Guide for Managing Light-Duty Electric Vehicle Fleet Charging

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Contents

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Introduction

While combustion vehicle fuel costs are dependent almost exclusively upon the number of gallons needed to fill the tank, plug-in electric vehicle (EV) owners should consider the electric energy needed to fill the battery, as well as how quickly that energy is supplied and the time of day the vehicle is charged. The amount of energy needed to power an EV is directly related to how far the vehicle is driven with some variations based on driving style, terrain, weather conditions, and heater or AC usage – just like for a gasoline or diesel vehicle. However, the timing and speed at which that energy is delivered to the battery is something the user can help determine through the selection of charging equipment and a variety of 'managed charging' tactics. Those tactics and their implications are the subject of this document.

Managed charging is the practice of controlling the time and/or power level associated with recharging EV batteries. In the right applications, managed charging can significantly reduce capital costs for charging infrastructure installations as well as ongoing operating costs of EVs while still meeting vehicle operational requirements.

Managed charging can be as simple as directing a mechanic to plug vehicles in no earlier than 10:00PM every day, or as sophisticated as a software platform that makes smart charging control decisions automatically in real-time based on grid conditions.

This document is a resource for Vermont fleet operators, and other electric vehicle stakeholders on assessing the potential benefits of managed charging, strategies to implement managed charging, and evolving opportunities related to managed charging.

Why Does it Matter When Electric Vehicles Charge?

Electric utilities in Vermont strive to provide their customers with straightforward, predictable energy costs. However, the actual costs to supply electricity are highly variable based on the location, available sources of grid power generation, and demand from utility customers.

About half of a Vermont utility's electricity costs are not for the energy itself, but instead go towards the electric grid *capacity* needed to deliver power at any particular instant. Grid capacity is a function of available energy supply (power plant) and transmission line capacity, both of which require significant capital investment and on-going maintenance costs. Since grid capacity must always exceed regional demand requirements to avoid blackouts, it must be carefully calibrated to meet the needs of all users at all times. Thus, a portion of the utility bill for most non-residential customers refers to "demand charges" which are based on the peak demand, or highest amount of power used in a 15 or 30 minute time period. As a result, high-intensity energy users are charged more for their higher-rates of consumption.

In addition, some utilities manage grid capacity costs by incentivizing customers to shift their load to periods of the day when there is less demand on the system (known as “time-of-use rates”), or by compensating customers for shedding load or adding capacity at particular times.

As fleet operators begin to deploy increasingly large numbers of EVs in their fleets, it is important they carefully consider the financial implications of how and when they charge (and possibly discharge) those vehicles. By reducing peak demand, and optimizing charging to match time-of-use rates, fleet operators can greatly reduce the costs of deploying and operating plug-in electric vehicles.

Benefits of Managed Charging

Operational Savings

To assess the potential benefits of managed charging, fleet managers need to know how their electricity rate is structured and what other rate options are available (see Appendix A: Electric Rate Structure). Table 1 shows the impact that time-of-use rates and demand charges have on the potential for managed charging to minimize operational costs.

Table 1. Potential for Operational Savings from Managed Charging

Utility Rate Structure		Potential for Operational Savings
Time-of-Use Rates	***Demand Charges***	
×	×	**None**
×	✓	**High**
✓	×	**High**
✓	✓	**Highest**

To illustrate the issue, take the extreme ends of the spectrum of options for charging a fleet of ten electric pick-up trucks. If each vehicle travels 1,000 miles per month (25 business days), this equates to around 16 kWh each day based on EPA ratings for all-electric pick-up truck models. On one end of the spectrum of charging options, the organization might purchase a single, high-powered, 250 kW fast charger to ensure the trucks charge very quickly (~5 min) as soon as they return from the field. This would be similar to having a company gas pump on site.

In an unmanaged charging scenario, trucks would likely be plugged in when they return to the lot, and charged to full as fast as possible, potentially incurring a peak demand of 250 kW (assuming back-to-back charging). This fast charging could occur in the early evening, which is likely to be within the utility's 'peak period' when costs are highest.

If peak energy costs $0.12 per kWh, then kWh for the fleet for the month would cost: 10 Trucks x 16 kWh/day x 25 days x $0.12/kWh = $480/month. However, this approach to refueling would add considerably more expense in demand charges. If peak demand charges are $16 per kW, then monthly demand charges would come to: 250kW x $16/KW = $4,000/month.

In contrast, the use of managed charging technology would result in significant cost savings. In this case, all vehicles are kept plugged in overnight and software controls when each truck starts charging. Three tactics can be employed to reduce costs: shifting charging to off-peak periods, staggering the times when the vehicles charge, and reducing the level of power draw while lengthening the duration of draw via the purchase of ten 25 kW chargers rather than the single bigger unit.

