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How charging in buildings can power up the electric-vehicle industry

More than 50 million electric vehicles could be sharing roads in the next five years. Updating charging infrastructure is key to scaling the industry.

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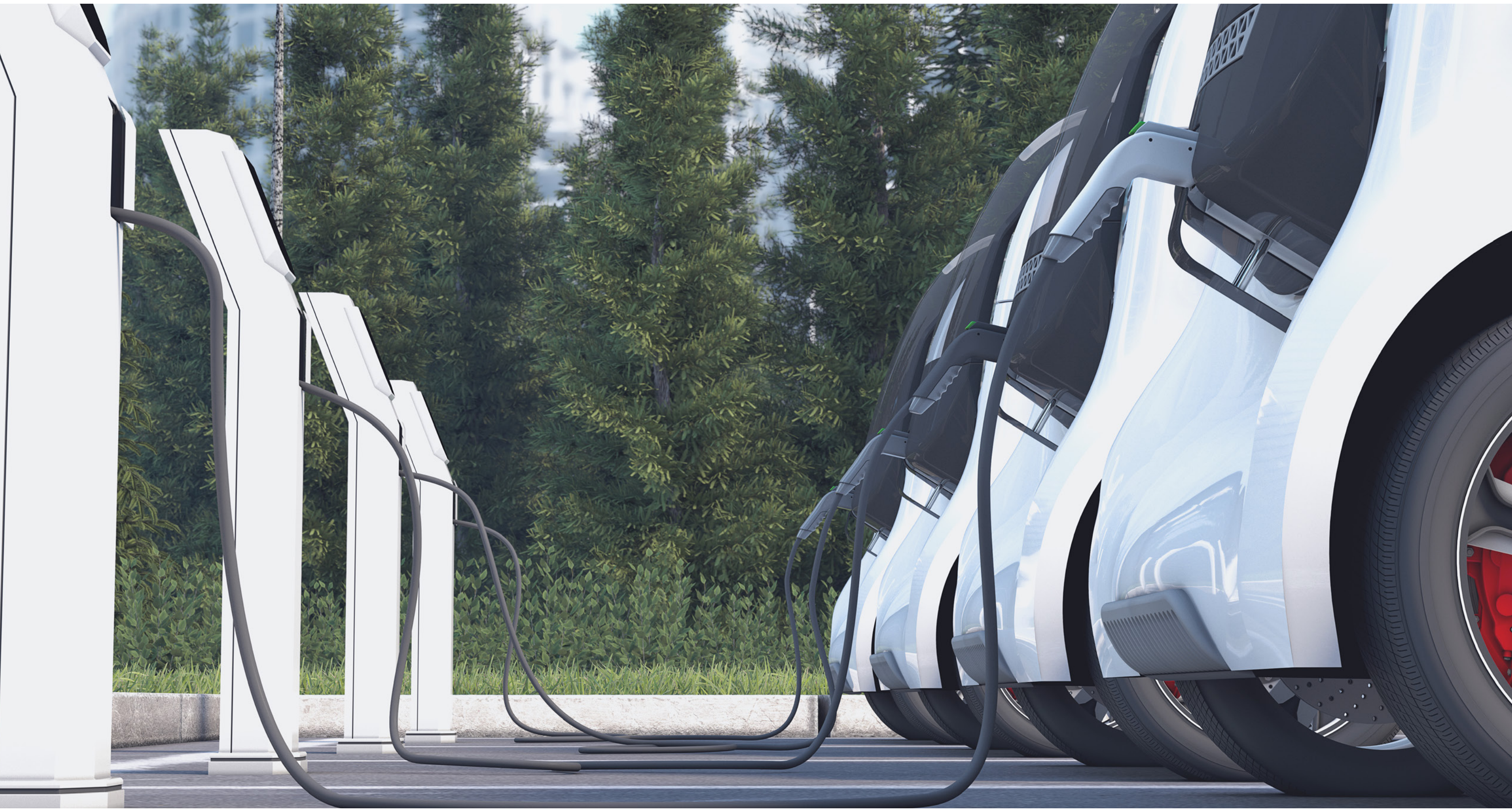

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E-mobility has reached a tipping point. More than 250 new models of battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) will be introduced in the next two years alone, and as many as 130 million EVs could be sharing roads the world over by 2030.[1] To support these numbers, significantly expanded charging is required—and it will not be cheap. In fact, an estimated $110 billion to $180 billion must be invested from 2020 to 2030 to satisfy global demand for EV charging stations, both in public spaces and within homes.

