Quick Insights

Full-Autonomy Electric Vehicles: Charging Infrastructure and Other Implications

RESEARCH QUESTIONS

How might widespread adoption of fully autonomous electric vehicles influence personal, fleet, and truck transport? What are implications for charging infrastructure needs, distributed energy resource opportunities, and transport sector decarbonization?

KEY POINTS

- Autonomous vehicle (AV) and electric vehicle (EV) technologies have important synergies: Electric power trains are inherently amenable to automation, and increased autonomy requires additional computing power and thus onboard electricity.
- Major automobile manufacturers are leading the development of partial automation and advanced AV technologies and are incorporating leading-edge features and systems in luxury EV models.
- Diverse companies are developing and deploying fully autonomous vehicles in over-the-road applications, not waiting to deliver a generalizable solution suitable for all driving situations in all climates.
- Full-autonomy EV (FAEV) technology is expected to transform the use—and the parking—of light-duty vehicles and fleets, with impacts on charging infrastructure needs and distributed energy resource (DER) capabilities.
- FAEVs could facilitate electrification and decarbonization of long-haul trucking by enabling novel duty cycles that alleviate the battery capacity and fast charging requirements set based on driver preferences.

INTRODUCTION

AV and EV technologies, though individually transformative and emerging at different rates, are often linked. For example, small-scale AV fleets that are providing over-the-road transportation services in U.S. and international applications today operate largely on all-electric or hybrid power trains. Leading EV manufacturer Tesla features its driver assistance innovations, and many incumbent manufacturers are outfitting EVs with advanced automation technologies.

This *Quick Insights* examines the potential implications of future widespread adoption of FAEVs for the electric sector, focusing on charging infrastructure and transport decarbonization but also considering DER possibilities. Other resources are recommended for readers interested in broader review of potential AV technology implications across myriad dimensions.[1,2]

EV AND AV MARKET STATUS

EV technology is a key component of global decarbonization efforts. The transport sector accounts for 37% of end-use CO_2 emissions worldwide,[3] and electrification allows substitution of wind, solar, and other clean energy sources for direct fossil fuel combustion.[1,2]

Technology innovation, government support, and consumer demand are driving the rapid growth in EV models and sales, manufacturing capacity, and market penetration. As shown in Figure 1, global EV adoption is expected to continue accelerating through 2030 under existing national-level policies but must occur even faster to enable transport sector electrification consistent with internationally agreed climate stabilization targets.[4]

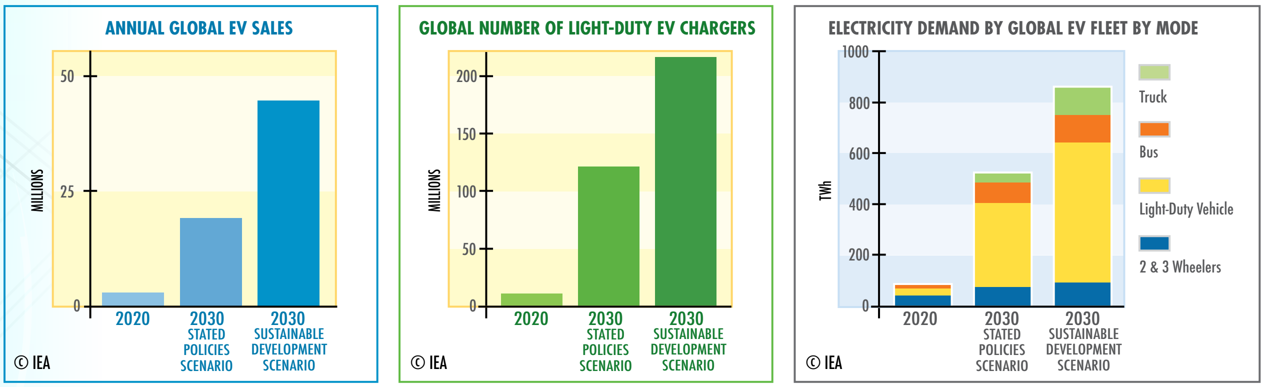


Figure 1: Growth in Global EV Sales, Charger Deployment, and Electricity Demand by Scenario[4]

