POWER RESILIENCY FOR ELECTRIC FLEETS

A practical guide for addressing resiliency in transitioning fleets

James Di Filippo & Daniel Wilkins

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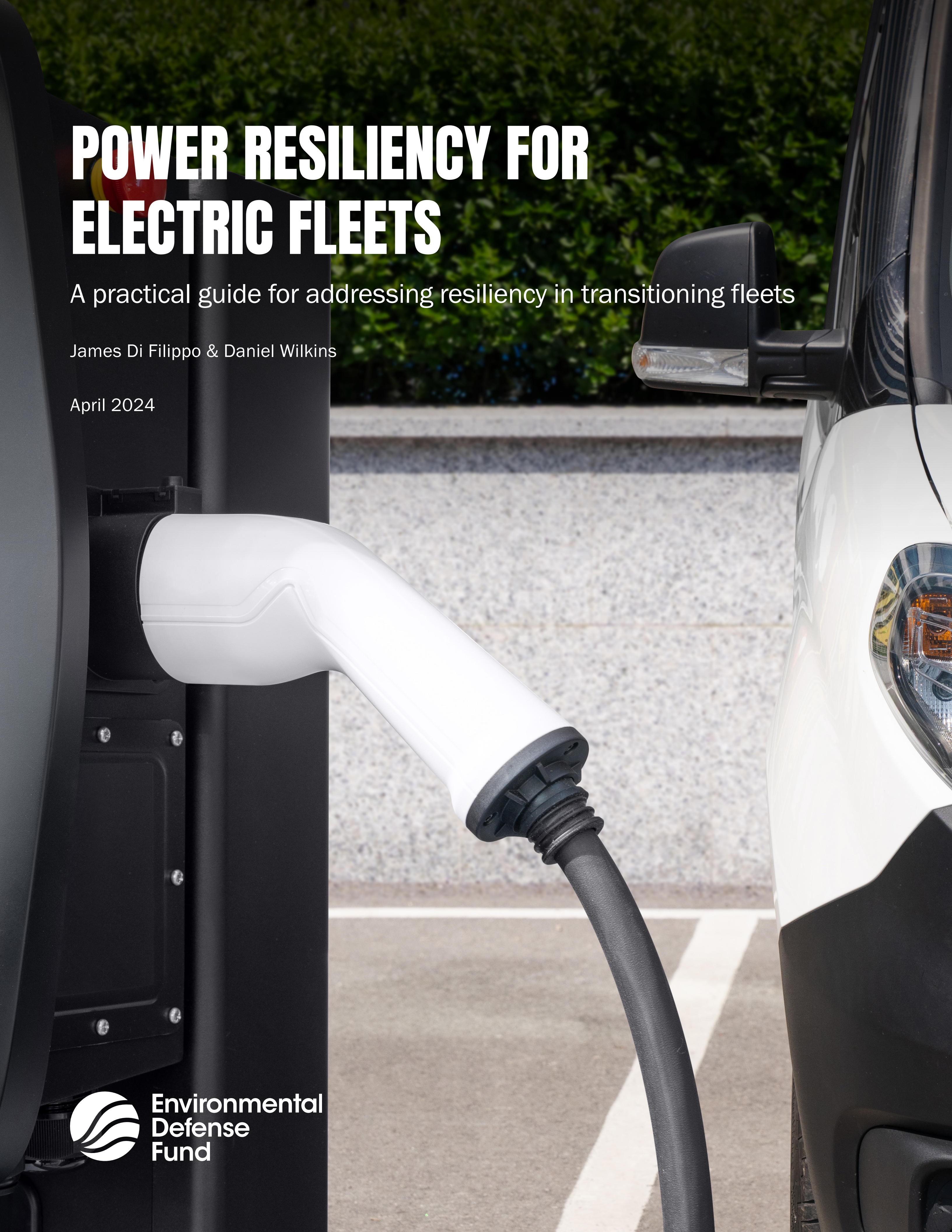

Environmental Defense Fund

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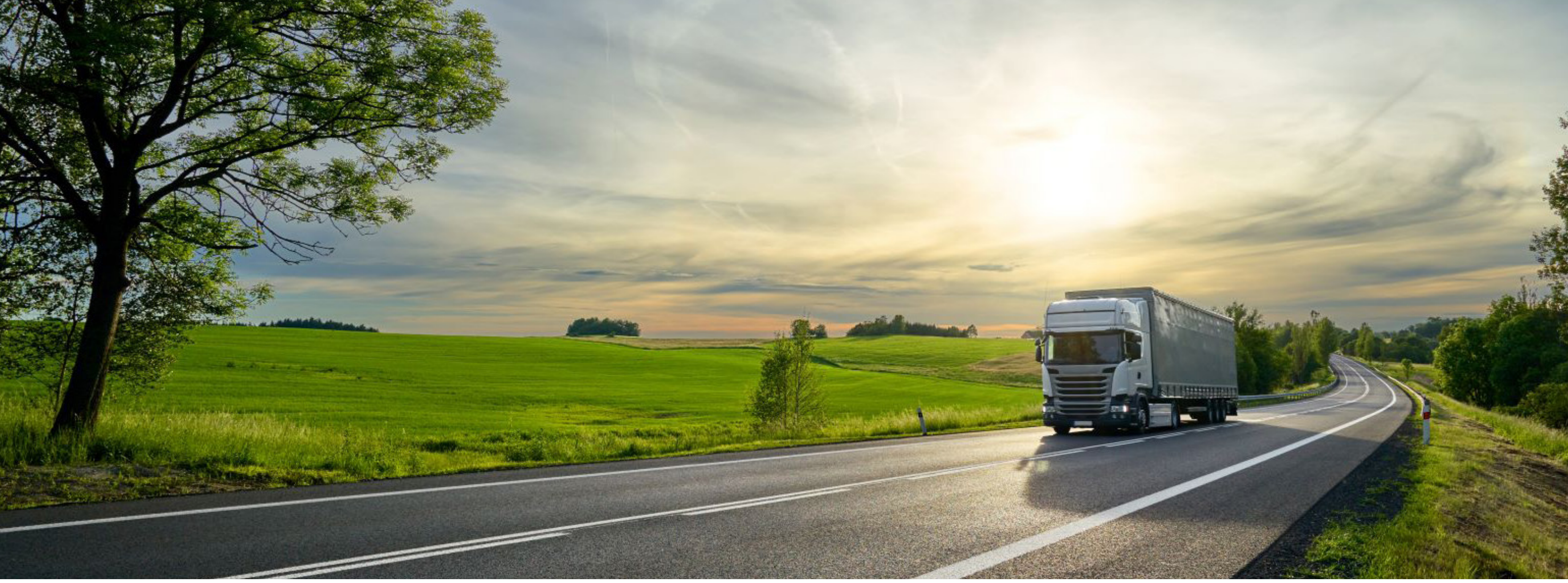


EXECUTIVE SUMMARY

When fleets trade in gasoline or diesel vehicles for electric vehicle (EV) models, they are also trading traditional fuel suppliers for electric utilities. Fortunately, electric power systems in the United States are extremely reliable—utility customers enjoyed 99.9 percent uptime in 2021 [1]. Due to that reliability, most fleets will find they can switch to EVs with little need to address outage risk. However, in some cases (such as vehicles that provide emergency services), power outages may pose a large enough threat to their fleet operations that the risk of outages must be mitigated with planning and backup power systems. EVs pose different challenges than fossil fuel systems, which are also vulnerable to disruption. These challenges include:

- More frequent and longer refueling sessions, increasing the impact of missing a refueling event or the need to fuel offsite.
- Considerably larger backup power systems than onsite fuel pumps require.

Many industries have long been critically reliant on electric power and thus there are established strategies and backup systems to mitigate the risk of outage. There are resources and industry experience fleets can pull from when assessing and deploying back-up power solutions. Fleets that determine backup power is right for them will find that existing solutions are available that can be adapted to meet their needs.

SOLUTIONS

Fleets have options to increase their resiliency to power disruptions without investing in costly backup power systems.

Increasing operational margins: Moderately oversizing vehicle batteries and charging equipment can provide an operating margin that can absorb the impact of a shortened or missed charging session.

Offsite charging: Unlike other equipment, vehicles can be moved to power. Fleets may be able to rotate vehicles to charge at unaffected facilities or charge at public chargers.

Increasing utility connection resiliency: Fleets may be able to request utilities build in additional redundancy to their grid connection, which can insulate fleets from local outages. Fleets that require additional resiliency, especially from long outages will likely require onsite backup power solutions such as:

Battery energy storage: Rechargeable batteries can store power from the grid or a solar array. Batteries are a flexible resource, which can provide value in non-emergencies and are eligible for incentives. However, they have high upfront costs and are less energy dense than stored fuel.

Solar photovoltaics: Solar energy generates clean energy from sunlight. It does not require any onsite fuel supply and can generate power indefinitely. Solar photovoltaics also provide electricity during non-emergencies and are eligible for incentives. However, because solar power only generates power in the day, it should be paired with batteries to store electricity for overnight charging.

Combustion generators: Backup power that runs on diesel, natural gas or propane has lower upfront costs and provides more power and stored energy capacity in a smaller footprint than batteries and storage. However, fossil-fueled generators emit both air pollution and greenhouse gases. They require fuel resupply in extended outages and much more maintenance than batteries and solar systems. Finally, they are not eligible for incentives or credits.

DECIDING ON SOLUTIONS

Fleets considering backup power solutions should engage in assessments of the risk of outage impacts, the costs of those impacts and the costs of solutions that can mitigate a given level of risk. However, fleets note that in-depth analysis is both technically challenging and suffers from data availability limitations.

Understanding outage impact risk: Outages will only have impacts on operations if they are at the right time and long enough to disrupt vehicle charging, meaning that fleets are most vulnerable to sustained outages during vehicle downtime. While shorter outages are common, long ones are rare, meaning that most fleets have a low risk of outages impacting their operations. However, risk can be higher in areas prone to causes of extended outages, such as public safety power shutoffs and hurricanes.

