

THE FUTURE IS ELECTRIC

Marketing Insights Indicate
EVs Growth Acceleration



Honeywell

EXECUTIVE SUMMARY



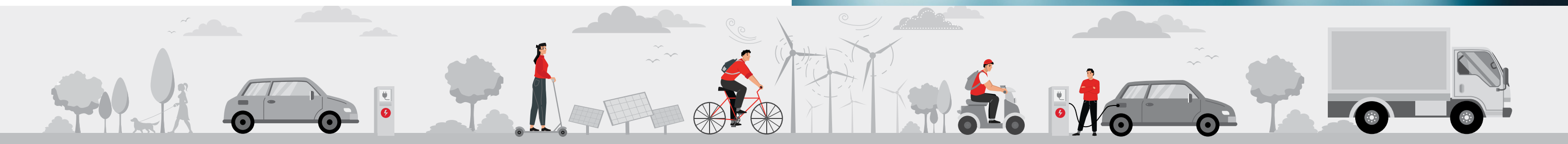
The electric vehicle (EV) market is one of the most exciting, significant new markets in many years, and arguably one of the top two or three so far this century. Right now, the field of companies both within the industry itself and tangential to its effective and efficient global implementation is crowded with players both large (multinational) and small (niche).

The market is also maturing very quickly for such a multi-faceted, complex enterprise: as such, it is rapidly cycling through multiple industry segments in parallel. New players, processes, materials, and regulations displace others in what seems like only months. An important key to long-term participation, therefore, is the ability to stay current on the field overall.

As a leader in several areas of EV production and utilization, Honeywell believes it is important to share our substantial body of knowledge and insight into where electric vehicles are today and where they are anticipated to be over the next few decades. From factory floor operations to on-vehicle devices to applications within the charging infrastructure, our experience and expertise can be a competitive advantage for organizations breaking into or already serving the fast-paced transition to broad EV acceptance. Working on behalf of our customers, we can also leverage our extensive industry-wide partnerships in related fields that are necessary for the widespread adaptation of EVs.

This document provides a very high-level look into the many fields of interest involved in the global shift to EVs. We have gleaned this information from a wide variety of reputable, well-supported research firms and organizations throughout the world.

Let Honeywell's engineering talent, knowledge of EV technologies, and substantial offerings for the EV vehicles and related industries of today and tomorrow – backed by decades of additional experience as a leader in devices and equipment for the gas-fueled vehicle market – put you in the driver's seat in the EV ecosystem. We enable clean energy. We are excited about the future. And that future is electric!



