Maximizing the Benefits of Transportation Electrification in Pennsylvania

The Role of Rate Design

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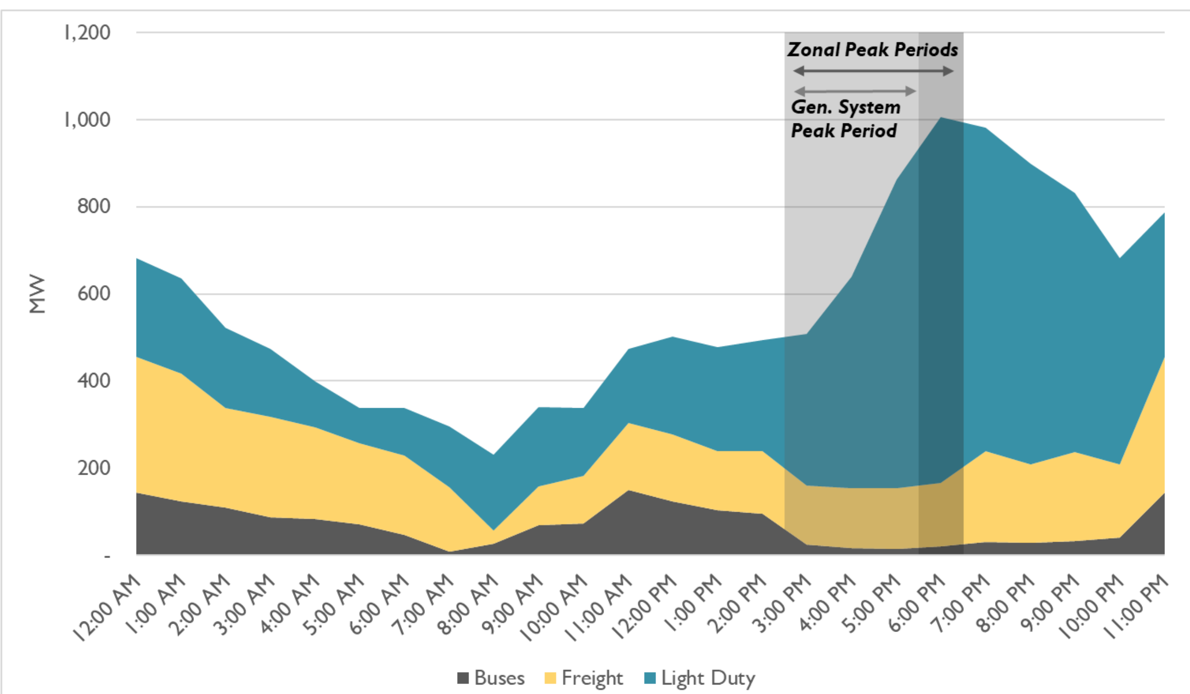
Executive Summary

Transportation electrification has the potential to provide myriad benefits to Pennsylvania by reducing greenhouse gas emissions and local air pollution, cutting the cost of vehicle ownership, and exerting downward pressure on electricity rates for all utility customers. This report analyzes the impacts of electric vehicle (EV) adoption in Pennsylvania out to 2030. Under our base case forecast, we expect that more than 900,000 vehicles in Pennsylvania will be electric by the end of this decade. These EVs will reduce annual transportation-related carbon dioxide (CO_2) emissions by an estimated 2 million metric tons (MMT) and ozone-producing nitrogen oxides (NO_x) by nearly 1,100 metric tons. At the same time, EVs are expected to increase electricity consumption by approximately 4 percent.

The timing of EV charging can have significant impacts on electricity rates. If EVs charge primarily during hours when the grid has excess capacity, the costs imposed on the grid will be minimal and EVs will help reduce electricity costs for all customers through spreading the fixed costs of the grid over greater electricity sales. However, if EVs tend to charge when the grid is near capacity, EV load could result in millions of dollars of additional electric grid investments that are not fully offset by the revenues from EV charging.

By 2030, we estimate that the combined load impact of light-duty vehicles, medium and heavy freight vehicles, and buses during peak periods could add up to 1,000 megawatts (MW) of demand in Pennsylvania. Under current charging patterns, much of this demand is likely to be coincident with current system peaks, as shown in the figure below, which will add to system costs.

Figure ES-1. Combined load impact of EVs in 2030 without alternative rate designs



The overall impact of EVs on electric rates will depend on the extent to which the revenues from EV charging outweigh the costs of serving additional EV load. By providing price signals that encourage EV customers to charge during low-cost hours, electric utility rate design can help to maximize the benefits of EV adoption for all customers by ensuring that the revenues from EVs outweigh the costs imposed on the grid. In addition, well-designed electricity rates can facilitate greater EV adoption by maximizing fuel cost savings.

Rate Design Options

Electricity rates intended to shape EV charging load and support EV adoption have been widely adopted across the United States. Many of these rates have been found to be highly effective in shifting load to lower-cost hours and addressing challenges for customers with high peak demands but low overall energy usage.

Residential EV Rates

For residential customers, the most common EV rates in place across the United States are time-of-use (TOU) rates, which are comprised of two or more pricing tiers based on pre-set time periods. Electricity is priced higher during periods when costs on the system are highest, and lower during periods when costs tend to be low. These rates encourage customers to charge EVs during lower-priced off-peak hours and are simple for customers to understand. Most utilities offer whole-home TOU rates, while some utilities also offer EV-only TOU rates where EV load is metered separately from the rest of the household load. Of the rate schedules reviewed, the majority have an on-peak to off-peak price ratio of 2:1 or higher in at least one season. Recent data from California indicates that EV customers on TOU rates charge their vehicles outside of on-peak hours between 83-92 percent of the time.

Another option for residential customers is a bill credit or other incentive for charging during off-peak hours. Instead of requiring customers to enroll in a separate rate, these programs simply reward customers for charging during off-peak hours with a bill credit or other incentive. These programs tend to be highly popular with customers, but implementation costs can be high.

Finally, residential EV rates may also include subscription rates, in which a customer pays a flat monthly fee for unlimited off-peak charging. These rates are not common but tend to be highly effective. However, they may require additional submetering costs.

Commercial EV Rates

For commercial customers, including fleet operators and direct current fast charger (DCFC) operators, the most common rate designs mitigate demand charges in some manner. Demand charges are applied to a customer's maximum consumption, measured in kilowatts (kW), during a month. For customers with high peak demands but low overall energy consumption, demand charges can dominate customers' bills and make it difficult to earn sufficient revenue to cover their costs. Alternatives to demand charges include:

- Conversion of demand charges to volumetric rates (either flat or time-varying rates);
- Elimination of demand charges during off-peak hours, while retaining demand charges during hours when the system is most stressed;
- Low load factor rates, which cap a customer's billed demand at a certain percentage of the customer's average energy usage; and
- Subscription rates, in which customers subscribe to a specified level of capacity.

In addition, some jurisdictions have elected to implement temporary EV rates based on economic development rate principles. These rates aim to support EV load growth by providing temporarily discounted rates, while ensuring that the rates still recover marginal costs. The motivation is to encourage additional EV load in the utility's territory beyond what would have occurred without the discount. As long as rates are set above marginal cost, the additional load provides benefits to all customers by spreading the fixed costs over additional electricity sales.

Recommendations

Although transportation electrification is still in its early stages in Pennsylvania, it is expected to grow substantially over the remainder of this decade. Thus, Pennsylvania has a window of opportunity now to investigate and implement rates that will ensure that EVs charge in beneficial ways and avoid unnecessary grid upgrades. Further, the rates adopted in the near-term will also help steer the trajectory of EV adoption in the state. Because vehicles are long-lived investments, implementing rates that encourage drivers and fleet operators to choose EVs now will help set Pennsylvania on a trajectory of rapid EV adoption and help the state achieve its energy policy goals.

To maximize the benefits of transportation electrification in Pennsylvania, we recommend evaluation of the rate options discussed in this report and the development of a strategy for implementing EV rates prioritizing the following topics:

1) **Modifications to existing TOU rates for residential customers** to increase bill savings from off-peak EV charging and to attract greater participation in this rate option for consumers. Our research indicates that on-peak to off-peak price ratios for volumetric rates of at least 2:1 are required to provide sufficient bill savings to motivate customers to enroll in these rates. Currently, residential bill savings associated with charging EV load on Pennsylvania utilities' existing TOU rates range from approximately $1/month to $11/month, which are unlikely to attract broad participation. On-peak to off-peak price ratios can be strengthened in multiple ways, including:

    a. Shortening the off-peak period to eight hours or less, reflecting only the lowest-cost hours.

    b. Introducing a super-off-peak period, in addition to the standard on-peak and off-peak periods.

c. Adding time-varying components to transmission and distribution volumetric rates. Currently the utilities' TOU rates apply only to electricity generation supply rates, which comprise about half of a customer's bill.

d. Offering subscription rates with unlimited off-peak charging as a variant of standard TOU rates.

2) **Development of submetering standards** to allow customers to affordably meter their EV load separately without the cost of installing a separate meter. Submetering EV load can be attractive to customers who are otherwise reluctant to enroll their entire household load on a TOU rate. Submeters can also be used to provide bill credits or other incentives to motivate customers to charge during off-peak hours without the need for implementing a separate rate. To fully enable submetering, the Pennsylvania Public Utility Commission may need to approve separate submetering accuracy standards. To develop separate submetering standards appropriate for Pennsylvania, we recommend:

    a. Review the results of submetering pilots in Maryland, Minnesota, and California;

    b. If warranted, propose a submetering pilot for Pennsylvania; and

    c. Consider proposing adoption of submetering standards from other states (such as California).

3) **Alternatives to traditional non-coincident demand charges for commercial customers**. A non-coincident demand charge is applied to a customer's maximum consumption, measured in kW, during a month. Demand charges can significantly increase electricity costs for EV charging customers, particularly operators of public DCFCs and certain commercial fleets requiring high-powered chargers typically ranging from 50 kW – 350 kW. These customers tend to have brief periods of high demand, measured in kW, but relatively low energy consumption, measured in kilowatt-hours (kWh), overall. Under such conditions, demand charges dominate customers' bills and make it difficult to earn sufficient revenue to cover their costs. Without sufficient deployment of public DCFCs, EV adoption may be stymied due to drivers' concerns that they will not be able to recharge. Further, it also raises equity issues since many less-affluent customers lack access to at-home charging options.

    We recommend the evaluation and development of alternatives to non-coincident demand charges. In Pennsylvania, these charges generally range from $4/kW to $10/kW. Alternatives to non-coincident demand charges include:

    a. Time-limited demand charges, which apply only during peak hours and more precisely target the hours that the system is most stressed.

    b. Conversion of demand charges to volumetric rates for low load factor customers, at least temporarily, while EV charger utilization is low. Such rates could be offered permanently or phased out as EV adoption reaches a critical mass.

c. Load attraction or economic development rates designed to support the growth of the nascent EV market. This approach would temporarily offer rates based on marginal costs to encourage transportation electrification. Over time, the rates would be increased to recover the full embedded costs assigned to these customers.

4) **Education and outreach initiatives**. To maximize enrollment in beneficial rates, robust education and outreach programs will be needed. These programs should look beyond standard marketing activities to consider additional tools and outreach opportunities, such as educating dealership sales staff on EV programs and rates and providing dealerships with tools to educate their customers. We recommend that the development of guidelines for such programs be based on the successful approaches taken in other jurisdictions outlined in this report.

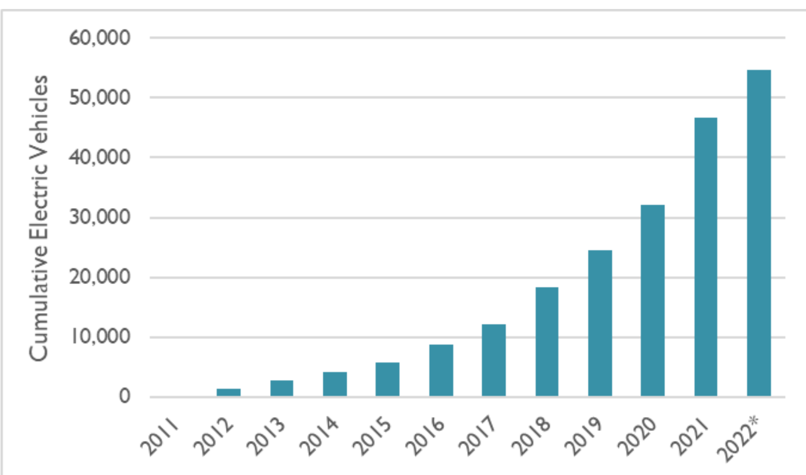
No obvious legislative or regulatory barriers to implementing these recommendations were identified. New tariffs are often introduced in the context of a rate case, but new revenue-neutral rate designs can also be introduced between rate cases through a utility tariff filing. While we recognize that highly accurate utility system cost data may take time to develop, marginal cost estimates used in other proceedings (such as energy efficiency cost-effectiveness tests) can be leveraged along with class load profiles to develop reasonable cost estimates.

1. BACKGROUND

Transportation electrification has the potential to provide myriad benefits to Pennsylvania by reducing greenhouse gas emissions and local air pollution, cutting the cost of vehicle ownership, and improving the efficiency of the electricity grid. However, these benefits are not a given; the extent to which Pennsylvania attains these benefits depends in large part on utility rate designs, which determine how much EV customers pay for the electricity they consume from the grid and can significantly influence the timing of when EV customers charge their vehicles.

There is no doubt that transportation electrification is occurring and is gaining momentum in Pennsylvania. From 2013 through the first half of 2022, the EV share of new light-duty vehicle sales in Pennsylvania increased from 0.24 percent to 3.85 percent.[1] As of November 2022, there were approximately 54,684 EVs registered in Pennsylvania,[2] which constitutes roughly 0.5 percent of total vehicle registrations.[3] While nationwide most EVs are light-duty vehicles due to their widespread availability, medium- and heavy-duty vehicles sales are now beginning to rise rapidly as well.

Figure 1. Electric vehicle growth in Pennsylvania



Source: Alliance for Automotive Innovation and Pennsylvania Department of Transportation. 2022 values are as of November.

[1] Through the first half of 2022. Alliance for Automotive Innovation (2022). Get Connected Electric Vehicle Quarterly Report, Second Quarter, 2022. Available at https://www.autosinnovate.org/posts/papers-reports/Get%20Connected%20Electric%20Vehicle%20Quarterly%20Report%202022%20Q2%209-13-22.pdf and Alliance for Automotive Innovation (2022). Advanced Technology Vehicle Sales Dashboard. Available at: https://www.autosinnovate.org/resources/electric-vehicle-sales-dashboard

[2] This value includes 40,599 battery EVs and 14,085 plug-in hybrid EVs.

[3] Unpublished information provided by the Strategic Development and Implementation Office within the Pennsylvania Department of Transportation's Transformational Technology Division.

This growth is only expected to increase in coming years. By 2030, we estimate that nearly 9 percent of registered light-duty vehicles, 5 percent of medium-duty vehicles, and 6 percent of heavy-duty vehicles in Pennsylvania will be electric, based on recent Bloomberg New Energy Finance forecasts.[4] Table 1 shows the current number of registered vehicles in Pennsylvania, as well as the number of registered EVs in 2021 compared to the forecasted number of EVs in 2030.[5] We have also included high and low sensitivities of +/-30 percent to account for the uncertainty surrounding EV adoption rates.

Table 1. 2021 Registered Vehicles and 2030 Electric Vehicle Forecast for Pennsylvania

	2021		2030 Registered EV Forecast		
Category	**All Registered Vehicles**	**Registered EVs**	**Base Case**	**Low (-30%)**	**High (+30%)**
Light duty vehicles	9,824,000	46,660	870,000	610,000	1,100,000
Medium-duty freight trucks	340,471	590	17,000	12,000	22,000
Heavy-duty single unit freight trucks	124,896	51	7,800	5,500	10,000
Heavy-duty combination freight trucks	96,724	57	6,100	4,300	8,000
Buses	56,462	320	17,000	12,000	22,000
Total	**10,442,553**	**47,678**	**917,900**	**643,800**	**1,162,000**

Source: EV forecast adapted from Bloomberg New Energy Finance forecasts (2022)

EVs can charge at a range of speeds, each of which has different impacts on the grid:

- The slowest charging speed – Level 1 – uses a standard 120-volt alternating current (AC) outlet and draws only about 1 kW of power. These chargers add between 3.5 – 6.5 miles of range per hour.
- Level 2 chargers have a demand ranging from 7 kW – 19 kW and can add between 14 – 35 miles of range per hour. These chargers can use a standard 240-volt outlet and are common for both residential and public charging.
- DCFCs typically range from 50 – 350 kW, although very few vehicles are currently capable of drawing more than 200 kW. Higher power chargers (including chargers with a charging capacity rating of more than 1,000 kW) are also under development, but have not been widely rolled out. Today, most DCFCs add about 100 miles of range in 30 minutes.[6]

[4] Bloomberg New Energy Finance (BNEF). 2022. Long-Term Electric Vehicle Outlook, as reported by BofA Global Research. https://rsch.baml.com/report?q=WCfBJmf-PxHbUk763NuZcw.

[5] We expect that the total number of registered vehicles in Pennsylvania in 2030 (including non-EVs) will increase slightly from 2021 values.

[6] Pennsylvania Department of Transportation. Electric Vehicles and Alternative Fuels. 2023. Available at: https://www.penndot.pa.gov/ProjectAndPrograms/Planning/EVs/Pages/default.aspx.

If all EVs charged simultaneously using a Level 2 charger for light- and medium-duty vehicles and 50 kW DCFCs for heavy-duty vehicles and buses, this would add 7.9 gigawatts (GW) – an increase of about 27% – of demand to Pennsylvania's grid, relative to current peak loads of approximately 30 GW.[7] Fortunately, this need not be the case. Because EVs are often parked for long periods of time, there is generally some flexibility regarding the timing of EV charging as long as the vehicles are ready to drive when needed. This inherent flexibility opens up the possibility of encouraging efficient charging practices without inconveniencing consumers.

Given the rapid pace of EV adoption and the potentially large positive or negative impacts that EVs could have on the grid, it is critical that states establish frameworks to enable EVs to be integrated into the grid in a low-cost manner and avoid increasing grid costs. Electric utilities can play a prominent role in this regard, as the rates they set provide price signals to customers that can encourage EV owners and operators to charge in a manner that is consistent with grid conditions.

1.1. Benefits of transportation electrification

Below we briefly describe the primary benefits associated with transportation electrification, followed by a discussion of the role of rate design in achieving these benefits.

Emissions Benefits

Because they have no tailpipe emissions, EVs help reduce ozone-forming NO_x emissions and greenhouse gas emissions even after accounting for the emissions associated with their electricity consumption. Motor vehicles currently account for approximately 20 percent of greenhouse gas emissions in Pennsylvania, with more than 50 MMT of carbon dioxide equivalent (CO_2e) emitted annually through the combustion of motor gasoline and diesel.[8]

By 2030, we estimate that EVs will reduce annual tailpipe emissions in Pennsylvania by more than 3 MMT of CO_2e – about 6 percent of current motor vehicle tailpipe emissions. This means that, on average, each EV in Pennsylvania reduces tailpipe CO_2e emissions by more than 3 metric tons annually. When the electricity that these vehicles consume is also factored in, the net emissions reduction totals approximately 2 metric tons CO_2e annually, per vehicle.

[7] Pennsylvania Public Utility Commission. August 2022. Electric Power Outlook for Pennsylvania 2021-2026, p. 25. Available at https://www.puc.pa.gov/media/2013/epo_report_2022.pdf.

[8] Pennsylvania Department of Environmental Protection. 2022 Pennsylvania Greenhouse Gas Inventory Report. October 6, 2022. Available at https://files.dep.state.pa.us/Energy/Office%20of%20Energy%20and%20Technology/OETDPortalFiles/ClimateChange/PennsylvaniaGreenhouseGasInventory2022.pdf.

