Electrifying trucks and other fleets: Utility infrastructure will be critical

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Abstract

As electric grids get cleaner, the use of electric vehicles becomes a central decarbonization strategy; this means trucks as well as passenger vehicles. In the U.S., buses and freight trucks account for less than 5 % of vehicles but about 28 % of greenhouse gas emissions. Many trucks are part of fleets, including delivery vehicles, buses, garbage trucks and tractor-trailers. Discussions with electric truck manufacturers indicate that a large barrier to fleet electrification is having adequate power on-site to charge vehicles. Fleet charging can require several megawatts of power, with loads of 20 MW or more in some applications; fleet depots can have power needs similar to many factories. In order to supply this power, utilities need to assess customer charging needs and incorporate findings into the planning of local distribution grids. Needed updates will often include new transformers, sometimes include new feeders, and at times require substation upgrades. In the U.S. a few utilities are taking a proactive approach to prepare for fleet electrification, but most utilities have barely started. This paper characterizes this emerging issue and provides case studies on how several leading utilities are preparing for electric fleets, providing models for other utilities.

Introduction

In the U.S., buses and freight trucks account for less than 5 % of vehicles but about 28 % of greenhouse gas (GHG) emissions from all vehicles, as presented in Figure 1. Many trucks are part

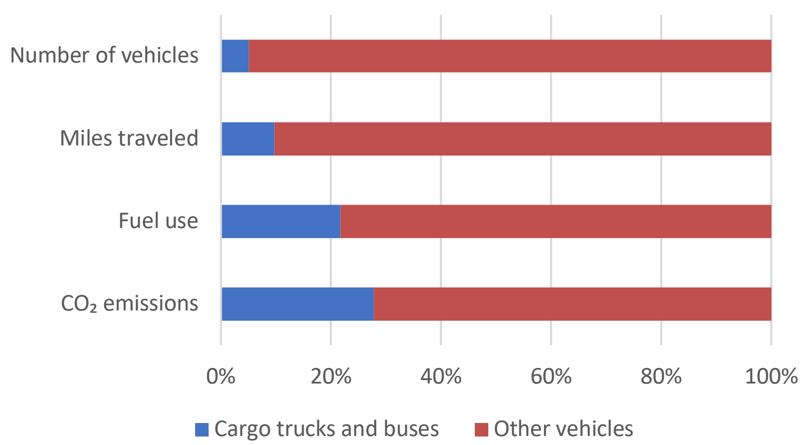

Figure 1. Freight trucks and buses (vehicle Classes 3–8) in the U.S. as a proportion of all vehicles (Nadel and Huether 2021).

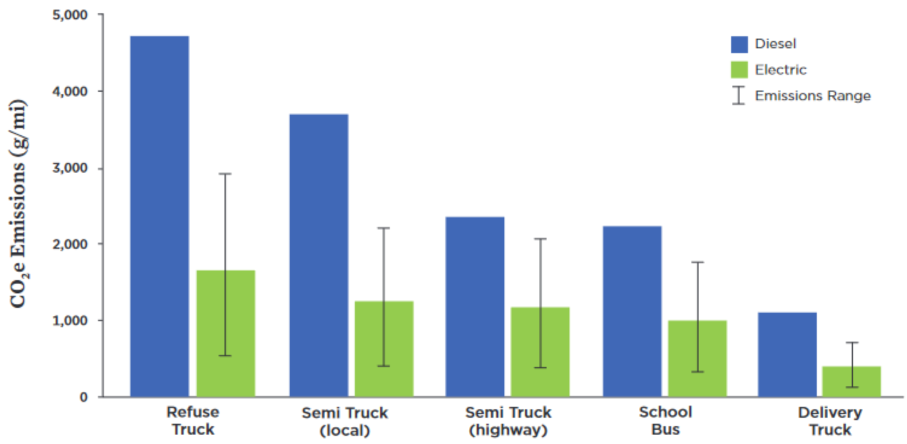

Figure 2. Life-cycle greenhouse gas emissions from different types of vehicles. For electric emissions, the green bar is for average 2016 emissions per kWh; the whisker is based on the range of emissions per kWh across regions (O'Dea 2019).