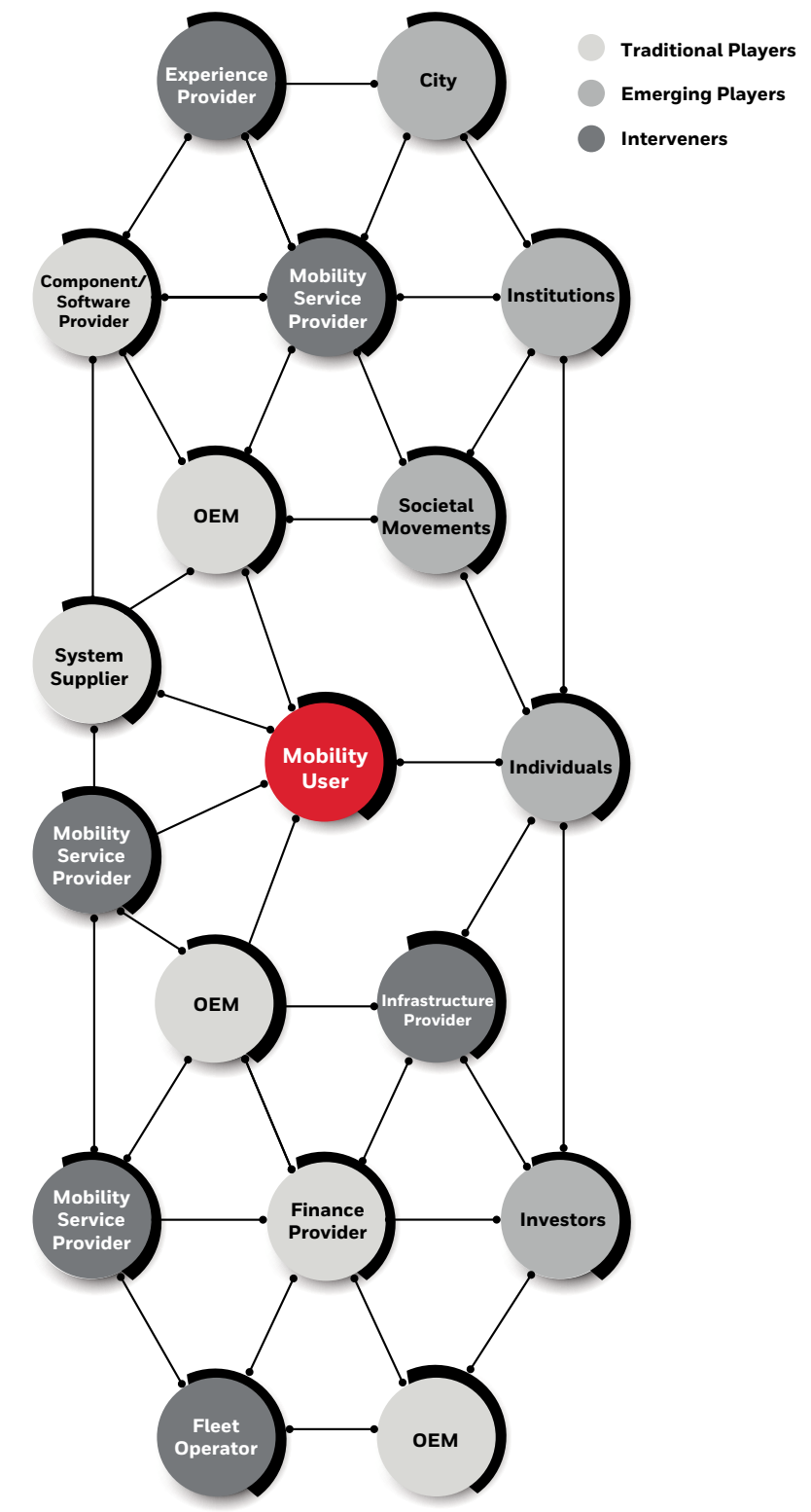
EV ECOSYSTEM

The transition from internal combustion engines (ICE) to EVs encompasses much more than just introducing new models of automobiles. Because of the charging infrastructure associated with their use and the impact of that necessity on any country's electrical grid, successful EV adaptation requires thinking through entire ecosystems. Doing so allows all the players within the system to address shifting user preferences by going beyond a traditional auto industry frame of reference to involve a broader network of technology, energy, and financial players. McKinsey aptly demonstrates this model as in Figure 1.

Of course, this type of market upheaval requires substantial investments from the vehicle manufacturers themselves and also opens the door to a myriad of opportunities for companies serving vehicle manufacturers, both of which are presented in some detail in the rest of this report. Consumer expectations, of course, also figure prominently in both the types of offerings and how quickly they are planned to come to market. This is summarized well in the following data from Plante Moran, which expects global EV volumes to grow at a 22% annual growth rate (CAGR) through 2035, as shown in Figure 2.

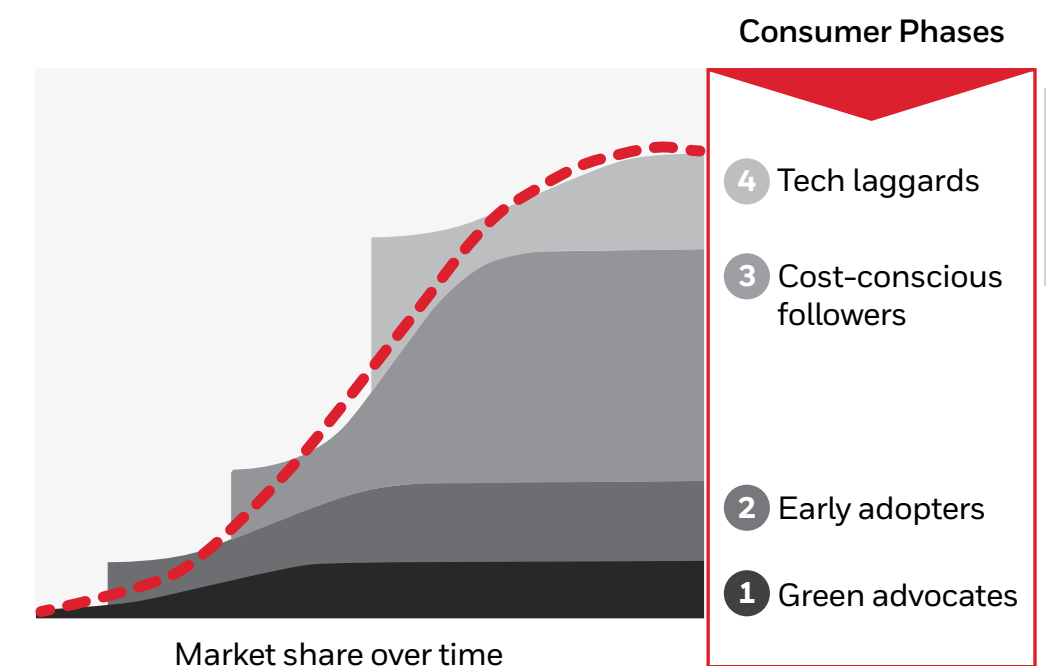
Using the concept of an EV ecosystem as a broad framework, the huge new "EV market" can be summarized in large categories as shown on page 2, although it bears reiterating that these are very intertwined through both traditional vehicle manufacturing processes as well as completely new connections between them all.

