STEEP CLIMB AHEAD

How Fleet Managers Can Prepare for the Coming Wave of Electrified Vehicles

BY LYNN DANIELS AND CHRIS NELDER

ABOUT US

ABOUT ROCKY MOUNTAIN INSTITUTE

Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

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EXECUTIVE SUMMARY

The transportation sector is the largest contributor to greenhouse gas emissions in the United States.[1] In order to align with the 1.5°C global climate goal, well over 20% of all US vehicles need to be electric by 2030. To address this challenge, nearly all fleet managers in the United States are exploring ways to decarbonize their operations. Most have embarked on the journey toward electrification as their primary strategy, but only a few have grasped how important it is to consider a long-term strategy in planning their near-term actions.

Although fleet vehicles in the United States comprise only 3% of all registered vehicles, fleets can have outsized influence on the successful electrification of the entire transportation sector—including the much larger personal vehicle market. Large fleets drive scale, which results in reduced costs of vehicle technology and infrastructure. And fleets have the market influence to help drive costly inefficiencies out of the system, resulting, for example, in streamlined permitting processes and prioritized utility interconnect processes.

Based on a survey of 91 fleet managers operating large fleets, plus 18 in-depth interviews we conducted with fleet managers representing a cross-section of fleet types, this report offers a window into the expectations of major US fleet managers about fleet electrification. It also explores the current landscape of electric vehicles and charging infrastructure and identifies what will be required to scale up electric vehicle (EV) adoption.

Key findings from the survey and our interviews include the following:

- All organizations recognize their responsibility to be good citizens from an environmental perspective, with a keen awareness that the fleet sector needs to electrify faster. Every internal combustion engine (ICE) vehicle procured today represents an 8 to 10-year delay before that vehicle will be replaced with an EV.

- In many organizations, if an EV is considered to have an acceptable price and to be suitable for a given use case and duty cycle, the default is to purchase the EV preferentially, even if the EV is more expensive. In fact, fleet managers would have to make a compelling argument for why an EV is unsuitable before receiving approval to buy a conventional ICE vehicle.

- Over the next decade, most fleet managers expect to adopt electric models for the majority of their light-duty cars, trucks, and SUVs.

- Fleets are approaching this transition differently. Where battery-electric vehicle (BEV) substitutes are available today, some fleets plan to wait until their existing ICE vehicles reach their planned retirement point before replacing them, while others plan to retire the existing ICE vehicles early in order to capture operational savings from BEV replacements. But fleet managers are still waiting for suitable BEV replacements to become available for many Class 2–8 vehicles in their fleets.

Our conclusion from this research is straightforward and unambiguous: All fleet managers need to begin serious planning immediately for how they are going to undertake the electrification of their fleets.

Although many fleets have already implemented pilot programs—usually consisting of a few EVs and low-powered chargers, acquired at modest expense—electrifying a fleet at scale involves much more than just adding more EVs and chargers incrementally. For many organizations, it will mean restructuring their internal business processes, including procurement, accounting, long-term capital project planning, fiscal budgeting, operations, and more. It will require them to engage in a much more extensive relationship with their local utilities. And it will mean much more proactive involvement with city and county officials, including local building and planning authorities. As shown in Exhibit ES1, the vast majority of surveyed fleets are beginning to electrify, whether they have internal fleet electrification goals or not.

As fleets begin to operate more EVs, scaling up charging infrastructure to accommodate higher rates of charge from more expensive chargers in far more complex installations will quickly become the most significant challenge. In particular, as fleets adopt more EVs, we highlight some important considerations:

- Ideally, the charging infrastructure should be deployed before EV purchase, minimizing the risk that inadequate charging infrastructure deployment will act as a cap on EV adoption.

- The type of planning required to deploy charging infrastructure before vehicle procurement is an enterprise-wide challenge that requires an enterprise-wide response.

- Fleets must engage with their local utilities as early as possible, especially for charging infrastructure serving truck stops and fleet yards with medium- and heavy-duty trucks. The power requirements of these vehicles will be substantial. Installation requires planning by both the utility and fleet operator years in advance.

- Utility engagement can also help organizations minimize fuel costs by understanding their utility rate structure and the impact of demand charges on their utility bill.

- Fleet managers may have unrealistic expectations about being able to use public chargers opportunistically or install only Level 2 chargers. At scale, many fleets will need to deploy direct current fast charging (DCFC), which costs more to build and operate.

- Internal budgeting processes are another hurdle that prevents the true value of fleet electrification from being understood. In many cases, one organizational budget pays for EVs while another pays for the charging stations that serve them, such that the actual return on investment (ROI) of all vehicles on a total cost of ownership (TCO) basis is not clearly visible to management.

- At scale, managing the charging of vehicles around their duty cycles takes concerted effort and is not a trivial task. Fleets may want to consider "charging as a service" as one solution.

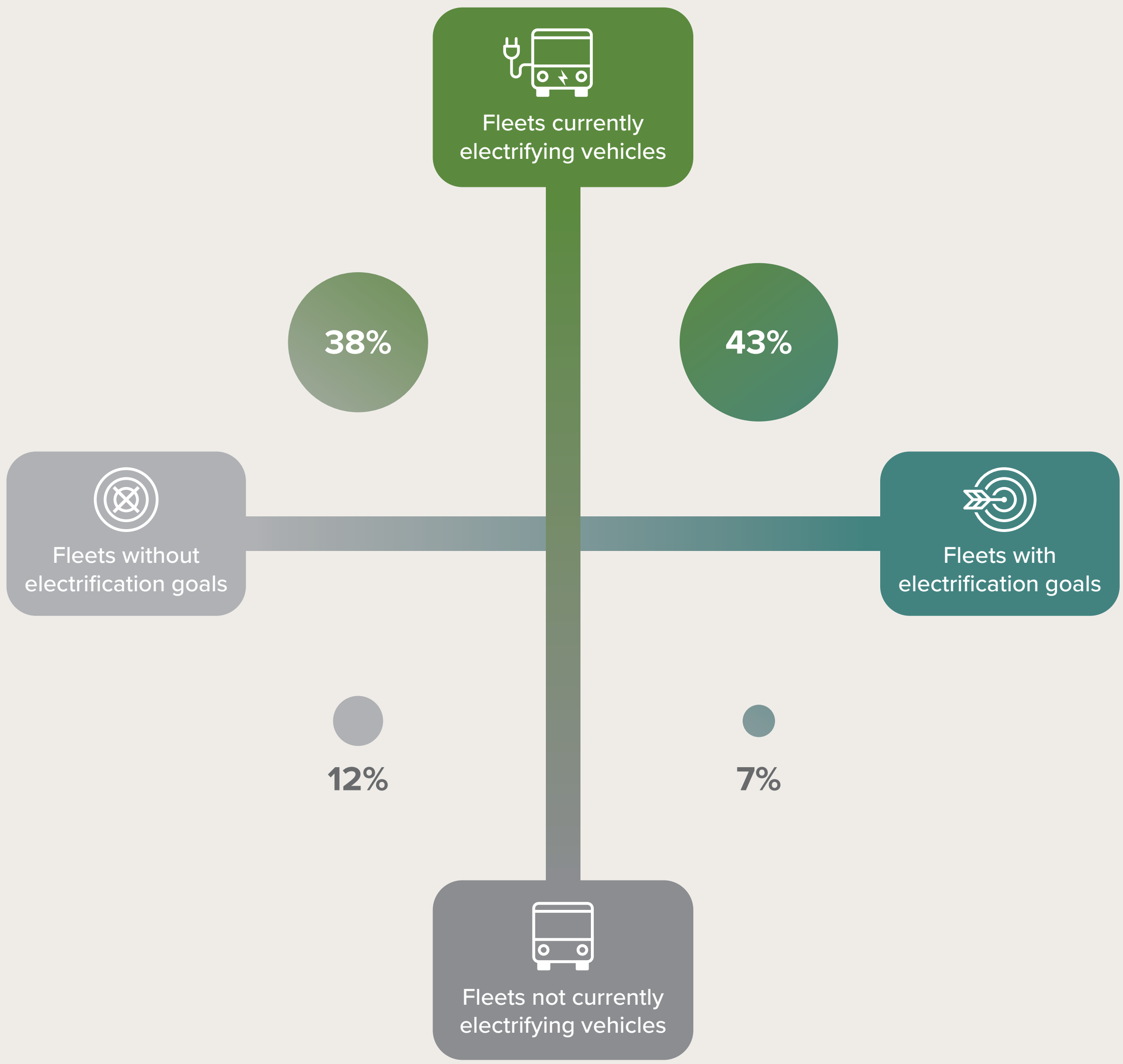
- Many organizations must also consider how to prepare for grid power disruptions. Depending on the fleet, backup power requirements could be very substantial, and installing the requisite capacity could be complex.

In short, fleet electrification is not just a task for fleet managers. It requires a cohesive, integrated strategy across an organization. Done right, it's a fundamental business restructuring challenge for entire organizations. Done badly, it can be a series of very costly errors. And thanks to increasingly stringent restrictions on vehicle emissions, as well as the ongoing retooling of the global vehicle manufacturing industry to produce electric vehicles, electrification is coming to all fleets, whether they are ready for it or not.

Fortunately, the journey will be worth it. Electrification can result in significant cost savings for all fleet operators and across all vehicle classes. By understanding the opportunities and challenges we detail in this report and undertaking the careful organizational planning that is required for a successful electrification strategy, organizations of all kinds and sizes can significantly reduce their carbon footprints, reduce costs, and use energy more efficiently.

EXHIBIT ES1

Fleet Electrification Goals and Current EV Adoption Status



Note: Combined survey responses to the questions "Does your organization have an explicit goal for electrifying your fleet or reducing your fleet's emissions?" and "Have you begun to transition any of your fleet vehicles to electric?"

EXHIBIT ES2

Installation of Your First Chargers

Preparing for Electrification

- Establish a transparent budgeting process to track all EV costs over the vehicle lifetime, in order to ascertain total cost of ownership savings.
- Engage utility to understand how to optimize charging around the time-of-use rates and avoid demand charges.
- Consider charging management solutions including charging as a service.

Planning to Electrify Fleet Vehicles

- Conduct a feasibility study to understand which vehicles are economic to electrify, and when, based on use case.
- Establish cross-organizational team with executive support.
- Develop a long-term fleet electrification plan, based on the feasibility study, with input from full organization.
- Obtain training for all staff who need to learn about EVs and charging.
- Engage your utility about your long-term goals, and explore how to optimize charging around utility tariffs to minimize costs.

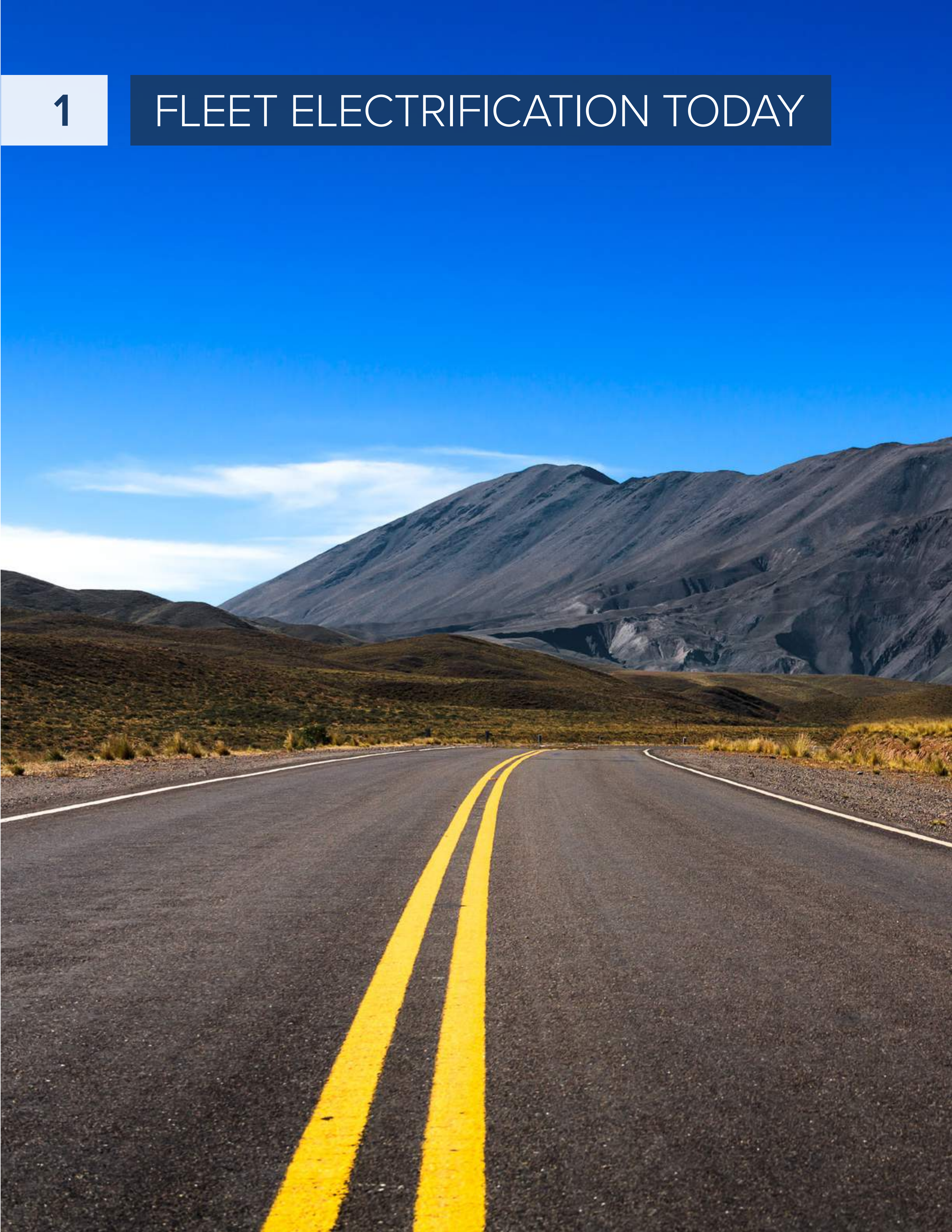
Procuring Charging Equipment

- Based on your long-term plan, identify when vehicles will charge, how many and what types of chargers will be required.
- Engage with utility to understand site grid capacity limits and any utility upgrades required. Inquire about make-ready support they may offer.
- During installation of your first chargers, futureproof by doing trenching and wiring required for future charging infrastructure.

Procuring Electric Vehicles

- Identify EVs that meet use case needs, including range and all functional requirements.
- Develop a five-year outlook for new EV models that will become suitable.
- Streamline procurement processes that may be barriers for EV adoption.
- Engage with dealers and manufacturers, especially if required to buy from an approved buy list.
- Identify rebates and grants available for vehicle purchase.

1 FLEET ELECTRIFICATION TODAY



FLEET ELECTRIFICATION TODAY

In the latter half of 2020, we surveyed managers of large fleets (over 50 vehicles) and asked them to give us some basic information about their existing fleets and their electrification intentions. We received 91 responses. We also conducted 18 in-depth interviews with fleet managers representing a cross-section of fleet types including cities and states, utilities, universities, private technology companies, and delivery services.

We conducted the survey and interviews on condition of protecting the anonymity of the respondents, and we present the findings from those activities in an aggregated and anonymized fashion.

In this report, we will explore how fleet managers have been going about EV procurement to date, as well as what their procurement expectations are for the next few years. We identify the types of conventional vehicles that are suitable for replacement with EVs today, and how fleet managers will evaluate the suitability of new classes of EVs that manufacturers have said they are planning to produce over the next several years. We also assess the charging infrastructure that these organizations are using today, and what organizations will need to do to provide the charging infrastructure that their electric fleet vehicles will require when their fleets are electrified at scale.

TERMINOLOGY NOTE

In this report, we refer to battery electric vehicles (BEVs) when we are talking about vehicles that exclusively use electricity. When referring to hybrid vehicles that can be plugged in to charge a battery that can run the vehicle for some distance, then revert to a gasoline engine to extend its range, we refer to them as plug-in hybrid electric vehicles (PHEVs). When referring to both BEVs and PHEVs, or where the distinction between them is not relevant, we simply refer to electric vehicles (EVs). In this report, we do not separately refer to conventional hybrid vehicles that cannot be plugged in. We refer to conventional hybrids and conventional internal combustion engine (ICE) vehicles that run on gasoline or diesel as "ICE vehicles."

Where the distinction is relevant, we refer to chargers by their maximum power output. "Level 2" chargers typically supply around 7 kilowatts (kW) of power to a vehicle but can supply as much as 19 kW. We refer to DC fast chargers, also known as "Level 3" chargers, as "DCFC." DCFC can typically supply 50 to 350 kW of power to a vehicle, although there are some exceptions. Most public DCFC being deployed today are 150 kW chargers. For more on the various types of chargers, see *Appendix C: Types of Chargers.*

SURVEY RESULTS

As shown in Exhibit 1, survey respondents represented a broad cross-section of fleet sectors and fleet sizes. About 40% of respondents were municipal or government fleets, with a mixture of logistics, delivery, and corporate fleets making up an additional 30% of responses. Fleets selecting the "Other" category included utilities, waste and recycling collection, telecommunications, and service fleets associated with business operations.

Respondents also represented fleets of varying sizes, as shown in Exhibit 2: 16% of responses were from small fleets under 100 vehicles; 23% represented mid-sized fleets between 100 and 499 vehicles; and slightly more than half of respondents represented large fleets with more than 500 vehicles.

While some respondents had fleets comprised of only one class of vehicle (e.g., light-duty cars only), the average respondent had a mix of vehicles in their fleet, as shown in Exhibit 3. In total, survey respondents manage 253,048 light-duty vehicles, 195,367 medium-duty vehicles, and 77,815 heavy-duty vehicles.

