Automotive & Assembly Practice

Building Europe's electric-truck charging infrastructure

Charging has become an integral part of the electric truck. Players compete to offer end-to-end solutions, but challenges among vehicles, charging, and the grid remain to be solved at scale.

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with Henrik Becker

The expected global mass rollout of electric trucks is going to require a dense charging network to keep these zero-emission vehicles moving. For Europe, McKinsey estimates that, by 2030, more than 300,000 public and private charge points will be required across the continent for medium- and heavy-duty trucks, up from roughly 10,000 today.

The creation of this new infrastructure represents a significant challenge. Building out robust networks of chargers will require approximately €40 billion of capital investment until 2040. Of this, €7 billion of investments are needed until 2030, less than a quarter of which has been publicly committed today.[1] Charging-network build-out will also be energy-intensive, consuming 20 terawatt-hours of electricity annually by 2030, roughly 0.5 percent of Europe's total electricity demand. Gaining access to all this energy will often mean securing additional capacity on an already congested grid.

At the same time, the possibilities are wide open. With no incumbent players fully established in the electric truck–charging market, companies from a variety of arenas have an opportunity to shape the ecosystem of market participants, creating new businesses or forging strategic collaborations.

This article is based on charging-infrastructure research from the McKinsey Center for Future Mobility and McKinsey's EV Charging Infrastructure service line.[2] We look at how Europe's charging network will evolve over the next decade and beyond, identifying major challenges players will need to solve for. Our analysis also details the steps fleet operators will need to take as they develop strategies for a successful scale-up of their truck charging infrastructure—efforts that will inevitably require collaborative actions from fleet operators; truck manufacturers; turnkey engineering, procurement, and construction (EPC) firms; finance providers; and energy and infrastructure players.

How will electric trucks be used across Europe?

Europe's first wave of commercial electric trucks will be those used for single-day travel. This includes distribution from a central facility, municipal routes, intermodal shuttles, and short hub-to-hub trips. The regular and predictable operating patterns of these trucks will allow them to recharge overnight at their depot with a low-power charger or to top up with a fast charger during, for instance, loading or unloading duties. Many of these trucks will not necessarily require public charging. Until 2030, these use cases will cover more than 50 percent of the continent's electric trucks.

Another 40 percent of Europe's electric trucks will do single-day, hub-to-hub transport of industrial or consumer goods on highways.[3] Daily distances for these trips will vary—ranging from 250 kilometers to more than 800 kilometers—but are typically regular for each vehicle. Given the longer distances involved, many of these trucks will need to supplement their depot charging with stops at public charge points.

Multiday, long-haul travel makes up the remaining 5 percent of trucks. This category of vehicles will be the slowest to electrify. Because they typically travel beyond their home base, drive long daily distances, have highly varying trip distances and destinations, and do not have many natural loading or unloading breaks in fleet depots, these electric trucks will be heavily reliant on public charging. Over time, this share of both single-day and multiday long-haul electric trucks will increase significantly as public charging becomes more available.

For each use case, fleet operators will have to navigate multiple trade-offs to define their optimal vehicle specifications. While larger batteries offer a longer driving range, they are expensive and heavier and thus have a reduced payload capacity. The more fast-charging stations available, the smaller (and lighter) truck batteries can be while still offering sufficient operational flexibility. Fast charging to top up the battery during mandatory driver breaks can be an attractive option for trucks with regular usage patterns, such as line-haul or private fleets (Exhibit 1).

In practice, such optimization is often complicated by the structure of Europe's logistics industry. Much of the road transport market does not consist of private fleets used on specific, predictable routes, but is typically deployed in ad hoc setups for individual trips or as part of short-term contracts with durations of less than three years. As such, when optimizing their vehicle specifications, most fleet operators will need to allow for a high degree of flexibility in their operations, making the planning for charging infrastructure more challenging.

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1 Based on McKinsey analysis from the McKinsey Center for Future Mobility and the EV Charging Infrastructure service line Charging Infrastructure Outlook. The €7 billion of investments includes funding for direct-charging hardware, planning, engineering, and installation, while excluding potential grid or site upgrades.