Figure 1. Illustrative Mobility Ecosystem



Source: Capturing Growth in Asia's Emerging EV Ecosystem

Figure 2. Consumer Uptake Phases of New Technology



Input variables to project EV growth

Market dynamics	Government regulations	Technology advances	Consumer perceptions
- Fuel prices - Electricity prices - Number of models - Infrastructure availability - Population demographics	- Incentives - Emissions and fuel economy regulations - Infrastructure investment	- Technology maturity - Cost of technology to consumer - Vehicle range - Usability and convenience	- Green and social pressure - Performance and reliability - Driving habits - Vehicle ownership

Source: EV Disruptive Technologies, Plante Moran



FINANCIAL

- Investments and plans of vehicle manufacturers themselves
 - Autos and heavy-duty vehicles
 - Other types of electric powered vehicles
- Interveners who can shape the market
 - Governments at all levels, throughout the globe
 - ◆ Climate-related legislation
 - ◆ Market growth incentive legislation
 - Sales channels

TRANSITION OF VEHICLE PLAYERS

- Vehicle manufacturers
 - Workforce implications
 - Safety
- Battery production
 - Geopolitical concerns
 - Safety
- Battery recycling
 - Safety

TECH GIANTS

- Vehicle components/user data
- Influencers
- Buyer behaviors

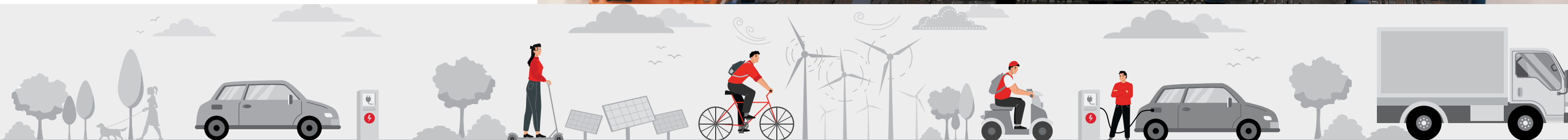
INFRASTRUCTURE (ENERGY)

- Energy
- Charging
- Workforce implications
- Safety

This report is organized into these categories, but once again, it cannot be overstated how interconnected the players are.

“The tipping point for EVs has happened, given the economic parity we see in multiple use cases. There will be challenges and they will be of significance. But we’re past the tipping point.”

McKinsey, Electric Vehicles Are Here and Large-scale Adoption Is ... Near?, Nov 2022



FINANCIAL

INVESTMENTS AND PLANS OF VEHICLE MANUFACTURERS

Autos and light-duty vehicles

The EV market, while most often associated most with automobiles, actually encompasses many other types of vehicles as well, including scooters, bikes, buses, consumer-market trucks, commercial trucks, other types of fleet vehicles (e.g., taxis), and even some leading-edge types of advanced air mobility. All utilize similar technologies but each sub-group also offers, and indeed requires, opportunities for customized implementation. All are expected to grow exponentially over the next couple of decades.

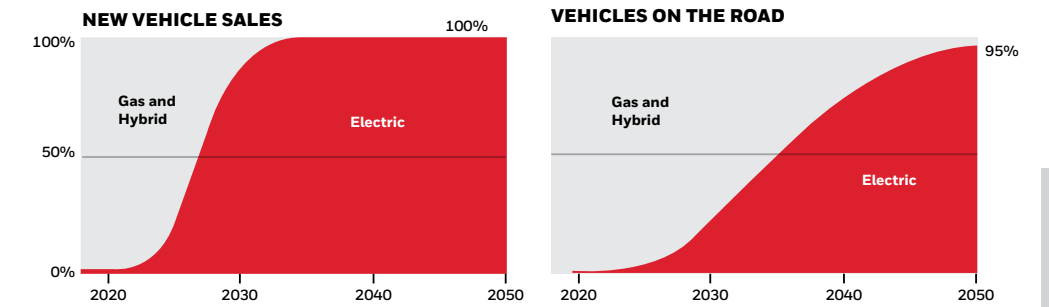
This report primarily discusses battery electric vehicles (BEVs), and that is the focus of the climate-related emissions goals for countries and vehicle makers even though there are still many hybrid vehicles being sold today. As those vehicles age off the road, the intent is to be able to replace them with fully electric models. There's one use case with a huge tailwind that favors electric vehicles: fleets, where the benefits of EVs meet economies of scale. The fleet industry is currently in a state of transition as they plan to move in that direction (see Figure 3).