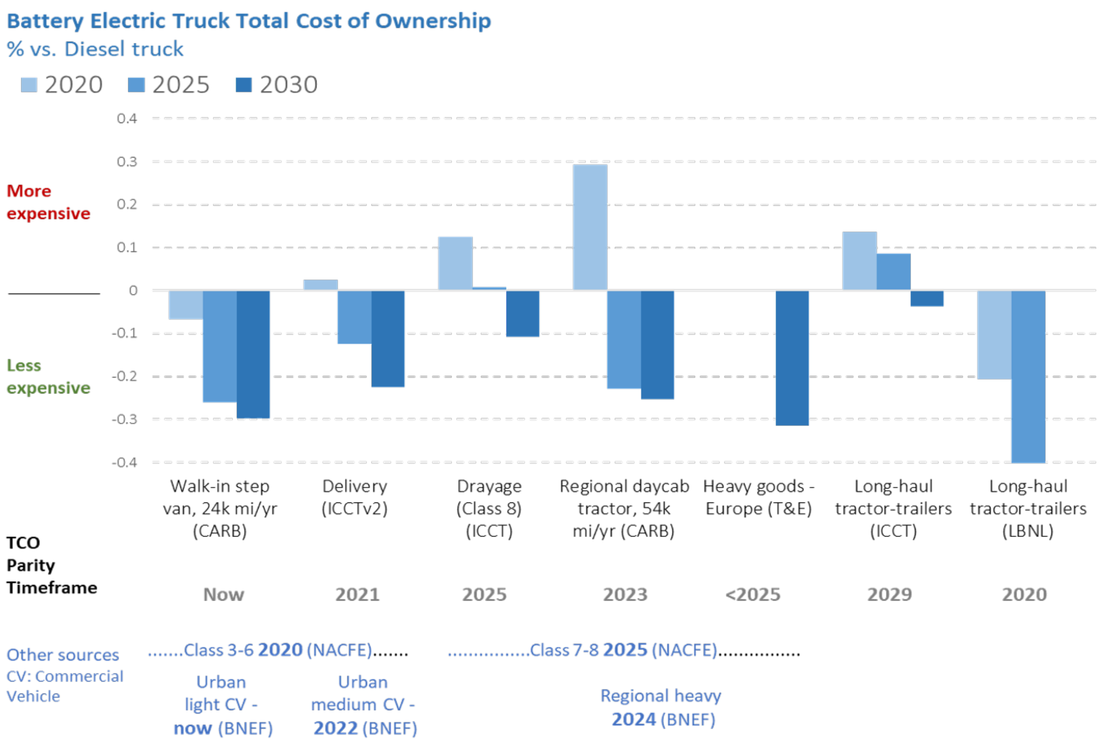

Figure 3. Comparison of diesel and battery-electric trucks on the total cost of ownership (TCO). CARB=California Air Resources Board. ICCT=International Council on Clean Transportation. T&E=Transport and Environment. LBNL=Lawrence Berkeley National Laboratory. BNEF=Bloomberg New Energy Finance. NACFE=North American Council for Freight Efficiency (Hewlett Foundation 2020.)

of fleets, including delivery vehicles, buses, garbage trucks and tractor-trailers. Recent product developments offer growing opportunities to electrify trucks and buses and slash their emissions, as discussed in the next two sections of this paper. Additionally, many countries, states and cities are adopting policies to encourage bus and truck electrification, as discussed in the following section. As more electric buses and trucks travel on roads, future fleets will require a lot of electricity for charging. Utilities will need to be ready to power electric fleets, which in many cases require improvements to distribution systems. While some utilities in California and elsewhere are planning for an increase in power demand, as discussed in several case studies later in this paper, most utilities have yet to do so and need to get started.

This paper draws from extensive data on these issues in the U.S., but we also include some examples from other countries. All countries with plans to electrify substantial portions of their bus and truck fleets will need to address these issues.

Figure 4. Tesla Semi (left) and Daimler e-Cascadia (right). Sources: (Lambert 2018); (Hirsch 2018).