EXHIBIT 1

Survey Responses by Fleet Sector

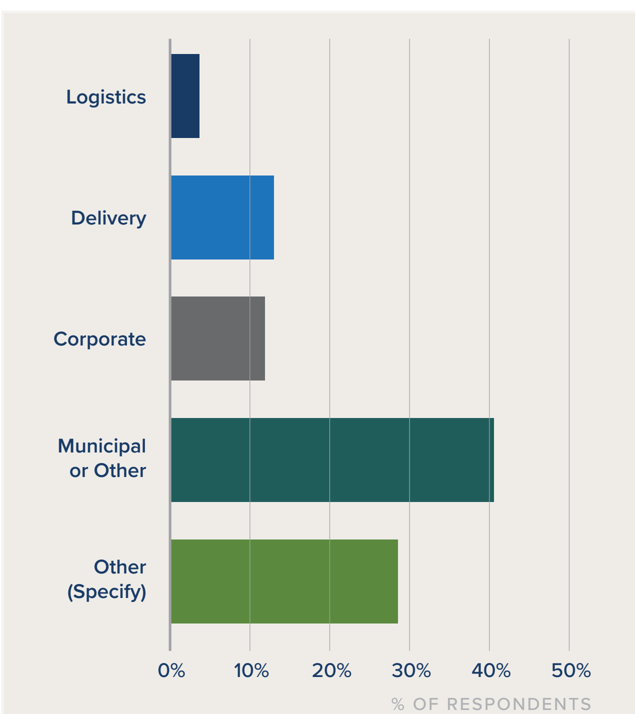
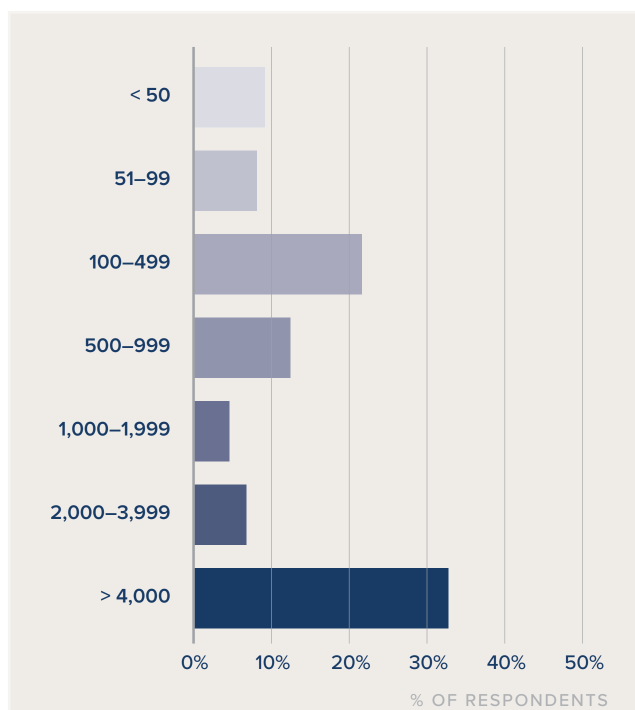


EXHIBIT 2

Survey Responses by Fleet Size



Our survey also asked fleet managers what is motivating them to pursue electrification and what issues most concerned them. Exhibit 4 shows the main motivations for electrification, with nearly three-quarters of respondents noting they were acting in response to organizational sustainability goals. Respondents were also able to provide a freeform response to identify other motivating factors, which included leading by example, improved vehicle performance, and the availability of grants to purchase electric vehicles.

Exhibit 5 shows the biggest concerns that fleet managers have today about electrifying. Perhaps unsurprisingly, the higher upfront cost of EVs was of greatest concern as well as the lack of available vehicle models to meet fleet needs. Of least concern today are the costs of charging, future increases to the costs of gasoline and diesel, and unfamiliarity with EV operations. Respondents were able to provide a freeform response to identify other concerns and noted lack of EV infrastructure hardware and installation, insufficient maintenance support or know-how, and uncertain resale value.

To explore their decision-making processes, we asked respondents to assess how different factors would impact future decisions to electrify on a scale from 1 to 5, shown in Exhibit 6. Respondents rated all of the proposed factors as fairly important, with the least important factor (lowering the cost of charging) averaging a 3 out of 5.

EXHIBIT 3

Average Number of Vehicles by Class for a Survey Respondent

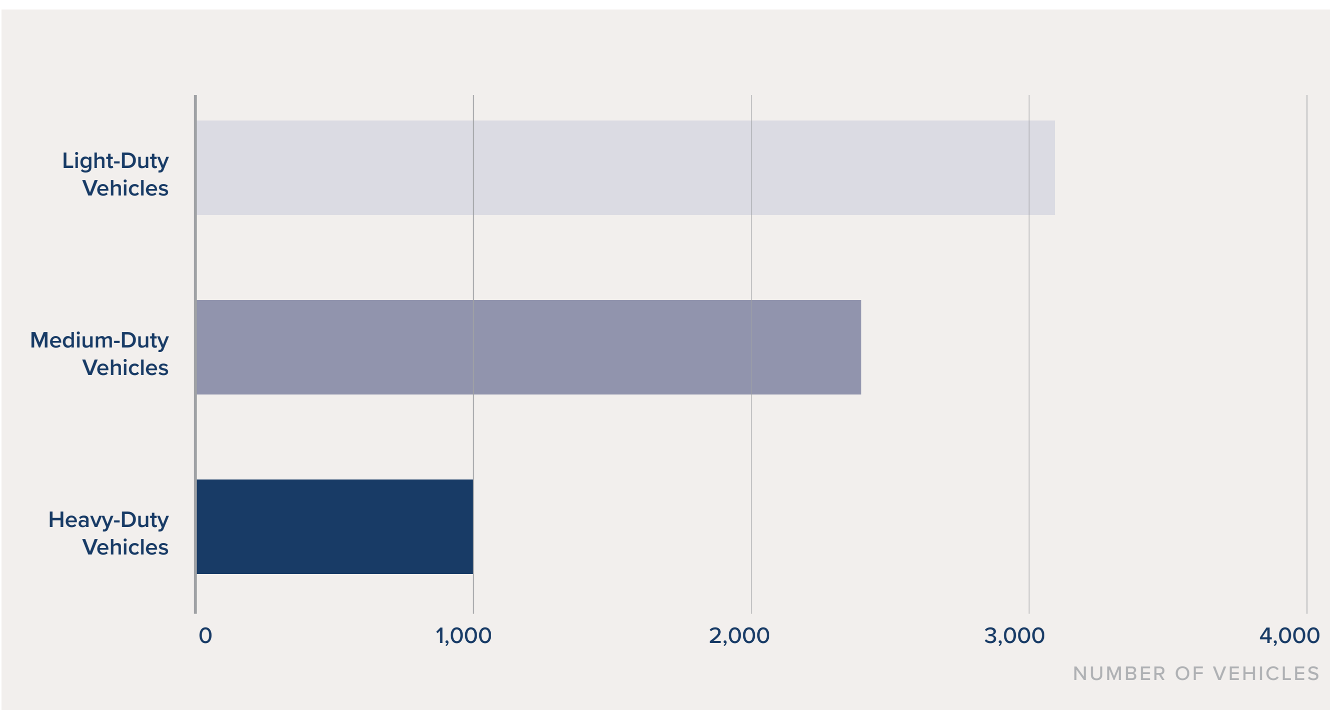


EXHIBIT 4

Motivations for Electrifying

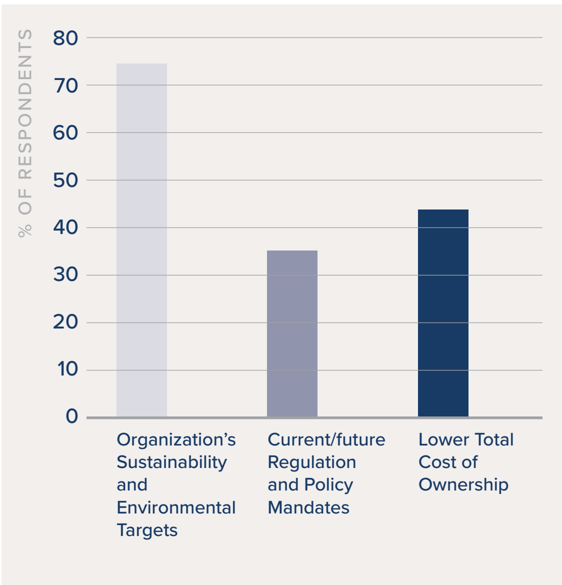


EXHIBIT 5

Biggest Concerns and Barriers Regarding Electrification

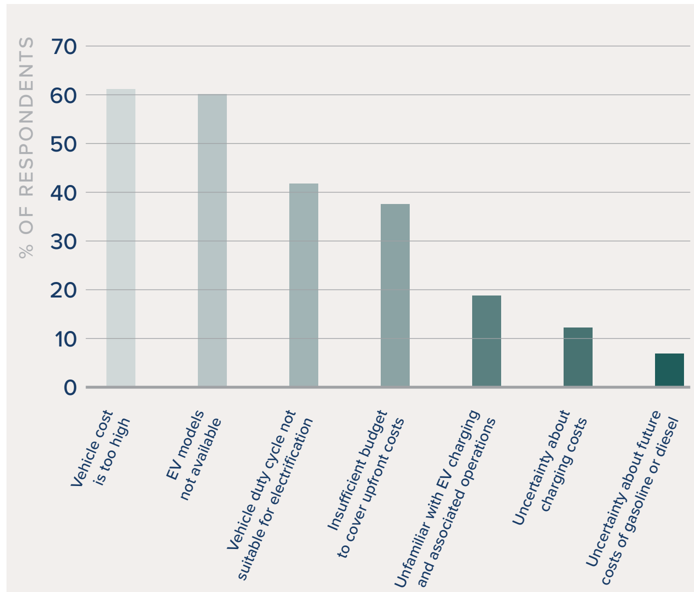
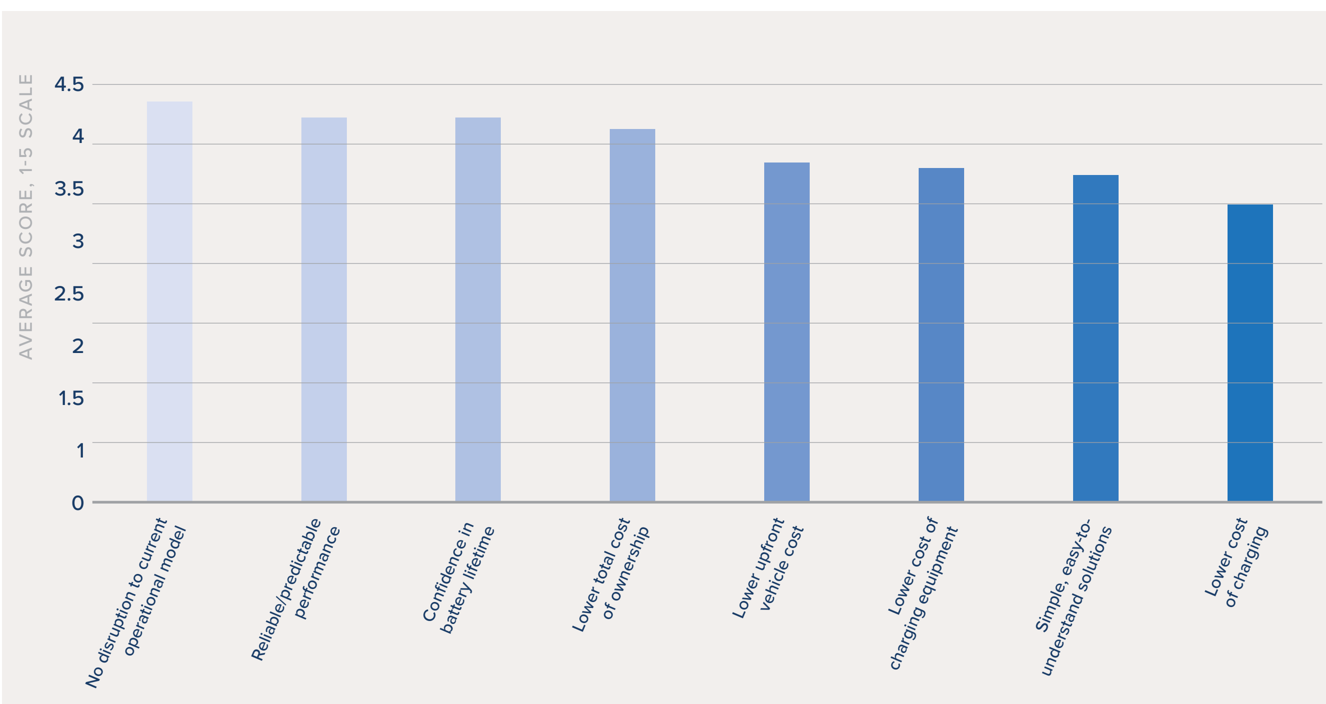


EXHIBIT 6

Rating of Factors Influencing Decision to Electrify



DRIVING TOWARD SUSTAINABILITY

Most of the fleet managers we interviewed are operating under organizational targets for reducing emissions and meeting sustainability goals. Even where there were no formal or quantified goals, the organization's management had indicated support for pursuing sustainability objectives and an interest in reducing their organization's carbon emissions. No organizations were agnostic about their responsibility to be good citizens from an environmental perspective. In fact, they are keenly aware that the fleet sector needs to electrify faster, because every year that they procure more ICE vehicles amounts to a setback of 8–10 years—the expected operating life of those vehicles before they will be replaced.

As more countries implement strong emissions-reduction policies, diesel vehicles are rapidly becoming disfavored or banned outright.[2] In Europe, more new EVs than diesels were registered for the first time in history in September 2020.[3] Major fleets, with vehicles spread across the globe, are deploying EVs in parts of China and Europe because it is compulsory. These fleet managers are more familiar with EVs, and tend to see the electrification of fleets in the United States as more of an inevitability.

Organizations may find that their goals for reducing their carbon footprints through fleet electrification can be in tension with other goals such as minimizing total fleet costs, having fleet vehicles that are highly reliable and suitable for a given use case, and being able to repair their fleet vehicles in-house. The fleet managers we interviewed navigate this tension by setting the carbon reduction goal as their ultimate objective, but then allowing other considerations to take precedence. Vehicle suitability for a given use case (such as towing capacity and range) is generally the dominant priority.

SUITABILITY

Currently in the United States, only light-duty (Class 1 and 2) EVs are broadly available for purchase and suitable for typical passenger vehicle use, but over the next five years, EVs are expected to become available in nearly all vehicle classes. But availability isn't the only consideration. For fleet managers to adopt them at scale, BEVs have to be suitable for a given use case.

GEOTAB SUITABILITY ASSESSMENT

The suitability of an EV for a given use case is measured with a mix of criteria:

- **Cost:** Will an EV have a similar cost as an ICE vehicle equivalent? Unlike average consumers, who tend to only consider the purchase price of a vehicle, fleet managers typically judge the cost on a TCO basis, taking into account:
  - Initial purchase price;
  - Available incentives or rebates;
  - Cost of maintenance and insurance;
  - Cost of refueling or recharging; and
  - Residual value of the vehicle when it is sold.
- **Capabilities:** Can this new EV do the same job as the ICE model we've been using? Capability is a particularly important consideration for pickup trucks, vans, and medium/heavy-duty vehicles, where fleet managers and vehicle users want to know if the EV alternative can:
  - Tow trailers;
  - Haul the required payload;
  - Complete a route on a single charge; and
  - Perform adequately in all kinds of weather, including in extreme temperatures and snow conditions.
- **Duty cycle:** Is there enough time in the duty cycle of the vehicle to recharge it? It is important to know if the daily distance is within the electric range of the vehicle, in all temperature conditions. This will help determine if overnight charging is sufficient, or if the operator will need to consider en-route or daytime charging. This is primarily relevant for battery-electric vehicles that don't have an alternative fuel source, and for vehicles with very high usage, or those that operate throughout the day and night.
- **Durability:** Is the service life of the vehicle acceptable, and can it perform all required tasks for the full duration of its service life?

The market is still young for medium- and heavy-duty vehicles, with many more options set to arrive over the next few years. On the light-duty side however, consumers have quite a few choices when it comes to cars and SUV models already on the market. For this segment, the primary factors for EV suitability are duty cycle—specifically daily range requirements—and total cost of ownership.

Geotab reviewed the actual driving patterns of approximately 179,000 light-duty fleet vehicles across North America (cars, SUVs, and minivans spanning 24 industry segments and about 3,500 fleets), and found that nearly two-thirds of all vehicles would be capable and would save the fleet money if they were replaced by a battery electric or plug-in hybrid electric vehicle, rather than a gasoline-powered substitution.

Can battery electric vehicles deliver on range?

Analyzing a year's worth of driving behavior for all 179,000 vehicles, Geotab found that 48% would be range capable for at least 98% of driving days with an all-electric vehicle substitute, even after factoring in range loss during very cold or hot days. This means a battery-electric vehicle can do the job in nearly half of all car and SUV fleet use cases, only charging when the vehicle is parked overnight. However, because of today's higher upfront costs for EVs, without incentives only 15% would also save the fleet money from a TCO perspective (compared with purchasing and operating an equivalent gas vehicle over a seven-year service life). A $4,000 EV rebate or incentive would bump economic viability to 32%.

Assessing cost-effectiveness for BEVs and PHEVs

When including plug-in hybrid electric vehicle replacement scenarios in the assessment, 64% of all vehicles analyzed could save the fleet money by going electric, even before incentives.[i]

If all vehicles that had an economically preferable EV option were to be replaced, the cumulative emissions savings would be 375,550 metric tons per year.

