OHIO

DriveOhio

The Future of Smart Mobility

FREIGHT ELECTRIFICATION

Last-Mile ▪ Medium-Duty ▪ Heavy-Duty

SUMMARY REPORT

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DriveOhio drive.ohio.gov

Ohio Department of Transportation

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contents

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ACRONYMS AND **ABBREVIATIONS**

AEP	American Electric Power	**kW**	kilowatt
AFDC	Alternative Fuels Data Center	**L2**	Level 2
Btu	British thermal unit	**MW**	megawatt
CMAQ	Congestion Mitigation and Air Quality	**MPO**	metropolitan planning organization
DC	direct current	**MUD**	multi-unit dwelling
DCFC	direct current fast charger	**OAQDA**	Ohio Air Quality Development Authority
DOE	U.S. Department of Energy	**ODAS**	Ohio Department of Administrative Services
EPA	U.S. Environmental Protection Agency	**ODOT**	Ohio Department of Transportation
EV	electric vehicle	**ODE**	Ohio Department of Education
EVSE	electric vehicle supply equipment	**OEM**	original equipment manufacturer
FCEV	hydrogen fuel cell electric vehicle	**OTR**	over-the-road (freight)
gge	gasoline gallon equivalent	**PUCO**	Public Utilities Commission of Ohio
H2	hydrogen	**SAE**	Society of Automotive Engineers
ICE	internal combustion engine	**TCO**	total cost of ownership
IOU	investor-owned utility	**U.S.**	United States
IFTA	International Fuel Tax Association	**USDOT**	U.S. Department of Transportation
kV	kilovolt	**ZEV**	zero-emission vehicle

Summary

As the auto industry diversifies into alternative fuels, Ohio is focused on maintaining its position as a manufacturing leader. Favorable policies, advancing powertrain and battery technology, expanding electric vehicle (EV) availability, longer driving ranges, faster charge times, lower costs, and superior performance will continue to accelerate market adoption.

EVs likely will supplant internal combustion engine vehicles in short-range, regional and fixed-route applications, as EVs' advantage in total cost of ownership (TCO) increases; however, **without aggressive efforts to address transition barriers on a national scale**, even freight use cases with TCO parity today likely will not fully electrify before 2030.

This report addresses electrification of the following four vehicle types:

Terminal and Off-Road

Initial deployments are underway for these terminal tractors used to move cargo around terminals, ports or warehouses.

Last-Mile Delivery

As demand for home delivery of goods rises along with increased EV van production, these vehicles are expected to be the first to substantially electrify.

Local Freight and Drayage

By 2025, midrange EV trucks are expected to find cost parity with diesel-powered medium-duty freight vehicles. In anticipation, manufacturers are racing to provide the best technology to scale production.

Regional and Long-Haul

The transition for Classes 7-8 freight vehicles likely will be delayed due to the high cost of chargers and lack of long-range vehicle options.

Performance and range requirements are critical factors for commercial operators; the typical semitruck averages 63,000 miles per year compared with 13,476 for a passenger vehicle.

Based on current fuel taxes and commercial vehicle registration fees, electrifying Classes 2b-8 vehicles could result in a 13% drop – $103 million per year by 2035 – in Ohio's commercial vehicle tax revenue. This equates to an average annual tax revenue loss of $800 per medium-duty and $5,000 per heavy-duty vehicle. Annual per-vehicle registration fees, motor fuel equivalency taxes, and fees assessed by vehicle miles traveled potentially could offset lost gas-tax revenue.

UPS, FedEx, DHL, Bimbo Bakeries, PITT Ohio, Firefly Transportation Services (now Lazer Spot Inc.) and R&L Carriers **give the following reasons for electrifying their fleet operations in Ohio**:

- **Competitive edge**
- **Increased safety**
- **Drivers prefer EVs**
- **Reduced carbon emissions**

The EV ecosystem is still evolving in the United States, which is on-shoring key supply chains by investing $22 billion dollars in domestic manufacturing and research. The viability, pace and ultimate success of transitioning the freight sector to EVs will require collaboration across all levels of government, utilities, the freight/logistics industry, original equipment manufacturers, equipment providers, and the financial sector.

The state's and region's existing automotive manufacturing and end-to end supply-chain infrastructure gives Ohio a competitive advantage and can reap the benefits of the EV transition.

Figure 1: Vehicles Included in this Study

Class	TERMINAL/ OFF-ROAD	LAST MILE	LOCAL FREIGHT AND DRAYAGE	REGIONAL AND LONG-HAUL
2		Step Van, Utility Van		
3		City Delivery, Walk In		
4		City Delivery, Large Walk In	Conventional Van	
5		City Delivery, Large Walk In	Large Walk In	
6		Beverage	Beverage, Large Walk In, Rack, Single Axle Van	Single Axle Van, Stake Body
7	Yard Tractor	Furniture	Furniture, High Profile Semi	Medium Semi Tractor
8	Yard Tractor		Dump, Heavy Semi Tractor	Refrigerated Van, Semi Sleeper, Heavy Semi Tractor

Ohio has an opportunity to help lead the shift to a 21st century transportation economy.

Introduction

At 17%, manufacturing makes up the largest sector of Ohio's economy by gross domestic product. Its two largest export commodities are machinery and motor vehicles.[1] Ohio produces the most engines and second-most transmissions in North America – within one day's drive of 72% of the continent's auto assembly plants, and it has a robust end-to-end automotive supply chain.[2]

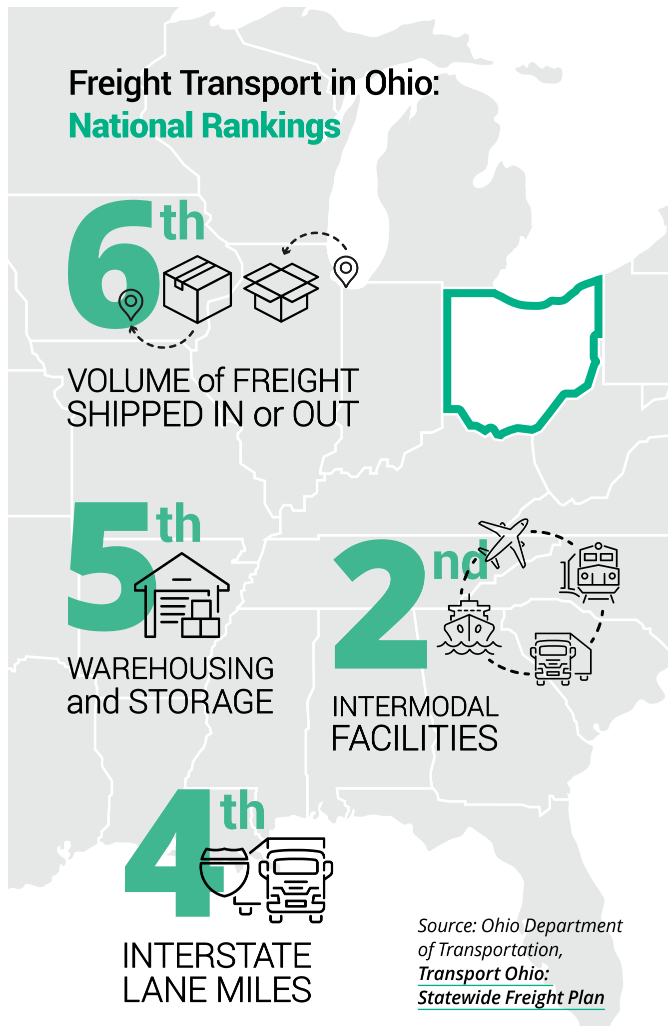
This report builds on the ***Electric Vehicle Charging Study*** for passenger vehicle electrification, which the Ohio Department of Transportation (ODOT) published in June 2020, but with a focus on truck freight.[3] This report reviews the status of the last-mile, medium- and heavy-duty electric vehicle (EV) market, and identifies actions for Ohio stakeholders that help facilitate the transition to an EV future.

The following four categories comprise the discussion of freight EVs:

1. Terminal and off-road
2. Last-mile delivery
3. Local freight and drayage
4. Regional and long-haul

The following five categories comprise this report's recommended frameworks for stakeholder support:

1. Federal government
2. State government
3. Regional and local agencies
4. Private shippers, carriers and third-party logistics providers
5. Utility companies



As the auto industry diversifies into alternative fuels, Ohio is focused on maintaining its position as a manufacturing leader.

Ohio's Freight Story

Two-thirds of freight traffic in Ohio moves by truck.[4] Nationally, Ohio ranks fourth in Interstate miles, second in intermodal facilities, and fifth in warehousing.[5] Many Ohio fleets currently have EV yard or terminal vehicles, and they expect to deploy medium- or heavy-duty freight EVs in the next few years.

Almost all ODOT funding comes from the motor fuel tax, the total of which 25% generally comes from diesel fuel purchasing – primarily for freight vehicles. In 2020, traffic volumes were down 15.5% compared with 2019, resulting in a revenue shortfall.[6] In contrast, truck traffic rebounded by June 2020 and exceeded 2019 numbers, as U.S. e-commerce grew 33% with the shift toward direct-to-consumer brands.[7] Most analysts believe the shift to online shopping will continue.[8]

Momentum of Electric Vehicles

China has invested heavily in the EV industry with the goal of transitioning to all electric or hybrid cars by 2035, and Europe saw significant policy changes in 2020, resulting in more than 260% year-over-year growth in EV purchasing.[9]

In the U.S., General Motors committed to spending $35 billion on EVs and autonomous vehicles (AVs) through 2025,[10] and Ford increased its EV spending to over $30 billion by 2030.[11]

Favorable policies, advancing powertrain and battery technology, expanding EV availability, longer driving ranges, faster charge times, lower costs, and superior performance will continue to accelerate market adoption. These and other dynamics are driving substantial changes in the over-the-road (OTR) freight sector, where medium- and heavy-duty trucks account for 5% of the road fleet, yet 20% of the greenhouse gas emissions.[12] The speed of fleet transition to EVs will vary by vehicle type.