While EV charging stations in private residences are quite common today, on-site commercial charging will need to become a standard building feature in the next ten years to meet consumer demand. Across the three most advanced EV markets—China, the EU-27 plus the United Kingdom , and the United States—charging in residential and commercial buildings is the dominant place for the foreseeable future and will remain key to scaling the industry. Yet without upgrading buildings' electrical infrastructure, there simply will not be enough accessible EV chargers to satisfy demand. Further complicating matters, EV charging at scale requires careful planning of a building's electrical-distribution system as well as local electric-grid infrastructure.

To make EV chargers more accessible and affordable, urban planners, building developers, and electrical-equipment suppliers must integrate charging infrastructure into standard building-design plans. In this article, we detail the effects of expanding EV charging on infrastructure planning cycles and adjacent services. Our resulting considerations and recommendations can inform the decision making of four distinct groups of influencers: developers and property owners, urban planners and regulators, grid operators, and electrical-equipment providers.

How to integrate electric-vehicle charging into existing building and grid infrastructure

Initial attempts to mass-market EVs in the early 2000s faced technological limitations, particularly limited driving range, and ultimately failed. Today's EVs have a range of 150 to 300 miles per charge, making them more than sufficient for the 95 percent of vehicle trips that are less than 30 miles.[2] Today, the potential bottleneck is deploying charging infrastructure to service the projected density of EVs.

Over the next five years, EV sales are expected to at least quadruple in the EU-27 plus the United Kingdom and more than double in the United States, resulting in the adoption of more than 50 million passenger vehicles and more than four million commercial vehicles in China, the EU-27 plus the United Kingdom, and the United States combined. As EV prices decrease and more models become available, EV ownership will reach a broader swath of the vehicle-owning population, encompassing more than 10 percent of sales by 2025 and 20 to 30 percent of sales by 2030.

Additional regulatory support may accelerate these trends. In recent months, Denmark and the United Kingdom announced bans on sales of gasoline-fueled vehicles after 2030, while California has set a similar target for 2035. Some cities are going even further, with plans to ban gasoline- and diesel-fueled vehicles entirely over the next decade. For example, Amsterdam is already implementing a requirement that all commercial vehicles within the city center produce zero emissions by 2025, and all traffic throughout the city, including passenger cars, must produce zero emissions by 2030.

In terms of electricity distribution, a vehicle fleet this size would drive additional annual power