While not detailed in this report, an entire subset of EVs are Level 4 and 5 vehicles that do not require much – or any – driver control. Level 4 is essentially “hands off” operation and Level 5 is “mind off,” where drivers are not engaged at all in the direction or the speed of the vehicle. Depending on geographies and regulations, these may begin to be seen by 2028. Many regulation and safety studies still lie ahead before these vehicles are widely accepted by buyers. (40)

As we explore the transition to EVs, then, let's first take a look at autos and trucks, currently the largest segment of the market. As demonstrated earlier by McKinsey, the EV is a radically different type of vehicle – and it requires a radically different approach to manufacturing and set of offering advantages for customers. Automotive OEMs will have to reconceive their business models to create new income and profit streams for EVs, which can be outlined in more extensive documents. McKinsey supports this position by noting that moving into EV production is not a short-term bet; it requires high upfront investment and ROI is generally low in the first few years. (6)



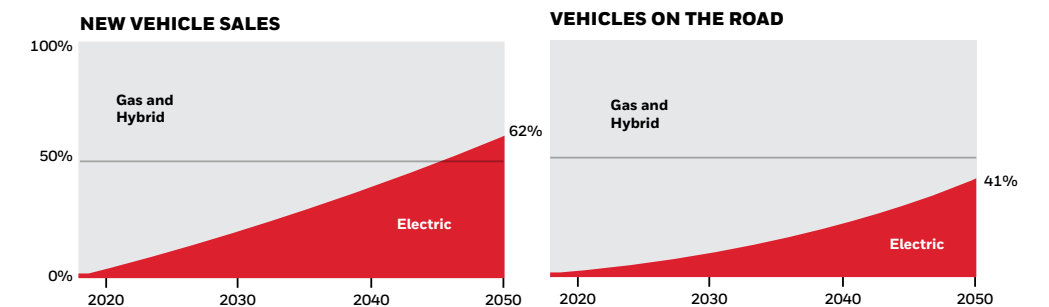
Figure 3. Tipping Points for EVs



Sources: Fleet turnover model via Alarfaj, Griffin and Samaras in Environmental Research Letters; Electric vehicle sales projection via IHS Markit

How 'Fleet Turnover' Lags New Car Sales

If electric vehicle sales gradually ramped up to 60 percent over the next 30 years, as projected by analysts at IHS Markit, about 40 percent of cars on the road would be electric in 2050.



In order for almost all cars on the road to be electric by 2050, new plug-in sales would need to quickly ramp up to 100 percent in the next 15 years.

Source: New York Times, Mar 2020



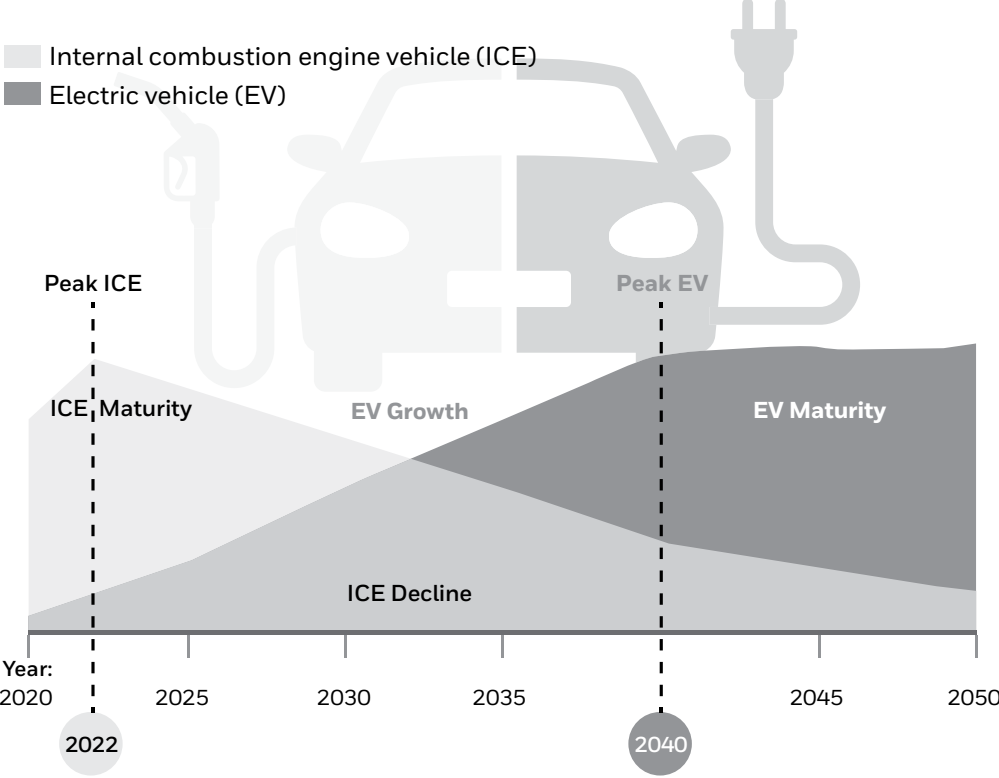
Plante Moran predicts that EV technology will reach full maturity by 2040 and the resulting impact on internal combustion engine vehicles (ICEs) will be momentous (see Figure 4).

