Are You Ready for the Future with Electric Trucks and Electric Buses?

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ABSTRACT

With the rise of electric cars and EV charging, vehicle electrification has begun to be included in infrastructure planning. But are we missing a key piece to this growth – medium- and heavy-duty electric vehicles such as electric buses and trucks? Due to large battery capacity, clustered charging activities, and high utilization rates, one charging station for medium- and heavy-duty electric vehicles can be 10 MW or more. Cumulatively, they might challenge the existing transmission infrastructure and require expensive projects to interconnect or upgrade the existing system. To provide support for these loads, it is imperative to predict the location of these transmission level charging stations and understand their load profile and electricity packages required to serve them. This report will outline what medium- and heavy-duty EV charging will look like from the utility perspective using current data and predictions, as well as explore potential mitigation solutions.

I. INTRODUCTION

With the introduction of hybrid and fully electric consumer vehicles to the United States transportation market, electric utilities have, at the very least, become aware that the transition from fossil fuel powered vehicles to electric-powered vehicles will have a correlating increase in electric charging demand. This increasing in charging demand on the consumer level can be forecasted with some certainty by observing the rate of electric vehicle purchases and spreading the corresponding charging load across residential neighborhoods where overnight charging will most likely take place.

Are electric utilities overlooking the real issue to come: commercial and industrial level electric vehicles, primarily medium- and heavy-duty delivery trucks and vans? Unlike consumer vehicles, medium- and heavy-duty commercial vehicles are not yet as widespread in their usage. As a result, there is a smaller sample size to forecast not only the rate of electrification of these vehicles, but what the charging of these vehicles will look like.

With the uncertainty of what medium- and heavy-duty vehicle charging might look like, most electric utilities have not given much attention to this potentially developing issue. A mindset has yet to develop toward recognizing this developing issue. Another question begs to be asked, are electric utilities providing a correct approach toward industrial and commercial electrification? The authors of this paper pose electrical utilities can forecast the electrification needs of increased commercial vehicle use and provide preemptive steps to mitigate large future charging loads.

II. CAUSES OF ELECTRIFICATION

There are multiple factors advancing the switch to commercial and industrial electric vehicles, the most apparent driver being the cost of fuel. In June of 2022, the price of diesel in the U.S. reached the highest monthly average in history at $5.754 per gallon [1]. Adjusting for inflation, the price of diesel has increased 50% since the beginning of 2010.

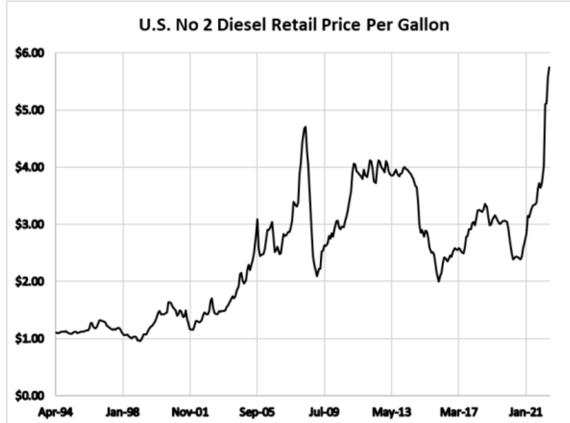

Figure 1. U.S. No 2 Diesel Retail Price Per Gallon

In contrast, the average retail price per kilowatt-hour in the U.S. has decreased by 16% since 2010 when adjusted for inflation [2]. From a cost standpoint, this shows a clear incentive to switch from diesel fuel consuming vehicles to electric powered vehicles.

Since the end of the twentieth century, many companies have pushed to convey “green”, environmentally friendly operation. Some companies like Amazon have made pledges to achieve “carbon-neutrality”. Amazon has a contract with electric van maker Rivian to produce 100,000 all-electric delivery vans by 2050, with 10,000 of those vans on the road by 2025 [3]. Amazon is not alone, with delivery services such as UPS, FedEx, and USPS making similar commitments to an electrified delivery fleet. But why the focus on delivery vehicles? The U.S. Department of Energy estimates that on average, a gasoline powered vehicle has an annual equivalent emission rate of 11,435 pounds of CO2, while an all-electric vehicle has an annual equivalent emission rate of 3,932 pound of CO2 [4]. With a potential to reduce their vehicle carbon emission to nearly a third, it makes sense that larger delivery companies would feel some obligation and expectation from the public to make the switch to electric vehicles.