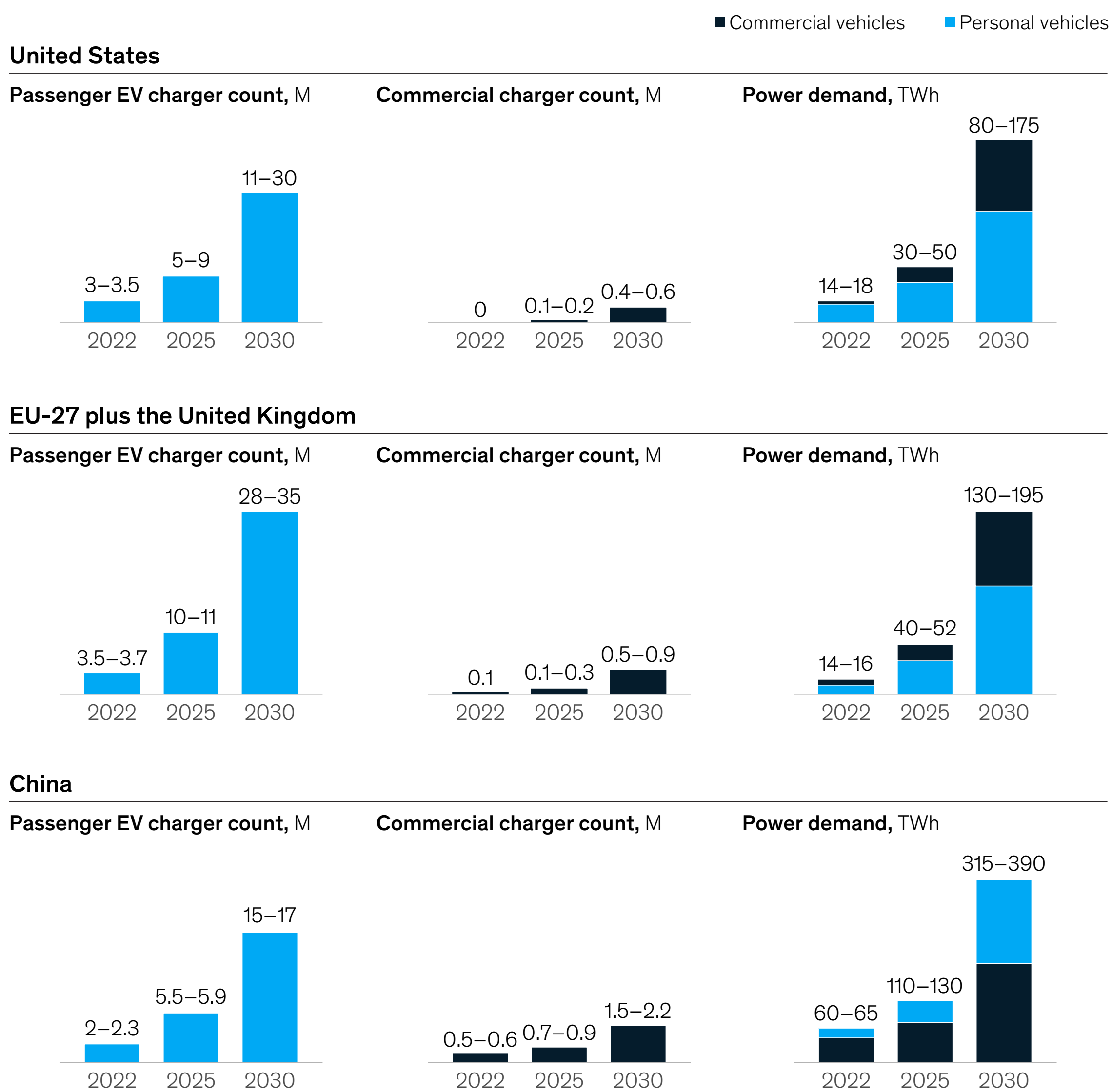
[1] Global EV outlook 2018, International Energy Agency, May 2018, iea.org.
[2] Summary of travel trends: 2009 national household travel survey, Federal Highway Administration, June 2011, nhts.ornl.gov.

demand from 180 to 235 terawatt hours (TWh) by 2025 and 525 to 770 TWh by 2030 across China, the EU-27 plus the United Kingdom, and the United States. Meeting this demand will require property owners to deploy portfolios of dedicated charge points—AC level 2 chargers[3] and DC fast chargers (DCFCs)[4]—across their facilities over the next decade. We estimate 22 million to 27 million combined charge-point units in China, the EU-27 plus the United Kingdom, and the United States by 2025 and upward of 55 million charge points by 2030 (Exhibit 1).

[3] AC level 2 chargers can supply up to 19 kWh. They run on AC power, which is the same current as other electrical components within buildings.
[4] Direct-current fast chargers (DCFCs) are the fastest chargers on the market and capable of providing up to 350 kWh. These enable passenger cars to charge in a fraction of an hour and are critical to charging the much larger batteries in commercial vehicles. However, handling higher electricity levels requires more sophisticated equipment.

Exhibit 1

The electric-vehicle market in 2030 will require more than 55 million chargers in buildings, consuming at least 525 TWh per year.



Where charging occurs and how much electricity is used depends equally on driving patterns and the availability and accessibility of infrastructure. Charging from home is currently the most prevalent option in both the EU-27 plus the United Kingdom and the United States due to the low cost of residential retail power and high rate of home ownership among affluent early adopters of EVs. Notably, those EV owners are also willing to pay for the necessary home electrical upgrades that can add $500 to $1,000 to the cost of a home AC charge point.

As EVs are increasingly adopted by less affluent buyers and those who live in multiunit housing (with limited access to home charging), public charging stations in workplaces, as well as dedicated EV charging hubs will become more commonplace. This is especially true in China and the EU-27 plus the United Kingdom, where the sparsity of single-family homes with in-home parking has resulted in a higher ratio of EVs to charge points than in the United States.

Put simply, the location of charge points will continue to expand beyond single-family homes to affect a wide range of building types. This is especially true of areas that attract large numbers of vehicles, such as apartment complexes, offices, fleet depots, parking lots, and commercial centers.

AC level 2 charge points will constitute the majority of passenger-car charging stations, as they are typically tied to homes, workplaces, and temporary destinations such as stores or street parking. While a full vehicle charge could require anywhere from two to eight hours on an AC level 2 charger, it is rare for an EV battery to be fully depleted outside of long-distance trips. Even so, the amount of time a car is parked at any of these locations, whether it be overnight or during work hours, is adequate to constantly maintain a full charge under all use cases. Supporting passenger EVs will require more than 50 million AC level 2 charge points in homes, workplaces, and other temporary destinations by 2030 across China, the EU-27 plus the United Kingdom, and the United States.

