benefits of EVs warrant public support of employer-provided charging stations, and theorize that people will be more likely to acquire EVs when they see their coworkers doing so—and getting preferred parking and charging as perks of employment.

Level 1 and Level 2 charge stations are becoming commonplace at parking garages, retail stores,

motels, shopping malls and other public locations. These privately financed public charge stations are often provided at little or no cost to the user, a promotional model that may have limited application and does not accommodate the fast charging needed for long trips.

Until 2017, Tesla provided Level 3 fast charging to its customers for free on its expanding DCFC network along several interstate highway routes and in high traffic areas. Under a revamped policy, owners of current Tesla models will pay for charging after the first 400 kWh (about 1000 miles) annually. The impending Model 3 may not be eligible for any free charging. Tesla's charging structure and fees will vary from state to state, not just due to electricity price variation, but because some states prohibit volumetric fees for non-utility charge providers and allow fees to be assessed only by length of charging session. Meanwhile, as part of a strategy to make its technology the global standard for fast chargers, Tesla has said it will open up its proprietary system to other manufacturers if fair compensation can be worked out, though none have yet taken up the offer. Nissan is also building out a fast charging network and—for now—offering its use for free to Leaf buyers. But Nissan cars cannot plug into the Tesla network, and vice-versa. This lack of interoperability is a challenge to EV expansion.

Interoperability Is Essential to a Seamless Network

Today there are three incompatible fast-charge plug standards in use by EV manufacturers. Each claims to have technological and customer advantages over the others. While this poses no problem for an EV owner plugging into a home charger, on the road a common technology is essential for consumers to be able to get a quick-charge when and where they need it. Otherwise each station would need to be equipped with costly multiple connectors and equipment. One standard may come to dominate the market eventually, as occurred with other new technologies such as video cassettes more than 30 years ago. Such a sorting out process, however, could take many years and be very costly, posing an obstacle to EV growth if not addressed through collaboration among vehicle manufacturers.

A greater barrier lies in the multiple networks for customer transactions, which do not provide a simple and seamless experience for the customer. Making it easy for a driver to charge at any station anywhere in the country is perhaps the most daunting challenge facing the EV charging industry. Interoperability from the customer's point of view—where a driver can plug into any charger and get service from any provider, much like they can use their cell phone on any network—should be a key objective of EV-supportive public policy. State utility commissions as well as regional and national regulatory and advocacy organizations, such as the National Association of Regulatory Utility Commissioners (NARUC) and the National Association of State Consumer Advocates (NASUCA), can play roles in pushing the industry toward interoperability.

Interoperability from the customer's point of view—where a driver can plug into any charger and get service from any provider, much like they can use their cell phone on any network—should be an objective of EV-supportive public policy.

System Benefits Require Smarts

While it is not true that EVs pose an immediate threat to reliability—most Level 1 chargers draw less current than a hair dryer, or about 10-12 amps—high EV penetrations could pose problems if many people charge simultaneously, especially at high Level 2 current flows, which could reach 60 amps or more. Congestion could occur on a weekday evening in an EV-intensive area if people arrive home from work and plug in to charge simultaneously. If it happens to be a hot day when air-conditioners are also being turned up at the same time, the distribution circuit—and perhaps the local substation—could become overloaded. Meanwhile, at off-peak times and periods of high local solar and wind generation output, the electric system has extensive underutilized distribution and generation capacity that could be used to charge EVs at little incremental cost. The keys to both avoiding the potential problems posed by EV loads and to maximizing their system benefits lie in the application of smart rate design and smart charging, as we discuss in the next section.

The keys to both avoiding the potential problems posed by EV loads and to maximizing their system benefits lie in the application of smart rate design and smart charging.

Smart Rate Design Is Fundamental to Sound Policy

The structure of electricity rates has a big effect on how much of it is consumed and when consumption occurs. Raising the cost of a kWh will cause people to use less of it. Raising prices at certain times and lowering them at other times will move some usage from the higher priced to the lower priced periods. The amount by which consumers will use less when the price goes up—the elasticity of demand—is relatively low for an essential commodity like electricity, which has some usage that can't be controlled. We can't turn the refrigerator off, no matter the price. But some of us would do the laundry on nights or weekends if the price were discounted, and would turn up the temperature on the AC unit during high priced periods, especially if it were done automatically. If the overnight electricity price were cheap enough we might even take advantage of thermal storage technology such as an air-conditioning unit that makes ice at night to store cold for use during the day (or electric radiators that store heat). And we would certainly want to charge an EV when electricity rates were cheapest, as long as the car is ready to go when we are.

There are at least as many rate designs as there are utilities, but all are intended to provide opportunity for recovery of an amount of annual revenue determined by regulators to be sufficient for long-term reliable service (including an adequate return on investment), while fairly spreading the costs among customers.[36] In rate design theory, fairness is closely aligned with the aim of "assigning costs to cost causers," a principle subject to the overarching public interest standard that utility rates must be "just and reasonable."[37] Ratemaking has always been subject to an array of social goals, including economic development, universal service, support for renewables, load building, load shedding, and load shaping. These sometimes conflicting objectives make rate design proceedings adversarial, as the allocation of the revenue requirement appears at the outset to be a zero-sum game: when somebody's bills go down, somebody else's must go up. While this may be true in the short term, over time rate

36 Many jurisdictions allow "performance-based" or "alternative" rate plans that may boost or shrink utility earnings based on performance relative to certain standards, but these generally do not factor into cost allocation and rate design and are not discussed here.