Strategic and timely charging infrastructure deployments and expansions are essential for mitigating range anxiety and speeding mass-market adoption. For the electric sector, EV-driven demand growth has grid reinforcement, resilience, and reliability implications, with targeted deployment and coordinated charging representing potential mitigation options.[5] Additionally, chargers with bi-directional power flow may allow EVs with vehicle-to-grid (V2G) capability to serve as DERs.[6]

AV adoption is in the early stages, leveraging advances in artificial intelligence, robotics, connectivity, EV, and other technologies. Developers, users, and regulators are not waiting for a generalizable solution suitable for all driving situations in all climates. Instead, light-duty AVs—including purpose-built platforms and retrofits of existing vehicles, both with and without safety observers—are being deployed to provide passenger and delivery services within limited geographic areas and under certain driving conditions. Meanwhile, manufacturers are continuously rolling out EV models—and software updates—with new automation capabilities.

Figure 2 characterizes the five generally accepted levels of vehicle autonomy.[7] Most vehicles on the road today are considered Level 0 (not shown), offering limited features such as emergency braking and traditional cruise control. Level 1 includes driver assistance tools such as adaptive cruise control, which manages acceleration and braking to maintain separation distance but requires active steering. Many EV manufacturers offer Level 2 partial automation systems, where the

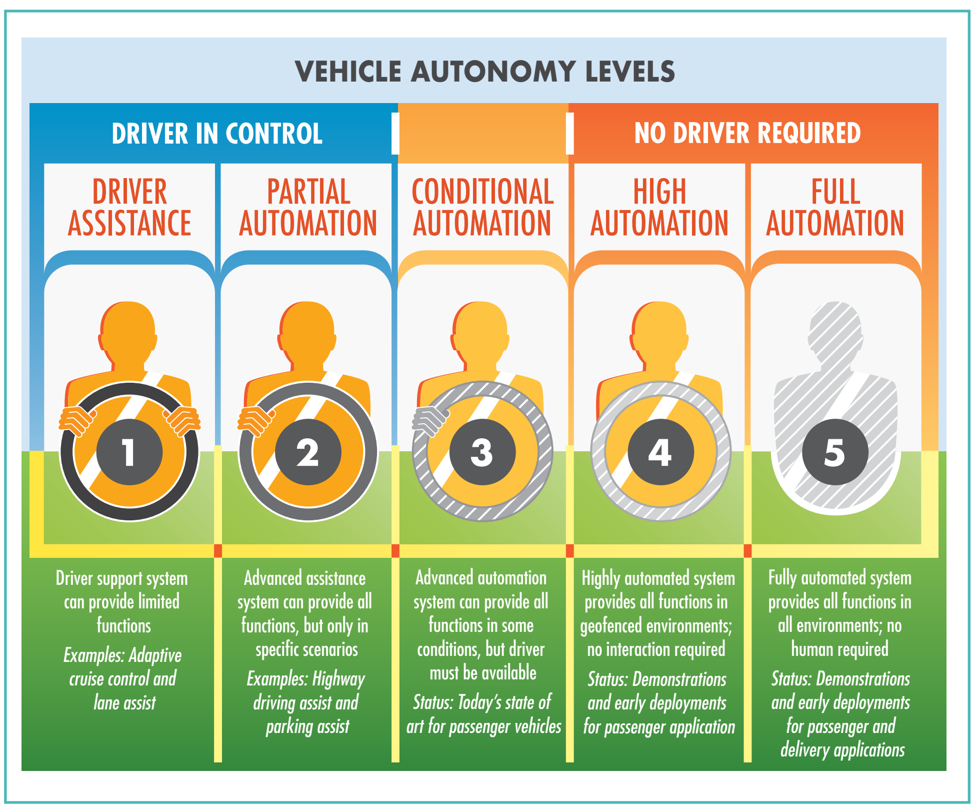


Figure 2: Vehicle Autonomy Levels

driver remains responsible but can cede control of acceleration, steering, and braking in very limited circumstances and only under active supervision.