Possible Freight Futures

Planning for a lower-carbon freight future includes the following three possible scenarios:

- ★ **EV Scenario:** Technology advances allow for trucks – even some challenging long-haul vehicles – to convert to electric power by 2035. Short-range EV operations such as drayage, terminal, last-mile delivery, and regional logistics are likely to make up over a third of the market by 2035.
- **Mixed-Fuels Bridging Scenario:** For the foreseeable future, a mix of the following slowly evolving low- to net-zero technologies will apply to over-the-road freight:
  - EVs
  - Renewable natural gas (RNG)
  - Renewable diesel and biodiesel
  - Plug-in hybrids (PHEV)
  - Other efficiency technologies and processes
- **EV + Hydrogen Fuel Cell EVs Scenario:** By 2035, a significant portion of trucks will transition to EVs for short-range operations such as drayage, terminal, last-mile deliveries, and regional logistics. Hydrogen fuel cell EVs (FCEVs) will more frequently power longer-haul operations regionally and on Interstates.

This report focuses on the **EV Scenario**, which currently is also the focus of most private investment and public policy.

Favorable policies, advancing powertrain and battery technology, expanding EV availability, longer driving ranges, faster charge times, lower costs, and superior performance will continue to accelerate market adoption.

Reasons to Electrify – from Companies that Have

UPS, FedEx, DHL, Bimbo Bakeries, PITT Ohio, Firefly Transportation Services (which yard-management services provider Lazer Spot Inc. acquired in spring 2021), R&L Carriers, and other fleets operating in Ohio gave the following reasons for electrifying their vehicles:

COMPETITIVE EDGE

Regulations and original equipment manufacturer (OEM) commitments indicate EVs are where the commercial vehicle market is moving. Fleets want to lead, not be left behind. After overcoming installation hurdles, EVs offer many potential benefits. Balancing higher upfront costs, EVs are cheaper to operate – even if use taxes or electricity rates rise. Fleets that can successfully transition sooner are likely to benefit most.

INCREASED SAFETY

EVs offer a competitive edge in safety features compared with conventional vehicles, more often having safety features such as lane-departure warnings, driver-assist features, and up to Level 3 automation. While lithium-ion batteries are flammable, batteries are far less flammable than liquid fuels, thereby presenting less explosion risk in crashes or from fuels pooling after an accident.

DRIVERS PREFER EVs

Truck EVs are much quieter and do not vibrate – leaving drivers with less ear-ringing and back pain. EVs don't emit diesel fumes, reducing associated health risks. Fleets noted that drivers appreciated the clean technology and even took fewer sick days in a zero-emissions environment. Drivers also enjoyed learning new skills to maximize the EV efficiency. Firefly (now Lazer Spot) provides 100% electric trucks for yard-management operations to create a safer and healthier work environment.[20]

REDUCED CARBON EMISSIONS

Environmental benefits of electrification are significant, and the most common reason fleets offered for electrifying. DHL has a goal of using clean transportation for 70% of their first and last mile services by 2025.[21] Bimbo Bakeries had a global goal of 10% optimization by 2020 for use of energy and fuel. From 2018 to 2019, the company reduced their fuel usage by 9%, their natural gas use by 9%, and their diesel use by 18%.[22]

FedEx UPS DHL BIMBO

PITT OHIO SUPPLY CHAIN • GROUND • LTL • TL   LAZER SPOT   R+L CARRIERS

Freight Electrification Projections

Commercial freight consumers have a different set of constraints than passenger vehicle consumers when deciding which type of EV to purchase. Performance and range requirements are more critical factors for commercial operators, especially given that the typical semi averages 63,000 miles per year[13] compared with 13,476[14] for a passenger vehicle.

Increasing Truck Volumes

In Ohio, trucking is expected to experience the most freight transport growth. Truck traffic on Interstates and major U.S. and state routes is forecast to increase about 34% by 2035.[15] Trucked tonnage is projected to be evenly split between Ohio-based and through trips.[16] Nationally, 64% of freight tonnage and 69% of freight value is moved by truck. These percentages are expected to grow.[17]

The Transition to Electric Vehicles

Based on projections, it is likely that EVs will supplant internal combustion engine (ICE) vehicles in short-range, regional, and fixed-route applications, as EVs' advantage in total cost of ownership (TCO) increases, which **Table 1** shows. However, even freight use cases with TCO parity today likely will not be fully electrified before 2030 without aggressive efforts to address transition barriers on a national scale.

Table 1: Total Cost of Ownership by Vehicle Type

Note: Costs shown in 2021 dollars.

	LIGHT-DUTY	MEDIUM-DUTY	HEAVY-DUTY
Charger Type and Usage	L2[a] and 1-2 cycles/day	Average of L2 and DCFC[b] (50-150 kW) and 2-4 cycles/day	DCFC (350 kW - 1 MW) and 10 cycles/day
Vehicles Supported	Class 2b, mostly delivery vans	All commercial classes	Mostly Classes 7-8
Cost per Charger			
Chargers	$8,645 - $8,797	$30,790 - $91,490	$154,000 - $439,460
Make-Ready	$10,520 - $12,250	$13,340 - $28,490	$53,320 - $491,800
Annual O&M[c]	$3,010 - $7,400	$10,760 - $55,130	$52,120 - $169,350
Total Ownership Cost per Mile (Vehicle and Chargers)			
Electric	$0.67 -$0.82	$0.80 - $1.12	$0.77 - $0.93
Gas/Diesel	$0.62 - $0.68	$0.61 - $0.77	$0.76 - $0.83
Projected EV-ICE Cost Parity	2022	2025	2030

[a] *O&M = operations and maintenance*
[b] *L2 = Level 2; level refers to the voltage the charger uses (240 volts)*
[c] *DCFC = direct-current fast charger (over 400 volts)*

Availability of reliable charging infrastructure, for example, is key to the success of EV deployments. Freight operators whose vehicles return daily to a "home base" that provides charging infrastructure will have the greatest success.

As demand for home delivery of goods rises and EV van production ramps up, last-mile delivery vehicles are expected to be the first to electrify – as soon as 2022.

By 2025, midrange EV trucks are expected to find cost parity with diesel-powered medium-duty freight vehicles, and in anticipation, manufacturers are racing to provide the best technology to scale production.

The transition for Classes 7-8 freight vehicles likely will experience a delay due to the high costs of EV chargers and lack of long-range vehicle options. With current cost projections, heavy-duty EVs aren't expected to capture significant market share before 2025, and they are expected to achieve near cost parity around 2030.

Freight needs vary depending on what the vehicles are being used for – or their use case – as **Figure 3** summarizes; for example, smaller trucks usually take shorter trips.

As battery and charging technology improves, more use cases are becoming viable, encouraging development in adjacent market segments.

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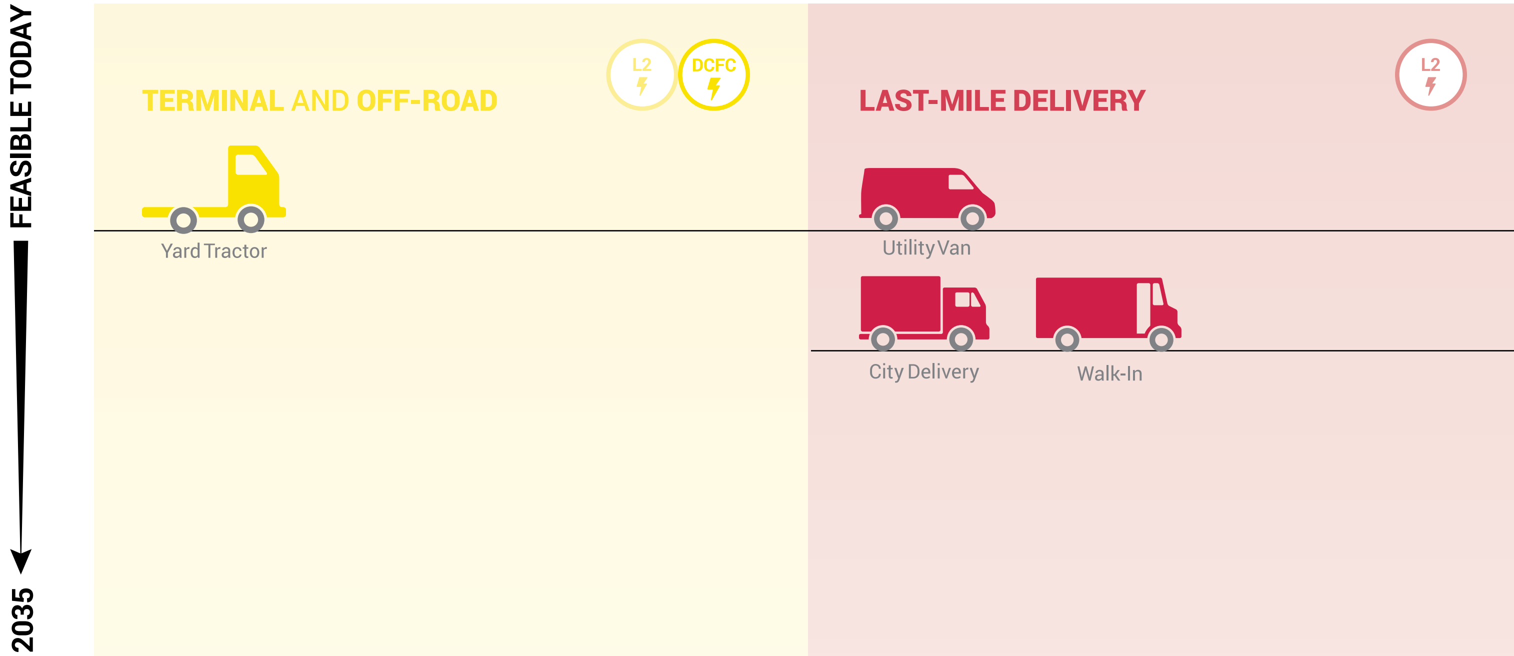
Figure 2: Timeline and Descriptions of Use Cases



Terminal and Off-Road

Status

✓ Initial deployments underway

Daily Range: Less than 100 miles

About Terminal and Off-Road Vehicles

Terminal tractors, also called yard spotters or yard tractors, are used mostly for off-road, low-speed (slower than 25 mph) operations. Rarely leaving home base, they move cargo around a terminal, port or warehouse for incoming and outgoing shipments.