Understanding costs of impacts: Commercial fleet impact costs are similar to existing vehicle downtime costs, including lost revenue and idle labor time. For non-commercial fleets, costs might be expressed in terms of lost services. Fleets should adjust their estimates of cost by their individual outage impact risk.

Comparing costs and benefits: A backup power solution's resiliency value is the sum of the risk-adjusted costs that backup solution can help avoid. This value should be compared with system costs to determine whether a solution is financially feasible. Because outage risks are typically small, and solutions are expensive, many commercial fleets may find that implementation is not worth it. Alternatively, public service fleets may find even small chances at disruption of critical services to be intolerable, making back-up solutions necessary. Finally, solar and battery solutions offer additional revenue and cost savings opportunities which may help to render them financially viable.

IMPLEMENTING BACKUP POWER SOLUTIONS

If fleets decide to pursue a backup power solution they must plan, coordinate and address a number of practical concerns before deployment and during operation.

Assessing power and energy needs: Fleets must identify how much power and stored energy they need. This will include an assessment of what loads are critical and whether they can scale back vehicle operations. Armed with information on power energy and needs, fleets can plan and size their backup systems accordingly.

Deploying systems: Many contractors offer planning, design and construction services for backup power systems. Fleets should find those with experience and good reputations.

Engaging utilities: Utilities are valuable sources of outage information and necessary partners for electrical infrastructure deployment, especially those that require grid interconnection such as solar and battery storage. Additionally, fleets that are participating in utility make-ready programs should discuss the implications of installing backup power in conjunction with those programs.

Permitting: Fleets should anticipate needing multiple permits to deploy backup power systems. Installation of a generator will require air quality permits in many jurisdictions.

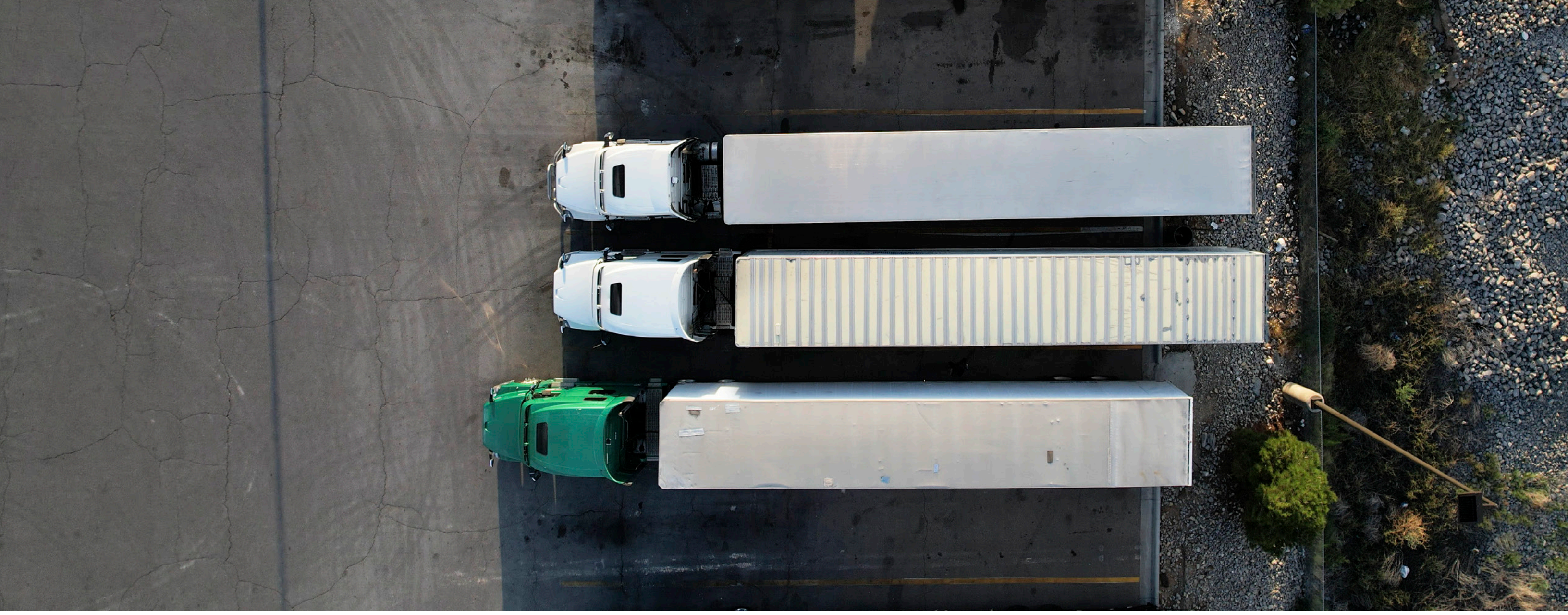
Operations and maintenance: Fleets should regularly test backup systems to ensure that the system responds to outages, power is switched over successfully and that vehicles resume charging on backup power. All systems require regular service to ensure reliable operation and generators require a well-maintained fuel supply.

CONCLUSION

Powering fleets with electricity requires a paradigm shift in thinking about secure, resilient fuel supply. The U.S. electrical grid will offer exceptionally reliable fuel supplies for most fleets, allowing them to operate with minimal or manageable disruption. However, fleets (especially those in higher outage hazard areas) should develop an understanding of how outage risk might impact them, and whether a backup power solution is viable. Those fleets that do pursue a backup power solution should plan carefully, engage their utility and carefully test and maintain their systems to ensure they can be called upon when needed.

Key Terms

Term	Definition
Air Pollutant Emissions	Emissions that degrade air quality and harm human health.
Ancillary Value	Secondary benefits or services provided by a system besides its primary function.
Backup Power Systems	Equipment designed to provide electricity during a grid power outage.
Downtime Costs	Costs associated with the time equipment or systems are out of service.
Energy Arbitrage	The practice of buying electricity when it's cheap and selling or using it when it's more expensive.
Energy Density	The amount of energy stored in a system or region per unit of volume.
Greenhouse Gas (GHG) Emissions	Gases that trap heat in the atmosphere, contributing to the greenhouse effect and global warming.
Peak Shave	Reducing energy consumption during peak demand periods, often to save on costs.
Power Density	The amount of power (rate of energy flow) per unit volume.
Public Safety Power Shutoff (PSPS)	A safety measure where electricity is turned off during extreme weather conditions to prevent wildfires.



INTRODUCTION

Among the changes that fleets must navigate as they electrify their vehicles is ensuring a reliable supply of electricity. Much of the focus of planning for fleet electrification has been on securing an electrical service sufficient to power fleets. Fleets must also recognize that as electric utilities become the new fuel suppliers for fleets, power outages become fuel supply disruptions. While electric grids are very reliable overall, in some cases power outages may pose an intolerable risk to fleet operations. In those cases, resiliency planning, and backup power systems are necessary to ensure power (and thus fuel) supplies.

While fleet electrification is rapidly expanding, its relative newness means that there is limited experience developing power resiliency in a fleet context. However, in general, developing resiliency against power outages is not a new concept. Many other industries, from datacenters to hospitals to grocers, have long relied on backup power to mitigate risks to operations from loss of grid electricity. Many fleet operators may even be familiar with the backup power needs of their buildings. So, while electric vehicles (EVs) introduce some unique dimensions and challenges to the subject, fleet operators can learn from the extensive experience of other industries.

This report draws on lessons and best practices from established literature for resiliency and backup power, interviews with utilities and early fleet electrification practitioners, and subject matter expertise on fleet electrification. It provides fleet operators with context, background, decision-making tools, and practical implementation guidance. The report is focused on fleets that operate out of yards or depots, and where maintaining power supplies for charging fleet vehicles is the primary concern, though it has relevance for fleets housed at facilities with other onsite critical electric loads.

Challenges with electric fuel supply resilience

Developing electricity supply and EV fueling resilience is varied and complex.

- Compared to combustion vehicles, EVs generally have less built-in fuel (battery) capacity, and therefore need to be refueled more often, increasing the impact of missed fueling opportunities.
- EVs take longer to refuel than liquid fueled counterparts meaning that emergency fueling at an offsite location will take longer and thus have a larger

impact on operations compared to refueling diesel.

- Much larger alternative onsite power supplies are needed to provide the power needed for charging an EV than are needed to run fuel pumps.
- Compared to many other backup power needs, EVs have high power and energy demands.

While electric fueling brings challenges for fuel supply security, it also can have advantages. Onsite renewables paired with storage can provide fuel cost savings during normal operations in addition to their resilience value. Moreover, in the case of a severe disaster where fuel supply chain breakdowns may ground non-EVs, electrified fleets with onsite solar power may be able to support some operations with their locally generated power.

Risks to electricity supply

Overall, the electricity supply is quite reliable, with the average U.S. utility customer enjoying greater than 99.9 percent uptime in 2021. Average U.S. outage statistics, however, mask substantial variation in reliability by geography. An example of this variability can be found in Louisiana where utility customers experienced more than 10 times as many outage hours as the average American in 2021 due to the impacts of Hurricane Ida. While storms like Ida will not strike Louisiana every year, even their infrequent occurrence render Louisiana's grid less reliable on average over time. Similarly, anywhere with more exposure to extreme weather will have a less reliable grid on average. However, some locations had much more reliable electric service than the national average. Washington D.C. had the most reliable power in 2021 with the average customer there experiencing seven times fewer outage hours than the typical U.S. utility customer.

Power disruptions can arise due to several scenarios from the routine to the exceptional. They can last minutes, hours, or even days, and they may be easily foreseeable or completely unpredictable [1].

Local interruptions caused by equipment malfunction and accidents are frequent but unpredictable and are usually confined to a small area and repaired quickly [1].