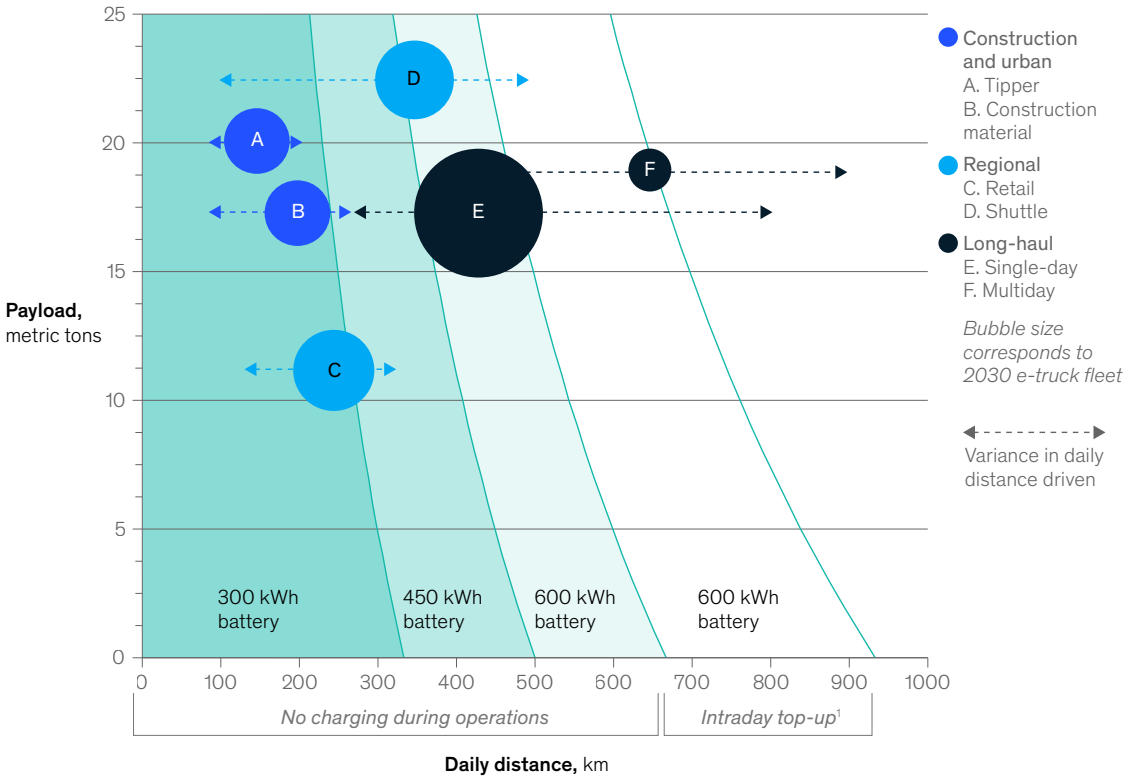
2 Unless otherwise noted, all data is from the McKinsey Center for Future Mobility.

3 Includes the 27 EU member countries, the United Kingdom, and four European Free Trade Association countries (Iceland, Liechtenstein, Norway, and Switzerland).

Exhibit 1

Charging infrastructure, driving patterns, and battery sizes have to be optimized in concert to efficiently electrify truck operations.

2030 view, use cases



[1]Assumes charging during mandatory break of 45 minutes at 400 kW DC charger.

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Europe's charging infrastructure deployment will happen in two phases

Mirroring these truck electrification trends, Europe's first phase of charging infrastructure will be installed in private fleet depots or semipublic hubs. After 2030, a second phase will allow the scaling of public charging infrastructure, given the expected additional access and capacity upgrades of medium- and high-voltage grid locations.

Between now and 2030, charging installations close to major industrial sites or logistics hubs, or even within private hubs, including directly at loading docks, will represent more than 90 percent of all charging infrastructure, requiring a total investment of €5.5 billion, and expected to cover 75 percent of the electricity demand for trucks by 2030. These chargers will serve the distribution or hub-to-hub use cases that will account for most of the first-generation electric trucks in operation. Depending on the operational requirements, fleet hubs will leverage a mix of chargers (including AC 40 and DC 50 to 400 or more kilowatts), with lower-power, slow chargers fueling vehicles overnight and higher-power, fast chargers providing top-up charging during operations, such as while loading or unloading at the ramp or during driver shift changes. This infrastructure can be deployed incrementally to synchronize with the growth of an operator's electric-truck fleet. However, the speed of rollout may also be dampened by local grid constraints for larger installations, especially in the short term.