Driver Experience

- Significant amount of time spent idling
- Used to move cargo after long-distance drayage shipment delivery
- Each transport mode has its own carrier and contract

Last-Mile Delivery

Status

✓ Initial deployments underway
- Requires minor improvements in battery technology
- Requires infrastructure/policy for depot charging

Daily Range: A few blocks to 100 miles

About Last-Mile Delivery Vehicles

Used mostly for deliveries – usually beyond 1 mile but within an urban region or close by. Vehicles may be small, sometimes even light-duty, but they typically are Classes 2-7 vans and trucks. Example operators include DHL, UPS, Amazon, FedEx and JB Hunt. Routes can vary but include fixed, back-and-forth trips between a terminal or warehouse and another location, with multiple stops. As online, on-demand retail grows, more vehicles within this subsector deliver directly to people's homes.

Driver Experience

- Low to moderate speeds with frequent stops/starts
- Vehicles may return to base once or a few times per day
- Last leg of any delivery process
- No set route

FEASIBLE TODAY → 2035

LOCAL FREIGHT AND DRAYAGE

L2 DCFC

Large Walk-In

Beverage

High-Profile Semi

Status

✓ Initial deployments underway
- Requires minor improvements in battery technology
- Requires infrastructure/policy for depot charging

Daily Range: Up to 500 miles

About Local Freight Vehicles

Move goods between two fixed points each workday, sometimes in multiple shifts. Generally Classes 6-8, they serve various needs for manufacturing supply chain logistics, finished products, package transport and more.

Driver Experience

- Travel distances range from a few to 500 miles
- Same route(s) every day
- Vehicles return daily to home base

About Drayage Vehicles

Over-the-road, heavy-duty trucks that transport containers and bulk to and from ports and intermodal rail yards, and to many other locations.

Driver Experience

- Short distances after receiving long-distance shipments
- Vehicles run in the same metro area or close by

REGIONAL AND LONG-HAUL

DCFC MW H2 FCEV

Single-Axle Van

Heavy Semitractor

Heavy Semitractor

Status

- Requires significant investment in battery technology
- Requires significant investment in power grid upgrades

Daily Range

- Up to 600 miles

Driver Experience

- Regular set of routes
- Away for multiple days

About Regional/ Multistate Vehicles

These are Class 8 vehicles that take regional trips longer than 500 miles but within 1,000 miles of home-base operations.

Status

- Requires significant investment in technology development
- Requires significant investment fueling infrastructure

Daily Range

- Quick fueling; non-issue if stations are available

Driver Experience

- Always different route
- Vehicles return to base every 2-3 weeks

About Long-Haul Vehicles

These vehicles travel routes typically longer than 1,000 miles (could be intercontinental). Routes may be fixed or variable, depending on needs of shipping clients and drivers' situations.

CALSTART's Zero-Emission Technology Inventory (ZETI) tool,[18] used to develop **Figure 3**, tracks the number of announced truck models in the U.S. and Canada – and shows significant growth over the next few years. Industry projections also indicate, as **Table 2** shows, that the EV market is advancing rapidly and becoming more distributed.[19]

Figure 3: Total Cumulative Number of Electric Vehicle Models by Type and Year

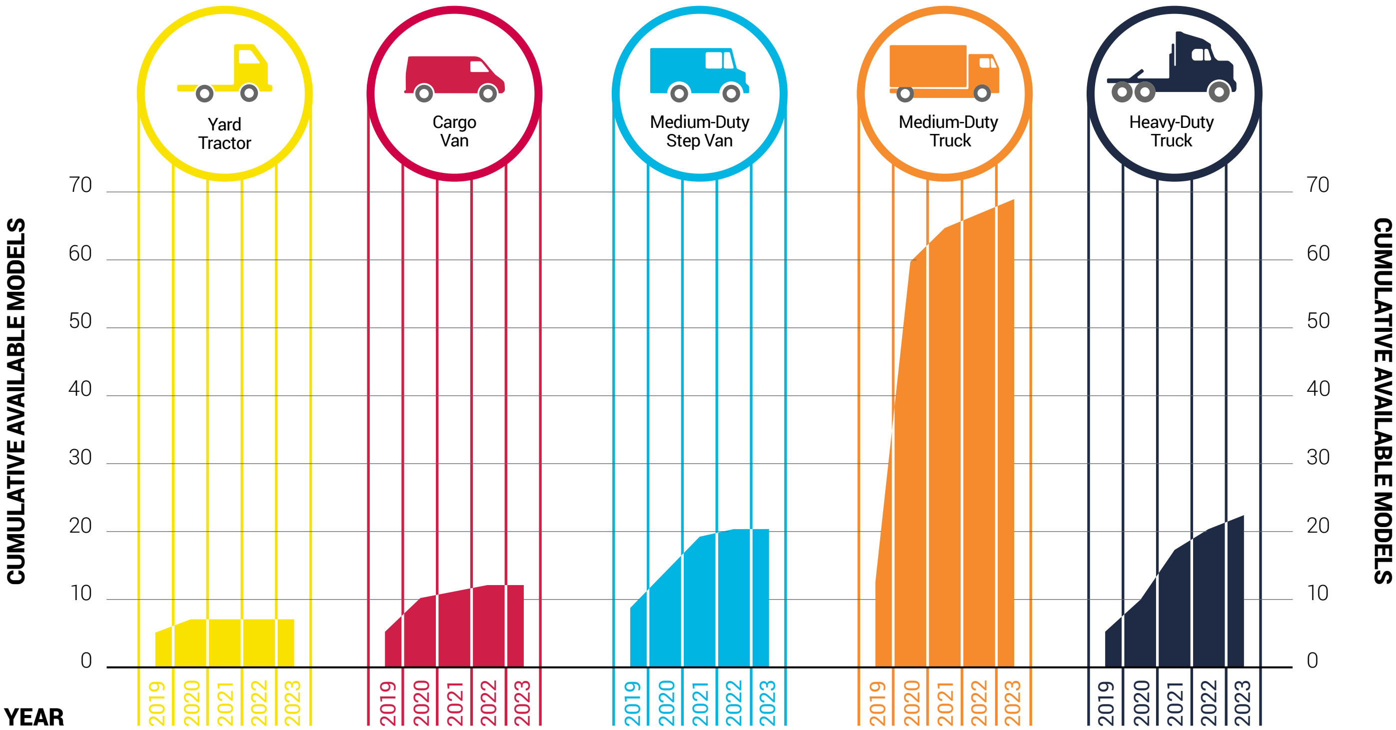


Table 2: Predictions on Prevalence of Electric Vehicles

	2025	2030	2045 AND BEYOND
California Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment		• 180,000 medium- and heavy-duty zero-emission vehicles (ZEVs) • 157,000 DCFCs • 16,000 of these > 350kW	
McKinsey Global Institute		• < 5% heavy-duty vehicles • 15% medium-duty vehicles	
North American Council for Freight Efficiency Guidance Report on Electric Trucks	Classes 3-6 tare (empty) weight parity	• Classes 3-6 max daily range parity • Classes 7-8 tare weight and max daily range parity	Mixed fleets the norm through 2050
Stark Area Regional Transit Authority Market Demand for FCEVs	.05%-.01%	.01%- 0.25%	30%- 35% (2050)

Ohio's EV-Related Taxes and Fees

Ohio implemented a motor fuel tax rate for alternative fuels including CNG, diesel and biofuel based on the relative British thermal units (Btu) of each fuel, equalized to the fuel tax rate for conventional fuels such as gasoline and diesel. Ohio has no fuel consumption tax for EV charging; however, the state imposes annual registration fees of $200 and $100 for EVs and plug-in hybrids, respectively.

Twenty-four states have some sort of fee for electric or hybrid vehicles, according to the National Conference of State Legislatures.

Tax Impacts of Commercial Electrification

State and federal motor fuel taxes make up most of ODOT's total annual revenue. Diesel fuel tax accounts for about 25%; however, during the COVID-19 pandemic in 2020, this trended a few percentage points higher.

States will experience tax implications as fleet operators begin replacing ICE vehicles with newer EVs. Adoption rates were estimated from now until 2035 to determine how many miles and revenue (**Figure 4**) and how many vehicles (see **Table 3** on **Page 9**) Ohio can expect to be electric.

Figure 4: As Electric Fleet Vehicle Stock Grows over Time, Gas Tax Revenues Decline