On the commercial side, major fleet operators will accelerate their depot electrification as EVs become cost competitive for an increasing share of routes. Local and regional routes will likely be the first to electrify by utilizing vehicles such as delivery vans that can be charged overnight using AC power. Thus, AC level 2 chargers will drive most of the three million commercial charge points by 2030 in China, the EU-27 plus the United Kingdom, and the United States. Only toward the end of the decade do we expect a significant increase in commercial DCFCs, driven by the large batteries required for electric heavy-duty transport.

The 'hidden costs' of electric-vehicle chargers

The costs of charging hardware, power distribution, and software and services far exceed the hardware cost of the charger unit alone (Exhibit 2). And while this can create headaches for building owners and grid operators who have not planned for future charging needs, it can also create opportunities for vendors who are able to adapt to the energy transition.

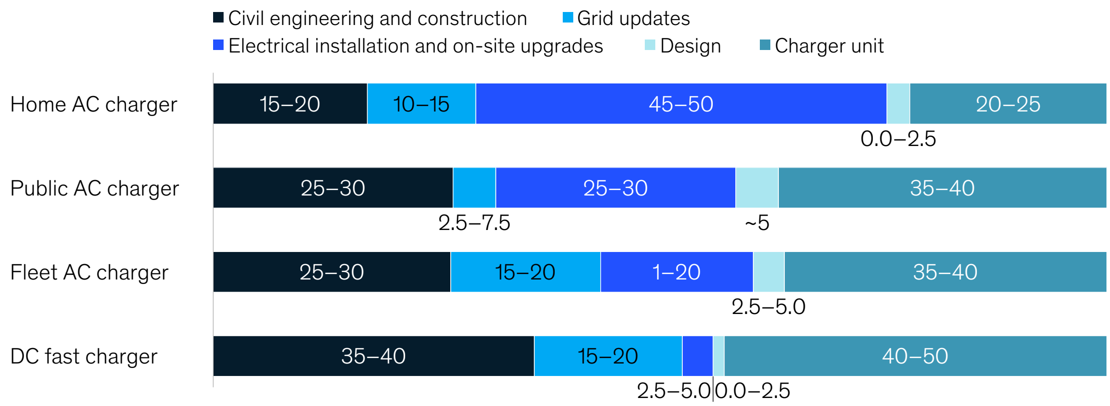
Charger-unit costs can be as low as $400 for home charge points, $2,400 for public AC level 2 charge points, and more than $30,000 for lower-end—50 to 150 kilowatts (kW)—DCFC points. When combined, however, the following additional costs can represent a majority of the total up-front costs of an EV-charging solution:

— Electric-grid upgrades are necessary when on-site power availability is inadequate. For small deployments of AC chargers (homes and small businesses) these costs are unlikely to be significant in the near term, as the density of chargers located in the same area is not high enough to overload the local infrastructure. However, the picture is different for large

Exhibit 2

Depending on the type of charger, hidden costs can represent 50 to 75 percent of total up-front costs.

Total up-front costs by component, %



deployments of AC level 2 chargers as well as for any number of DCFC chargers. In these instances, it is almost always necessary to upgrade the power supply (main breaker) and distribution transformer, which can represent on average 15 to 20 percent of project costs. In particularly large deployments, it may also be necessary to upgrade the distribution grid feeder and substation. Where such major grid upgrades are needed, the lead times required for the local grid operator to execute the work can introduce significant delays of 12 to 18 months, depending on how the work is prioritized. Fortunately, many of these costs and delays can be mitigated by planning for future EV-charging demand during building constructions and retrofits. New solutions for coordinated vehicle charging (smart charging) will also enable more vehicles to charge on a constrained electrical system without causing power outages.

— Civil construction (trenching and boring) projects will be necessary to retrofit buildings designed before EV-charging needs were considered. The cost of new civil construction projects can be several times that of the charger itself, reaching as high as 15 to 30 percent of total up-front costs for AC level 2 chargers and 35 to 40 percent for DCFCs. Perhaps more crucially, these costs are unpredictable and frequently depend on site limitations that are not known in advance. This is another scenario where advance preparation can significantly reduce costs. Building owners who choose to run electrical conduit to parking spaces during initial construction (at less than $50 per parking space) can then install chargers in the future with no additional civil construction costs and potentially save thousands of dollars.