For fleet operators that maintain their own logistics operations, the development of depot-based infrastructure offers a solid business case, given the predictable routes of short-haul trucks and the visibility operators have. For outsourced logistics operations, shared charging parks located close to hubs can help to facilitate truck electrification while also limiting the investment and operational risks for each player. Across the continent, an EBIT profit pool of €200 million is expected between now and 2030. This represents profits from turnkey solutions or from the combination of distinct charging-hardware sales, design, engineering and installation, and charge point management software on 300,000 chargers, plus wholesale energy profits.

[4] Including functionalities such as asset management, load management, and fleet dispatching.

Compared with depot-based charging, Europe's public charging infrastructure will be slow to develop. By 2030, the continent will have just 4,000 public charging points for slower, overnight charging and 12,000 fast-charging points, requiring a total investment of €1.5 billion. With an expected higher average power rating and utilization, public charging stations are expected to account for 25 percent of the electricity dispensed by 2030.[5] After 2030, however, as more and more long-haul electric trucks hit the market, public-infrastructure development will scale up. By 2040, we expect a total of 100,000 public charging points installed at locations along European highways, providing 45 percent of the total electricity used by electric trucks. These charging networks, which will be shaped by regulatory targets such as the European Union's Alternative Fuels Infrastructure Regulation or various national subsidy programs, are likely to be built and operated by specialized charge-point operators (CPOs).

We expect that public fast chargers will be the most profitable type of infrastructure, with a profit pool valued at €500 million between now and 2030. This is because fleet operators are expected to be willing to pay a premium for fast charging, such as during drivers' mandatory breaks, thus minimizing downtime. In addition, when fast chargers are being sufficiently utilized, they draw high volumes of daily energy, allowing CPOs to sell substantial quantities of this premium-rate electricity.[6] Conversely, public fast chargers carry significant commercial risk given the slower initial adoption of long-haul trucks and the larger geographic area that has to be served. CPOs may want to cover their investment risk by making some fleet operators anchor customers that guarantee a certain utilization of energy. CPOs could then charge a premium to à la carte customers.

Public overnight charging represents the smallest profit pool (€30 million), given the small number of use cases that will require this type of charging (Exhibit 2).

These projections assume that European truck manufacturers continue to develop batteries that are tailored to a given truck and not meant to be swapped between vehicles. This alternative approach of battery swapping, in which a discharged battery can be replaced with a fully charged one within a few minutes, is already popular in China, where roughly half of electric heavy-duty trucks are capable of battery swapping. Although this approach offers advantages (such as even higher vehicle uptime than current fast-charging protocols and the extension of a battery's total lifetime due to slower charging while the batteries rest in the swapping stations), bringing it to Europe would require not only a shift toward standardized (and not differentiated) battery packs but also new business models for battery financing and battery-swapping networks.

Setting up the optimal charging infrastructure means being in the driver's seat for every aspect

When planning to electrify fleet hubs, operators will need to consider a number of constraints, such as operational requirements and available grid capacity. To optimize costs and vehicle uptime for both fleet hubs and public locations, operators can follow five sets of activities.

Creating a blueprint for a cost-optimized charging infrastructure. To determine the types (size and power rating) and number of chargers needed, as well as their placement, fleet hub operators need a detailed understanding of their future electric-fleet operations. Ideally, this entails a detailed analysis of every specific truck use case, including the daily distance a truck travels, its battery size, whether charging on the go is needed, the payload the truck will be carrying, and the number of stops it will make throughout the day. Depending on the planned charging patterns, available space, and truck specifications (width, length, and turning radius), chargers can be installed at loading docks, in waiting areas, or at parking spaces. For outsourced logistics operations, charging-infrastructure needs are best evaluated in collaboration with relevant transport providers. To maximize both operational flexibility and charger utilization, these setups will often skew toward higher-power chargers in shared locations.

To avoid operational complexity, operators may want to consider installing only a limited number of different charger types at a given location. In addition, exploring changes in driver shifts or other operational patterns may help operators optimize their charging-infrastructure utilization and reduce the total number of chargers needed. All designs will need to be checked for compliance with applicable building or safety regulations (for example, insurance or fire safety) and initiated with enough time to acquire the necessary approvals.