37 Complicating things a bit further is the fact that in some jurisdictions electricity rates are decoupled—rising slightly to make up for shrinking sales volumes due to utility energy efficiency efforts or adjusting to account for weather and other variables. Some states use "formula rate" adjustments to assure achievement of an immediate return on new technology investment and/or to pass through operational savings to customers. Such annual changes are based on the view that "regulatory lag" between rate cases increases risk and diminishes utility incentives to make investments. Others point out that regulatory lag tends to discipline utility costs.

design can have a big effect on overall utility cost levels as well as economic, social and environmental impacts. No matter how and where you set them, rates send signals as to how electricity is to be valued, which influence the behavior of all actors in the chain of supply and demand, including electricity users, producers, distributors and markets.

An optimal rate design can be win-win-win-win: making EVs more economical, making the system more efficient, improving reliability, curtailing emissions and reducing average unit costs of electricity—while better aligning the interests of the utility and its customers.

An optimal rate design can be win-win-win-win: making EVs more economical, making the system more efficient, improving reliability, curtailing emissions and reducing average unit costs of electricity—while better aligning the interests of the utility and its customers. But the right rate design can be quite different from place to place because it must take into account a long list of variables including market structure, load characteristics, meter technology, generation mix, economic drivers, distributed resources, climate factors and social goals. For example, a largely rural winter-peaking state like Maine, with relatively high industrial load and electricity sourced primarily from hydro, gas and wind may design rates quite differently from a state like Arizona, with a small industrial sector, high air-conditioning use, heated swimming pools, and substantial solar energy development.

Rate designs usually include a combination of monthly fixed fees and volumetric charges. Commercial and industrial rates often have a three-part rate with a demand charge based on maximum usage. Rates of a vertically integrated utility—one that owns and operates power plants as well as the distribution system—are generally "bundled" to recover all costs of service in one set of charges for delivery and supply (often with an adjustment to account for the fluctuating costs of fuel and purchased power). In about half of states, restructuring of the industry is reflected in "unbundled" rates, which separate charges for the monopoly utility system from competitive power procurement. A restructured state like Illinois, with smart meters in place, has a different set of rate options from its vertically integrated neighbors in Indiana and Wisconsin. And each state has its own set of laws and regulatory rules.

Rate design is a way to allocate a known or projected amount of costs among customers, not a determinant of the revenue or earnings of a utility. Elements of typical traditional rate designs and their implications for EV charging include:

- **Fixed Monthly Basic Customer Charge:** Fixed fees are generally set to recover the costs associated with a customer's service that do not vary with usage, such as the connection, the meter, billing and other customer-based costs. These costs are not different if there is an EV in the garage.
- **Fixed Monthly Distribution Charge:** Because the costs of electric system infrastructure—the poles, wires, transformers and other equipment needed to provide service—do not vary significantly with usage, utilities often would prefer to recover most of these costs through fixed monthly charges rather than volumetric usage rates. Higher monthly fixed charges mean lower per-kWh rates, thus benefiting relatively high volume customers such as EV owners but raising the bills of low volume customers. High fixed charges combined with low volumetric charges also reduces the customer savings from energy efficiency measures and leaves a smaller portion of costs available for time-based rate treatment. For these reasons, consumer and environmental advocates typically advocate for lower fixed charges.
- **Volumetric Distribution Charge:** The portion of delivery services not recovered through fixed charges is collected in each kWh consumed. Most of today's residential rate designs assign an average amount of cost to each unit of energy, without variation by usage volume, time of use, or season. This flat rate provides no opportunity to influence EV charging patterns.
- **Inclining Block Charges (aka Inverted Block Rates):** In an effort to incent energy conservation, some rate designs increase the costs per unit of

energy as a customer's monthly volume increases.[38] This increases the costs of higher volume customers and provides a big disincentive to EV ownership because the cost of charging is inflated regardless of when it occurs.

Optimizing EV charging patterns requires sending price signals to customers indicating when—from the point of view of the electricity system—are the best times to charge. Measuring when usage occurs in addition to how many kWh of electricity are used in a month entails meters that record and retain usage data in each hour or smart meters that communicate consumption levels and other data to the utility in near-real time. Time-based rate options include:

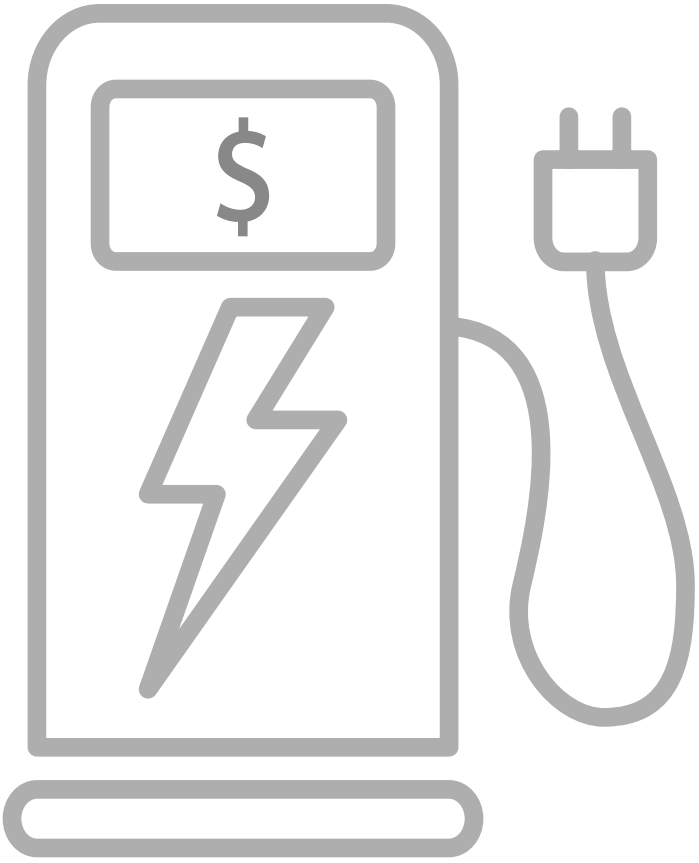
- **Time of Use (TOU) rates:** By charging higher prices in peak periods and lower prices off-peak, rates influence customer usage patterns. The efficacy of a TOU rate structure depends on the pattern and magnitude of its price variation. A market-based rate schedule that approximates differentials between average wholesale prices at different times is not as effective at influencing usage patterns as rates with larger and more uniform price variations. So TOU rates can be calculated using a predetermined Peak to Off-Peak Price (POPP) ratio. For example, off-peak, shoulder peak, and peak rates could be set at easily understood ratios such as 1-2-4 or 1-3-6.

- **Renewable Output Rates:** Variable output of renewable generation can have a dramatic effect on the resource mix, and price signals can optimize use of this zero-incremental cost energy. For example, electric rates could be reduced during peak periods of wind or solar output, and/or EV charging could be managed to coincide with it. However, the difference in impact on local wires systems between distributed rooftop solar and central station solar generators complicates these considerations and requires smart charging technology.

- **Real-Time Pricing (RTP):** In restructured states, where rates for commodity energy are unbundled from delivery services, RTP programs can tie retail energy rates directly to wholesale market price, changing each hour. To date, the only state that offers optional residential RTP is Illinois. While it exposes customers to potential price spikes, experience over eight years in Illinois has shown so far that most customers would see lower bills under RTP.[39] Because off-peak competitive energy prices often are very low—occasionally dropping to zero or below in some wholesale markets—RTP can substantially reduce EV charging costs, particularly when combined with TOU distribution rates and price-responsive smart charging equipment.

- **Demand Based Rates (DBR):** Demand Based Rates collect a portion of delivery costs according to how much electricity is used by a customer at one time, rather than by monthly energy volume or in fixed monthly fees. Generally, DBR rewards customers with flatter load shapes at the expense of customers with steep peaks and valleys of usage. Demand rates are a common component of

38 Declining block rates, under which prices decrease with higher usage, are still employed in some jurisdictions to support large industrial facilities but have largely disappeared from smaller customer rate design.



39 See: https://hourlypricing.comed.com/ and https://www.powersmartpricing.org/

commercial and industrial rates and more than 15 utilities offer some form of optional DBR to residential customers. Their effect on EV costs depends on how the demand charge is calculated. For example, if it uses a simple "ratchet" based on maximum usage in any hour of the month, an EV owner could see high demand charges, particularly if they charged the car while using other appliances and lighting. However, if the DBR was calculated only on demand during peak periods, such as daytime afternoons, a more powerful signal would be sent to charge EVs at night or on weekends, as off-peak charging would incur no demand charges.

High demand charges present a big challenge to cost recovery for the "peaky" load shapes of public fast-charge stations, which may require special rate designs to be commercially viable.

One rate structure is usually applied to all usage on a customer's meter. However, a different set of rates can be used for EV charging through a separate meter or a sensor attached to the EVSE. Disaggregation software with the capability of dividing a household's overall electricity usage into its end use components can also allow vehicle charging costs to be calculated under distinct rates. Separately calculating EV charging costs can be a boon to adoption by customers who fear having all their household usage priced under time of use rates. But it raises the question of whether such a carve-out is appropriate. Under a pilot program of utility PEPCO in Maryland, EV owners could choose to have their EV usage metered and charged separately or to have whole-house TOU rates. Most chose separate EV rates, and in both cases TOU rates had a significant effect on charging behavior.[40]

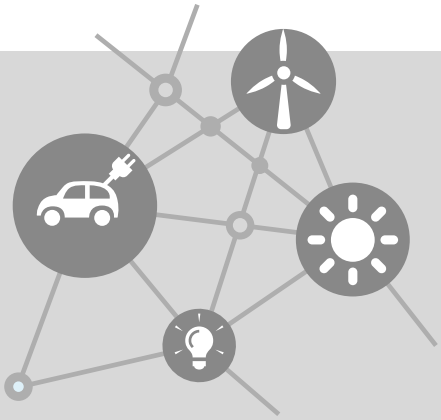
EVs offer the perfect type of load shape for dynamic pricing, so that kind of rate design should be utilized. Time-based rate options are clearly effective at motivating EV owners to charge their vehicles when they will not burden the utility system. But to further capture the system benefits of EVs' load flexibility requires an additional technology: smart charging.