Routine weather-related impacts caused by regular storms, lightning, and ice are more predictable in advance, but also may cause longer outages across wider areas. Routine seasonal variation in electricity demand can also cause temporary outages when peak demand exceeds system supply (i.e., on the hottest summer days of the year) [1].

Exceptional weather events such as hurricanes, tornados, floods, heatwaves, and blizzards usually come with advance warning, but have the potential to knock out power for days at a time as repair crews are overwhelmed by extensive damage. Additionally, fleets located in the U.S. West Coast might face preemptive public safety power shutoffs during high-fire hazard weather conditions [1].

Earthquakes and other non-weather disasters such as physical or cyberattacks on grid infrastructure may cause extended power outages without warning. Fortunately, these disasters are infrequent [2].

While some outage risk is present everywhere, weather-based and other disaster risk depends on location. For instance, fleets with operations in the hurricane-prone Southeastern United States, or high wildfire risk areas on the West Coast should more carefully consider how power loss may affect their operations. Fleets should also expect that some causes of sustained outages may also interrupt their own operations because of damaged road infrastructure, decreases in demand for services, or other non-electricity supply related issues. This means that the need for backup power might be reduced in more extreme disaster scenarios.

Notably, current conditions are also not perfect indicators of future risks. When planning for the longer term, fleets should also consider the upward pressures on outage risks through climate change-related increases to the frequency and intensity of storms and heat impacts [2].

Planning for Power Resiliency

Developing power resiliency reduces risks that fleets will experience operational downtime due to power outages. However, completely eliminating risk is unlikely to be technically feasible or cost effective. The level of acceptable risk will differ from fleet to fleet. Emergency vehicle fleets are likely to tolerate very little risk of interrupted operations while non-emergency public service fleets are likely to have a higher threshold for risk. On the private side, some commercial fleets may decide that no special resiliency measures are warranted if they decide that the costs outweigh the likely loss in revenue from operational downtime. Regardless, all fleets should consider the risks that power interruptions pose to their fleet and plan for their response to outage events.

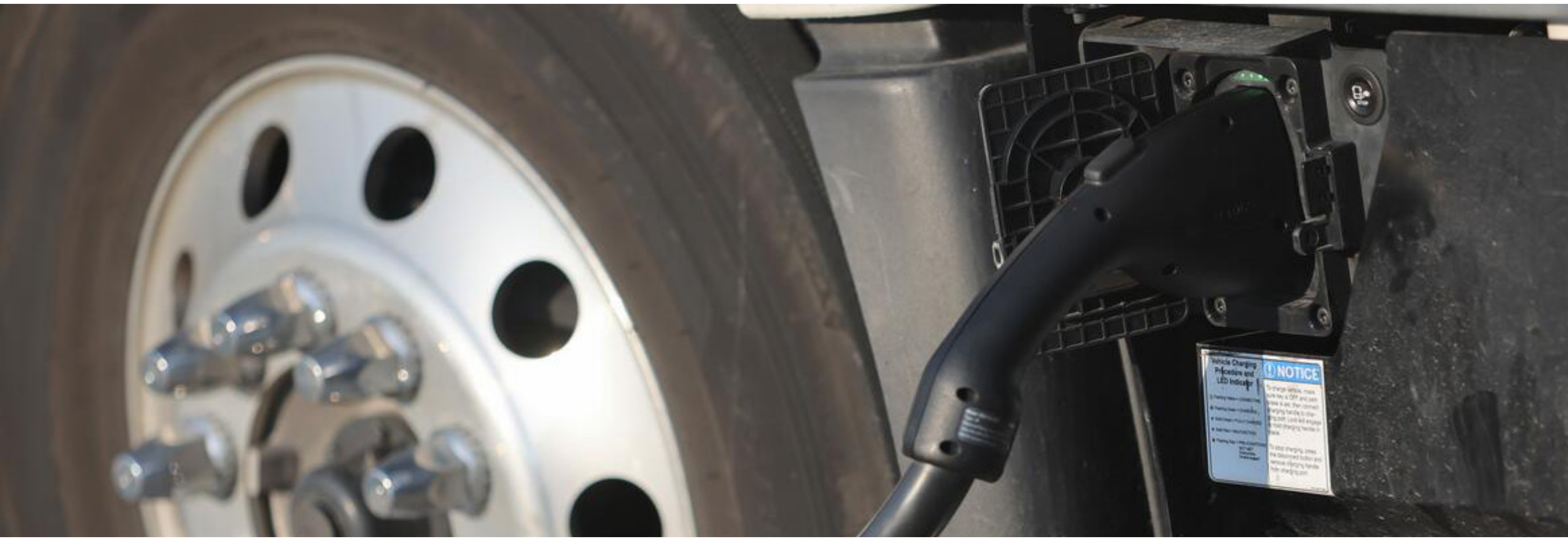
While fleets are mid-transition, having both electric and internal combustion vehicles in a fleet will soften the impact of outages. As operational improvements and policy and sustainability goals drive fleets towards full electrification, the need to address outage risk will increase. In many cases, resiliency may be an ancillary benefit that fleets should consider when planning onsite renewables and storage options that are primarily intended to reduce charging costs or overcome challenges with securing enough grid-supplied power.

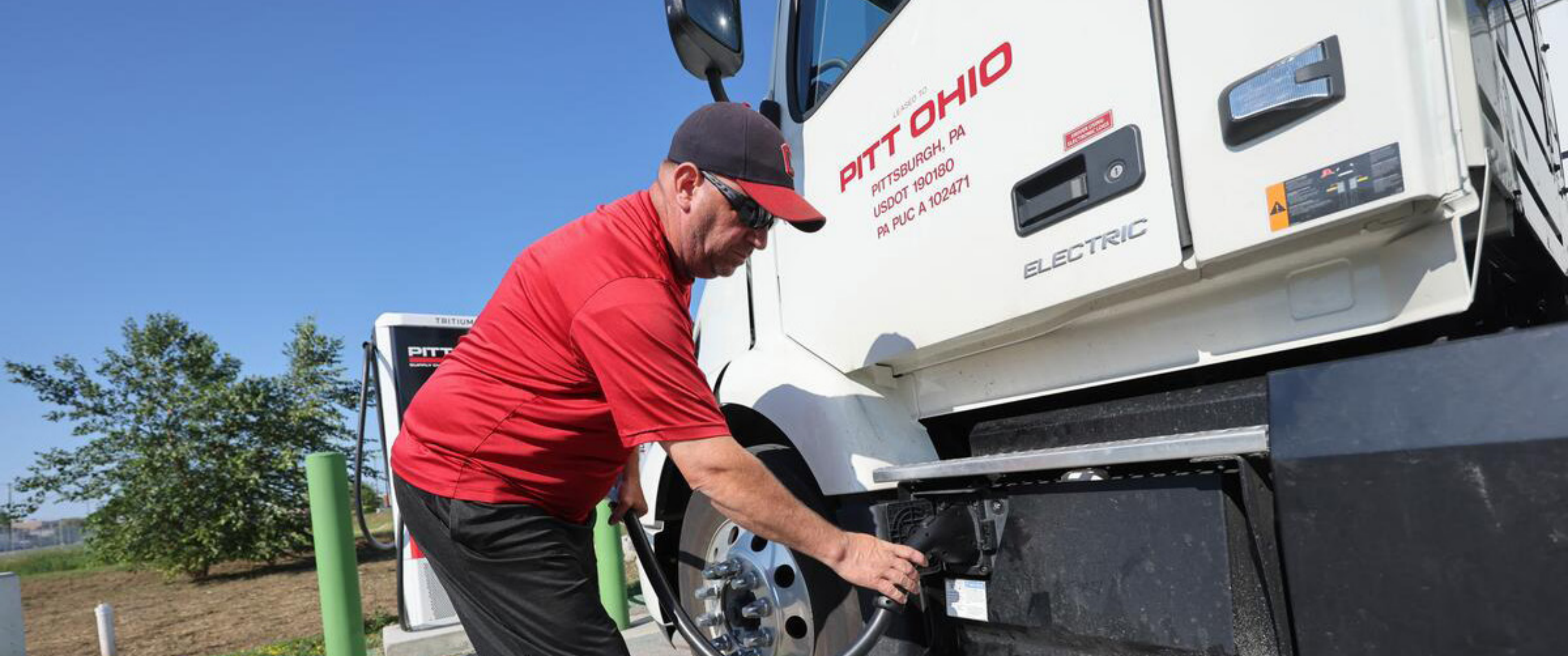
The following sections of this report guides fleets along a pathway towards understanding:

a) What resiliency options exist and how they relate to fleet needs;

b) How to decide what solutions (if any) are economically justified and how to evaluate tradeoffs of different solutions; and

c) High-level guidance on how fleets should approach resiliency planning and implement solutions.





RESILIENCY SOLUTIONS AND MEASURES

For as long as businesses and organizations have relied on electrical power for critical operations, there has been a need for backup or emergency power supplies in case of grid failure. Backup generators were the only option for decades, but recently, backup power systems based on battery energy storage and onsite renewable generation have become more popular. As the upfront cost has fallen and the bill-saving attributes of distributed energy generation have become apparent, backup power users have increasingly adopted those solutions. Additionally, fuel-cell based energy storage systems have found use in some niche applications. Fleets looking to increase the resiliency of their power supply will consider the same set of solutions, though with specific considerations unique to fueling vehicles with electricity.

Power Resiliency and Electric Fleets

EV charging has different electrical usage patterns than most users that have traditionally pursued resiliency solutions. Many of those users—data centers, manufacturing facilities, and telecom hubs—have constant energy use patterns. In contrast, charging EVs typically involves shorter periods of high-power use while charging, followed by longer idle periods while vehicles are in operation or fully charged. This difference means that some lessons learned in more constant-load facilities like data centers might not directly apply to EV fleets. In addition, unlike data centers or manufacturing, where momentary power loss can cause data loss or equipment damage, EVs and charging equipment usually do not have such vulnerabilities.