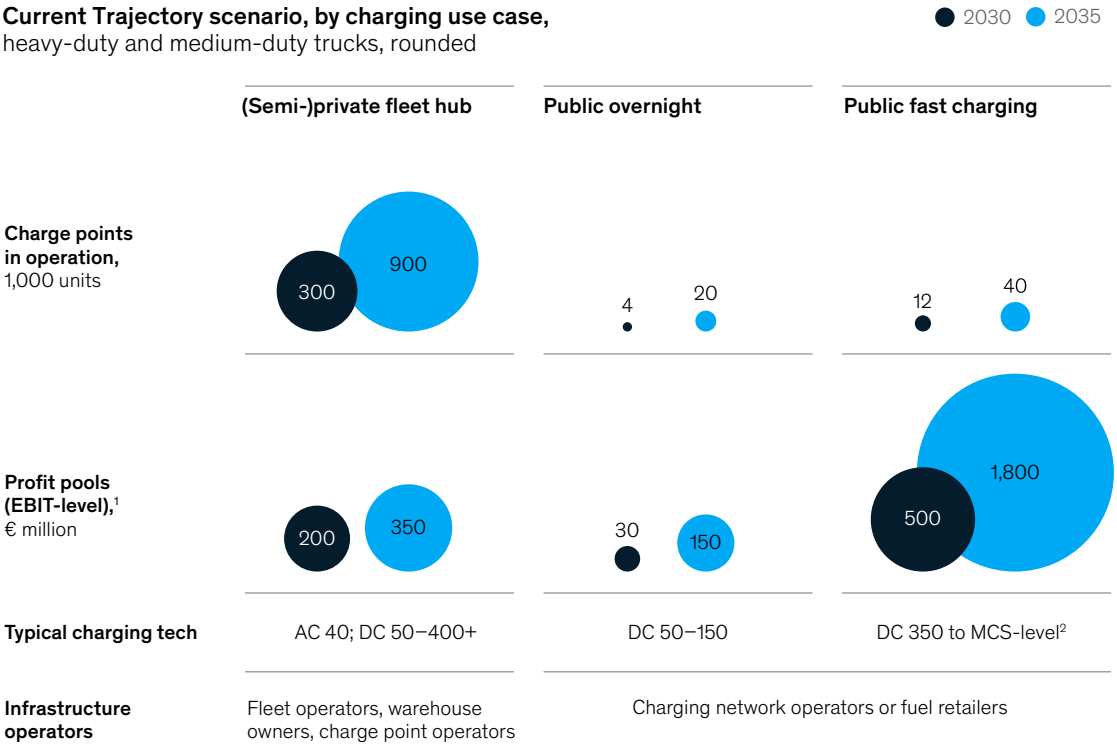
[5] Although the European Automobile Manufacturers' Association predicts 40,000 public chargers by 2030, its analysis does not consider the business case behind the rollout. Our analysis assumes 20 percent utilization of public charging infrastructure in 2030, with CPOs aiming for profitable network operations by this time. The more comprehensive the charging network becomes, the more it supports large-scale uptake of electric trucks, including across long-haul operations.

[6] An announced tender for electrification of parts of the German highway truck stop network aims to limit energy resale profit opportunities by introducing an option to leverage a fleet operator's commercial electricity rates ("Durchleitungsmodell").

Exhibit 2

Between 2030 and 2035, the number of charge points and profit pools is expected to greatly increase.

Current Trajectory scenario, by charging use case, heavy-duty and medium-duty trucks, rounded



[1]Includes EBIT pools for hardware, software, installation, energy resale, and charge point operator business.
[2]Megawatt charging system.
Source: McKinsey Center for Future Mobility; McKinsey EV Charging Infrastructure service line

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Estimating power requirements. Most fleets of electric trucks will require sizable loads of electricity. By understanding their total power demand and its distribution throughout the day, fleet operators can determine the size of the connection they will need to the electricity grid. Operational adjustments, such as changes to truck ramp times and driver schedules and breaks, can result in a more balanced distribution of power demand throughout the day, potentially reducing the costs associated with upgrades to the existing grid connection and with the total number of charging points required.

Buffer (or backup) batteries—which are charged when fewer trucks are at the station and then discharged to refuel trucks during peak demand times—can also help shave off power requirements from the grid. In addition, by avoiding expensive peak-demand charges, they can help to reduce the average cost of electricity. Such local microgrids can be further complemented with local power generation, such as through solar or wind.