In this scenario, the off-peak energy cost is $0.08 per kWh and off-peak demand cost is $4.50 per kW. The monthly energy cost would come to 10 Trucks x 16kWh/day x 25 days x $0.08/kWh = $320. At only a 25kW power draw, all ten trucks can still charge overnight, one at a time, within a ten-hour window. If that window matched the off-peak period, the demand charge would be: 25kW x $4.50/kW= $112.50. Table 1, below, shows the total monthly and annual costs for energy and demand using the example values above.

Table 2. Unmanaged vs Managed Charging Sample Costs

	Unmanaged Charging	Managed Charging	Potential Managed Charging Savings
Monthly Energy Charges	$480	$320	*$160*
Monthly Demand Charges	$4,000	$113	*$3,887*
Total Monthly Cost	$4,480	$433	*$4,047*
Total Annual Cost	**$53,760**	**$5,196**	***$48,564***

Note that swapping from a single 250kW charger to ten 25kW chargers does not alone bring about the savings seen above. Using the lower power units, if all ten trucks are plugged in at closing time to start charging, then the same 250kW of draw still hits the grid during peak hours. The capital costs between the two setups are reasonable similar. The savings come from the ability to better manage *when* each vehicle takes a charge and at what power level. Plus, having ten chargers rather than one means having some redundancy should a charger breakdown for some reason.

Key VT Utility Rates

Two key factors are needed to be able to project the various options noted above: typical miles driven (combined with vehicle efficiency to get kWh required per day), and the utility rates at which one will be charged for that energy. Electric rates, more formally known as tariffs, are based on customer type (business, residential, industrial, etc), the physical service type (typical distribution, or high-voltage transmission), and most importantly the amount of energy used and speed of delivery (kW). It is important to know both what your current usage caps are, and what your costs will be if you surpass those caps and get kicked into a higher service tier.

Some smaller fleets might choose to have drivers charging at home to reduce costs. In that instance, they may be able to access off-peak, residential rates without time-of-use or demand charges. The EV-specific rates from GMP and BED would streamline reimbursing employees for charging costs as the charging is broken out on the bills. If the organization prefers to charge at a company owned location, but operations would not be disrupted by allowing the public to also use the chargers some of the time (some chargers can be set to have different billing setups for different users), then the company may be able to take advantage of carve-out rates for public chargers and reduce their operating expenses. This could also provide a small revenue stream to offset some of the costs.

Table 3 below includes a summary of the more common commercial rate structures found in the State of Vermont that might apply to fleet electrification programs.

Table 3. A Sample of Current Vermont Electric Utility Rates

Utility	Rate Label	ON-peak kWh	OFF-peak kWh	ON-peak kW	OFF-peak kW	Daily charge	Max kWh allowed	Max. kW allowed	Peak hours	Rachet
GMP	6	$0.17141	$0.17141	-	-	$0.612	7600 (Unlimited for general public EV only)	200 (Unlimited for general public EV only)		
GMP	63/65	$0.11055	$0.08401	$15.666	$4.511	$3.982	-	-	6am-11pm, M-F	50% of annual max kW
VEC	Non-demand	$0.16361	$0.16361	-	-	$0.62867	15,000	500		
VEC	Demand	$0.09364	$0.09364	$21.57	$21.57	$1.048	-	500		80% of annual max kW
VEC	Indust.	$0.09291	$0.09291	$20.54	$20.54	$8.00533	-	-	6am-10pm, M-F	80% of annual max kW
WEC	Small Comm.	$0.20136	$0.20136	-	-	$0.883	7,200	30		
WEC	Large Power	$0.11434	$0.11434	$16.53	$16.53	$1.05967	-	-		90% of winter max kW
BED	Large General Service	$0.08826	$0.08826	$21.38	$21.38	$1.368				50% of summer max kW
BED	Large General Service TOU	$0.12126 Blended summer & winter	$0.08168	$26.82	$4.88	$1.459			Jun-Sep: 12pm-6pm Dec-Mar: 6am-10pm	50% of summer max kW

Other Benefits of Managed Charging

As noted above, reducing peak demand and extending the duration of charging, along with moving charging to off-peak hours, can significantly reduce the ongoing operating costs for an electric vehicle fleet. There are other benefits to this strategy as well.