With electric pickups around the corner, initial analysis by Geotab suggests that over half of fleet pickup trucks have daily needs that fall within the range capability of electric trucks coming to market over the next few years. The number of them that will offer a lower total cost of ownership will ultimately depend on the price point of these vehicles. An economical electric pickup could be a game changer for North American fleets.

With EV costs trending downward and range increasing, EV suitability will continue to improve over time. Fleets that start the transition now with their light-duty vehicles can take advantage of economic savings already on the table, and gain the experience needed to successfully electrify the rest of their operations as new vehicle options become available. Fleets can start with their own EV suitability assessment with Geotab to identify best fit replacements.[4]

EXHIBIT 7

Vehicle Replacement Recommendations

The most common vehicles in this assessment included:	
Vehicle type	**Top replacement recommendations**
Cars: Ford Fusion, Chevrolet Sonic, and Chevrolet Malibu	Prius Prime PHEV/Hyundai Ioniq BEV
SUVs: Ford Escape	Kia Niro PHEV/Kia Soul BEV
Minivans: Dodge Grand Caravan	Chrysler Pacifica PHEV

Source: Geotab

[i] Analysis assumes no EV incentives, only overnight charging, and over a seven-year lifecycle.

DETERMINING FINANCIAL SUITABILITY

One of the clear drivers persuading fleet managers to electrify their fleets is that EVs are generally cheaper to own and operate than ICE vehicles. Unlike individual consumers who primarily compare the cost of different vehicles on a sticker-price basis, fleet managers typically look at TCO, which represents the full lifetime cost of owning a vehicle. This includes initial purchase price, lifetime fuel costs (electricity for BEVs and a combination of electricity/gas for PHEVs), insurance, maintenance, repairs, and licensing. EVs can save fleet managers money primarily via lower refueling, maintenance, and repair costs. Maintenance costs are lower because EVs don't need things like tune-ups, oil changes, and frequent brake pad replacements. Repair costs are lower because with hundreds fewer parts in an EV than an ICE vehicle, there are simply fewer things to break and replace.

However, refueling costs are not automatically lower for EVs relative to ICE vehicles. The structure of the utility tariff under which an EV charger is billed is a critical factor in the cost of operating an EV. When charging EVs at Level 2 speeds—suitable for most light-duty vehicles that can spend eight hours or more recharging when needed—it's almost always cheaper to recharge a vehicle with grid power than fill its tank with gasoline or diesel. However, for light-duty vehicles that are in use most of every day, like police cruisers, or for medium- and heavy-duty vehicles with larger battery sizes, faster DCFC is often necessary.

DCFC charging can make it more expensive to recharge a vehicle than to refuel it with gasoline or diesel, depending on the utility tariff. Where utility tariffs are structured so that they do not burden EV charging with excessive costs—particularly demand charges applied to the peak load of a facility—it is cheaper to recharge EVs than to refuel with a liquid fuel. Actively managing charging of vehicles at a centralized facility to smooth out its utility load can also help mitigate utility costs. For certain use cases and duty cycles, like package delivery, fleet managers told us that electricity is the cheapest fuel.

Good utility rate design and progressive guidance by utility regulators can reduce the excess costs of fast charging embedded into certain utility rates, particularly in the form of demand charges, and ensure that the TCO of all classes of EVs is lower than that of ICE vehicles. With thousands of different utilities in the United States, all offering different tariffs to their customers, this is an extremely complex cost component for fleet managers to contend with, especially for those who operate interstate fleets. We do not delve into it in the present report, but our previous reports, *Reducing EV Charging Infrastructure Costs,*[5] *EVgo Fleet and Tariff Analysis,*[6] and *DCFC Rate Design Study,*[7] explore these issues in depth.

Uneven incentives can also influence or even distort purchasing decisions. For example, a truck that runs on renewable natural gas (RNG) can be cheaper than a diesel equivalent because of government rebates and funding mechanisms; without those incentives, diesel Class 8 trucks would be $40,000–$60,000 cheaper than an RNG truck. Some fleet managers have the latitude to select an EV that is not the cheapest option for a given use case, but new vehicle choices still have to make financial sense.

Although we did not attempt to comprehensively quantify the price premium that fleet managers may be willing to pay for an EV, they did give us a few examples: If a BEV model for a given vehicle costs 15%–20% more than the ICE vehicle it is replacing, fleet managers will be interested. But if the BEV costs twice as much as the ICE vehicle, they probably will not be.

The determination of whether a given EV is financially sensible and suitable for a given use case or duty cycle can vary considerably from organization to organization. Some organizations—particularly states and municipalities—flatly require purchasing the lowest-cost vehicle that is deemed to be suitable for a given use case. If a state wanted to buy an EV for a given use case that was significantly more expensive than an ICE equivalent, the fleet manager likely would need to go to the legislature for the extra money.

DETERMINING OPERATIONAL SUITABILITY

For larger organizations and state or municipal agencies, buyers often must choose a vehicle from a pre-approved bid list or vendor. (For more on this topic, see *Procurement Restrictions* on p. 23.) In a few cases, the department or agency that uses the vehicle has complete authority to select the vehicle they want without restriction, as long as it is within their budget. More often though, the determination is made through a case-by-case negotiation between fleet managers and whoever requisitions the vehicle. The fleet manager would have to make a compelling argument for why an EV is unsuitable before receiving approval to buy a conventional ICE vehicle. In most organizations, if an EV is considered to have an acceptable price and to be suitable for a given use case and duty cycle, the default is to purchase the EV preferentially, even if the EV is more expensive.

The unique performance characteristics of EVs are likely to play an increasingly important role in determining suitability. For example, the performance of EVs in very cold weather might remain a deterrent for some use cases, since the vehicle must be heated by its battery, reducing the vehicle's range. Conversely, one state fleet manager told us that its Department of Corrections is building a new prison with dedicated fast-charging infrastructure built in because EVs have better zero-to-60 performance than ICE vehicles in the same price range.

ELECTRIFICATION TRENDS

Generally speaking, the larger the fleet, the earlier management started exploring alternatives to conventional gasoline- and diesel-powered vehicles in order to reduce their fleet's emissions and start taking action on new corporate sustainability goals. In the late 90s and early 2000s, the largest fleet managers began looking into alternatives, starting with E85 as vehicle models and the fuel became available. Fleet managers then began moving to natural gas and propane vehicles, and more recently, hybrid vehicles, then plug-in hybrids became the preferred options.

Today, large fleet managers are focusing almost exclusively on full battery electric vehicles (BEVs) for all but the largest and heaviest vehicle classes. The rapid decline in BEV costs over the past five years has mostly eliminated any price disadvantage that the earlier alternatives had, and the zero-emissions nature of BEVs has made them the preferred option, particularly where organizational goals to reduce emissions have become more urgent and binding. (The only other zero-emissions vehicle options are hydrogen fuel cell vehicles, but they face much bigger challenges to get to commercial scale; see *What About Hydrogen Fuel Cell Electric Vehicles?* on p. 60 for more on how fleet managers view those vehicles.)

Over the next decade, most fleet managers indicated that they expect to adopt electric models for the majority of their light-duty cars, trucks, and SUVs. Based on manufacturers' announcements, most fleet managers do not think electric pickup trucks will be suitable for their purposes until the 2022 model year, implying that purchase orders for them could go out in late 2021 at the earliest. Medium- and heavy-duty vehicles are expected to become available around 2024.

The long-term targets for fleet electrification vary from organization to organization. The only identifiable trend is that most fleet managers expect to fully electrify nearly all of their Class 1 vehicles within the next five years or so. Where BEV substitutes are available today, some fleets plan to wait until their existing ICE vehicles reach their planned retirement point before replacing them, while others plan to retire the existing ICE vehicles early in order to capture operational savings from BEV replacements. But fleet managers are still waiting for suitable BEV replacements to become available for many Class 2–8 vehicles in their fleets.

In addition to the aforementioned utility targets, electrification targets from other organizations include:

- A small city will electrify 80% of its fleet by 2030.
- A midsized city will electrify 22% of its fleet by 2028, starting with purchasing EVs for 8% of its new vehicle purchases in 2019, then gradually scaling up the share of EVs purchased.
- A large city will electrify 50% of its fleet by 2025, 80% by 2035, and 100% by 2040.
- A county transit bus system expects to deploy BEV buses in 22-bus tranches, including the associated charging infrastructure at its bus depot (because the bus parking at the depot has 22 parking spaces in a row). It expects to electrify the first tranche over the next five years, and then electrify another 22. By 2050, it hopes to fully electrify its fleet.

Over the longer term, it is not just the composition of the fleets that will change. The size of fleets, and how fleet vehicles are used will also change. Some fleet managers in fading industries are expecting their fleets to shrink—like telephone landlines and wired cable television, while other fleet managers, particularly those in the package delivery business, are expecting significant growth in their fleet sizes in the coming years.

2 VEHICLE PROCUREMENT

VEHICLE PROCUREMENT

Major fleet managers have no doubt that their fleets will be largely electrified in the coming years. They recognize the many benefits of EVs, including their lower TCO, and report that their employees that drive EV fleet vehicles love using the vehicles. The main uncertainty that fleet managers have is about when, not if, electric models will be available for the specific use cases that their current fleet vehicles need to perform.

Light-duty vehicles (Class 1–2) are generally viewed as being ready for adoption for most use cases now. Medium-duty vehicles (Class 3–6) suitable for substitution are expected to become available over the next 5–10 years. Most fleet managers believe that manufacturers will need to accelerate their production plans for heavy-duty vehicles (Class 7–8) and some of the heavier medium-duty vehicles in order for fleets to be able to meet their electrification targets by 2040. (See *Appendix A: Vehicle Weight Classes and Categories* for detail on vehicle weight classes.)

PROCUREMENT RESTRICTIONS

Some organizations have certain restrictions on the vehicles they can buy, which can limit their choices when procuring EVs. These procurement restrictions detailed below can create procedural hurdles that slow the pace of EV adoption in fleets. Organizations will need to consider how they should amend these legacy processes to better respond to rapidly changing EV technology.

For example, organizations such as cities and states often have a “bid list” from which they buy vehicles exclusively. The bid list consists of approved dealer offers and is updated annually. Thus, if a particular vehicle is not available from a dealer who submits a bid to the bid list, it is effectively unavailable to those organizations. This bid list process can be a barrier to startup manufacturers that may not want to engage in a price-competitive bidding process that will erode their margins just as they are launching their first vehicles. Consequently, those buyers that procure EVs from a bid list are more likely to buy EVs from the established major manufacturers (though even established manufacturers find this to be a hurdle as they rapidly introduce or change their vehicle offerings).

Other organizations, such as universities, may have a requirement that they can only buy from a local dealer who is on an approved vendor list. This requirement also tends to screen out startup manufacturers that do not have an extensive network of dealerships, so those purchasers typically buy only from established major manufacturers. For some fleets, there may also be a requirement that the purchaser get at least two bids from local dealers. If there are not two local dealers for a given vehicle brand, this requirement can make it difficult for fleet managers to buy, even if the brand is made by a major established manufacturer.

Very large fleets often have enough market power to strike long-term purchase agreements with manufacturers to supply a particular vehicle at a certain price. This type of buying arrangement would also likely be a hurdle for startup manufacturers and creates inertia in favor of ICE vehicles. This is because fleet managers can more easily just order another unit under their standing purchase order rather than actively seek out more expensive vehicles that are harder to buy.

In some cases, a buyer may be able to procure a vehicle that is not on an approved bid list or from a pre-approved local vendor. However, they may have to go through a more complex process and get additional approvals to do so, which can in itself be an impediment. For example, one city fleet manager we interviewed said that if an agency wanted to buy a vehicle that was under $50,000 and was not on the bid list, they would have to get three separate quotes from dealers and choose the lowest one. For vehicles over $50,000 that aren't on the bid list, the buyer would have to procure it through an RFP process.

The procurement process can restrict the vehicles that fleet managers can buy in other ways as well. Some organizations require their constituent departments or agencies to contribute annually to a vehicle replacement fund, which is then used to pay for replacement vehicles. This tends to create an implicit "like for like" requirement, making it far more difficult to replace an existing ICE vehicle with an EV that can perform all of the same functions but costs more—even if the TCO of the EV is lower.

This is because the replacement fund anticipates that the replacement vehicle will have the same upfront cost as the current vehicle, without factoring in lifetime operating savings. This puts EVs at a disadvantage since they typically have a higher upfront cost and lower operating costs than ICE vehicles. The purchasing entity must then seek out additional funds to cover the upfront cost premium since the replacement funds are insufficient. (See *Distributed Budgets Make Total Costs Unclear* on p. 56 for more discussion on TCO considerations.)

LIGHT-DUTY PASSENGER VEHICLES

Most electric fleet vehicles today are light-duty (Classes 1 and 2) passenger vehicles with a sticker price under $40,000. They are typically used for largely administrative tasks, such as simply transporting a driver (perhaps with a light toolkit) from one place to another. These users typically have non-critical roles in administration, management, sales, inspections, and the like.

These vehicles are typically four-door sedans, like the Chevy Volt and Bolt and the Nissan Leaf, and PHEV SUVs (including "crossover" SUVs) like the Ford Escape and the Mitsubishi Outlander. Fleets that were early adopters of EVs tend to have a significant share of PHEVs acquired over the past decade or so but increasingly prefer BEVs while phasing out hybrids. Although Tesla is far and away the dominant manufacturer of EVs in the light-duty vehicle retail segment, there are few of them in fleets because they are perceived as being too expensive or as "luxury" vehicles that would be inappropriate for cost-conscious fleet managers.

PICKUP TRUCKS AND VANS

The next major vehicle segment that is likely to electrify is pickup trucks and vans. All of the fleet managers we interviewed have a significant number of pickups and vans in their fleets, which are used for a wide variety of tasks, including maintenance, light hauling, and other kinds of hands-on work.

All-electric vans have been slower to arrive in the United States than the UK. A few models, such as the Workhorse C-Series van, are now being deployed in the United States (particularly for electric "last-mile" delivery applications) but they are still very much in the early days of adoption.[8] Electrified vans in fleet use

THE PICKUPS ARE COMING!

The most-wanted EV on fleet managers' wish lists are electric pickups. Pickups are an essential part of the fleets we interviewed, and they have a wide variety of use cases.

Currently, there are no commercially available fully electric pickup trucks, but that is about to change:

- Ford's F-150 EV is probably the most hotly anticipated model, primarily because its gasoline counterpart has been America's best-selling truck for nearly 40 years. Ford sold nearly 900,000 of the conventional F-150s in 2019, easily outpacing its rivals. Ford has released few details about the electric F-150, but has said that it plans to begin production in 2022.
- Tesla's Cybertruck is scheduled to begin production in late 2021. The first models are expected to be tri-motor models with a starting price of $69,900, about 500 miles of range on a charge, and 14,000 pounds of towing capacity. Lower-cost, single- and dual-motor models at lower prices are expected after that.
- GMC's Hummer EV, a fully electric version of the Hummer, is expected to have a range of about 350+ miles. It has fully subscribed reservations for the first year "Edition 1" with a price tag of $112,595. GM unveiled the pickup truck in October 2020, and has announced a fall 2021 start of production.
- Rivian's R1T was expected to begin production in 2020, but the company pushed back the timeline to June 2021 due to the coronavirus. The R1T is expected to come in several configurations, one with a top range of 400 miles with a 180 kWh battery pack, and to be priced starting at $69,000.
- Bollinger's B2 pickup is expected to begin production in 2021, and come in a variety of configurations, with the largest battery pack being 180 kWh. The starting price is expected to be $125,000.
- Lordstown Motors expects to begin shipping its Endurance pickup in January 2021, with entry-level models starting at $52,500.
- A handful of other pickups from Fisker, Nikola, Atlis XT, and other startups have also been announced, but analysts have less confidence in their production announcements and details are scarce.

today are primarily PHEVs like the Chrysler Pacifica. Still, fleet managers are eager to adopt electric vans when they are suitable for the use cases, especially electric cargo van substitutes for their existing work vans used by tradespeople.

Based on our interviews with fleet managers, it appears that pickup trucks need to be able to drive at least 200 miles on a single charge in all kinds of weather, with air conditioning or heat running constantly, to be considered suitable substitutes for ICE pickups. When suitable electric pickup trucks become available, provided they are within roughly the same price range as a conventional pickup, they should be in high demand, because many fleets have a large number of pickups that they would like to electrify. But they will have to prove their mettle in the field under all sorts of conditions before fleet managers will be willing to adopt them at scale.

This does not mean that all fleet vehicles need to be able to go 200 miles on a charge, however. In fact, a mix of available battery sizes makes it easier for fleet managers to match a vehicle's route to its battery range. For example, one fleet manager cited a parcel delivery van route in New York City that averages only about six miles a day, implying a battery requirement that's probably under 10 kWh. If most available trucks only have 80 kWh battery packs available, those trucks will be hauling around excess battery weight for no benefit when a 20 kWh battery pack would be sufficient.

MEDIUM-DUTY VEHICLES

The package-delivery service fleets we interviewed are aggressively adopting electrified versions of the vehicles they use most, like box trucks and delivery vans. Because these vehicles are the backbone of their business, package-delivery services are keenly aware of the cost savings they can realize by electrifying their fleets.

The fleet manager with the largest package-delivery service we interviewed said that they believe that 70% of their delivery vehicles could currently be operated on electric, and that 84% of its fleet could be electrified at TCO parity with ICE vehicles in the foreseeable future.