Smart Charging Turns Aggregated EV Loads into Valuable DER

Unmanaged charging whenever the owner plugs in the vehicle can be called "dumb charging." But at

40 http://www.utilitydive.com/news/how-pepco-is-finding-ways-to-shift-demand-through-maryland-ev-pilot-program/434156/

EVs, DER AND THE RISE OF THE "PROSUMER"



The rise of electrified transportation coincides with the emergence of distributed energy resources (DER) as key elements of tomorrow's energy mix. Wind and solar are becoming leading supply technologies while demand response and energy storage are beginning to help balance loads and improve efficiency. Smart grid deployment is creating a more resilient and decentralized electricity system, allowing a growing number of electricity customers of all sizes to become "prosumers"—not just consumers of electricity but compensated participants in DER markets. Some states are considering fundamental and unprecedented changes to the utility concept itself, moving from the traditional hub-and-spoke model with the utility at the center—acquiring, selling, and distributing power and energy to its customers—to a network platform over which the utility facilitates energy resource transactions. EVs could become pivotal distributed energy resources under this evolving utility paradigm, with managed charging to optimize system load shape and the potential to discharge stored energy back to the grid in times of peak demand.* Integrating all these innovations and trends to maximize system efficiency and reliability will be a key mission of the utility of the future.

*Note: Such "V2G" (Vehicle to Grid) transactions are not imminent—constrained by both the deleterious effect on batteries of additional cycling and the lack of a viable V2G business model—however, the systems to make it work are being developed.

relatively low concentrations of EVs using standard 120 V wall sockets for Level 1 charging, it poses few problems, as the draw of an EV on a slow charge is no more than a toaster or hair dryer. However, high neighborhood concentrations of Level 2 chargers could change system dynamics and increase capacity needs, particularly if many vehicles are charging simultaneously.

A smart charger communicates with the utility or central controller and adjusts charging based on real-time circumstances, creating a flexible and manageable distributed resource that can improve the system load shape while saving money for the customer. Controlling variables could include overall demand on the system, local grid conditions, real-time output of renewable generation, marginal plant carbon emissions, and variable electricity prices under the customer's rate plan. Smart chargers could allow aggregated charging demand to be used as regulation service to address momentary fluctuations in voltage and power flows, making chargers into grid-support resources for system operators. By filling in the valleys of system load shape, smart charging can allow high EV penetration while minimizing the need for expanded generation or distribution capacity. Smart charging allows curtailment during critical peak periods, protecting reliable service. As in other direct load control programs, the value of smart charging can be monetized for participants as a demand response resource. And car owners can retain the ability to get a charge whenever they need it or to specify the time by which they need to have a full charge.

A smart charger communicates with the utility or central controller and adjusts charging based on real-time circumstances, creating a flexible and manageable distributed resource that can improve the system load shape while saving money for the customer.

Smart charging aggregation programs are beginning to be designed and piloted. How they will be organized and operated at scale is not yet known; there are many potential service providers and business models. As distribution system operators responsible for maintaining reliable service, utilities may be well-equipped for dispatch of EV charging as a demand response resource under direct load control and as curtailment service bid into wholesale markets. However, aggregation and other smart charging services eventually could be provided by other entities with established customer relationships. These could include retail energy providers, independent charging providers, sellers of charging equipment, curtailment service providers, and vehicle manufacturers. BMW has a smart charging pilot underway in northern California in which its EV owners are paid for responding to charging signals provided by the utility during peak periods. In some cases, BMW supplies "second use" batteries for on-site backup charging service where they can be used instead of real-time generation when advantageous.[41] The company reports 94% success in meeting its load shifting goals.

Incentives for EV owners and charge providers to acquire and use smart chargers may be the most effective application of public investments to support healthy EV growth. Combined with time-based electric rates designed to save customers money when they optimize charging patterns, smart charging is crucial to capturing the potential system benefits of electric vehicles. Another crucial element is utility involvement, and regulators have myriad options in developing regulatory policy.

41 https://chargedevs.com/newswire/next-phase-of-bmws-chargeforward-program-pays-drivers-to-use-smart-charging/

Regulators Have Many Options for EV Support

EV adoption is supported by a range of state policies including purchase rebates, charging infrastructure investment, tax abatement, electric rate options, parking preferences and road privileges. The options for regulatory policies to address EV-related issues range from doing nothing beyond responding to reliability-related issues if and when they arise, to stimulating EV market growth by publicly funding construction of a charge station network—with a long list of choices in between. Options along the continuum of utility involvement in EV support include:

CONSUMER EDUCATION

Utility provides customers with material to educate and inform them about EV options such as:

- General information on EVs, including:
  - ~ Charging options and other considerations for prospective buyers
  - ~ Available rate options and demand response programs
  - ~ Shadow billing to compare projected costs of charging under different rate plans
- Public charge station location database
- Nearest immediately available public charge location
- Available incentives

A media plan to educate consumers about EVs could involve pushing information to customers using print, broadcast, apps and online media, perhaps including outreach through community organizations and institutions. The extent of such efforts would depend on whether the public goal is to accelerate EV growth or just to accommodate it.

CUSTOMER SUPPORT

Utility provides assistance to facilitate EV ownership such as:

- Expedited permitting and interconnection for home and workplace EVSE coordination with local authorities who regulate connections, license charge station installers or issue permits
- Aggregation of EV demand and implementation of smart charging programs
- Rebates for smart chargers at homes and workplaces

Costs/benefit analysis could be used to set rebate amounts and other program budgets.