Reduced Infrastructure Requirements and Utility Upgrades

Managed charging can help reduce the infrastructure requirements and utility service line upgrades needed to support the fleet. Electrical infrastructure to support a site is always sized to handle the peak demand at that site, plus a safety factor. Transformers, for example, are sized in terms of kVA and come in set sizes: 75, 112.5, 225, 300, 500, 750, 1000, 1500, 2000, and 3000 kVA are some commonly found options. While not directly equivalent, the max kW output for a charger can be used as a rule of thumb to find how many chargers a given transformer can safely handle.

An important consideration in the near term for infrastructure sizing is that in addition to avoiding a potentially costly utility upgrade there is a transformer shortage causing long lead times in the industry right now. A managed charging approach could allow a fleet to electrify sooner by not requiring an upgrade right away.

Ten 50 kW chargers might be put on a 500 kVA transformer, but an increase in either the number of chargers or the max power per unit would require going to the next size up transformer. Additionally, this may have significant impacts on other costs, such as the increase in weight requiring a pole-mounted transformer to be changed to a ground based one (with added excavation, conduit, and foundation work), the need to move to the next size up ground vault, or the wire gauge, conduit size, and panel rating to be increased to handle the added load. Due to these step changes in infrastructure requirements and associated costs, careful planning will help avoid early upgrade costs and/or constrained electric fleet operations in the future. In the other direction, it is also important to plan for future upgrades and fleet expansions – it is much cheaper to add another breaker to a panel than it is to re-dig a trenched conduit!

Charging infrastructure costs can vary considerably based on charging station power, features, and amenities. Table 4 lays out the low-end costs for EVSE. Note that expenses will increase with higher-end, fully featured options that include extended warranties, maintenance contracts, higher annual network fees and more consumer-oriented optional amenities (such as cable management, pedestal mounts and user payment interfaces).

Table 4. Comparative Costs of Basic vs High-end Level 2 Networked Charging Stations (Per Port)[1]

Costs Per Port	Basic Level 2 EVSE	High-end Level 2 EVSE
Purchase Cost	$1,300	$3,500
Installation Cost	$3,000	$3,000
Annual Maintenance	$95	$250
Annual Network Fees	$120	$220
Ten-Year Total Cost	**$6,450**	**$11,200**

The difference of $4,750 in per-port EVSE lifetime operating costs at the bottom line of Table 4 is a key factor in EV cost-effectiveness. If a fleet owner chooses to deploy a single higher-end charging station port, lifetime savings (which range up to $4,700 per vehicle for Light Duty pickups) will likely *decrease* by up to $2,900 per vehicle.

Medium-powered DC fast chargers (25kW) are more expensive ($10,000-$15,000 for more basic equipment to more than $40,000 for larger, more powerful stations, and typically $50,000 or greater for high-powered DC fast charging stations (50kW or greater).

Installation costs are highly variable based on many site-specific considerations, such as whether existing electrical infrastructure needs to be upgrade and/or run to a new location, and whether trenching will be required. Table 4 provides a placeholder Level 2 charging station installation cost value of $3,000 per port for high-level planning purposes, but those costs at specific sites could vary between $1,000 to over $10,000 per port for installation (depending on the complexity/difficulty).

Medium and high-powered charging stations have considerably higher installation costs due to more robust electrical infrastructure requirements (such as 480V, three-phase power supply). These costs can range $4,000 to $15,000 per port on the lower end to over $50,000 for larger and more complex projects.

Managed Charging Technologies

There are various methods available to manage when and at what level charging occurs. These can include manual control (a person physically plugging/unplugging a charge port), mechanical timers, on-board vehicle controls (an in-dash scheduling function in some vehicles), a 3rd-party networked

[1] EVSE equipment and networking cost estimates came directly from EVSE manufacturers. Maintenance costs were estimated based on data provided by current fleet and commercial EVSE owners.

software system ties into the chargers, or any combination of the above. The considerations for each are noted in Table 5 below, with greater descriptions provided in the following paragraphs.

Table 5. Advantages and Disadvantages of Various Managed Charging Strategies

	Pros	Cons	Cost range
Manual Control	* Simple and easy * No additional equipment/software needed	* Greater variance of exact timing * Not conducive to regular work hours * Prone to unreliable execution	Labor costs only
Mechanical Timers	* With exception of seasonal changes, this is a 'set it & forget it' solution * Can be deployed as a "fail-safe" for software-based methods	* Periodic changes in operations or rate structures require reconfiguration that can be overlooked * Often comes with a manual override that can be useful or lead to expensive mistakes * Not very sophisticated - if not carefully staggered, can lead to large fleet demand charges	$250 - $1000 per unit
On-board Vehicle Control	* A good digital fail-safe * Scheduling each vehicle with intention can allow for staggered charging * May allow for throttling of power draw to extend charge times while reducing demand costs * Potentially able to be networked across fleet if vehicle software allows	* Level of controllability (and reliability) will vary from vendor to vendor *See notes for mechanical switches above	Included with some EV purchases
Networked Software	* May tie into vehicle telematics for greater monitoring capabilities – if telematics are available * Allows for visibility across fleet to more closely tailor charging to operations/ maintenance/ facility power draw * Remote access, control, troubleshooting * Precise, easily alterable control of timing and charging level	* More expensive * Quality of software usability and features varies by vendor * Typically requires ongoing paid subscription	Up to $2,000/port/ year Included in the purchase of some chargers