Fuel Cost Savings

Fuel cost savings for EV drivers are significant. We estimate fuel cost savings for light-duty EVs in Pennsylvania to total approximately $700 annually at $2.00/gallon gasoline prices and more than $1,700 annually at $4.00/gallon gasoline prices.[9]

Downward Pressure on Electricity Rates

A substantial portion of electricity costs are associated with grid capacity – the generation, transmission, and distribution infrastructure required to serve peak demand. However, most of the time demand is well below peak, resulting in underutilized capacity. Charging EVs primarily during off-peak hours can improve grid utilization by spreading out the fixed costs of capacity over a greater volume of sales, which puts downward pressure on rates for all customers.

1.2. The Role of Rate Design

Electricity rates that convey efficient price signals are critical for both spurring EV adoption and minimizing the costs of serving additional EV load. Low electricity rates provide greater fuel cost savings for EV owners relative to internal combustion vehicles, which is an important factor for drivers when considering whether to purchase an EV. On the other hand, if electricity rates are set too low, transportation electrification may be accelerated, but non-EV customers may end up unfairly subsidizing EV customers. Therefore, electricity rates should be set to convey accurate price signals regarding the costs to serve additional EV load, while providing maximum cost savings to EV customers. This encourages EVs to charge during hours when grid costs are low, which improves the efficient utilization of the grid and puts downward pressure on rates for all customers. If rates fail to communicate such price signals, EV load will result in higher costs on the grid, potentially increasing costs for all customers. For example, if EVs charge when electricity demand is high, more expensive electric generation capacity will be required to serve Pennsylvania load, leading to higher wholesale capacity costs for all customers. At the local level, if EV charging occurs when the local distribution system is peaking, utilities may need to make costly upgrades to transformers or substations to meet the additional demand.

In Pennsylvania, the rates proposed by investor-owned electric utilities are reviewed and approved by the Pennsylvania Public Utility Commission. Rates are typically designed with multiple goals in mind, including: being sufficient to recover the utility's costs; appropriately allocating costs across rate classes; providing efficient price signals; and being simple and understandable.[10]

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[9] Calculated using the current proportion of battery-powered EVs (BEVs) and plug-in hybrid EVs (PHEVs) and an average electricity price of $0.094 cents/kWh, based on regional retail electricity prices from the U.S. Energy Information Administration's 2022 Annual Energy Outlook. Increasing the retail electricity rate to $0.13/kWh reduces the annual fuel savings to $500 - $1,600 using a range of gasoline prices of $2-$4/gallon.

[10] These principles roughly encapsulate the key principles described by Professor James Bonbright in his seminal work, *Principles of Public Utility Rates* (1961).

Each electric utility customer takes service on a "rate schedule," which specifies how electricity is priced for customers in their rate class. The rate schedule is intended to allow utilities to recover an approved amount of revenue from each rate class, based on the total cost to serve that class of customers. It is also intended to convey price signals to customers to encourage economically-efficient decisions.[11]

Although rate schedules are established to recover a set amount of revenue per rate class, the specific design of the rate schedule will impact customers within a rate class differently, since each customer uses electricity in a unique way. In other words, there are many different rate designs that will yield the same amount of total revenue for a rate class, but with different implications for individual customers' bills.

Understanding how different rate designs impact the bills of various types of customers is important for designing rates that are aligned with energy policy goals, such as transportation electrification. In addition, different rate designs will send different price signals to customers about the cost to produce and deliver electricity, which impacts customer decisions about how and when to consume electricity. This has important ramifications for influencing when customers decide to charge EVs, and ultimately the total cost associated with electrifying the transportation sector.

Many utilities offer customers a choice of rate schedules so that customers can choose the rate design that works best for them. For example, residential customers with EVs tend to be good candidates for more sophisticated optional rates (such as TOU rates), as EV charging represents a large amount of flexible load relative to standard household load. Allowing EV customers the option of taking service on more sophisticated rates can thus result in cost savings for both the utility and the customer.

The three most common rate elements are described in the next section, followed by an overview of rate design options for each of these three rate elements.

1.3. Core Elements of Utility Rates

A rate schedule is generally comprised of one or more of the following three rate elements:

- **A fixed charge ($/month)**, which is a flat fee per month. This is commonly referred to as a "customer charge."
- **A volumetric rate ($/kWh),** which charges customers based on the quantity, measured in kWh, of electricity consumed.

[11] Economic efficiency is achieved when customers choose to consume a good based on whether the value to the customer exceeds the marginal cost of producing the good. For electricity, the cost of producing and delivering it varies throughout the day and year. If customers do not know the cost of producing electricity, they cannot make economically-efficient consumption decisions.

- **A demand charge ($/kW),** assessed based on the customer's maximum usage during the month,[12] measured in kilowatts (kW). While demand charges are common for commercial and industrial customers, they are very rare for residential customers.

Many design options exist within each of these three rate elements. For example, volumetric rates ($/kWh) may be stable throughout the day, as is common for residential flat rates, or they may be higher or lower during certain hours to better reflect changes in system energy costs. Fixed charges can also be set higher or lower, which impacts how much customers can control their bills by modifying their consumption. Demand charges may be based on a customer's maximum demand during the month in any hour, or only during certain hours when the system tends to be most stressed.

The sections below describe common rate designs in more detail.

1.4. Rate Design Variations

Fixed Charges

The primary design decision associated with the fixed charge is how high to set it. The higher the fixed charge, the lower the other charges on the rate schedule. For example, if a fixed charge is set at $10/month, the associated volumetric rate might be $0.15/kWh. If the fixed charge is $50/month, the commensurate volumetric rate might be $0.09/kWh. Both rate designs will yield the same total revenue for the rate class as a whole, but higher fixed charges result in lower bills for customers with higher-than-average usage. This is shown in Table 2 below, for "Rate Schedule A" with a $10/month fixed charge and "Rate Schedule B" with a $50/month fixed charge. While the average customer would still pay $109/month, the high-usage customer would pay a lower bill with the $50/month fixed charge than with the $10/month fixed charge. Likewise, the lower-usage customer would be better off with the rate schedule with the lower fixed charge.

Table 2. Bill Impact Comparison of Rate Schedules with Different Fixed Charges

			Monthly Bill		
	Fixed Charge	Volumetric Charge	Low-Usage Customer (100 kWh)	Avg.-Usage Customer (660 kWh)	High-Usage Customer (1500 kWh)
Rate Schedule A	$10	$0.15	$25	$109	$235
Rate Schedule B	$50	$0.09	$59	$109	$185

Because residential EV customers tend to use more electricity than the average residential customer, rate schedules with higher fixed charges tend to result in lower bills for EV customers. In a few cases, utilities have established "subscription rates" that only have a fixed charge and no volumetric rate. Such

[12] Demand charges are typically assessed based on a 15-minute, 30-minute, or 60-minute period.

rate designs are similar to unlimited cell phone pricing plans that allow customers unlimited usage for a fixed monthly rate.

Although higher fixed charges may benefit higher-usage customers, there are several common criticisms associated with them. First, higher fixed charges reduce customers' ability to control their bills through modifying their electricity consumption, since customers cannot influence the fixed portion of their bill. Second, because higher fixed charges reduce the volumetric rate, incentives to invest in energy-efficient appliances are also reduced. Finally, there may also be equity concerns associated with higher fixed charges, such as potential adverse impacts on low-income customers.

Volumetric Rates

The cost of producing a kilowatt-hour of electricity can vary tremendously over the course of a day and year. When electricity usage is highest, the most expensive "peaker" power plants are dispatched, resulting in high electricity costs. Likewise, periods of excessive electricity usage – however brief – result in the need to construct more system capacity (i.e., power plants, transmission lines, and distribution equipment), increasing electricity system costs. There is a wide range in the extent to which volumetric rates convey such cost information to customers through price signals, as discussed below.

Flat Volumetric Rates

Residential customers are often billed for electricity based on a flat rate, which only reflects average electricity costs over time. Sometimes flat rates vary seasonally (e.g., with higher prices in the summer than winter), but otherwise the price signals provided by flat rates are limited to the volume of electricity consumed. There are two key reasons for this:

- Historically, residential electricity meters were only capable of recording the total volume of electricity used during a month, rather than *when* the electricity was consumed.[13] This technological constraint meant that customers were charged the same price for a kilowatt-hour of electricity, regardless of whether that kilowatt-hour was produced during the most or least expensive hour of the day. In recent years, Pennsylvania's major electric utilities have substantially completed mandatory smart meter deployment plans which enables implementation of volumetric rates that vary according to electricity costs.
- An important objective of rate design is for rates to be simple and understandable. Rates that fluctuate frequently can be difficult for customers to understand or respond to, particularly for residential customers.

Flat rates are especially problematic when considering transportation electrification. First, these rates do not encourage EV adoption by offering discounted prices for charging when costs are low. As a result,

[13] Meters capable of registering usage during different hours have been available for decades, but were historically cost prohibitive for the residential class.

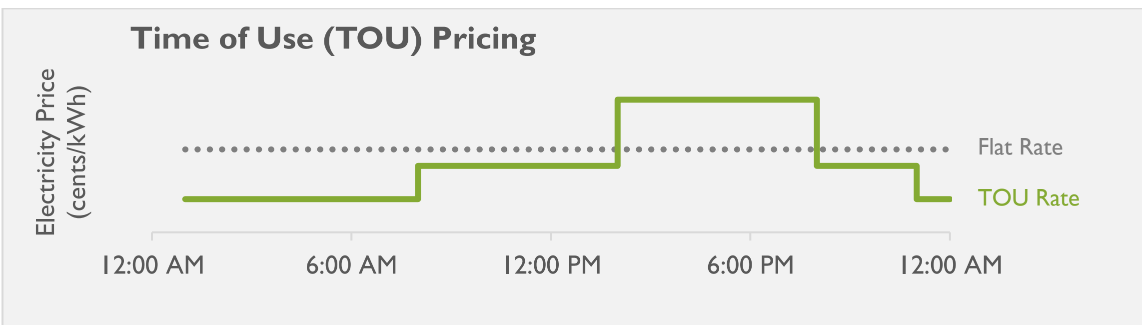
prospective EV customers face higher costs than necessary for recharging, thereby reducing the cost savings relative to gasoline.

Second, flat rates provide no incentive to customers to charge when the grid is least utilized. Instead, customers are apt to charge when it is most convenient to them (generally when returning from work in the early evening when the grid is nearing its peak), which can strain the grid and increase costs for all customers.

Time-Varying Rates

In contrast to flat rates, time-varying rates convey more accurate price signals to motivate customers to shift usage away from peak times while saving customers money by charging off-peak. For residential customers, these rates tend to be optional, rather than mandatory. The most common forms of time-varying rates are described below, along with a stylized depiction of how each rate could be implemented.

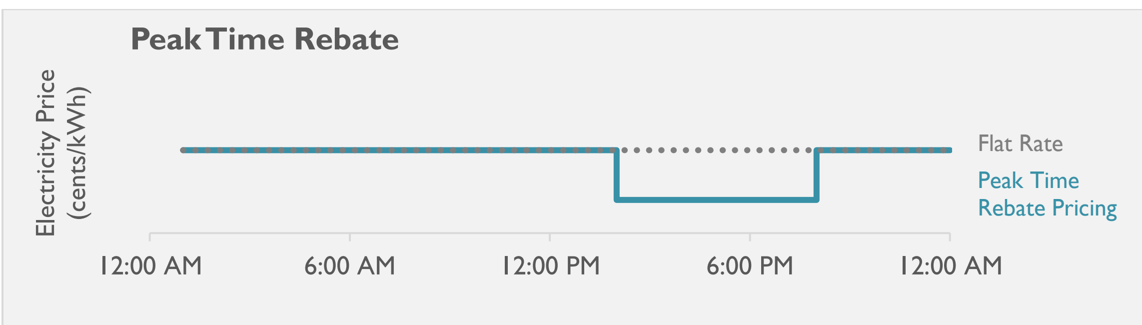
- *TOU Rates*: TOU rates are comprised of two or more pricing tiers, based on pre-set time periods. Electricity is priced higher during hours when costs on the system are highest, and lower during hours when costs tend to be low. While this rate structure can be attractive to customers because the prices and peak hours are known ahead of time, it generally represents only a rough approximation of actual system costs.



- *Critical Peak Pricing (CPP)*: This rate structure imposes a very high price (typically in the range of $0.50 – $2.00/kWh) that is only triggered for a limited number of specific events, such as system reliability or peak electricity market prices.[14] These events generally last for only 2 – 6 hours, and whether an event will be called is not known to customers until a day (or less) in advance. The maximum number of CPP events in a year are limited, often in the range of 10 – 20 events. In exchange for high prices during CPP event hours, customers receive lower rates during other hours.

[14] Hledik, R. et al., 2016.

- *Peak Time Rebates (PTR)*: A PTR program is similar to CPP, except that customers earn a financial reward for reducing energy relative to a baseline, instead of being subject to a higher rate. As with CPP, the number of event days is usually capped for a calendar year and is linked to conditions such as system reliability concerns or very high supply prices.[15] While PTR programs tend to be widely accepted by customers, they have two drawbacks relative to CPP:
    - Baseline usage can be difficult to determine with accuracy. For example, a customer may earn a reward simply because the customer was out of town on the day of the event rather than because the customer actively reduced their electricity consumption in response to the event.
    - PTR tend to result in lower electricity reductions than CPP. Customers generally respond more strongly when they are faced with paying more for consumption during peak hours than when they are offered a reward for lowering consumption.

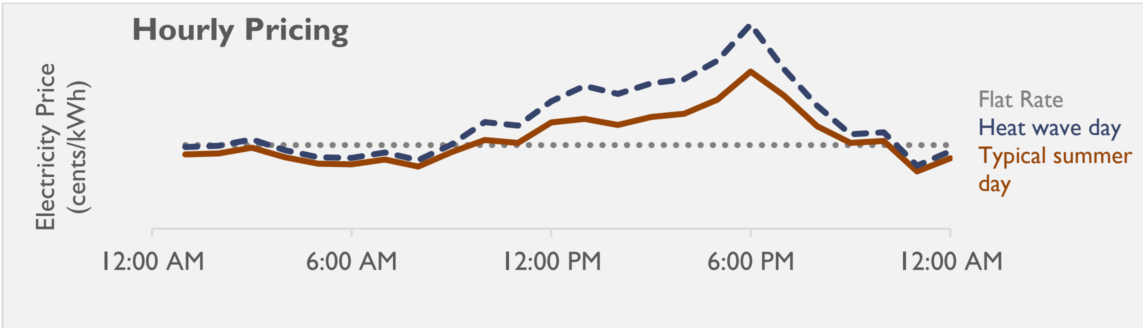


- *Real-Time Pricing and Hourly Pricing*: These rates charge customers for electricity based on actual market or operational costs rather than a pre-set rate schedule with prices defined in advance.[16] Rates fluctuate hourly or in 15-minute increments, reflecting changes in the cost of generating electricity. Customers may be notified of prices on a day-ahead or hour-ahead basis. These rates tend to be rare for residential customers, who tend to lack the ability or desire to closely monitor prices and manage electricity

[15] United States of America. Federal Energy Regulatory Commission. *Assessment of Demand Response and Advanced Metering.* Washington D.C.: United States, 2010.

[16] *Id*.

consumption levels. They also introduce significantly greater risks for customers than prices that are known in advance.



Demand Charges

Many commercial utility rate schedules include a demand charge, which is applied to a customer's maximum consumption, measured in kW, during a month, as measured over a 15-minute period, 30-minute period, or hour.[17] Although demand charges are common for large commercial customers, they are rare for residential and small commercial customers.

By billing customers based on their maximum hourly or sub-hourly usage during a billing period, demand charges attempt to reflect the costs associated with supplying adequate system capacity to meet the customer's maximum requirements. However, demand charges can hinder development of fast charging infrastructure (50 kW and above) and EV adoption if they result in prohibitively high operating costs.

Demand charges can pose a particular barrier for public DCFCs. These charging stations frequently experience low load factors, where the quantity of electricity consumed (kWh) is low but the demand (kW) is high. Low load factors often occur because (1) EV adoption has not yet reached levels where DCFCs are frequently used, and (2) public DCFC stations seek to provide sufficient chargers so that there is minimal queuing for customers. This can result in occasional spikes in demand with low average usage levels. Under such conditions, demand charges dominate DCFC customers' bills and make it difficult to earn sufficient revenue to cover their costs.[18]

Access to fast-charging infrastructure is critical for facilitating both long-distance travel and EV adoption among customers without access to at-home charging (such as those living in apartment buildings). Poor economic returns to DCFC station owners are likely to result in fewer DCFC stations being constructed, which contributes to drivers' range anxiety – a significant factor hindering EV adoption. Alternatively,

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[17] In some cases, demand charges are applied to some measure of a customer's maximum consumption over the course of a year. For example, a demand ratchet could base billed demand on the higher of the customer's maximum demand over the past month, or some percentage (e.g., 75%) of the customer's maximum demand over the past 11 months.

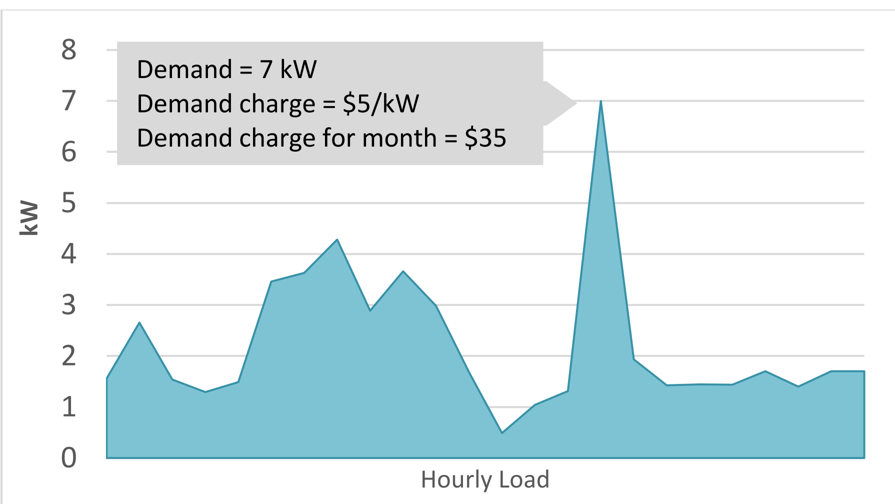
[18] *See, for example:* Fitzgerald, Garrett, and Chris Nelder. DCFC Rate Design Study. Rocky Mountain Institute, 2019. Available at http://www.rmi.org/insight/DCFC-rate-designstudy and Garrett Fitzgerald and Chris Nelder, EVgo Fleet and Tariff Analysis. Rocky Mountain Institute, March 2017. Available at: www.rmi.org/wpcontent/uploads/2017/04/eLab_EVgo_Fleet_and_Tariff_Analysis_2017.pdf

DCFC customers may pass on the costs to EV charging customers in the form of higher charging prices. Of course, high charging prices make it more costly to own and operate an EV, potentially also reducing EV adoption rates, particularly for customers in dense urban settings who lack access to at-home charging options. Not only can this hinder transportation electrification, it also raises equity issues regarding who benefits from transportation electrification, since charging options would be limited for customers in multi-family housing, many of whom are lower-income customers.

Similarly, medium- and heavy-duty EVs (such as buses and freight trucks) may require fast charging capabilities to quickly recharge their large capacity batteries between routes. Demand charges may impede adoption of medium- and heavy-duty EVs that do not have the luxury of long dwell times to recharge at lower power levels. Lower adoption of medium- and heavy-duty vehicles also has equity implications, as lower-income customers are more likely to utilize public transit and live in communities that suffer from high levels of air pollution from vehicle operations.