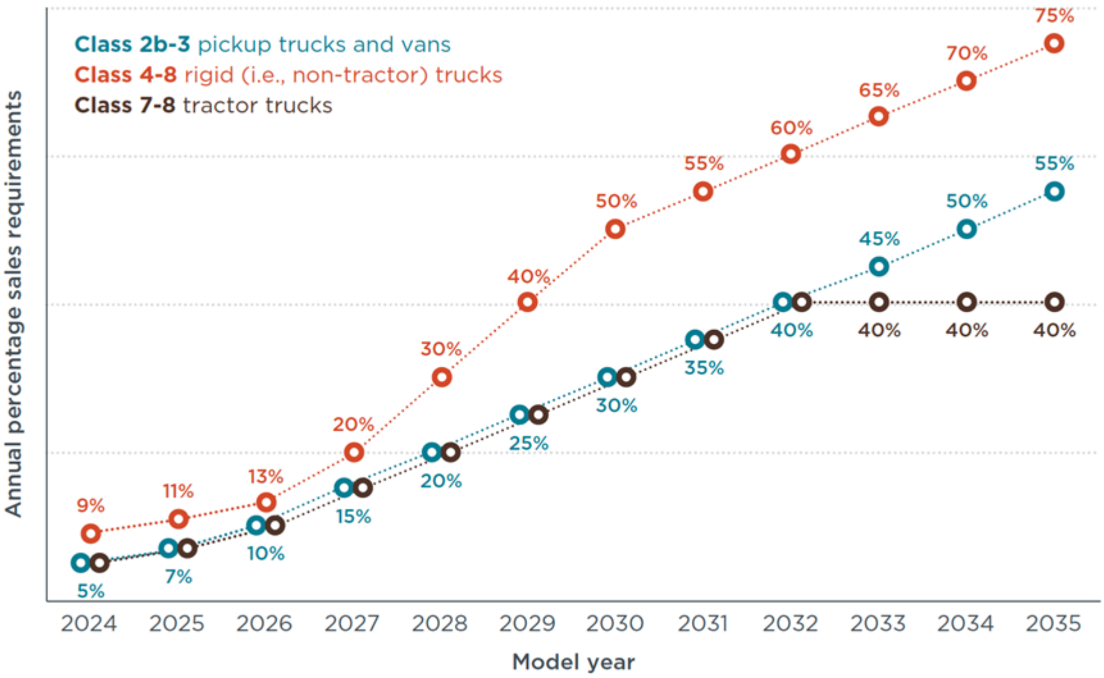

Figure 5. California zero-emissions sales percentage schedule by vehicle group and model year (Buysse and Sharpe 2020).

Why electric trucks and buses?

Electric trucks and buses are growing in popularity because they have substantially lower emissions than diesel and gasoline vehicles and increasingly, they can provide lifecycle cost savings. The emissions benefits of electric trucks and buses are illustrated in Figure 2, and a summary of recent studies on electric truck economics can be found in Figure 3. Figure 3 shows that electric delivery and other small trucks are often cost-effective today, while large tractor-trailers will likely be cost-effective in a few years. Electric transit buses are often cost-effective today in large and medium cities (Marcacci 2018).

There are also a number of other advantages to electric vehicles such as quieter operation, reduced emissions of harmful pollutants such as NOx and fine particles, reduced maintenance expenses, and higher torque (Nadel and Huether 2021). However, electric vehicles also face challenges – a 2018 survey of fleet owners found that the top three challenges are high purchase price, inadequate charging infrastructure, and inadequate product availability (UPS and GreenBiz 2018). One major truck manufacturer we interviewed, wishing to remain unnamed, views grid limitations as a key obstacle to truck electrification.

Growing availability and sales of electric trucks and buses

In the past few years, the availability and sales of electric trucks have increased substantially. Amazon contracted to purchase 100,000 electric delivery vans and plans to have 10,000 of these vehicles on the road by the end of 2022 (Ferris 2021). United Parcel Service will buy 10,000 electric vans from UK-based Arrival (Fretty 2020). Various other manufacturers have announced delivery van as well as medium-duty vocational truck models (Nadel and Huether 2021).

Electric buses are now widespread in China. In the U.S., New York City, Los Angeles, San Francisco, Baltimore and Washington DC have made commitments to switch all municipal buses from diesel to electric buses by 2030–2040 (varying by city) (Nadel and Huether 2021). California has a regulation that specifies the percentage of purchases that must be zero-emission, ramping up to 100 % in 2029 (Kane 2018). Many other transit agencies are gradually introducing electric buses into their fleets. Likewise, school bus purchases are starting to transition to electric, driven in part by concerns about the effect of diesel emissions on children (e.g., see U.S. PIRG 2022). The state of Maryland in the U.S. has legislated that new school bus purchases be zero emissions as of 2020, dependent on availability of funding from the state (Peetz 2019). Maryland and many other states are using funds from the Volkswagen "Dieselgate" settlement to purchase electric school buses.

Likewise, refuse trucks are a growing application for electric vehicles. These trucks can be a good early application of electric heavy-duty vehicles because EVs are better suited than diesel or gasoline vehicles to stop-and-go driving at low speeds over short distances. Stop-and-go driving increases diesel maintenance expenses (Daniels and Nelder 2021). One estimate (from an electric truck vendor) is that a diesel truck costs $5,000 per month for fuel and maintenance, and that electric trucks can reduce this by 80 % (Lovely 2020). California is leading the way with incentives available for $120,000 per refuse truck and a requirement that 75 % of truck sales be zero-emission by 2035 (Nadel and Huether 2021).