Manual Control

A human being can physically plug-in/unplug vehicles. Some fleet operators are able to reduce energy costs by creating standard operating procedures around plugging in vehicles. The most basic strategy is to have drivers leave vehicles unplugged, and then rely on mechanics or other staff to plug-in vehicles after a certain time of day.

Though effective in theory, this system usually breaks down over time and as fleets scale up. The result is often higher-than-necessary energy costs and recriminations between staff. As discussed in **Appendix A: Electric Rate Structure,** under certain rate structures, making a mistake for even a single 15-minute period could inadvertently set the ratchet for the entire rest of the year, incurring thousands of dollars in utility charges. Manual control is not recommended as a long-term solution for fleet electrification.

Mechanical Timers

A mechanical timer device can be installed to prevent charging during certain hours of the day for many EVSE options. These simple timers are inexpensive, and do not require any monthly or annual fees. Programming these timers can be tricky work, so generally they should be set up to operate on the same schedule every day. Timers must be checked regularly for accuracy, and to account for daylight savings time. Experience has also shown that timer system overrides may be triggered by staff and then forgotten. Timers can be a very economical solution for basic control of fleet charging because there are no subscription fees and installed costs are under $1000 for a device that can control many vehicles

On-Board Vehicle Control

Some electric vehicles have onboard controls and monitoring that allow operators to schedule charging start and stop times as well as trend state of charge, odometer mileage, fault codes, and other key metrics. These controls vary greatly in availability and capability. Some on-board controls can throttle the amount of power they draw. This allows the site to reduce demand chargers for normal operations, with the ability to boost their charging level should a future need arise or at more favorable times of the day. In some cases, onboard vehicle charging controls can be a suitable alternative to manual control for small EV fleets. Fleets with more than two or three vehicles may struggle to keep all vehicles properly programmed without a central control system (see Networked Control below). Some newer on-board controls may be able to be networked and would follow a similar approach to what is below.

Networked Software Control

With modern internet-of-things networking, both chargers and vehicles can be connected to web-based software platforms that allow fleet operators to monitor and control which vehicles are charged when, where, and at what level. These systems may be simple or increasingly dynamic. The overall effect is much tighter control on both operations and power demand. Many EVs come with cellular connectivity allowing the onboard telematics system to integrate with the charge management and EVSE systems. This provides the system operator with indicators for a vehicle's current state of charge, how long it will need to draw power to get back to full, and when it is ready for service again. Depending on the EVSE installed, operators may also be able to throttle charging power to a desired level or deliver the minimum energy needed for a vehicle to complete its next run. Or this might be done through on-board vehicle controls. In either case, by spreading charging out over a longer period of time and minimizing peak energy demand, networked charging systems can reduce the demand charges incurred with the electric utility.