CHARGE STATION SUPPORT

Utility offers assistance, services and incentives to charge station developers/owners/operators:

- Identification of optimal charge station locations based on existing electricity infrastructure or other characteristics
- Incentives for locating charge stations in where they will maximize system benefits
- Identification of optimal vehicle fleet siting locations based on existing infrastructure and other considerations such as local distributed generation output
- Incentives for optimized EV fleet siting in light of system benefits.

INFRASTRUCTURE FOR NON-UTILITY CHARGE STATIONS

Joint participation in equipping charge station sites:

- Utility provides “make ready” infrastructure such as high voltage service drop and trenching:
  - ~ upon application of a site owner, or
  - ~ at locations selected in a planning process
- Independent charge vendors install and operate charge stations under contract with site owners
- Competitive bidding process could use reverse auctions for lowest required subsidy to install stations at commission-approved sites
- Utility provides assistance but has no stake or responsibility for outcomes
- Subsidies could vary with:
  - ~ preferred locations
  - ~ charge speeds
  - ~ number of connections
  - ~ other factors such as pricing options

- Subsidies for charge stations might be contingent on:
  - ~ open access and interoperability
  - ~ supply at EV-charge tariffed prices
  - ~ restrictions on retail pricing, terms and conditions
- Could include deployment of energy storage coupled with time-variant rates and smart charging

SUBSIDIES FOR NON-UTILITY CHARGE STATION DEVELOPMENT

Utility functions as conduit for charge station support with regulatory commission-approved customer funding through ratebase or expenditures.

- Rebates to employers who install interoperable workplace charging sites
  - ~ Rebates could vary depending on factors such as charge levels deployed and utilization frequency
  - ~ Contingent on participation in direct load control and/or TOU rates, smart charging programs
- Rebates to individuals for home or business EVSE, contingent on certain requirements, such as:
  - ~ Smart chargers
  - ~ Professional installation
  - ~ Participation in charge management programs
- Rebates to landlords and/or tenants for installation of EVSE in multi-unit buildings (with similar requirements)
- Incentives to serve underserved/disadvantaged communities, including:
  - ~ Subsidized EV car-sharing service or other mechanisms to introduce EVs in low-income neighborhoods where conditions are not conducive to EV acquisition
  - ~ Targeted subsidies for charge stations
  - ~ Added rebates, other incentives for individuals
  - ~ Special incentives for school buses, public transit

UTILITY CHARGE STATION DEVELOPMENT

Utility builds or funds a charge station network in its service territory.

- Regulatory commission approves a deployment plan after docketed proceeding considering:
  - ~ public need and social goals
  - ~ projected costs/benefits
  - ~ optimal locations
  - ~ competitive effects
- Charge network optimized for system benefits:
  - ~ Employ smart charging, energy storage, other technology
  - ~ Regulated rates and consumer protection rules
  - ~ Pilot programs to test assumptions and projections
- Incentives to promote development, minimize costs, maximize usage/performance
- Utility owned or leased sites—possible public-private partnership with site owners
- Rate-based EV supply equipment and infrastructure investment; regulated cost recovery of expenses net of revenues

While "future-proofing" charge station policies is challenging, given uncertainties about how the EV market will evolve, flexible, scalable approaches that can respond to advancing technologies and changing markets will be keys to successful charge network projects.

Jurisdictions Are Beginning to Authorize Customer-Funded Charge Stations

Many states are beginning to consider or implement supportive policies for EV charging infrastructure, including Washington, Nevada, Oregon, Massachusetts, Michigan, Connecticut, Maryland, Rhode Island, Vermont and Missouri. They are coming to different conclusions about the appropriate role of utilities at this stage of EV development. California—home to more than half of today's U.S. EV fleet—is furthest down the road to testing different models of direct utility participation under regulatory oversight. It passed legislation in 2015 requiring utilities to include electrification of transportation in integrated resource plans and giving the green light to customer funding of infrastructure support—if approved by state regulators as cost-effective.[42] That law precipitated a series of proposals to the California Public Utilities Commission (CPUC) for EV charge

42 SB 350: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350; for summary see: http://www.energy.ca.gov/sb350/

network development. The initial proposals were scaled back after opposition from consumer advocates concerned about the costs and from charge station companies who see utility charging investment as anti-competitive and likely to stifle innovation. The CPUC has now approved three utility pilot programs intended to test the charging market and different models of utility participation in serving it:

- San Diego Gas & Electric was authorized to invest $45 million in 3,500 utility-owned and operated charge stations over three years—up to ten each at 350 businesses and multi-unit residential sites.[43] Half of the stations will be installed in multi-unit dwelling complexes and 10% will be in disadvantaged communities. The pilot will also test response to a variable rate plan to encourage charging at off-peak times and when renewables like solar energy are at maximum output, and it will include optional demand response programs for Level 2 chargers. When fully in place, the charge program will add about $2.75 per year to the bill of a typical household. The utility's original proposal was for 5,500 stations at 550 sites at a cost of $103 million.