Globally, McKinsey shows that vehicle OEMs are responding to forecasts such as this by gearing up fast (see Figure 5).

As implied above, the competitive landscape for EVs will be bruising. While the landscape will represent fierce competitive battles, the International Energy Agency (IEA) nonetheless forecasts by 2030, EVs will represent the following percentages of vehicles in key areas of the world leading the charge in EV usage with vehicles manufactured by the companies mentioned above as well as others:

Table 1. Country	% of EVs
China	70 %
Europe	almost 50 %
Japan	37 %
Canada	30+ %
India	29 %
All other countries, combined	22 %

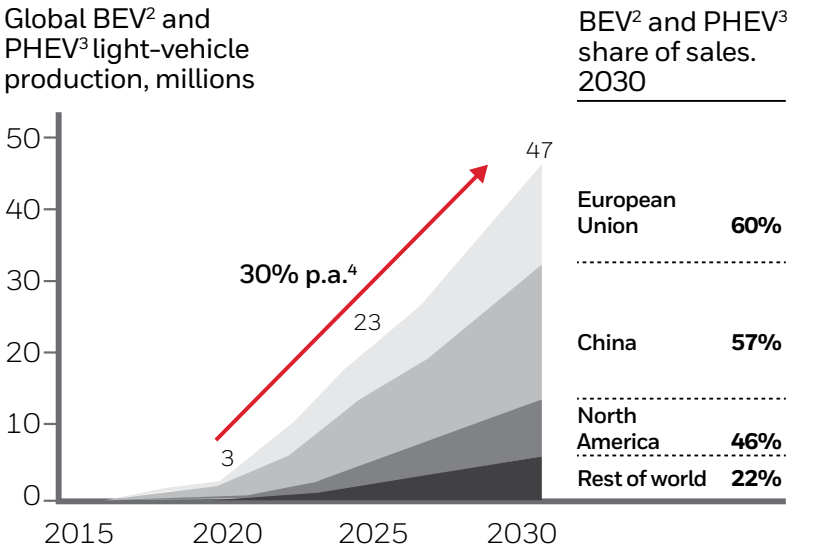
Figure 4. Propulsion Technologies Drive Change and Shift Revenue Sources



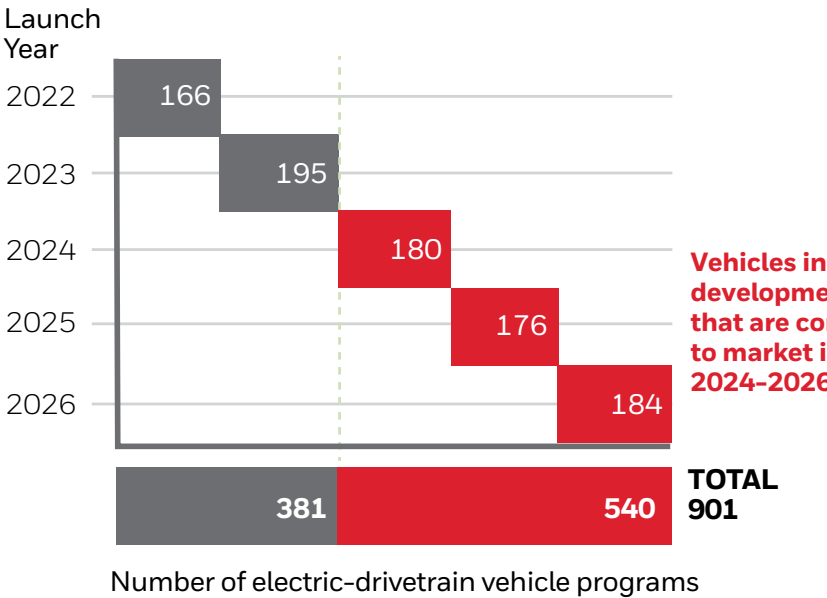
Source: Plante Moran

Figure 5. Tomorrow's Vehicle Architecture Being Defined Today

Global EV¹ market growth is strong and accelerating



More than 500 EV¹ programs coming to market in 2024-2026



¹ Electric vehicle
² Battery electric vehicle
³ Plug-in hybrid electric vehicle
⁴ Per annum
Source: IH5 Market; McKinsey Center for Future Mobility



This is based both on the governmental mandates put forth in many countries as well as the reality that in order for the transition to occur, vehicle manufacturers must step up in very material ways: worldwide, as IEA further describes, 18 of the 20 largest automobile manufacturers have committed to expand their EV offerings, substantially in many cases (see Figure 6).