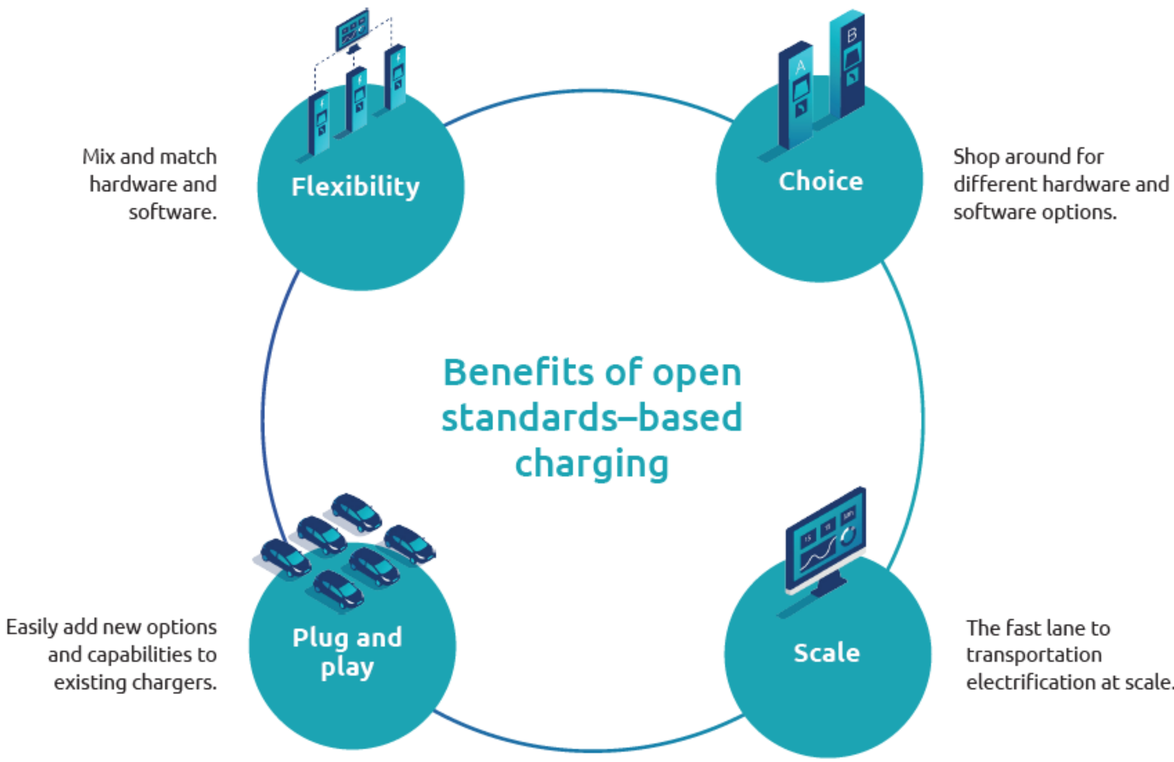
Open vs. Proprietary Charging Networks

Key to this communications platform working is the software interoperability between the vehicles, the EVSE, and the management platform. There are two types of networks for centralized, cloud-based control of electric vehicle charging: Closed (or proprietary networks), and networks based on the Open Charge Point Protocol (OCPP).

Proprietary networks are built upon EVSE hardware and software that are developed together by the same company. These networks can ensure seamless control, since the EVSE design, its software, and the cloud platform are all controlled by one entity. However, hardware that is sold with proprietary networking software generally cannot be unlocked for use with other software providers, thus locking users into subscription fees to maintain network connectivity through the vendor.

Open Charge Point Protocol (OCPP) is a set of international standards for communication between EVSE and central management software systems. OCPP-compliant EVSE can communicate with any software platform that also speaks OCPP. OCPP-compliant EVSE still requires subscriptions to cloud-based software platforms to control charging, but the owner of an OCPP-compliant EVSE can switch to a new software provider without needing to buy new hardware. Figure 1 below illustrates some of the benefits of using an open standard while Table 4 below includes a summary comparison of OCPP and proprietary network EVSE.

Figure 1. Benefits of Open Standards-based Charging[2]



Note that most proprietary charging networks are capable of controlling OCPP equipment.

[2] Source: Greenlots *Open vs. Closed Charging Stations: Advantages and Disadvantages* - *https://greenlots.com/wp-content/uploads/2018/09/Open-Standards-White-Paper.pdf*

Table 6. Open vs Proprietary EV Charging Comparison

	OCPP-Compatible EVSE	Proprietary Network EVSE
Requires software subscription?	Yes	Yes
Can switch software vendor?	Yes	No
Can be controlled by proprietary network software?	Yes	Yes (manufacturer's software only)
Can integrate other brands of OCPP EVSE?	Yes	Yes (integration fees may apply)
Can be integrated with another vendor's proprietary system?	Yes (Integration fees may apply)	No

Planning Ahead for Managed Charging

Opportunities for Managed Charging as Fleet Electrification Increases

Most Vermont light-duty fleet operators are only in the planning stages of electrification. A few may begin testing out a small number of electric vehicle deployments in the next few years, and at those numbers, charging concerns may be minimal. However, as fleets plan for greater electrification (and potentially near or full transition to electric vehicles in the future) the benefits (and necessity) of managed charging will become more considerable for both fleet operators and utilities.

Given that charging stations may remain functional for over ten years, selecting units with the capability to provide networking, managed charging and/or grid interactive charging may reduce or eliminate the need for early replacement if those features are desired later as the electric vehicle fleet grows before the end of the charging station's useful life. A cost-benefit analysis should be conducted to estimate the expected return on investment in these capabilities based on a particular fleet operator's utility rate structure, operational profile, and fleet roadmap.