Finally, efforts are beginning to electrify the workhorse of American roads, the 18-wheel tractor trailer (Figure 4). Volvo is now manufacturing electric tractors in the U.S., and other major manufacturers are preparing to begin production in 2022 or 2023. This includes a new truck manufacturer – Tesla (Nadel and Huether 2021).

Policies will drive substantial sales growth

In many countries, growth in electric truck and bus sales are being driven by policies. In the U.S., two policies, in particular, are worth noting. First, the California Air Resources Board (CARB) has adopted minimum requirements for the percentage of truck sales that are zero emissions. The percentages, which vary by vehicle type and year, are illustrated in Figure 5. Fifteen other states plus the District of Columbia have committed to exploring similar rules (NESCAUM 2021) with New Jersey, New York, Oregon and Washington recently adopting the California rules. Second, the U.S. House of Representatives has passed a bill that would provide a 30% federal tax credit for purchases of zero emission medium- and heavy-duty vehicles. The legislation is pending in the Senate, with a vote likely taking place early in spring 2022.

Electric truck and bus fleets need substantial power; distribution planning will be critical

NEEDS AND COSTS

Electric vehicles add a substantial load to power grids, which will affect the need for generation, transmission and distribution infrastructure. The overall growth in power needed is probably moderate relative to power demand for all uses. For example, a Eurelectric study (2018) estimated that if 80 % of all passenger cars become electric, this would lead to a total increase of 10–15 % in European electricity consumption by 2050. Electric trucks and buses would add additional power needs. A report by the U.S. Department of Energy (DOE) on the U.S. found roughly similar impacts, noting that this growth in electricity demand is less than power plant build rates during the late 20th century (US Drive 2019). Probably a bigger issue is that this power demand is not evenly distributed but will be concentrated in locations with many chargers, such as fleet depots. Utilities need to plan their distribution systems to meet this localized need for more power.

Power for trucks and buses is generally more of an issue than for cars because trucks typically have larger batteries and because trucks and buses are often parts of fleets with many vehicles that charge at the same location and often at the same time. For example, a Tesla Model 3 battery stores 82 kWh; a Proterra transit bus battery stores 220–660 kWh (Lambert 2020, Proterra 2021). In Amsterdam, a 100-bus transit fleet is powered by a set of slow and fast chargers that together have a peak load of 13 MW (Manthey 2018), which is equivalent to the power that might be used by large factory. They are thinking of expanding the fleet to 250 buses (Manthey 2018).

Many other fleets will also need a lot of "juice." For example, a rough estimate of the power needed to serve a fleet of 200 delivery vans at an Amazon fulfilment centre is about 4 MW (Kellison 2019). For electric 18-wheelers, chargers may need up to 2 MW of power each; a recent proposal calls for charging stations located every 100 miles along the U.S. West Coast's I-5 corridor, each with a peak load of 23.5 MW (HDR et al. 2020).

These examples show the need for more power at a given site than most utilities can provide without substantial planning and investment. Meeting these needs will often require changes to primary and secondary power distribution systems (feeders that deliver power to distribution transformers and to end customers) and substation upgrades. For large loads, a new substation may be needed. A paper recently released by CalETC (2020) estimates that for loads over 5 MW, distribution system and substation upgrades will be needed most of the time. According to the paper, typical utility costs are $1,000,000–9,000,000 for substation upgrades, $150,000–6,000,000 for primary distribution upgrades, and $5,000–100,000 for secondary distribution upgrades. Black & Veatch (2019), in their paper on electric fleets, also provide general guidance (see Table 1), while recognizing that each site is unique.

INSTALLING CHARGERS

Choosing the correct type of charger, and where to install it, will require several major considerations. First, the type of vehicle and how it is used will determine the battery's size and capacity. Next, characteristics of the business or fleet and how quickly a vehicle must return to the road will determine the charging level. Finally, and perhaps most importantly, selecting a site for chargers will require consideration both of where the vehicles will be used and stored, and of the availability of sufficient grid infrastructure to meet the expected electrical demand.

For delivery vehicles and transit busses, business owners and fleet operators generally prefer that charging take place where the vehicles are typically parked when not in service, such as in a warehouse parking lot or at a bus depot. Long-haul trucks could also charge at a warehouse, but for longer routes, such as those made by sleeper cabs, the trucks will ideally use chargers en route, such as at rest stops. This presents multiple challenges for the grid infrastructure, especially given the likelihood of multiple chargers operating simultaneously.

Table 1. Distribution upgrades typically needed as a function of new load (Black & Veatch, 2019).