— Design and engineering are key for complex on-site solutions (public AC, fleet AC, and DC fast chargers) and can represent anywhere from 2.5 to 5.0 percent of total costs. These charges are less prevalent in home-charging solutions, though a growing number of jurisdictions now require electricians to obtain building permits for AC-charger installations.

— Electrical installation and on-site upgrades, which include panels, circuit breakers, new cables and wiring, and upgrades for metering and power distribution, as well as electrician labor, can comprise as much as 15 to 30 percent of up-front costs for public AC chargers and 45 to 50 percent for home AC chargers. These costs will typically be a lower share of the overall project for DCFC installations.

Charging network fees and data coverage are a much smaller percentage of the overall up-front costs but represent recurring operating costs for the life of the charging unit. So-called soft costs such as overhead, marketing, and opportunity costs can also vary by project type and region. For example, many charging developers cite negotiations with property owners for use agreements as the largest driver of project delays and associated costs.

The largest hidden cost is often the electricity itself. Peak demand charges, which are based on increments of time when power use is at its highest, can be significant in the United States, especially if many EV owners charge their vehicles at the same time. Demand charges for a 16.8 kW charger in the United States can reach $1,600 per year, at a typical value of $8 per kW per month. To put this cost into perspective, it represents 30 percent of the charger cost on a recurring basis.

Further compounding these challenges, directly maintaining and operating public chargers can be onerous. Instead of managing maintenance, customer service, and billing activities directly, many building owners are turning to charge-point operators to provide these services.

Viewed in isolation and on a per-charger basis, these costs seem reasonable, at least when compared with the cost of the vehicle. However, in the aggregate, they suggest the need for significant investment associated with electrifying both personal and fleet vehicles.

The coordination and involvement of various entities

Given the challenges and costs detailed thus far, as well as the need to integrate chargers with the existing building and grid infrastructure, installing the number of stations needed to scale EV adoption will require the coordination and involvement of entities that may have conflicting interests:

Building developers and owners bear the cost for installing charging infrastructure on-site. Currently, charging units are often perceived as an amenity rather than a direct source of revenue, and building owners are incentivized to meet customer demand at the lowest price point possible. As a result, most building owners may delay the installation of charging units at the risk of paying more in the long term for expensive retrofits.

Urban planners and regulators can limit costly retrofits by setting standards for charging-infrastructure build-out that drive deployment of cost-efficient power capacity in greenfield construction. Already in 2020, the International Code Council added a provision in the model-building code that sets minimum thresholds for EV-capable and EV-ready parking spaces.[5] The EU-27 plus the United Kingdom now requires member states to enact regulations on the installation of a minimum number of charging points for all nonresidential buildings with more than 20 parking spaces by January 1, 2025.[6]

Electrical consultants, engineers, and architects define the electrical-distribution requirements and parking layout for new developments and renovations for medium-size buildings. Many building owners do not think of or plan for EV-charging needs five to eight years out, even when conducting a ten- or 20-year site plan. Electrical experts brought in to advise on the overall power needs of buildings can help building owners save thousands of dollars through simple preparation such as running an electrical conduit to parking spaces where it can be easily accessed for future charging installation.

[5] Michael Coren, "New US building codes will make every home ready for electric cars," Quartz, January 9, 2020, qz.com.
[6] Benjamin Uyttebroeck, "New buildings in Europe required to have EV charging points," Fleet Europe, April 20, 2018, fleeteurope.com.

Charge-point operators will play a key role in managing public chargers and in offering a wide range of charging options best suited for public building needs, from turnkey models to pay-per-minute or per-kWh models.

Distribution operators and utility companies should be consulted on nearly all projects that exceed approximately 10 kW to study the implications on power-distribution equipment. More comprehensive feeder and medium-voltage network upgrades should be considered for DCFC projects and large deployments of AC level 2 chargers. Early planning and adoption of charge-management and building-energy-management solutions are likely to save major fleet and commercial customers millions of dollars in feeder upgrades and demand charges.

Charging equipment providers will likely be brought in by other players, such as designers, electricians, or installers. However, several providers are racing to differentiate themselves by offering user-friendly, interoperable solutions with low total cost of ownership. Their ability to bundle EV charging with energy and energy storage—and even solar power—will be crucial due to the high costs of the required site-level and grid-side upgrades, as well as the impact of peak demand charges.