- In a $22 million pilot of Southern California Edison, the company's customers will subsidize up to 1,500 charging stations but they will be owned and operated by third parties, not the utility.[44] This is known as the "make-ready" approach, in which the utility furnishes, installs and owns all infrastructure installed at a site except the charge stations. Ratepayer-funded rebates also cover a portion of the site-owner's costs to purchase EVSE from pre-qualified vendors, with whom the utility coordinates installation. Under this turnkey approach, site-owners are responsible only for ongoing costs of repairs, maintenance, and electricity. Rebates to site-owners are 25% of a set standard cost for chargers at workplaces and fleet sites, 50% at multi-unit dwellings, and 100% for charge stations installed in disadvantaged communities. In the pilot, program costs will be expensed, not rate-based, so the utility will not profit on the investment. If successful, a rollout of up to 30,000 stations at an investment of $333 million could follow—adding about one dollar per month to residential electric bills.

- The most ambitious utility proposal was by PG&E, originally put forward at $654 million for 25,000 Level 2 charge stations, but scaled back in a "settlement agreement" with some (but not all) parties to be proportional to the approved SDG&E program—7,500 utility-owned Level 2 charging stations and 100 DCFC stations, at a cost of $160 million. In response to concerns that this is still too large for a pilot program and is still utility-dominated, the CPUC order provides for 2,625 utility-owned charging stations—35% of the total—to be located in multi-unit dwellings and disadvantaged communities.[45] PG&E will provide "make-ready" infrastructure for up to 7,500 charging ports at other sites including workplaces, with a total program cost of $130 million over three years. Energy purchased at charging stations would be priced at time-variant rates intended to ensure "charging is not cost-prohibitive." The proposal to include 100 utility-owned DC fast chargers in the pilot was rejected. As in the other California pilots, a stakeholder Program Advisory Council will oversee program execution.

43 Decision at: http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M158/K055/158055671.PDF
44 Tariff sheets: https://www.sce.com/NR/sc3/tm2/pdf/ce361.pdf
45 http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M171/K219/171219240.PDF

Oregon passed a law in 2016 allowing rate-base treatment of a utility's "transportation electrification program" and laying out six criteria for approval. The Public Utility Commission must consider whether the proposed investment and/or expenditures:

- Are within the service territory of the electric company;
- Are prudent as determined by the commission;
- Are reasonably expected to be used and useful as determined by the commission;
- Are reasonably expected to enable the electric company to support the electrical system;
- Are reasonably expected to improve the electric company's electrical system efficiency and operational flexibility, including the ability of the electric company to integrate variable generating resources; and
- Are reasonably expected to stimulate innovation, competition and customer choice in electric vehicle charging and related infrastructure and services.

These criteria outline a pre-approval decisional framework starting with traditional regulatory principles and adding goals of renewable integration and support of competition. While few possible outcomes are excluded by this list of considerations, the final clause indicates that the Oregon legislature supports development of a competitive charging market intended to be utility-supported but not dominated.

State regulators in Massachusetts had already encouraged utilities to propose EV-supportive investment as part of grid modernization plans when the law was changed to explicitly allow public utilities to own and operate charging stations, provided regulators find that it is in the public interest and does not "hinder the development of the competitive electrical vehicle charging market."[46] In an initial test of this standard, the state's largest utilities have proposed charging infrastructure plans now pending before regulators. The 2017 law also prohibits public charging providers from requiring drivers to pay membership or subscription fees, but they are allowed to charge preferential prices conditional on such membership. Regulators are given authority to adopt interoperability standards for billing and payment of charging fees, and state building and electrical codes are allowed to include EV-capability requirements.

Other states have taken different approaches. For example, Washington law allows regulators to approve an "incentive rate of return" for utility provision or subsidization of EV charging infrastructure up to a maximum overall rate impact of .25%.[47] On the other hand, some states have decided not to subsidize EV charging at this time. Kansas City Power and Light pursued its own charge station pilot without regulatory preapproval from either state in which it operates. When neither Kansas nor Missouri regulators would allow any portion of its costs for 1,000 installed charge stations (with 2,000 ports) to be recovered through general rates, the cost and risk were absorbed by the utility, which has initiated the service at no cost to users.[48] The Missouri PSC decided to take a deeper look at EV policies in a separate proceeding, in which the commission staff report concluded that under existing law, all firms that sell electricity or charging service to the public are subject to state regulatory jurisdiction.[49] The Kansas City experiment in unsubsidized utility-provided charge stations may provide an initial test of the effect of infrastructure investment on EV adoption. If relatively more people there decide to buy EVs, the "build it and they will come" theory may be vindicated.

Funding of Charge Stations by Utility Customers Must Maximize Grid Value

Proposals are emerging across the country for utilities to build out or subsidize public EV charging networks. These proposals are responsive to a growing constituency of EV owners (and potential owners), and are aligned with the natural utility incentive to make new investments, increase revenues, and offer new

46 https://malegislature.gov/Laws/SessionLaws/Acts/2016/Chapter448

47 Text of statute at: http://lawfilesext.leg.wa.gov/biennium/2015-16/Pdf/Bills/Session%20Laws/House/1853-S.SL.pdf

48 http://estar.kcc.ks.gov/estar/ViewFile.aspx/20160913110134.pdf?Id=4b0556f3-425d-4469-8eb1-a105109511ec

49 See MPSC Staff Report: https://www.efis.psc.mo.gov/mpsc/commoncomponents/view_itemno_details.asp?caseno=EW-2016-0123&attach_id=2017002326

services. In some jurisdictions, statutory directives to accelerate EV market penetration and develop distributed energy resources invite such utility investment. In others, public need for rate-based utility investment in charge stations is premised on a set of implicit assertions:

- Use of charging stations will be sufficient to justify their installation.
- Without utility support they won't be built—or at least not soon and not in optimal locations.
- Any net ratepayer costs will be exceeded by system and social benefits.