Establishing grid access. Depending on a fleet operator's location and power requirements, new electricity capacity may not be available from existing grid connections and contractual frameworks. Fleet operators will need to know what's involved in upgrading their grid connection. Is it simply a commercial negotiation to change power contracts (if sufficient overhead capacity is still available), or does it take actual construction work and additional deployment of power equipment? Will they need to upgrade the substation or connect directly to the transmission network?

Grid upgrades can be costly and time-consuming, with timelines ranging from months to years, depending on the type of upgrades required. Due to these long lead times, fleets will want to develop their electrification and charging infrastructure road maps multiple years ahead of any meaningful deployment of trucks on the road. Requesting grid upgrades early could potentially lead to preferential access to any available unused capacity, reducing costs and shortening timelines.

Offering end-to-end charging-infrastructure solutions will be key for the electrification of fleet hubs.

Planning for implementation. Fleet hub operators will typically follow a step-by-step approach to installing their charging infrastructure. Determining the right ramp-up sequence and timeline will depend on the expected rate of truck electrification and the level of operational disruptions that can be tolerated during the construction phase. Operators can mitigate the costs and impacts on daily operations by selecting construction firms that specialize in the installation of charging infrastructure.

Defining the operating model. Executing on the above steps will require a variety of skill sets. These include in-depth technical expertise on charger hardware and a market understanding of permitting, standards, and energy sourcing. In addition, setting up and running charging infrastructure will mean establishing local networks to do the planning, engineering, and construction work, as well as developing the capabilities for maintenance protocols, electricity sourcing, and potentially pricing and payments for public chargers.

Some fleet operators may choose to develop these capabilities in-house, owning their chargers and building their entire value chain of electric-truck charging infrastructure themselves. Most, however, will want to consider other operating models, including outsourcing their charging infrastructure and operations to specialized CPOs or turnkey solution providers that support the operations with dedicated servicing agreements. This arrangement allows fleet hub operators to focus on their core business and avoid a capital expenditure investment. However, CPO contract durations can be lengthy, and careful partner selection is necessary because partner capabilities are frequently overestimated and service-level agreements are not always properly constructed. Another option is a collaboration among various partners, such as utility companies, charging-hardware players, and CPOs, each of which provides a particular part of the value chain.

The market for fleet hub charging is still nascent

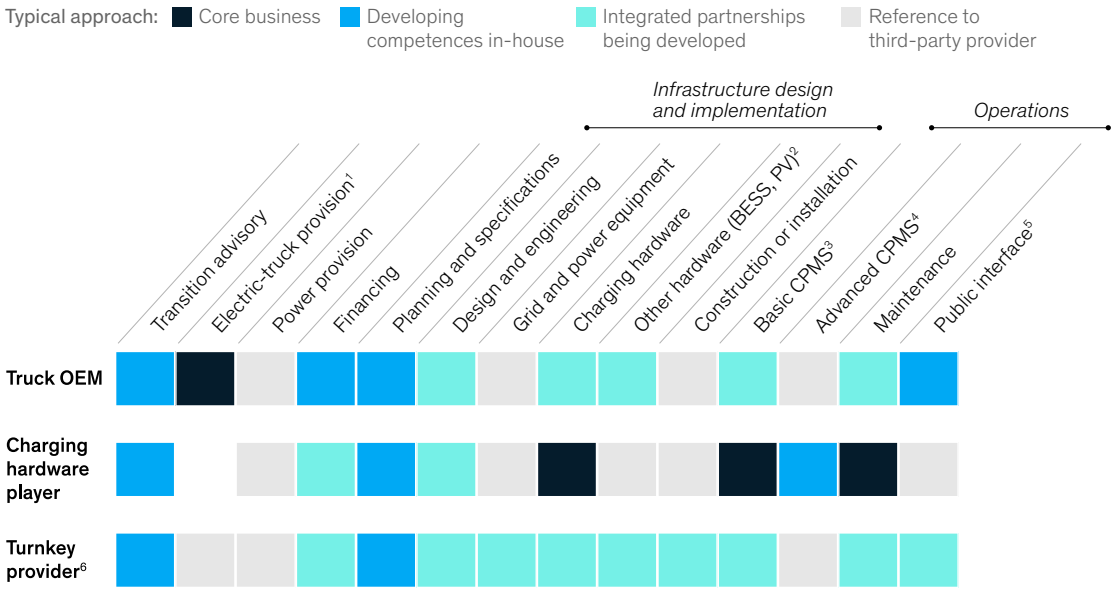
Few fleet operators have all the capabilities necessary to address each step required to deploy truck charging infrastructure in-house. Most will need support for a variety of skill sets—for example, in-depth technical insights on the interoperability of charging hardware, an understanding of permitting and energy sourcing, or the development of local networks for engineering and construction.