Along with growing social awareness of the impacts of carbon-based fuels, end consumers are demanding suppliers reduce carbon emission throughout the entire supply chain. Consumer brands, such as Nike, The Home Depot, and

Unilever are demanding their suppliers and venders reduce their carbon footprint. The entire logistics industry is experiencing a rapid change. As a result, the pressure for electrification has cascaded down to the shipping, trucking, and last-mile delivery stages.

There is not only pressure from the public but from government and regulatory bodies as well. Some states have mandated the switch to electric vehicles. California has mandated that all commercial truck manufacturers start selling electric powered trucks starting in 2024, and all trucks in the state are required to be fully electric by 2045 [5]. Starting in 2035, diesel trucks will be heavily limited in being able to enter major ports in California. The federal government has plans to end purchases of gas-powered vehicles by the year 2035 [6], with the Biden administration setting a 2030 greenhouse gas pollution target [7]. With a continued push on the state and federal level for increased environmental regulations, a more mandated drive for a switch from gasoline to electric powered vehicles is to be expected.

III. TYPES OF VEHICLES BEING CONVERTED

There are three main types of medium- and heavy-duty vehicles that will likely be subject to electrification in the next two to three decades: short-range delivery vehicles such as Amazon/UPS/FedEx vans, long-range delivery vehicles such as semi-trucks, and public transportation such as public buses and school buses. Though there are other large vehicles that will likely face electrification in the future such as utility bucket trucks, garbage trucks, and cement trucks, the three described types are the ones that will likely show the most challenge to electric utilities because they tend to be on a larger fleet-scale, as opposed to only having a few vehicles within an area.

In the short-range delivery category, every major delivery service (Amazon, UPS, FedEx, and USPS) has some contract or commitment in place to increase their electric vehicle fleet. Amazon has a contract with Rivian to produce 100,000 electric vans by 2050 [3]. UPS has committed to purchase up to 10,000 EVs from U.K. startup Arrival [8]. FedEx has committed to having 50% of new vehicle purchases be electric by 2025, 100% of new vehicle purchases by electric by 2030, and their entire parcel pickup and delivery fleet converted to EVs by 2040 [9]. USPS has recently placed an order with Oshkosh Defense for 50,000 next generation delivery vehicles, 10,019 of which will be fully electric [10].

Long-range delivery vehicles are expected to make a similar push to electrification but have not yet made large strides in that direction. Amongst the largest trucking companies in North America (CSA Transportation, Atlas World Group, Marten Transport LTD), there has not been the same level of commitment towards a transition to fully electric vehicles as those companies on the short-range delivery side. Some companies like ocean shipping giant Maersk have made commitments that all newly purchased trucks will be electric or operate on low-carbon fuels. The challenges of scaling long-range delivery trucks include the lack of mature products offered by manufactures in the market, battery capacity limiting distance coverage without charging, and the cost of electric trucks versus diesel trucks. Even with these challenges, long-range delivery vehicles are still expected to electrify as cost and charging options become more appealing. Research has shown that an electric truck would break even at about 30,000 annual miles over the vehicle's lifetime compared to a new diesel truck [11].

Public transportation, being susceptible to an increased level of government pressure and regulation, have predictably begun the transition to fully electric vehicles with many larger cities already making commitments to full electrification. The city of Denver has committed to 100% electric transit by 2050 [12]. The city of Los Angeles passed a motion to mandate 100% electric public transit by 2030 [13]. With aging public transportation infrastructure across the country, many large cities have indicated that any diesel-powered public transportation to be replaced will be substituted with an electric alternative in the coming years.

IV. Charging Types

With Level-1 EV charging being primarily used for at-home charging where only a 120V-AC connection is available, medium- and heavy-duty charging will most likely consist of Level-2 and Level-3 charging. Level-2 charging is a 208 or 240V-AC connection (typically 208V in commercial applications). Level-2 chargers can operate at up to 80A and 19.2kW. The available charge rate is dependent on the charge circuit configuration, however, any charge circuit capable of 40 amps or more requires a dedicated 40A circuit to comply with the National Electric Code requirements in Article 625 [14]. It is to be expected that in a commercial or industrial charging setting, most EV owners utilizing Level-2 will opt for an 80A/19.2kW charge rate if the EV is capable to minimize downtime spent charging.

Level-3 charging is currently the fastest type of charging available. Level-3 charging (often called DC Fast Charging or Supercharging) is a 400 to 900V-DC connection [15]. The power delivery rate for Level-3 chargers falls within the 24 to 350kW range, with 350kW sometimes considered "Extreme Fast Charging" (XFC). The typical capacity of these chargers is 150kW. Depending on the desired charge rate, multiple trucks/vans can be charged off a single charging station at one time.