Also, fleet charging usually occurs at night during post-operational hours which contrasts with most other power users that usually see their highest power demands during the day. Therefore, EV operations are likely to be more vulnerable to overnight outages, but more naturally resilient to daytime power loss. Understanding EV's unique consumption patterns and their implications is crucial for devising effective resiliency strategies. Some aspects of EV charging make them less impacted by short term outages. Though, just like other industries reliant on electric power (including diesel and gas fueling infrastructure), longer disruptions, such as those caused by extreme weather events or grid failures, will affect EV operations. Guarding against more prolonged outages will require resiliency solutions.

Resiliency Without Backup Power

Before considering backup power solutions, fleets should first consider how they can build resilience into their infrastructure and vehicle planning. Because EVs run off an internal battery, they have built in energy storage that can be used to increase short term resilience to power outages. For example, fleets can hedge against short outages that coincide with charging times by moderately oversizing charging infrastructure size relative to their typical energy recovery needs. This allows a vehicle to sufficiently charge even if a brief outage shortens its charging window. Fleets also may consider vehicles with slightly larger internal batteries, so that missing some or all of a single charging session will not completely knock them out of service.

Building in this flexibility provides resiliency value and provides greater general operational flexibility to recover from non-outage issues such as a charger failure, a missed charging session, or the occasional abnormally high mileage day. While increasing charger power and vehicle battery size is not free, moderate increases in either may prove to be a low-cost solution for eliminating risks from most short power outages while supporting greater operational flexibility. Of course, in cases where vehicles are operating at or near the edge of their capability, adding substantial flexibility will not be possible.

Additionally, because vehicles can travel beyond their depot or yard, there are opportunities to supply them with power elsewhere unlike the stationary power needs of buildings. Fleets with multiple nearby locations might be able to maintain operations (even if in a reduced capacity) by rotating fleet vehicles into a facility that has not lost power. Public fast charging infrastructure that can handle large vehicles is not yet common, but light-duty and smaller medium-duty vehicles may be able to charge at unaffected public fast charging locations. If possible, fleets should develop operational plans for offsite fueling in case of outage.

Utilities may offer fleets the ability to increase resiliency by building redundant grid connections such that if there is power loss on one feeder, the fleet location does not lose power. This will insulate fleets from incidental local power loss, and can provide increased resiliency in inclement weather, but only provides limited insulation from widespread, systemic outages or public safety power shutoffs. Additionally, building that redundancy comes with added costs that utilities pass on to their customers.

Backup Power Solutions

Developing resiliency to longer duration power outages will likely require onsite backup generation and/or energy storage solutions. Solutions vary in complexity and capability to supply power, but all share a basic set of required features:

- **A fuel source:** whether this is a tank of diesel, grid energy stored in a battery, or sunlight for a photovoltaic system, all backup power requires some sort of fuel.
- **A generator or power source:** such as a photovoltaic array, a fuel cell, or a battery system.
- **Isolation from the grid:** Whether through a subpanel with a transfer switch or a complex microgrid, backup power must be isolated from the grid to prevent harmful electrical backfeeding.

Unlike many other industries, fleets are unlikely to need standby power or uninterruptable power supplies because charging systems should easily recover from momentary power loss. However, automated switchover systems will be valuable because staff may not be present to switch over to off grid power during overnight outages when vehicles are charging. The following is a list of backup power systems that may be suitable for fleet operations.

Battery Energy Storage typically uses rechargeable lithium-ion batteries to recharge vehicles at will. Battery systems have both power ratings (in kilowatts), which determine how much instantaneous power they provide and energy capacity ratings (in kilowatt-hours) that determine how much total electrical energy they can provide. Batteries come in a wide variety of power and energy ratings to meet differing fleet needs. Because batteries output direct current (DC) power, batteries need inverters to feed alternating current (AC) systems, which is typically used for EV charging below 20 kilowatts. Since high power charging takes DC power, fleets may find systems where batteries can directly power chargers to be a superior solution because it avoids the need to inefficiently convert power from DC to AC and back again.

Batteries do not generate their own power, so they must store power either from the grid or generated onsite and are often best paired with solar photovoltaics [3, 4]. Batteries can be used to reduce electricity bill costs outside of power loss events and are eligible for tax credits and incentives.

Solar Photovoltaics (usually called solar panels) generate power from solar energy. Vehicle chargers can be powered using just solar power. Since solar power is intermittent and only generates during the day, solar panels have limited resilience value for most fleets unless paired with battery energy storage. Batteries can store solar power and recharge vehicles overnight or augment solar output during daytime charging for a faster charge. Solar array capacity can be scaled by adding more panels as much as space and budgets permit.

Like batteries, solar arrays require an inverter. While solar panels can generate power any time the sun is up, solar power output varies greatly by direct sun exposure which depends on the season, time of day, and cloud cover [3]. Solar panels will generate useful energy throughout the year, offsetting electricity bills when not providing backup power. They also qualify for tax credits and other incentives.

Fuel Cells are a niche solution that converts a fuel (usually natural gas in backup power applications) to electricity through an electrochemical process. Fuel cells can be thought of

as almost a hybrid of a battery system and a generator. Like generators they convert fuel to electricity (rather than being charged by electricity), but the fuel cells themselves work like a battery outputting DC power [3]. Fuel cells may be eligible for incentives in some jurisdictions.

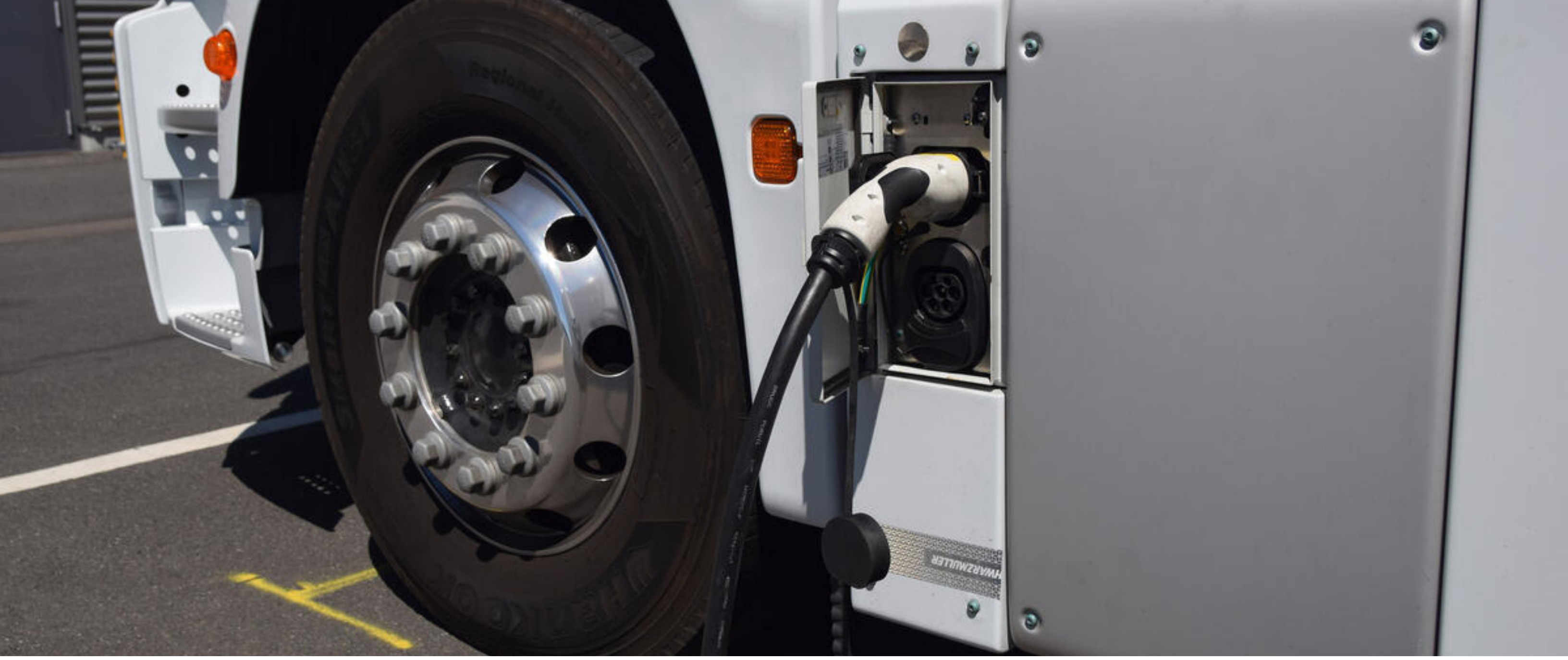
Combustion-based Generators (often simply called generators) that burn fuels such as diesel or natural gas are the most common solution for backup and temporary power needs. Generators are reliable and available in a wide range of power configurations to suit the large power loads caused by fleet charging. Bi-fuel or multifuel generators offer added fuel supply resiliency at the cost of higher prices premiums and reduced equipment reliability. Generators need onsite fuel storage or a gas line and will rely on fuel deliveries to cover extended outages—which may cause challenges if fuel supply chains are disrupted in a disaster scenario [5, 3]. In the short term, fleets transitioning from a diesel- or natural gas-powered fleet will have substantial experience with fuel logistics and may even have existing fuel storage facilities on site, though that expertise may diminish as fleets electrify.

Generators require consistent upkeep and emit GHG. Pollutants emitted by generators both pose a hazard to local air quality and present an acute risk to onsite personnel who are directly exposed to carbon monoxide, nitric oxides and particulate matter which are linked to poor occupational health. Unlike other solutions in this list, combustion generators are usually ineligible for incentives and tax credits available for other solutions.