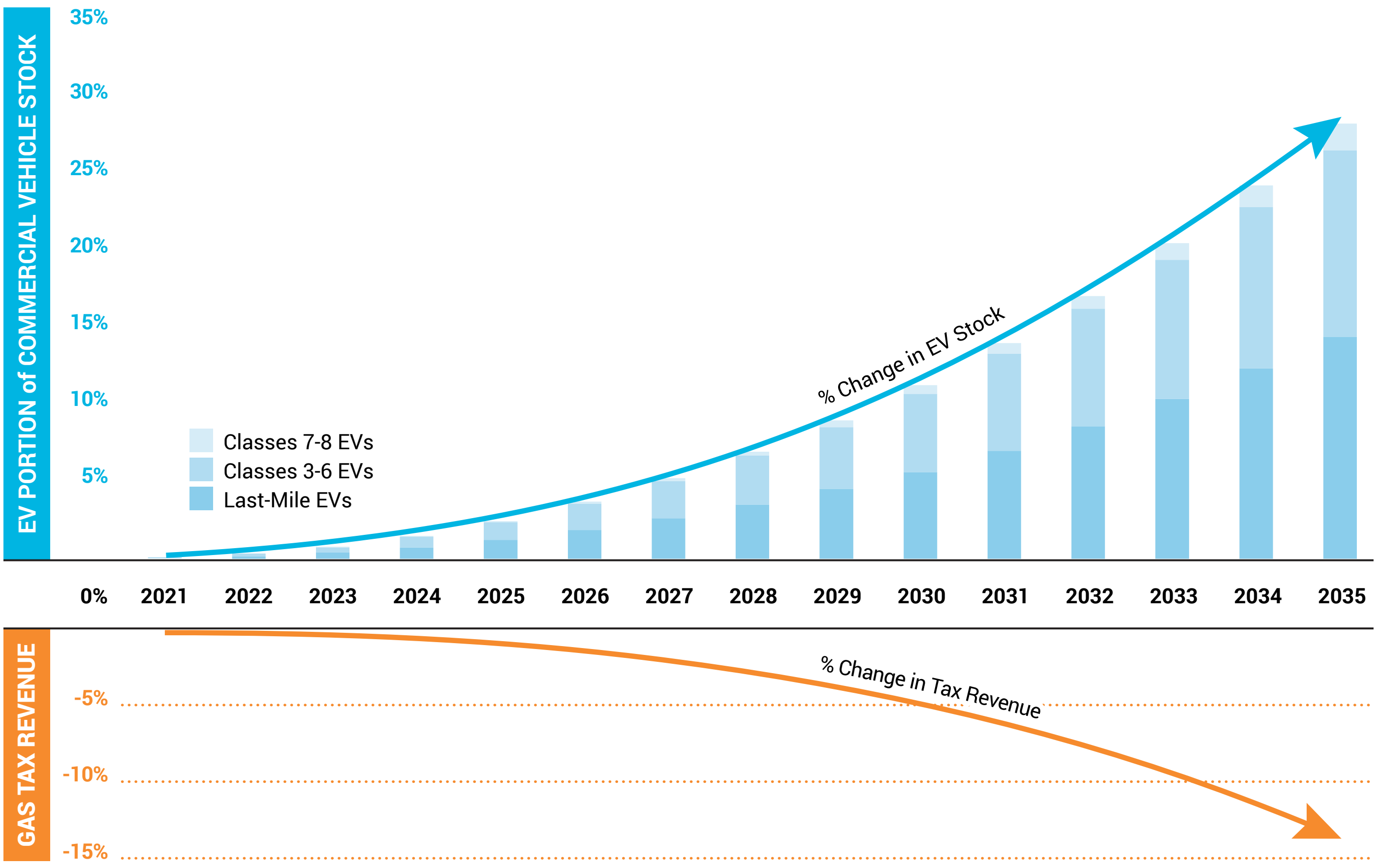


Table 3: Electric Vehicle Adoption Projections for 2035

	LAST-MILE (CLASS 2b COMMERCIAL)	MEDIUM-DUTY (CLASSES 3-6)	HEAVY-DUTY (CLASSES 7-8)
Total EVs	83,575	70,070	9,879
% of Vehicles on Road	36%	33%	7%

Based on current fuel taxes and commercial vehicle registration fees, the electrification of Classes 2b-8 vehicles is projected to result in a 13% drop in Ohio's commercial vehicle tax revenue – $103 million per year by 2035. This equates to an average per-vehicle annual tax revenue loss of $800 for medium-duty vehicles and $5,000 for heavy-duty vehicles.

Freight electrification comes with the following tax concerns and considerations:

- Compliance of vehicle owners due to unfamiliarity with the new tax
- Differing opinions about how to establish equitable tax rates and vehicle registration fees
- Potential **International Fuel Tax Association (IFTA)** implications if implementing a motor fuel tax on the electricity used to power vehicles

Revenue Recovery Mechanisms

Several approaches address the loss of tax revenue related to electrifying fleet and commercial vehicles. **Table 4** outlines the fees that would be needed to offset the state fuel taxes by vehicle class, where appropriate, or by unit of fuel (kWh), along with pros and cons to utilizing each revenue recovery method.

» The motor vehicle registration fee is calculated by vehicle class using average miles traveled, fuel economy and the applicable tax rate.

» The motor fuel tax shows the kWh equivalent of the current Ohio state gasoline tax rate based on the gasoline gallon equivalent (gge) energy.

» The vehicle miles traveled fee would recoup the state tax revenue lost due to electrification based on average number of miles traveled.

These recovery mechanisms could be used in combination with one another to provide a holistic approach to vehicle taxation based on vehicle class, use and the IFTA implications of use.

Table 4: Potential Methods for Offsetting Lost Gas-Tax Revenue

METHOD	EQUIVALENT FEE	PROS	CONS
Motor vehicle registration fee (per vehicle, per year)	• Class 2b: $250 • Classes 3-6: $800 • Classes 7-8: $5,000	Reliable means of collection	• Not directly related to driver usage • Vehicles traveling from other states will not pay registration fees
Motor fuel tax (gge)	• $0.0115 per kWh • Pennsylvania, first IFTA jurisdiction to implement a motor fuel tax on the electricity that powers vehicles, set tax at $0.0172 per kWh	Btu-rate-based method is consistent with other alternative fuels	• Requires new method of revenue grade metering for vehicle charging • Requires new IFTA standards for heavy-duty vehicles
Vehicle miles traveled fee (per mile)	• Class 2b: $0.022 • Classes 3-6: $0.064 • Classes 7-8: $0.078	Accurate tax based on usage	Requires new methods for measuring vehicle miles traveled

Technological Considerations

The ecosystem for gasoline and diesel vehicles is well-established and robust, while the EV ecosystem is still heavily evolving. This section discusses important technology elements to consider when planning a fleet transition to EVs.

Batteries

Reduced battery costs and energy density increases have helped drive a rapid reduction in electric powertrain costs, as **Figure 5**[23] shows.

Trucks typically need much larger batteries that require higher charging power than the smaller batteries in light-duty EVs.

Vehicles that require on-route charging burden their batteries – the less an EV needs to be fast-charged, the better for all system elements. Current, typical DCFCs range from 125 kW to 250 kW, with 350 kW becoming more widely available. Units with more capacity – up to 1 MW – likely will be needed to satisfy the range requirements of long-haul trucking.

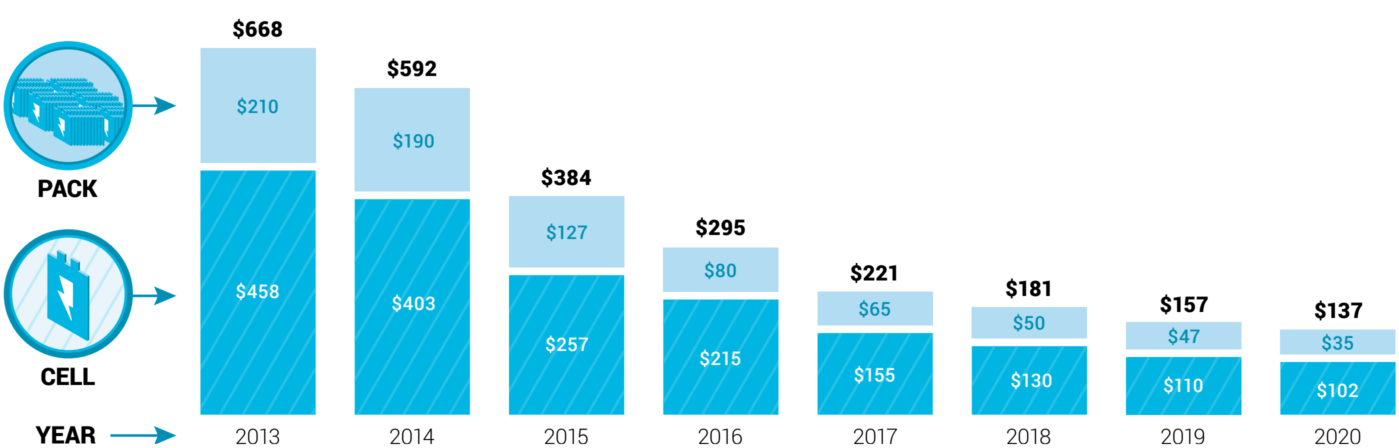
BATTERY REUSE

Heavy-duty fleet vehicles have batteries that may have useful life even after they are no longer suitable for transportation; they potentially could be repurposed as stationary battery storage for a microgrid system (see **Page 14**), adding to its resiliency and value, and flattening demand from the grid – particularly in regions where high-power charging is delivered to heavy-duty trucks. The battery can be charged during off-peak times, "filling in" excess generation capacity, and it can be used to meet demand during peak times, "flattening" the demand curve.

BATTERY SWAPPING

It is possible to replace in an EV a depleted battery with a fully charged one. In existing design configurations, batteries are usually stored in the center chassis for protection, so accessing them to replace them is not trivial; they are usually highly customized to the shape of the chassis and operating requirements of the vehicle. No unified design exists or is likely to.

Figure 5: Volume-Weighted Average Battery Pack and Cell Price Split



Fleet operators must consider the safety of drivers and the needed EVSE when evaluating new sites or making changes to an existing one.

Electric Vehicle Supply Equipment

Fleet depots are often crowded, and operators must consider the safety of drivers and the needed EV supply equipment (EVSE) when evaluating new sites or making changes to an existing one.

- **Wireless charging** is being tested for in-road applications and is more commonly used at depots that do not require driver interaction. Research on wireless charging in the 20-100 kW DC range is progressing, but that speed is not fast enough for large trucks. Wireless charging generally requires a standardized receptor under or on top of the vehicle; however, undercarriages and tops vary significantly among trucks and are consistent with their work functions. Trucks also have large-capacity batteries that require high-power chargers, which limits wireless options.
- **Plug-in:** Combined charging system cables in today's market can handle up to 0.5 MW charge rates, and megawatt charging systems being development can charge at rates up to 4.5 MW.[24] Tesla is developing a charger for its semi-trailer truck with rates of up to 1.6 MW.

  To prevent cable overheating, chargers that provide about 50 kW or more require active cooling systems, which adds complexity to the overall electrification system.
- **Pantograph:** SAE J3105 is the standard for overhead, pantograph charging that many bus fleets are currently using, capable of charging at rates of 600 kW and above. While this approach works for buses, which don't have equipment on their roofs, it will have limited use among heavy-duty freight trucks, particularly tractor-trailer vehicles.

- **In-road charging** places cables and charging equipment in the roadway to charge EVs while they're driving. This solution shifts the burden from the vehicle (and its need to carry a large battery) to the roadway; however, this approach probably will not see adoption in the near-term, except in a few extremely high-traffic locations.
- **Automated features:** The EVSE obtains data from the vehicle to turn off the charger when charging is complete, also sending a message to inform the driver. This can be helpful at a truck stop where other trucks are waiting to charge. The EVSE-driver interface can also send an invoice to the driver and the trucking company. In the future, connecting and disconnecting the EVSE to and from the vehicle may be automated.