Charging Level	Power Delivery Rate
Level-1	1.0-1.4 kW
Level-2	3.9-19.2 kW
Level-3	24-350kW

Figure 2. Charging Level vs. Power Delivery Rate

It is expected that short and long-range as well as public transportation vehicles will use some blend of Level-2 and Level-3 charging, with Level-1 charging not being typically applicable for commercial use. To what extent Level-3 charging will be used over Level-2 charging will be dependent on the company's mission requirements, with companies with more available time to charge using the less power intensive Level-2 chargers.

V. Charging Location and Schedules

The questions of "when" and "where" medium- and heavy-duty electric vehicles will charge should be the point of most interest to an electric utility trying to anticipate these vehicles. The vehicles that will be hardest to predict are the short-range delivery vehicles, such as delivery service vans. Most "last-mile" delivery routes have their vans driving under 100 miles, with the exception of longer rural routes. For vans like Amazon's EDV 700 with a range of 201 miles, this means that overnight charging at the delivery facility on a Level-2 charger would be sufficient to supply all the charge needed for an entire delivery day [3]. For vans with less charge range or longer delivery routes, it would be expected that mid-day, mid-route charging would be required to complete the entire day. For this intermissive delivery route charging, it is more likely that Level-3 chargers would be used, either at the delivery facility, or somewhere mid-route. Delivery services generally lack transparency in charge schedules and routing, therefore it will be up to the utility to try to anticipate the charging needs of short-range delivery services that expect to transition to EVs and collaborate with the logistics industry.

While predicting schedules for long-range EVs may be a challenge, charging locations are much more straight-forward to anticipate. Almost all long-range delivery vehicles, such as semi-trucks, are charged at a shipping depot. Semi-trucks cannot typically fit in public locations where public Level-3 chargers are available, so charging is limited to places sized to accommodate large shipping vehicles. Most shipping routes using electric semi-trucks are planned so that the battery capacity will be able to take the truck from shipping depot to shipping depot on a full charge, eliminating the need for any mid-route charging stops. There are also emerging innovative arrangements being considered where a fleet operator would consider utilizing a charging station at their delivery location or a nearby truck stop to extend their range of activities before coming back to the depot. The Tesla Semi, for example, has a 300 to 500-mile battery range [16], meaning most short to medium-range trucking routes are feasible on a single charge. The upcoming Nikola Two semi-truck (available in 2024) is advertised to have a 900-mile range [17]. This does create a limitation for long-range trucking routes that require a delivery destination without an overnight charging depot nearby. With non-depot charging demand brought forth by the growth of fully electric semi-trucks, demand will most certainly grow for mid-route charging at rest areas and truck stops. With the large battery capacities of these trucks and the limited rest time truckers face, there will likely be a blend of Level-2 and Level-3 chargers at these locations. The schedules of vehicles using these chargers will be hard to forecast, as charging is expected to happen throughout all hours of the day and night.

In terms of charging schedules and locations, the easiest of the medium- and heavy-duty electrical vehicles to predict will likely be the public transportation vehicles. These vehicles are subject to much more consistent schedules, and with them being government owned, the routes and charging schedules are more likely to be publicly available to the utility. Public transport buses for example have consistent routes throughout the day and evening, with scheduled stops back at the bus station where they will assumingly require Level-3 charging in order to complete the full day. Once done with the full day’s schedule, the buses will likely require Level-2, or potentially Level-3, overnight charging to accumulate enough charge for the next day’s route. Luckily for the utility, this schedule should be fairly consistent day to day, and therefore simple to forecast. Similar scenarios are to be expected for vehicles like electric school buses, which are already being adopted in some cities like Boston and New York [18]. These buses can be expected to have a very consistent Monday through Friday charge schedule, charging after the morning student pick-up and afternoon student drop-off.

VI. Effects of Charging On the Utility Grid

Medium- and heavy-duty EV charging, particularly fleet vehicles, are expected to present some unique challenges to the utility electric grid. With these vehicles primarily relying on the faster Level-2 and Level-3 chargers, rather than the consumer grade Level-1 and slower Level-2 chargers, the instantaneous load demand seen by the utility can drastically change just by plugging in a few of these vehicles at a time. For a weak or unprepared electric grid, this could cause power quality issues such as flicker and low voltage on feeders. From a capacity standpoint, most systems are built out to withstand at most the 10-year forecasted load. Many utilities have not included the charging of these large EVs into their load forecast models. With the combined charging load of some short- and long-range delivery facilities ranging upwards of 10 MW, some utilities will be faced with large unplanned system upgrade costs to be able to handle the charging load, often under the customer’s pressing timeframe to come online.