System Configuration and Microgrids

Backup power systems configurations can be quite simple, with just a single switch that transfers the critical load from the grid to a single backup system on grid outage. However, solutions that incorporate multiple generation or energy storage assets or work in concert with grid power (like solar and storage) require more complex solutions. Microgrid controllers manage, prioritize, and balance power sources and load connected to the system and control interaction with the grid. This added complexity increases design, equipment, and engineering costs but can provide substantial value over backup-only systems, particularly in the case of solar plus storage solutions where the system can provide cost savings during non-emergency operations.

Systems can also be built modularly, with added backup power assets added as more EVs are added to fleets and power and energy requirements increase. The value of as-needed upgrades should be weighed against the cost of repeated construction.



DECIDING ON SOLUTIONS

Deciding on and between different resiliency solutions is an exercise in evaluating criteria, assessing trade-offs, and examining the costs and benefits of solutions. Fleets should consider the tradeoffs and limitations of each solution, including their feasibility, challenges to deployment, and alignment with other goals such as environmental sustainability, availability of public funding, and reducing operating costs and barriers to EV deployment. Additionally, while vehicle downtime due to power loss can be costly and damaging, power resiliency solutions are also often expensive to implement. Therefore, fleets should analyze the economics of potential solutions to decide whether they provide sufficient value to justify their expense while also considering whether operational modifications can provide sufficient resiliency value to meet their needs. Fleets with different resiliency needs, power requirements, priorities, and economic conditions will likely come to different conclusions about which solutions (if any) are right for them.

Evaluating Backup Power Systems

Backup power systems each come with their own strengths and weaknesses that affect their effectiveness under different conditions, their cost, and their attractiveness to different fleets.

Costs

Backup power system costs vary in upfront cost of installation, operating cost, and maintenance and repair costs to ensure continuing reliability. In addition, costs scale with the amount of power output and energy storage that is needed, meaning that costs increase depending on the number of vehicles that need to be recharged and the number of recharge cycles that must be covered. Notably, battery energy storage system costs are much more dependent on energy storage needs than generators, because additional batteries are considerably more expensive than a larger fuel tank. In addition to varying by performance parameters, costs also vary by installation complexity, local labor costs, and other geographically defined cost factors. Table 1 provides a high-level summary of upfront, non-fuel operation costs for different systems assembled from national lab studies estimates. Readers should note that while generators are mature technologies with long-run stable prices, both solar power and battery energy storage systems are experiencing considerable

TABLE 1

Evaluating Backup Power Systems

Backup power systems each come with their own strengths and weaknesses that affect their effectiveness under different conditions, their cost, and their attractiveness to different fleets.

Diesel Generators	High fuel efficiency Lowest upfront cost High durability & longevity Widely available fuel Highest energy and power density	Highest GHG and air pollutant emissions Highest fuel cost High maintenance needs Subject to fuel disruption Permitting challenges Fire risk Noise impacts
Natural Gas Generators	Pipeline access to fuel Relatively low and stable fuel costs High energy and power density Fewer permitting issues Lower upfront costs	GHG and air pollutant emissions High maintenance needs Fire risk Lower fuel efficiency Subject to fuel disruption
Natural Gas Fuel Cells	Low maintenance Very reliable High energy density Minimal air pollutant emissions	GHG and other emissions Very high upfront cost Subject to fuel disruption Fire risk Lower power density
Battery Energy Storage System	High flexibility Provides non-emergency value Low and stable fuel costs Can be charged by onsite power Very reliable Low maintenance Eligible for incentives and tax credits	Low energy density High upfront costs Performance degrades over time Fire risk Requires electricity to refuel
Solar Power	No fuel costs or dependency No air pollutant or GHG emissions Provides non-emergency value Very reliable Low maintenance Eligible for incentives and tax credits	Intermittent power generation Needs energy storage to maximize resiliency value Low power density High upfront costs

year-over-year price declines as those technologies scale.

Funding Availability

Public funding is available that can significantly defray the upfront costs of solar and battery-based backup power systems. All fleets should be able to benefit from the investment tax credit contained in the Inflation Reduction Act of 2022 (IRA) that allows for an up to 30 percent tax credit for qualifying solar and energy storage projects [6]. Additionally, other state-based programs may provide added funding for battery storage systems. For example, a fleet located in California may be eligible for a $350 per kWh incentive through the Self-Generation Incentive Program (SGIP). Qualified fleets in low-income areas may be eligible for incentives up to $850 per kWh through the same program [7]. Some utilities also provide incentive programs for customers to install batteries such as Green Mountain Power's

TABLE 2

Example Average Costs for Backup Power Systems

System[a]	Upfront Costs	Non-fuel Annual Operating Costs	Fuel Costs
Diesel Generators	$800/kW [3]	$35/kW [3]	$0.27/kWh[c]
Natural Gas Generators	$1,000/kW [3]	$35/kW [3]	$0.10/kWh[d]
Solar Power	$1,630 – 1,840/kW [4]	$5-6/kW [4]	$0/kWh
Battery Energy Storage System	$392 – 493/kWh[b] [5]	$4-5/kWh [5]	$0-$0.13/kWh[e]

a. Due to its niche applications, backup power fuel cell system costs are not widely reported.
b. The relevant cost metric for battery storage systems is energy (kWh) rather than power (kW).
c. Based on $4 per gallon offroad diesel price.
d. Based on $10 per thousand cubic feet commercial gas price.
e. Lower end assumes onsite solar generation and upper end based on average commercial electricity cost.

Bring Your Own Device program that provides incentives up to $900 per kW. Fleets should identify whether they can benefit from these incentives or others available in their area and include them in their financial calculus when comparing to generator-based systems that will not be eligible for public funding.

Ability to Cover Outages

Fleets charging can result in very high power and energy demands compared to most typical building loads. Power demands in the high hundreds of kilowatts (kW) and even megawatts (MW) are not uncommon for larger fleets or those with heavy duty vehicles. Moreover, daily energy demand by fleet vehicles can easily top 20 megawatt-hours (MWh) for those same fleets. High energy demand and power demands are a concern for all backup power solutions but are most acutely challenging for solar and battery systems. Both solar and storage cost considerably more on a per-kWh and kW basis than competing solutions and have lower energy and power densities. This means that for any given system size, solar and storage solutions will be more expensive (upfront) and larger than alternatives that use diesel or natural gas.

Outside of cost, size can be a considerable constraint for fleets that already must trade valuable yard real-estate for charging equipment. For example, a five MWh battery system capable of outputting about 2.5 MW will take up about the same volume as a 20-foot shipping container. Solar systems have even larger footprints, with the average 1 MW solar array needing at least six acres of rooftop or ground space [8]. While some fleets may be co-located with large warehouses with sufficient unused rooftop space, many fleets will find it challenging to accommodate large solar arrays.

In comparison, a 2.5 MW diesel generator will be of comparable size to the five MWh / 2.5 MW battery described above. Because diesel fuel is far more energy dense than lithium-ion batteries, it will need just five percent of the volume of the battery system to power the generator and produce an equivalent amount of energy.

In addition to lower storage costs and space requirements, fuel supplies can also be augmented by fuel deliveries. In an extended

BOX 1

Example Fleet Vehicle Outage Exposure

For a simplified example, consider a delivery van that:

a) drives about 50 miles per day and has a range of about 80 miles
b) can recover about 7 miles of charge per hour on a dedicated L2 charger
c) has a 10-hour overnight charging window (8 pm to 6 am)

Assuming a full charge during the prior charging window, this van only needs to recharge 30 miles worth of range (about 5 hours) to be able to run the next day with a generous 20 percent safety margin. This example vehicle can withstand a 5-hour outage during its charging window with no impact on operations, making 5+ hour outages the threshold for impacts on this fleet vehicle.

disaster scenario fuel or natural gas supplies may be disrupted, making additional fuel expensive and difficult to obtain. Solar power is fueled by sunlight, meaning that a solar plus storage solution can continue to provide power almost indefinitely in an extended outage.

Environmental Concerns

Electrifying a fleet substantially reduces its environmental footprint, and fleets may wish to deploy other zero-emission technologies in their backup power generation system to further cut harmful emissions. Generators will produce both greenhouse gas and air pollutant emissions when running. Additionally, many jurisdictions require air permits for diesel and natural gas backup power generators, a challenge not faced by low or zero emissions options. Solar and storage solutions are by far the most environmentally advantageous because they provide clean power all year-round, including during outages. Fleets concerned about environmental impacts but unable to use solar and storage might wish to consider fuel cells but should expect to pay a large premium while still emitting greenhouse gases on site if using natural gas as a fuel.

Ancillary Value

Batteries and solar can provide substantial ancillary value and additional revenue streams during use in normal operations. Solar power can be used to reduce utility electricity costs, while batteries can peak shave, provide valuable grid services, and even perform energy arbitrage. Moreover, solar and battery storage solutions may also be able to augment grid power to the extent that fleets may avoid high costs to upgrade electrical service. In fact, it is likely that the value a solar plus storage system provides in normal operations will eclipse the resilience value of those assets (see Box 3), making resiliency the ancillary value in that equation [9]. Fleets should note that using batteries for grid services or peak shaving will reduce their average charged capacity, which reduces their value during an unexpected outage. When outages are predictably imminent, such in the case of a forecasted storm or public safety power shutoff, fleet operators can put battery systems into an energy conserving mode.

On the other hand, other generator types are generally only of use during a power outage. In most cases energy generated by generators is more expensive than utility provided energy. Moreover, most backup generators do not have emissions ratings that allow them to run in non-emergency situations and those that do are considerably more expensive.

Risk-Based Economic Analysis

Fleets deciding on whether or not to employ a resiliency solution, and if so, which solution to pursue, should put considerable focus on the risks of outage impacts, the cost of those impacts (in terms of lost revenue or impeded operations), and the cost of solutions that can mitigate that risk. Fleets should note that such analyses are both technically challenging and marked by data availability limitations. Full quantitative analyses may be difficult or impossible for many fleets to conduct but that does not mean that fleet managers should not do their best to assess the costs and benefits of potential systems.