In another report, IEA outlines the ambitions of key automakers over the next decade:

TABLE 2. MAJOR AUTOMAKER ANNOUNCEMENTS ON ELECTRIFICATION, 2021-2022		
Automaker	Announ. Date	Ambition
Toyota	2021	3.5 million annual electric car sales by 2030 and the rollout of 30 BEV models
Volkswagen	2021	All-electric vehicles to exceed 70% of European and 50% of Chinese and US sales by 2030, and by 2040 nearly 100% to be Zero Emission Vehicles (ZEVs)
Ford	2022	One-third of sales to be fully electric by 2026 and 50% by 2030, with all-electric sales in Europe by 2030
BMW	2021	50% of vehicles sold to be fully electric by 2030 or earlier
Volvo	2021	Become a fully electric car company by 2030
Geely	2021	20% of car sales to be electric by 2025
Mercedes	2021	All newly launched vehicles will be fully electric from 2025
General Motors	2022	30 EV models and BEV production capacity of 1 million units in North America by 2025, plus carbon neutrality in 2040

Source: IEA Electric Vehicles, Sep 2022

Within the U.S., Tesla is the biggest player by far, but other manufacturers are becoming more consequential (see Figure 7).

Technically, it's somewhat easier to make the physics and economics work with autos. This is changing quickly as larger electric passenger vehicles really start to come into play. In the U.S., where we have been slower to adapt to EVs in general, a large percentage of the new EVs being sold are pickup trucks and SUVs. McKinsey notes that if there is to be full adoption of EVs in the U.S., electric pickups and SUVs must be a significant part of the vehicles on offer. (40)

Figure 6. 18 of the 20 Largest OEMs Have Committed to Increase the Offer and Sales of EVs

Based on electric light-duty vehicles

OEM	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Number of new EV models										
BMW Group			25							
BAIC Group	2									
Changan Automobile Group					33					
Daimler		10								
Dongfeng Motor Co.	1		1		1				1	1
Ford		40								
GM Group			22		30					
Hyundai-Kia					29					
Mazda		1								
Renault-Nissan		20								
Maruti Suzuki	1									
SAIC										30
Toyota Group	1				15					
Volkswagen					75					
Volvo (Geely Group)	1	1	1	1						
Percent of electric sales										
BMW Group					15-25					
BAIC Group										50
Daimler					25					50
Dongfeng Motor Co.		30								
FAW					40					60
Ford						100 ¹				
Honda										40
Mazda										5
Renault-Nissan		20								
SAIC					30					
Stellantis					38 ¹					70 ¹
					31 ²					35 ²
Volkswagen					20					70 ¹
										50 ²
Volvo (Geely Group)					50					100 ¹
Annual sales in millions										
BAIC Group					1.3m					
GM Group						1m				1m
Hyundai-Kia					1m					
Maruti Suzuki										1.5m
Toyota Group										>1m
Volkswagen			1m		3m					
Cumulative sales in millions										
BMW Group										10m
Volkswagen									26m	