Where operating fleet vehicles is not the core business of an organization, fleet managers are less aggressive and more willing to wait for the suitability of EVs to be demonstrated. Electrified substitutes for medium-duty Class 3 vehicles that are often used for hauling and other work, like the Ford F-350, are beginning to come to market. However, fleet managers said their prices would have to come down significantly or grants and other external funding would have to sweeten the deal before the vehicles could be considered. With sticker prices in the range of $150,000 for a cabin chassis with a dump-truck body, these EVs are roughly twice the price of an ICE option.

Fleet managers are also eager to electrify vans and box trucks, which are typically subject to heavy use. But proving that the vehicle is fit for its use case and duty cycle is critically important. Fleet managers are also less inclined to risk buying these vehicles from startups. This is due to having been burned before by buying vehicles from companies that went out of business and saddled the fleet manager with the difficult task of finding parts and qualified staff to perform repairs.

HEAVY-DUTY VEHICLES

We found no fleet managers who expected heavy-duty (Classes 7 and 8) BEV trucks to be available at scale before 2024. Their expectations may underestimate the influence of California's Advanced Clean Truck regulation, issued in June 2020, which requires manufacturers of commercial vehicles to start selling electric trucks in 2024, and to sell only electric trucks in California by 2045.[9]

However, a few BEV Class 8 trucks and tractors are currently being tested in the field, according to the fleet managers we interviewed. These demonstration vehicles are running shorter local routes—typically, under 150 miles a day—with vocational applications, such as dump trucks, concrete trucks, refuse trucks, and snowplows. These vehicles typically come in complex configurations with accessories that consume power, and return to a base every day, which makes charging them relatively straightforward. BEV Class 8 trucks and tractors currently being tested will be able to serve a significant share of the vocational market.

Class 8 vehicles that are not yet ready for electrification include regional and long-haul applications where the routes are longer than the range of today's BEV trucks. Long haul sleeper tractor trailers have disparate, unpredictable routes, and typically need 400–600 miles of range. Regional haul tractors, such as daycabs and sleeper tractor trailers that run variable-length routes, typically need 300–500 miles of range. These vehicles may have routes of highly variable length and destination, making it uncertain where they will return to a base for recharging. Fleet managers remain open-minded but skeptical about BEV trucks being able to offer over 500 miles of range, affordably, without adding significant battery weight.

The fleet manager with the largest package-delivery service we interviewed said that some additional advancement in battery technology would make it cost-effective for them to buy Class 8 BEVs. This is due to their use case for those vehicles being for routes of 250 miles or less, making it feasible for them to electrify 95% of their fleet.

Refuse trucks are likely to be among the earliest types of heavy-duty vehicles that fleet managers will electrify, because electric vehicles are far better-suited to stop-and-go driving at low speeds over short distances than diesel or gasoline vehicles. Stop-and-go idling increases the maintenance costs of diesels, whereas BEVs can recapture energy from regenerative braking and do not need brake pad replacements as often, which reduces their overall maintenance costs.

Electric BEVs are also much quieter than conventional diesels, making them far preferable for urban environments. However, BEV refuse trucks may be more practical in situations where they only have to deliver garbage to a transfer station near their pickup routes. Where refuse trucks have to drive their full loads longer distances to a dump outside of town, it may be longer before BEVs have the necessary range to serve the route.

Fleet managers with vehicles that perform critical services, such as refuse trucks, fire trucks, and mail delivery vehicles will not be tempted to buy BEV substitutes for those vehicles until they are capable of performing every aspect of their use cases reliably in all kinds of weather. Depending on the use case, these vehicles may need to be able to operate reliably during grid blackouts or when other systems (like communications) are not operable in the aftermath of a disaster.

BUSES

Transit agencies that would like to switch to electric buses will continue to rely on incentives such as rebates and cost-sharing grants typically, to pay for the premium cost of those vehicles over an ICE bus. The most common such grant program is the Low or No Emission Vehicle Program (Low-No) operated by the Federal Transit Administration (FTA). Transit organizations are chronically under-funded and need regular financial assistance to merely replace their existing buses with a conventional ICE model. Paying the premium for an electric bus puts those vehicles out of reach in the absence of another source of financial support. One transit fleet operator told us that a BEV transit bus can cost $200,000–$500,000 more than an equivalent diesel bus. Another transit fleet operator said that a typical diesel or CNG bus typically costs $650,000, whereas a comparable PHEV bus is $750,000 and a BEV bus is $850,000.

Consequently, most transit organizations that have deployed some BEV transit buses did so under an FTA Low-No grant, but that funding is usually only adequate to support the purchase of a few buses per year, which makes for a very slow transition path. The replacement cycle for transit buses is also slow, at 12 years, because that is the standard for FTA grants. Transit bus operators typically have a few hundred diesel buses that they would like to replace with BEVs, so they are constantly in search of funding.

The economics of transit bus fleets are complex, and most transit fleet managers are working with incomplete data or data that is not suitable for making an apples-to-apples comparison between a BEV and a conventional diesel bus. It is difficult to compare the scant performance data across manufacturers and local climatic conditions. In addition, there is no long-term maintenance data available and even short-term maintenance data is meager. Finally, because electric buses are so new, supply chains are not yet mature, meaning that there are no aftermarket or refurbished replacement parts, which makes parts supply relatively expensive. All of this combines to create an environment in which transit agencies must make long-term decisions with incomplete and rapidly changing information.

One transit bus fleet operator in a temperate climate who was able to give us fairly complete modeled data indicated that electric buses offer a $0.38/mile savings on fuel over conventional diesel buses. On an annual operating cost basis, including fuel and maintenance every 60,000 miles (the typical annual mileage of a bus), they modeled that a conventional diesel bus costs about $78,000 a year, a hybrid electric bus about $62,000, and a BEV bus about $49,000. Most of the savings are from the cost advantage of electricity over diesel.

However, the same operator found that bus maintenance, parts, and labor are more expensive for BEVs, at $0.64/mile, as compared with $0.53/mile for a legacy diesel bus and $0.47/mile for a hybrid electric bus. In addition, charging infrastructure is a significant start-up capital cost which must be accounted for in budget planning. The infrastructure cost can vary significantly depending on the details of the site, how much capacity is needed, etc. However, this is all modeled data. We did not find any transit fleet operators who felt that they had complete telematics and analytics data for all of the buses and their associated refueling requirements, such that they could make a comprehensive judgement about the economics of electrifying their fleets.

To the extent that operational savings do exist from electric buses that can offset the purchase price premium of a BEV bus, in 2020, the price premium is still often too large for these savings to compensate for it. And even if it were sufficient, the internal budgeting of transit operators may not offer a straightforward way to count an operational savings against a capital expense. This is due to the fact that capital and operating budgets are often managed by different departments with minimal visibility into each other's expenditures and have different funding sources. See *Distributed Budgets Make Total Costs Unclear* on p. 56 for more on that topic.

FORKLIFTS, OFF-ROAD, AND OTHER SPECIALTY VEHICLES

Some vehicles have unusual use cases that can make them awkward to electrify. For example, in some cities, refuse trucks and various sizes of work trucks can be expected to act as snowplows during severe and infrequent winter storms. Fleet managers who need to evaluate the suitability of EVs for these use cases may find that an EV fits the duty cycle of its primary use case perfectly well, but that it cannot manage the duty cycle of snowplowing as well because of its charging time. This does not make the EV option unsuitable, necessarily, but it may require the fleet manager to come up with a creative solution for that particular use case.

For another example, pickup trucks used in an agricultural college may need to perform a wide variety of tasks, such as pulling animal trailers or small combines loaded onto a trailer in snowy winter conditions. Before EVs would be considered by such a fleet, they would need to prove their towing capacity and all-weather suitability, at a minimum.

A wide variety of off-road vehicles are also getting electrified, particularly in city fleets. These vehicles include forklifts, scissor lifts, backhoes, trenchers, ATVs, mowers, cable-handling trailers, boats for emergency rescue, and other special-purpose vehicles.

While we did not attempt a comprehensive assessment of the need for electric off-road vehicles—a very diverse group—a number of the fleet managers we interviewed indicated that electric forklifts were increasingly part of their fleets. Very large warehouse operations that have been eager to adopt new technologies already operate fleets of hydrogen fuel cell forklifts, because charging or swapping batteries for electric forklifts has not been a good match for their duty cycles, where the forklifts are in operation too much of the time to make charging or swapping batteries operationally practical.

However, the fleet managers we interviewed indicated that they were primarily planning to adopt BEV forklifts in the future, and not fuel cell forklifts, provided they can perform the duty cycle. Further study is needed to understand and compare the respective growth trajectories for battery electric and hydrogen fuel cell forklifts.

ICE VEHICLES WITH ELECTRIFIED ACCESSORIES

Fleets with medium- and heavy-duty work trucks, like utilities, have been adopting electrified accessory equipment known as “idle mitigation equipment” on conventional diesel trucks for a while now and seem to be quite comfortable with deploying it at scale. This equipment includes bucket lifts, digger derricks, work lights, asphalt heaters on pothole trucks, and HVAC equipment that can be powered by on-board batteries instead of by the truck’s idling engine. Charging of the idle mitigation equipment is done at Level 1 speeds, so no special charging equipment or infrastructure is needed. If the battery powering the accessories runs low, or the vehicle is working in the field without a place to plug in and recharge, the accessory equipment can revert to being powered by the vehicle’s diesel engine.

Electrified accessories on a conventional diesel work truck are more cost-effective than fully electrified trucks. Today, diesel bucket trucks cost around $225,000 with an additional $40,000–$60,000 to be outfitted with electrified accessories, as compared with a $350,000 upfront cost for a current all-electric bucket truck model. Plus, the electrified accessory equipment is typically modular so that it can be transferred to a new vehicle when the old vehicle is retired.

For trucks that may be parked at a work site for six to seven hours daily, idle mitigation equipment can materially reduce the truck’s emissions. In addition to reducing emissions, accessory electrification saves fuel and reduces noise, making it popular with field technicians. Noise reduction is considered to be important so that crews do not have to shout over the idling diesel engine and neighbors (especially those working from home in this era of COVID) do not have to listen to the trucks all day. Fleet managers suspect there are additional, albeit unquantified, health benefits to workers not breathing diesel exhaust all day as well.

REFRIGERATED TRUCKS

Refrigerated trucks are an important part of certain fleets. For example, an agricultural college we interviewed uses them for veterinary field work. These trucks are generally Class 7 or 8 and do not yet have electrified drive trains. But, like the electrified accessories of idle mitigation equipment, the refrigeration component of a trailer may be electrified to obviate the need to run the truck’s engine to power the refrigeration units.

One grocery delivery service we interviewed that runs refrigerated trailers plugs the trailers in to grid power at its facilities for 6–10 hours a day while the vehicles are parked for loading. (While in transit, the refrigeration units are still powered by the truck’s diesel engine.) The trailers are equipped with a refrigerator from Carrier that is designed to run a full cooling load using grid power. This fleet is gradually building out electrical plugs for these refrigerated trailers at its locations and, by 2025, it wants all of its facilities to be equipped to provide full “shore power” (grid power) electrification. At the first facility it equipped for this, it installed 42 outlets, and found that its ROI on the investment was less than one year because of the savings from not having to idle the diesel engines.

Another new method of powering refrigerated trailers has been introduced by Advanced Energy Machines, which makes a trailer that generates electricity from a roof-mounted solar array and recaptures energy with regenerative braking. According to the manufacturer, the system has enough capacity to run two or three-zone refrigerator/freezer delivery trailers ranging in size from 28 to 53 feet, and includes an electric motor, lithium batteries, solar panels, a master control board, an auxiliary power unit for shore power, compressor, evaporator, and custom air control systems.[10] Small solar systems have been used for several years already to power the liftgates on trailers instead of having to run the truck’s engine or draw power from the truck’s battery.[11]

3 CHARGING INFRASTRUCTURE PROCUREMENT

CHARGING INFRASTRUCTURE PROCUREMENT

"Electric vehicles are the next frontier in the clean energy transition, and we are committed to making charging EVs easy, convenient, and affordable for customers."

—Ben Fowke, chairman and CEO of Xcel Energy.

"Charging infrastructure," one fleet manager told us, "is the long pole in the tent." It is the core element that supports everything else, including the organization's broader electrification strategy. As such, a lack of chargers was reported as a limiting factor for continued EV adoption by several fleet managers we interviewed. But it appears that most organizations are thinking about charging last...if they are thinking about it at all.

Charging infrastructure is also the largest area of concern and uncertainty for fleet managers working on fleet electrification. It is fraught with difficult questions which have no obvious answers and few best practices, such as:

- Which vehicles need chargers installed at centralized depots, and which ones can employees take home to charge?
- If employees take company vehicles home to recharge them, how does the company manage the liability of installing chargers at employees' homes, and how should the costs be compensated or allocated?
- Is the organization going to retain its fleet facilities long enough for it to make sense to make a 10-year investment in charging infrastructure?
- How can the cost of installing chargers be reduced? And to the extent that "future-proofing" an installation seems cost-effective, how far into the future can such planning go?
- What kind and what power level of chargers should the organization deploy, recognizing that vehicle manufacturers have been increasing battery sizes and maximum charging speeds?
- How should the costs of installing charging infrastructure and paying utility bills be allocated within the organization? Should they be paid as part of an organization's general overhead, be allocated to the various departments within an organization, or be allocated to individual users?

Out of necessity, the most aggressive adopters of EVs, like package-delivery services, are also the most aggressive about building their own charging infrastructure to support their fleets. Because delivery vehicles are the backbone of their business, these organizations must be in complete control of their charging infrastructure and must have the in-house expertise to build and operate it on their own premises. This forces them to deploy it at their own facilities where they have to contend with the many hurdles that entails, as we detailed in our report, *Reducing EV Charging Infrastructure Costs*.[12]

Although there are no hard and fast rules about how other organizations provide for their charging needs, many public organizations, like cities and universities, intend to rely in part on parking spaces equipped with chargers that are also open to employees and the public.

Private sector companies are more likely to rely on charging infrastructure that they build, own, and operate for their own purposes exclusively. Some

CITIES AND STATES

In addition to fleet vehicles for common use cases, cities are eyeing early adoption for certain kinds of EVs for reasons other than their costs and carbon emissions:

- Electric refuse trucks are favored because they are much quieter than conventional refuse trucks and won't wake residents up at early hours.
- EV pickup trucks and 15 cubic yard BEV hauler trucks are favored for city parks because visitors do not want to breathe in their exhaust.
- Electric transit buses and school buses are heavily favored because they are both quieter and do not generate exhaust.

Municipal agencies, like police, sheriff, and fire departments, can be exempt from local laws and procurement rules governing fleets. As a result, it appears that they may be more likely to adopt EVs earlier than other agencies for non-critical and administrative uses like traffic enforcement and school safety. This highlights an interesting tension that these fleets have, because they are also likely to be late adopters of EVs for emergency response or other critical municipal services, at least until EVs are thoroughly field-tested and demonstrated to be suitable for the purpose.

In addition to operating their own fleets, cities are hosts to major fleets, and their support (or lack thereof) for fleet operators has a significant influence on whether or not these fleets will electrify their vehicles. Where cities have adequate grid power supply for charging depots, and where they offer incentives for EVs (or at minimum, do not throw up hurdles), fleet managers will respond to the opportunity.

organizations intend to restrict the use of their in-house charging facilities to their fleet vehicles, while others are contemplating allowing employees to use the chargers for their personally owned vehicles as well. At this point in time, there is too little charging infrastructure built, owned, and operated by private sector companies to identify any clear trends or best practices in usage restrictions.

Most organizations just have a small number of Level 2 chargers and have not yet begun to grapple with the real challenges they will face as they proceed to electrify most of their fleet vehicles, as discussed in *Challenges Ahead* on p. 51. Once these organizations are paying the utility bills for a significant number of chargers, including DCFC, developing policies for their use will become much more of a priority.

Our research indicates that taking a long-term view toward building charging infrastructure is key to reducing the total cost of the infrastructure.[13] These techniques include:

- controlling utility costs by managing the overall charging load;
- optimizing the charger-to-vehicle ratio;
- centralizing high-powered chargers at a single location;
- “future proofing” charging sites by installing utility infrastructure during initial construction to enable later expansion of the chargers; and
- building charging infrastructure under a single master contract in order to ensure equipment and platform interoperability.

In order to capture such cost efficiencies, an organization must develop fairly detailed projections for the number of EVs it will have in its fleets, and their charging requirements, years into the future. Only the largest organizations we interviewed have begun to undertake such forecasting. Most organizations are still adding a few EVs and a few chargers to support them incrementally each year. That is the most expensive way to develop a fleet’s charging infrastructure and can, in fact, become an impediment to future optimization because the ever-growing investment in infrastructure must be recovered over future years.

UTILITIES

Utilities have an obligation to keep the lights on for their customers, and to respond to outages and natural disasters quickly. Meeting that high standard of performance is their number-one objective and it is not negotiable. Vehicle range, local temperatures and weather, and highly specific requirements for duty cycles and use cases are all essential characteristics that utilities will take into account as they consider electrifying their fleet vehicles.

Consequently, utilities are generally unwilling to risk nonperformance in their fleet vehicles, which are overwhelmingly dominated by work trucks. As such, utilities are typically not early adopters, preferring instead to buy the best available technology from an established manufacturer, rather than projecting the kinds of vehicles that might be available in the future, or trying out a new vehicle from a startup manufacturer.

Utilities typically have existing purchase agreements with established manufacturers that largely confine their choices in purchasing. Utilities typically have additional regulatory restrictions related to cost recovery that can make them more likely to buy than lease, making them even less likely to try a new vehicle model that they would have to own for its full life rather than being able to replace it when its lease expires.

Because they are so focused on vehicle reliability and availability, utilities are less likely to use techniques that other organizations might use to minimize costs, like managed charging (see *Operationalizing Charging Will Be Challenging* on p. 57) and will optimize for vehicle availability instead.