Microgrids

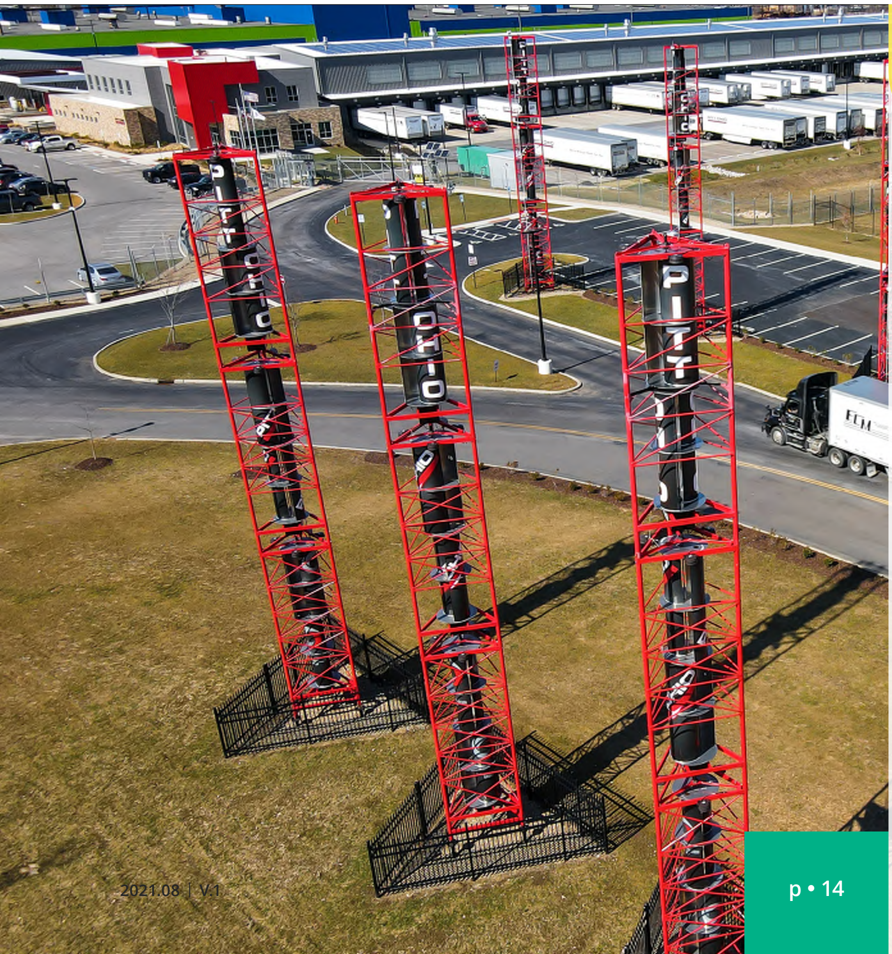
A microgrid is a small subsection of the grid that can operate on its own using local generation during a power outage. It typically integrates renewable solar or wind generation, batteries, distributed generators, and it can power building operation and charging infrastructure. Microgrids typically are designed to reduce critical load.

Automated Trucks

The high cost and shortage of long-haul drivers has spurred AV driving technology development to improve safety and efficiency. Autonomy does not require electrification; however, most commercially demonstrated AVs are also EVs. Commercial AVs are not currently available, but a number are in various stages of testing.

Broadband Internet

To fully leverage the benefits of electrification, such as remote management and peak flattening, operators will require widespread access to broadband internet. These features are key to enabling reliability and lowering electricity rates. Providing reliable internet access to all areas, particularly those outside of major cities, will be another critical prerequisite for fully enabling the advantages of EVs.



We strive to be leaders in our industry, setting an example of what is possible. We are doing this at our facilities, with our fleet and within the communities we operate, and it has created a sense of pride within our organization that crosses over to our customer base."

TAKI DARAKOS
Vice President,
Vehicle Maintenance and
Fleet Services, PITT Ohio

Pitt Ohio operates a fleet of about 800 Class 8 tractors, 2,100 trailers, 600 Classes 6-7 units, and 100 light-duty Sprinter and Transit vans. Wind turbines in conjunction with rooftop solar generate the electricity used to power their electric forklifts.

Fleet Feedback

Lion Electric, Volvo and other companies are building out **SUPPORT ORGANIZATIONS** to address power planning, mechanic training and fleet support, roadside assistance, telematics software, and grant opportunities.

A market for lead acid recycling already exists. Fleets want to understand the upstream and end-of-life use for **BATTERIES**.

Simplicity, consistency and predictability can be even more important than expediency when **PERMITTING EV CHARGERS**. These vary substantially by jurisdiction. Often, multiple departments must approve permits, so the process can take up to two years.

There can be unknown or hidden costs. **TOTAL COST OF OWNERSHIP** includes EV, EVSE installation, maintenance, driver and technician training, electricity and warehousing costs, and battery recycling.

As with charger permitting, **UTILITIES COORDINATION** is time-consuming, and – most critically – timelines are unpredictable.

ELECTRICITY PRICES may be more variable than conventional fuel-hedged contracts – especially when utility peak demand charges are unknown in advance and may change as EV fleets scale.

The Path Forward

The viability, pace, and ultimate success of transitioning the freight sector to EVs will require collaboration across all levels of government, the utility sector, the freight/logistics industry, OEMs, equipment providers, and the financial sector.

Recommended Strategic Support Frameworks

In this section we identify policy items to track at the federal level, as well as practical ways that state and local governments, the logistics industry, and utility companies can support the transition to an electrified future.

FEDERAL LEVEL

Federal funding is currently available for EV charging infrastructure on the national highway system through existing DOT funding and financing programs, although many of these programs are oversubscribed.[25]

As part of an overall climate and economic reinvestment agenda, the current presidential administration is working to greatly expand the federal role in clean transportation.[26]

U.S. Congress members and interested parties are advancing additional proposals, some aligned with and others that would expand on the administration's agenda. Some of these policies and programs seem likely to be enacted in some form.

These federal efforts could help Ohio close the gap with states that have accelerated freight electrification efforts. Given the importance of Ohio's manufacturing and logistics sectors, federal policy is likely to provide relatively greater benefits to Ohio than many other states.

Table 5 identifies some of the potential federal policy actions that may be used to advance EVs in the next few years.

STATE LEVEL

Ohio uses the following tools and strategies across multiple departments to help prepare for freight electrification and advanced transportation technologies:

- Direct incentives
- Financing
- Taxation
- Codes and standards
- Procurement specifications and direct purchases
- Study, education and convening authority

Table 6 identifies specific actions the state can take to advance EV adoption – many of which do not require capital expenditures.

COUNTY, REGIONAL AND LOCAL LEVELS

Metropolitan planning organizations (MPOs) play critical convening and education roles, bridging the gap between statewide and local governments. Counties can also support progress, especially in more rural parts of the state. Ohio's local governments are important to the business community, and specifically for last-mile vehicle electrification.

Table 7 lists several actions MPOs, counties and local governments can take to initiate or advance electrification in their jurisdictions.

Goods Movement Use Cases

TERMINAL AND OFF-ROAD

As EV adoption in this subsector, last-mile delivery, and drayage and local freight grows, governments, utilities and private stakeholders can work together to provide larger, multiport, high-power charging infrastructure near logistics centers that can serve all types of freight vehicles.

These charging facilities will need to provide numerous, fast-charging ports that could require a combination of significant distribution utility upgrades and onsite battery storage.

DRAYAGE AND LOCAL FREIGHT

As defined, local freight trucks will require charging only at or close to termination points.

Charging facilities generally will be housed "behind-the-fence" at trucking or intermodal terminals to keep power demands and charge rates lower, and avoiding the costly grid infrastructure and equipment upgrades that would be needed for on-route charging.

Shared, fast-charging infrastructure may need to be constructed in areas with clusters of local freight vehicles as more EVs are deployed.

LAST-MILE DELIVERY

Large-sized and many medium-sized fleets want sufficient charging infrastructure at their facilities, and some would prefer to share charging facilities with other freight subsectors.

In many cases, the higher end of L2 – up to 19.2 kW – likely has a rate of charge sufficient for vehicles domiciled for eight hours.

To extend delivery ranges, last-mile delivery vehicles could share fast-charging assets in urban and suburban areas with taxis, transportation network companies and others. For larger vehicles, separate but co-located charging ports may be needed for adequate access and power levels. Fleets relying on this setup likely will need charging management, a reservation system, or near-real-time awareness of the charger status.

REGIONAL AND LONG-HAUL FREIGHT

Public-private partnerships involving state and federal governments, utilities and their regulators, the trucking industry, manufacturers, retailers, commercial truck stops, owners of potential truck parking facilities, and a wide range of technology solution providers will be needed for this sector to electrify successfully.

Terminal, last-mile delivery and local freight/drayage vehicle charging happens on private land, and fleet owners can electrify by coordinating with their landlords and local utility companies; long-haul vehicles, however, depend on the availability of public chargers.

Coordination among utilities, government planners, and freight suppliers will be critical as transportation electrification accelerates. While utilities likely have sufficient generation capacity for near-term vehicle electrification, coordination can help facilitate longer-term energy needs.