Amount of new load (MW)	Upgrade typically needed
20	New substation
10	New transformer bank
5	New circuit
2	Customer needs to take higher voltage service
1	Upsizing wire or cable to the site or reconductoring

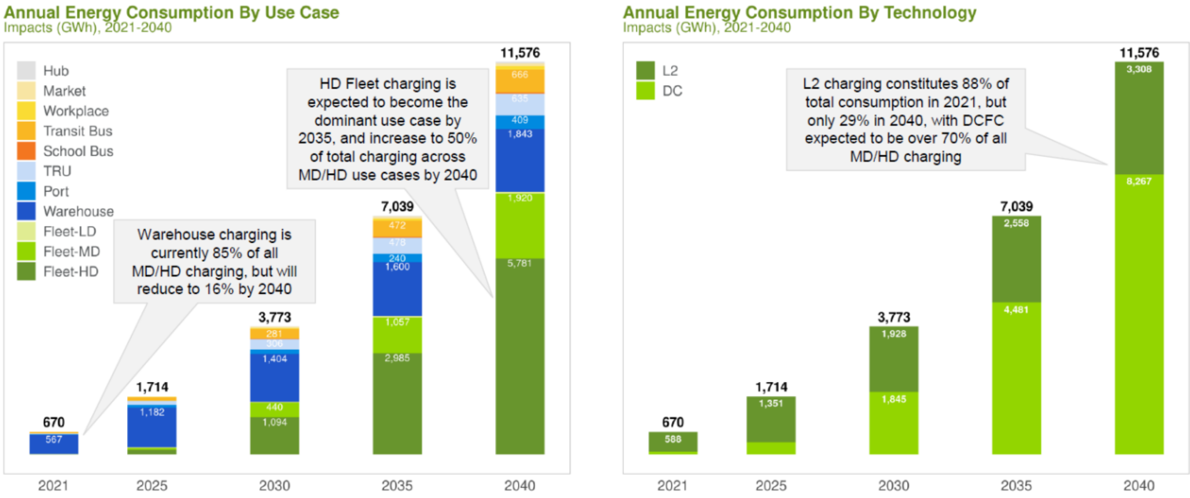

Figure 6. California forecast of energy needed for medium- and heavy-duty vehicles (Guidehouse 2021).

Installing several chargers at a depot, truck stop, or filling station involves many players to obtain permits, undertake construction, and work with the utility to ensure that adequate power is available when and where needed. NACFE (2019) and CalETC (2020) have both laid out recommended processes. Combining these two sources, results in the following approximate process: (1) engage utility, (2) choose vehicles, (3) determine charging needs, (4) assess incentives and financing, (5) design site plan, (6) apply for permits, modifying plans if needed, (7) procure charging components and (8) deploy charging infrastructure. Engaging the utility is first so the utility can begin to think about power needs well before the power is needed and also because utility input may affect subsequent stages. CalETC (2020) estimates the process can take 9–18 months, and 24 months or more for large and complex projects. Although some large companies may undertake the process themselves, many will need guidance from a firm specializing in this process. To provide just one example, Siemens has a growing business building truck chargers and managing their installation (Fehrenbacher 2019).

CALIFORNIA FORECAST

A picture of the magnitude of the needed effort is provided by an October 2021 report forecasting vehicle and load growth for medium- and heavy-duty vehicles in California (Guidehouse 2021). They estimate that power needs were modest in 2021, but will grow more than 5-fold by 2030, and about 17-fold by 2040. Initially, power demand will be focused on warehouses, but after 2025, most of the growth will be for fleets, including heavy-duty fleets in the 2030s. Initially, much of the power will be used in level 2 chargers (~240 volts), but after 2025, most of the growth will be in DC fast chargers (Figure 6).

They also examined the load shape of this power demand and estimate that currently truck power demand is relatively even throughout the day, but over time much of the load will be in the evenings and night as fleets plug in at the end of the workday (Figure 7). Power availability is generally good overnight, but EV trucks and buses will contribute to evening peaks unless this charging load can be shifted to later in the night.

Case studies

CALIFORNIA LEADING THE WAY

In the U.S., California utilities are leading the way on this issue. In California, state agencies and a state-wide effort called CALSTART have been funding demonstration projects and vehicle and charger purchases for several years. As noted earlier, the California Air Resources Board has mandated that, beginning in 2024, manufacturers must increase their zero-emission truck sales to 30–50 % by 2030 and 40–75 % by 2035. By 2035, more than 300,000 trucks will be zero-emission vehicles (Guidehouse 2021). California utilities operate programs that work with fleet owners to install the necessary infrastructure for electric vehicle fleets, an example is discussed in the next section.