Because of widely differing circumstances and conditions, jurisdictions are coming to dissimilar conclusions about these assertions and what they mean for regulatory policy.

In formulating policy, lawmakers and regulators must consider whether advantages of using utilities to build out public charging infrastructure outweigh concerns that utility-owned charging facilities would shut out competitors and stifle innovation. In addition to being service and price-regulated and accountable to regulators, utilities generally have access to low-cost capital, ability to integrate EVs as DER, call center capability, established customer relationships, and other incumbent and legacy advantages. However, construction and operation of EV facilities may not be within the core competency of utilities and they may lack the incentives and entrepreneurial culture of unregulated firms. Costs and risks of utility investment may be borne by non-participants, and customers may be at greater risk of stranded costs in the event of underperforming or obsolete facilities. These difficult issues raise fundamental questions of whether public charging networks—particularly DCFC—have "natural monopoly" characteristics, and whether the need for accountability through the regulatory process necessitates a leading utility role.

In formulating policy, lawmakers and regulators must consider whether advantages of using utilities to build out public charging infrastructure outweigh concerns that utility-owned charging facilities would shut out competitors and stifle innovation.

EV Infrastructure Investment Highlights Many New Regulatory Issues

Involvement of public utilities in charge station development raises myriad regulatory questions beyond competitive market effects, including risk and cost sharing between site owners and utility customers, how siting decisions are made, what (if any) technology requirements are specified, physical and cyber security, amounts, allocations, terms and conditions of any subsidies, and public charging policies (and how to enforce rules). Each jurisdiction grappling with these issues may come to different conclusions in context of their particular laws, circumstances, and regulatory goals.

If utility funding or construction of charging infrastructure is found appropriate, one option to pay for it is by simply adding the costs to rate base. Treating these investments as capital expenditures much like wires, poles, and other equipment allows longer term amortization, and a return on investment adds incentive for the utility. Alternatively, support for charging infrastructure can be recovered as operating expenses, or a combination of methods could be used for different types of support, as is being tested in the California pilots.

Utility-owned charge stations are under the purview of state regulators, which can approve tariffs and

TAXES AND EVs

Higher efficiency vehicles—whether ICE or EV—will make gas taxes a shrinking and outdated source of funds for road maintenance, which could be replaced by taxes based on vehicle miles traveled (VMT), which is a more fair and reliable method.* But ten states have imposed fees on EVs and hybrids to make up for lost gas tax revenue, and six more are considering it. Several are now testing VMT taxes.

*http://www.sierraclub.org/compass/2017/02/flurry-state-bills-introduced-likely-backed-oil-industry-penalize-electric-car

Regulators should consider whether subsidies for independent charge stations should be contingent on acceptance of model rate structures and price constraints.

enforce consumer protection rules. Depending on state law, independent third parties may be subject to far less, if any, jurisdiction. In an effectively competitive public charging market, competition would constrain prices and protect consumers, but the very fact that subsidies are needed to induce market entry shows that a robust market does not exist. When shopping for gasoline, there are usually multiple choices of where to fill up, but when a driver with a low battery pulls up to a remote public charge station, she may be facing a situational monopoly, with no choice but to pay whatever fees are assessed.

Charge providers in the initial stage of the industry have introduced a number of business models, including closed networks and monthly fee requirements, which may not be appropriate for publicly subsidized facilities. Regulators should consider whether subsidies for independent charge stations should be contingent on acceptance of model rate structures and price constraints.

Regional Approaches May Be Most Effective and Efficient

A 10% penetration of the car market—25 million EVs on American roads—would pose challenges to electric system operators. For example, imagine a super-fast charging station at a highway exit with 20 cars plugged in. The combined maximum load could be more than 2,000 kW (2 MW), or enough juice to supply the average demand of 1,000 homes. Put several of those at an interchange and it's the equivalent of adding the electric load of a large industrial facility—but with huge peaks and valleys of usage. To serve driver needs, highway charging stations may need far more capacity than would be used on an average day in order to serve high demand on a holiday weekend. Complicating the issues surrounding utility investment is the fact that DCFC charge stations may primarily serve non-local drivers who are just passing through a utility service territory.

A multi-state approach may be an effective way to share the costs and benefits of highway fast charge infrastructure and to provide a seamless network and uniform customer experience. Such a coordinated regional approach has been agreed to by Nevada, Utah and Colorado, with the goal of allowing BEVs to drive "from the Rockies to the Pacific."[50] How the network will be developed and paid for has not been announced but the principle is in place: drivers will derive maximum benefit and the EV market will be advanced if states jointly develop regional charge networks.

The Midwest lacks a coordinated multi-state effort but several environmental groups have formed "Charge Up Midwest" to initiate a regional approach to EV infrastructure development. In the Northeast, seven public, private and coop utility systems formed the Regional Electric Vehicle Initiative to advance regional EV planning efforts.[51] Several interstate highways in the area have been designated "alternative fuels corridors" by the Department of Transportation and targeted for charge station development by the Northeast Electric Vehicle Network, a consortium of 11 states and the District of Columbia.[52] Similar designations cover 48 highways over 25,000 miles in 35 states, sketching out the map of a national charging infrastructure plan.