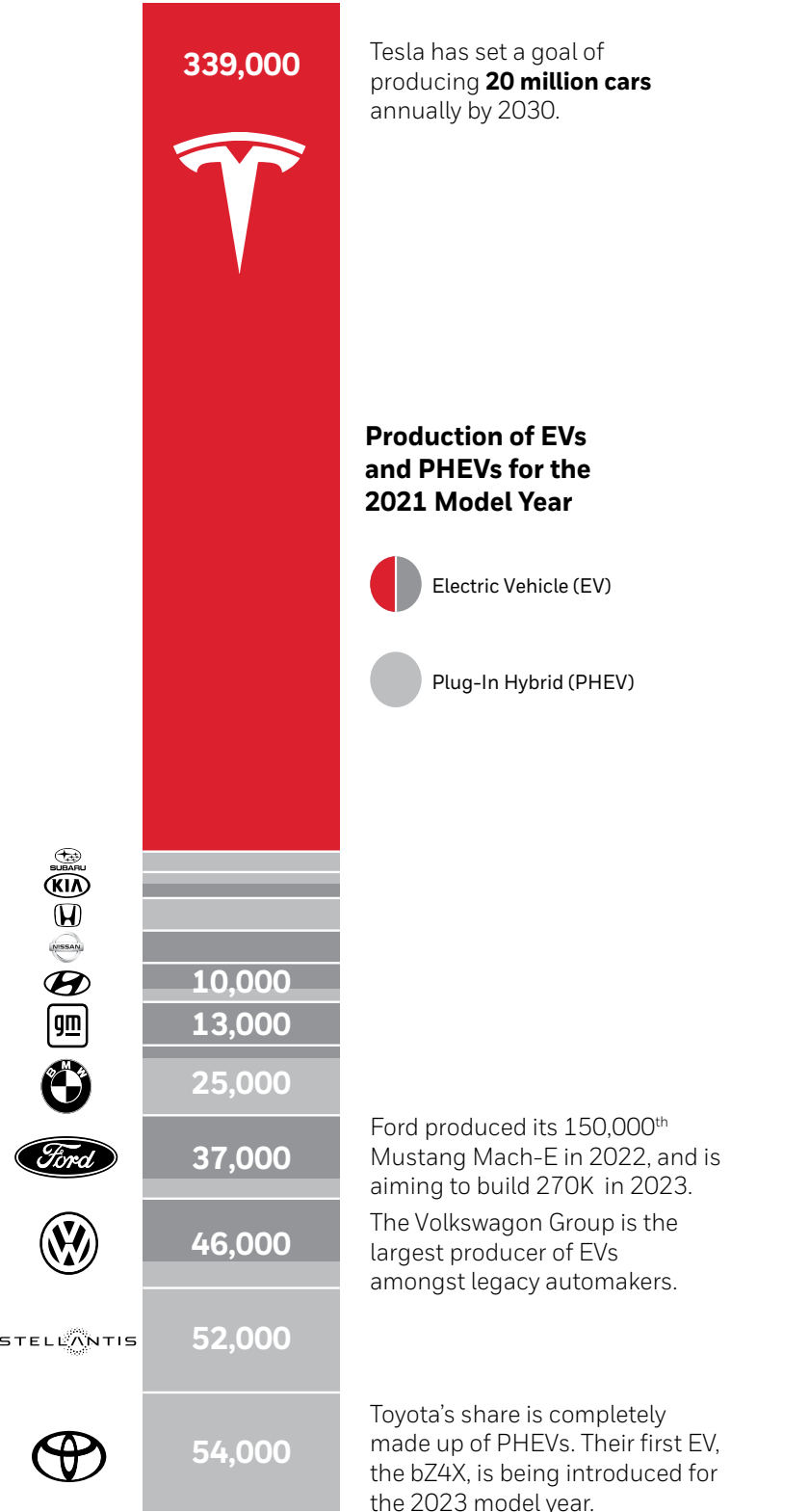
¹ European market only

² Chinese and US markets only

³ Includes both EVs and FCEVs

Source: IEA; Global EV Outlook 2021

Figure 7. Electric Vehicle Production by Brand



Tesla has set a goal of producing **20 million cars** annually by 2030.

Production of EVs and PHEVs for the 2021 Model Year

Electric Vehicle (EV)

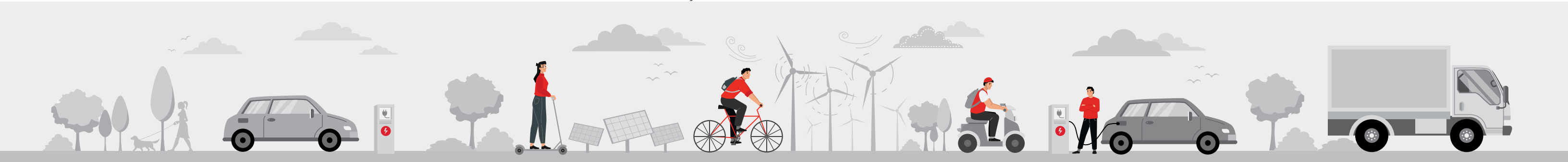
Plug-In Hybrid (PHEV)

Ford produced its 150,000th Mustang Mach-E in 2022, and is aiming to build 270K in 2023.

The Volkswagen Group is the largest producer of EVs amongst legacy automakers.

Toyota's share is completely made up of PHEVs. Their first EV, the bZ4X, is being introduced for the 2023 model year.

Source: Visual Capitalist, Visualizing EV Production in the U.S. by Brand, Dec 2022





As a quick case study, look at the Ford F-150 Lightning. The gas-powered F-150 has been the best-selling vehicle in the U.S. for over 40 years. Without the federal tax credit from the U.S. government, the price for the electric F-150 Lightning is just under \$40,000; with the credit the cost comes down to about \$32,500. This in itself is surprising to many potential buyers who have been conditioned to often believe that EVs of any type are more expensive than gas-powered versions, mostly due to the high-end offerings from Tesla and other luxury carmakers who provided early entries in EVs. The price point for the F-150 Lightning, with tax credit, is only about \$4,000 more than its gas-burning alternative.