It may be possible to push this even further in the future. As renewable energy generation continues to increase, grid operators increasingly face oversupply in the middle of the day and dramatic demand ramp up in the evening. Rate makers are already considering opportunities for incentivizing midday charging to consume that extra energy on the grid. Expanding the viable hours for charging means that lower power draws can be used over more hours to supply the same amount of energy. In the future, this may present opportunities for electric fleets with any midday electric vehicle downtime opportunities to partially or fully charge midday at a lower speed (and potentially lower cost) than overnight.

V2X Technologies: Pulling power back out of EVs

As highlighted on some of the new electric trucks coming out, EVs can be more than just an efficient, emission-free form transportation. A mobile battery pack with several times more energy than the daily consumption of a single-family home offers interesting potential. The various modes of energy transfer and the relevant systems/components have each begun to acquire their own acronym and categorization. **Appendix B: V2X Technologies** lists out most of those being discussed in the market today and provides some descriptions.

The costs for setting up a bi-directional vehicle-to-grid (V2G) or uni-directional vehicle-to-grid (V1G) system depends on the features required. Several charging stations available on the market now allow for utility signal inputs to drive functionality for only minor increases in cost, with varying levels of sophistication. For a more complicated system such as a microgrid, critical operations center, or system using a price signal integrated controller, hiring a third-party to manage the software may be worth the added expense. Overtime, these services may become more common place and cheaper, but are again still somewhat experimental in Vermont and the needed markets are still developing.

Over the next few decades, utility rates are likely to increase and load balancing will become increasingly difficult. This is due to a steady increase in renewable energy sources, the added loads of building heating and transportation becoming electrified, and larger and more severe weather events brought on by climate change. The financial incentives for customers to allow utilities to increase their control over large battery systems are projected to see steady growth over the coming years. As the technological hurdles are also tackled and overcome, V2G systems may soon become a major part of grid operations. However, it may be a few years before we see this control scheme developed to a level of sophistication that can handle the operational demands of a fleet operator.

Appendix A: Electric Rate Structures

Utilities determine their rates in much the same way as other companies might determine their product prices, with one key exception: because there is no market competition, state regulators must agree to the rates. At its most basic level, the utility tallies up all their capital and operating expenses, accounting for outstanding debts, taxes, depreciation, and allowable profit margin, and uses this information to come up with the revenue required to keep the business running and provide customers with reliable service.

Rates for distinct types of service (i.e., residential, small businesses, commercial and industrial) are proposed to the Vermont Public Utility Commission (PUC) that fit customer needs while making sure that the utility's rate basis is met as customers' usage and power demands increase and decrease. Rates set through this process typically include a flat daily rate for the cost of service, costs for energy usage during peak and off-peak hours, and possibly an added cost component for power demand (the speed at which energy is consumed) during peak or off-peak hours. Finally, taxes and tariffs are added on to calculate the total customer bill. The PUC reviews the proposed rates through public processes, and once approved by the PUC the utility can offer the rates to customers.

Energy Charges

The costs for energy used over a month are usually straightforward; the amount of energy used directly determines the amount of fuel needed by power plants, the labor requirements for the utility and plant operators, the amount of energy lost during transmission ("line losses"), and the portion of any repairs or district build-out costs that are needed. Thus, a rate can be determined that simply assigns a cost per kilowatt-hour (kWh) of energy used. This is often the way that residential accounts are billed, as their usage is relatively small, and simplicity of billing is helpful for customers to understand the impact of their power consumption on their wallets. Some rate structures use a tiered approach, where an initial tier of energy use is provided for the first few hundred kWh, with higher costs (or lower depending on the intent) per kWh being added as total monthly usage falls into the next tier.

Fleet operators, as typically commercial entities with greater usage, may still be small enough to be on a simple $/kWh rate structure, but are more typically placed on other rates that involve time-of-use and demand charges. If increases in usage cause a customer to get pushed from a flat rate into a time-of-use rate class, the effects on billing can be dramatic if the time when vehicles are being charged is not accounted for and carefully managed.

Time-Of-Use Rates

While a flat charge is convenient, it does not accurately reflect the patterns of usage on the grid and thus is not connected to the variable cost burden placed on the utility. To help cover the added expense associated with peak times larger utility customer accounts often have time-of-use rates that are higher during the peak hours and lower during off-peak. These broad categories of peak and off-peak times are steady and based on the same hours and days throughout a season or entire year. This rate structure has greater economic efficiency by reflecting the changes in cost for energy across the day and week while still providing a rate that is clearly defined and can be planned against. The charge to the customer is a product of the energy used and the cost per kWh for the time and day in which the energy was used.