Mercedes-Benz's "Drive Pilot" is the first Level 3 system approved for use on public roadways in Europe, initially in Germany as of May 17, 2022, on about 13,000 km (8100 miles) of highway at speeds of 60 km per hour (37.5 mph) or less.[8] Under such conditions—representative of traffic congestion on these geofenced roadways—this highly automated system requires drivers to respond and assume control when summoned but otherwise allows for extended disengagement.

Many other major vehicle manufacturers and component suppliers are pursuing Level 3 approvals and advanced automation technologies. Startups, high-tech companies like Microsoft and Alphabet, and transportation providers such as Uber also are involved in AV research and development (R&D), testing, and early deployment.[9] Level 4 and Level 5 vehicles and enabling technologies are being evaluated for passenger and delivery applications on test tracks, in small-scale demonstrations, and in geofenced settings around the world.[10]

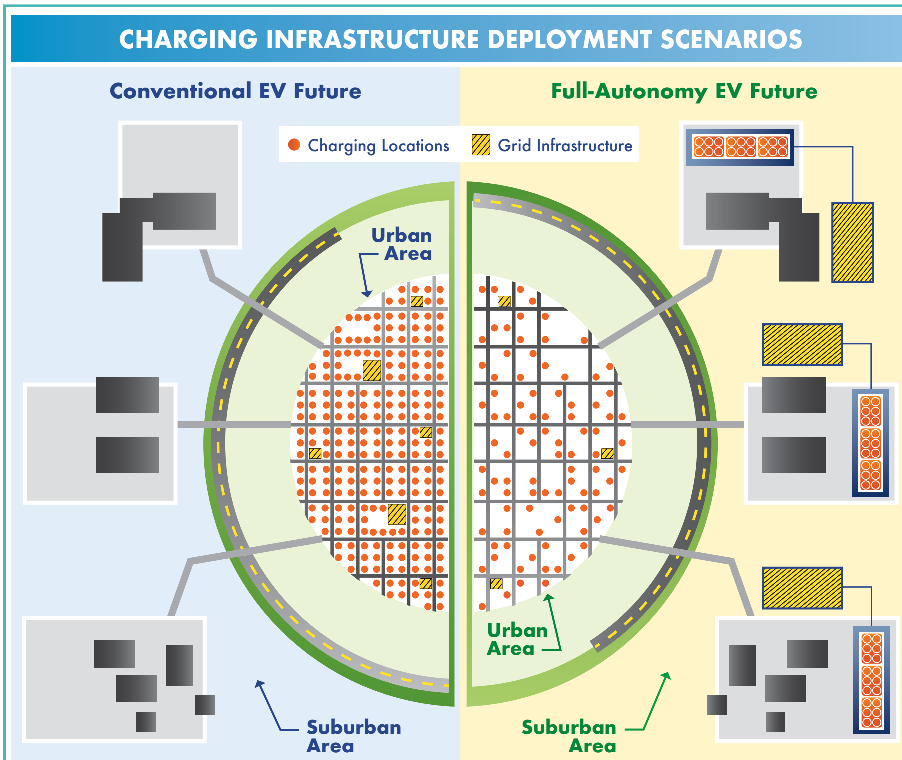
Anticipated societal benefits from broad AV technology adoption include improved road safety, reduced traffic congestion and air emissions, and enhanced mobility for individuals unable to drive due to age or disability. Fully autonomous vehicles also turn drivers into passengers and enable unmanned over-the-road operation, creating potential for transformative effects on personal and commercial transportation, including in areas such as commuting, parking, fleet operations, and trucking.

TRANSPORT SYNERGIES AND POSSIBILITIES

In support of decarbonization efforts, vehicles operating on rechargeable batteries, rather than liquid fossil fuels, are starting to change the energy basis of over-the-road transport. Relative to conventional vehicles, electric power trains are inherently amenable to automation, due both to overall simplicity and reliance on electrical rather than mechanical systems. EV batteries also can supply the additional computer, sensor, and processing power needed to support reliable autonomous operation. These synergies, combined with market trends, highlight the possibility for future widespread FAEV deployment.

