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CHARGING BEHAVIORS IN URBAN CENTERS

THE NEED FOR AN INTEGRATED EV ENERGY ECOSYSTEM

The transition to electric mobility represents a systemic transformation that extends beyond vehicle technology to encompass distributed energy production and grid integration. This study examines EV adoption patterns and charging behaviors among GenZ and Millennials across Europe and Asia to understand consumer readiness for Vehicle-to-Grid (V2G) paradigms. Through survey-based research conducted by Mobius Lab in 2025, we analyzed responses from 5,650 urban residents born between 1980–2008 in five major countries (France, Germany, Great Britain, China, and India). Our findings suggest that sustainable urban electric mobility necessitates integrated energy ecosystems combining distributed self-production, V2G technology, and supportive policy frameworks. The research provides empirical evidence for policy choices moving toward decentralized urban energy systems where vehicles function as mobile energy storage units.

ELECTRIC VEHICLES (EV)//VEHICLE-TO-GRID (V2G)//INNOVATION//ENERGY//SUSTAINABILITY

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Despite recent years of turbulence – driven by competition from Chinese manufacturers and the political exploits of its founder – Tesla will always mark a turning point in mobility history. The company, in fact, introduced two systemic innovations: first, autonomous driving, which will revolutionize how we move across short, medium, and long distances; second, an integrated ecosystem of electric energy production and storage for mobility. Tesla was the first (and is still the only) EV manufacturer to offer solar panels and electric energy storage systems, conceptualizing EVs not merely as electric-powered vehicles, but as batteries on wheels.

To grasp the implications, consider cars parked throughout the day on city streets. Those vehicles contain hectoliters of stationary fuel – energy sitting idle, waiting to be released in only one way: by starting the engine. Now imagine when all those fuel tanks become batteries. That means thousands of kilowatts ready for use not only to power the car, but in countless other applications too, when connected to the grid. Unlike fuel, electric energy requires no pipes to be transported, just a cable connection (or even wireless transmission). Thousands of vehicles would be charging when and where energy costs the least (at home with solar panels, or overnight when kW rates drop), ready to channel surplus energy back into the grid when parked, meeting demand peaks during the city's daily activities.

From this perspective, the electric mobility revolution transcends vehicles and transportation, inaugurating a cleaner, more distributed approach to energy production and grid integration. Roadside charging stations would evolve beyond mere refueling points, becoming exchange hubs between the grid and all those mobile batteries on wheels. Consider this scenario: An owner recharges her battery using energy from her own solar panels, uses a portion of it to drive her car, and then feeds the excess back into the grid when and where it's needed. Alternatively, she purchases energy during low-cost periods (when demand is lower, such as overnight) and finds herself with surplus energy to sell back during peak demand. This is the V2G (Vehicle to Grid) concept, now commercially available. Two major European automakers launched V2G solutions in 2025: a leading French manufacturer introduced the first V2G-ready charging station in spring, while a famous German brand launched the first in a family of models based on a new technological platform supporting both V2G and V2H (Vehicle to Home) in September.

The EU's Horizon program earmarked its largest resource allocation in the most recent edition for electric energy storage systems. Renewable sources like solar and wind require such systems because their production depends on atmospheric conditions, making output inconstant and unpredictable. These sources can't respond to demand fluctuations without storage infrastructure. Electric vehicles represent a compelling solution to this challenge, harmonizing mobility needs with clean energy production requirements.

To deliver genuine benefits to EV owners, this approach works best when paired with energy self-production, or at least access to private charging points like wallboxes rather than public stations. As any EV owner knows, at equivalent mileage and moderate speeds, energy costs at current kW prices from charging stations exceed fuel costs at gas pumps. Currently, one kW enables approximately five kilometers of travel (source: Electric Vehicle Database, 2025), extending to six kilometers through energy recovery systems[1]. Given that one kW at public European charging stations costs between 29 and 89 euro cents, with an average of 59 (European Alternative Fuels Observatory, 2025), simple math reveals that operating costs favor ICE vehicles.