Table 5: Federal Support Framework

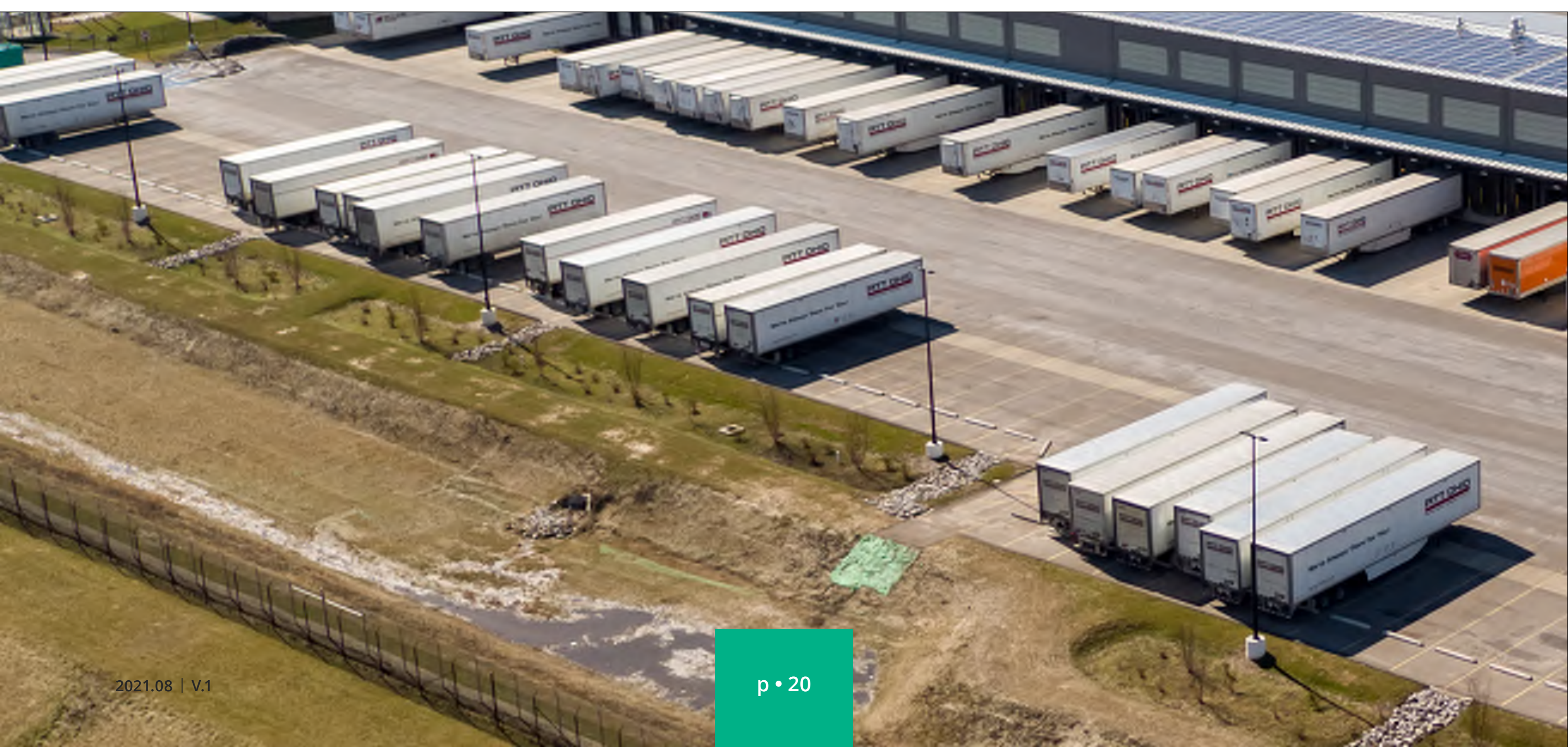
TYPE	AGENCY	POTENTIAL FUTURE POLICY ACTION
Vehicle Incentive	EPA	**Diesel Emissions Reduction Act:** Fund only advanced vehicles, not diesels, and convert the program from grants to simple, point of sale vouchers and significantly increase funding
	USDOT	• **Congestion Mitigation and Air Quality (CMAQ) Program:** Create new Buy America policy governing Federal Highway Administration, restoring CMAQ as a source of funding for clean vehicles, while driving American jobs into sector. Increase CMAQ funding to states with guidance to create voucher or rebate programs and utilize the public private partnership provision of CMAQ to include awards to private fleets. Provide funding needed to regional or state agencies to serve as public sponsors. • **Financing tools:** Direct state DOTs to use existing financing tools for clean vehicles and infrastructure projects. Provide more federal resources and/or new programs for that purpose. Consider how green bonds (bonds that have environmental benefits) can be integrated into a broader financing strategy. Allow stacking of financing and vouchers/grants.
Charging Incentive	USDOT	**EV charging:** As part of new infrastructure bill, provide funding to state DOTs for EV charging stations, including charging for commercial and government medium to heavy-duty fleets. Allow terminal and public fleet charging to be eligible.
Taxation	Internal Revenue Service	**Federal excise tax:** Eliminate the 12% federal excise tax on purchases of new clean, advanced commercial vehicles.
	USDOT	**Highway taxes:** Develop and implement pilot program to tax advanced commercial EVs based on VMT, rather than energy consumption.
Demonstration	USDOE	• **Vehicle and charging demos:** Expand competitive grant funding for advanced vehicle and charging demonstration programs. Include technologies at early stages of commercialization. Allow localized and multi-state projects. • **Vehicle/grid/building integration:** Fund vehicle-to-building and vehicle-to-grid integration demonstrations in a variety of utility markets. Include freight vehicles in these demos.
Standards	USDOE	**High-power charging:** Facilitate industry stakeholder process to adopt single standard for high-powered charging. Tie government funding for charging infrastructure to adherence to the standard.
	EPA and USDA	**Renewable fuels standard:** Expand and reform the standard to include all lower net CO2 transportation technologies, including EVs, not just the four renewable fuel categories currently included (biomass-based diesel, cellulosic biofuel, advanced biofuel, and total renewable fuel). Tie credit values to science-based carbon intensity scores.
	USDOT	• **Trucking regulations:** Ensure hours of service regulations are in line with developing trends in automation and electrification. • **Fuel surcharges:** Allow carriers to gain at least a partial windfall based on the difference between the cost to fuel EVs and other advanced vehicles and the market prices of diesel fuel that otherwise would be used, and upon which the surcharge is based.

Table 6: State Support Framework

TYPE	AGENCY	POLICY OPTIONS
Data	ODOT	• Continue to provide latest trends on EV adoption by zip code, city, and county to local and regional agencies. • Ensure state vehicles have telematics capable of reporting state of charge and other key indicators.
Fleet	ODOT	Evaluate state fleet and duty cycles to determine which vehicles are appropriate for EV or hybrid conversion to hit 15% adoption by 2026.
Planning	ODOT	Plan freight-oriented EV corridor charging: gap identification and power supply analyses to prioritize private EVSE sites.
Guidance	ODOT	• Provide visible leadership to cities, counties and metropolitan planning organizations by convening meetings among government, utilities and private freight stakeholders • Conduct statewide EV freight analysis on a recurring basis by making EV a key part of statewide freight plan updates. • Provide guidance to local governments on permitting, right-of-way easements, standardized EVSE layouts and specifications, and ideal locations for freight EV charging.
Education	ODOT	Identify ODOT point person knowledgable about freight-related EV grant funding, learnings from other jurisdictions, and who would lead the ODOT and state EV infrastructure efforts on transportation electrification.
	ODE	Develop technical training programs in partnership with Ohio's community colleges, leading universities, Jobs Ohio, OEMs, and fleets. Include medium- and heavy-duty EV training in curriculum. Include EVSE training in partnership with electrical trades. Link graduates of these programs to jobs in the sector.
Incentive	OAQDA	• Consider a "green bond" financing program, which OAQDA manages, for freight vehicles and charging. • Utilize existing ODOT financing tools.
Promotion	JobsOhio	Promote Ohio's capacity and resources for OEMs such as the Transportation Research Center.
Procurement	ODAS	• Maintain and publicize to Ohio agencies EV chargers that are on the state's universal term contract list. • Add and publicize to Ohio's state and local governments EV models that are on the state's universal term contract list.
Promotion	ODOT, Ohio EPA	Identify and promote top location targets for charging.
	JobsOhio	Identify and promote vehicle battery recycling efforts.
Grid	PUCO	• Study level of investment, policy and mechanisms needed to fund upgrades in grid infrastructure to supply power to freight EVSE, include freight terminals, truck stops and other appropriate locations. • Plan for grid resilience in the face of storms or other unforeseen events.
Rates	PUCO	Evaluate alternative utility rate structures.
Taxation	ODOT	Further evaluate transportation funding options to fill the tax shortfall that would occur with a conversion of medium and heavy-duty vehicles to electric.

Table 7: County, Regional and Local Support Framework

TYPE	POLICY OPTIONS
Fleet	• Set local fleet electrification goals. • Analyze opportunities to add EVs to local government and other fleets, including federal grants. • Ensure vehicles have telematics capable of reporting state of charge and other key indicators. • Support used EV market by facilitating transfer of fleet EVs to second owners.
Charging Prioritization	Conduct assessments of public access charging needed to serve regional fleet needs, especially last-mile delivery involving multiple stops at retail sites, businesses, and residences.
Charging	Support matchmaking of site hosts, OEM suppliers and dealers (including EVSE), utilities, permitting agencies, incentive programs, and funding opportunities.
Education	• Publicize to member agencies EV models that are on the state universal term contract list. • Educate members about needed local policies, and educate elected officials and staff about fleet electrification and grid impacts. • Provide forums to consider electrification of government fleets and strategies to incentivize electrification of private fleets. • Provide opportunities for governmental staff to be educated on EV transition activities.
City Ordinance or Regulation	• Adopt a building code requiring wiring and proper site design for EVSE during construction or significant renovations. • Pass regulations that prohibit non-EVs from parking in designated EV spaces. • Adopt rules clearly governing process for installing EVSE in public right of way. • Simplify and shorten EVSE installation permitting processes. Link permits to effective design (e.g. pull-through charging at truck stops, mix of charging levels, charging connectors, etc.)
Municipal Procurement	Require thorough review of feasibility to integrate EVs and other low net CO2 alternatives into government fleets. Use life-cycle cost accounting to determine feasibility.
Curb Space	Conduct and follow through on studies addressing curb space, loading zones, and district-specific emission caps.
Data	Gather and maintain regional EV data to facilitate planning and grant applications.



SHIPPERS, CARRIERS AND THIRD-PARTY LOGISTICS PROVIDERS

Shipping/receiving carrier fleets and third parties managing warehouses, terminals and other facilities largely will determine the pace of freight electrification progress.