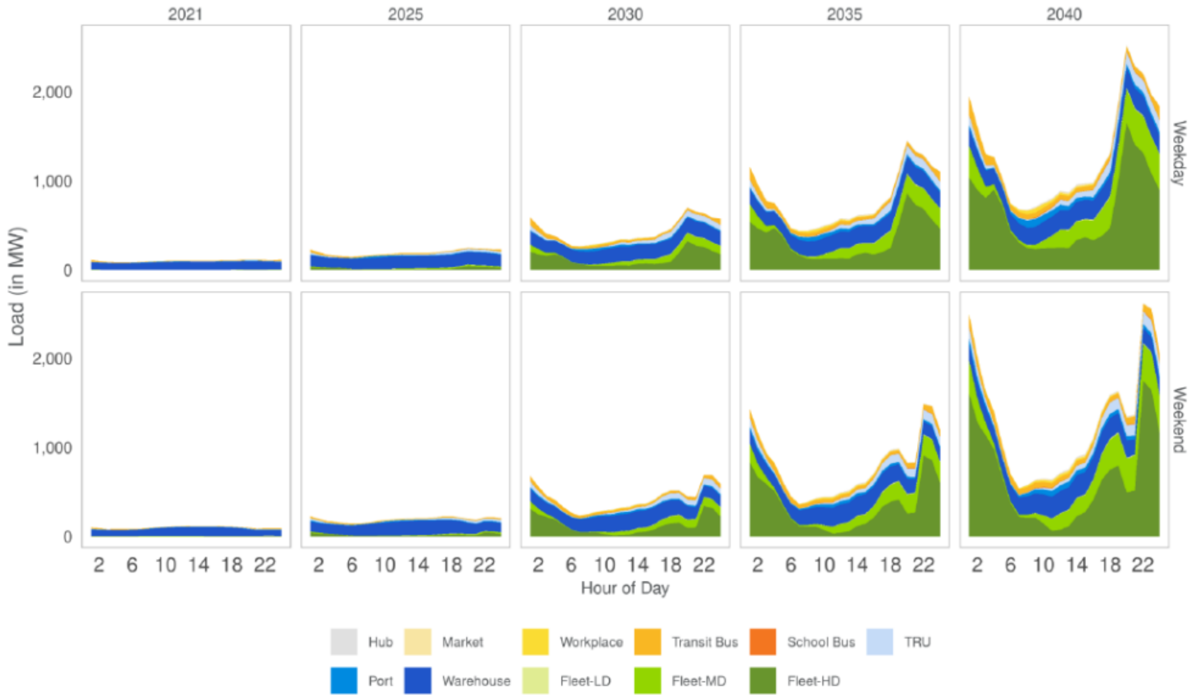

Figure 7. California forecast of power needs for medium- and heavy-duty vehicles (Guidehouse 2021).

Southern California Edison[1]

Southern California Edison, an investor-owned utility, serves much of the Los Angeles basin and points north, south and east. They operate the Charge Ready Transport (CRT) program for medium- and heavy-duty fleets. Normally, when customers request new or upgraded service from the utility, there are fees associated with the new upgrade. Through Charge Ready, the utility generally pays these costs for qualifying participants, and in some cases it will pay up to half the cost of chargers; the customer is responsible for the other half and for charger installation costs (managed charging is encouraged). Sites procuring at least two electric vehicles are eligible, but more vehicles are often needed for the economics to make sense for the utility.

One way to do this is to develop and implement a phased plan, with some components sized for future planned growth and other components added as needed. They note that most fleets they work with are so far choosing to electrify only a modest portion of their fleet (e.g., 10 %).CRT has 64 commitments (signed contracts) so far. Utility "make ready" upgrades have been completed for 27 sites to support 311 medium- and heavy-duty EVs. An additional 73 customer applications are now being evaluated. Of the 137 contracts and pending applications, more than 4,000 electric trucks and buses may be served. CRT has a 5-year goal of 870 sites, with an average of 10 chargers per site. The utility notes that one charger can usually serve several vehicles and that cycling of charging, some storage, and other load management techniques can potentially reduce capacity needs depending on a customer's level of resiliency risk. They also find that some customers initially think they will need high-power draw chargers but upon examination find that lower power levels (e.g. <50 kW) will serve the need. They are targeting more than one vehicle per charger, if suitable for a customer's operations, and are striving for at least 40 % of the sites to be in low- and moderate-income communities.

As part of the program, they ask customers about their electric vehicle plans for the next ten years and incorporate this information in a database. California transit agencies are now doing the planning to meet a California Air Resources Board mandate for 100 % zero-emission buses by 2040 (generally electric or fuel cell); utilities are talking with the agencies and their consultants as part of this process. When the utility gets requests for charger connections outside of the Charge Ready program, they also ask about future plans and log this information. These plans in turn are inputs considered in distribution system planning.