Most of the EVs that utilities have in their fleets today are PHEVs, because they like the ability to refuel them with gasoline at any time. Even in a future when fleets mostly consist of EVs, utility fleet managers expect to continue using some gasoline-fueled work trucks in the event that they are needed for emergency response. This is particularly true for vehicles that may need to respond to an emergency in another state or another utility's service area, under longstanding conventions of mutual aid.

For some utilities, pre-positioning their fleets to prepare for natural disasters is a fairly common occurrence. However, we did not find any utilities that had begun coordinating efforts to ensure that there was a functional and suitable network of DCFC to connect their fleets for mutual aid purposes. This will be an essential requirement if utilities are ever able to transition to fully electric fleets.

EVs also represent the best opportunity for load growth on utility systems in the near and medium term, a most welcome opportunity since utility load has been flat or declining in most of the United States for over a decade. And since utilities can buy or generate power at the lowest possible cost of any electricity user, their cost of operating an EV fleet can easily beat the cost of operating a conventional fleet.

Accordingly, utilities are eager to electrify their own fleets as a way of reducing their own operational costs and building credibility with external stakeholders and customers who may be skeptical about EVs. When customers approach a utility about electrifying their fleets, one of their first questions to the utility is "What have you done with your fleet?" Therefore, "walking the talk" is important.

Initially, most of the fleet vehicles with electric drive trains that utilities have adopted are light-duty passenger vehicles used for noncritical, nonemergency administrative tasks, because those are the EVs that are readily available in the market at reasonable prices. However, more than half of the utilities' fleets typically consist of small SUVs and extended- or crew-cab AWD/4WD pickup trucks, like the Mitsubishi Outlander PHEV, with a minority share of sedans. When automakers bring electric versions of these vehicles to market, utilities can be expected to buy them at scale if they are reasonably priced.

Building on a 2014 pledge by the member companies of the Edison Electric Institute (EEI), a utility industry trade group, EEI's member companies are now on track to electrify more than one-third of their total fleets by 2030, including two-thirds of the passenger vehicles in their fleets. For example:

- Xcel Energy plans to electrify all of the company's sedans by 2023, all light-duty vehicles by 2030, and 30 percent of its medium- and heavy-duty vehicles by 2030.
- Hawaiian Electric's fleet is currently 25% electric and will be 100% by 2035.
- American Electric Power (AEP) plans to replace 100% of its 2,300 cars and light-duty trucks with EVs and 50% of its forklifts with electric versions by 2030. AEP currently has 85 EVs and more than 230 charging ports throughout its 11-state service territory. AEP plans to electrify 40% of its entire fleet of nearly 8,000 vehicles, including medium- and heavy-duty vehicles, by 2030.
- Exelon aims to electrify 30% of its utility vehicle fleet by 2025, and 50% by 2030. Starting in 2025, the utility will replace light-duty vehicles with electric options when they reach their end of life, with the goal of having an all-electric light-duty vehicle fleet by 2030.
- Southern California Edison plans to have electric models of every passenger car and small-to-midsize SUV in its fleet by 2030, along with 30% of its medium-duty vehicles and pickup trucks, 8% of its heavy-duty trucks, and 60% of its forklifts.
- Southern Company plans to electrify half of its cars, SUVs, minivans, forklifts, and miscellaneous equipment (including ATVs and carts) by 2030. Class 1 and 2 vehicles comprise 35% of the company's fleet.
- Duke Energy plans to move to EVs for 100% of its nearly 4,000 light-duty vehicle fleet. It also plans to move to EVs or other zero-carbon alternatives for 50% of its approximately 6,000 medium-duty, heavy-duty, and off-road vehicles by 2030.
- Portland General Electric plans to electrify more than 60% of its fleet by 2030, including 100% of the utility's Class 1 vehicles and forklifts (by 2025), 70% of its Class 2 vehicles, 40% of its medium-duty vehicles, and 30% of its heavy-duty vehicles.

Utilities are also adopting electrified accessory equipment on their work trucks, such as bucket lifts, digger derricks, work lights, and HVAC equipment, as described in *ICE Vehicles with Electrified Accessories* on p. 38.

Utilities are starting to actively encourage their larger customers to transition to EVs. Leveraging their own experience to demonstrate the business case for vehicle electrification, utilities are advising them on the best practices for electrifying their fleets, sharing operational data and experience with them, and encouraging them to electrify their fleets. The most progressive utilities in this regard are now developing outreach programs to engage with their large fleet customers to help them plan their electrification strategy. The utilities can then use that information for their own resource planning purposes, so that they will be able to meet the new demand when those customers undertake electrification of their fleets.

CONSIDERING THEIR OPTIONS

One city fleet manager we interviewed said the city is considering deploying dedicated DCFC chargers at fueling depots they already own and use for their existing ICE fleet vehicles. This strategy will certainly ease the siting hurdles that are typical for a DCFC installation, but cities have to clear another major hurdle: figuring out how much new power supply the chargers will need and then bringing that new grid capacity to the charging depots.

Conversely, organizations that currently house their vehicles at dispersed facilities and carefully analyze the charging requirements may discover that equipping all of those facilities with chargers would be much more expensive than charging them all at centralized charging depots. But if they do not have any centralized facilities, the long-term cost savings of using one could be overshadowed by the complexity of building one and then managing the operational complexities of reorganizing the way that vehicles are used and where they are housed.

A few cities are using portable “solar carport” units from Beam (formerly Envision Solar) to meet modest charging needs for noncritical EVs, because the units do not require a grid interconnection or permanent installation and are thus easy to deploy quickly where and as they are needed. However, this solution would not be suitable for many fleet vehicle duty cycles, as the battery capacity of a unit tops out at 40 kWh, about two-thirds of the battery capacity of a 2020 Chevy Bolt.[14]

Some organizations that have more remote sites where chargers are needed for light-duty passenger vehicles, like parks and tourist attractions, have considered using on-site solar arrays to power the chargers with an off-grid, self-contained installation. However, we did not hear about major successes with this strategy. Typically, these sites need DCFC, which has power demands so high that they would essentially require an expensive microgrid, complete with a large, ground-mounted solar array, batteries, and other associated equipment. A further complication for such a concept is that these organizations can typically obtain grants for the chargers or grants for the solar system, but not grants for both.

Most organizations need to undertake a comprehensive assessment considering the pros, cons, and costs of their charging infrastructure options in order to understand how they should proceed. But very few organizations have recognized the need for such an assessment, let alone undertaken one.

UNIVERSITIES

The university fleet managers we interviewed reported strong interest in EVs among all subgroups of the university populations, including students, faculty, administrators, and maintenance staff. However, all indicated that the charging infrastructure of their campuses was very limited, and that plans to deploy more chargers and accommodate the influx of EVs that they all anticipate had yet to be developed or funded.

Some universities require their transportation services to be completely self-funded, which in the time of COVID-19 has essentially halted any progress on deploying more charging infrastructure. Clearly, universities will need funding support in order to be able to serve the future demand for charging services on their campuses and across their fleets.

HOW MUCH POWER DOES A CHARGING FACILITY NEED?

Determining the power requirement for a centralized facility like a charging depot, bus barn, or vehicle yard can be a surprisingly difficult challenge. Because the vehicles themselves are still undergoing rapid development, the types of duty cycles they can accomplish are increasing every year along with the size of their battery packs. For example, the 2018 Chevy Volt, a PHEV, had a modestly sized 18.4 kilowatt-hour (kWh) battery pack. The 2020 Chevy Bolt has a 66 kWh battery pack. And the 2020 Tesla Model X has a 100 kWh battery pack. Those vehicles, which are within two model years of each other, have a five-fold difference between their battery capacities.

The maximum rate of charge that chargers can deliver also varies significantly, from Level 1 charging at about 1.2 kW, to 7.2 kW from a Level 2 charger, to 150 kW at a modern public DCFC, to 250 kW rates of charge on the newest chargers in the Tesla Supercharger network. (See *Appendix C: Types of Chargers* for more on the power levels of chargers.)

The battery capacities and charging speeds become even more extreme for medium- and heavy heavy-duty vehicles. Proterra's Catalyst buses, for example, have battery capacities up to 660 kWh, and Proterra offers chargers that deliver 60 to 500 kW of power. Similarly, many other types of medium- and heavy-duty vehicles also have large ranges in battery capacity and maximum charging speeds.

Therefore, understanding how much power a charging facility needs is a complex calculation in which one must know the duty cycle expected of each vehicle, for how long and when they need to charge, how many of each type of vehicle will need to charge simultaneously, and at what power levels. For example, a fleet of a dozen light duty vehicles might be able to get by with one Level 2 charger per vehicle, for a total simultaneous aggregate demand of 86 kW. But a package delivery service with 100 vehicles at a warehouse might need 1–3 MW of power supply at that facility, depending on the charger speeds.

One should also know the extent to which those parameters are flexible. For example, is it operationally permissible to shift the charging periods of different vehicles in order to flatten the overall power demand curve, or to take advantage of low-cost hours in a time-of-use (TOU) utility tariff? What is the minimum charger speed that a given vehicle needs in order to get the level of charge it requires, within the available charging interval, in order to complete its duty cycle? Which vehicles can share chargers, and which ones can only use chargers with certain speeds or connector types? Which vehicles need exclusive use of a charger during their charging intervals? And so on.

CHARGING AS A SERVICE

Realizing the significant complexity involved in planning, procuring, operating, and maintaining charging infrastructure, some organizations are beginning to look for charging-as-a-service (CaaS) providers to relieve them of those burdens. CaaS can include services such as procuring charging hardware, installing and configuring chargers, planning for future system expansion, and coordinating installation with the local utility. It can also manage charging to minimize utility bills, guarantee that vehicles will be charged and ready to go when they are needed, optimize the whole system of vehicles and chargers, and perform maintenance and billing. One large utility told us that it would rather contract with a charging infrastructure service provider than develop all the necessary expertise in-house, even though it already has partner vendors helping it build and manage its charging infrastructure.

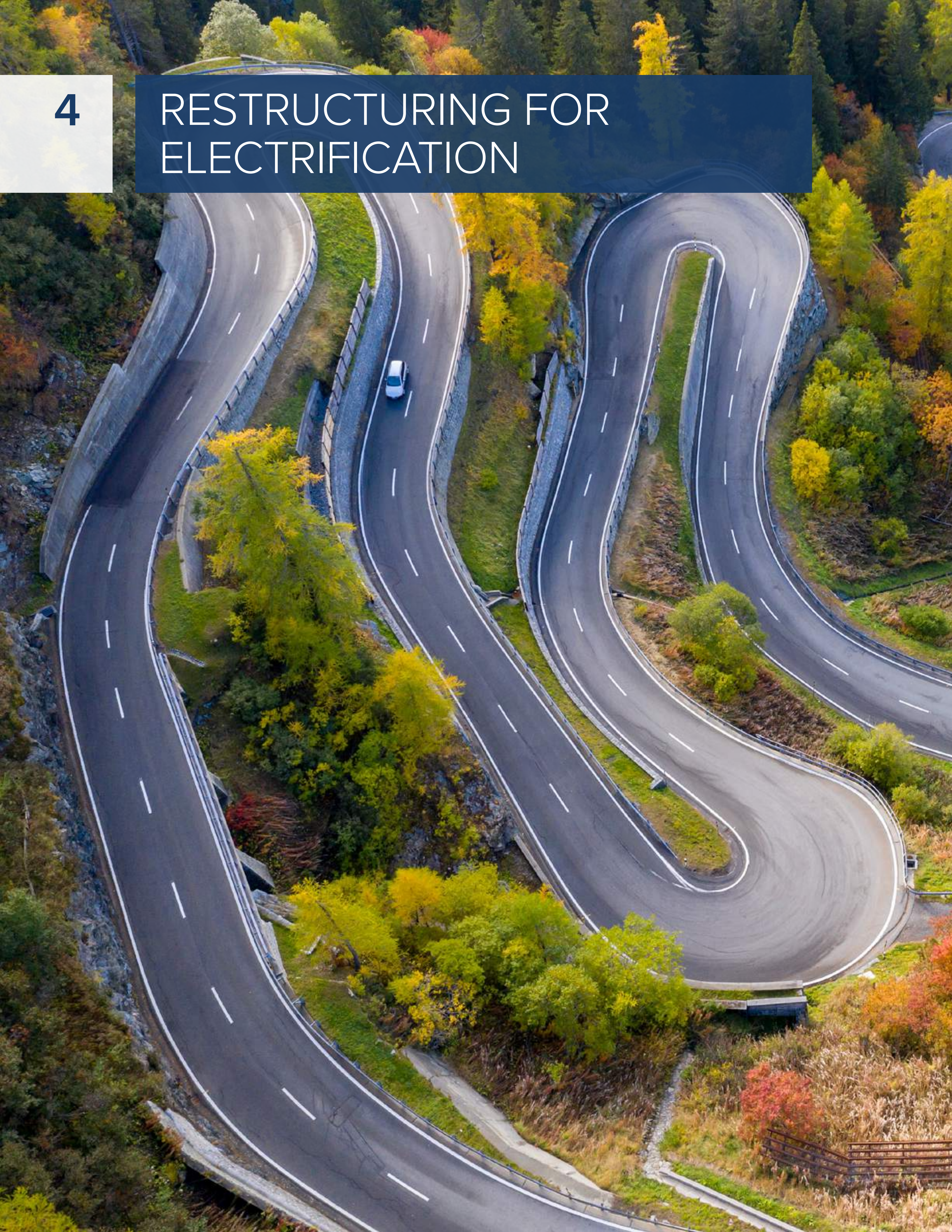
Importantly, charging as a service shifts the technology and performance risk from the fleet operator onto the CaaS provider. For example, a CaaS contract can be structured on a pay-as-you-go basis with a long-term fixed price per kilowatt-hour, incentivizing the CaaS provider to optimize charging and minimize operational costs.

The CaaS sector is nascent at best, but it is emerging in response to fleet demands. For example, a large municipal fleet in the United States will be issuing an RFP for a CaaS provider to manage all the operations of its fleet, and expects the contract cost to be fully offset by operational savings.

A few other major US utilities are beginning to explore CaaS offerings as well. For fleets that would find it difficult to hire suitable personnel to manage the charging infrastructure piece of their electrification programs, a utility-run CaaS could be a cost-effective and expedient option.

4

RESTRUCTURING FOR ELECTRIFICATION



RESTRUCTURING FOR ELECTRIFICATION

Preparing for fleet electrification at scale will pose fundamental challenges to many organizations. They will need to address how and when EVs are approved to replace existing ICE vehicles, how capital investment decisions are made, the basis on which they are made, and how costs are accounted for. Organizations will also have to address what strategy they decide to take in providing charging infrastructure, how the operations of fleet vehicles will need to change to accommodate charging, and many other issues.

MANAGING UNCERTAINTY

Plug-in EVs are still a nascent technology in many ways. However, vehicle manufacturers are expanding their product lines, rolling out new designs and updated models, improving the technology, increasing the size and maximum charging speed of vehicle batteries, and enhancing the capabilities of their various models, even as they continue trying to reduce the vehicles' prices. These evolutions are happening at breakneck pace, relative to the history of conventional vehicle development, so fleet managers must find ways to manage the uncertainty about which vehicles they buy, and when. The fleet managers we interviewed explained the kinds of uncertainty they face and the various ways that they deal with it.

VEHICLE LONGEVITY AND RESIDUAL VALUE

The plug-in hybrid version of the Toyota Prius, the first hybrid to enjoy mass adoption, was only rolled out to the US market in 2011. The first sales of Chevrolet's first PHEV, the Chevy Volt, occurred in February 2012. The first major BEVs in the consumer market (leaving aside several boutique and expensive predecessors) launched around the same time, like the Nissan Leaf in 2011 and the Tesla Model S in 2012.

Therefore, essentially all modern EVs are under 10 years old, which makes even the residual value of a used PHEV or BEV hard to gauge, because there are so few of them on the market. The first wave of electric vehicle retirements is only just beginning because many of the existing used EVs have not yet reached the point where fleet managers are confident that it would be better to retire and replace them than to continue maintaining them.

Leased vehicles are typically sold before they reach a high odometer reading—while they still have a reasonably high residual value. The fleet managers we interviewed who lease vehicles typically lease light-duty vehicles for around seven years, and larger trucks for around 10 years. Then they either buy the vehicles outright or sell them at auction.

Most fleet managers generally aim to replace a vehicle at around 60,000–70,000 miles or six years of age, in order to avoid expensive repairs and fetch a reasonably high residual value when the vehicles are auctioned off. Maximizing the residual value is a bit different with EVs than with conventional vehicles, in that there is a greater risk of technology obsolescence with an EV that is close to 10 years old. Therefore, fleet managers are careful not to let EVs get too old before reselling them.

However, some departments may keep vehicles for longer, like eight years or 80,000 miles, or 10 years or 100,000 miles. Vehicles like police cruisers that are used nearly 24 hours a day, 7 days a week, are replaced more often. Shipping and delivery fleets report keeping their walk-in vans for 12–15 years. Light-duty vans appear to be heavily used by several different kinds of fleets and are typically replaced after 5–8 years.

Even the basic maintenance costs of EVs are still difficult to know, because many of them have not yet reached old age and started to need major repairs. Data on the maintenance costs of EVs is meager compared with the equivalent data on ICE vehicles. And this data is essentially non-existent for vehicles of Class 3 and higher because there are so few of them on the road and they have seen very little use yet. This presents a novel problem for managers of large fleets, who are accustomed to being able to project costs and plan budgets five to seven years in advance, in accordance with the expected vehicle life. The fleet managers we interviewed generally did not have, or were unwilling to share, data on the savings they realize by switching to EVs from ICE vehicles. As we discuss below (see *Distributed Budgets Make Total Costs Unclear* on p. 56), the lack of data to demonstrate the savings from fleet electrification is often structural in these early days of the transition.