Industry collaboration can set goals, identify barriers, conduct demonstrations, share data and lessons learned, and work with government to devise and test solutions. For example, leading commercial vehicle manufacturers Volvo Group, Daimler Truck and the TRATON GROUP signed an agreement in July 2021 to install and operate a high-performance public charging network for EV heavy-duty, long-haul trucks and coaches across Europe.[27]

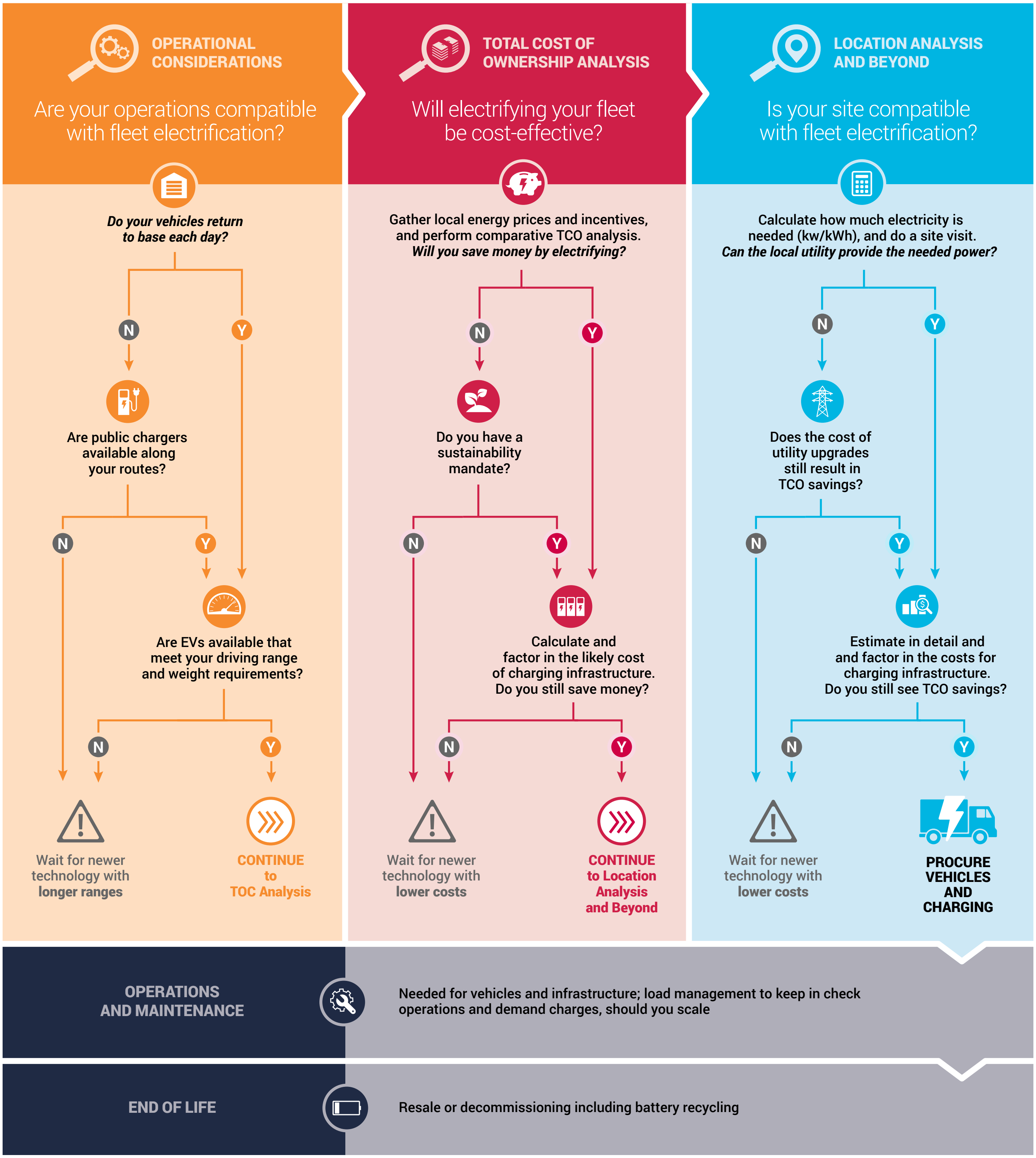
Table 8 identifies ways fleets can advance the electrification ecosystem.

Table 8: Logistics Industry Support Framework

TYPE	POLICY OPTIONS
Financing	Consider innovative financing (bond or investor financing, longer leases) that enable positive return on investment for terms longer than the typical industry lease.
Messaging	Ensure EV roll outs generate driver enthusiasm by confirming new equipment works as intended and issues are resolved ahead of time, as much as possible.
Utility Coordination	Work with utilities early in the process to assess potential needs and costs for distribution grid upgrades for EV charging.
EV Charging Rates	Leverage the value of renewable energy and battery storage technology, where appropriate, to lower charging costs in a demand-based utility rate structure.
Contracting	Ensure contracts with EVSE vendors provide sufficient maintenance and support.
Demonstration	Undertake projects to put equipment into service, gain operating experience, gather data, and obtain results that can be validated and shared.
Operations	Evaluate the use of networked chargers to manage demand as fleets scale.
Replication	• Share lessons learned with others. • Explore how to simplify transferring used EVs between fleet operators to maximize useful life.

Figure 6 maps out the high-level decision-making process for fleets evaluating a transition to EVs.

Figure 6: Fleet Electrification Implementation Flow Chart

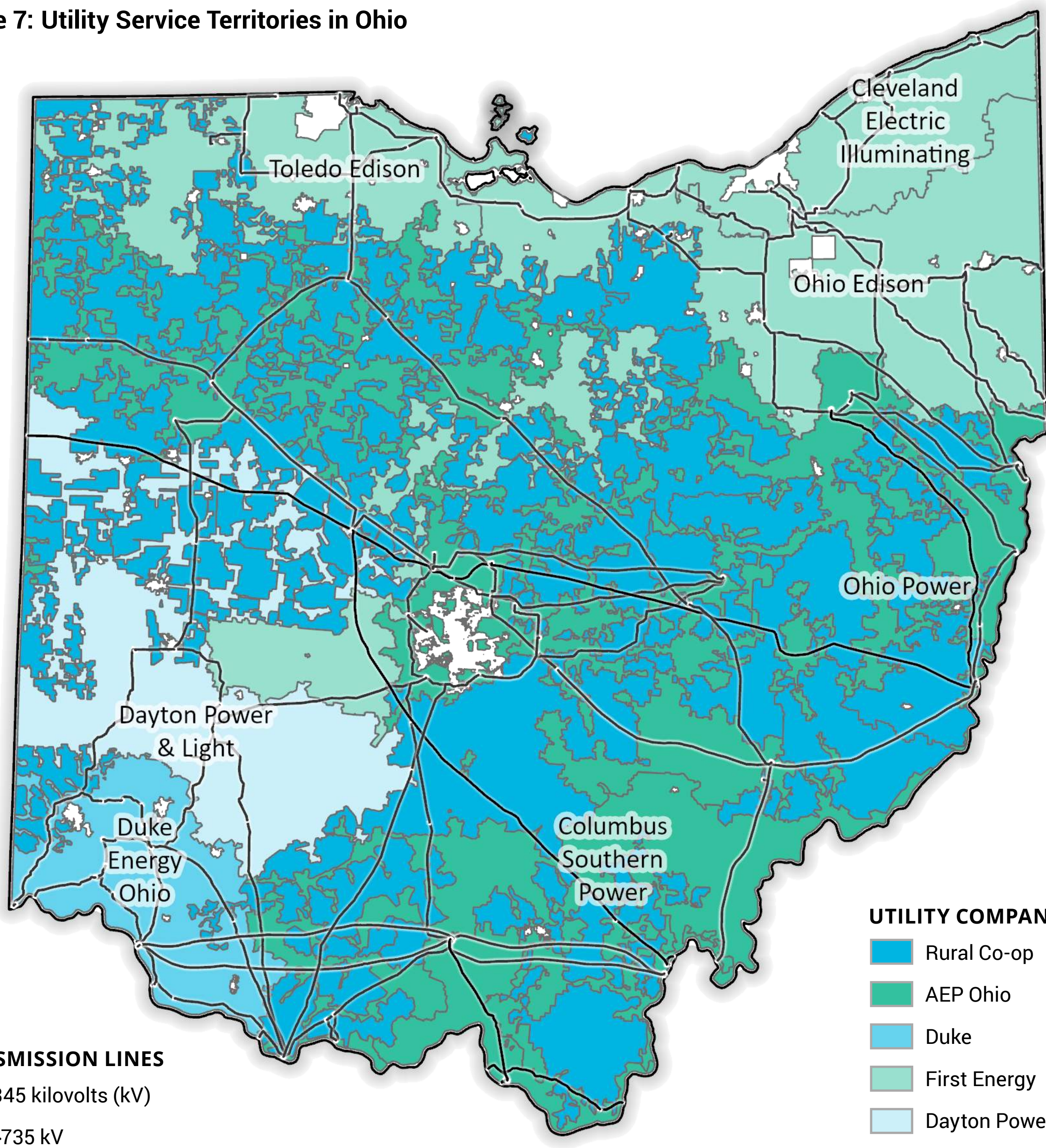


UTILITIES COMPANIES

As **Figure 7** shows, Ohio has four investor-owned utilities (IOUs), 85 municipal power companies, and 25 utilities co-ops. The transition of the goods-movement industry to EVs will call on all utilities, regardless of type.

The IOUs, working with regulators at the Public Utilities Commission of Ohio (PUCO), can create financial structures to upgrade electricity distribution grid, battery storage infrastructure, and potentially microgrids to power an electrified freight sector.

Figure 7: Utility Service Territories in Ohio



TRANSMISSION LINES

- 345 kilovolts (kV)
- >735 kV

UTILITY COMPANY

- Rural Co-op
- AEP Ohio
- Duke
- First Energy
- Dayton Power & Light
- Municipalities

Note: Satellite imagery provides transmission line data; voltage levels are approximate.

IOUs and regulators also can create rate systems to help overcome the barrier of demand charges. As IOUs develop financial solutions, municipal and co-op utilities may be able to use these as models. However, these nonregulated utilities will need help from state or federal resources.