So far, the utility is generally finding that grid capacity is adequate in the short term to serve charging needs, but that upgrade needs will likely grow in the medium term (e.g., 7–10 years out) as fleets steadily electrify. For now, they can generally manage grid needs with good planning (e.g., school buses can generally be charged overnight and do not need fast chargers), load management techniques, and some battery storage to address peak needs. But in the area around the Ports of Los Angeles and Long Beach, where many fleets are located, electric trucks and buses are already being factored into grid upgrade plans. This area is known for air quality problems and conversion to electric vehicles is expected to help improve air quality. They anticipate phased grid upgrades in quite a few areas as they approach 2030.

SEVERAL OTHER UTILITIES ACTIVE, PARTICULARLY IN THE NORTHEAST U.S.

Planning and programs are also starting in the Northeast U.S. For example, the Massachusetts Clean Energy Center is hiring technical consultants to provide fleet electrification analyses,

1. Personal communication with Justin Bardin, Senior Manager, eMobility Program, Southern California Edison, Jan. 14, 2022.

conduct site assessment and charging analyses and support procurement efforts (Mass CEC 2021). Massachusetts and New York are particularly active as discussed in the National Grid case study below. Several other utilities in these states have somewhat similar programs.

In addition to these states, other utilities with somewhat similar efforts include Portland General Electric, which offers a "Fleet Partner" program serving the Portland, Oregon area (PGE 2022), and Xcel Energy in Colorado which has a "Municipal Refuse Fleet" pilot program (Xcel 2022).

As part of our research, we talked with several other utilities and found that they have not yet looked at how fleets might relate to grid planning. However, several of these companies expect to develop plans to look into these issues soon.

National Grid US[2]

National Grid US is an investor-owned utility serving parts of Massachusetts, New York and Rhode Island. They are owned by the UK company of the same name. They have a variety of "Electric Vehicle Fleet" offerings in all three states they serve, with details varying somewhat by state. The program includes a no-cost service to advise on vehicles and infrastructure, funding for make-ready infrastructure and charging stations for fleet operators of all types, and fleet ambassadors to help connect customers to other programs (National Grid 2022).

In each state they also offer free fleet studies. In Rhode Island they provide such studies to a dozen customers and some of these customers, such as a local bus system and local school district, are starting to purchase electric vehicles. Purchases of electric vehicles have been less than they hoped, but high initial costs have been an issue, despite lifecycle cost savings. These studies have accelerated the decision-making process for fleet operators, and the studies are easy to update, include customer follow-up discussions, and they expect the electrification plans of these customers to lead to significant EV purchases by these customers in the near future. In Massachusetts they have approval to offer fleet studies to 100 public-sector customers, with more than 20 studies completed and an additional 15 underway. Several of these customers have already purchased EVs. So far, approximately 90 % of the studies have been for fleets located in low- and moderate-income communities. Health benefits in these communities have been a key selling point of the program to both regulators and customers. They are proposing to expand the program to serve more customers including private-sector and non-profit customers, but this proposal is still under discussion with regulators. In New York State the fleet assessment services program is available to all customers and includes a site feasibility study and rate analyses. The state also has a Medium- and Heavy-Duty Vehicle pilot program to support make-ready infrastructure, though the program has eligibility guidelines on who they can fund (only participants in a state vehicle rebate program that has funding and other limitations) and what they can fund (only investments on the utility side of the meter). These guidelines have led to a lot of customer engagement, with limited investment in projects to date, though the active pipeline of projects continues to expand, with fleets such as schools, municipalities, delivery companies, and dealerships actively pursuing electric vehicles. They hope to begin discussions on modifying this program to accelerate deployment as part of a program mid-term review.

National Grid has also begun work to integrate fleets into their grid planning. They conducted a joint study with Hitachi ABB to look at the grid impacts of electric fleets on 19 distribution feeders that all served a substantial number of fleets. The study found that of the 19 feeders, 13 would eventually need to be upgraded when nearby fleets fully electrify. Impacts would also be seen at the substation level, with one substation eventually seeing a 60 % increase in peak load. The study noted that on some feeders, upgrades will be needed before full electrification, especially when electrification of light-duty vehicles and space heating loads are also considered. However, they also found that different charging strategies can reduce the magnitude and duration of peak loads, and thus charging management needs to be an important part of future efforts. The study concluded that additional more-detailed study is needed that delves into these issues (National Grid and Hitachi 2021). The utility is now discussing if and how to conduct more detailed infrastructure studies for these large clustered fleets in Massachusetts and New York. They believe that distribution upgrade costs can be significantly reduced if grid upgrades for an entire corridor are planned as a system and are not done piece meal.