Determining necessary upgrades will be a challenge in itself. Historically, the annual peak load for the majority of power distribution systems in the U.S. typically occurs in the hottest parts of summer, where there has been a series of hot days in a row. This correlates to a high air-conditioning cooling load which will happen mid to late afternoon after many people have left work and returned home to a house that they would like cooled from the heat of the day. This peak may not necessarily line up with the peak of medium- and heavy-duty EV charging though. With the bulk of the Level-2 charging occurring in the evening and overnight after the delivery and transport vehicles have finished their routes for the day, new overnight peak times may occur in some areas. With this being the case, utilities will face the challenge of not only having to determine if their daily peak time has changed, but also determining to what extent the large EV charging will worsen the existing peak and cause equipment overloading or voltage issues. If a utility assumes their peak charging load will occur at the same time as their existing non-charging load, they may rush to propose that equipment upgrades are needed, when in reality the coincident load peak of these two load curves may not actually warrant any equipment upgrades. Without good data and specialized analysis, decisions on projects costing millions of dollars might be misled.

Some assumptions and generalization can be made for time-of-use charging based off measured data. ElectroTempo's forecasted average charging demand load profile for Houston in 2033 shows the daily peak for all categories of local fleet vehicles happening around 6 p.m., with a secondary smaller peak occurring closer to midnight. For Houston in particular, this could mean local fleet vehicles will add a significant contribution to the typical daily peak after most people get off work late in the afternoon, and then additionally contribute to the peak charging load for individual consumer vehicles that would charge overnight. With different types of local fleets being prevalent in different areas of the U.S., load forecasting like this will be needed on a by-area basis to assess the effects of medium- and heavy-duty vehicles to a specific area.

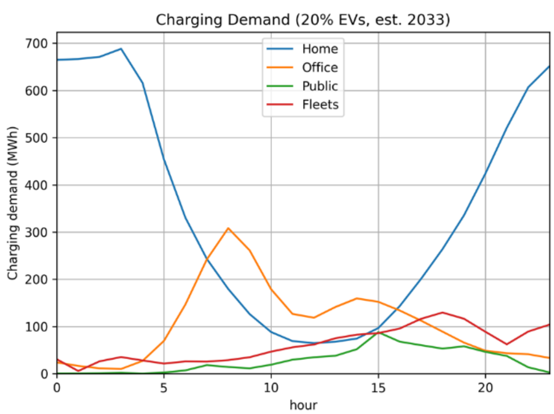

Figure 3. Forecasted Houston Local Charging Demand in 2033

The State of California Energy Commission has released similar data analytics showing their expected state-wide hourly charging load profile for the year 2030 [19]. One can readily notice the different load shapes between Figures 3 and 4 once long-haul trucking is considered.

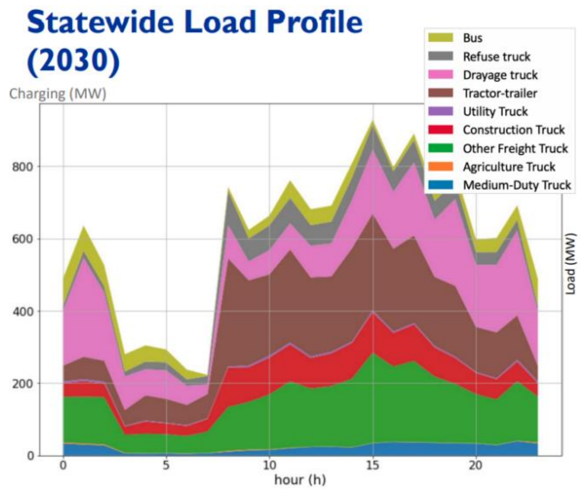

Figure 4. California Forecasted Load Profile in 2030

VII. FORECASTING

With the knowledge that fleet-scale medium- and heavy-duty vehicle electrification is on the horizon, the first challenge to electric utilities is forecasting the electric load growth due to charging these vehicles. In general, there are a few methodologies of growth scenarios that can be used to forecast this growth. The first scenario, being the worst-case scenario in terms of electrical demand, is the "Announced Pledges Scenario" (APS). The APS shows growth to the extent of all announced ambitions and targets for vehicles electrification by large companies and governments to reach a goal of net zero emissions by 2050. This scenario would have the U.S. growing from around 200,000 medium- and heavy-duty electric vehicles in 2022 to around 1,900,000 in 2030, approximately a 950% increase over 8 years [20].