Table 9 summarizes past and anticipated utility incentive programs and funding sources. **Table 10** identifies steps IOUs and their nonregulated counterparts are taking or can begin to take, in some cases, to prepare for a future of vehicle electrification.

Table 9: Electric Vehicle Charger Incentives and Funding Sources

SOURCE	ELIGIBILITY	FUNDING NOTES
AEP Ohio	AEP Ohio Territory	**Past:** • DCFC Level 2 public, multi-unit dwelling (MUD), workplace • $10 million total from 2017 to 2020 **Potential future:** • Filed, pending PUCO action • $4 million annually, recurring • DCFC, Level 2 public, MUD and workplace
Dayton Power & Light (DP&L)	DP&L Territory	**Approved:** • $5.1 million • DCFC, Level 2 public, MUD and workplace
Duke	Duke Territory	**Potential future:** • Filed, pending PUCO action • $15 million • DCFC, Level 2 public, MUD and workplace
Municipal and Co-Op Utilities	Any site type	**Potential future:** • Subject to approval by utility boards

Table 10: Framework for Utilities Support

CATEGORY	POLICY OPTIONS
PUCO Coordination	Collaborate to proactively plan for grid investments to support commercial EV transition.
Rate Structure	Evaluate rate structures, including providing off-peak EV rates to commercial users.
Renewable Generation	Enable wind, solar and battery energy systems on the distribution network for peak resiliency.
Battery Storage	Enable battery storage so fleets can charge vehicles during peak times at lower cost and with less strain on the grid.
EVSE Incentives	Provide flexible incentives for EVSE which do not preclude use cases.
EVSE Sites	Identify and promote low-cost EV fleet expansion sites (e.g., underutilized grid infrastructure).

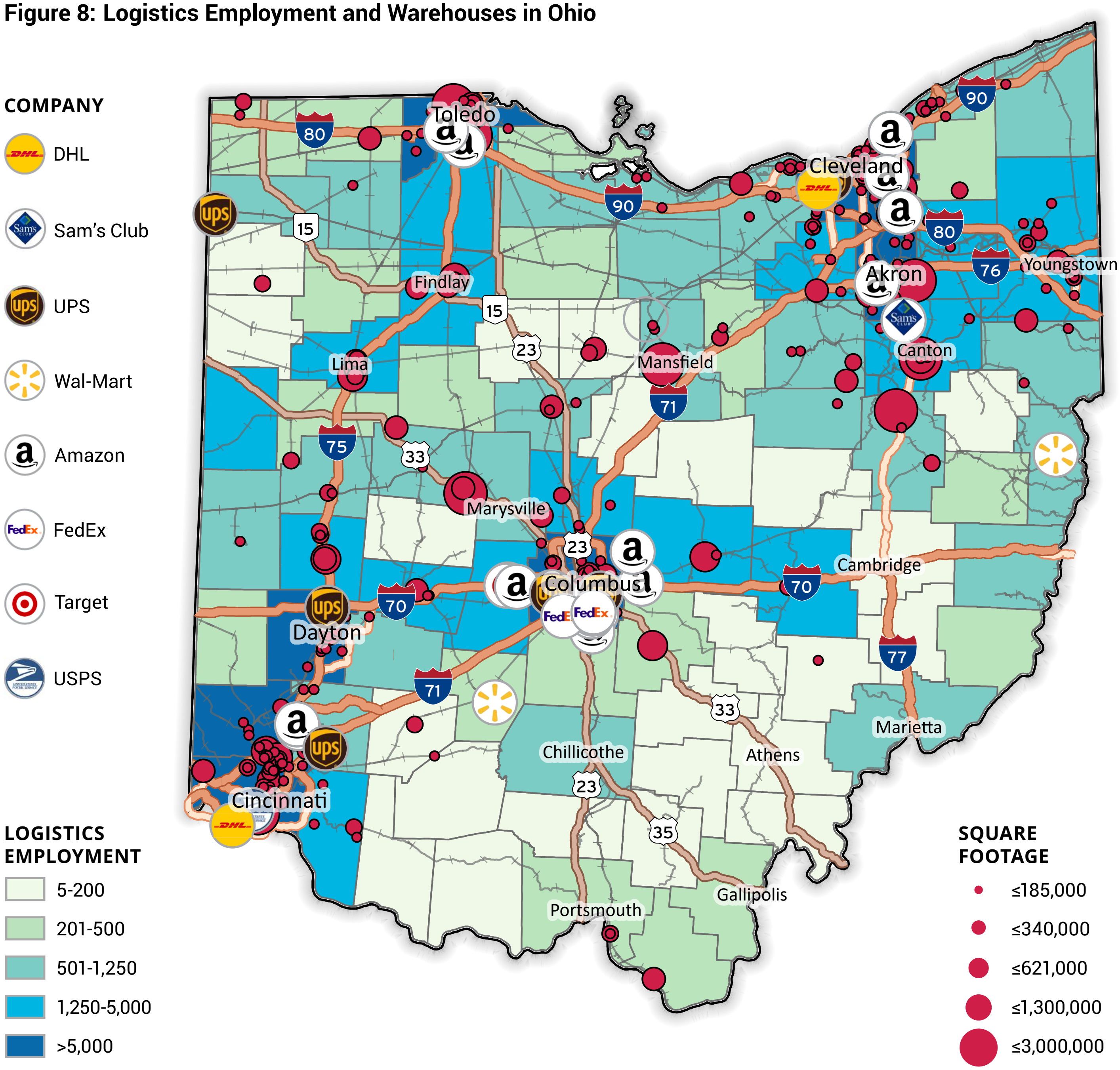
Workforce Considerations

The freight and logistics and the automotive sectors each support over 100,000 jobs in Ohio, which ranks fifth among U.S. states in warehousing, storage services and freight logistics.

DriveOhio gathered data about warehouse locations for major shippers including Amazon, FedEx and UPS to convey Ohio's freight capabilities and needs (see **Figure 8**).

A reputation for supporting the transition to electric freight vehicles will help attract more manufacturing investments and spur parallel investments in automation transforming the freight industry.

Figure 8: Logistics Employment and Warehouses in Ohio



Because EVs have about 40% fewer parts and generally are easier to assemble than ICE vehicles, there likely will be fewer auto-manufacturing jobs in the future;[28] however, it is important to note that EVs and other advanced automotive technologies have the potential to replace many lost jobs related to ICE-powered vehicle manufacturing.

To offset diesel manufacturing unemployment during the transition to EVs, the U.S. is looking to on-shore more of the semiconductor chip, lithium-ion battery, and other emerging automotive technology supply chains. Currently, shortages among semiconductor supplies are causing several automakers to cut back on vehicle production.[29] These supply chains are critical for current and future EV production and to the national and global competitiveness of Ohio and the U.S., respectively in the automotive industry.

Attracting advanced technology supply chains to Ohio will create many scientific, technical and manufacturing employment opportunities.

The battery manufacturing process begins in China, South Korea or Japan, where the cells are produced.[30] The U.S. then imports these cells and assembles them into battery modules and packs,

The opportunities in Ohio for employment as an electrician are unparalleled. EV infrastructure, beneficial electrification, data warehousing, and utility-scale solar projects currently being constructed and 'on the books' represent a massive quantity of labor hours, likely in the millions. It will require a concerted effort to ensure adequate training exists for these skilled tradespeople, many of whom are not yet a part of the existing workforce. This is particularly true when it comes to the most technical, electronic and computer-based facets of this work."

DAN SPURGEON
Vice President,
Service and Special Projects
The Superior Group

The Superior Group, headquartered in Columbus, Ohio, represents over 800 electricians.

To offset diesel manufacturing unemployment during the transition to EVs, the U.S. is looking to on-shore more of the semiconductor chip, lithium-ion battery, and other emerging automotive technology supply chains.

so they can be installed into vehicles. On-shoring the battery supply chain – from the material acquisition of lithium, cobalt and other key raw earth materials to assembly – will replace obsolete ICE vehicle positions.

The semiconductor supply chain also offers many high-demand employment opportunities. With costly shortages in the market, semiconductor availability is critical to the production of EVs and other electronics. The U.S. has acted to secure and on-shore this supply chain, investing $22 billion in domestic manufacturing and research.[31]

Over the next decade, 29 major global automakers are investing at least $300 billion into EVs.[32] Given the importance of the automotive industry to Ohio's economy, the impetus is greater than ever to capitalize on this transition and utilize the automotive resources and infrastructure already established here.

As a longtime leader in automotive manufacturing, Ohio is well-positioned to see the benefits of EV technology and manufacturing. With existing automotive manufacturing and end-to-end supply-chain infrastructure in the state and Midwest region, Ohio has a competitive advantage and can spearhead the EV transition. The economic impact of EV manufacturing in Ohio alone is projected to create 2,000 jobs, putting $135 million more annual wage dollars into the state economy.[33]

Equity Considerations

Disadvantaged communities have typically borne the brunt of expanding logistics because freight operations such as distribution centers and intermodal hubs are often built near residential communities with low-income and minority populations. These areas are also frequently located in environmental nonattainment zones.

Electrifying freight trucks would improve air quality and reduce noise pollution – two immediate, quantifiable benefits to residents.

Programs that encourage EV adoption also help address these kinds of equity concerns. For example, a Massachusetts program[34] that extends subsidies to businesses for the purchase of medium- and heavy-duty EV trucks boosts the incentives for operators whose trucks work primarily in low-income areas. Tracking the effectiveness of programs like this can also uncover lessons learned or reveal certain solutions that Ohio could utilize to encourage EV fleet adoption near disadvantaged communities.

Moving Forward

Favorable policies, advancing powertrain and battery technology, expanding availability, and superior performance will continue to accelerate market adoption of EVs, driving substantial changes in the freight sector. The speed of this transition will vary by vehicle type.

Because transportation electrification is well underway, it is important to accelerate actions to capitalize on the transition. Ohio is already in a strong position to collaborate across all levels of government and stakeholder industries.

Leveraging the state's extensive manufacturing infrastructure to streamline the transition to freight EVs, Ohio can reap the related workforce and economic opportunities for generations to come. ■

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