Truck manufacturers, utility companies, turnkey EPC firms, charging-hardware players, and CPOs can all offer value here (Exhibit 3). Yet, with the truck-charging ecosystem still evolving, protocols still maturing, and technologies still not standardized, only a few players are currently able to provide convenient, plug-and-play offerings. Offering these end-to-end charging-infrastructure solutions will be key for the electrification of fleet hubs.

A significant growth opportunity exists for players that are able to construct an attractive value proposition. The key success factor is the ability to combine subject matter expertise, power sourcing, access to financing at a national or regional level, and local networks for implementation (construction, installation, operations, and maintenance). Given the complex implementation path, a strong offering

Exhibit 3

Player types have different core competencies as starting points for integrated offerings.



[1]In many cases, charging infrastructure in fleet hubs will mainly serve subcontracted truck fleets. In such cases, there typically is no direct link between individual truck sales and charging infrastructure deployment.
[2]Battery energy storage system; photovoltaic.
[3]Basic charge point management system (CPMS) includes asset management.
[4]Advanced CPMS includes dynamic load management, grid services, and fleet management.
[5]For semipublic or public hubs: e-mobility service providers and payment solutions.
[6]For example, engineering, procurement, and construction firms; passenger car charge-point operators; utilities; and oil and gas players.
Source: McKinsey EV Charging Infrastructure service line

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in advisory, planning, and financing will be a major differentiator in attracting customers. In addition, excellence in implementation and high charger uptime will be key drivers to create sticky customer relationships, especially given the long lifetime of charging infrastructure. Both elements can create a significant first-mover advantage. Multiple players, such as truck manufacturers, utilities, hardware players, and CPOs, have a right to win in the space.

Players will need to solve for key challenges

Before any significant value can be created or momentum achieved, players will need to solve several significant challenges. In addition to the energy-sourcing issues mentioned above, fleet operators and other players face challenges related to grid upgrades, financing, approvals for charging stations, physical-space constraints, and market structure.

Grid upgrades. While pilot-scale deployment of up to ten electric trucks is often feasible with existing grid connections, most fleet hubs will require some degree of upgrades to their grid connection to charge larger numbers of electric trucks, especially when relying on fast charging. With lead times of multiple months or even years for the approvals alone, these additions are typically not only costly but also time-consuming. Additionally, there is often limited transparency about how much capacity is available at the substation and transformer level, as well as what investments and upgrades distribution system operators (DSOs) have in the works. A fragmented landscape further limits visibility. Some countries, for instance, have hundreds of different DSOs.

In a phased rollout of electric trucks, operators can kick-start the transition with a small subfleet of electric trucks and then scale up once an upgraded grid connection is available. To minimize the amount of grid upgrades needed, players could take several actions. In addition to employing smart-charging strategies that take advantage of lower time-of-use electricity rates, fleet operators and other solution providers could consider implementing

battery storage systems that would allow them to store cheaper electricity for later use. Installing microgrids of solar panels or instituting station-level load balancing could also help shave off peak power demand from the grid.

For the deployment of electric trucks at scale, most fleet operators will need strategic upgrades of transmission and distribution grids. As a first step, a centralized database of available grid capacity would significantly help accelerate and improve the energy planning process.

Financing. Charging infrastructure is a significant capital expenditure investment that many fleet operators, especially smaller ones, will be unable to shoulder on their own. At the moment, financing options are limited. Truck manufacturers and OEMs could participate via their financing arms, but infrastructure financing is far from their normal business model. Green investment funds can supply capital but will likely struggle to identify opportunities large enough to fit their typical requirements. Local banks could step in, but they typically lack the market understanding to correctly appraise the risk and long-term return profile of charging-infrastructure investments.

To support the broad rollout of charging infrastructure, new public or private funding is needed. Such schemes will need to be tailored for long-term return profiles and be able to manage relatively small investments for individual fleet locations. Additionally, aggregator players such as CPOs, which own and manage charging infrastructure at multiple sites, may achieve sufficient scale to attract interest from private sector investors. To attract the participation of financing focused on different asset classes, they could offer portfolios of varying sizes, configurations, and risk profiles.