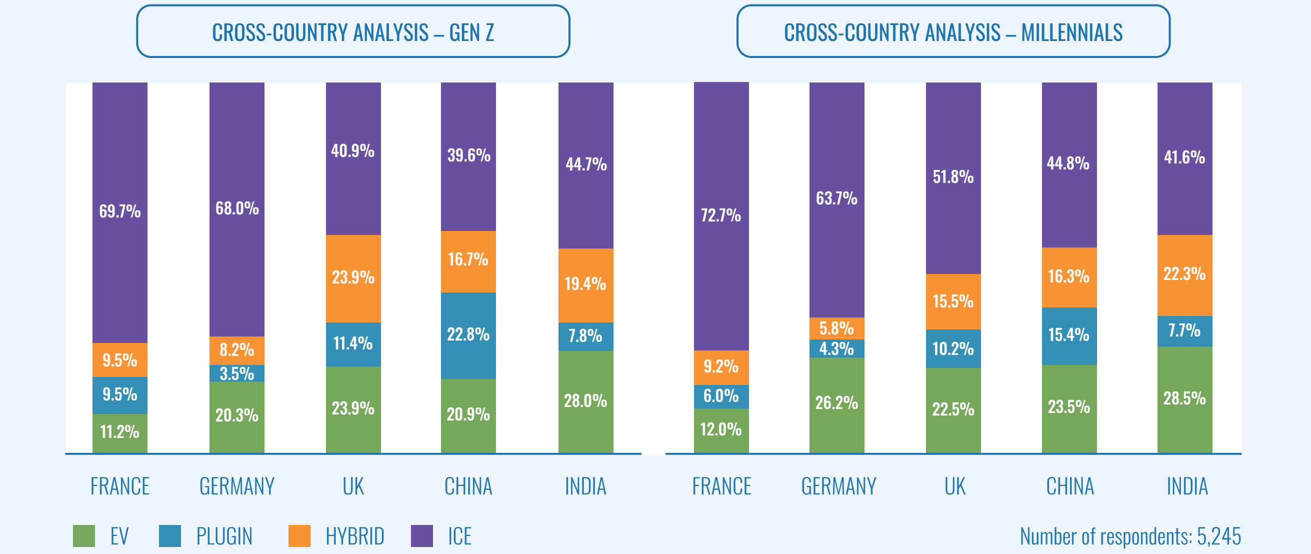
Setting aside various incentives, EV operating costs become competitive only when energy is self-produced (or obtained at rates below public charging point prices). Put simply: EV ownership incentivizes investments in private production systems. Approaching electric mobility without this systemic perspective obscures the true scope of the transformation underway.

This phenomenon represents both opportunity and necessity, one that will become increasingly apparent as electric vehicle numbers grow. Estimates suggest that if all currently circulating vehicles worldwide were battery-powered, electricity production would need to surge more than tenfold. This scenario would create energy production bottlenecks, driving up kW prices at charging points and pushing EV owners toward investments in private production systems (typically solar panels and micro-wind installations). Given current technology, electric mobility and distributed self-production emerge as the twin pillars of urban mobility. The V2G framework facilitates such investments by enabling owners to offset system costs by selling battery-stored energy.

If this marks our destination, we must understand consumer readiness to embrace this

1 Automakers are investing in R&D to improve the efficiency of electric motors, but currently they don't exceed eight kilometers per kW.

FIGURE 1. POWERTRAIN TYPE OF CAR OWNED, BY COUNTRY AND GENERATION



paradigm. Radical innovation adoption benefits from easy associations between new and familiar technologies (Arts et al., 2011). In other words, when new technology usage methods resemble established ones, familiarization and adoption become easier. Let's explore this further. Charging an EV differs dramatically from refueling an ICE vehicle. For instance, it takes far longer to recharge than it does to refuel; a full charge lasts far less than a full fuel of gas; and the concept of channeling battery-stored energy back into the grid when the car is parked contrasts sharply with the experience with a fossil fuel vehicle. In light of all this, it becomes apparent that understanding current EV owner behaviors, their charging experiences, and the reasons why they chose their vehicle helps discern future leverage points for V2G adoption (Morissey et al. 2016; Pagani et al, 2019; Varasipuram et al., 2021; Kamana, 2024).

Valuable insights emerge from research conducted in 2025 by Mobius Lab across five major countries (France, Germany, Great Britain, China, and India). In the study, interviews were conducted with 5,650 drivers living in major urban centers, born between 1980 and 2008 – in other words, Millennials and Gen Zers from large cities. These individuals will drive for decades to come, so they represent the critical demographic for electric mobility paradigm success. Researchers examined urban mobility behaviors of these generations to spot patterns that could map out the possible future evolution of urban infrastructure. A specific research component zeroed in on charging behaviors among EV owners, yielding data that confirms the viability of future urban mobility that will be integrated with decentralized electric energy production and distribution systems.