For personal EVs, private ownership and at-home charging currently are the most common practices. FAEVs are expected to transform commutes—creating time for business, rest, or entertainment—and to expand shared ownership, developments that could influence parking habits and charging requirements, especially in urbanized areas. When not needed for transport, personal and shared light-duty FAEVs could navigate to remote charging stations co-located with inexpensive or free parking, then return for owner use when needed. Medium-duty box trucks and other commercial FAEVs could do the same thing during unutilized hours.

Shopping centers, office parks, public buildings, and other suburban and exurban locations could become charging hubs as shown in Figure 3. Similarly, operators of FAEV fleets could prefer to set up charging infrastructure in less developed and rural areas, to develop large depots serving broader regions, or to co-locate charging with renewable generation. Because of the diversity in duty cycles across different types of FAEVs and uses, remote infrastructure could achieve high utilization rates.



Today's EV owners do the majority of charging at home. Full-autonomy EVs could independently navigate from urban centers to parking lots at malls and other suburban locations, influencing load growth and shifting needs for charging stations and supportive utility infrastructure.

Figure 3: Charging Infrastructure Deployment Scenarios

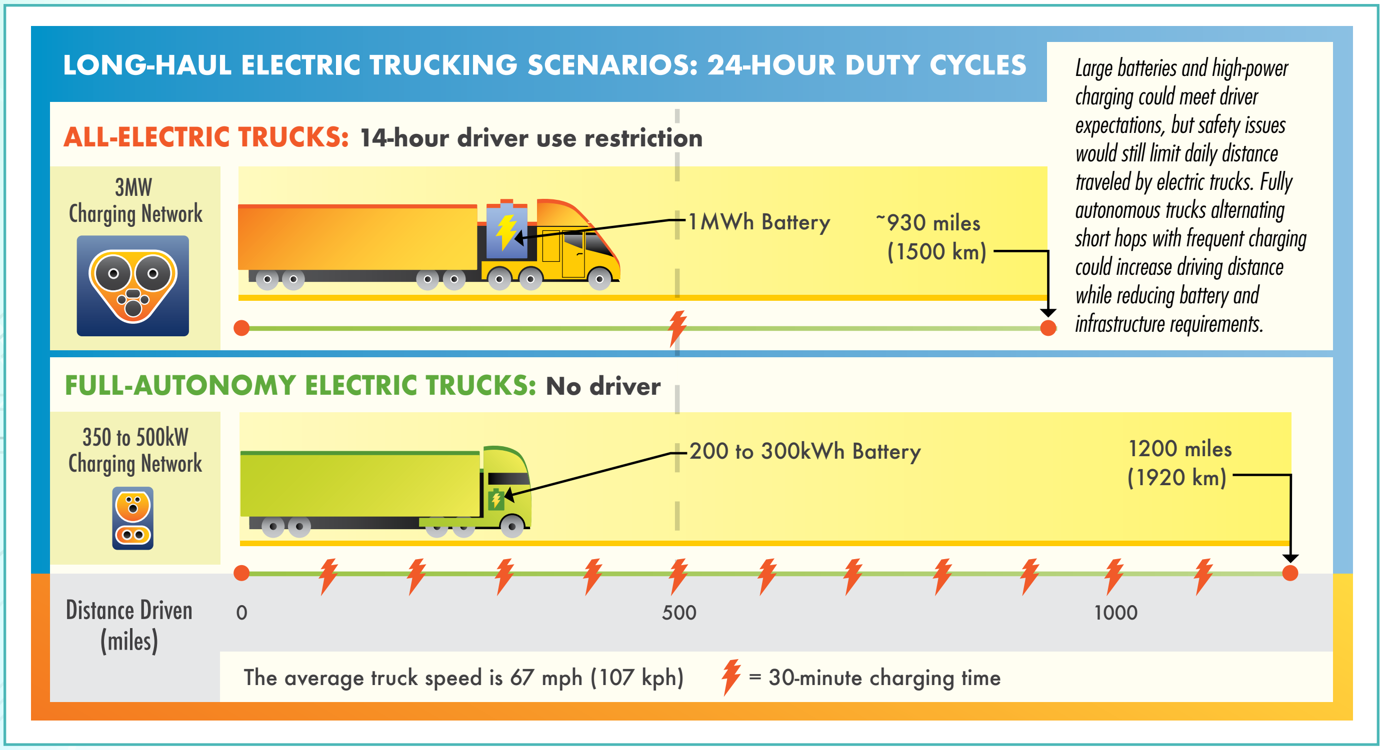


Figure 4: Long-Haul Electric Trucking Scenarios: 24-Hour Duty Cycles

FAEV platforms could also lead to increased electrification of over-the-road heavy-duty trucks, as many challenges revolve around meeting the expectations of today's drivers, which are based in part on safety requirements. U.S. regulations, for example, effectively limit drivers to a maximum of 14 hours of driving within 24 hours,[11] or about 1500 km (940 miles) at highway speeds. A conventional all-electric truck would need a 1MWh battery—preferably based on a new, lightweight battery chemistry—to achieve a driving range of at least 800 km (500 miles), while a 3MW highway charging network would be required to minimize downtime to about half an hour.

AV technology could substantially reduce battery and infrastructure requirements and costs associated with heavy-duty transport electrification—while still creating significant demand growth—by supporting a novel duty cycle involving shorter legs, more frequent stops, and driverless vehicles, as shown in Figure 4. For example, an FAEV with a 300kWh battery served by a 500kW charging network, or a 200kWh battery with 350kW charging, could travel 160 km (100 miles), recharge for about 30 minutes, and repeat, over and over. At highway speeds, this would correspond to a driving distance of about 1920 km (1200 miles) in 24 hours—about 25% farther than with an individual driver behind the wheel, but at substantially reduced cost.