Figure 2 illustrates how a demand charge functions. In this scenario, the figure depicts a hypothetical day when the customer had a maximum demand of 7 kW. If 7 kW was the maximum demand the customer had throughout the entire month and the utility's demand charge was set to $5/kW, then the customer would be assessed $35 in demand charges that month. This holds true despite the fact that the customer's average demand throughout the day was much lower than 7 kW.

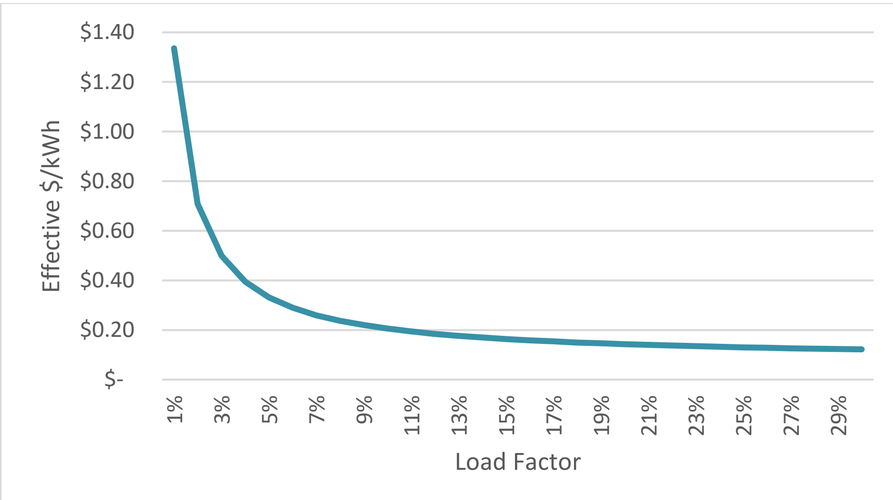
Figure 2. Hypothetical demand charge example



For a DCFC station, demand charges can be substantial. Consider a scenario in which a DCFC station has four 150-kW ports. On occasion, all four of these ports might be used simultaneously, resulting in a billing demand of 600 kW. If the station has a low load factor of 5 percent, demand charges will likely comprise the majority of the station operator's bill. For example, if the station owner faces a monthly customer charge of $100, a demand charge of $9/kW, and an energy supply charge of $0.08/kWh, their monthly bill would be $7,252, of which 75 percent ($5,400) would stem from the demand charge.[19] In this example, the effective volumetric rate paid by the customer would be $0.33/kWh.

Demand charges become less burdensome to customers as the load factor increases, as illustrated in Figure 3. The analysis is based on the same hypothetical utility rates listed above with a billing demand of 600 kW, but with varying levels of electricity consumption, and thus varying load factors.[20] At a load factor of only 1 percent, the effective rate paid by the site operator is $1.34/kWh, but this declines to $0.16/kWh at a load factor of 15 percent and $0.12/kWh at a load factor of 30 percent.

Figure 3. Hypothetical effective volumetric rate by load factor



Non-Coincident versus Time-Limited Demand Charges

Demand charges can apply during any hour (a "non-coincident" demand charge), or they can be designed to be time-limited (or "coincident" with hours in which the system tends to peak). These two types of demand charges differ in significant ways, with important implications for the effectiveness of price signals and EV adoption.

Generally, non-coincident demand charges are less cost-based than time-limited demand charges, particularly for portions of the grid that are shared by multiple customers. For example, if a customer's peak demand occurs at 2 am, this demand likely has little impact on generation, transmission, or distribution capacity needs because overall demand is low during overnight hours. The exception would be for local distribution system equipment (such as the final line transformer) that may need to be sized to serve the individual customer's maximum demand, regardless of when it occurs.

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[19] Assumes a billing demand of 600 kW and 21,900 kWh monthly electricity consumption.

[20] At a 1% load factor, the site electricity usage is 4,380 kWh/month. At a 30% load factor, the site electricity usage is 131,400 kWh/month.

A time-limited demand charge that applies only during certain hours of the day reflects costs on the system more accurately, as it is assessed only during hours in which the system tends to be stressed. For example, if peak demand for a utility typically occurs between the hours of 4 pm and 8 pm, a demand charge might be designed to only apply during these hours. This generally represents a closer approximation of a customer's contribution to capacity costs than a non-coincident demand charge.

The use of time-limited, rather than non-coincident demand charges can improve the economics of electrifying fleets significantly. Fleet vehicles often return to a central depot to charge overnight, which allows for charging when demand on the system is low. By assessing a demand charge only during peak (daytime) hours, a time-limited demand charge reduces charging costs for fleets that can shift their charging to off-peak hours.

In contrast, non-coincident demand charges simply encourage customers to spread their charging evenly over the course of the day. This could have the perverse incentive of encouraging some charging to shift from off-peak to on-peak hours to flatten demand, despite the system facing capacity constraints only during on-peak hours.

Low Load Factor Provisions

Some rate schedules provide demand charge relief for customers with low load factors. A "demand limiter" is one such example, which operates by constraining the monthly demand charge according to a customer's average energy consumption. For example, the demand charge may have a cap equal to 10 times the customer's average hourly demand. If the customer's average hourly demand were 20 kW, then the demand charge would be limited to 200 kW for the month. Thus, the demand charge only fully applies if the customer's load factor (ratio of average demand to maximum demand) is 10 percent or higher.

Other Rate Options

Load Attraction/Economic Development Rates

In addition to variations in the core rate elements, in some cases utilities have opted to provide across-the-board discounts in a manner akin to load attraction or economic development rates. Such rates typically offer temporary discounts[21] to attract new businesses to locate in the utility's service territory. The theory is that by attracting additional load, the fixed costs of providing electricity will be spread over greater electricity sales, resulting in lower rates for all customers. Similarly, EV rates that provide a discount for some period of time are intended to encourage the addition of new, beneficial load on the system, beyond the level that would occur under existing rate structures.

[21] As long as rates are set above the marginal cost of providing electricity, utility customers as a whole will be better off with the addition of new load. Over time, the rates are generally increased to reflect total embedded costs, rather than only covering marginal costs.

Subscription Rates

Subscription rates can take various forms. Some subscription rates function similarly to demand charges but require the customer to subscribe to a pre-determined level of peak demand in advance. In other cases, the customer simply pays a flat fee for unlimited usage up to a pre-set level (with unlimited usage typically limited to off-peak hours). The impacts of subscription rates are highly dependent on the specific design of the rate, but in general these rates attempt to simplify the rate for customers and provide greater bill stability.

Off-Peak Charging Incentives

Although not technically a form of rate design, bill credits or other incentives, such as gift cards, provided for off-peak charging have proven highly effective at encouraging customers to charge their vehicles during off-peak periods. These programs often utilize submetering technologies, avoiding the need for whole-home rates or for second utility meters to separately meter EV load.

1.5. Existing Pennsylvania Electricity Rates

Residential

The sections below summarize the current residential electric rate designs for four of Pennsylvania's largest electric utilities: PECO, Duquesne Light Company (Duquesne Light), PPL Electric Utilities (PPL), and Metropolitan Edison Company (Met-Ed). Each of these utilities offers an optional TOU rate for generation supply service (i.e., energy purchased from the wholesale market), but not for the distribution portion of the bill. We present the volumetric rates as the bundled distribution, transmission, and generation supply rates current as of May 2022, excluding riders and surcharges. We note that customers may take generation supply service from a competitive generation supplier,[22] and that these rates may differ from the default supply service rate offered by the electric utilities.

In addition to describing each rate, we quantify the potential cost savings for an EV customer who uses 300 kWh/month[23] during the off-peak period on the TOU rate as compared to the same usage on the standard (flat) residential tariff. The potential savings offers an indication of the strength of the incentive provided by TOU rates for customers to shift load to off-peak hours, as well as the relative attractiveness of TOU rates for EV drivers.

[22] Approximately 25% of residential customers in Pennsylvania take service from a competitive electric generation supplier, rather than on their electric utility's default supply service rate. *See:* Pennsylvania Public Utilities Commission, Bureau of Technical Utility Services. Retail Electricity Choice. January 2023. Available at https://www.puc.pa.gov/media/2203/retail-elec-choice-report-21draft11622-communications-edits-with-covers-011323.pdf.

[23] A full battery electric vehicle is assumed to consume approximately 300 kWh/month, although this can vary significantly based on a customer's driving patterns and the efficiency of the EV.

PECO

Out of the four largest Pennsylvania utilities' residential rates, PECO's TOU rate has the highest on-peak to off-peak price ratio, which provides the greatest incentive for customers to shift load to off-peak hours and the highest potential bill savings for customers who shift load.

PECO's TOU rate has three prices: an on-peak rate from 2 pm – 6 pm Monday to Friday, an off-peak rate, and a super-off-peak rate. The bundled on-peak rate is approximately $0.29/kWh, while the bundled super-off-peak rate is $0.11/kWh, for an on-peak to super-off-peak price ratio of approximately 2.6 to 1. This allows customers to save nearly $0.18/kWh by shifting load.[24] This price ratio results in potential annual savings for EV customers of $116 from charging during the super-off-peak period compared to the standard flat rate – the most out of any Pennsylvania utility surveyed. As of May 31, 2022, 906 residential customers were enrolled in PECO's TOU rate.[25] At least 123 of those customers were EV customers.[26]

PPL

The TOU option for PPL's residential customers features rates that vary by season and by on-peak and off-peak period. In the summer, the bundled off-peak rate is three cents lower ($0.10/kWh) than the on-peak rate ($0.13/kWh) for an on-peak to off-peak price ratio of 1.3 to 1. In the winter, the off-peak rate is just one cent lower than the on-peak rate ($0.14/kWh versus $0.13/kWh), for an on-peak to off-peak price ratio of 1.1 to 1.[27] In the summer, the on-peak period is from 2 pm – 6 pm, whereas, during the winter, the on-peak window is from 4 pm – 8 pm.

Assuming an EV customer charges 300 kWh/month off-peak, PPL's TOU rate could provide $64 in annual savings relative to the standard flat residential service rate. PPL estimates that between 10,000 and 15,000 customers in its territory have EVs as of June 2022. As of August 2022, 684 customers had enrolled in PPL's TOU rate.[28]

Met-Ed (First Energy)

Met-Ed's residential TOU option only applies during the summer months from June to August. During these months, the off-peak rate is approximately three cents less than the on-peak rate for an on-peak

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[24] Rates are rounded to the nearest cent in the text, but the on-peak to off-peak price ratios are calculated using rates expressed to the fifth decimal place.

[25] PECO Energy Company. 2021-2022 Default Service Program Time-of-Use Annual Report. Docket Number P-2020-3019290. October 21, 2022.

[26] As evidenced by having previously applied for an EV-related rebate.

[27] Riders and surcharges were generally excluded from our analysis. However, PPL's residential distribution rate as presented in its tariff includes three riders: Act 129 compliance rider, the universal service rider, and the storm damage expense rider. These riders are included in the values reported here.

[28] PPL Electric Utilities. PPL Electric's Default Service Program, Billing & Load Data, Available at: https://ppldsp.com/wp-content/uploads/2022/09/BillingData-2010updated13Sept2022.xlsx.

to off-peak price ratio of 1.3 to 1. The on-peak period in the summer lasts 12 hours each day from 8 am – 8 pm weekdays. Because the TOU rates only apply for three months out of the year, this rate structure provides customers with potential annual savings of just $11 for charging off-peak compared to charging on the standard residential rate.

Duquesne Light Company

Since June 2021, Duquesne Light has offered an Electric Vehicle Time-of-Use (EV-TOU) Pilot rate which provides time-differentiated supply charges. This rate applies to the entire load at the customer's premises, rather than only the EV load. Customers on this rate can save six to seven cents (depending on season) if they charge during the super-off-peak period relative to the on-peak period for an on-peak to off-peak price ratio of 1.6 to 1. The on-peak duration is eight hours from 1 pm – 9 pm. This rate offers $110 in annual savings compared to charging under the standard residential rate.

Approximately 7,300 EV customers take service from Duquesne Light. The utility offers a $50 incentive for customers with EVs to register with the utility, which enables the utility to provide education and outreach on EV rates to these customers through mail or email. Although 1,644 customers have claimed the registration incentive, only 522 customers have enrolled in the EV-TOU rate as of December 2022.[29]

Residential Rate Summary

All of the Pennsylvania utilities surveyed offer whole-home TOU rates for residential customers, and none impose demand charges on these customers. While the TOU rates offer potential savings relative to the flat rate for customers who charge during off-peak hours, these savings total less than $10/month for an EV customer charging 300 kWh/month off-peak. In one case, the potential savings amount to less than $1/month. It is unlikely that this magnitude of savings will drive high levels of customer enrollment in the TOU rates or provide noticeable additional cost savings for EV customers. The bundled rates[30] offered as of May 2022 are summarized in Table 3 below.

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[29] Personal communications with Emily Phan-Gruber and Lindsay Baxter of Duquesne Light Company on June 27, 2022.

[30] Bundled rates include generation, transmission, and distribution costs, but exclude riders and surcharges.

Table 3. Comparison of residential flat rates and TOU rates

	PECO	*PPL*	*Met-Ed (FirstEnergy)*	*Duquesne Light*
Fixed Charge ($/month)	$10.51	$16.50	$11.25	$12.50
Bundled TOU Rates ($/kWh)				
Non-Summer - On-Peak	$0.29	$0.14	$0.12	$0.19
Non-Summer - Off-Peak	$0.13	$0.13	$0.12	$0.13
Non-Summer Super-Off-Peak	$0.11			$0.12
Summer - On-Peak	$0.29	$0.13	$0.14	$0.18
Summer - Off-Peak	$0.13	$0.10	$0.10	$0.13
Summer - Super-Off Peak	$0.11			$0.12
Standard Bundled Flat Rate ($/kWh)	$0.14	$0.13	$0.12	$0.15
Potential annual savings for charging 300 kWh/month on off-peak vs. flat	**$115.78**	**$64.48**	**$11.07**	**$109.81**

None of the utilities surveyed offer EV-only TOU rates for residential customers. Although it may be technically possible for some residential customers to separately meter their garage or other parking area, the cost of doing so likely presents a significant barrier. The costs of installing a second meter may include electrician labor and materials as well as an additional service charge from the utility.

Based on the available data, we note that enrollment in whole-home TOU rates is low in Pennsylvania. Low enrollment could be due to a variety of factors, including the relative newness of the rates, impacts of the COVID-19 pandemic (with customers home more, they may be less willing to switch to a TOU rate), as well as minimal potential savings from shifting load.

Commercial Rates

Most Pennsylvania utilities provide a TOU option for supply service for commercial and industrial customers, but not for distribution rates. The distribution rates typically feature a form of non-coincident demand charges, although some utilities are piloting programs to mitigate these charges for DCFC customers. In addition, transmission rates may also include demand charges.

For each of the utilities' commercial rates, we estimated the potential savings from shifting 300 kWh of EV charging load from the standard flat generation rate to the off-peak TOU rate, where TOU generation rates are available.

Separately, we estimated the monthly distribution bill and effective $/kWh distribution rate for several different types of vehicles and charging configurations, as shown in Table 4 below. The effective distribution rate (in $/kWh) was estimated by calculating the monthly distribution bill for customers (which is driven primarily by demand charges)[31] and dividing by the customer's energy consumption (kWh) as shown in Table 4. Riders and surcharges were excluded in our analysis.

We also report the effective bundled rate (generation, transmission, and distribution, excluding riders and surcharges) for customers who take service on the utility's default supply rate. However, we note that approximately 41 percent of non-residential customers take generation supply service from a competitive generation supplier,[32] and that these rates may differ from the default supply service rate offered by the electric utilities. Data indicate that customers who take service from competitive generation suppliers do not do so on TOU rates, but that 4 percent of these customers take service on hourly rates or real-time-pricing rates.[33]

In each scenario modeled, we assumed that vehicles are capable of staggering charging so that not all vehicles begin charging at the same time. We report the cost of DCFC charging at 5 percent load factor for each utility and present the full results of all scenarios at the end of this section.

Table 4. Scenarios modeled for commercial rates

	Load Factor	Number of Vehicles at Site	Max Simultaneous Demand / Vehicle	Monthly Energy (kWh)
DCFC	5%	4	150	21,900
	10%	4	150	43,800
Transit Bus	10%	25	49	89,608
	37%	25	13	89,608
School Bus	10%	20	48	70,082
	34%	20	14	70,082
Medium Duty Truck	10%	30	18	39,364
	23%	30	8	39,364
Tractor-Trailer	25%	10	150	275,180
	61%	10	62	275,180

[31] The site demand in each scenario is the product of the number of vehicles and maximum simultaneous demand per vehicle.

[32] Approximately 25% of residential customers in Pennsylvania take service from a competitive electric generation supplier, rather than on their electric utility's default supply service rate. *See:* Pennsylvania Public Utilities Commission, Bureau of Technical Utility Services. Retail Electricity Choice. January 2023. Available at https://www.puc.pa.gov/media/2203/retail-elec-choice-report-21draft11622-communications-edits-with-covers-011323.pdf.

[33] Through 2021, no customers were enrolled on TOU rates through a competitive generation supplier. Pennsylvania Public Utilities Commission, Bureau of Technical Utility Services. Retail Electricity Choice. January 2023. Available at https://www.puc.pa.gov/media/2203/retail-elec-choice-report-21draft11622-communications-edits-with-covers-011323.pdf.

PECO

PECO's General Service rate includes a non-coincident demand charge of $8.81/kW assessed based on the customer's maximum demand during the month. The optional volumetric TOU rate has three periods: an on-peak, off-peak, and super-off-peak period. The on-peak to off-peak price ratio for the bundled volumetric TOU rate is nearly 5 to 1 (approximately $0.16 to $0.03/kWh). This is the largest price ratio of any of the Pennsylvania utilities' TOU rates. For comparison, the standard bundled volumetric rate is $0.07/kWh. However, only customers with demands up to 100 kW are eligible for TOU rates, as customers with demands of 100 kW or more that take supply service from the utility are required to take service on hourly rates.

Under this schedule, customers could save approximately $131/year on a per-vehicle basis by charging during the super-off-peak hours, assuming 300 kWh/vehicle/month.

The non-coincident demand charge encourages customers to flatten their load profiles, but, by itself, does not encourage customers to shift that load to off-peak hours. To mitigate the impact of the demand charges, PECO implemented a temporary demand charge discount for public DCFC providers available until June 2024. This discount provides an on-bill credit equivalent to 50 percent of the customer's connected DCFC nameplate capacity.[34] This rider helps to alleviate some of the operating cost hurdles from demand charges faced by DCFC providers, but its expiration in 2024 means that new DCFC stations will not benefit from the discount for long.

We estimate that a DCFC station with a monthly demand of 600 kW and a 5 percent load factor would face an effective distribution rate of $0.24/kWh without the DCFC discount and an effective distribution rate of $0.12/kWh with the DCFC discount. If coupled with the standard (flat) generation and transmission charge, this would result in an effective bundled rate of $0.31/kWh without the DCFC discount and $0.19/kWh with the DCFC discount.

PPL

Under PPL's Rate Schedule GS-1, customers pay a non-coincident distribution demand charge of $4.36/kW[35] alongside a flat volumetric transmission rate and a flat supply rate or the optional supply TOU rate. The bundled summer TOU on-peak rate ($0.09/kWh) is in effect from June through November and is only three cents higher than the summer off-peak rate ($0.06/kWh), while the winter bundled on-peak rate ($0.10/kWh) is only one cent higher than the winter bundled off-peak rate ($0.09/kWh). For comparison, the bundled flat volumetric rate is approximately $0.10/kWh.

[34] For example, a DCFC station with a nameplate charging capacity of 200 kW would receive a demand credit each month of 100 kW. Since, the station's billed distribution demand may not reach 200 kW in any month, this program could provide more than a 50% reduction in distribution demand charges.