REASONS WHY YOUNG PEOPLE PREFER EVS

In the largest urban centers across observed countries, younger generations demonstrate strong interest in battery-operated vehicles, both electric and plug-in hybrids. While powertrain penetration varies between countries and generations (as shown in Figure 1[2]), these vehicles represent a notable market share.

2 Only 5,245 out of 5,650 owned a car.

China and India show higher battery vehicle penetration: Over one-third of owners report having electric or plug-in hybrid cars. Significant differences exist between countries regarding battery engine types, plus there are generational variations as well. In China, 43.7% of Gen Z and 38.9% of Millennials own battery-operated cars, while in India these percentages drop to 35.8% and 36.2% respectively. The battery car fleet composition varies in interesting ways by generation: Chinese Gen Zers favors plug-in hybrids, while Millennials prefer the opposite. In India, both Gen Zers and Millennials demonstrate clear preferences for pure electric vehicles.

European countries show equally divergent patterns. While UK respondents report one-third battery vehicle ownership (split between one-third plug-in hybrids and two-thirds pure electric, without substantial generational differences), in Germany and France there is lower penetration. In Germany, 23.8% of Gen Zers and 30.5% of Millennials own battery-powered cars, with pure electric vehicles considerably outnumbering plug-in hybrids. France shows battery car penetration around twenty percent (20.7% Gen Z, 18% Millennials), with Gen Z opting more often for plug-in hybrids (half of total battery vehicles versus one-third for Millennials).

Despite cross-country differences, younger generations welcome battery vehicles, with Gen Z particularly attracted to plug-in hybrids – a choice that appears to mitigate range anxiety while offering flexibility to leverage different traction types as needed. Research indicates pure electric vehicles often serve as a household's second car, while current Gen Z members typically own only one vehicle.

Various factors explain the heterogeneity of battery vehicle penetration across countries: differences in purchase and usage incentive systems (at national and local levels, creating intra-national variations); vehicle price differences (Chinese battery-run cars sell at prices similar to ICE cars); variations in the cost of electricity; urban charging point coverage (both private and public), influenced by large city infrastructure. Asian metropolis expansion represents a recent phenomenon, facilitating state-of-the-art infrastructure implementation compared to European cities which developed over seventy years ago.

Focusing on pure electric vehicles, generational and cross-national purchasing motivations differ. Figures 2[3] and 3[4] illustrate the weight attributed to relevant EV selection drivers by country.

Gen Z demonstrates greater heterogeneity across countries, while Millennial motivations appear more aligned. Economic motivation proves to be fundamental: lower costs both to purchase (thanks to incentives) and to use EVs (tool road discounts, insurance, property tax). Generally, except for German Gen Zers, economic savings influences adoption decisions to a great extent, while incentives eliminating mobility constraints appear less salient (access to traffic-restricted area, free parking in otherwise paid parking zones). French Gen Zers differ widely, showing greater sensitivity to environmental impact, as do their Indian counterparts. A silent drive emerges as highly relevant for Chinese and British GenZers.

Millennials show similar cross-country preference profiles, differing from Gen Z in that they pay more attention in general to environmental impact and a quiet engine.

PRIVATE VS PUBLIC CHARGING POINTS

While economic factors are priority motivations behind driving choices, given the above cited cross-country and generational differences, this intensifies when vehicle owners can self-produce electric energy. Figure 4 reports EV purchase motivations, distinguishing responses from people who have home charging points (exclusive, shared, or under construction) versus those who don't.