The path forward

Short-sighted decisions made today over electrical and civil infrastructure and the capacity and technology of charging solutions could cause EV-infrastructure costs to compound to hundreds of billions of dollars. Added to the already-severe costs of peak demand charges and grid upgrades, the impact of this additional investment could stall the progress of fleet electrification as well as affordable, unhindered access to EV charging. Market participants that hope to stay competitive should adhere to the following best practices:

Property owners and building operators

Plan early, think long term: Building out electrical capacity and running conduits during greenfield construction or planned retrofits can help prevent expensive additional work down the road. Owners and operators should integrate this into the capital planning process. In fact, the additional costs of a retrofit can be up to five times the cost of deploying chargers during initial construction.

Consider energy management as an alternative to electrical capacity: Building your site's electrical capacity to solve for peak load may cost more than an integrated site energy solution that relies on energy-management technology to control charger use. On-site generation and storage solutions may also be economical. These solutions can enable you to avoid expensive demand charges that may not be a consideration today but could become considerable with high EV adoption.[7]

Match solution to brand: Owners and operators should identify the types of chargers and payment offers that fit their customers or employees. This can be accomplished by asking a series of key questions: What power level do you offer? Do users pay? Do you provide an inexpensive connector cable or a high-end charge point? Does the charging interface link to other payment profiles or accounts (such as payments tied directly to monthly rent or reviewable through a web portal)?

Identify the right business model: Do you want to own and operate the charger; own and contract the operations; or have customers, tenants, or employees pay a third-party provider for charging as a service?

Grid operators or integrated utilities

Proactively engage high-potential customers on their charging needs: Today, major fleet operators, shopping centers, and corporate offices are faced with decisions that will affect their ability to cost-effectively host EV chargers on their premises. Identifying opportunities to mitigate grid upgrades or coordinate their development with the grid-expansion plan could lower costs for all customers and drive electrification in operators' service territories.

[7] For more on EV adoption, see Stefan Knupfer, Jesse Noffsinger, and Shivika Sahdev, "How battery storage can help charge the electric-vehicle market," *McKinsey on Sustainability*, February 23, 2018, McKinsey.com.

Ensure fair pricing: While demand-based, time-of-use rates and other complex rate-design mechanisms can be a headache for customers, they represent a price signal that could be an incentive for coordinated charging behavior. A stable price signal that truly represents the underlying grid infrastructure and energy costs will be key to ensuring that customers make thoughtful decisions to minimize costs.

Integrate EV-charging forecasts with grid-expansion plans: The impact of EV charging on grid infrastructure will be unevenly concentrated in specific regions. Concentrated residential chargers and massive DCFCs will likely be significant drivers of power demand. Every grid operator should have a geospatial model of EV-charging uptake as well as a hosting-capacity map of areas of the grid where DCFCs can be installed at low cost.

Create mechanisms for capturing flexibility: EV charging can bring more than 140 TWh of flexible load in the United States and more than 200 TWh in the EU-27 plus the United Kingdom by 2030. Except for fast charging, drivers are likely to be indifferent to the exact timing and rate of charging. This unprecedented level of demand-side flexibility can be used to balance the intermittency of renewables and avoid curtailments. The load of utilities will be key in providing the price signals and mechanisms to capture this flexibility.

Charging-solution providers and operators

Build nuance in the business case: Hidden costs are likely to make or break the business case for an EV-charging station. When siting a station, the decision might depend on geospatial features (flat and free of existing structures and obstacles) as well as on the spare capacity of the local transformer and substation.

Coordinate for open-charging standards: Open-charging protocols and standards and charger interoperability will be key to unlocking an ecosystem of charger operators, charging network providers, energy aggregators, and energy-management providers.

Design for the needs of buildings: Charging-solution providers have made strides in designing user-friendly solutions tailored to EV owners' needs. That said, it is also key to design with building owners and operators in mind. Lowering installation costs by facilitating low-cost electrical upgrades, enabling cross-charger coordination and energy management, and planning for future expansion will be critical in the years to come. Considering EV-charging infrastructure outside of the context of a building's total energy demand, existing electrical infrastructure, and grid connection will determine the total cost of ownership for the site owner.

EV-charging infrastructure will operate at the nexus of three different sectors with distinct but interdependent roles in the energy transition: electric power, buildings, and transportation. There is an opportunity today to shape EV-charging strategy to benefit each of these sectors independently, accelerate the progress of the energy transition, and reduce costs for consumers, EV owners, and nonowners alike.

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