[35] A customer's monthly demand is assessed on a 15-minute basis.

Over the course of a year, customers who switch from charging under the standard supply rate to charging during an off-peak TOU rate would save $62/vehicle/year, assuming 300 kWh/vehicle/month. We estimate that a DCFC station with a monthly demand of 600 kW and a 5 percent load factor would face an effective distribution rate of $0.12/kWh under PPL's GS-1 rate schedule. If coupled with the standard (flat) generation and transmission charge, this would result in an effective bundled rate of $0.22/kWh.

Met-Ed (First Energy)

Met-Ed offers two general service rates that are most applicable to EV customers: GS-Medium (up to 400 kW of demand) and GS-Large (demand greater than or equal to 400 kW). GS-Medium features a demand charge of $5.11/kW. GS-Large has a $4.16/kW demand charge. For both rate schedules, the demand charge is assessed based on the greater of the customer's maximum 15-minute measured demand during on-peak hours, 40 percent of the maximum demand during off-peak hours, or 50 percent of the highest billing demand during the preceding eleven months.

Met-Ed does not offer TOU supply rates to its general service customers. Instead, GS-Medium customers with demand less than 100 kW[36] may choose to take supply service on the Company's flat default supply rate (approximately $0.07/kWh) or on its hourly pricing default service rider. All GS-Large customers taking supply service from the utility are served on the hourly pricing default service rider.

We estimate that a DCFC station with a monthly demand of 600 kW and a 5 percent load factor would face an effective distribution rate of $0.13/kWh under Met-Ed's GS-Large rate schedule. There is no flat default supply rate available to GS-Large customers for estimating a bundled rate. However, if the flat default supply rate were the same as for GS-Medium (approximately $0.07/kWh), the effective bundled rate would be $0.20/kWh.[37]

Duquesne Light Company

Duquesne Light offers two commercial and industrial rate schedules most applicable to EV customers: Rate GM >25 kW for medium general service customers with demand between 25 – 300 kW, and Rate GL for large general service customers (demand at or exceeding 300 kW but less than 5,000 kW).

Rate GM >25 kW has a $7.26/kW non-coincident distribution demand charge (measured as the maximum 15-minute usage in the billing period) and a $1.57 transmission demand charge. Rate GL assesses a minimum distribution demand charge of $3,500 applicable to the first 300 kW or less of demand. Once a customer's demand passes 300 kW, there is an additional $9.80/kW non-coincident distribution demand charge (also assessed on a 15-minute basis). In addition, customers pay a transmission demand charge of $4.97/kW.

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[36] As measured in any month from April 1 – March 31 of the preceding year.

[37] Values may not add due to rounding.

Only customers on the GM rate schedule with demand less than 200 kW are eligible to take supply service under the Company's EV-TOU pilot rate. Large general service customers who take supply service from the utility are required to do so on the day-ahead hourly price rider.

For GM >25 kW customers on the EV-TOU supply rate, the bundled on-peak rate is approximately 6 cents higher than the super-off-peak rate during the summer and 9 cents higher in the winter. The on-peak period is from 1 pm – 9 pm Monday through Sunday. If customers charge during the super-off-peak under this TOU option, they would save $135/vehicle/year relative to the flat rate (which is priced at approximately $0.09/kWh).

We estimate that a DCFC station with a monthly demand of 600 kW and a 5 percent load factor would face an effective distribution rate of $0.29/kWh under Duquesne Light's GL rate schedule. The transmission charge for GL customers is $4.97/kW, which adds another $0.14/kWh to the effective rate paid by a DCFC customers with a 5 percent load factor. There is no flat default supply rate available to GL customers for estimating a fully bundled rate. However, if the flat default supply rate were the same as for GM >25 kW, the effective bundled rate would be $0.50/kWh.

Commercial Rates Summary

All of the Pennsylvania electric utilities impose non-coincident distribution demand charges on commercial customers, although Met-Ed's rates only measure 40 percent of the demand during off-peak hours. Duquesne Light assesses a transmission demand charge of $1.57/kW for GM customers and $4.97/kW for GL customers. Non-coincident demand charges can be challenging for DCFC customers and customers who seek to electrify their fleets, as the charges apply regardless of the time of day when a customer's maximum demand occurs. Thus, fleets that charge overnight are charged the same as those that charge during the middle of the day. For distribution equipment shared by many customers, such as feeders and substations, non-coincident demand charges may poorly reflect the actual costs caused by these customers. In addition, non-coincident demand charges do not provide price signals that encourage customers to shift their load to off-peak hours.

Several Pennsylvania utilities offer TOU supply rates to commercial customers, which provide moderate savings for customers who charge off-peak. PECO, Met-Ed, and Duquesne Light require their larger customers to take supply service on hourly pricing rates, which can introduce significant volatility to customers' bills, but may offer greater savings than TOU rates for customers who charge overnight. Such hourly rates can pose a challenge to customers who are considering electrifying their fleets due to the potential risk of price spikes but may also provide substantial cost savings.

Table 5. Comparison of commercial rates

	PECO	PPL	Met-Ed		Duquesne Light	
	GS	*GS-1*	*GS-Medium*	*GS-Large*	*GM*	*GL*
Customer or Min. Charge ($/month)	24.21	22.00	24.07	270.09	60.00	3,500
Distribution Demand Charge ($/kW)	8.81 (50% DCFC credit)	4.36	5.11	4.16	7.26	9.80 >300 kW
Transmission Demand Charge ($/kW)	n/a	n/a	n/a	n/a	1.57	4.97
Transmission Volumetric Charge ($/kWh)	0.00	0.02	n/a*	n/a*	0.01	0.01
Generation TOU Rates ($/kWh)						
Non-Summer Peak	0.16	0.08	n/a	n/a	0.10	n/a
Non-Summer Off-Peak	0.05	0.07	n/a	n/a	0.05	n/a
Non-Summer Super-Off-Peak	0.03	n/a	n/a	n/a	0.04	n/a
Summer Peak	0.16	0.07	n/a	n/a	0.10	n/a
Summer Off-Peak	0.05	0.04	n/a	n/a	0.05	n/a
Summer Super-Off-Peak	0.03	n/a	n/a	n/a	0.04	n/a
Non-TOU Generation Flat Rate ($/kWh)	0.06	0.08	0.10*	Hourly*	0.07	Hourly

**Note: Met-Ed does not report transmission rates separately. Transmission rates are included in the table in the generation charge.*

The impact of the demand charge on the effective distribution rate (i.e., the distribution bill divided by energy consumption) by load factor can be seen in Figure 4 below. At a load factor of 2 percent, the effective distribution rate ranges from $0.29/kWh to $0.68/kWh. At load factors of 10 percent, the effective distribution rate ranges from $0.06/kWh to $0.14/kWh.

It is also important to note the impact of non-distribution demand charges on the effective rates paid by customers. A DCFC customer with a 2 percent load factor would face an effective transmission rate of $0.34/kWh on Duquesne Light's GL rate schedule. This would increase the effective bundled rate to over $1.00/kWh.

Figure 4. Effective distribution rates for Pennsylvania utilities

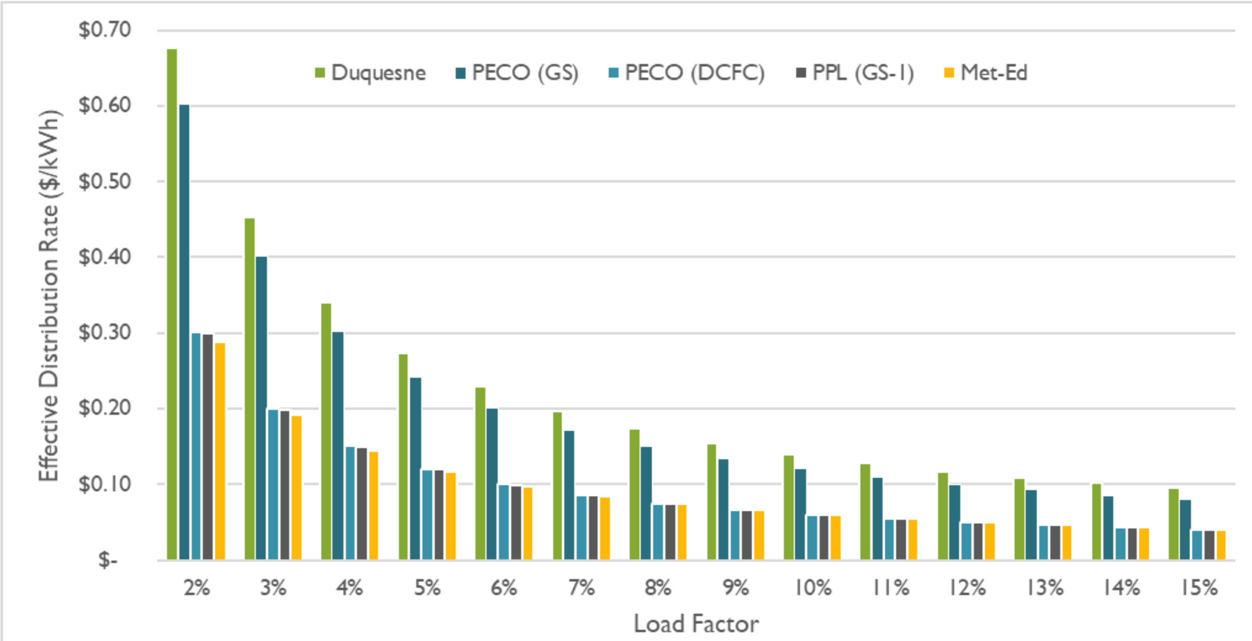


Table 6. Effective distribution rate comparison across various charging scenarios

	Load Factor	PECO		PPL	Met-Ed		Duquesne Light	
		GS	*DCFC*	*GS-1*	*GS-Med*	*GS-Large*	*GM*	*GL*
		$/kWh	*$/kWh*	*$/kWh*	*$/kWh*	*$/kWh*	*$/kWh*	*$/kWh*
DCFC	5%	0.24	0.12	0.12		0.13		0.29
	10%	0.12	0.06	0.06		0.06		0.15
Transit Bus	10%	0.12		0.06		0.06		0.14
	37%	0.03		0.02	0.02			0.04
School Bus	10%	0.12		0.06		0.06		0.14
	34%	0.04		0.02	0.02		0.04	
Medium Duty Truck	10%	0.12		0.06		0.06		0.15
	23%	0.05		0.03	0.03		0.06	
Tractor-Trailer	25%	0.05		0.02		0.02		0.06
	61%	0.02		0.01		0.01		0.02

1.6. Future Impacts of EV Load

Electric vehicle adoption in Pennsylvania will have considerable impacts on total electricity consumption, transportation fuel consumption, CO_2 emissions, and emissions of other pollutants. Depending on the price signals provided to customers through rates, and how customers respond to these prices, EVs may also substantially impact peak demand and electricity costs in Pennsylvania. To analyze these impacts, we first forecasted EV adoption in Pennsylvania through 2030, as described below, and then applied charging load curves to estimate the impacts on peak demand.

Pennsylvania Electric Vehicle Forecasts

Our analysis relied on forecasted EV adoption from Bloomberg New Energy Finance's (BNEF) 2022 *Electric Vehicle Outlook*, as reported by Bank of America Global Research, adjusted to Pennsylvania.[38] To account for the uncertainty of EV adoption forecasts and the sensitivity of results to EV adoption forecasts, we also created EV adoption sensitivities that are 30 percent higher and lower than the base BNEF forecast. We selected 30 percent as a sensitivity because the historical standard deviation for the year-to-year rate of change in Pennsylvania's market share was 27 percent.

Light-Duty Vehicle Adoption Forecast

Under the base case forecast, EVs are projected to comprise nearly 9 percent of both light-duty car and truck stock in Pennsylvania by 2030. Table 7 shows the annual stock of electric light-duty cars and trucks, along with +/- 30 percent sensitivities.

Table 7. Forecast of light-duty electric vehicle adoption in Pennsylvania (stock)

Vehicle Type	Sensitivity	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Light-Duty Cars (stock)	Base Case	0.3%	0.4%	0.6%	0.9%	1.2%	1.7%	2.3%	3.2%	4.3%	5.6%	7.2%	8.9%
	+30%	0.3%	0.5%	0.7%	1.1%	1.6%	2.2%	3.0%	4.1%	5.6%	7.3%	9.3%	11.6%
	-30%	0.2%	0.3%	0.4%	0.6%	0.8%	1.2%	1.6%	2.2%	3.0%	3.9%	5.0%	6.3%
Light-Duty Trucks (stock)	Base Case	0.2%	0.4%	0.6%	0.8%	1.2%	1.7%	2.3%	3.1%	4.1%	5.5%	7.0%	8.7%
	+30%	0.3%	0.5%	0.7%	1.1%	1.5%	2.2%	2.9%	4.0%	5.4%	7.1%	9.0%	11.3%
	-30%	0.2%	0.3%	0.4%	0.6%	0.8%	1.2%	1.6%	2.2%	2.9%	3.8%	4.9%	6.1%

[38] Bloomberg New Energy Finance (BNEF). 2022. Long-Term Electric Vehicle Outlook, as reported by BofA Global Research. https://rsch.baml.com/report?q=WCfBJmf-PxHbUk763NuZcw. Past BNEF forecasts have been relatively accurate in forecasting the national EV adoption trends from 2017 to 2021, and the 2021 BNEF forecast also aligns with forecasts from other leading industry sources, such as IHS Markit, which forecasts that EV sales will reach 32% of total light vehicle sales by 2030 in the United States, compared to 35% forecasted by BNEF. Because BNEF's forecast is provided at a national level, we adjusted the BNEF forecast by the ratio of historical EV adoption rates in Pennsylvania to the national average. Historically, the share of EVs in Pennsylvania has been approximately 57% of national levels for light duty vehicles and 55% of national levels for trucks, as calculated using Alliance for Automotive Innovation data and Federal Highway Administration (FHWA) Highway Statistics available here: https://www.fhwa.dot.gov/policyinformation/statistics.cfm.

Medium- and Heavy-Duty Vehicles

Medium- and heavy-duty vehicles are grouped into four different categories: medium-duty freight trucks, heavy-duty single unit freight trucks (trucks on a single-unit frame), heavy-duty combination freight trucks (trucks with more than one unit), and buses. Medium-duty vehicles are vehicles with a gross vehicle weight between 10,001 and 26,000 pounds, whereas heavy-duty vehicles are vehicles with a gross vehicle weight greater than 26,000 pounds.

Table 8 summarizes our estimates of the number of medium- and heavy-duty vehicles that have been electrified in Pennsylvania through 2021.

Table 8. Current stock of medium- and heavy-duty vehicles in Pennsylvania

Category	Total Stock	EV	Non-EV	Percent Electrified
Medium-duty freight trucks	340,471	590	339,879	0.17%
Heavy-duty single unit freight trucks	124,896	51	124,845	0.04%
Heavy-duty combination freight trucks	96,724	57	96,667	0.06%
Buses	56,462	320	56,147	0.56%

As with light-duty vehicles, we used BNEF's 2022 forecast as reported by Bank of America Global Research to forecast future adoption of medium- and heavy-duty EVs.[39] This forecast provides the percentage of vehicles electrified in each year. Because the percentage of electric medium- and heavy-duty vehicles in Pennsylvania has been the same as nationally, no adjustments of the national BNEF forecast were necessary.[40] As with the light-duty vehicle forecast, we created sensitivities that are 30 percent higher and lower for both medium- and heavy-duty vehicles.

Medium-Duty Vehicle Forecast

By 2030, EVs are projected to make up 4.8 percent of medium-duty vehicle stock in Pennsylvania, according to the base case forecast. Table 9 shows medium-duty EV adoption in Pennsylvania, with 30 percent sensitivities.

[39] Bloomberg New Energy Finance (BNEF). 2022. Long-Term Electric Vehicle Outlook, as reported by BofA Global Research. https://rsch.baml.com/report?q=WCfBJmf-PxHbUk763NuZcw.

[40] As determined using state-level data from the Federal Highway Administration (https://www.fhwa.dot.gov/policyinformation/statistics.cfm) relative to national data from the U.S. Energy Information Administration's 2019 Annual Energy Outlook *Freight Transportation Energy Use,* available at https://www.eia.gov/opendata/v1/qb.php?category=3161918.

Table 9. Forecast of medium-duty electric vehicles in Pennsylvania (stock)

Vehicle Type	Sensitivity	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Medium Freight (stock)	Base Case	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.6%	1.0%	1.6%	2.5%	3.5%	4.8%
	+30%	0.0%	0.0%	0.0%	0.0%	0.1%	0.4%	0.8%	1.3%	2.1%	3.3%	4.6%	6.2%
	-30%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%	0.7%	1.1%	1.8%	2.5%	3.4%

Heavy-Duty Vehicle Forecast

Table 10 shows the forecast of heavy-duty EV adoption in Pennsylvania. By 2030, EVs will make up 6.2 percent of all heavy-duty vehicle stock in Pennsylvania, according to the base case forecast.

Table 10. Forecast of heavy-duty electric vehicle stock in Pennsylvania (excluding buses)

Vehicle Type	Sensitivity	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Heavy Duty (stock)	Base Case	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.8%	1.4%	2.2%	3.3%	4.6%	6.2%
	+30%	0.0%	0.0%	0.0%	0.0%	0.1%	0.4%	1.0%	1.8%	2.9%	4.3%	6.0%	8.1%
	-30%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.6%	1.0%	1.5%	2.3%	3.2%	4.3%

Bus Forecast

Table 11 shows the forecast of EV bus adoption in Pennsylvania. The base case forecast indicates that electric buses will comprise 30.1 percent of bus stock in Pennsylvania by 2030.

Table 11. Forecast of electric buses in Pennsylvania (stock)

Vehicle Type	Sensitivity	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Bus (stock)	Base Case	0.6%	1.7%	2.2%	3.0%	4.3%	5.9%	8.3%	11.0%	14.5%	18.6%	24.1%	30.1%
	+30%	0.8%	2.2%	2.9%	3.9%	5.6%	7.7%	10.8%	14.3%	18.9%	24.2%	31.3%	39.1%
	-30%	0.4%	1.2%	1.5%	2.1%	3.0%	4.1%	5.8%	7.7%	10.2%	13.0%	16.9%	21.1%

Impacts of Forecasted EV Adoption in Pennsylvania

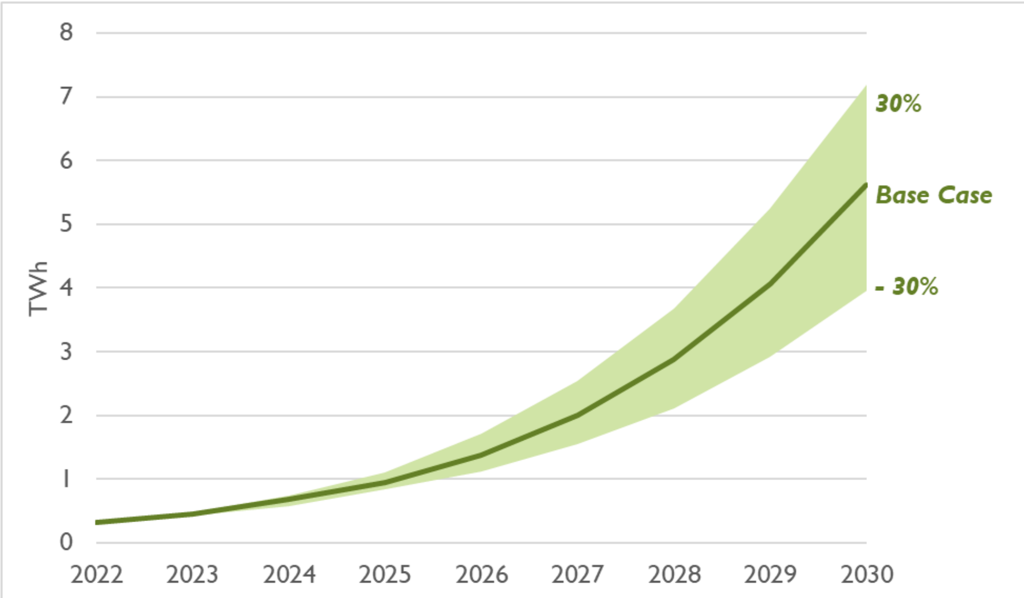
Using our forecasts of EVs in Pennsylvania, we calculated the impacts of increased EV adoption on electricity consumption and peak demand, electricity costs, fuel consumption, and emissions.