UNCERTAIN PERFORMANCE AND MANUFACTURER LONGEVITY

Fleet managers who are generally early adopters may be even more cautious about trying out new EV models than later adopters. This is because they have had the experience of trying out a new type of alternative fuel vehicle only to discover that it did not really perform as advertised and was not a suitable replacement for a conventional vehicle.

Fleets that adopted CNG vehicles because they were cleaner a decade ago, only to discover that many of the promised benefits of CNG and many of the promised CNG vehicle models did not materialize, are notably averse to this risk. This is particularly true for the ones who invested millions of dollars into a proprietary CNG refueling network. Fleet managers can be “once bitten, twice shy” as a result, making them less willing to adopt cutting-edge technologies.

This issue applies to the manufacturers themselves as well. Unlike the conventional ICE vehicle sector, in which manufacturers have consolidated down to a relatively small group over many decades through mergers and acquisitions, the EV sector has a relatively large number of manufacturers. These include companies that are still young, like Tesla and Workhorse; startups that have yet to ship their first units, like Rivian and Lordstown Motors; and established conventional automakers. Fleet managers are naturally more confident about buying new vehicles from the established big automakers, but some of the most cutting-edge innovations can often be found in the younger upstarts.

Fleet managers are thus faced with a conundrum: How can they accelerate their fleet electrification programs without taking undue technology risk? Fleet managers who were early adopters of EVs and other alt-fuel vehicles have already seen some manufacturers go out of business, leaving them stuck with trying to find parts and qualified repair technicians for their vehicles, which can quickly become more of a headache than it is worth. Some of them have vowed that they are unlikely to risk buying vehicles from startup manufacturers ever again.

Others will only buy EVs from manufacturers that can provide maintenance and parts locally. The lack of local service facilities (or even qualified service technicians) for EVs is a hurdle to adoption that several fleet managers emphasized—particularly the fleet managers who have had to pay for expensive towing of their previous CNG and early-edition EVs to a distant service facility.

Others, particularly the ones with the largest fleets, have adopted a “go-slow” approach in which they might buy a few units from a newer manufacturer in order to test out the technology. Or they might just wait a few more years for the more established manufacturers to come out with a similar vehicle, while they continue buying the bulk of their vehicles from the established manufacturers.

Large fleets are also more inclined to service their fleet vehicles in-house but have been frustrated by a lack of training offered by manufacturers for the fleet’s service technicians. Some manufacturers will not allow their customers’ technicians to even service the vehicles, instead requiring them to call the dealership or the manufacturer for support. If training for service technicians were available from manufacturers, we suspect that fleet managers would be more willing to adopt EVs more aggressively.

STRATEGIES FOR MANAGING UNCERTAINTY

One strategy that fleet managers use is to scale up purchasing of different models gradually by buying a few units of a new model and testing them under real-world circumstances for a year or two. They see how they perform and get feedback from drivers, before deciding whether they want to buy more.

Organizations that prefer to lease their fleet vehicles deal with uncertainty by turning over their EV fleets fairly rapidly, keeping the vehicles no more than a few years and then replacing them with a newer model. This strategy can be a way to take advantage of innovations in the newer models and falling sticker prices while limiting the technology risk of being an early adopter, albeit at a somewhat higher lifetime cost than buying the vehicles outright.

Even organizations that generally prefer to own their vehicles to the end of their useful lives report using this strategy for newer or untested vehicles. And they will probably continue to use it until a given model and manufacturer has been in production for several years and seems to have staying power. One major fleet manager referred to this risk as “infant mortality,” pointing to $80 million worth of failed “science projects” sitting at one of their locations because their startup manufacturers went out of businesses and could not support the vehicles, leaving the fleet manager unable to get parts.

Some organizations prefer to own their fleet vehicles and do not allow leasing, because they are more concerned with economics on a TCO basis. These fleets drive vehicles to the end of their useful lives and tend to take more of a wait-and-see approach. They slowly integrate new EV models into their fleets while seeing how long the vehicles actually last and what their latter-year maintenance costs are. This helps them obtain detailed information about EV performance that they currently lack, in sharp contrast with the information they have about their ICE vehicles. Fleet managers of larger fleets often have a fleet and fuel management system they can use to generate reports on the miles traveled, fuel and maintenance costs, and more for every vehicle in their fleet.

When leasing vehicles and then returning them after just a few years of use, it’s not really possible to gather this important data about their performance and cost of operation over the long term. Only full vehicle ownership can reveal that information in totality.

Telematics can provide valuable information about both BEVs and ICE vehicles that fleet managers can use to help manage uncertainty. Nearly all fleet managers we interviewed have either installed telematics on their fleet vehicles or plan to. Telematics data is critical to understanding the actual costs of operating fleet vehicles so that fleet managers can make an accurate comparison between an EV and an ICE vehicle for a given use case (for example, without telematics, it’s difficult for fleet managers to know how much electricity the vehicles are using).

However, instrumenting fleet vehicles with telematics and compiling telematics data into useful information is not a task that some smaller organizations can afford to do. For fleets that can afford to outfit their fleet vehicles with telematics and analyze the data, telematics is a more accurate and less expensive approach than using data taken from costly networked “smart” chargers.

Several fleet managers told us that a lack of analytics (informed by telematics data) makes it very difficult for them to compare the true cost of owning and operating a mix of vehicles, especially diesel, electric, and natural gas Class 8 trucks. Transit fleet managers who are evaluating BEVs for their fleets are beginning to operate a handful of BEV buses just to collect data on their performance, without actually displacing their conventional diesel buses. Alternately, some transit bus fleets are reconfiguring routes around the capabilities of the BEV buses, rather than trying to get BEV buses that can operate on exactly the same duty cycle as an ICE bus.

The lack of telematics data can likewise make it difficult for fleets to justify purchasing EVs, particularly if the fleet manager needs to produce a financial justification to obtain approval from another body. For example, if a state fleet manager can't produce data proving the actual operational costs of EVs and comparing them accurately with the ICE vehicles already in the state fleet, risk-averse legislators are unlikely to grant them the budget authority to buy EVs.

The State of California is a notable example in the use of telematics. It has a fleet of 50,000 vehicles worth a combined $2 billion and a goal to make half of the state's light-duty vehicles zero-emissions by 2025. The state realized that it needed much better data so that it could track its progress against the goal and ensure that its fleet vehicles were well-used in a cost-effective manner. In early 2020, the state awarded a single-source blanket purchase agreement to supply the state and participating local government agency fleets with a telematics platform from Geotab after a two-year RFP and evaluation process. The State of California is now beginning to deploy Geotab's solution across its entire fleet.

IMPACT OF COVID-19

As with everything else, the COVID-19 pandemic has affected the transportation electrification efforts of fleet managers. Demand for passenger vehicles has been lower for many fleets, as employees work from home and non-essential projects and tasks have been put on hold.

Bus fleets have been challenged by both low ridership and drivers' unwillingness to risk their health by returning to work, which has sharply reduced the revenues of transit agencies and made it more difficult for them to proceed with new electric bus purchases. Bus fleets that generated supplementary income from chartering their buses have seen that revenue all but disappear since the pandemic began.

EV procurement and the construction of new chargers also slowed, as organizations temporarily clamp down on spending and reassess future demand on their infrastructure under various COVID recovery scenarios. While budgets are restricted and charging infrastructure construction is on hold, it is unlikely that these organizations will continue procuring new EVs.

Conversely, organizations in the package delivery business have seen demand for their services increase, although the degree to which that has affected their electrification efforts is unclear.

WHO'S DRIVING DECISIONS?

The fleet managers we interviewed represent a variety of organizations and sectors with different vehicle needs, objectives, strategies, governance, and procurement methods. As a result of these differences, some organizations find it easier to plot a path forward than others.

Large organizations are likely to have different departments or agencies that have responsibility and authority over different aspects of their EV fleets. For example, one department might be responsible for understanding the strategic direction of the business and setting targets for both the size of the staff and the number and type of vehicles they might need. A procurement department might control the actual purchasing of vehicles but does not specify the type of vehicles that each user will get. A separate fleets group interfaces with the manufacturers and decides which vehicles will be purchased when, as well as when older vehicles will be replaced. A separate finance group controls the budget, and facilities or parking departments may have authority over locations where charging infrastructure must be installed. And the actual drivers of the vehicles all belong to still different business units or departments.

Cities and universities are an example of such a distributed set of decision makers. On the other hand, police departments and fire departments may manage their own fleets, while other municipal fleet vehicles are managed directly by the city. In such an environment, a city would have to deliberately seek to centralize policy decisions and distribute operational decisions in order to have a coherent and coordinated city-wide approach to EV procurement.

In other organizations, one department may have the decision-making authority to choose the vehicles it wants, without regard for procurement guidelines established by another department or by the organization's leadership. In such a situation, leadership support and accountability for fleet electrification may be necessary but not sufficient; it doesn't actually guarantee that the organization will preferentially choose EVs.

When decision-making is distributed across many different departments within an organization, it can be harder for the organization to understand the actual total cost of ownership of EVs and make sensible decisions accordingly. For example, vehicle costs (including purchasing, maintenance, and insurance) may be paid through one business unit, capital projects like charging infrastructure paid through another, and utility bills paid by a third business unit. Therefore, it can be very difficult for the organization to understand the actual cost of their EV fleet. (See *Distributed Budgets Make Total Costs Unclear* on p. 56 for more on this issue.) Most of the fleet managers we interviewed were aware of this issue but said that their organizations had yet to develop internal procedures to address it.

5 CHALLENGES AHEAD

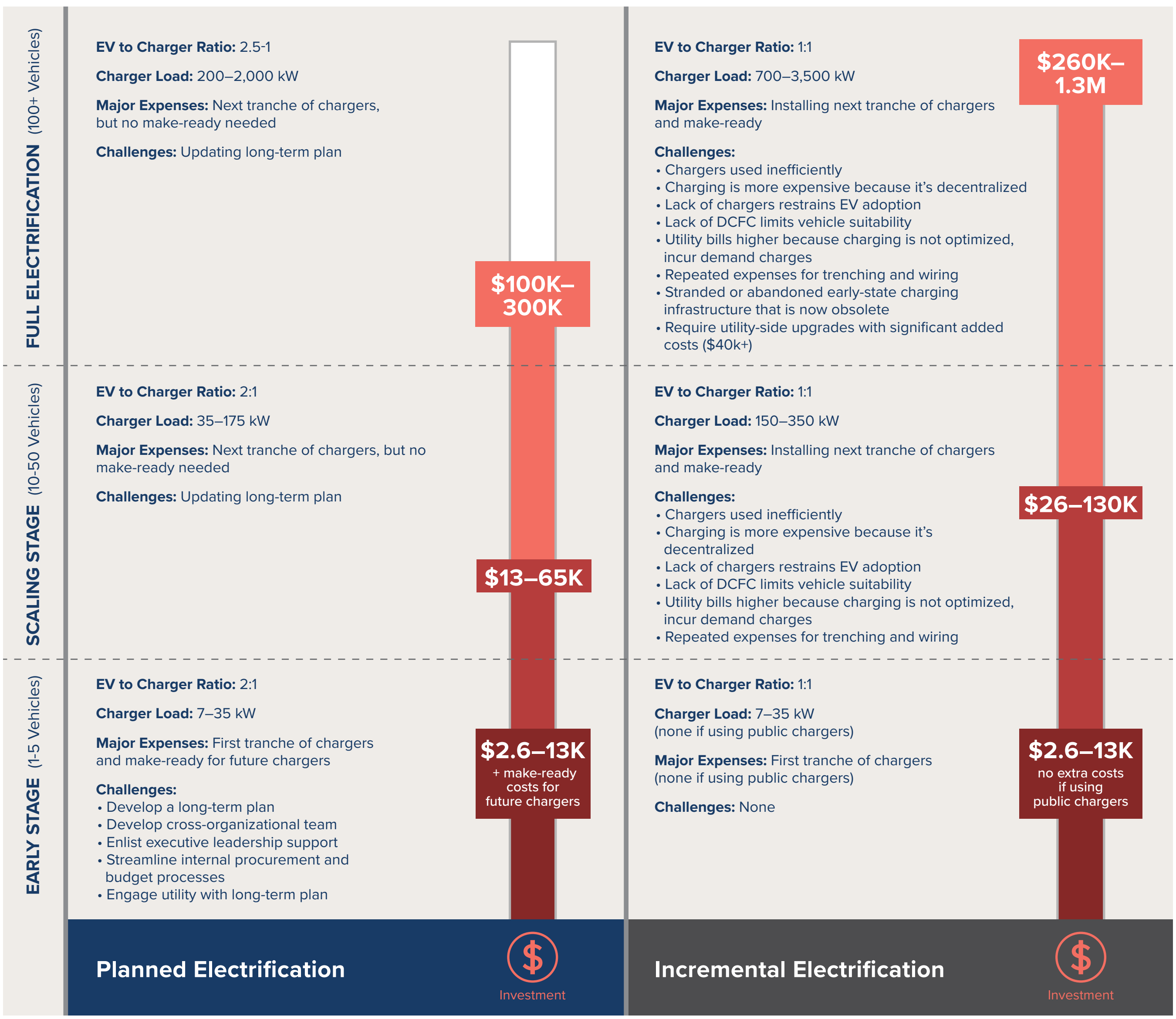
CHALLENGES AHEAD

Most organizations are still in the early days of electrifying their fleets and are just beginning to look beyond their initial pilot programs. So far, they have managed to get by using inexpensive Level 2 chargers and haven't had to do anything more ambitious than operate a handful of light-duty vehicles.

But as fleet managers move beyond pilots and into operating EVs at scale, the road ahead will get steeper. Operating many more vehicles that demand much higher rates of charge from more expensive chargers in far more complex installations is only the beginning of the challenges that fleet managers must begin to grapple with now.

EXHIBIT 8

Illustrative Example of Incremental Electrification versus Planned Electrification



THE BIGGEST CHALLENGE: CHARGING INFRASTRUCTURE

All of the fleet managers we interviewed who are well into their fleet electrification programs agreed that getting enough charging infrastructure is currently the biggest and hardest challenge they face. Their experience in buying and operating conventional vehicles is largely transferrable to a fleet of EVs. But charging infrastructure is an entirely new domain where they have very little useful experience—and where a great deal of the long-term costs are found. We emphasize this in Exhibit 8 where we illustrate the complexity of charging as fleets scale up their adoption of electric vehicles. In particular, we note two different pathways that result in markedly different costs when the fleet is fully electrified. One pathway is an incremental approach that is common today where fleets buy a few vehicles and chargers at a time. The other is an approach where the fleet develops and implements a long-term plan.

“Fleets have to build charging infrastructure earlier, faster, and sooner than you would think.”

The biggest risk in not deploying adequate charging infrastructure is that the lack of it will act as a cap on EV adoption. Ideally, the charging infrastructure should be deployed before purchasing EVs. Fleet managers may be excited about the impending possibility of buying electric F-150 trucks, but if there isn’t suitable charging infrastructure where the vehicles are housed, they won’t be able to buy them. As one fleet manager told us, “Fleets have to build charging infrastructure earlier, faster, and sooner than you would think.”

Right now, most fleet managers have more EVs in their fleets than they have chargers to serve them, and that gap is only getting wider. Part of the reason for this is that many organizational units have never had to budget for charging stations before. Unlike vehicle procurement, which has been a feature of organizational budgets forever, budgets for charging infrastructure are an entirely new line item, and a highly variable and opaque one at that. As fleets begin to deploy EVs at scale, they will also need to provide charging infrastructure at scale. And they should be thinking about that infrastructure with a view toward what they will need at least several years in advance.

Few organizations appear to be prepared to do that long-term planning, however. In the early days of fleet electrification, many organizations bought vehicles and Level 2 chargers for them in an ad-hoc way. But that approach won’t work for electrifying a majority of a fleet. What organizations need now is to start internal conversations around the operational impacts of a largely electric fleet, in order to build the early, enterprise-wide support of leadership and operational staff alike, and develop long-term plans for their charging infrastructure. This urgent task cannot be left up to fleet managers, who already have full-time jobs managing their vehicles. It’s an enterprise-wide challenge requiring an enterprise-wide response.

Currently, nearly all organizations have far more Level 2 chargers than they do DCFC, because they’re much cheaper to buy and install, and require far less grid power supply, which makes them cheaper to operate. But this is another example of how the road ahead is about to get steeper: Most organizations need to start building far more DCFC chargers, which are much more expensive to buy and install. While many organizations may simply hope that someone else will install the charging infrastructure that they will need for their fleets, it is imperative that fleet managers plan to provide for their own fleets.

Some organizations, especially universities, which often have their own on-site generation, may be prohibited from reselling power, either by state statute or regulation, or by the organization’s own rules. This can be a hindrance where employees, visitors, or other non-fleet users need access to a

charging station on the host organization's premises. If the organization is unable to charge a fee for using its chargers and is unwilling to shoulder the cost of providing that service, these organizations may have no other options but to contract with a third-party charging service provider, integrate the cost of charging into a parking fee, or find some other way to work around this complication. Contracting with a third-party service provider is probably the most desirable approach in that it could work for a wide variety of chargers and power levels and use cases, but it can also be the most administratively complex and slowest approach to implement.

UTILITY ENGAGEMENT IS CRITICAL

Planning for charging infrastructure is not just a matter of determining what an organization needs to provide for itself, however. Fleets must also engage with their local utilities to ensure that they can provide the power that the fleet's chargers will need, when they need it. Utility resource planning is typically a slow process, in which a typical integrated resource plan might take 18–24 months to be reviewed and approved to proceed.