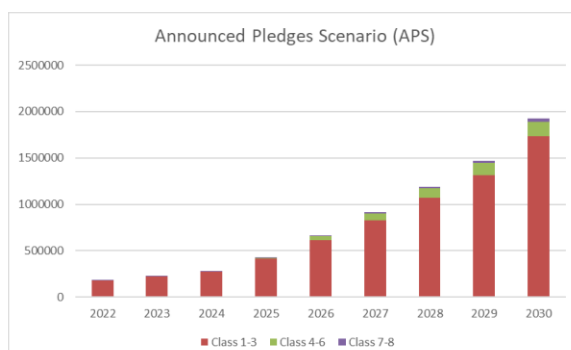

Figure 5. Announced Pledges Scenario Graph

The next growth projection is the "Stated Policies Scenario" (STEPS). The STEPS shows a more conservative growth rate in which all announced policies and pledges are met up to 2030. This scenario would have the U.S. growing from around 200,000 medium- and heavy-duty electric vehicles in 2022 to around 1,400,000 in 2030, approximately a 700% increase over 8 years [20].

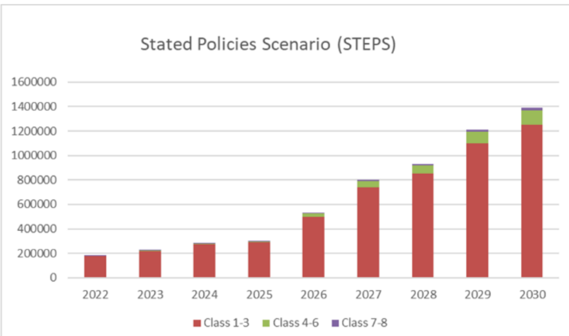

Figure 6. Stated Policies Scenario Graph

The most conservate growth projection is the "Business As Usual Scenario" (BAU). This projection keeps the current growth rate of EVs in the U.S. constant, with no additional growth rate change due to electrification policies or commitments and no decrease in growth rate. This scenario would have the U.S. growing from around 200,000 medium- and heavy-duty electric vehicles in 2022 to around 800,000 in 2030, an approximate 400% increase in 8 years [20].

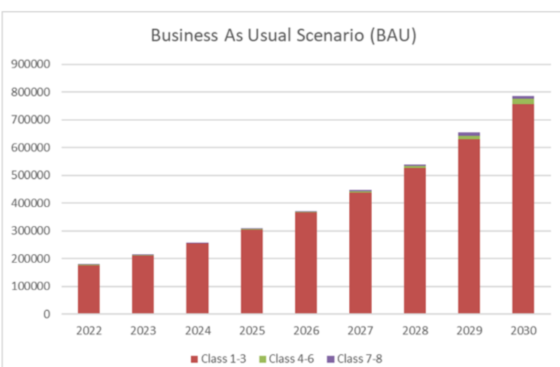

Figure 7. Business As Usual Scenario Graph

Looking at the equivalent annual growth rate of these three scenarios, APS forecasts a nearly 106% equivalent annual growth rate, STEPS forecasts a nearly 75% equivalent annual growth rate, and BAU forecasts a nearly 38% equivalent annual growth rate.

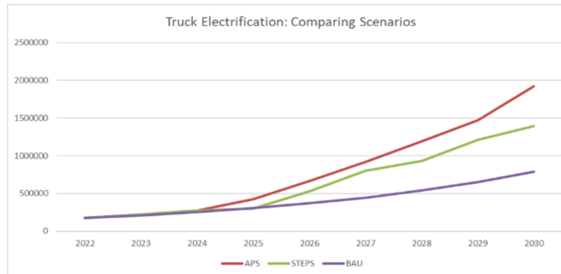

Figure 8. Comparison of APS, STEPS, and BAU Graph

For most electric utilities, these electric vehicle charging loads will far exceed the typical expected annual growth rate (on average a couple percent) per feeder. Because the charging locations for electric fleet vehicles are typically in very specific areas such as ports, warehouse districts, fleet depots, airports, and commercial districts with high trip endings, electric utilities will need to anticipate these high spot-load increases.