Illinois and Commonwealth Edison

Illinois utilities will be developing plans for electric vehicle fleets as part of a "Beneficial Electrification" plan to be filed with the Illinois Commerce Commission (ICC) in July 2022. The plans will be reviewed by the ICC, with final decisions planned for the end of 2022, potentially leading to new programs starting in 2023. These plans are required under a new Illinois law enacted in the fall of 2021. The ICC will provide guidance on these plans in March 2022 based on a series of workshops they have been hosting. Two of the workshops focused on fleets, one on fleets overall, and the second specifically on public transit and school buses. Material presented at the workshops emphasized how each fleet has unique needs and requirements and that a substantial portion of fleets are located in or near low- and moderate-income communities. Thus, fleet electrification can be an important step to reducing diesel emissions in these communities and thereby improving community health. While some fleets are large, many are small. Presentations at the workshops discussed the need to educate fleet decision-makers about electric vehicles, good initial markets for electric fleet vehicles (drayage [hauling freight around ports, rail yards and trucking terminals], delivery vehicles, and medium-duty trucks) and recommendations for utility efforts (fleet planning services, total cost of ownership analyses, preliminary site assessments, early engagement on grid capacity issues and planning, incentives, and considering rate design issues).[3]

Commonwealth Edison (Com Ed), serves the greater Chicago area and is the largest utility in Illinois by load served. Prior to the Illinois workshops, Com Ed was already exploring fleet electrification issues. They held a workshop on electric vehicles

2. Personal communication with Ryan Wheeler, Clean Transportation – Fleet Electrification program, National Grid, Jan. 14, 2022.

3. Material from the workshops can be found at: www.icc.illinois.gov/informal-processes/beneficial-electrification-workshops-2021-2022.

for fleet managers, conducted a few pilot analyses for fleets on total cost of ownership, and have been gathering information on electric vehicle plans by their large customers through regular discussions between these customers and Com Ed customer service representatives. Information from these processes will feed into their beneficial electrification plan. They file grid investment plans periodically with the ICC. Fleet electrification has not yet affected these plans, but could in the future.[4]

Discussion

These case studies show that when utilities and states are proactive in educating and assisting fleet owners to consider electric vehicles, substantial uptake can happen, as illustrated by the more than 4000 trucks and buses that Southern California Edison is assisting with. As this education and assistance happen, attention needs to be paid to serving more than one vehicle per charger and to considering what power level is needed. Customers should be encouraged to share their EV plans for future years and this data should be logged to assist with distribution planning. For example, useful information might include number of vehicles of different types, about how far they travel each day and when (affects charging), a sense of vehicle replacement schedules (number per year or per an episodic schedule), and how far each fleet customer currently is in considering electric vehicle purchases for their fleet.

As National Grid has found, fleets are often grouped together, and these local areas will often need distribution system upgrades by the time fleets fully electrify. Often these fleet-intensive areas are in low- and moderate-income communities; these communities will benefit from reduced diesel emissions as vehicles are electrified. Other growing electric loads, such as for light-duty vehicles and heat pumps, will contribute to the need for distribution system upgrades. Utilities should work with fleet owners to understand their vehicle electrification plans so that they can plan to have adequate power available when needed. Since many fleet owners do not yet know their plans, utilities will need to plan for uncertainty but can reduce this uncertainty by regularly talking with their fleet owners to keep abreast of the latest information and to spot nascent trends. Given these uncertain but evolving trends, distribution planning analyses may need to occur more frequently for circuits with many fleets. These efforts should consider major trucking corridors together, as there are interrelationships along these corridors and potential economies from systematic planning that avoids many piecemeal upgrades.

Regulators should encourage utilities to expand distribution planning to consider fleet needs. In addition to the utilities covered in our case studies, we also had discussions with several other utilities who asked to be unnamed because they were not yet ready for regulators to learn about their planning for electric fleets. In our view, regular and open discussions between regulators and utilities about these issues would be useful, so that grid upgrades can proceed in an orderly way to help meet fleet needs and state decarbonization and environmental justice goals, while minimizing long-term costs to consumers.

4. Philip Roy, Manager, Energy Policy, Commonwealth Edison, personal communication, Jan. 21, 2022.

Conclusion

Based on these cases, it appears that fleet electrification is slowly gaining momentum and can have a substantial impact on electric grids. While grid impacts are small at present, they will likely grow over time. Fleet owners, electric utilities, and utility regulators need to start planning for these impacts now, so that grid improvements can be made steadily as electric fleets grow. Fleet and grid planning should happen in parallel, so that grid upgrades do not happen sooner or later than needed but are in place when needed. These grid impacts can be managed and planned for, but the time to begin this planning is now.

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