3 Gen Zers in the sample who own an EV numbered 458.
4 Millennials in the sample who own an EV were 876.

FIGURE 2. MOTIVATIONS FOR PURCHASING EVS IN DIFFERENT COUNTRIES, GEN Z

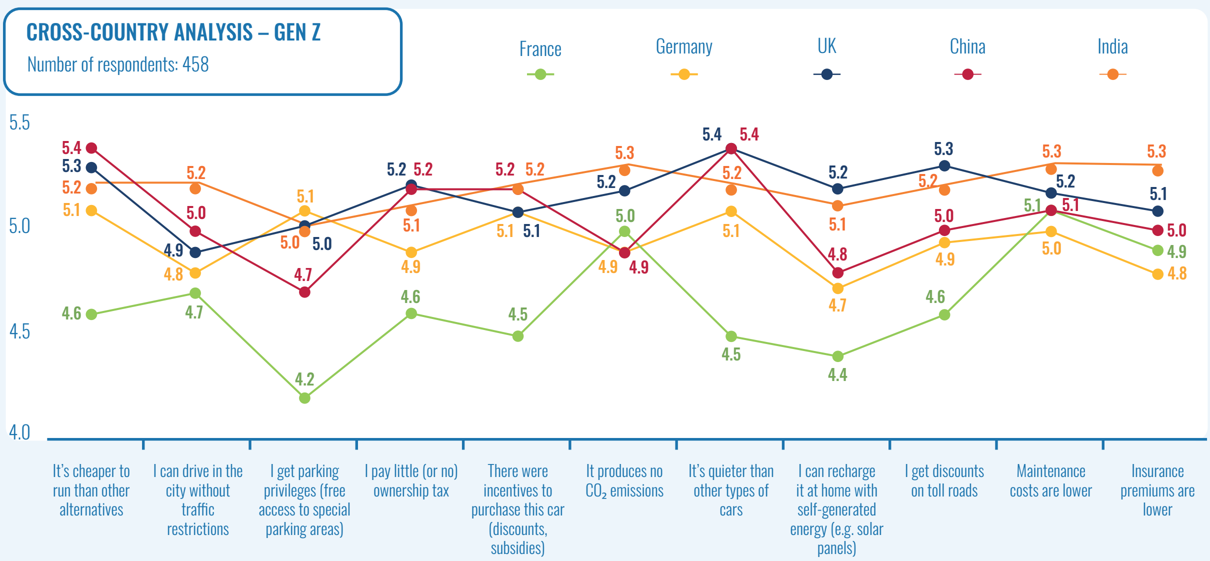
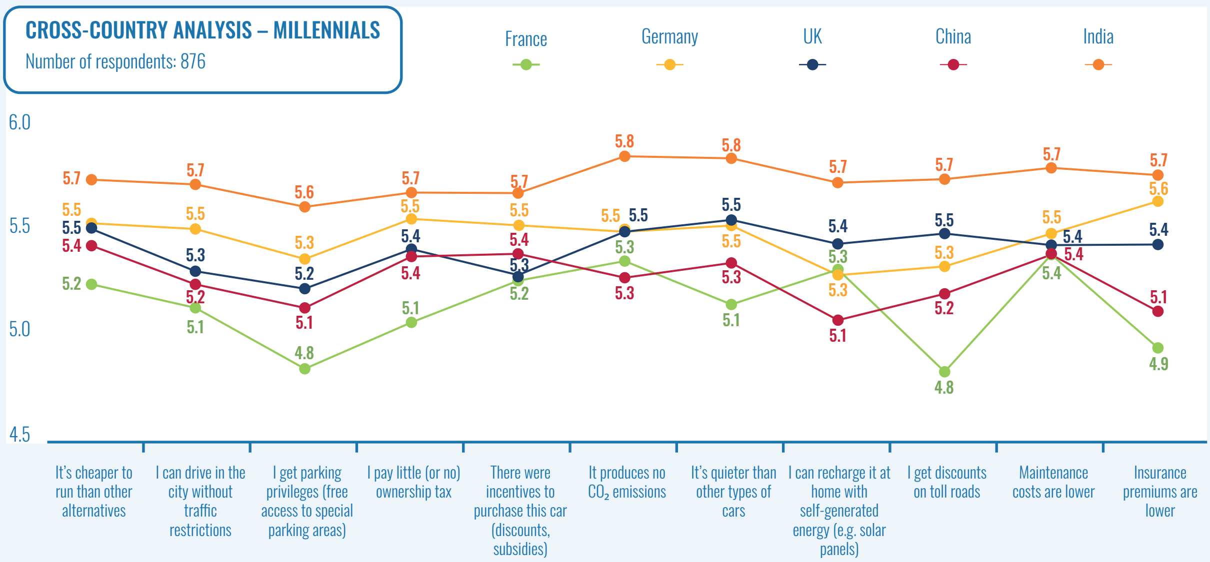


FIGURE 3. MOTIVATIONS FOR PURCHASING PURE EVS IN DIFFERENT COUNTRIES, MILLENNIALS



Following similar logic, Figure 5 reports choice motivators, distinguishing between people with or without workplace charging points (exclusive or shared).