DISTRIBUTED ENERGY RESOURCE POSSIBILITIES

Supplying transportation represents the first priority for FAEVs, but parked vehicles with V2G features will have the capability to supply diverse energy services to owners, charging station hosts, and the grid. *Importantly, DER uses at any given time will be contingent on having the state of charge—or time to recharge—needed for meeting the transport needs of personal FAEV owners or fleets.*

An FAEV-driven switch from residential and small commercial charging to larger stations, as illustrated in Figure 3, suggests the possibility of coordinated, continuously optimized charge and dispatch across aggregations of dozens to hundreds to thousands of intelligent FAEVs, including commercial fleets and heavy-duty trucks, based on time-varying transport needs for individual vehicles, charging rates, and revenue opportunities.

As mobile DERs, FAEVs could navigate to charging locations to provide peak shaving in specific load zones or temporary reinforcement of damaged or at-risk assets. They could charge at rural and suburban stations—perhaps drawing on nearby solar or wind power that might otherwise be curtailed—and travel for partial dispatch where and when advantageous. FAEVs also could swarm toward disaster zones then pre-charge to support emergency response and outage recovery.

Utilities are exploring a variety of use cases for transportable storage.[12] Autonomous mobile batteries could even serve as dedicated grid assets. In 2019, the U.S. Federal Energy Regulatory Commission (FERC) considered a concept involving transportable battery storage for "transmission of electric energy in interstate commerce." The proposal was dismissed due to lack of specificity, rather than on its merits as a novel non-wires alternative.[13]

IMPLICATIONS AND NEXT STEPS

The potential for broad FAEV deployment raises important questions for electricity providers, utilities, regulators, fleet operators, and other stakeholders involved in developing charging infrastructure and planning for mass-market EV adoption.

EPRI is planning a deep-dive assessment of AV technologies, R&D status, and adoption pathways for over-the-road FAEV applications, addressing diverse factors that could influence deployment timelines and charging requirements for light-duty vehicles, trucks, and other platforms. This will include the development of frameworks for evaluating

- The costs of providing charging service in dense urban areas, suburbs, and less developed regions;
- The options for meeting charging needs for over-the-road EV and FAEV fleets; and
- The potential for DER applications of FAEVs, addressing transport needs and utilization rates, customer and grid support opportunities, and cost and value of service.

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