Electricity Consumption

The increased number of EVs of all types on the road will lead to greater electricity consumption in Pennsylvania. Our modeling projects an increase in electricity consumption of 5.6 terawatt-hours (TWh) by 2030 due to EV adoption (Figure 5). Relative to Pennsylvania's expected total retail electricity sales of

138 TWh in 2030,[41] this represents an increase of approximately 4 percent over the baseline forecast for 2030.

Figure 5. Total annual energy consumption from EVs (all vehicle types), with ±30% sensitivity bands



Of the additional 5.6 TWh of electricity consumed by EVs, approximately two-thirds (3.5 TWh) of the impact is due to light-duty EV adoption and one-third of the impact (2.2 TWh) is due to medium- and heavy-duty EVs. Our sensitivities predict a range between 2.4 and 4.4 TWh by 2030 for light-duty EVs and 1.5 TWh to 2.8 TWh by 2030 for medium- and heavy-duty EVs.

We then estimated the increased sales from forecasted EV adoption for the six largest utilities in Pennsylvania,[42] as shown in Table 12. Although the average increase is approximately 4 percent, the increase varies across utilities from a low of 3.5 percent (West Penn) to a high of 5.65 (Duquesne Light).

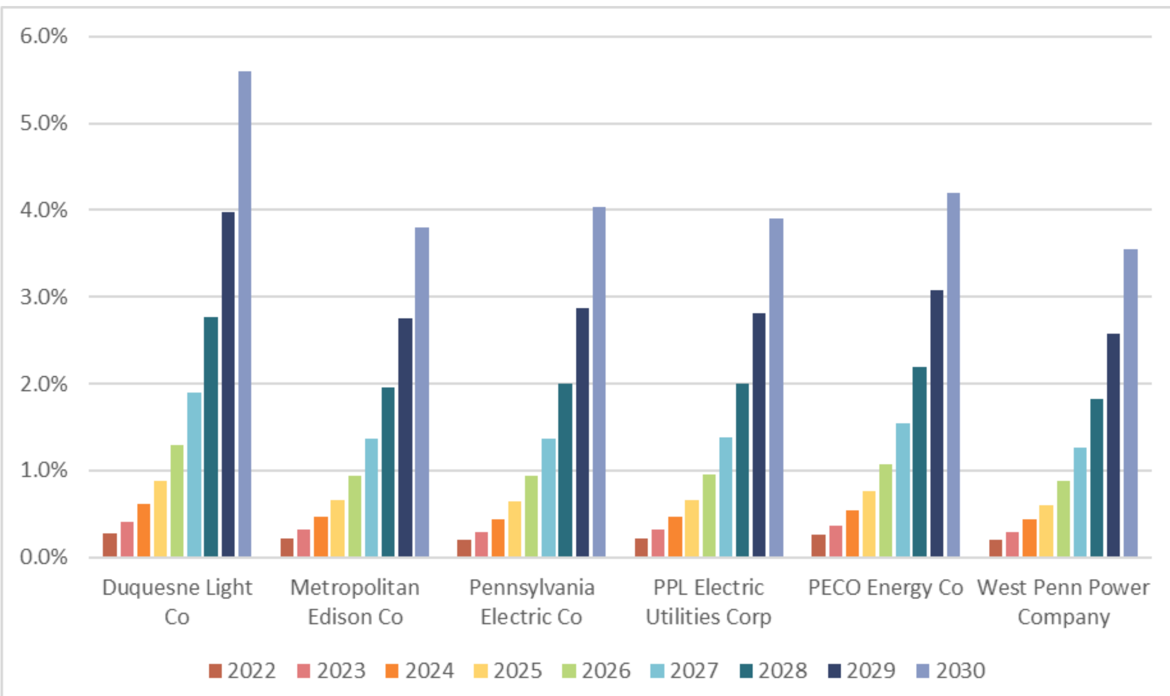
[41] Using average annual growth estimates from 2021 to 2026, for each utility's annual sales, provided by Pennsylvania Public Utility Commission. August 2022. Electric Power Outlook for Pennsylvania 2021-2026, p. 29-41. Available at https://www.puc.pa.gov/media/2013/epo_report_2022.pdf. To estimate sales beyond 2026, we assumed that the 2021-2026 annual growth rate remained the same to 2030.

[42] The total forecasted electric light-duty vehicles for each year were allocated to each utility based on their proportion of residential customers in Pennsylvania in 2021. Medium- and heavy-duty vehicles, including buses, were allocated to each utility based on their proportion of commercial and industrial energy sales in 2021.

Table 12. Additional electricity sales (TWh) and percent increase relative to utility-specific baseline forecasts

Utility		2022	2023	2024	2025	2026	2027	2028	2029	2030
Duquesne Light	EV TWh	30	50	70	100	150	210	310	430	600
	% change	0.3%	0.4%	0.6%	0.9%	1.3%	1.9%	2.8%	4.0%	5.6%
Met-Ed	EV TWh	30	50	70	100	140	210	300	420	580
	% change	0.2%	0.3%	0.5%	0.7%	0.9%	1.4%	2.0%	2.8%	3.8%
Penelec	EV TWh	30	50	70	100	140	200	290	420	580
	% change	0.2%	0.3%	0.4%	0.6%	0.9%	1.4%	2.0%	2.9%	4.0%
PPL	EV TWh	70	120	180	250	360	520	750	1,000	1,500
	% change	0.2%	0.3%	0.5%	0.7%	1.0%	1.4%	2.0%	2.8%	3.9%
PECO	EV TWh	90	140	200	280	410	590	840	1,200	1,600
	% change	0.2%	0.3%	0.5%	0.8%	1.1%	1.5%	2.2%	3.1%	4.2%
West Penn Power	EV TWh	40	60	90	120	180	260	380	540	760
	% change	0.2%	0.3%	0.4%	0.6%	0.9%	1.3%	1.8%	2.6%	3.5%

Figure 6. Electricity consumption increase relative to the baseline forecast



The additional load from EV charging (and associated revenues) has the potential to put upward or downward pressure on electricity rates, depending on when the load occurs. If the load primarily occurs during high-cost hours, then the cost of serving this additional load could outweigh the revenues generated from EV charging. Conversely, if the load primarily occurs during low-cost hours, then the revenues from EV charging could outweigh the costs, resulting in downward pressure on electricity rates for all customers. These impacts are discussed in the following sections.

Peak Demand

A large portion of electric system costs are directly related to peak demand on the utility's system at different levels:

- At the bulk power system level, peak demand drives electric generation capacity costs. This capacity is purchased in the wholesale market (administered by PJM, a regional transmission organization) based on each utility's demand during the highest peak load hours across the region.[43] In recent years, these peak hours have tended to occur during the late afternoon and early evening between the hours of 3 pm and 6 pm.[44]
- Transmission system costs are driven by peak loads in the applicable PJM transmission zone for each utility. For Pennsylvania utilities, these zonal peaks tend to occur during the summer between 3 pm and 7 pm.[45]
- Local distribution capacity costs are driven largely by peak demands at the substation and feeder level. These peaks vary across the distribution system, but the majority of the load tends to peak in a manner similar to the zonal (transmission) peaks. At the individual circuit level, however, peaks can be diverse.

The extent to which the adoption of EVs adds to peak capacity needs depends on how coincident that load is with the rest of the system load (at the wholesale market level, transmission zone level, and relevant distribution system level).

Based on simulated EV load profiles from the U.S. Department of Energy,[46] without rate designs that encourage customers to charge during off-peak hours, light-duty EV charging is likely to occur primarily during the early evening hours between the hours of 5 pm and 8 pm as drivers return home from work and plug in their vehicles. We estimate that more than 870,000 light-duty EVs will be on the road in Pennsylvania by 2030, potentially adding nearly 850 MW of peak demand when the system is most stressed in the early evening hours, resulting in peak demand at the generation and transmission levels increasing by approximately 2 percent.

By 2030, we estimate there will be approximately 30,900 electric medium- and heavy-duty freight trucks, and approximately 17,000 electric buses, including school buses and public transit buses, on Pennsylvania roads. While these vehicles' larger battery sizes mean they too can cause additional stress to the electric grid, their charging patterns tend to be more evenly distributed across the hours of the day. For instance, based on load profiles developed by the Lawrence Berkeley National Laboratory,[47]

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[43] The PJM region spans 13 states and the District of Columbia.

[44] Based on a review of PJM RTO Coincident Peaks (5CP), from 2018 through 2022, available at www.pjm.com.

[45] Based on a review of PJM Network Transmission Service Peak Loads (metered demand coincident with zonal peak loads) from 2018 through 2022, available at www.pjm.com.

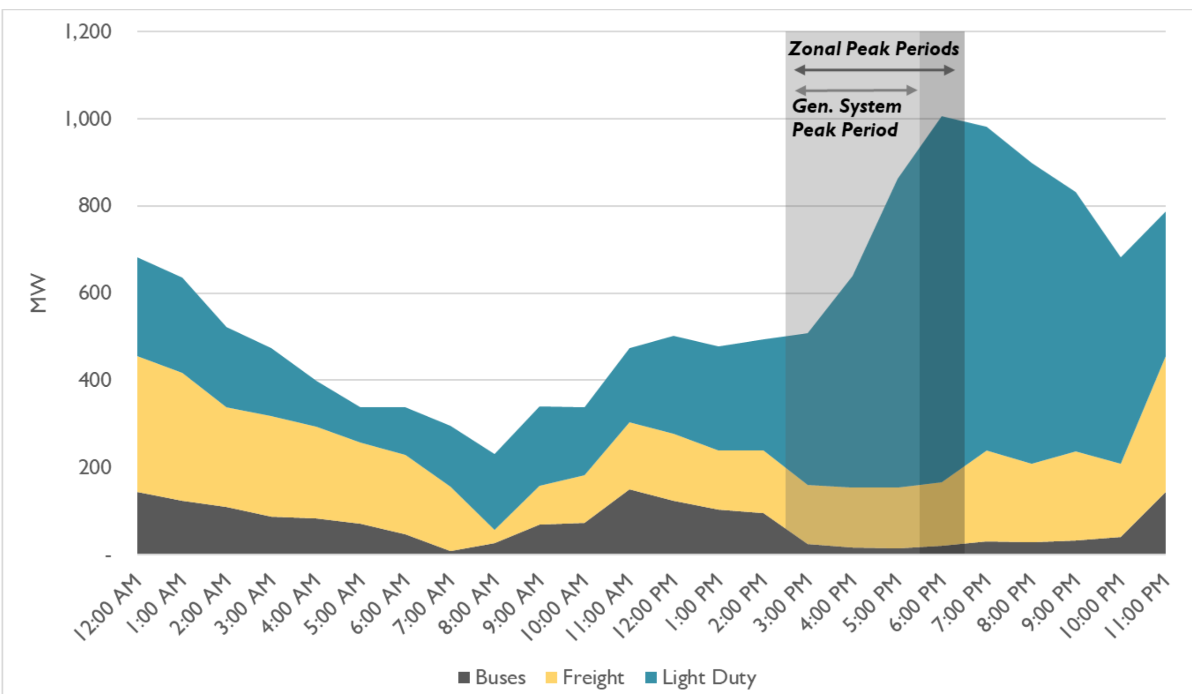
[46] U.S. Department of Energy, Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite, available at: https://afdc.energy.gov/evi-pro-lite/load-profile.

[47] Lawrence Berkeley National Laboratory. HEVI-Pro load profiles. Provided in August 2022.

transit buses tend to charge overnight when ridership is lowest, and school buses tend to charge most frequently during school hours or overnight. Similarly, a significant portion of freight vehicle charging occurs overnight (after 10 pm and before 4 am), although approximately 13 percent of freight charging still occurs during afternoon peak periods between 3 and 7 pm.

The combined load impact of light-duty vehicles, medium- and heavy-duty freight vehicles, and buses during peak periods could add up to 1,000 MW of demand by 2030, with light-duty vehicles responsible for the majority of this additional demand (Figure 7). The 920,000 EVs on the road by 2030 may also shift the transmission and generation system peak periods more reliably towards 6 to 7 pm and away from the 3 to 5 pm peaks we have historically seen. We estimate that the additional capacity costs associated with EVs could total an additional $85 million annually[48] in 2030, when an estimated 920,000 EVs will be on the road. Our sensitivities predict a range of additional costs associated with increased EV demand of between $60 million and $108 million in 2030 (as displayed in Figure 8).[49] (The net impact of EVs on electricity rates is discussed in the next section.)

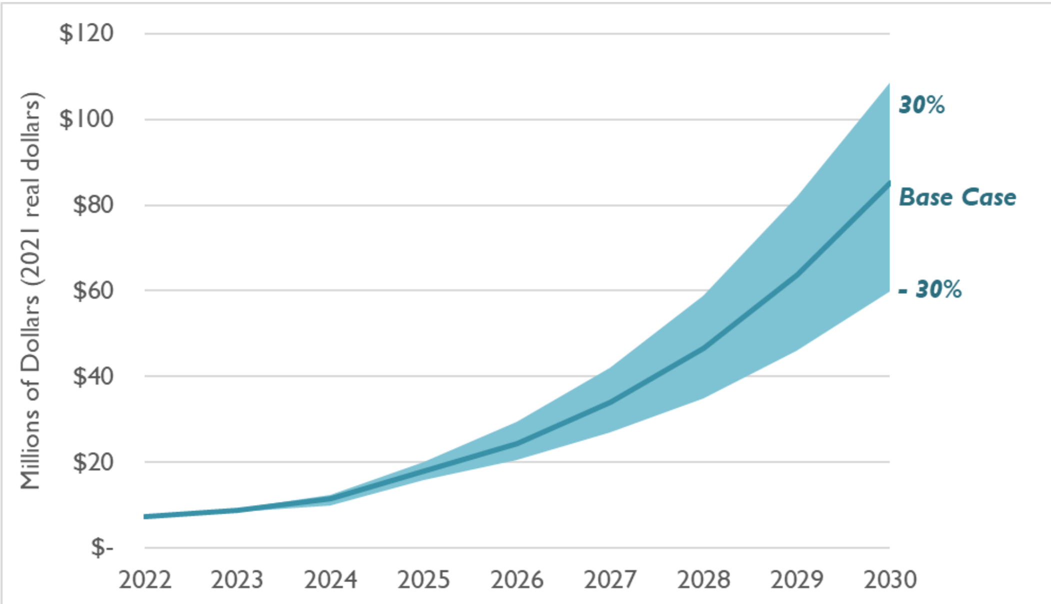
Figure 7. Combined load impacts of buses, medium- and heavy-duty vehicles, and light-duty vehicles, in 2030 without alternative rate designs. Typical zonal and generation system peak periods are highlighted.



48 Our sensitivities predict a range of $60 million - $108 million in additional costs from EV demand in 2030. All dollar values are presented in 2021 real dollars.

49 Marginal transmission and distribution costs for each utility were sourced from data provided for energy efficiency cost-effectiveness analyses. Pennsylvania Public Utility Commission. Final Order. 2021 Total Resource Cost (TRC) Test. December 19, 2019, p. 45-50. Avoided cost of generation capacity were estimated using methodologies described by the Pennsylvania Public Utility Commission, December 2021. Total Resource Cost (TRC) Test, p. 42-45.

Figure 8. Forecasted increase in transmission costs, distribution costs, and generation capacity costs due to EV load without alternative rate designs (2021)



Distribution system costs, such as the upgrades to transformers and substations required to meet new demand, are responsible for roughly 65 percent of total costs, while generation capacity and transmission costs represent 25 percent and 10 percent of total cost impacts, respectively.

We estimate that 2030 peak demand across the utilities will be approximately 2.5 percent higher than baseline forecasts due to the additional demand from EVs, although the magnitude and associated costs vary by utility.[50] Utility-specific load and costs depend on the coincident demand during both the zonal peak periods (the timing of which varies, but is usually between 3 pm and 7 pm[51]) and the peak period for the entire PJM territory (historically between 3 pm and 6 pm[52]). Table 13 shows the additional average load for each utility during its historical zonal peak period, and the relative percent change compared to its baseline demand forecast.

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[50] Using utility-specific average annual growth estimates of demand for 2021 to 2026, provided by the Pennsylvania Public Utility Commission. August 2022. Electric Power Outlook for Pennsylvania 2021-2026, p. 29-41. Available at https://www.puc.pa.gov/media/2013/epo_report_2022.pdf. To estimate sales beyond 2026, we assumed that the 2021-2026 annual growth rate remained the same to 2030.

[51] Based on a review of PJM Network Transmission Service Peak Loads (metered demand coincident with zonal peak loads) from 2018 through 2022, available at www.pjm.com.

[52] Based on a review of PJM RTO Coincident Peaks (5CP), from 2018 through 2022, available at www.pjm.com.

Table 13. Transmission zone peak demand impacts from EVs and the percent change relative to the baseline forecast

Zonal Peak Impacts		2022	2023	2024	2025	2026	2027	2028	2029	2030
Duquesne Light	Additional Peak MW	4	4	8	11	16	22	32	45	62
	% change	0.1%	0.2%	0.3%	0.4%	0.6%	0.8%	1.1%	1.6%	2.2%
Met-Ed	Additional Peak MW	6	8	12	16	23	33	46	63	86
	% change	0.2%	0.3%	0.4%	0.5%	0.8%	1.1%	1.5%	2.1%	2.8%
Penelec	Additional Peak MW	4	6	9	12	17	25	35	49	68
	% change	0.1%	0.2%	0.3%	0.4%	0.6%	0.9%	1.3%	1.8%	2.5%
PPL	Additional Peak MW	13	18	27	37	51	73	103	140	200
	% change	0.2%	0.2%	0.4%	0.5%	0.7%	1.0%	1.4%	2.0%	2.7%
PECO	Additional Peak MW	17	24	35	48	67	95	130	180	250
	% change	0.2%	0.3%	0.4%	0.6%	0.8%	1.1%	1.6%	2.1%	2.9%
West Penn Power	Additional Peak MW	7	11	16	21	30	43	60	84	110
	% change	0.2%	0.3%	0.4%	0.6%	0.8%	1.1%	1.6%	2.2%	3.1%

Additional load coincident with zonal peaks is the driving force behind increased costs for transmission capacity, and also provides an indicator of the need for distribution network upgrades. Together, transmission and distribution costs represent three-quarters of incremental EV-related capacity costs in 2030. In addition, we project that the peak load increases that drive generation capacity needs will be similar in magnitude to the zonal coincident peak demand presented above in Table 13.

On a per-utility basis, the annual peak demand cost impacts range from approximately $4.3 million for Duquesne Light to almost $35 million for PECO in 2030, as shown in Table 14. We note that distribution costs vary widely, in large part due to very different estimates of marginal distribution costs for each utility.[53]

[53] Marginal distribution costs ranged from a low of $16/kW-year for Duquesne to $121/kW-year for PPL. Pennsylvania Public Utility Commission. Final Order. 2021 Total Resource Cost (TRC) Test. December 19, 2019, p. 45-50.