From response profiles, two distinct pure EV buyer types emerge among younger generations:

- Those prompted primarily by cost-saving motivations (while considering environmental impact and a silent drive).
- Those guided by both environmental concerns (CO_2 reduction) and comfort (a silent drive), with less emphasis on savings.

FIGURE 4. EV PURCHASE MOTIVATIONS BY AVAILABILITY OF PRIVATE RECHARGING POINTS AT HOME

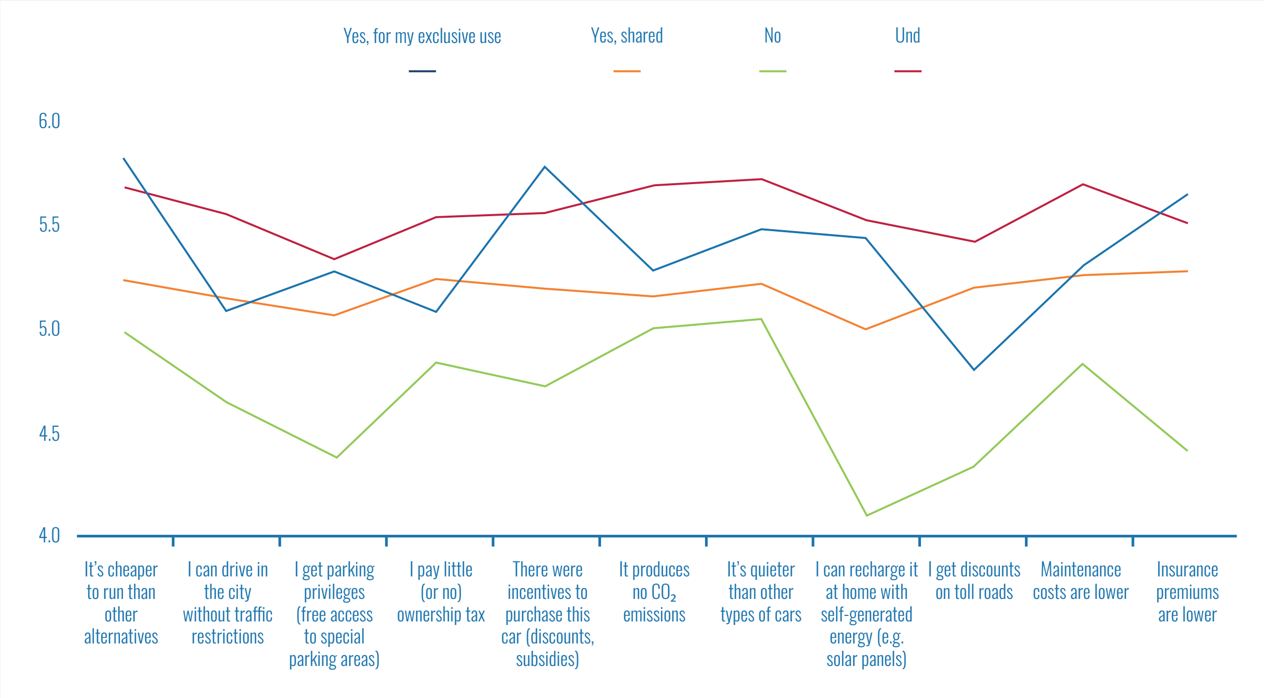
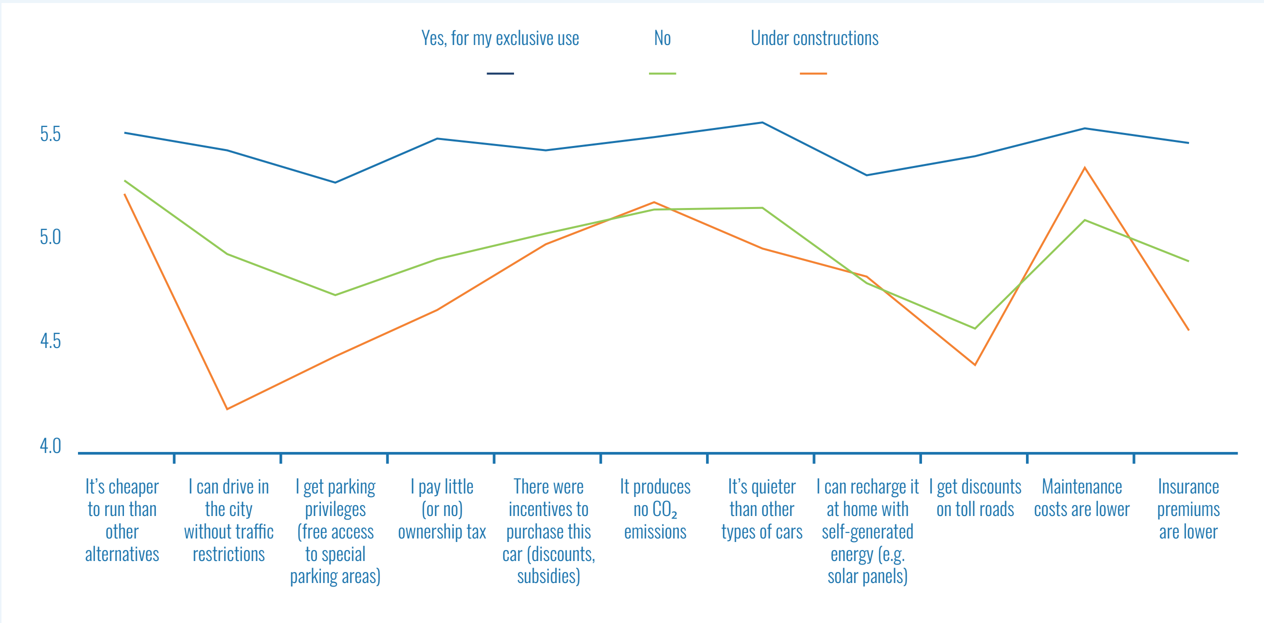