Fleets that are already considering onsite renewable generation and battery energy storage to offset their utility bills should consider the resiliency value of that system in their financial calculus. Doing so may render the project more financially feasible or justify the deployment of a more robust system [9].

Understanding Outage Risk

Quantifying the risk of outages is complicated. Fleets can often get some understanding of the average frequency and duration of outages in their specific area from their utility. Additionally, data on average outage frequency and duration for each U.S. utility is also available from the Energy Information Agency's Form 861 data that reports both System Average Interruption Frequency and Customer Average Interruption Duration indices (SAIFI and CAIDI) [10]. SAIFI provides the number of outages the average customer experiences in a year, and CAIDI, the average length of those outages.

While these average statistics are useful to get a general understanding of outage risk, they are not sufficient for precise quantitative analyses because they do not convey recurrence probabilities—the likelihood of an outage over a specified length (e.g., 6 hours or 12 hours). Without this information, it is difficult to understand how outages might impact a fleet because EVs may be able to withstand shorter outages, even when those outages coincide with the time when the vehicle would normally be charging. This means there will be a threshold where an outage begins to affect vehicle operations. Due to these threshold effects, a single averaged outage duration number or a single statistic on the annual frequency of outages cannot be used to precisely predict a fleet's exposure to outage impacts.

The threshold where outages begin to affect operations is dependent on how much energy vehicles must recover and the length of time they have to charge. Box 1 provides an example of a vehicle with a moderate risk of outage impact. A vehicle with a heavier duty cycle, larger energy demand, or a shorter charging window than the example would have a higher exposure to outage risk and, in the opposite case, a more lightly used vehicle would have less.

Unfortunately, securing granular information on outage risks is challenging. Lack of data is a barrier to cost benefit or cost-effectiveness analyses of resiliency solutions across industries. In a novel 2022 study, the National Renewable Energy Laboratory (NREL) developed probability estimates for the recurrence interval of outages of varying lengths in the United States [11]. The research provides the most current and best publicly available information about outage risk. This report confirms the overall reliability of the U.S. electrical grid, showing that on average, customers experience relatively few outages—only 1.2 outages less than 12 hours per year and vanishingly few outages over 12 hours per year. When outages do happen, only about half will exceed 12 hours duration. The report highlights variation in risk due to specific hazards, reporting that almost 70 percent of hurricane-induced outages exceed 12 hours in length and 52 percent last longer than a day. The same statistics for public safety power shutoffs are worse, at 87 percent and 66 percent, respectively.

Even armed with this state-of-the-art research, fleet managers will have to make assumptions about outage risks that fall between reported outage length bands. When making assumptions about outage risk, fleets should consider whether their fleet locations are acutely vulnerable to common causes of longer-than-average power outages such as hurricanes or public safety power outages. Utilities also may be able to provide precise historical records of outages at the circuit level for a fleet's specific location which could be used to better inform risk analysis.

Risk Tolerance and the Cost of Outages

Understanding the risk and exposure to outages is important, but just as important is understanding tolerance of risk and of the potential costs of outages. Fleets that serve public safety purposes such as emergency medical services or firefighting should have a low tolerance of risk, because interruptions in services could easily come at the expense of lives. Bus services or similar public fleets may have a higher tolerance of outage risks because, while they offer a critical public service, the consequences of reduced transit services are less likely to be life threatening. It is difficult or impossible to put a monetary value on the loss of these public services, meaning that these fleets must find a balance between the cost of adopting resiliency solutions and the operational risks they are willing to tolerate.

Commercial fleets can more readily monetize their risk assessment as a function of lost revenue, lost reputation, or other impacts of interrupted service which they can then weigh against the cost of solutions. Calculating the cost of an outage impact for a commercial vehicle is similar to calculating the downtime costs for other conditions that might take a vehicle out of service (such as maintenance or repair). Calculating this cost

BOX 2

Example Resiliency Benefit Estimate

Consider a fleet of 20 delivery vans with the exposure to outage described in Box 1 (impacts after five hours of coincident outage). Downtime costs for these vans are $1,000 per day, prorated to $100 per hour of downtime. The outage risk is taken from NREL's estimates. Based on these inputs, our simplified annual benefit value estimation (by outage length) is shown in the table below.

Annual Benefit

0-12 hours:	$6,250
12-24 hours:	$149
1-2 days	$508
2-3 days:	$394
3-5 days:	$526
5-7 days:	$242
7+ days:	$253
Annual total	**$8,323**

If the resiliency solution has a life of 20 years, and it generated these benefits in each year, then that solution would be worth about $123,000 in present value. Note that this value is directly proportional to changes in both outage risk and downtime costs. Because risk of outage decreases as duration increases, value does not decrease proportionally to the length of outage that a given resiliency solution can cover. For example, a solution that can only cover two days is 3.5 times less capable than one that can cover over seven days but delivers about 83 percent of the value.

is widespread practice for fleets, and there are a number of guides and calculators fleets may find useful for this exercise. These guides typically cover lost revenue, unproductive wages, reputational impact, and other costs. Fleet managers should also consider the extent to which lost power might knock out all or a large part of their fleets, potentially exposing them to damaging impacts to operations, revenue, or company reputation that might not occur with only a few downed vehicles.

Because commercial fleet risk is predominantly a function of lost revenue, commercial fleet operators might wish to insure against the risk of loss with a utility interruption insurance policy instead of pursuing direct risk-mitigation options such as backup power systems. While such policies will not insure against reputational losses, they may offer a very cost-effective option to mitigate risk to business revenues.

Modeling the Benefits and Costs of Solutions

Economic analysis of resiliency can be very complex and challenging and may be beyond the in-house capabilities of many fleet operators. This section provides a simplified example analysis to illustrate how fleets might conduct their own first-cut analyses of resiliency solutions.

Outage resilience benefits are the avoided costs of vehicle downtime that a resiliency solution will provide if it eliminates (or reduces) the risk of outage impacts. For example, if the cost of an outage is $1,000 and the probability that outage will occur in a given year is 1 in 10, then the value at risk in any given year is the product of $1,000 and 1/10 ($100). For non-commercial fleets, costs might be better expressed by of hours of lost service, or a similar operational metric. See Box 2 for a simple example of a resiliency benefit estimation for a fleet of delivery vans with monetized downtime cost.

The example analysis in Box 2 is of course very simplified. Among others, it makes strong assumptions about the distribution of outage risk that underlies the banded risk data sourced from the NREL report [11] and assumes that the cost of downtime is constant, rather than changing based on duration. However, this level of analysis is also simple to accomplish with basic spreadsheet modeling and limited downtime cost and risk data.

Modeling Costs and Comparing to Benefits

Cost modeling is complex and depends on local factors. It is also difficult to directly compare the costs of differing backup power systems on a perfect apples-to-apples comparison. However, it is important to develop reasonable estimates of overall cost as a benchmark to compare against benefits. As an illustrative example, consider the example in Box 3.

Readers should note that the modeling presented in Box 3 is meant to be illustrative and is therefore very simplified. It does not account for finance costs, replacement, or real estate costs (if solutions cannot be sited on existing property) or other site-specific challenges. The systems modeled in this example are also sized to prevent the impact of any outage, which may not be possible given space limitations or other constraints. Note that smaller systems might provide substantial benefits with a smaller footprint and lower upfront costs.

This type of rough analysis is a useful exercise for fleets to undertake to understand the rough magnitude of system costs to support their fleet. If roughly estimated costs are substantially higher than expected benefits, that is evidence that a backup power system is not practical. On the other hand, if benefits are similar to or outweigh costs in this simple analysis, that should indicate to fleets that in-depth, expert analysis of options is called for. For public fleets, such analyses can inform budget conversations and help decision makers understand the costs they might expect to achieve varying levels of resilience to power outages. When conducting these analyses, fleet managers should not neglect the value of solar and storage solutions to provide bill savings value, which can meaningfully affect project economics.

BOX 3

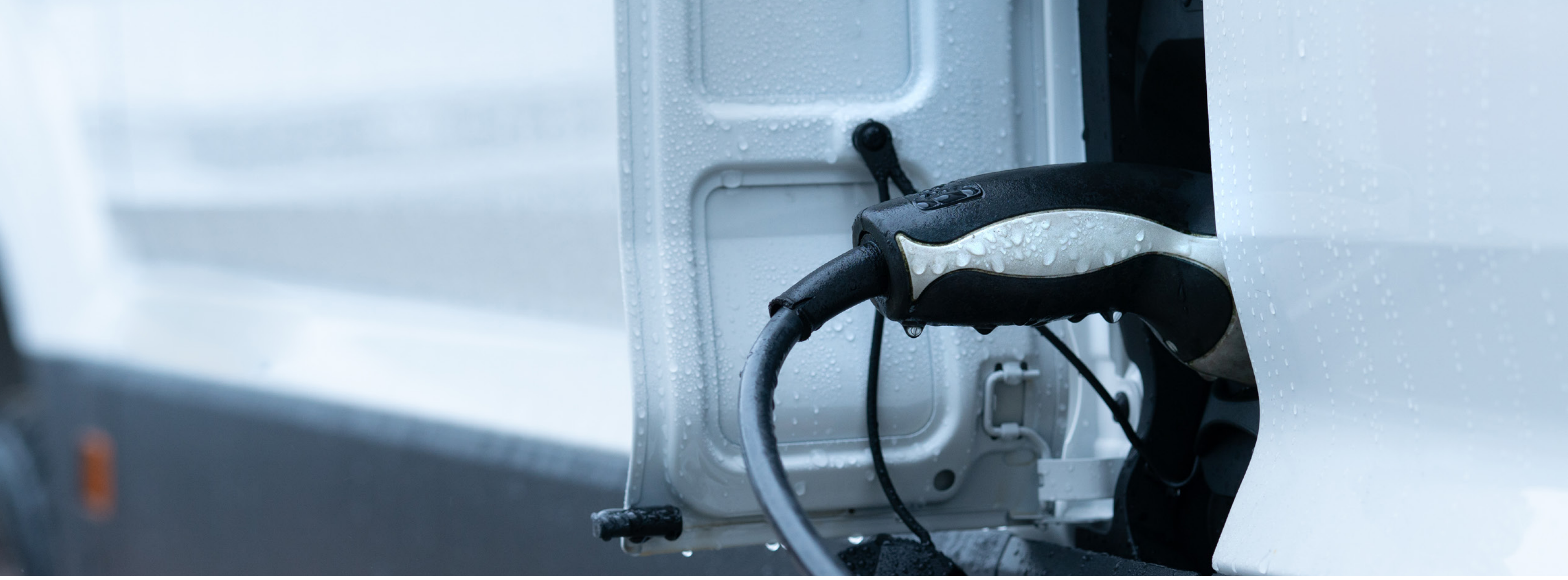
For a simplified example of a project level cost model, take the following model of a system to support a California-based fleet of delivery trucks described in Box 2. This fleet of vehicles requires 1.5 MWh of energy recovery each night and has a peak power draw of 200 kW. Each of the systems modeled below could cover a sustained outage of a week or more in length, delivering about $123,000 in avoided downtime costs over a 20-year period. The project is eligible for IRA tax credits and California's $350/kW SGIP battery incentive.