Table 14. Estimated increase in annual transmission costs, distribution costs, and generation capacity costs in 2030 (in real 2021 dollars) without alternative rate designs for each major utility

Utility	Transmission Capacity	Distribution Capacity	Generation Capacity	Total Capacity Costs
Duquesne Light	$1,640,000	$850,000	$1,850,000	**$4,340,000**
Met-Ed	$1,840,000	$5,130,000	$2,230,000	**$9,200,000**
Penelec	$1,760,000	$2,670,000	$2,210,000	**$6,640,000**
PPL[54]	--	$20,230,000	$5,650,000	**$25,880,000**
PECO	$5,270,000	$22,350,000	$7,030,000	**$34,650,000**
West Penn Power	$17,000	$2,270,000	$2,260,000	**$4,547,000**
Total	**$10,527,000**	**$53,500,000**	**$21,230,000**	**$85,257,000**

Net Impact on Rates

Electric vehicle charging will generate substantial new revenues for electric utilities. The overall impact of EVs on electric rates will depend on the extent to which these new revenues outweigh the costs of serving additional EV load, as discussed above.

To estimate the net impact on rates, we used the default charging patterns developed by the U.S. Department of Energy for light-duty vehicles[55] and Lawrence Berkeley National Laboratory[56] for medium- and heavy-duty vehicles, as depicted in Figure 7. We then compared these load profiles to each utility's load to determine the impacts on each utility's load factor (the ratio between average and peak demand). If EVs use the grid efficiently, average load will increase more than peak demand, benefitting all ratepayers by spreading the fixed costs of the grid over more electricity sales.

Our analysis reveals that the overall load factor for each utility remains relatively unchanged after adding the additional EV load under default charging patterns. This implies that, under the load profiles analyzed, EV load will not improve the overall efficiency of the grid or exert downward pressure on rates unless rates are adopted that encourage shifting of EV load to off-peak hours.

To illustrate our analysis, Figure 9 below depicts the load curve for Duquesne Light and the projected EV charging load over a 24-hour period (scaled to allow for comparison). The utility's current hourly load curve exhibits an afternoon peak between 3 and 5 pm, after which load declines until the next morning. The aggregate EV load curve is somewhat similar, but EV use peaks later in the day at around 7 pm.

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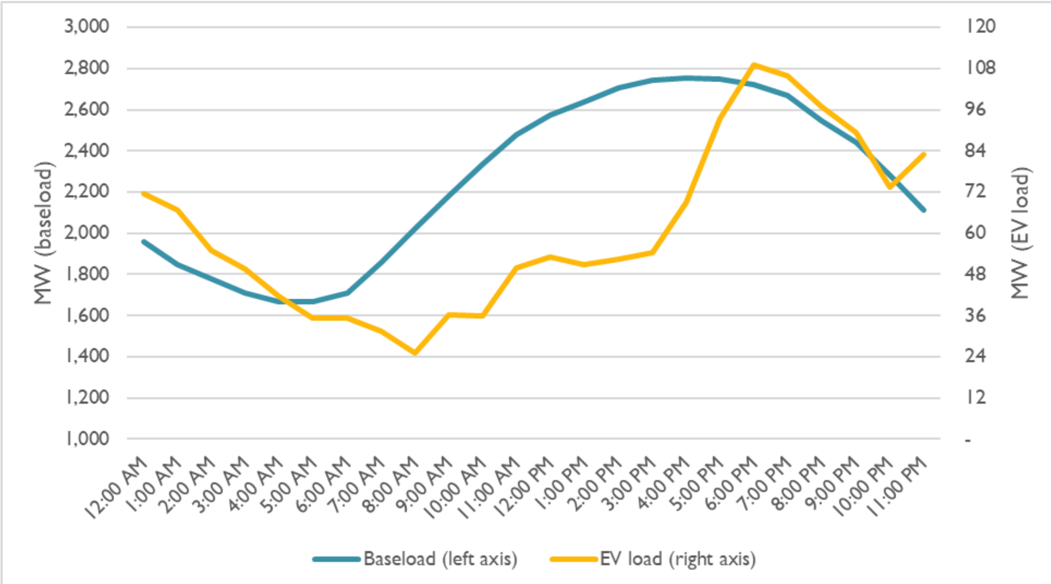
[54] Avoided transmission costs were not available for PPL.

[55] U.S. Department of Energy, Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite, available at: https://afdc.energy.gov/evi-pro-lite/load-profile.

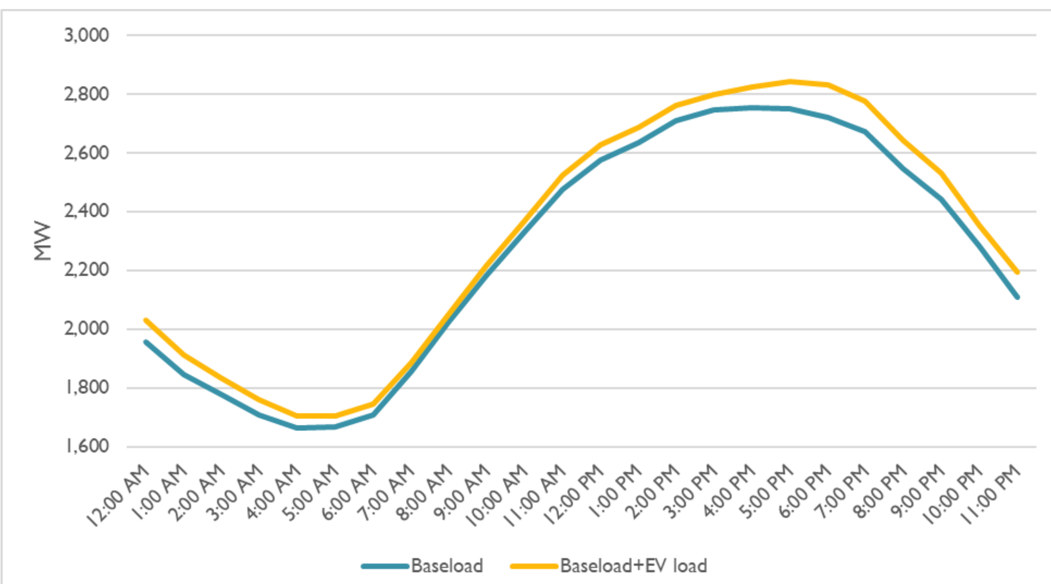
[56] Lawrence Berkeley National Laboratory. HEVI-Pro load profiles. Provided in August 2022.

Figure 9. Duquesne Light Company hourly load curve and forecast 2030 aggregate EV load curve



When the two load curves are added together as shown in Figure 10, the overall peak for Duquesne Light shifts to later in the day. Although peak demand increases, the average energy consumption over all hours is expected to increase relatively proportionately, resulting in minimal system load factor impacts.

Figure 10. Load curve for Duquesne Light Company before and after EV load in 2030



The projected minimal change to the overall system load factor by 2030 implies that EV charging will have little impact on rates – either upward or downward – unless provided with more sophisticated price signals.[57] To maximize the benefits of EVs for all customers through more efficient system utilization, EVs should be provided with price signals that encourage charging when the system is underutilized. In this way, EVs will be able to put downward pressure on rates, benefitting all customers.

Fuel Consumption

Adoption of EVs will naturally lead to reductions in gasoline and diesel consumption across Pennsylvania. Excluding reductions in gasoline consumption due to fuel efficiency improvements, we expect EVs will avoid 280 million gallons of gasoline consumption in 2030, with a sensitivity range between 200 and 360 million gallons. The reduction in gasoline consumption from EVs represents about 26 percent of the total reduction in gasoline from both fuel efficiency improvements and EV adoption over the 2020 – 2030 time period.[58]

Across medium- and heavy-duty vehicles, we expect annual avoided diesel consumption from electrification to total 74 million gallons in 2030, excluding the effects from fuel efficiency improvements. Our sensitivities range from 52 million to 98 million gallons. This represents about 36 percent of the total reduction in diesel from both fuel efficiency improvements and EV adoption.[59]

CO_2 Emissions

Increased adoption of EVs in Pennsylvania will also reduce annual transportation-related CO_2 emissions, reaching 2 MMT in 2030. This represents a decline of nearly 5 percent relative to annual transportation-related CO_2 emissions of 41 MMT in 2030.[60] This analysis accounts for both the reduction in tailpipe CO_2 emissions and increased electric sector CO_2 emissions from additional electricity consumption. Because tailpipe emissions decrease much more drastically than the increase in electric sector emissions, EV adoption results in a net decrease in CO_2 emissions. This impact is strengthened by the trend in grid decarbonization, as energy generation shifts away from coal and towards renewables, resulting in a reduction in electric generation emissions intensity reductions of about 25 percent between 2020 and 2030.[61]

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[57] We note that this analysis only considers EV load curves relative to current load curves. By 2030, however, the system load curve could shift later in the day, which would intensify the peak load and cost impacts of additional EV load.

[58] Vehicle efficiency improvements alone will likely reduce gasoline consumption by nearly 800 million gallons by 2030.

[59] Diesel consumption is likely to decline by approximately 130 million gallons by 2030 due to vehicle efficiency improvements alone.

[60] This is down from approximately 49 MMT in 2020, but a large portion of this reduction is due to vehicle efficiency improvements.

[61] We expect the electricity sector emissions intensity to fall from 0.28 MMT CO_2/TWh in 2020 to 0.21 MMT CO_2/TWh in 2030. Calculated using historical emissions data and net generation data from EIA 2019. *Electricity Emissions by State (1980 – 2016).* https://www.eia.gov/environment/emissions/state/excel/electricity.xlsx and EIA. 2018. *Net Generation by State by Type of Producer by Energy Source.* https://www.eia.gov/electricity/data/state/annual_generation_state.xls.

Most of the reduction in CO_2 emissions arises from light-duty vehicles (reaching 1.5 MMT CO_2e in 2030, with a sensitivity range of 1.0 – 1.9 MMT CO_2e in 2030). Increased adoption of medium- and heavy-duty EVs in Pennsylvania will also lead to modest avoided CO_2 emissions annually, with avoided emissions reaching 430,000 metric tons CO_2e by 2030 (with a sensitivity range of 300,000 – 560,000 metric tons CO_2e in 2030).

Air Pollution

Increased EV adoption, along with improvements in fuel efficiency in non-electric vehicles, will result in improvements in air quality across pollutants (NO_x, $PM_{2.5}$) that cause health problems such as cardiovascular and respiratory illnesses. We predict significant avoided emissions of NO_x by 2030 for both light-duty and medium- and heavy-duty vehicles after controlling for improvements due to fuel efficiency. Avoided NO_x is expected to total nearly 350 MT by 2030 due to light duty vehicle adoption and 720 MT due to medium- and heavy-duty vehicle adoption.

We predict small decreases in $PM_{2.5}$ by 2030 for both light-duty and medium- and heavy-duty vehicles, totaling approximately 27 MT. Avoided $PM_{2.5}$ emissions from EV adoption are small after accounting for fuel efficiency improvements. However, small reductions in $PM_{2.5}$ emissions can result in significant improvements in avoided health impacts.

2. Rate Design Case Studies

2.1. Residential Rates

Time-Varying Rates

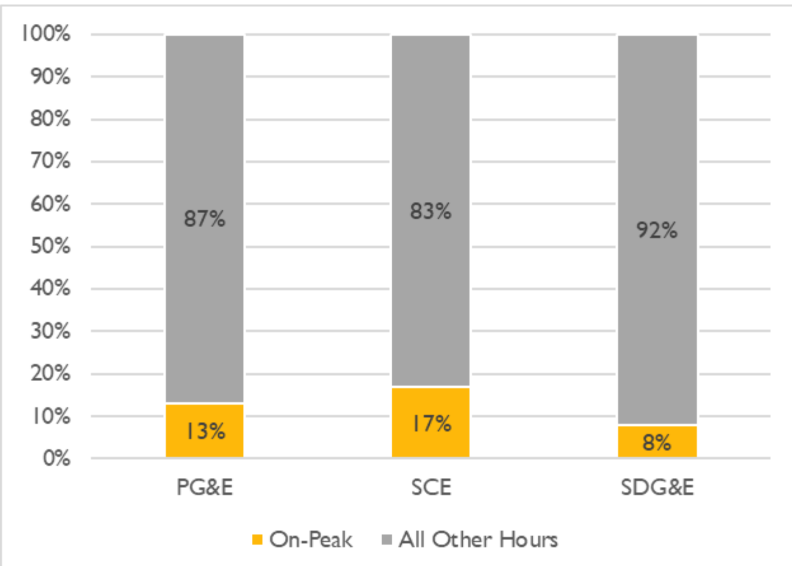
Numerous utilities offer TOU rates to EV customers. The table below illustrates examples of such rates for residential customers for 10 different utilities across the United States.

Table 15. Residential time-of-use examples

Utility	Rate	Season	On-peak to off/super-off-peak price ratio	Whole-house or EV only
SDGE (CA)	TOU-5	Summer	6.3:1	Whole-house
		Winter	4.2:1	
	TOU - 2	Summer	2.8:1	Whole-house
		Winter	1.9:1	
	EV TOU	Summer	2.8:1	EV Only
		Winter	1.9:1	
Con Edison (NY)	TOU Residential	Summer	14.2:1	Either
		Winter	5.2:1	
SCE (CA)	TOU Residential	Summer	3.7:1	EV Only
		Winter	2:1	
PSEG (NY, Long Island)	Short Peak - TOU Residential	Summer	1.7:1	Whole-house
		Winter	1.5:1	
		Shoulder	1.3:1	
	Early Peak -TOU Residential	Summer	1.6:1	Whole-house
		Winter	1.5:1	
		Shoulder	1.3:1	
Hawaiian Electric Company	TOU-RI, separately metered EV	No seasonal variation	2.2:1	EV only
Pepco (MD)	Plug-in Vehicle (PIV) TOU	Summer	1.4:1	EV Only
		Winter	1.8:1	
	Residential Plug-in Vehicle (R-PIV) TOU	Summer	1.3:1	Whole-house
		Winter	2.1:1	
Northern States Power – Xcel Energy (MN)	Electric Vehicle Home Service	Summer	8.2:1	EV Only
		Winter	7.2:1	
	Res. EV Svc (EV Accelerate at Home)	Summer	3.2:1	EV Only
		Winter	2.6:1	
PacifiCorp (OR)	Separately Metered EV Service	Summer	1.4:1	EV Only
		Winter	1.2:1	
Baltimore Gas & Electric (MD)	Residential EV TOU	Summer	2.3:1	Whole-house
		Winter	2.3:1	
Salt River Project (AZ)	Residential EV Price Plan	Summer	3.8:1	Whole-house
		Winter	1.6:1	
		Shoulder	3.3:1	

The majority of these rates have relatively high on-peak to off-peak price ratios (greater than 2:1) for at least part of the year, which facilitates considerable savings for customers who charge their vehicles during off-peak hours. The greatest benefits are associated with rates offered by the California utilities, where shifting 300 kWh/month from on-peak hours to off-peak hours can save customers between $950 and $1,500 annually, depending on the rate schedule. Such savings may be a key reason why approximately 20 percent of EV customers were enrolled in TOU rates prior to the recent implementation of default TOU rates.[62] The California TOU rates have also shown great success in shifting EV load to off-peak periods. Recent data provided by the California utilities indicate that EV customers on TOU rates charge their vehicles outside of on-peak hours between 83 percent and 92 percent of the time, as shown in Figure 11.[63]

Figure 11. Share of charging during on-peak and other hours



Similarly, Xcel Energy in Minnesota found that only about 2 percent of charging occurred during on-peak hours on the separately-metered EV rate.[64]

Many of the rates illustrated in Table 15 provide an option for customers' EV load to be metered separately, allowing only the EV load to be subject to TOU rates. This reduces risk for customers who are less able to shift their typical household load to off-peak hours. However, as discussed later in this report, where utilities require a separate meter to be installed, the cost of enrolling in a separately-

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[62] 10th Joint IOU Electric Vehicle Charging Infrastructure Cost Report, filed in Rulemaking 18-12-006. April 1, 2022.

[63] *Id*. Data for non-NEM customers, pp. 19, 57, and 89.

[64] Xcel Energy. Annual Report Electric Vehicle Charging Tariffs, Programs, And Pilots Docket Nos. E002/M-15-111, E002/M-17-817, E002/M-18-643, E002/M-19-186, E002/M-19-559, E002/M-20-711, E002/M-20-745, E002/M-21-101. June 1, 2022. Available at: https://www.edockets.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId={508D2481-0000-CB2E-8FE0-C811E8D737AF}&documentTitle=20226-186302-10.

metered rate may not be worth the benefit to customers. For this reason, some utilities allow the use of pre-approved submetering equipment.

A relatively new, but highly successful TOU rate is Xcel Energy's "EV Accelerate At Home."[65] This rate features an on-peak to off-peak price ratio of approximately 3:1, but also allows customers to separately meter their EV load through a utility-approved Level 2 charger (or electric vehicle supply equipment, "EVSE").[66] Further, Xcel offers customers a turnkey service whereby the utility manages the EVSE installation process by partnering with vetted electricians. This process not only reduces costs, but greatly simplifies the experience for customers. The rate was initially piloted in 2018, and then was formally approved by the Minnesota Public Utilities Commission as a permanent offering in 2020. Since becoming available to customers in December 2020, the program has attracted great interest and participation, with more than 1,100 customers participating as of June 2022.[67]

Residential Subscription Rates

Subscription-based rates for residential customers are generally similar to TOU rates, but with free off-peak charging and a higher fixed charge. Examples include:

- Austin Energy in Texas offers a subscription pricing program called "EV360" for unlimited charging during off-peak hours between 7 pm and 2 pm. The monthly fee is $30 for customers with charging demand of less than 10 kW and $50 for customers with demand of 10 kW or more. Customers who elect to charge during on-peak hours face a volumetric rate of $0.40/kWh during the summer and $0.14/kWh during the winter.[68] By pairing the subscription pricing with high on-peak prices, the program encourages customers to shift usage to off-peak hours, with 99 percent of charging occurring outside of peak hours.[69] It also ensures that customers who use the grid more intensively pay a higher subscription fee. Participation in the program requires the installation of a separate submeter circuit.
- Xcel Energy in Minnesota is piloting a residential subscription service that provides unlimited charging from 9 pm to 9 am for a monthly subscription fee of $42.50. Customers

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[65] Formerly named "Residential EV Service."

[66] Minnesota Public Utilities Commission. Staff Briefing Papers. E999/CI-17-879. In the Matter of a Commission Inquiry into Electric Vehicle Charging and Infrastructure. Available at https://efiling.web.commerce.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId=%7B7015F977-0000-C37F-8E7A-F2C9C65E3C3D%7D&documentTitle=20213-171536-04.

[67] Xcel Energy. Annual Report Electric Vehicle Charging Tariffs, Programs, And Pilots Docket Nos. E002/M-15-111, E002/M-17-817, E002/M-18-643, E002/M-19-186, E002/M-19-559, E002/M-20-711, E002/M-20-745, E002/M-21-101. June 1, 2022. Available at: https://www.edockets.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId={508D2481-0000-CB2E-8FE0-C811E8D737AF}&documentTitle=20226-186302-10.

[68] Austin Energy. *EV360 Whitepaper.* Available at https://austinenergy.com/wcm/connect/b216f45c-0dea-4184-9e3a-6f5178dd5112/ResourcePlanningStudies-EV-Whitepaper.pdf?MOD=AJPERES&CVID=mQosOPJ.

[69] McDougall, Lindsey. Austin Energy's EV360-A Residential Subscription Rate Pilot Plan for EV Charging. Presentation. June 27, 2019. Available at https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=936237280.

that charge during on-peak hours are charged $0.20/kWh in the summer and $0.17/kWh in the winter.[70] This rate benefits customers who require substantial energy to charge their vehicles off-peak.

Off-Peak Charging Incentives

Instead of requiring customers to enroll in a separate rate, some utilities have used incentives such as bill credits for customers who charge during off-peak hours. Because this approach does not impact the underlying rate structure and only provides rewards to customers, it does not necessarily require the same stringent metering standards as traditional utility rates. These programs tend to be highly popular because they present low risk to customers. However, program administration costs (including the cost of submetering) can be high.