If the host utility is expected to provide significant new capacity to a facility—such as megawatts of new service capacity—a fleet customer should begin discussions with the utility at least three years before they expect to actually need the power. Most fleets have not yet begun to think about the utility support they'll need given such long lead times. Neither have many host utilities, which likewise should be embarking on outreach programs to help them understand the power requirements of their large fleet customers.

In fact, the largest and most sophisticated fleets now find themselves pushing their host utilities to plan for the power they will need, to offer tariffs appropriate to their use cases, and to develop strategies for co-investment in the distribution grid capacity that will be needed. The most advanced fleet manager we interviewed said that their pace of electrification would be faster if not for the bottlenecks they face in the speed of building new charging infrastructure. They also need utilities to provide them with sufficient grid power capacity at their facilities, calling the existing grid at those locations "antiquated."

All too often, we heard similar accounts of utilities not actively seeking the opportunity to support charging infrastructure. One fleet manager said that when their organization's sustainability program reached out to their local utility about provisioning power to their parking lots, they encountered a distinct unwillingness among the utility staff to wade into a complex new business area. "Most are hoping they'll retire before they have to figure that out, and let the next generation figure it out," they said.

MUCH MORE FAST CHARGING IS NEEDED

Most prospective EV drivers think about EV charging by analogy to pumping a liquid fuel into a conventional vehicle. This isn't really the right way to think about it; charging should be done while the driver is doing something like shopping or working, instead of as an errand and a destination unto itself like a visit to a gas station. But some use cases where vehicles do not have at least six hours a day where they can be parked and connected to a charger do require fast charging, more akin to refueling at a gas station. Overcoming the uncertainty about the availability of fast charging is an important hurdle in getting drivers to adopt their first EVs.

Anecdotal evidence indicates that a prospective EV buyer may overestimate their need for fast charging before they buy their first EV, and only later discover that they have many other options for recharging and really don't use public DCFC that often. However, the availability and visibility of DCFC are very important in making drivers comfortable with adopting their first EVs. That is as true for fleet vehicle drivers as it is for members of the general public. Many more public DCFC—especially highly visible ones—will be needed before most drivers feel comfortable with adopting EVs.

The ability to get a sufficient charge to continue their journey in 20 minutes on a DCFC, instead of waiting 8 hours or more to charge on a Level 2 charger, makes an enormous psychological difference to drivers, regardless of how much they use each type of charger in practice. Fleets that use public DCFC contribute to the demand for them, which helps create a positive feedback loop encouraging public DCFC network providers to build more charging stations.

The availability of high-powered DCFC also has important "network effects" in making it possible to complete longer journeys with acceptable rest periods for charging. For example, the in-house service technicians for large fleets need to travel regularly beyond the range of a single charge. If there are enough DCFC along the routes that the technicians drive, they can adopt EVs, but if there aren't, they can't. The same is true for utility first responders. Waiting for a vehicle to recharge at Level 2 rates is simply untenable for their use case.

Looking farther into the future, DCFC power demands can be expected to increase. The typical speed of a new public DCFC has already increased in recent years from 50 kW to 150 kW. Some public chargers can already support 350 kW rates of charge, although very few light-duty vehicles can. BEV transit buses that can be charged overnight at a depot often use 60–80 kW chargers today, but en-route charging can require much more power, such as 250 kW for inductive wireless chargers and as much as 500 kW for Pantograph chargers. En-route chargers also need to be located at bus stops, where it is much more expensive and complex to provide the power than at a bus barn or depot.

Truck stops and fleet yards that serve Class 8 semi-tractors can expect to need enough power supply for "ultra-fast" chargers of 1.7 MW or more per charger. For a depot or fleet yard that needs to recharge many such vehicles at once, the power requirements could be very substantial—measured in the tens of megawatts. Provisioning power at that scale takes significant planning by both the utility and the fleet operator and could take several years to accomplish. Fleet operators who expect to need to serve loads of that magnitude should begin their planning efforts and engage with their local utilities now, well before production vehicles become available for purchase.

CHARGING INFRASTRUCTURE COSTS ARE UNANTICIPATED

Apart from the largest package delivery service we interviewed, which has begun serious capital project planning for its requisite infrastructure, all of the fleet managers acknowledged that they are still in the early stages of deploying charging infrastructure. Some of them have not begun deploying any chargers at all and are simply using existing public chargers or Level 1 charging (in which the vehicle is plugged directly into a standard outlet, without the use of a charger). Others have been getting by with a pilot installation of a few chargers that were either donated or bundled with a larger purchase (like a Level 2 charger included with the purchase of a new EV). Still others have deployed only as many Level 2 chargers as were needed to support a pilot purchase of EVs, without considering what the long-term requirements may be for a fully electrified fleet.

The costs of building and operating DCFC can be substantial, and organizations must plan to ensure costs are minimized and the benefits and savings of EVs are realized. For example, the full cost of a single installation of two 150 kW public DCFC can be $500,000, or considerably more. The cost of charging infrastructure for a large fleet depot or bus barn can run into the tens of millions of dollars. For example, one transit bus fleet manager told us that in order to fully electrify their bus fleet, they estimate they would need 17 MW of power at their bus depot. This would cost an estimated $20–$30 million, including charging stations, distribution system transformers, and switchgear on the premises.

Where high-speed DCFC chargers will be required, such as for fleets of transit buses and medium- and heavy-duty vehicles, most of the organizations were still unaware of some of the major challenges that they will soon encounter. These include the very high cost of buying and installing the charger hardware, and the impact of demand charges on utility bills. (Our previous reports, such as *Reducing EV Charging Infrastructure Costs*,[15] *EVgo Fleet and Tariff Analysis*,[16] and *DCFC Rate Design Study*,[17] explore these issues in depth.) Only one large fleet operator we interviewed had taken action to mitigate the cost of demand charges by using microgrid and battery storage units preconfigured in the size of a shipping container, that are able to deliver 1 MW of power. This allows the facility to keep its demand on the utility grid relatively flat while delivering its maximum power level to the chargers 24 hours a day.

Perhaps understandably, no fleet managers we interviewed had a complete understanding of what will be required to charge their fleets when fully (or even mostly) electrified. We also did not find any organizations with well-defined plans to determine those requirements and begin appropriate capital planning to procure and install the requisite chargers. For example, a fleet manager who manages a mid-sized city fleet said that he believed the city would need about $15 million in charging infrastructure to support its burgeoning fleet of EVs. He noted that the city leadership was very supportive of transportation electrification but had not done any capital planning for an expense of that magnitude.

Perhaps most worrying is the lack of engagement that many organizations have had with their local utilities. They do not yet understand that a large vehicle yard or depot may have power requirements measured not in kilowatts but in megawatts—even for fleets that can largely rely on lower-powered Level 2 chargers. Therefore, they have not yet realized that providing that level of power might be a non-trivial exercise for their host utility and could take a year or more to provision.

Equally, most utilities are only beginning to develop outreach strategies that will allow them to begin appropriate system planning to meet the power demands of their fleet customers. There is a significant and worrisome gap between fleets and utilities that must be addressed. This gap could be particularly difficult to close if, for example, fleet vehicles are being procured by one department in an organization and building charging infrastructure is being handled by another.

We strongly suspect that many fleet managers are in for some unpleasant shocks when they receive the first utility bills for their first set of DCFC, particularly for the organizations that might expect to deploy hundreds or thousands of DCFC across their operations. Accordingly, we believe it is absolutely vital for organizations of all kinds to get up to speed on these issues now. It is not too early to start making serious plans for how they are going to finance and build charging infrastructure, pay their utility bills, and try to reduce their long-term charging infrastructure costs by doing long-range planning. In this domain, mistakes can be very expensive ("Nobody told us that we needed to build a $1 million substation!") and long-range planning can help avoid duplicative and unnecessary costs.

Fleet managers that have not yet planned out how, where, and when their vehicles will be charged when a large share of the fleet is electric, may have unrealistic expectations about being able to use public chargers opportunistically instead of building dedicated chargers for their own fleets. They may also have unrealistic expectations for being able to meet their fleet's charging needs with under-powered Level 2 chargers. In order to avoid discovering too late that their charging infrastructure is not up to the task of recharging vehicles that have already been procured, it's essential that fleet managers undertake a serious planning exercise for how charging will be operationalized. They must analyze when and where every single vehicle will be recharged in keeping with its expected duty cycle.

DISTRIBUTED BUDGETS MAKE TOTAL COSTS UNCLEAR

As we discussed above (*Who's Driving Decisions?*), organizations where different cost components of running an EV fleet are distributed across several business units or budgets will be particularly challenged to understand their actual total costs. For example, if one budget pays for EVs while another pays for the charging stations that serve them, it can be difficult for organizations to understand the actual costs of electrification, and challenging for them to procure adequate chargers for the EVs they're buying. These organizations will need to implement new business procedures to distinguish, aggregate, and accurately report the costs of running an EV fleet.

Finance departments may account for short-term capital expenses separately from operating expenses, making it difficult to understand the TCO of EVs versus ICE vehicles. This is particularly true where vehicles are purchased through one department's capital budget for vehicles, while maintenance and charging operating costs are paid through a different budget. Such organizations will have to make a deliberate effort to stitch together a coherent picture from those various costs—particularly if some costs, like the electricity consumed by EV chargers, are not separated from other costs, like all other appliances behind an organization's utility meter.

This may be particularly an issue for smaller organizations that do not have a robust staff of managers able to devote time and effort to careful cost controls. Such fleets will be more likely to buy ICE vehicles as a short-term fix to their immediate problem of replacing worn-out vehicles if they're cheaper on a sticker price basis, even if they suspect that EVs might be cheaper on a TCO basis. Only when the actual ROI of all vehicles on a TCO basis is clearly visible to management, and the reliability of EVs has been demonstrated, can this kind of short-term thinking be overcome, and the true value of fleet electrification be understood.

There is also a significant risk that charging costs will not be visible to management where, for example, utility bills are paid through a general overhead account instead of being charged back to the driver or the driver's department as a fuel cost. The cost of recharging fleets may come as an unexpected surprise to management, and lead to a backlash against fleet electrification efforts and a delay in EV adoption precisely when meeting emissions targets will demand an acceleration in those efforts. Indeed, such an accounting system can have some unintended consequences. For example, simply electrifying a fleet could shift refueling costs that used to be paid directly by departments that used the vehicles to a separate budget that pays the utility bills for the entire organization.

To avoid such an unfortunate eventuality, it's essential to begin implementing processes for appropriate cost allocation and capital planning on an organization-wide basis immediately. A cross-functional team of staff from fleets, operations, facilities, finance, and purchasing departments with executive leadership support should collaborate to understand the TCO of fleet electrification accurately. This need to overhaul the internal accounting for EVs and charging infrastructure cropped up in many of our interviews with fleet managers.

Procuring vehicles and chargers as a package deal can be one way to gain an integrated view of the capital costs. However, it does not give visibility into the operational costs of charging and other ongoing operational fleet expenses. Few vehicle manufacturers offer such package deals for light-duty vehicles, because other than Tesla, vehicle manufacturers do not sell charging infrastructure hardware or charging management systems.

OPERATIONALIZING CHARGING WILL BE CHALLENGING

With so few EVs and chargers in their current fleets, most fleet managers have not yet had to grapple with the challenges of operationalizing charging across their fleets. Our experience in working with utilities and fleet managers has made it clear that this is a non-trivial issue, and that managing the charging of vehicles such that it does not interrupt their duty cycles takes concerted effort.

Managing charging can also have a large effect on the bottom line. Done well, it can reduce the cost of charging. Done poorly or without planning, it can quickly increase those costs. Understanding how and when to charge vehicles, particularly in light of the specific utility rate structure under which the chargers will be billed, can be a complex task requiring specialized expertise that many organizations currently lack.

Demand charges (an element of some commercial utility rate structures) can be particularly punishing for fleets that require DCFC—so much so that they can cause an electrified fleet, such as a transit bus fleet, to cost more money to operate than a conventional diesel fleet. While only a few fleet managers have developed expertise about how to work with their local utility's rate structure in order to control these costs, more fleet managers must make engaging with their local utility and developing this knowledge a top priority. For more information on managing charging and the cost impact of demand charges, see our reports *EVgo Fleet and Tariff Analysis* and *DCFC Rate Design Study* listed in *Appendix D: RMI Reports on Vehicle-Grid Integration.*

BACKUP POWER REQUIREMENTS ARE UNKNOWN

Only one or two of the fleet managers we interviewed said that their organizations are thinking about how they will provide backup power for their BEVs in the event of a grid power outage. For critical applications, like transit buses, fire and safety vehicles, and refuse trucks, the risk of not being able to run the vehicles is simply unacceptable. Resiliency, writ large, is also an increasing focus for many organizations as they think about how to prepare for grid power disruptions and other hazards associated with wildfires, earthquakes, and major storms.

Organizations must begin thinking through the backup power requirements that their fleet vehicles will have. For medium- and heavy-duty fleet vehicles, especially when hundreds of them are housed at a single location, the backup power requirements could be very substantial, and installing the requisite capacity will be a complex challenge.

A particularly challenging case will be bus barns for transit bus fleets: At 400 kWh per bus per day, a bus barn that recharges 250 buses would dispense 100 MWh (100,000 kWh) each day. Providing that amount of backup power can be expensive and needs to be part of an integrated design. Other strategies, like keeping a backup fleet of semi-retired diesel buses operational for the next few years, may be wiser. Only a thoughtful, informed, and comprehensive analysis of the various options could answer such a question.

One fleet manager of a major package delivery service suggested that they could scale up the electrification of their fleet more quickly if they had a better way to facilitate the backup power requirements. They estimated that $35–$40 million in new investment will be needed outside of their buildings, plus another $50 million inside the buildings. We are not aware of any utility programs that are aimed at addressing a need of this kind and magnitude in the United States. From the perspective of this fleet manager, the key elements they need to see in order to deploy EVs in a given location include utility support, local and state regulatory support for building charging infrastructure, and a local supply chain within the city for maintenance and support.

One manager of a city fleet compared the challenge of providing backup power to the first band practice of a seventh-grade band—it doesn't sound too good and needs a lot of work. A "transformative conversation" has to take place, he said, involving personnel who work in real estate, planning, the local utility, city government staff, and more. None of the cities we interviewed appeared to be organizing themselves to tackle these challenges yet. The fleet manager we interviewed suggested starting with a plan identifying the charging and backup power requirements.
The next steps are to identify any new permitting requirements and codes that need to be implemented in order to clear a path for deploying more charging infrastructure, and then to explore how to retrofit existing facilities with the requisite grid power and backup power capacity.

OPTIONS FOR POWERING CHARGERS ARE POORLY UNDERSTOOD

Large organizations with large fleets may want to explore several ways of optimizing their EV fleet costs. For example: Is it better to deploy some on-site solar and battery systems to supplement utility power and mitigate demand charges? Or is it better to optimize the use of Level 2 chargers, limit the need for DCFC, and just pay the electric bill? What would the ROI of either option be? Can portable “solar carport” units not connected to the grid provide the level of charging capacity that a fleet needs? And what is the best investment from a TCO standpoint?

Another complication for organizations like a major shipping company is that it might lease a building for 10 years, but the solar and charging infrastructure that it would like to deploy at the building might have an expected service life of 15 years or more, and it’s difficult to move those systems to a new location once they are installed.

Only the largest fleets we interviewed have performed this kind of sophisticated analysis. However, it is the kind of analysis that organizations running major fleets will have to undertake if they want to capture the cost benefits of fleet electrification. It will help them avoid their EV fleet costing them more money than their conventional ICE fleet did, simply because they had inadequate visibility on costs and insufficient cost controls in place. This can also happen if they lack the expertise to understand how to control costs or can’t find a good match between the lifespan of equipment and the lease of the building where it is installed. This is an area where utilities could be helpful, by offering to buy out installed solar equipment, offering charging infrastructure as a service, or providing some other creative financing arrangement.

ELECTRIFICATION MAY MEAN CULTURE CHANGE

The willingness to adopt an EV over an ICE vehicle may depend as much on the culture of an organization or department as it does on the costs and capabilities of the vehicles themselves. One way to overcome cultural resistance to electrification is to highlight the real-world experience of EV users and deliberately foster inter-agency cooperation. This gives non-users a chance to hear a positive testimonial from someone they respect or someone who is a peer.

Organizing cooperative dialogue between fleet industry organizations like NAFA and their local chapters; local cities, counties, and school districts; and state and federal agencies, so that they can share their real-world experience can be enormously helpful. Utilities and EV advocacy organizations can encourage and support such dialogue as ways of encouraging EV adoption in their communities. Accompanied by reporting adoption rates and other measures across various departments and organizations, these dialogues can be a way of motivating more cooperation through peer pressure; no one wants to look like a laggard in adopting EVs.

EV LITERACY NEEDS IMPROVEMENT

EVs are still a fairly new technology, and drivers and fleet managers still have much to learn to acquire full literacy in the sector. We found very few fleet managers who were truly conversant on the battery capacity of vehicles, the energy per mile they require, the recharging rate of vehicles, the power ratings of charging stations, and the components of charging infrastructure. In addition, very few were knowledgeable about the structure of utility tariffs and the cost of various tariff components, the grid power requirements of a given charging station or depot, and charging management techniques. This is certainly understandable, given the newness of the vehicles and charging systems. However, most fleet managers are able to calculate how many gallons of gasoline a work truck might need in a day and the fleet's fuel economy—"fueling" knowledge that is crucial to fleet management.

It may be possible to go along without that knowledge in the early days of fleet electrification, when the fleet has only a few EVs that are being used for non-critical tasks. But as EVs begin to make up larger shares of the fleet, that knowledge will be critical. To avoid having to learn about this new domain via painful experience, fleet managers and all organizational staff associated with fleet operations should educate themselves on these topics.