Power Demand Charges

Although time-of-use rates correlate more closely with grid fluctuations than flat energy rates, the reality is that the grid is in a constant state of flux as users across a region ramp up and down their consumption as needs require. ISO New England is the grid operator for Vermont and the surrounding states. As such, it and is entrusted with ensuring sufficient power is available, that voltage across the grid stays within an acceptable range, and that no region within its territory has a surplus or deficit that could affect customer equipment or facilities. The speed of the energy draw is called power, or demand, and it must be constantly matched to the capacity, or supply. As demand increases across a region, untapped resources must be brought online to meet the needed capacity. And since ISO New England uses the least expensive power sources first, the price of that extra capacity increases non-linearly as additional sources are brought online.

Users who create large spikes in demand carry a proportionately larger burden of the added cost. This 'demand charge' is often calculated by looking at two values: the largest 15-minute average power draw for the month at hand, and some percentage of the largest 15-minute average power draw over a longer time-period, usually a year. Whichever value is higher is then multiplied by the rate-listed cost per kilowatt (kW) of power to determine the demand charge billed to the customer. The reason for looking at the highest 15-minute average over a longer period is because the grid must be prepared to meet that higher demand in advance of it occurring. This is sometimes called a 'rachet' effect, as a single overly large 15-minute power draw may inadvertently end up increasing, or ratcheting up, a customer's electric bills across all other months in the year.

Time-of-use rates and demand charges are often built into the same rate structure, so once again one must not only look at how much energy was used (kWh) and how quickly it was used (kW), but also from what time of day those values were derived.

Real World Example

Champlain Water District's (CWD) is looking to replace their fleet of fullsize pickups with Ford F-150 Lightnings and/or electric Chevy Silvarados over the coming years. The recommended replacements are anticipated to consume roughly 3,750 kWh of electricity per vehicle per year, assuming they travel 6,500 miles/year. The recommended Ford F-150 Lightning Pro draws up to 11.3 kW of power when charging with its standard onboard charger.

CWD's electric rate class was assumed to be Rate 63 from Green Mountain Power (GMP)[3] for their various buildings and parking facilities. Rate 63 is a Time of Use (TOU) rate, with volumetric energy costs ($/kWh) and power demand costs ($/kW) differing between peak times (6am-11pm Monday-Friday) and off-peak times (all other hours). These rates are:

Peak kW: $16.401

Off-peak kW: $4.723

Peak kWh: $0.11573

Off-peak kWh: $0.08795

VEIC estimated that approximately 80% of CWD's EV charging will occur during off-peak hours between 11pm and 6am, with 20% occurring during the day on weekdays (to account for any midday charging opportunities that CWD may choose to utilize). As a result, VEIC developed a blended rate of $0.0935/kWh to reflect this anticipated charging approach, and used this rate for all Total Cost of Ownership calculations.

The roughly 8,000 kWh of electricity consumption at a rate of $0.0935/kWh would cost roughly $350 per year. If the electric pickup was charged when the facility electricity demand was already at its highest point, the overall electricity demand of the facility would increase by up to 11.3 kW. If this occurred during off-peak hours, this would result in a demand charge increase of $53/month (or $640 annually). If this occurred during on-peak hours, this would result in a demand charge increase of $185/month (or $2,225 annually).

[3] Rate-63-65-Commercial-and-Industrial-10.1.21.pdf (greenmountainpower.com)

Appendix B: V2X Technologies

Basic managed charging programs are proactive in nature; fleet operators know when to avoid charging (based on their utility tariff) and use the technologies described in early sections above to ensure that vehicle charging does not occur during those peak times. In contrast, Grid Interactive Charging goes a step further and is *interactive*. It is the practice of taking a signal from the utility to inform whether charging should be turned on, delayed, or even if the vehicle should push power back out onto the grid. By avoiding peak demand periods and providing power back onto the grid when it is needed most, grid interactive charging can help reduce energy costs for EV fleet operators.

Table 7 lists out several of the options this technology might support now or in the future.

Table 7. Vehicle to "X" Technologies

EV Charging Connection Type	V2X Acronym	One-way charging	Set time of charge	Set charging power	Access energy markets	Store + discharge energy	Sell energy back to the grid
Basic charging		✓					
Smart charging		✓	✓	✓			
Vehicle-to-grid unidirectional charging	**V1G**	✓	✓	✓	✓		
Vehicle-to-building / vehicle-to-home bi-	**V2B / V2H**	✓	✓	✓	✓	✓ **Behind the meter**	

directional charging						**backup power**	
Vehicle-to-grid bi-directional charging	**V2G**	✓	✓	✓	✓	✓	✓
Vehicle-to-load	**V2L**					✓ **Vehicle directly powers equipment**	
Vehicle-to-vehicle	**V2V**	✓				✓ **Vehicle is used to charge other stranded vehicles**	

Nuuve, an EVSE manufacturer has a nice description of the various options noted above on their website: [The Real Deal About The Different Types of Electric Vehicle Charging - NUVVE Corp.]