Approvals for charging stations. Getting a new charging station up and running typically requires approvals from multiple local and country-level authorities first. Currently, lead times for these go-aheads range from three to 18 months, which can cause significant delays in implementation. Requirements that vary both by country and by local jurisdiction further complicate processes and delay rollouts. To quickly achieve scale in Europe's charging infrastructure, approval processes will need to be standardized and accelerated. Governments may also want to consider proactively identifying and preapproving potential locations.

Physical-space constraints. Many truck stops along highways, as well as fleet hubs, already face challenges in accommodating the current numbers of diesel trucks. Electric charging will exacerbate this. Significant amounts of additional space are required not only for the infrastructure itself but also for trucks that will need to be parked for longer periods of time. A first-step solution can be an integrated planning system that is used to identify and reserve additional space for both on- and off-highway truck charging. This intelligent reservation system could also help increase the utilization of available charging infrastructure. As electric-truck charging begins to scale, however, significant spatial extensions of truck stops along highways and near fleet hubs will be required.

Market structure. With most of Europe's fleet operators outsourcing their logistics operations, several practical challenges arise when designing cost-efficient charging infrastructure. For example, while slow overnight charging in a private fleet hub is a favorable option for distribution, it may not be feasible when the fleet hub and trucks belong to different companies. In addition, the short-term contract durations between freight buyers and truck operators make it hard for truck operators to tailor their vehicle specifications to specific use cases because they risk losing the ability to serve other customers efficiently.

Solutions that can help give fleet operators more visibility into the demand for their electric trucks include extending the contract durations for logistics services and using freight forwarding platforms that specialize in green logistics. In addition, shared charging parks next to private fleet hubs can offer the benefits of slow overnight charging near the trip's starting location. Such shared charging parks would require cooperation between different fleet hub operators that may be competing logistics players.

Truck manufacturers have a unique role to play

Truck manufacturers have a daunting mandate. Complying with the European Union's CO_2 emissions standards for new heavy-duty vehicles will mean aggressively introducing electric trucks into the market. For the average manufacturer, missing these targets by 1 percent could trigger fines of approximately €90 million.[7]

Yet without sufficient charging infrastructure, electric-truck sales are at risk. In addition, customers perceive charging infrastructure to be part of a differentiated electric-truck product and expect manufacturers to treat it as a core part of their offering. As a result, electric-truck manufacturers have started to enter the charging

business. Recently, some companies have set up stand-alone organizations, allocated dedicated budgets, and created competence centers for charging infrastructure. This includes a group of large European truck manufacturers that formed a joint venture to collaboratively build out a core network of public truck-charging infrastructure along major highway corridors, as well as several manufacturers that have announced their own services for depot-based charging and fleet hub electrification.