System planners will need to anticipate where these large spot loads will appear as well as determine an aggregate coincident peak electric demand in order to determine system upgrades. One of the largest challenges will be determining primary service voltage for these new loads. In some scenarios, the existing distribution-level voltage system will be adequate to serve the new charging loads. For many large fleet businesses, the late-evening and overnight charging load can easily exceed 10-15 MVA of required capacity, meaning a dedicated distribution substation connection or a primary feed from a medium- or high-voltage transmission line will be needed.

For planners of small electrical distribution systems, it may be manageable to enquire about anticipated charging capacity needs and schedules of individual businesses. For larger systems, large-scale data analytics and forecasting methodology such as that performed by ElectroTempo may be required. Such analytics can help utilities forecast the size and location of charging infrastructure and allow the utilities to incorporate the by-area forecasted charging load data by rolling up load into a by-substation forecasted load profile. This will be immensely beneficial in determining future capacity needs in creating an asset development strategy to be able to handle future charging requirements.

VIII. Mitigation and Potential Solutions

There are multiple ways CMY Solutions has found that utilities can prepare for the upcoming influx of medium- and heavy-duty electric vehicle charging. The first and likely most import task will be to produce good forecasts on size and location of where these EVs will charge, either by forecasts created by the system planner or by data analytics services provided by companies such as ElectroTempo. Once the utility has an idea of where charging load will accumulate, they can create a plan for future-proofing their distribution and transmission systems. If, for example, they expect a large delivery fleet charging load to materialize at a delivery depot on the outskirts of town, they should assess if the current distribution infrastructure can handle that load increase. If it can't, can certain elements such as substation transformers or line conductors be upgraded to handle the load increase? If not, maybe the utility should create a plan for building new transmission lines and an entirely new substation close to where this load could materialize. The important thing is to have a plan, start preliminary engineering, and create space in future budgets for these potential upgrades that may be required.

In some scenarios, utilities may find value in exploring non-wire alternatives to system upgrade projects. If, for example, a large overnight fleet charging demand is expected to happen at night when local renewable generation such as solar is offline and this night-time peak is expected to cause voltage or conductor overloads going back to the substation, localized grid-scale battery storage could be an option. Similarly, if the new charging load causes issues in some contingency switching configurations, utility-owned batteries at the charging depot, enough to complete just the night-time charge cycle, could keep the utility from spending money on costly upgrades for an issue that may only happen during certain hours of the day in certain contingency scenarios.

If new charging load is expected to happen primarily during daylight hours, the utility could build new renewable generation on the distribution circuit near the charging load or offer incentives to developers to build in the area. Localized renewable charging in coordination with battery storage could be planned to service an entire large charging load without need for any further system upgrades. With the push for renewable energy generation in the past decade, offering incentives or rebates for solar or wind developers to develop in a specific area is a simple way for utilities to get generation where it's needed without large capital investment from the utility.

If there are not any feasible solutions to serve charging load as it would naturally come, or system upgrades would come at too severe of a cost, utilities could deploy methods to decrease the instantaneous charging load. This could involve grid digitalization solutions such as demand response and utility-controlled charging speed on EV chargers to match generation available at the time. Many utilities have had success with such opt-in programs, where customers give the utility control of high consumption loads such as A/C and refrigeration so that the utility can curtail these loads during peak load times in exchange for rebates on their power bill. For industries where charging schedules aren't as tight and they have the flexibility to delay charging for a few hours, the same strategy could work.

Time-of-use pricing could be used in the same manner to incentivize consumers to charge at times that are either off-peak or are concurrent with the localized generating times. This time-of-use strategy has historically worked for large industrial customers, where many will use the utility grid power during the night at off-peak times when electricity is less expensive, and then run their own private generation during the day when electric prices are the most expensive during their daily peak. These time-of-use prices can be staggered within a local area to incentivize large energy-consuming EV loads to charge non-concurrently with each other.

IX. Conclusion

Although the true rate of medium- and heavy-duty vehicle electrification remains to be seen, the electrification itself is certain. Through data analytics and system planning, these large charging loads do not have to be a "cross that bridge when we get to it" scenario, but rather an inevitable obstacle that all utilities will face that can be worked through with the right strategy.

Through coordination with businesses and industries with plans to electrify their van and truck fleets, utilities can gain the insight needed to anticipate and forecast the location and size of the charging load for these vehicles. These forecasts can be used to future-proof the electric grid in hopes of anticipating required system upgrades and giving utilities the needed time to consider different options on how to best serve these large loads.

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