Project Cost Breakdown

	200 kW Diesel Generator	200 kW Natural Gas Generator	400 kW solar array + 1.8 MWh Battery
Capital Cost	$160,000	$200,000	$526,000[a]
Operating Costs (annual)	$7,500	$7,200	$9,000
Avoided Electricity Costs (annual)	$0	$0	$50,000[b]
Present Value of 20-year Project Costs	$273,000	$310,000	-$137,000[c]

a. Includes IRA tax credits and SGIP incentive.
b. Does not include grid service value or arbitrage.
c. Negative costs indicate cost savings.

Notably, in this example, neither the diesel nor natural gas generator provides enough value in avoided downtime costs to justify their 20-year project costs. With the IRA tax credit and the SGIP incentive, however, the solar plus storage solution has a net negative cost over 20 years. That solution pays for itself through avoided electricity costs, and actually provides more value through electricity generation than it does through resilience.



PLANNING FOR AND IMPLEMENTING SOLUTIONS

Outside of the complexity of analyzing competing solutions and evaluating the economic benefits and tradeoffs of deploying a backup power system, there are also many practical concerns to consider in deploying and maintaining those systems. Deploying backup power systems can be a major undertaking with all the planning complexities of any major construction project. This section offers a high-level look at some of those complexities. However, fleets should strongly consider seeking contractors and consultants that are well versed in backup power to aid in this process.

Assessing Power Need

Determining how much power and energy is needed to maintain operations is an important first step in developing a resilient backup power system [12], [13], [14]. It is also a critical input to the decision-making process described in the Deciding on Solutions section because power and energy need determines the cost and feasibility of varying systems and solutions. For traditional power users this exercise begins with identifying the critical and non-critical loads. In other words, what equipment is absolutely essential and what can be left off in a power outage.

In a fleet charging context, vehicle charging will usually be a critical load. For many fleets, however, individual vehicles may have differing priorities. If only a subset of the fleet's vehicles must have access to charging, then those vehicles' charging demand is the critical load. For example, a public service fleet might prioritize its most critical operations vehicles (for example, road repair vehicles or snowplows) to ensure that their most important vehicles remain operational. Fleets might also decide to tolerate reduced capacity during extended outages. A transit fleet might, for example, run on a reduced schedule during sustained outages to maintain a minimum of service while extending the capabilities of their backup power system.

Power needs are determined by sustained peak load (or highest kW power draw) of critical vehicle charging loads, along with any other critical loads (such as lighting) that are backed up on the same system. This is because backup power solutions must be sized (in terms of kW output) to meet the simultaneous demands of charging and other electrical loads when their sustained combined power draw is highest. Overloaded systems will shut down for safety reasons.

For generator-based or battery-only backup systems, system sizing is simply the rated (continuous) power output of the equipment. For solar plus storage systems—where fleet vehicles will charge during the day—determining sizing is more complicated because solar output varies both on time of day and seasonally. Fleets can use solar power calculators to assess the capabilities of a solar system to provide charging power.

Energy needs are a function of both how much energy recovery vehicles require, along with how long the fleet will operate without grid power. Additional considerations for energy need are standby loads for managed/smart charging systems and any other ancillary energy use, such as lighting, space heating, transportation refrigeration units, etc. Fleets should note that there will be minor energy losses when charging vehicle batteries and should take that into account when calculating energy need.

For generators, energy need determines the amount of fuel that fleets must store. For example, one gallon of diesel will generate about 15 to 17 kWh of electricity in a typical diesel generator, meaning that fleets can divide their estimated energy needs by about 16 to get a rough understanding of how much fuel storage they require. Battery-only storage systems will be rated by their maximum energy storage capacity, making sizing relatively simple. However, solar plus storage systems will recover energy while the sun is shining, meaning that fleets must estimate the energy output of a solar array to understand how much of their energy demand can be recovered by a given system size.

Fleets with existing operations can use telematics and charging station data to estimate how much power and energy their business or mission critical vehicles use. Fleets still in the planning phase for electrification can use the same vehicle power and energy use modeling needed to size charging equipment installations to also determine their resilience energy and power needs.

For a simple example, take a fleet with 100 electric buses that travel 100 miles a day, consume 2.5 kWh per mile, and require 50 kW charger to recover their daily energy. If no operational modifications are possible and all buses must charge simultaneously, then this fleet will require a backup power system capable of delivering 5 MW of power and 25 MWh per day of energy. If this bus fleet could modify service to limit the number of buses that need to be in operation and potentially allow for daytime charging (when solar is producing), then the fleet could make do with a smaller backup system.

Deploying Backup Power Systems

There are many contractors to choose from when looking to deploy a backup power system. Many companies offer turnkey solutions and fleets can seek out contractors that specialize in specific applications such as deployment of integrated EV charging with solar plus storage solutions. Like any other contracted work, fleets should seek out firms with expertise, experience and good reputations deploying backup power systems.

Fleets with many locations, complex installation needs, and/or high-power requirements should consider putting projects out to bid with established engineering consultant firms that can manage the planning, design and construction of backup power systems end to end and may even manage the deployment of charging equipment as well.

Utility involvement and engagement

Utilities are a critical partner in all aspects of vehicle electrification, including resiliency planning and backup power generation. Communicating with utilities early and often is common advice for fleets seeking to electrify their fleets and it is no less true for those looking to deploy backup power systems.

Outage Information

In addition to providing information about outage risk, utilities are the primary source of real time outage information. Many utilities provide live outage information on web portals. However, establishing lines of communication and building relationships with utility personnel responsible for managing power restoration and communicating information to customers in advance of power outages can simplify getting access to crucial information about power restoration efforts and timelines when an outage occurs. These contacts may also be useful for gaining information about when the utility foresees increased outage risk. Those fleets in areas subject to public safety power shutoffs should ensure they closely track shutoff information provided by their utility.

Interconnection of Distributed Generation

Switchover solutions that do not export power to the grid (such as backup generators) do not require special coordination with utilities. However, battery and solar systems that will be interconnected to the grid must go through utility interconnection processes, which include an analysis of whether existing grid infrastructure can handle increased distributed generation at a fleet's location. These processes are usually routine and well defined by utility regulators, but they may take a considerable amount of time to complete. Where the utility decides there is insufficient local hosting capacity, it may be the fleet customer's responsibility to pay for grid upgrades to deploy onsite generation and batteries. Many utilities provide hosting capacity maps that fleets can use to understand up front whether there are likely to face constraints in deploying solar and storage systems.

Interaction with Other Utility Programs

One particularly novel issue for fleets is the interaction of backup power planning and utility rules around their EV charging rates and incentive programs. Special EV rates often require a second metered service for EV charging equipment separate from other facility electrical load. This setup can increase the complexity of (or render infeasible) backup power solutions designed to cover both EV charging load and other facility load. Additionally, many utility incentive programs for EV charging deployment feature utility-owned onsite electrical infrastructure—such as switchgear, wiring, etc.—often referred to as customer make-ready. Utilities are unlikely to want fleets to build complex backup power systems onto utility-owned infrastructure. This means that fleets that wish to deploy backup power systems now or in the future, should work with the utility to determine a design that both maximizes incentives the utility may provide as well as allows for the operational needs of the fleet, including resiliency-driven backup systems. Separately, most utility programs provide optionality for the customer to receive rebates for customer side infrastructure they independently own and install.

Priority Power Restoration

Many utilities have priority power restoration lists for circuits serving public safety, health, and critical infrastructure—such as hospitals and fire stations. Utilities will respond to outages on these circuits quickly and before less critical areas. Fleets that fulfill a public safety critical role, such as emergency response, should discuss with their utility about the potential to include their facility on those priority lists once their fleet vehicles are electrified. Reduced service restoration time can meaningfully decrease the need for and size requirements of backup power systems.

Permitting

Fleets should be aware that deploying backup power systems will potentially require multiple permits from different local authorities. While permitting is a routine part of any construction project, it can take a substantial amount of time and can cause significant project delays. Moreover, some permit requirements may place constraints on deployment.

All backup power systems are subject to electrical permitting requirements. While these vary from jurisdiction to jurisdiction, fleets can expect that installation will require permits, just like any other electrical work. Permitting requirements will likely require work to be completed by a licensed electrician on plans from a licensed electrical engineer. Permits for backup power systems often require a load study that demonstrates that the backup power system can sufficiently cover the expected load it will cover. Because installing chargers will also require electrical permits, it will be helpful to build backup power systems out at the same time as charging station installation.