The ability to deliver power from vehicle batteries to the grid is often called Vehicle-to-Grid, or V2G for short. The controls for this exchange can be placed directly in the hands of the utility allowing them to tell selected participating chargers to switch from one charging or discharging mode to another. Alternatively, third-party operators may be tasked with maximizing V2G profits to the fleet operators, while also taking a percentage of that profit for their efforts. There is typically an opt-out feature, by which a customer may prevent V2G modes activating for a particular event if it is not convenient at the moment, but this may come with a penalty for non-participation depending on the utility, its rates, and customer agreements. In exchange for being able to use the customer’s vehicle as an on-demand power resource, utilities may offer some significant financial incentives including reduced charging rates, equipment rebates, and even direct payments. This is still a concept that is in the experimental phase in Vermont, but the utilities are actively working to prove out the value.

Between the two options above is another option that may be available, called ‘Controlled Charging,’ ‘Demand Response,’ or sometimes just ‘V1G’ as it still includes a signal from the grid but does not allow power to flow in two directions. It entails using a signal from the electric utility to tell chargers when they should and should not charge with a little more specificity than the broad ‘peak period’ brush strokes set up for time-of-use rate structures.

For any of the above options, the needs for the operation of the vehicles participating and how this interaction will be managed must be carefully considered in advance. A school bus which sits idle for many hours of the day may be an excellent candidate for such a program so long the system ensures that the bus has plenty of charge for its afternoon run. A transit bus, on the other hand, may have constant utilization throughout the day and must take charges quickly when it can to keep up route schedules, making V2G more challenging to implement and less lucrative to the transit agency. V2G activation signals are most likely to occur during certain times and days but there is still a bit of unpredictability in the arrangement given the enormously complicated interactions of grid inputs and draws.

Appendix C: Glossary

Managed charging terms and definitions:

AEV	All Electric Vehicle (*also commonly known as Battery Electric Vehicles (BEVs)*)
Capacity	The amount of power available for output from the electric grid at a given time
Demand	The average amount of power that is pulled from the electric grid by one or more sites for a specific 15-minute period.
EV	Plug-in Electric Vehicle, including both AEV and PHEV models
EVSE	Electric Vehicle Supply Equipment – in addition to chargers, this also includes all the supporting infrastructure such as mounting, charge cords and connectors, and protection features.
Grid-interactive charging	Charging management structure in which a signal from the utility or grid-operator is used to control the amount and direction of charging/power-offloading of vehicle batteries.
ISO New England	Independent System Operator of New England – this is the organization in charge of monitoring and controlling the combined power output and transmission of all power plant generation on the grid to maintain a balance between power available and power consumed, ensuring stable electricity parameters (voltages, frequencies, etc.), and forecasting and developing the energy marketplace to ensure adequate energy supplies in the future.
OCPP	Open Charge Point Protocol – an open (i.e., non-proprietary) standard for communications between electric vehicles and managed charging software platforms. The latest version is OCPP 2.0.
Off-Peak	The time period set by an electric utility for which electricity and power prices may be set lower due to a reduced average loading on the system. Exact days and times are set by the utility and are defined in the tariff sheet for each rate offered – typically overnight and weekends.
Peak-Period	Times and days of the week during which an electric utility may set costs higher for energy and/or power to disincentivize usage while the grid is heavily loaded, and generation is expensive. Exact days and times are set by the utility and are defined in the tariff sheet for each rate offered – typically mid-day and evening, Monday through Friday.

PHEV	Plug-in Hybrid Electric Vehicle
PUC	Public Utilities Commission – the public board charged with reviewing and permitting utility rates, defining utility regulations, regional utility infrastructure planning, and other regulatory services related to utilities.
Rachet	The effect on a customer's utility billing account whereby the highest 15-minute rate of usage in the last several months (typically a year) sets the minimum demand charge that will be billed.
V1G	A managed charging program where time or magnitude of charging is controlled in relationship to a signal provided by the utility in exchange for reduced billing rates, incentives, or other remuneration.
V2G	Any charging system in which power from electric vehicles is pushed back out onto the grid, usually at the request of the utility and according to an agreement for how the customer will be paid for the energy supplied.
VELCO	Vermont Electric Power Company – the organization that maintains grid transmission reliability within the state of Vermont, ensuring each of the state's 17 electric distribution utilities have enough capacity to meet demand.