- Con Edison's SmartCharge NY program rewards participants with e-gift cards or payments via PayPal for off-peak charging behavior anywhere in the Con Edison service territory.[71] Currently customers earn $0.10/kWh for charging between midnight and 8 am, and can earn $35/month for avoiding any charging during peak summer hours (2 pm – 6 pm).[72]

  Con Edison launched the program in April 2017 with 100 EVs with the C2 device. This device is installed by plugging it into the vehicle's on-board diagnostics port. The device then collects vehicle charging and driving data by decoding signals from the vehicle's internal computer system and sends the data securely to Geotab servers over the cellular network.

  In September 2017 the *Bring Your Own Charger Fleet Program* component was launched. In 2018, the program had achieved a 0.63 MW peak load reduction by charging 875 EVs off-peak.[73] The program has grown substantially in recent years, with more than 8,000 EV owners participating. Roughly 60 – 70 percent of current participants use an API with Tesla (an "onboard" telematic submeter), and the remainder use Geotab's mobile submetering C2 device. Approximately 25 percent of all light-duty EVs registered in New York City and Westchester County are enrolled in the SmartCharge NY program.[74]

  Through the use of a mobile submeter and rewards program, SmartCharge NY avoids the need for electricians or utility crews to install equipment, does not require a separate EV tariff, does not require complex billing processes, and avoids additional customer charges from the utility.

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[70] Xcel Energy. EV Subscription Service Pilot. 2022. Available at https://ev.xcelenergy.com/subscription-pilot-mn/.

[71] Sherry Login, "SmartCharge New York," January 22, 2018, 4, http://www.state.nj.us/bpu/pdf/publicnotice/stakeholder/20180205/NJ%20EV%20Stakeholders%20Meeting_January%2022%202018%20Con%20Ed.pdf.

[72] ConEdison. SmartCharge New York Frequently Asked Questions. Available at https://www.coned.com/en/save-money/rebates-incentives-tax-credits/rebates-incentives-tax-credits-for-residential-customers/electric-vehicle-rewards/electric-vehicle-charging-rewards-faq.

[73] Login, 16.

[74] Consolidated Edison. 2022. *Conversation with Sherry Login*, ConEdison's Electric Vehicle Program Manager; Consolidated Edison, "Con Edison & Geotab Energy Making it Easier for Tesla Drivers to 'Smart Charge'," Con Edison Media Relations, Sept 13, 2021. Available at: https://www.coned.com/en/about-us/media-center/news/20210913/con-edison-and-geotab-energy-making-it-easier-for-tesla-drivers.

The rewards offered for off-peak charging may also be updated as needed with no filing requirements, and EV owners do not have to be utility account holders.[75] Importantly, Con Edison has found that SmartCharge NY has higher enrollments than its TOU programs, with roughly 800 customers enrolled in whole-house residential TOU rates with a one-year price guarantee and just 12 customers enrolled in the EV-only residential TOU rate program, versus over 8,000 customers in SmartCharge.[76]

2.2. Commercial Rates

Many different types of commercial EV rates have been implemented in other jurisdictions. In most cases, the rates target reductions in the demand charge, either through a conversion to volumetric rates or through a cap for low load factor customers. Several rates include a subscription model instead of a traditional demand charge, while some utilities have implemented pricing based on load attraction/economic development principles.

Rates that reduce or eliminate demand charges are highly beneficial to low-load factor customers, which typically include fleets in the early stages of converting to EVs and most DCFC customers. Over the longer term, larger fleets that are able to stagger charging (such as buses) will be able to increase their load factors to the extent that demand charges are less of a barrier. However, demand charges are likely to continue to be a challenge for fleets with short depot dwell times that must rely on high-powered chargers to deliver the required energy. In addition, many DCFC sites will continue to have low load factors, since avoiding long queues is critical to the customer experience.

Commercial tariffs that utilize time-varying rates (such as TOU rates or hourly pricing) tend to benefit fleet customers that do not operate their vehicles overnight, or those that have considerable flexibility in their charging schedules. While DCFC operators have limited ability to control when EV drivers use their charging stations, they can encourage EV drivers to time their charging during off-peak hours by levying higher prices during on-peak hours.

Table 16 highlights several examples of EV rates for commercial customers from across the United States. Some of these rates were designed primarily to address barriers to transportation electrification by reducing electricity bills for EV charging customers, while others have dual goals of supporting transportation electrification while encouraging charging behavior that supports the efficient utilization of the grid. These examples are discussed in more detail in the following sections.

[75] Login, 18.

[76] Login; Information on TOU rates can be found at: https://www.coned.com/en/save-money/energy-saving-programs/time-of-use.

Table 16. Commercial EV rate examples

Utility	Partial or Full Volumetric	Time-Varying	Time-Limited Demand Charge	Low Load Factor Provision	Load Attraction/ Economic Development	Subscription
Public Service Company of Colorado	Partial; no expiration date	TOU + CPP				
Nevada Power Company	Full; 10-year phase-out	TOU				
Eversource (Connecticut)	Full; no expiration date	TOU				
Hawaiian Electric Company	Partial; expires after 5 years	TOU				
Dominion Energy (Virginia)	Full; no expiration date					
Public Service Company of New Mexico	Partial; no expiration date		No off-peak demand charge			
Madison Gas & Electric		TOU		Yes; no expiration date		
Arizona Public Service		TOU		Yes; 10-year phase out		
Ameren Illinois				Yes; 10-year phase out		
Alabama Power					Yes (6- or 10-years)	
San Diego Gas & Electric		TOU			Yes (based on marginal costs); 10-year phase-out	Demand-based subscription
Pacific Gas & Electric		TOU				Demand-based subscription

Conversion of Demand Charges to Volumetric Rates

Many utilities offer rates that convert some or all of the demand charges to volumetric (kWh) rates. Some of these rates are set to expire after a specified term, while others are permanent rate offerings. Not all of the volumetric rates include a time-varying component to disincentivize charging during peak hours, although some have sophisticated designs, such as critical peak pricing.

- Public Service Company of Colorado offers two rates to EV charging customers with a demand charge of only $3.01/kW – more than 50 percent lower than the standard distribution demand charge. Of these rates, Schedule S-EV-CPP is notable because it is one of the few EV rates across the country to feature a CPP component. During critical peak events, the price for electricity increases to $1.44/kWh. The utility can call up to 15 critical events per year, each with a duration of four hours between 2 pm and 10 pm. Due to the incorporation of the CPP component, the TOU prices for Schedule S-EV-CPP are reduced by nearly 50 percent compared to Schedule S-EV, the alternative EV-TOU rate. For example, Schedule S-EV has a summer on-peak price of $0.13/kWh,[77] while Schedule S-EV-CPP has a summer on-peak price of $0.07/kWh.[78] Because of the lower energy rates, this rate structure is particularly beneficial to customers with higher utilization rates that can schedule charging around critical peak events or use energy storage to offset charging load.

- NV Energy in Nevada offers a demand charge reduction with a commensurate increase in time-varying volumetric rates to DCFC customers through the EV Commercial Charging Rider Time-of-Use rate schedule. This rate begins with a 100 percent conversion of demand charges to TOU volumetric rates in 2019 and transitions back to full demand charges in 2029. The rate is limited to the first 500 meters.[79]

- Eversource Energy (Connecticut) offers an EV rate rider for publicly-accessible EV fast-charging stations that converts all demand charges to a volumetric equivalent for the otherwise-applicable rate schedule.[80] For most rate schedules, the volumetric rates are time-varying. There is no expiration on the term of this rate schedule, and thus new EV charging stations do not have to be concerned about the rate being phased out soon after the charging station is constructed.

- Hawaiian Electric Company has implemented several rate options for EV charging. Schedule EV-J is available to customers with demand up to 300 kW and is intended for workplace and public Level 2 charging stations, as well as small scale DCFC sites.[81] A similar rate, Schedule EV-P, is available for roadside charging facilities with demand of 300 kW or more. As compared to the standard Schedule J, the EV rate reduces the demand charge from $13.00/kW to $2.00/kW and converts the volumetric rates to

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[77] Public Service Company of Colorado. Schedule S-EV. Effective August 17, 2022. Available at https://www.xcelenergy.com/staticfiles/xe-responsive/Company/Rates%20&%20Regulations/Regulatory%20Filings/PSCo_Electric_Entire_Tariff.pdf.

[78] Public Service Company of Colorado. Schedule S-EV-CPP. Effective August 17, 2022. Available at https://www.xcelenergy.com/staticfiles/xe-responsive/Company/Rates%20&%20Regulations/Regulatory%20Filings/PSCo_Electric_Entire_Tariff.pdf

[79] NV Energy, Schedule No. EVCCR–TOU, Effective January 3, 2022. Available at https://www.nvenergy.com/publish/content/dam/nvenergy/brochures_arch/about-nvenergy/rates-regulatory/electric-schedules-south/EVCCR-TOU_South.pdf.

[80] The volumetric equivalent is determined in accordance with the Company's general service rate schedule that would otherwise apply to the load being served. Available at https://www.eversource.com/content/docs/default-source/rates-tariffs/ct-electric/ev-rate-rider.pdf?sfvrsn=e44ca62_4.

[81] The rate limits enrollment to a maximum of 1,000 customers.

time-varying rates. The conditions of service under this rate schedule allow the Company, in collaboration with the Customer, to curtail EV charging when there is inadequate generation supply, to support system reliability, or to respond to changing system costs.[82] This tariff is available for five years. The utility's benefit-cost analysis shows that the incremental revenues collected under schedule EV-J will outweigh the cost of serving EV load, thereby applying downward pressure on utility rates for all customers.[83]

- Dominion Energy (Virginia) offers Rate GS-2 to all commercial customers with demands between 30 kW and 500 kW. When a customer's load factor is below approximately 27 percent (200 kWh per kW), the customer is billed on a fully volumetric rate (for distribution, transmission, and generation). When the customer's load factor exceeds 27 percent, a demand charge (with a correspondingly lower volumetric rate) applies for each service (distribution, transmission, and generation). There is no scheduled expiration for this rate schedule.[84]

- Public Service Company of New Mexico (Xcel Energy) offers a technology-neutral rate to its commercial and industrial customers with low load factors. Rate schedule General Power Service (Low Load Factor) – Time-of-Use Rate converts the majority of the on-peak demand charge to time-varying volumetric rates.[85] There is no demand charge applied for off-peak demand. This rate has no expiration date associated with it.[86]

Elimination of Demand Charges during Off-Peak Hours

Although public DCFC stations have little control over the timing of peak demand at their facilities, many fleets are able to manage their charging to a much larger degree. In particular, some fleets return to central depots at night where they can complete most of their charging during off-peak hours. Demand charges that only apply during on-peak hours can greatly improve the economics for fleets that can charge overnight, while also encouraging charging practices that avoid hours when the grid is stressed.

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[82] Hawaiian Electric Company, Inc. Schedule EV-J. Effective March 18, 2022 to March 17, 2027.

[83] Hawaii Public Utilities Commission. Decision and Order No. 38157. Docket No. 2020-0152. December 30, 2021, pages 17-18. The net benefits associated with Schedule EV-J are lower than under the standard Schedule J, assuming the same electricity consumption. Since Schedule EV-J is intended to drive greater EV adoption, the total net benefits may ultimately exceed those that would have been achieved with lower adoption rates under the standard Schedule J.

[84] Dominion Energy. Schedule GS-2 Intermediate General Service. Effective January 1, 2021. Available at https://cdn-dominionenergy-prd-001.azureedge.net/-/media/pdfs/virginia/business-rates/schedule-gs2.pdf?la=en&rev=18a7ab2b6072468f8766b6e5c10aebae&hash=8C0D2D00EF20D5F242B133FA5D4A69C4.

[85] The summer on-peak demand charge is reduced from $25.47/kW to $8.10/kW, and the winter on-peak demand charge is reduced from $19.02/kW to $6.05/kW.

[86] Public Service Company of New Mexico. General Power Service (Low Load Factor) – Time-of-Use Rate. Effective January 1, 2019. Available at: https://www.pnm.com/documents/28767612/28775078/schedule_3_c.pdf/9328cd76-1c71-400b-8533-61aa570bb8b9?t=1546449975408.

In recognition of the lower costs associated with demand during off-peak hours, some utilities have eliminated or lowered their non-coincident demand charges (those that apply during all hours of the day) in favor of demand charges that apply only during on-peak periods. For example:

- In addition to offering public DCFC a low load factor rate (described below), Ameren (Illinois) has eliminated its off-peak demand charge for a limited number of education facilities, transit facilities, or public charging facilities with demands greater than 150 kW. The standard demand charge still applies during on-peak hours.[87]
- Public Service Company of New Mexico (discussed above) applies demand charges only to load during on-peak hours. Its demand charges are also seasonally-differentiated (with higher rates during the summer season) to better align rates with actual costs on the grid.

Low Load Factor Rates

Low load factor rates cap the billed demand at a certain percentage of the customer's average energy usage. Some low load factor discounts are permanent and technology-agnostic, while others are temporary or limited to EV-charging customers.

- Madison Gas and Electric's low load factor provision applies to any customer on a commercial and industrial TOU rate (Cg-4, Cg-2, or Cg-2A). The provision reduces the demand charge by 50 percent for any customer with an annual load factor of less than 15 percent.[88]
- Arizona Public Service's DCFC pilot rate limits the monthly billed demand faced by public DCFC customers with low load factors. The limiter applies to load factors of 25 percent or less for Period 1 (through mid-2025), load factors of 20 percent or less for Period 2 (July 2025 through mid-2028), and 15 percent or below for Period 3 (July 2028 through mid-2031). This rate design essentially caps the maximum billed demand for a customer at their average hourly energy usage divided by 25 percent, 20 percent, or 15 percent (depending on the period).[89]
- Ameren Illinois limits the monthly billed demand for public DCFCs. This demand limiter is set to phase out over a ten-year period, with the applicable load factor limit declining from 30 percent in 2022 to 10 percent in 2032. The 10-year duration and pre-established phase out of this rate schedule provides certainty to charging station developers.

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87 Ameren Illinois Company. Rider EVCP, DS-3 and DS-4 Charging Program. Effective July 15, 2021. Available at https://www.ameren.com/-/media/rates/files/illinois/aiel21rdevcp.ashx.

88 Madison Gas & Electric Company. Low Load Factor Provision. Effective January 1, 2021. Available at: https://www.mge.com/MGE/media/Library/pdfs-documents/rates-electric/electric-rates.pdf.

89 Arizona Public Service. Rate Rider DCFC General Service Direct Current Fast Charging Pilot. Effective December 1, 2021 in Decision No. 78317. Available at https://www.aps.com/-/media/APS/APSCOM-PDFs/Utility/Regulatory-and-Legal/Regulatory-Plan-Details-Tariffs/Business/Rate-Riders/dcfc_DirectCurrentFastCharging.ashx?la=en.

- Recently, National Grid in Massachusetts proposed a sliding scale for distribution rates, based on a customer's load factor. At low load factors, the rate would be fully volumetric. As the load factor increased, the demand charge would be phased back in.[90] This design differs from most time-limited low-load factor rates in that the phase-in of the demand charge is based on an individual customer's load factor, rather than a pre-set schedule. Although the rate is designed to expire after ten years, customers with low load factors could still benefit from primarily volumetric rates until the rate expiration.

Load Attraction/Economic Development Rates

Utilities frequently offer new customers temporary rate reductions to attract beneficial new load to the system. These reduced rates are generally referred to as "load attraction rates" or "economic development rates," and vary in magnitude and duration. For example, in Pennsylvania, PECO's Economic Development Rider offers a credit equivalent to 15 percent of the customer's Variable Distribution Service Charge for up to five years for qualifying customers.[91]

The rationale for load attraction or economic development rates is that a discounted rate is needed to attract additional load to the system – whether it be manufacturing or EV load – and this load will contribute greater revenues than costs, thereby putting downward pressure on rates. As long as the rates paid by new load are higher than the marginal cost to serve that load, ratepayers will benefit from the addition of new load.[92]

For similar reasons, some jurisdictions have elected to implement rates based on economic development rate principles for EV load. For example, the California Public Utilities Commission concluded that new EV load should be treated as retained or incremental load, recognizing that the purpose of the rate is "to attract participants who would not have adopted electric vehicles without a discount below standard commercial industrial rates."[93] Further, the Commission found that "revenues collected under the [EV] rate will benefit ratepayers as long as the … rate is set above a price floor of marginal costs and non-bypassable charges. . . Ratepayers benefit even if the revenues collected under the [EV] rate are substantially lower than would have been collected under [the standard commercial rate]." [94]

Examples of rates based on load attraction or economic development rates include the following:

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[90] National Grid. Direct Testimony of the Demand Charge Alternative Panel. Docket D.P.U. 21-91. July 14, 2021.

[91] PECO Energy Company. Economic Development Rider. Effective January 1, 2022. Available at https://www.peco.com/SiteCollectionDocuments/Current%20Elec%20tariff%20eff%20Sept%201,%202022.pdf.

[92] In most cases, electricity rates are higher than the marginal cost of serving additional load due to economies of scale and high fixed costs associated with power plants, transmission lines, and distribution equipment. Once those initial investments are made, small increments of additional load can be served at relatively low cost.

[93] California Public Utilities Commission, Decision 20-12-023, Decision Authorizing San Diego Gas & Electric Company Rate for Electric Vehicle High Power Charging, A.19-07-006, December 17, 2020, at 28.

[94] *Id.* at 29.

- San Diego Gas and Electric's high-power EV rate (EV-HP) was designed to only recover marginal costs during the initial period, and then to phase in the full costs over a ten-year period.[95]

- Alabama Power's Economic Development Incentive offers rate reductions to customers who add at least 250 kW of EV fleet load and who commit to a contract for a six-year or ten-year period. Under the ten-year contract, base rate charges are discounted by up to 45 percent in the first year, declining to 15 percent in the fifth year.[96]

Subscription Rates

To date, commercial subscription rates have primarily replaced traditional demand charges.

- Pacific Gas and Electric's Schedule BEV for commercial EVs replaces the customer charge and traditional demand charge with a subscription-based model. The subscription is offered in blocks of 10 kW for the BEV-1 rate and in blocks of 50 kW for the BEV-2 rate. Customers on this rate schedule choose a subscription level in advance based on their estimated need. If the customer exceeds their subscribed kW allocation for more than three billing cycles, they are subject to an overage fee.[97] The advantage of this subscription rate is that it may be simpler for customers to understand and budget for. A disadvantage is that the subscription price is still paid, regardless of whether the customer uses all of their subscribed demand. Further, customers may find estimating their maximum EV load in advance difficult if vehicle charging schedules are variable.

- San Diego Gas & Electric's EV-HP rate schedule (described above) also features a subscription component. Customers specify their anticipated maximum demand in 10 kW increments below 150 kW, and in 25 kW increments above 150 kW. This rate also includes volumetric TOU rates.

2.3. Considerations for Rate Implementation

EV rates should be designed with state energy policy goals in mind along with traditional ratemaking principles. These include broad goals such as reducing emissions through encouraging transportation electrification and reducing costs on the grid, but may also include more nuanced goals, such as ensuring equity through providing customers in multi-family housing with access to affordable public fast charging options. Once these goals have been clearly identified, rates can be designed to best achieve these goals. Key considerations for various goals are discussed below.

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95 *Id.* and San Diego Gas & Electric. Schedule EV-HP Electric Vehicle High Power Rate. Effective January 1, 2022. Available at https://tariff.sdge.com/tm2/pdf/tariffs/ELEC_ELEC-SCHEDS_EV-HP.pdf.

96 Alabama Power. Rate Rider EDI. Approved by the Alabama Public Service Commission in Docket # U-5017, February 1, 2022. Available at https://www.alabamapower.com/content/dam/alabama-power/pdfs-docs/Rates/EDI.pdf.