FIGURE 5. EV PURCHASE MOTIVATIONS BY AVAILABILITY OF PRIVATE RECHARGING POINTS AT THE WORKPLACE



In the research sample[5], the latter group (people without domestic charging points – neither exclusive, shared, nor under construction) represents 7.6% of EV owners in India, a figure which jumps to 26.6% in France (the country with lowest number of residential charging point). India and France also show respectively the highest (87.8%) and lowest (60%) availability of private charging points at the workplace. Together, these data suggest two key considerations.

A limited but notable segment of young consumers are attracted to EVs for reasons beyond the economic and functional incentives that are currently being offered. A strong relationship exists between pure EV ownership and private charging point availability. This supports the notion that owning such a vehicle pairs with more direct control over the energy source; the aim here is both to reduce kW costs (through self-production or grid optimization strategies) and minimize the uncertainty around available public charging space. Private charging points guarantee consistently charged batteries, at least for typical daily situations, since charging occurs during evening or nighttime hours (unsurprisingly, when private charging point owners typically plug in their cars).

For exclusive private residential charging points, what remains unclear is whether EV selection preceded or coincided with charging point availability (and possibly related self-production systems like solar panels). However, workplace charging points likely pre-dated vehicle purchases and facilitated purchase decisions. This suggests that employers influence pure EV diffusion by offering their personnel private charging point access during work hours (preferably at kW costs below public charging station rates).

Ultimately, younger generations in big cities are already appear to be leaning toward an energy ecosystem for mobility.

EV CHARGING BEHAVIORS IN YOUNG GENERATIONS

Public charging station behaviors confirm this trend. These are accessed primarily for fast charging, even in cities. In fact, public charging points are perceived not as long-stop locations, but as charging time optimization sites, despite higher costs. (The faster the charge, the higher the kW price.) Once their vehicle is parked, users prefer minimize charging time, especially during morning or afternoon hours. (Nighttime stops can extend longer, allowing slower, price-optimized charging speeds.) When EV drivers can plan their charging at a public station (which is common when they're moving around in the city), they pick their charging point prioritizing speed and pricing.

All this being said, charging points can actually be stopping destinations. Indeed, the practice of charging solely to exploit parking opportunities is widespread, particularly in congested cities where available parking spaces are scarce. But this battery vehicle advantage is stymied when stations are occupied by non-charging vehicles.