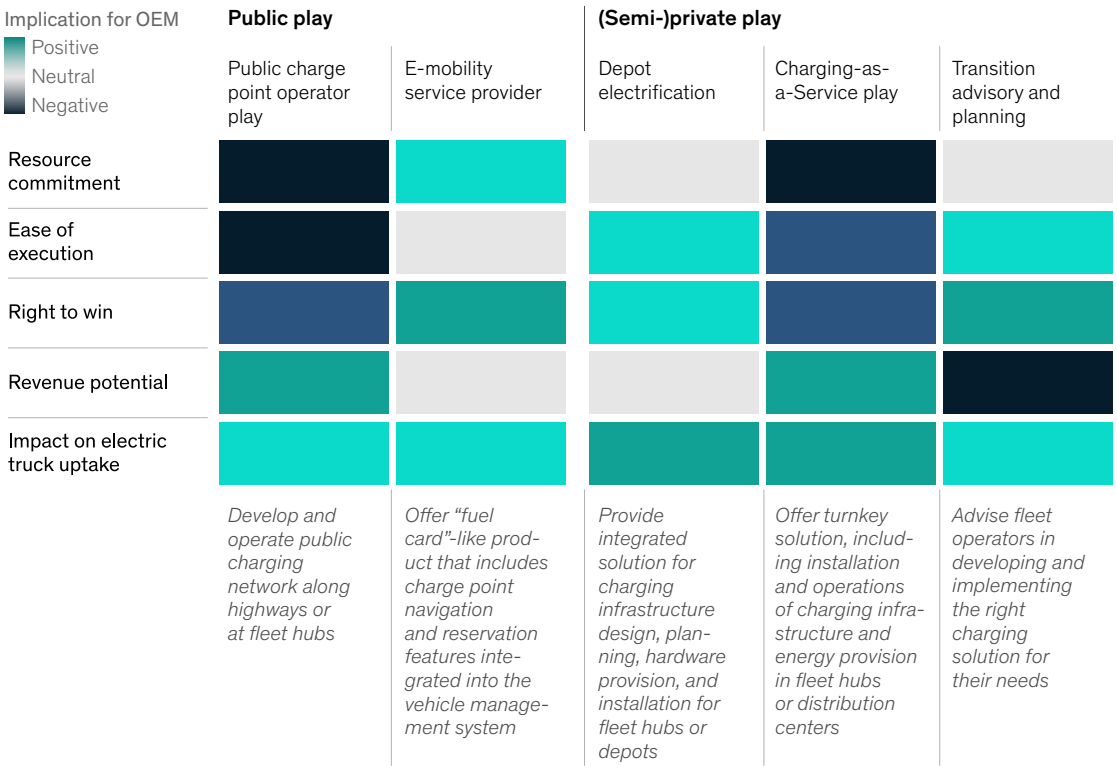
Necessary elements for a depot charging solution are planning, design, engineering, hardware procurement, financing, and business development. Beyond these table stakes, truck manufacturers can create a competitive product with differentiators such as load and energy management and e-mobility services. In the electric-bus space, for instance, electricity sourcing and vehicles sales are sometimes packaged into a bundled offering.

While there is tremendous value in offering an integrated solution, not everything has to be available in-house. A network of partnerships with local engineering firms, hardware players, and perhaps software providers can also be an effective way to address the market. The level of integration can range between a mere consulting-type approach all the way to a full CPO play (Exhibit 4). These strategies come with different risk/return

[7] Eamonn Mulholland, *The revised CO_2 standards for heavy-duty vehicles in the European Union*, International Council on Clean Transportation (ICCT), May 2024.

Exhibit 4

Truck manufacturers have a number of options to play in charging infrastructure.



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profiles, and the choice will depend on a company's ambition: is the goal to enable electric-truck sales and generate additional revenues, or is it to potentially build a whole new business?

Charging for commercial electric trucks is poised to become a fast-growing market with significant opportunities to capture value. Yet this growth could be held back by difficult challenges, including a dramatic lack of funding and a complex market structure, which would then imperil electric-truck sales.

To support the expected adoption of zero-emission trucks, €40 billion of capital investments will be required through 2040 to build up sufficient truck charging infrastructure across Europe. Until 2030, most of this infrastructure (90 percent) will be located in or near fleet hubs, supporting the electrification of distribution and hub-to-hub use cases. However, players also need to start the process of building public charging networks now to be ready to meet the fast-growing demand from long-haul use cases expected after 2030. These public charging networks offer the largest profit pools going forward.

Taking a basic infrastructure investment approach won't be enough. As players build their charging networks, they will have to navigate uncertainties about demand (given the complex market structure in logistics services) and technology risks (given how quickly charging technology is expected to advance). In addition, unlocking the full future potential of truck charging infrastructure is going to require smart approaches in new areas, such as local microgrids, energy management, and digital reservation systems.

Now is the time to create integrated solutions for truck charging that will also include financing offerings, support for electricity access, hardware, implementation, and operations. Players that enter the truck-charging market will do so with different motivations—for example, to boost vehicle sales, to create a stand-alone business, or to provide a stepping stone for an integrated offering that includes electricity solutions such as load management, energy management, and energy storage.

Regardless of motivation, all players will benefit from having both a short-term plan to start creating a product from their offering and a long-term plan to scale their offering across regions or even countries, customized to local environments. Such a go-to-market strategy also needs a clear understanding of the market dynamics that will inform what a differentiated customer offering looks like and which elements should be done in-house versus through partnerships.

Rewards exist for those who can solve today's formidable challenges. The prize is not only more electric-truck sales but also a whole new business opportunity. Once a sufficiently large fleet of electric trucks is on the road, charging players can boost utilization and tap into a more than €700 million profit pool that will be available by 2030—in a market with significant early-mover advantages and no natural incumbents.

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