Federal Support Would Accelerate Network Development

A robust DCFC network open to all makes and models and easy for the customer to use may be a prerequisite for mass EV adoption. However, at an estimated cost of $100,000 or more for each level 3 charge station unit, and higher for the next generation of super-fast chargers, a national network would be very expensive to deploy. UBS estimates Tesla's cost to expand its highway network to provide charging access spaced similarly to gas stations would require more than 30,000 chargers and investment of $8 billion.[53] An ample interstate network would often have enormous idle capacity, only needed during peak driving periods.

A sustainable business model for EV charging based on user fees has not yet emerged and may not be feasible. Without a viable privately funded business model, public or ratepayer-backed utility investments would be needed to build out DCFC infrastructure.

As in development of the interstate highway system itself, evolving transportation needs may call for federal funding, if state-fragmented regulation and private markets prove unable to deliver a seamless national network. Charging infrastructure is currently

50 https://www.colorado.gov/governor/news/governors-colorado-utah-and-nevada-announce-joint-action-build-regional-electric-vehicle
51 http://www.revi.net/
52 http://www.transportationandclimate.org/content/northeast-electric-vehicle-network
53 https://neo.ubs.com/shared/d1N4RjMdUf/

eligible for up to $4.5 billion in federal loan guarantees for energy innovation.[54] If the economic and social benefits of transportation electrification justify further public support for charging infrastructure, a program similar to the one that accelerated smart grid deployment through federal "stimulus" funding may be a good investment for America.

54 https://www.whitehouse.gov/the-press-office/2016/07/21/fact-sheet-obama-administration-announces-federal-and-private-sector

Concluding Recommendations

The electrification of transportation presents a rare opportunity to achieve gains for all stakeholders affected by electricity regulatory policy. The right set of policies can help achieve the traditional regulatory goals—safe, reliable, and affordable service—while advancing new goals of sustainability, efficiency, and customer choice.

Transportation electrification is in its infancy but is poised for rapid growth that should make it a focus of regulatory attention in coming years. This paper has laid out a set of recommendations for EV policy:

- Foster stakeholder communication and consensus-building—in a collaborative process convened by state regulators—to analyze key issues, and recommend regulatory options;
- Optimize system load shape by aggregating EV loads for use as a distributed energy resource;
- Adopt dynamic and time-variant rates to reduce EV operating costs and capture system benefits;
- Support cost effective utility programs to address public needs identified in strategic plans and supported by cost-benefit analyses;
- Promote customer interests through interoperability and seamless networks;
- Benefit disadvantaged and underserved communities; and
- Protect consumers while promoting innovation and market development.

Each state will be challenged to maximize the net benefits of EVs, based on its own laws, electric system characteristics, technology, market structure, regulatory framework, and social/environmental objectives. While the policy outcomes may be different, managing EV demand to create a more efficient, reliable, and less costly electric system is a universal goal. Achieving it will require an integrated approach using a common toolbox, which includes:

- Deployment of smart charging technology;
- Development of new rate designs;
- Support for infrastructure investment;
- Consumer education; and
- Regional cooperation and planning.

Nobody knows how long it will take for EVs to become a major factor in electric system dynamics, but the wheels are beginning to roll downhill and are unlikely to stop. Keeping up with this evolving market and ensuring it delivers system benefits will require proactive regulatory policies informed by input from a wide group of affected stakeholders. For utility regulators and consumer advocates, now would be a good time to start.

THE PUMP VS. THE CHARGING STATION

Collateral effects of transportation electrification may begin to be felt in the next decade. As in other technology displacements, there will be casualties, which could eventually include part of the petroleum industry—though not soon, as global demand for oil is anticipated to rise through at least 2030.* But today's ubiquitous gas stations may become fewer and farther between, and perhaps they will change their product offerings. Shell has become the first oil company to announce it will test installation of EV charging equipment alongside their gas pumps.**

*See World Energy Council 2016 global report: http://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Scenarios-2016_Full-Report.pdf

**In a 2017 pilot in the United Kingdom: https://cleantechnica.com/2016/09/14/shell-considering-creating-ev-charging-station-network-uk-2017/

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ABOUT THE CITIZENS UTILITY BOARD

The Citizens Utility Board (CUB) has been called the "gold standard" of consumer groups by the St. Louis Post-Dispatch. Since 1984, the non-profit consumer watchdog has saved consumers in Illinois more than $20 billion by advocating for investments in energy efficiency technologies and cleaner sources of power, while also policing against unwarranted utility rate hikes.

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Martin R. Cohen is a long-time energy issues leader. For 15 years he led the Citizens Utility Board (CUB), a group created by the Illinois legislature to represent the interests of residential customers in regulatory matters. After serving in state government from 2005 to 2007, including briefly as Chairman of the Illinois Commerce Commission, Mr. Cohen began consulting to consumer advocates, environmental groups, and public utilities on energy and consumer protection issues. He facilitated the Illinois Statewide Smart Grid Collaborative, and his consulting work has included expert testimony in regulatory cases and research and writing on energy policy.

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