This highlights a critical electric mobility challenge: To charge an EV, it has to occupy a charging station for an extended period of time – currently at least ten times longer than refilling a traditional car with a tank of gas. In other words, to fill up an ICE car a gas pump would be free in minutes, while charging points require approximately twenty minutes for an 80% battery charge. This means that each charging point can supply less than 10% of the vehicles served by a single gas pump. Replicating current capacity would require utilities to multiply charging points tenfold, sizing installations for connections and power – a massive investment. Automakers are making great strides to cut battery charging times, investing appropriately and achieving consumer-acceptable timeframes.

In this vein, research findings indicate that when drivers are forced to remain in their vehicles during charging (in other words, when they urgently need

5 As a reminder, this concerns Gen Zers and Millennials residing in each country's largest urban centers.

a charge, not when they can park and leave their car charging to run errands, for instance), acceptable time limits are thirty minutes, with cross-country variations. Germans show less patience (25 minutes) while Indians accept up to 38 minutes on average. The best available recharging technology now operates well below these limits. However, there are still not enough charging stations to power an entire fleet of fully electric vehicles. Furthermore, the issue encompasses not just the volume of available electric energy, but the number of charging points, especially if the same infrastructure must provide both charging and vehicle-to-grid energy transfer functions[6].

INSIGHTS INTO THE FUTURE OF URBAN ELECTRIC MOBILITY

The evidence presented here confirms that urban electric mobility requires a systemic perspective. Since most EV owners today have private charging points and are motivated by savings and functional benefits from incentives, questions arise about future scenarios when the proliferation of EVs will make incentives unsustainable, in both economic terms (property tax cuts, toll and parking discounts) and practically speaking (limited accessibility to restricted traffic zones, parking privileges in otherwise unavailable areas). Many currently attractive cost-reducing inducements would disappear when EV volumes exceed certain thresholds. Growing volumes would also strain public charging infrastructure. Unless ICE vehicle use is disincentivized by artificially ramping up operating costs (a challenging policy choice), incentives need to be offered (or barriers removed) for private charging points. This is necessary to lock in the economic advantages of EVs and mitigate the shortage of public charging stations. The barriers we mentioned include urban planning regulations (often discouraging individual citizens to proactively invest in solar panels or micro-wind systems) and private charging space availability. (Garages aren't common in central and semi-central areas of older European cities.) A move in the right direction would be to create energy communities, which could boost EV diffusion considerably.

At this point, we return to this article's opening premise: Pure EVs require a different energy paradigm based partially on self-production, for reasons of both economic convenience and energy production volume. The V2G evolution is a logical consequence, enabling citizens to use vehicles as storage batteries to monetize excess self-produced energy (providing additional stimulus for small-scale private production system investments).

What role will public charging stations play in this context? Most likely, they will serve their current functions, especially fast-charging stations which will replace gas. Long-distance travelers will always need to recharge when they're away from home. Residential demand should decline as home charging disseminates. Alongside charging stations, energy exchange infrastructure will presumably grow in V2G frameworks, although infrastructure and exchange systems are yet to be built.

This scenario appears plausible given the current technology. If nuclear energy production becomes prevalent in the near future (fission or fusion), public charging point systems are prone to be the dominant distribution model, like gas pumps in the fossil fuel era. The reason here is that nuclear production costs (especially fusion) could undercut small solar panel self-production. If this occurs, the number of recharging stations must grow exponentially through large-scale investments.

The timeline on the availability of nuclear fusion technology is still unclear. This means that the electric urban mobility represents an evolving ecosystem where the most dynamic innovators are not the utilities, but the automakers. This is especially applicable to European players who are

6 Interesting experiments are currently underway with distributed roadside charging points: street lighting poles in Great Britain, sidewalk curbs in Germany, and similar innovations. This indicates that V2G has true potential.

investing in more efficient electric engines, higher battery capacity, faster-charging batteries with longer charge-discharge cycle lifespans, and software systems to manage V2G and V2H interfaces. Their focus aligns with self-production energy systems, exactly the direction Tesla struck out in twenty years ago. How this integrates with autonomous driving technology opens fascinating possibilities for new business models and novel approaches to customer relationship monetization by automakers.

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