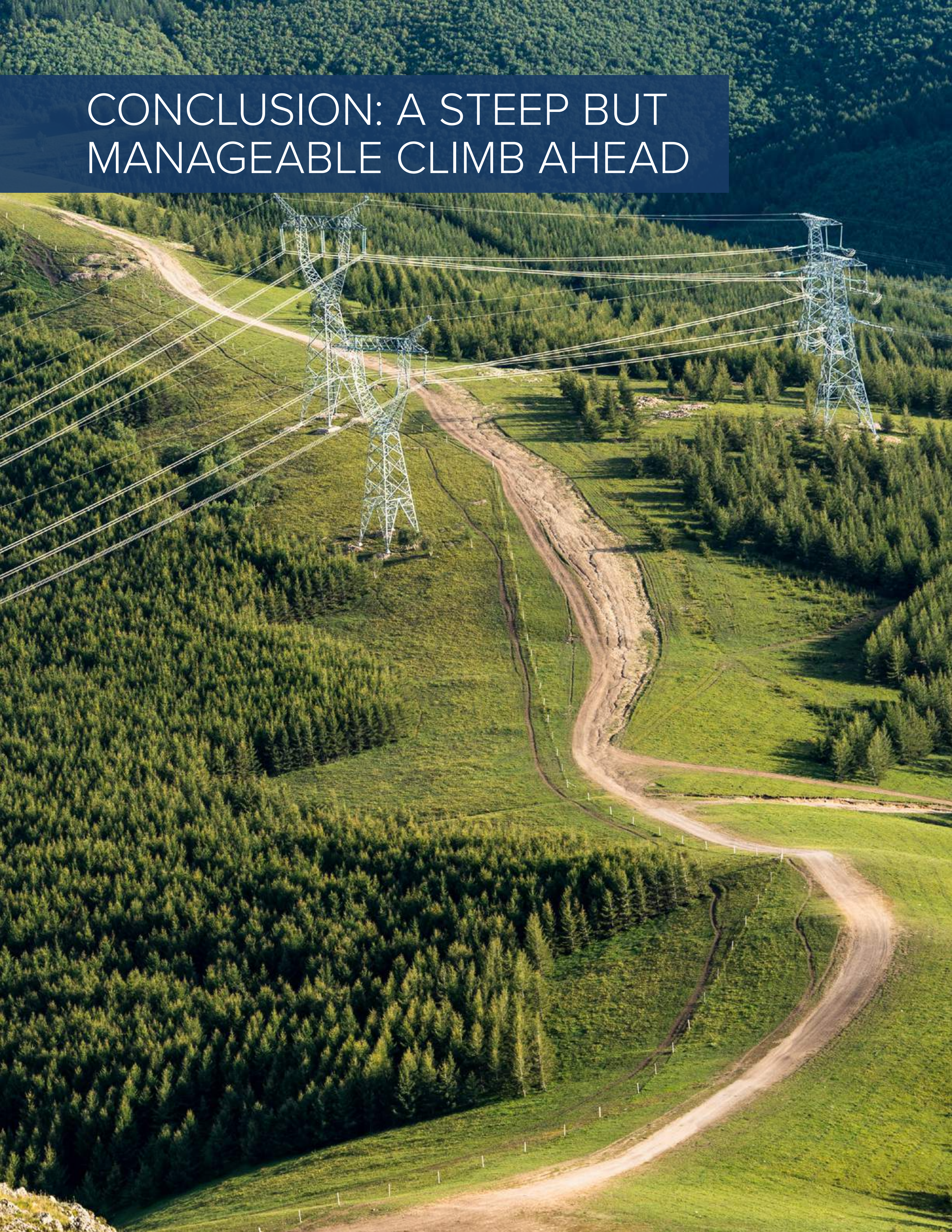
Alternatively, some organizations, particularly ones that do not expect to develop deep expertise in EV fleet management and vehicle-grid integration, may prefer to source the entire operation from a single vendor that can provide vehicles, chargers, charging management and monitoring software, telematics, and operational expertise as a turnkey solution. However, few vendors can provide the full suite of such services, and risk-averse fleet operators, like utilities, may not be interested in startup partnerships that attempt to mimic a one-stop shop. Before counting on this strategy, organizations should carefully evaluate the providers in the sector.

WHAT ABOUT HYDROGEN FUEL CELL ELECTRIC VEHICLES?

Many of the fleet managers we interviewed expressed a keen interest in next-generation battery-electric large trucks that need to be able to travel 200 miles or more—particularly ones used in utility service fleets. But the general view seems to be that they are about a decade in the future, and until they are available, fuel cell electric vehicles (FCEVs) are expected to be a better alternative. If FCEVs become available in the medium-term that can run 200 miles on a tank of fuel and provide exportable power without the need for an inverter, managers of heavy-duty fleets are likely to adopt them.

One manager of a very large delivery fleet told us that they didn't expect to use hydrogen vehicles except where they are mandated or where the duty cycle requires it, because of the space requirements and cost of refueling. In their view, BEVs should be able to serve all of their fleet's needs, for all vehicle classes.

CONCLUSION: A STEEP BUT MANAGEABLE CLIMB AHEAD



CONCLUSION: A STEEP BUT MANAGEABLE CLIMB AHEAD

Fleet managers today are just beginning to move beyond pilot programs in electrifying their fleets. At pilot scale, when a fleet is testing a handful of vehicles, electrification is pretty simple: Buy a vehicle, buy an inexpensive Level 2 charger, and you're done. But as fleet managers start electrifying a large share of their fleet vehicles, including vehicles that need to be charged at high speeds on DCFC, they will discover a much more difficult set of challenges.

In fact, we note that the factors that fleet managers surveyed as currently less important (Exhibit 5 on page 15) will take on increasing importance as fleet electrification scales. These include the cost and complexity of charging and associated infrastructure, and streamlining legacy internal processes that were designed for ICE vehicle operations. Fleet managers can get ahead of these challenges by asking the right questions and taking the right actions at each stage of their decision-making process. Exhibit 9 depicts a simplified version of the fleet electrification decision-making process and our recommendations for the critical actions fleets should take at each step to ease their transition to an electric fleet.

Done right, fleet electrification is a fundamental business restructuring challenge for entire organizations. Done badly, it can be a series of very costly errors. We urge fleet managers and their organizations to begin the work of planning for a successful electrification strategy now, in order to reap the rewards later: a reduced carbon footprint, more efficient energy use, and reduced costs.

EXHIBIT 9

Installation of Your First Chargers

Preparing for Electrification

- Establish a transparent budgeting process to track all EV costs over the vehicle lifetime, in order to ascertain total cost of ownership savings.
- Engage utility to understand how to optimize charging around the time-of-use rates and avoid demand charges.
- Consider charging management solutions including charging as a service.

Planning to Electrify Fleet Vehicles

- Conduct a feasibility study to understand which vehicles are economic to electrify, and when, based on use case.
- Establish cross-organizational team with executive support.
- Develop a long-term fleet electrification plan, based on the feasibility study, with input from full organization.
- Obtain training for all staff who need to learn about EVs and charging.
- Engage your utility about your long-term goals, and explore how to optimize charging around utility tariffs to minimize costs.

Procuring Charging Equipment

- Based on your long-term plan, identify when vehicles will charge, how many and what types of chargers will be required.
- Engage with utility to understand site grid capacity limits and any utility upgrades required. Inquire about make-ready support they may offer.
- During installation of your first chargers, futureproof by doing trenching and wiring required for future charging infrastructure.

Procuring Electric Vehicles

- Identify EVs that meet use case needs, including range and all functional requirements.
- Develop a five-year outlook for new EV models that will become suitable.
- Streamline procurement processes that may be barriers for EV adoption.
- Engage with dealers and manufacturers, especially if required to buy from an approved buy list.
- Identify rebates and grants available for vehicle purchase.

APPENDICES

Appendix A: Vehicle Weight Classes and Categories

Gross Vehicle Weight Rating (lbs.)	Federal Highway Administration		US Census Bereau
	Vehicle Class	GVWR Catagory	VIUS Classes
<6,000	Class 1: <6,000 lbs.	Light-Duty <10,000 lbs.	Light-Duty <10,000 lbs.
10,000	Class 2: 6,001–10,000 lbs.		
14,000	Class 3: 10,001–14,000 lbs.	Medium-Duty 10,001–26,000 lbs.	Medium-Duty 10,001–19,500 lbs.
16,000	Class 4: 14,001–16,000 lbs.		
19,500	Class 5: 16,001–19,500 lbs.		
26,000	Class 6: 19,501–26,000 lbs.		Light Heavy-Duty 19,001–26,000 lbs.
33,000	Class 7: 26,001–33,000 lbs.	Heavy-Duty <26,001 lbs.	Heavy-Duty <26,001 lbs.
>33,000	Class 8: >33,001 lbs.		

Gross Vehicle Weight Rating (lbs.)	EPA Emissions Classification			
	Heavy-Duty Vehicle and Engines			Light-Duty Vehicles
	H.D. Trucks	H.D. Engines	General Trucks	Passenger Vehicles
<6,000	Light-Duty Truck 1 & 2 <6,000 lbs.	Light Light-Duty Trucks <6,000 lbs.	Light-Duty Trucks <8,500 lbs.	Light-Duty Vehicle <8,500 lbs.
8,500	Light-Duty Truck 3 & 4 6,001–8,500 lbs.	Heavy Light-Duty Trucks 6,001–8,500 lbs.		
10,000	Heavy-Duty Vehicle 2b 8,501–10,000 lbs.	Light Heavy-Duty Engines 8,501–19,500 lbs.	Heavy-Duty Vehicle Heavy-Duty Engine >8,500 lbs.	Medium-Duty Passenger Vehicle 8,501–10,000 lbs.
14,000	Heavy-Duty Vehicle 3 10,001–14,000 lbs.			
16,000	Heavy-Duty Vehicle 4 14,001–16,000 lbs.			
19,500	Heavy-Duty Vehicle 5 16,001–19,500 lbs.			
26,000	Heavy-Duty Vehicle 6 19,501–26,000 lbs.	Medium Heavy-Duty Engines 19,501–33,000 lbs.		
33,000	Heavy-Duty Vehicle 7 26,001–33,000 lbs.			
60,000	Heavy-Duty Vehicle 8a 33,001–60,000 lbs.	Heavy Heavy-Duty Engines Urban Bus >33,000		
>60,000	Heavy-Duty Vehicle 8b >60,001			

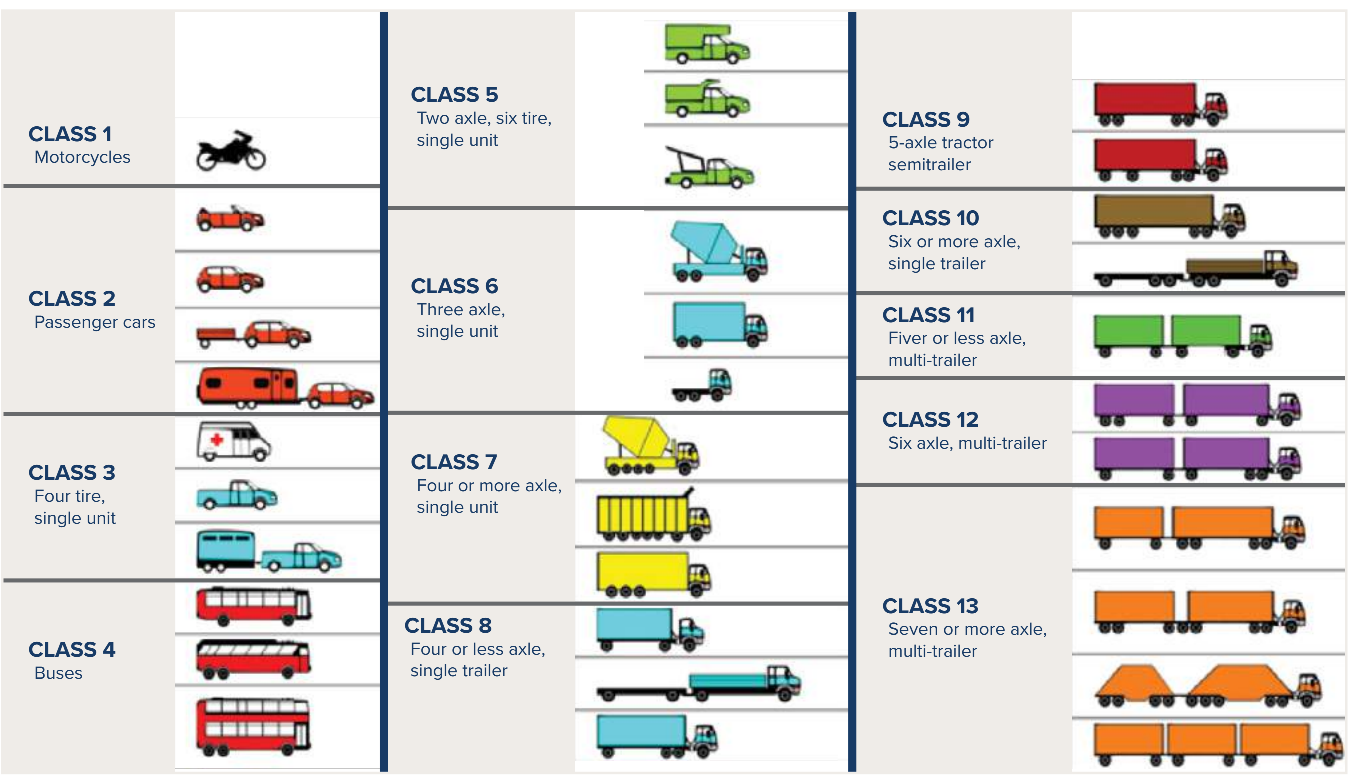
Source: US Department of Energy Alternative Fuels Data Center. **https://afdc.energy.gov/data/10380**

Appendix A: Vehicle Weight Classes and Categories

These charts illustrate the vehicle weight classes and categories used by the Federal Highway Administration (FHWA), the US Census Bureau, and the US Environmental Protection Agency (EPA). The vehicle weight classes are defined by FHWA and are used consistently throughout the industry.

These classes, 1-8, are based on gross vehicle weight rating (GVWR), the maximum weight of the vehicle, as specified by the manufacturer. GVWR includes total vehicle weight plus fluids, passengers, and cargo. FHWA categorizes vehicles as light duty (Class 1–2), medium duty (Class 3–6), and heavy duty (Class 7–8). EPA defines vehicle categories, also by GVWR, for the purposes of emissions and fuel economy certification. EPA classifies vehicles as light duty (GVWR < 8,500 lb.) or heavy duty (GVWR > 8,501 lb.). Within the heavy-duty class, there is a medium-heavy-duty diesel engine class for engine-only certification, but no medium-duty vehicle class.

The September 2011 US Department of Transportation (DOT)/EPA rulemaking on Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles uses categories and weights for heavy-duty vehicle classes 2b through 8, similar to the FHWA weight classes.



Source: Federal Highway Administration [18]

Appendix B: Glossary

Abbreviation	Full Name	Meaning
CNG	compressed natural gas	A type of vehicle that uses compressed natural gas as a fuel instead of a liquid fuel.
kW	Kilowatt	A measure of power, equivalent to 1,000 Watts
kWh	Kilowatt-hour	A measure of energy, equivalent to one kilowatt delivered for one hour
MW	megawatt	A measure of power, equivalent to 1,000 kilowatts
MWh	megawatt-hour	A measure of energy, equivalent to one megawatt delivered for one hour
TCO	total cost of ownership	The full cost of owning a vehicle, including initial purchase price, lifetime fuel (including electricity) costs, insurance, maintenance, and licensing.
W	watt	A measure of power equal to one joule per second. Volts times amps equals watts.

Appendix C: Types of Chargers

Abbreviation	Type	Voltage	Max Capacity (kW)
L1	Level 1	120	1.2 kW of AC power, delivered from a standard 30 A, 120 V outlet. No charger is needed for Level 1.
L2	Level 2	240	A charger that delivers up to 19.2 kW of AC power to a vehicle. They come in various sizes, but a typical Level 2 unit dispenses about 7 kW (6.6–7.2 kW) from a 30 A, 240 V circuit.
DCFC	DC fast charger (AKA “Level 3”)	480	A charger that typically delivers 25 kW or more of DC power to a vehicle. Most DCFC deployed in the 2010s were 50 kW units. Most DCFC deployed for public charging today deliver up to 150 kW. Bus chargers are often rated at 60 kW. High-powered DCFC used for fast-charging medium- and heavy-duty vehicles can deliver 350–500 kW. “Ultra-fast” DCFC, which are not yet a commercial reality, could deliver over 1,000 kW (1 MW) of power.

Appendix D: RMI Reports on Vehicle-Grid Integration

Fleet managers who are looking for more guidance on charging infrastructure planning and on the capital and operational costs of charging infrastructure are encouraged to explore these previous reports from RMI's Mobility practice.

Chris Nelder and Emily Rogers, **Reducing EV Charging Infrastructure Costs**, Rocky Mountain Institute, January 2020.

Garrett Fitzgerald and Chris Nelder, **DCFC Rate Design Study**, Rocky Mountain Institute, September 2019.

Lynn Daniels and Brendan O'Donnell, **Seattle City Light: Transportation Electrification Strategy Report**, Rocky Mountain Institute, August 2019.

Garrett Fitzgerald and Chris Nelder, **From Gas to Grid: Building Charging Infrastructure to Power Electric Vehicle Demand**, Rocky Mountain Institute, October 2017.

Garrett Fitzgerald and Chris Nelder, **EVgo Fleet and Tariff Analysis**, Rocky Mountain Institute, March 2017.

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