In many jurisdictions, installing a generator will also require an air quality permit from the relevant regulatory authority (usually an air pollution control district). While permitting emergency backup generators is usually straightforward, such permits typically come with limits on annual operating hours and in some cases may require fleets to buy generators with sophisticated emissions controls.

Finally, because fuel storage and battery systems are a fire risk, many jurisdictions have specific requirements for their installation. These may include both hardening requirements as well as safe distance requirements. Permitting schemes that require wide buffer spaces between fuel storage or battery systems and other structures may present an added challenge to space constrained fleet yards.

Operating and Maintaining a Backup Power System

Once systems are in place, they must be regularly maintained and tested to ensure operability when power failures arise. Different solutions require various levels of ongoing maintenance, but all systems require a minimum level of ongoing attention. In addition, staff must have procedures and training in place to ensure swift recovery in case of outage.

Maintenance and Testing

Regardless of the system type, fleets should run full tests of the backup systems on a regular basis and in anticipation of any upcoming weather event that is likely to cause a power outage [1], [12], [13], [15]. Testing should not be limited to just the backup power equipment itself, but the full system, including any charging management systems and the chargers and vehicles themselves. This means testing the entire system and confirming that power switches over from grid to backup sources and that chargers and vehicles recover from a temporary loss of power and resume charging.

Generators in particular have high maintenance requirements. Fleets must regularly service generators just as they would vehicle engines. Regular maintenance items include oil and filter changes, coolant checks and checks for wear or damage to parts such as belts and seals [12, 13, 14]. Solar, fuel cell and battery storage systems also require maintenance, although less so than a comparable generator set. Solar panels must be cleaned, tested, and checked for damage regularly to ensure they run at peak efficiency. Battery storage systems and fuel cells also require maintenance, particularly their temperature control systems, which must run well to ensure batteries or fuel cells are not subject to extreme heat or cold [13].

Ensuring Adequate Energy Supply

Fleets must also have procedures in place to ensure that they have an adequate energy supply in the advent of an outage. For battery systems, fleets should put procedures in place to switch the battery into an energy conservation mode (a mode where the battery prioritizes keeping a high state of charge) whenever outage risk is high. For fleets with generators, they must ensure they have enough fuel stored on site and have the ability to take fuel deliveries in the case of a long duration outage. Fleets should note that diesel fuel can degrade when stored for extended periods of time, so it is advisable to turn over or treat fuel stores regularly to ensure the fuel is in good condition when outages arise [1, 12, 15].

CONCLUSION

Understanding the risk that power outages might disrupt fleet operations and considering potential resilience solutions to counter that risk is a key area of focus when transitioning to electric fleet vehicles. Though U.S. electricity supply is exceptionally reliable, power outages are inevitable. Additionally, many fleets work in areas where grids are more vulnerable to extreme weather, disaster, and other risks to the power supply and weather-related risks are steadily increasing due to the impacts of climate change.

Power resiliency and backup power solutions are mature concepts in other power critical industries. Fleets can learn from those industries experience to develop an understanding of the risks of outages and the solutions that exist, but they also must translate those concepts into a fleet context where electricity use can be substantially different than traditional stationary and buildings based electrical loads.

By developing a sophisticated understanding of how outage risk interacts with their operations and the costs those outages can impose, fleets can make informed decisions about whether to pursue a backup power solution, what solutions are the best fit for their use case, and how to right size those solutions to fit their needs.

When deploying a solution, fleets should plan carefully, select the best contractors or vendors for their needs and engage with their utility early and often. Finally, with a solution in place, fleets must continually maintain and test their system's capabilities to ensure that it is in working order when a power outage strikes.

REFERENCES

1. S. Stout, N. Lee, S. Cox, J. Elsworth and J. Leisch, "Power Sector Resilience Planning Guidebook," June 2019. [Online]. Available: https://resilient-energy.org/training-and-resources/publications/73489-guidebook-final.pdf/view.
2. United States Department of Energy, "Transforming the Nation's Electricity Sector: The Second Installment of the QER - Chapter IV," U.S. Department of Energy, 2017.
3. S. a. D. O. Ericson, "A Comparison of Fuel Choice for Backup Generators," 2019.
4. V. J. Z. E. O. D. F. J. D. Ramasamy, "U.S. Solar Photovoltaic System and Energy Storge Cost Benchmark, With Minimum Sustainable Price Analysis: Q1 2022," United States Department of Energy, 2022.
5. R. Baxter and M. P. Energy, "Energy Storage Pricing Survey," Sandia National Laboratories, 2019.
6. U. S. I. R. Service, "Increased Credit or Deduction Amounts for Satisfying Certain Prevailing Wage and Registered Apprenticeship Requirements," Federal Register, August 2023. [Online]. Available: https://www.federalregister.gov/documents/2023/08/30/2023-18514/increased-credit-or-deduction-amounts-for-satisfying-certain-prevailing-wage-and-registered.
7. California Public Utilities Commission, "Self-Generation Incentive Program (SGIP): Energy Storage Rebates for Facilities Brochure," October 2020. [Online]. Available: https://www.cpuc.ca.gov/-/media/cpuc-website/files/uploadedfiles/cpucwebsite/content/news_room/newsupdates/2020/sgip-non-res-web-120420.pdf.
8. S. Ong, C. Campbell, P. Denholm and R. a. G. H. Margolis, "Land Use Requirements for Solar Power Plants in the United States," National Renewable Energy Laboratory, 2013.
9. National Renewable Energy Laboratory, "Valuing Resilience in Electricity Systems," September 2022. [Online]. Available: https://www.nrel.gov/docs/fy19osti/74673.pdf.
10. U.S Energy Information Administration, "Annual Electric Power Industry Report, Form EIA-861," eai.gov, October 2023. [Online]. Available: https://www.eia.gov/electricity/data/eia861/.
11. S. Ericson, J. Cox, M. Abdelmalak, H. Rabinowitz and E. Hotchkiss, Exceedence Probabiliites and Recurrance Intervals for Extended Power Outages in the United States, Golden, CO: National Renewable Energy Laboratory, 2022.
12. "Resilient Power Best Practices for Critical Facilities and Sites: Guidelines, Analysis, Background Material, and References," United States Cybersecurity and Infrastructure Security Agency (CISA), 2022.
13. S. Mullendore and L. Milford, "Solar + Storage 101: An Introductory Guide to REsilient Power Systems," Clean Energy Group, March 2015. [Online]. Available: https://www.cleanegroup.org/wp-content/uploads/Energy-Storage-101.pdf.
14. United States Environmental Protection Agency, "Power Resilience Guide for Water and Wastewater Utilities," 2016.
15. Pacific Northwest National Laboratory, "Best Practices for Standby Generator Operations and Maintenance," July 2021. [Online]. Available: https://www.pnnl.gov/projects/om-best-practices/standby-generators.
16. Valley Transportation Authority, "VTA Rolls Toward Cleaner, Greener Future Fleet," vta.org, January 2022. [Online]. Available: https://www.vta.org/blog/vta-rolls-toward-cleaner-greener-future-fleet.
17. Track Your Truck, "Effects of Downtime on Fleets," trackyourtruck.com, December 2020. [Online]. Available: https://www.trackyourtruck.com/blog/ways-to-avoid-fleet-downtime/#:~:text=In%20total%2C%20downtime%20expenses%20can%20run%20eight%20times,between%20%24850%20and%20%241%2C000%20per%20day%20on%20average..

NOTES

1 U.S. utility customers averaged just over seven hours of power outage in 2021 (just under 0.08 percent of total hours in 2021)[https://www.eia.gov/todayinenergy/detail.php?id=54639]

2 For example, Valley Transportation Authority has planned an on-site solar and battery storage system in concert with their bus electrification efforts [16].

3 Backfeeding happens when onsite generation feeds back into local distribution grids. Uninsulated systems can cause damage to local equipment and pose risk to utility workers working on nearby lines.

4 Charging management systems may require their own small uninterruptable power supply unit to prevent system reboots or damage from unanticipated power loss, but these do not need to cover the whole fleet facility.

5 The costs benchmark shown in Table 2 are suitable for high-level planning purposes but should not be considered substitutes for engineering cost estimates. These costs are the most recent available but have not been adjusted for inflation or cost declines since publication.

6 Green Mountain Power's program requires enrollees to make their battery capacity available to grid operators during periods of high energy demand. https://greenmountainpower.com/rebates-programs/home-energy-storage/bring-your-own-device/

7 Estimate based on analysis of several commercially available megawatt-scale battery systems.

8 Estimate based on analysis of several commercially available large diesel generator systems.

9 Recurrence intervals give the average number of years between outages of that duration. The reciprocal of the recurrence interval is the probability that an outage of that duration will occur in any given year.

10 See Table ES-1 of [11] for estimates of reoccurrence intervals for US regional electric grids.

11 E.g. https://www.atlassian.com/incident-management/kpis/cost-of-downtime..

12 $1,000 per day is a reference value from the top end of estimated costs of vehicle downtime provided by an informal source [17]. Hourly proration is based on a ten-hour operating day and the assumption that an hour of lost charging translates into an hour of lost revenue service.

13 Present value calculated using standard discount cashflow analysis using a 7% real discount rate.

14 There are a number of free solar power calculators available such as the PVWatts Calculator developed by the National Renewable Energy Lab - https://pvwatts.nrel.gov/

15 Charging losses range from 1 to 15 percent. Lower power AC chargers tend to be less efficient than higher power DC chargers. These losses mean that backup systems must supply a slightly higher amount of energy than the vehicle uses during operations.

16 Based on assumption of a 37-42 percent generator efficiency. Factors such as inefficient operation, extreme cold, or poor maintenance can reduce generator efficiency considerably.

17 This metric includes both energy used by the vehicle and charging losses.

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