97 Pacific Gas and Electric Company. Electric Schedule BEV. Effective May 1, 2020. https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDS_BEV.pdf.

Maximize Fuel Cost Savings to Facilitate EV Adoption

Fuel cost savings are a primary motivating factor for customers when choosing whether to purchase an EV. Cost-based time-varying rates with significant on-peak to off-peak price differentials can provide considerably greater fuel cost savings than those with mild differentials. Rate differentials can be enhanced by time-differentiating generation, transmission, and distribution rates, as opposed to simply generation rates. In addition, more TOU time periods with shorter windows can strengthen the price signal. For example, a rate with an on-peak, off-peak, and super-off-peak period will tend to have a greater price differential than a rate with only two periods.

For DCFCs and fleets, the reduction or elimination of demand charges generally has the greatest impact on fuel cost savings. Replacing demand charges with volumetric rates or providing a load attraction rate can support DCFC deployment in the early years of EV adoption. Even converting a non-coincident demand charge to a time-limited demand charge can have significant benefits to fleets that charge overnight.

Simplicity and Understandability

Rates that vary hourly convey the most accurate information regarding system costs, but most customers do not have the tools to respond to these rates effectively. As a result, complex price signals may simply be ignored. To be effective, rates should balance simplicity and understandability with the accuracy of price signals. For residential and small commercial customers, this may mean introducing simple TOU or subscription rates with simple on-peak and off-peak periods. For larger commercial customers, rates can introduce more complex components such as CPP or time-limited demand charges.

Duration of Rate Offerings

Some jurisdictions have approved permanent alternatives to high demand charges for customers with low load factors, but others have elected to phase out such rates over time. Where these rates have a sunset date, they are frequently designed with the objective of being of sufficiently long duration to allow the EV market to mature and overcome the low utilization rates experienced during the early years. EV charging rates that expire after only a few years may not be long enough to allow EV charging customers to recoup the cost of their investments. For example, in Massachusetts, National Grid testified that EV charging providers indicated that a three-year term would not provide sufficient price stability to motivate them to deploy DCFCs. For this reason, National Grid proposed a 10-year term for its rate offering.[98]

Where rates are phased out, it is more beneficial to customers to base the phase-out schedule on an individual customer's load factor, rather than a pre-set timetable. This enables EV charging customers

[98] National Grid. Pre-filed Rebuttal Testimony of the Demand Charge Alternative Panel. Docket D.P.U. 21-91. June 17, 2022.

who deploy DCFCs in less-traveled areas or who electrify their fleets later to continue to benefit from the rate offering, rather than simply rewarding the customers where EV adoption is greatest.

Customer Education and Outreach

The number of customers enrolled in an EV rate is a critical factor to its success. Low enrollment levels for time-varying rates will fail to encourage EV charging in a manner compatible with grid conditions, resulting in higher peak demand and higher costs. Low enrollment in commercial EV rates may signify that the rate does not provide adequate financial incentives to encourage additional EV charging station deployment or fleet electrification. Thus, utilities should strive to maximize enrollment through both designing rates that appeal to customers and educating customers regarding the benefits of these rates. For residential customers in particular, low levels of customer enrollment are common when customers are required to actively opt-in to the rate.

Utilities can utilize multiple approaches to encourage EV rate enrollment, including education, outreach, and incentives. Activities to maximize EV customer enrollment in EV rates may include:

- **Website Tools**: Rate comparison calculators provide an easy way for customers to compare their potential cost savings over several different rate options.
- **Dealership Education and Incentives**: Auto dealerships can facilitate customer education and enrollment in EV rates if they have an understanding of the rates available to EV drivers and the potential savings these could provide to customers. Xcel Energy in Minnesota has conducted at least 15 individual training sessions at dealerships to educate salespeople regarding EV charging and the utility's managed charging programs.[99]
- **Direct Outreach to EV Customers**: It can be difficult for a utility to identify which of its customers have purchased an EV, although advanced analytics of customer load data can help. Some utilities, such as Duquesne Light and PECO, offer a registration incentive to customers that notify their utility that they have purchased an EV. Establishing these points of contact can be an important first step to educating and enrolling customers in an EV rate.
- **Price Guarantees**: Price guarantees may be offered for the first six months or a year after a customer signs up for a new rate. These guarantees ensure that the customer will not pay more on the time-varying rate than they would on a standard rate, thereby reducing the customer's risk of signing up for a rate structure that is new to them.

[99] Xcel Energy. Annual Report Electric Vehicle Charging Tariffs, Programs, And Pilots Docket Nos. E002/M-15-111, E002/M-17-817, E002/M-18-643, E002/M-19-186, E002/M-19-559, E002/M-20-711, E002/M-20-745, E002/M-21-101. June 1, 2022. Available at: https://www.edockets.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId={508D2481-0000-CB2E-8FE0-C811E8D737AF}&documentTitle=20226-186302-10.

Alignment of Generation, Transmission, and Distribution System Peaks

When designing time-varying rates to reflect costs at both the generation and distribution system level, care should be taken so that distribution peak hours and bulk system peak hours are aligned as much as possible when defining TOU windows. Although this may result in broad on-peak periods of eight or more hours, this is generally less problematic for EV rates than more widely-applicable TOU rates. In fact, a narrow off-peak window concentrates the lowest-cost hours to enable the deepest discounts. This can be observed in rates that have "super-off-peak" periods of approximately eight hours with extremely low rates.

Submetering to Enable Affordable EV-Only Rates

The ability to enroll EV load on a separate, time-varying rate can be very attractive to customers, as EV load is much more controllable than general household or commercial load. Thus, separately metering EV load has the potential to significantly increase the number of EVs that enroll in time-varying rates, thereby mitigating peak demand impacts of EV charging. However, the cost and logistical challenges associated with installing a second meter has historically posed a barrier to separately metering EV load. Although a second meter makes it easy to apply EV rates only to EV charging, the additional meter and installation charges present a significant barrier to widespread adoption of EV-only rates. The Minnesota Public Utilities Commission notes that residential customers typically spend between $1,725 and $3,525 on electrical wiring and metering costs to enroll in Xcel Energy's EV tariff that requires a second utility meter.[100]

The substantial cost associated with installing a second meter has stymied enrollment in rates requiring second meters. For example, in 2021, nearly four times as many EV customers in Xcel Minnesota's territory enrolled in its EV rate requiring only a submeter, as opposed to the rate requiring a second utility meter.[101] Similarly, Dominion Energy encountered significant challenges in enrolling customers into its EV-only TOU rates during a pilot from 2011 to 2016 that required a separate second meter. As a result, the program reached only half of its enrollment cap.[102]

Addressing the high cost of installing a second utility revenue-grade meter has led utilities and regulators in multiple jurisdictions to begin investigating submetering options and standards, including California, Maryland, Minnesota, New Hampshire, and New York. Although EV load can be readily

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[100] Minnesota Public Utilities Commission, Order Approving Pilot Program, Granting Variance, and Requiring Annual Reports. Docket No. E-002/M-17-817, May 9, 2018, page 2.

[101] Compliance – Annual Report Electric Vehicle Charging Tariffs, Programs, And Pilots Docket Nos. E002/M-15-111, E002/M-17-817, E002/M-18-643, E002/M-19-186, E002/M-19-559, E002/M-20-711, E002/M-20-745, E002/M-21-101. June 1, 2022. Available at: https://www.edockets.state.mn.us/edockets/searchDocuments.do?method=showPoup&documentId={508D2481-0000-CB2E-8FE0-C811E8D737AF}&documentTitle=20226-186302-10.

[102] Under the EV-only rate, a dedicated hard-wired circuit is required, and an electrician may recommend changes to the existing electrical set up, which would incur additional costs. Under the whole-house TOU rate, service upgrades may be required due to the additional energy consumed at a home, which would incur additional costs from an electrician.

metered separately using submeters embedded into EVSE, mobile submeters, or through utilizing the telematics and on-board metering in the EV itself,[103] widespread adoption of submetering has been hampered due to rigorous testing and certification requirements for any form of electric meter used for billing.

While traditional metering standards ensure accuracy, the standards have been difficult to meet. Many existing telematic submetering device manufacturers have products on the market that can comply with National Institute of Standards and Technology (NIST) standards but not with American National Standards Institute (ANSI) electric metering standards.[104] However, the need for such rigorous standards applied to submetered EV load has been questioned, given that the total customer load will ultimately be measured using a utility revenue-grade meter that meets all certification requirements; it is only the EV portion of the load that would potentially be subject to less stringent standards through submetering.

California has actively sought to promote the development of submetering technologies as a lower cost option to traditional metering options. To that end, a two-phase multi-year pilot was initiated in California to test submetering functionality. These efforts culminated in the California Public Utilities Commission issuing an order in August 2022 to allow an EV's energy to be measured separately through submetering. The submetering data accuracy standards established through the Commission's order strike a balance between compliance with national standards with the need for lowering costs and barriers to adoption for EV owners. Instead of using traditional ANSI standards, the Commission approved the use of NIST standards that ratchet up after ten years[105] in an effort to reduce costs for consumers while also advancing national uniformity for submetering data accuracy standards.[106]

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[103] There are two primary types of submeters: those that utilize networked chargers (e.g., Level 2 EVSE installed where the vehicle is parked), and those that use vehicle telematics. Telematic submetering is the wireless collection, processing, and transmission of vehicle data such as energy consumption via a user-interface such as a web-portal. The hardware that enables EV telemetry falls into one of two categories: on-board submetering from original equipment manufacturers (OEMs), and third-party manufacturers' mobile in-car submeters.

[104] *Decision Adopting Plug-In Electric Vehicle Submetering Protocol and Electric Vehicle Supply Equipment Communication Protocols*, California Public Utilities Commission, R.18-12-006, Decision at 15 (August 4, 2022).

[105] Under the Order, the California CDFA-DMS standards will accept within 2.5 percent and 5 percent accuracy for in-lab versus in-field results from 2023 until 2033, when the standard will revert back to 1 and 2 percent respectively. *Decision Adopting Plug-In Electric Vehicle Submetering Protocol and Electric Vehicle Supply Equipment Communication Protocols*, California Public Utilities Commission, R.18-12-006, at 10-13 (August 4, 2022).

[106] The Commission also rejected utility calls to own the submetering technology, which could address issues related to meter accuracy, network reliability, data transfer, and cybersecurity. The Commission concluded that customer or a customer-selected third-party ownership is the most appropriate approach, citing market trends of EVSE embedding submeters into their products and the high cost of installing a separate utility-owned meter. *Decision Adopting Plug-In Electric Vehicle Submetering Protocol and Electric Vehicle Supply Equipment Communication Protocols*, California Public Utilities Commission, R.18-12-006, Decision at 15 (August 4, 2022).

In addition to California's policy, EVSE-embedded submetering has been implemented by Xcel Energy in Minnesota (as discussed in the TOU case studies) and Baltimore Gas & Electric in Maryland.[107] Mobile (in-car) submeters are currently in use for Con Edison's Smart Charge Rewards program and have also been used for pilots in Toronto and Arizona.[108] Using on-board vehicle meters with vehicle telemetry could offer another low-cost alternative submetering approach. By using the vehicle's built-in metering and telemetry capabilities, on-board telematic metering could avoid the need for a separate, external device and communications infrastructure altogether.

Ultimately, state regulators will need to review standards on metering accuracy, gauge which standards may be most appropriate, and balance the need for accurate submetering data against the benefits EVSE can provide in improving EV adoption.

2.4. Processes, Opportunities, and Challenges for Implementing Alternative Rate Designs

As evidenced by the case studies discussed above, a wealth of experience and data exists regarding innovative EV rates and their ability to enhance fuel cost savings for EV customers and shift load to off-peak hours, thereby facilitating greater EV adoption and exerting downward pressure on rates. These examples can be leveraged to inform EV rate designs in Pennsylvania to achieve state policy goals and maximize benefits for customers.

Although rate design can be a highly complex process, some of the rate designs discussed above could likely be implemented relatively quickly. For example, converting demand charges to volumetric rates for customers with low load factors can be done using existing class billing determinants from a utility's most recent rate case. More complex rates (such as time-varying distribution rates) can also be implemented using readily available data, and then refined over time as better information becomes available.

Although rate design is traditionally addressed during utility rate cases, rate cases can be infrequent. Thus, a separate proceeding can be an opportune avenue for addressing rate design matters, as long as the utility's overall revenue requirement (as approved in the most recent rate case) is not modified.[109] To accomplish this, a utility could file a petition with the Pennsylvania Public Utility Commission to

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[107] By waiving this requirement, the utility's EV charging program broadened eligibility and garnered greater interest because of the optionality it gave to participants. *In the Matter of the Petition of the Electric Vehicle Working Group for Implementation of a Statewide Electric Vehicle Portfolio, Electric Vehicle Work Group Statewide Electric Vehicle Portfolio Proposal*, Maryland Public Service Commission, Case No. 9478 (January 19, 2018).

[108] Toronto's program is called ChargeTO, and the results of its pilot are available from FleetCarma here: https://www.fleetcarma.com/resources/chargeto/. The Salt River Project's pilot results are available here: https://www.srpnet.com/newsroom/releases/011018.aspx.

[109] To avoid impacting the utility's approved revenue requirement, new rates should be designed to be revenue neutral at the class level. For example, a new residential TOU rate should be designed to yield the same revenues as the existing rate, using class average billing determinants.

introduce a new rate. Alternatively, the Pennsylvania Public Utility Commission could launch a rate design investigation and direct the utilities to file new rate designs within a specified time period.

When designing rates, it is important to ensure that rates reflect costs on the system to the greatest extent practical, while balancing the need to ensure that rates remain simple and understandable. With the implementation of more granular rates, utility cost data may need to be updated or expanded. For example, marginal cost of service studies may need to be performed to better understand marginal distribution costs. These studies may take time to develop. In the interim, marginal cost estimates used in other proceedings (such as energy efficiency cost-effectiveness tests) can be leveraged.

The design of time-varying rates for distribution rates typically utilizes data regarding the timing of feeder and substation peaks, which may also take time to gather if the utility does not currently maintain such records. While such granular data may not be immediately available, the data can be estimated based on the timing of the overall distribution system peak and class load profiles.

Addressing submetering issues for separately-metered EV tariffs may require a separate proceeding altogether. Metering standards are complex, and third-party submetering technologies may require additional testing and performance measurement prior to approval. As a first step, the Pennsylvania Public Utility Commission could grant a waiver for a utility to pilot third-party submetering technologies that meet less stringent metering standards. The information obtained through the pilot could then be used to inform a broader proceeding to address alternatives to using a separate utility-owned revenue-grade meters.

3. RECOMMENDATIONS

By 2030, we project that nearly 9 percent of the vehicles in Pennsylvania will be EVs under our base case forecast. These EVs will reduce annual transportation-related CO_2 emissions by an estimated 2 MMT and ozone-producing NO_x by nearly 1,100 metric tons. However, current charging patterns are not expected to meaningfully improve the efficient utilization of the grid, resulting in lost opportunities for EVs to reduce rates for all customers. This need not be the case. Electricity rates that provide improved price signals to customers could both encourage customers to shift load to off-peak hours, thereby reducing system costs, and accelerating EV adoption by maximizing fuel cost savings.

Although transportation electrification is still in its early stages in Pennsylvania, it is expected to grow substantially over the remainder of this decade. Thus, Pennsylvania has a window of opportunity now to investigate and implement rates that will ensure that EVs charge in beneficial ways and avoid unnecessary grid upgrades. Further, the rates adopted in the near-term will also help steer the trajectory of EV adoption in the state. Because vehicles are long-lived investments, implementing rates that encourage drivers and fleet operators to choose EVs now will help set Pennsylvania on a trajectory of rapid EV adoption and help the state achieve its energy policy goals.

To maximize the benefits of transportation electrification in Pennsylvania, we recommend evaluation of the rate options discussed in this report and develop a strategy for implementing EV rates. We further recommend prioritization of the following topics:

1) **Modifications to existing TOU rates for residential customers** to increase bill savings from off-peak EV charging and to attract greater participation in this rate option for consumers. Our research indicates that on-peak to off-peak price ratios for volumetric rates of at least 2:1 are required to provide sufficient bill savings to motivate customers to enroll in these rates. Currently, residential bill savings associated with charging EV load on the utilities' existing TOU rates range from approximately $1/month to $11/month, which are unlikely to attract broad participation. On-peak to off-peak price ratios can be strengthened in multiple ways, including:

    a. Shortening the off-peak period to eight hours or less, reflecting only the lowest-cost hours.

    b. Introducing a super-off-peak period, in addition to the standard on-peak and off-peak periods.

    c. Adding time-varying components to transmission and distribution volumetric rates. Currently the utilities' TOU rates apply only to electricity generation supply rates, which comprise about half of a customer's bill.

    d. Offering subscription rates with unlimited off-peak charging as a variant of standard TOU rates.

2) **Development of submetering standards** to allow customers to affordably meter their EV load separately without the cost of installing a separate meter. Submetering EV load

can be attractive to customers who are otherwise reluctant to enroll their entire household load on a TOU rate. Submeters can also be used to provide bill credits or other incentives to motivate customers to charge during off-peak hours without the need for implementing a separate rate. To fully enable submetering, the Pennsylvania Public Utility Commission may need to approve separate submetering accuracy standards. To develop separate submetering standards appropriate for Pennsylvania, we recommend that a stakeholder working group:

   a. Review the results of submetering pilots in Maryland, Minnesota, and California;

   b. If warranted, propose a submetering pilot for Pennsylvania; and

   c. Consider proposing adoption of submetering standards from other states (such as California.)

3) **Alternatives to traditional non-coincident demand charges for commercial customers**. A non-coincident demand charge is applied to a customer's maximum consumption (measured in kW) during a month. Demand charges can significantly increase electricity costs for EV charging customers, particularly operators of public DCFCs and certain commercial fleets requiring high-powered chargers typically ranging from 50 kW – 350 kW. These customers tend to have brief periods of high demand (kW) but relatively low energy consumption (kWh) overall. Under such conditions, demand charges dominate customers' bills and make it difficult to earn sufficient revenue to cover their costs. Without sufficient deployment of public DCFCs, EV adoption may be stymied due to drivers' concerns that they will not be able to recharge. Further, it also raises equity issues since many less-affluent customers lack access to at-home charging options.

   We recommend the evaluation and development of alternatives to non-coincident demand charges. In Pennsylvania, these charges generally range from $4/kW to $10/kW. Alternatives to non-coincident demand charges include:

   a. Time-limited demand charges, which apply only during peak hours and more precisely target the hours that the system is most stressed.

   b. Conversion of demand charges to volumetric rates for low load factor customers, at least temporarily while EV charger utilization is low. Such rates could be offered permanently or phased out as EV adoption reaches a critical mass.

   c. Load attraction or economic development rates designed to support the growth of the nascent EV market. This approach would temporarily offer rates based on marginal costs to encourage transportation electrification. Over time the rates would be increased to recover the full embedded costs assigned to these customers.

4) **Education and outreach initiatives**. To maximize enrollment in beneficial rates, robust education and outreach programs will be needed. These programs should look beyond standard marketing activities to consider additional tools and outreach opportunities, such as educating dealership sales staff on EV programs and rates and providing dealerships with tools to educate their customers. We recommend development of

guidelines for such programs based on the successful approaches taken in other jurisdictions outlined in this report.

We are not aware of legislative or regulatory barriers to implementing these recommendations. New tariffs are often introduced in the context of a rate case, but new revenue-neutral rate designs can also be introduced between rate cases through a utility tariff filing. While we recognize that highly accurate utility system cost data may take time to develop, marginal cost estimates used in other proceedings (such as energy efficiency cost-effectiveness tests) can be leveraged along with class load profiles to develop reasonable cost estimates.