In addition to speedy, smooth handling and the rugged reliability that has gained it fame, the F-150 Lightning has additional benefits that can be touted to buyers. For example, in the event of a blackout, its battery can store enough power to restore a house’s normal power usage for three days, or a week if the household works to conserve power. This could signal it’s becoming a non-traditional competitor for household generators.

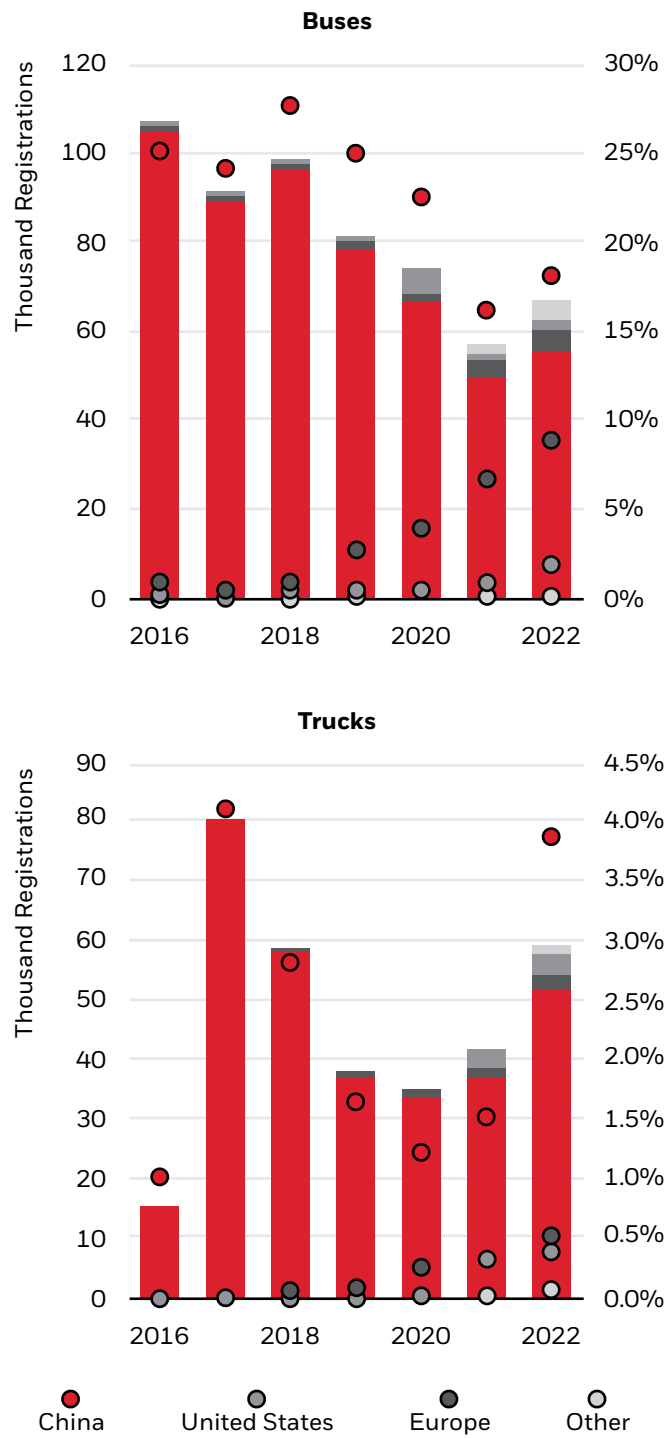
The target audience for the F-150 Lightning is not just consumers either: for the first time, Ford is selling a version of one of their truck models aimed at corporate fleet managers in a wide variety of industries ranging from landscaping to HVAC-repair companies or other types of companies that operate multiple trucks at once. In many ways, these fleets are even better suited for electrification than one-off consumer vehicles because they are driven every day, rarely travel long distances, and are usually stored in the same place overnight, making it simpler to recharge them. These benefits are certain to make them attractive to fleet managers and greatly increase sales opportunities for the manufacturer. (49)

Heavy-duty EVs (trucks, buses)

While not growing as quickly as electric autos and light-duty vehicles, the heavy-duty vehicle market has similar potential for expansion. IEA reports that electric bus and truck registrations expanded in China, Europe, and North America in 2020, with China leading the pack. Globally, there were 600,000 electric buses; China registered 78,000 new buses in 2020, up 9 % from the previous year. Local policies to curb air pollution are the driving force. The number of heavy-duty trucks worldwide was 31,000: China dominates this category as well, with 6,700 new registrations in 2020. This represented an increase of 10% but was still much lower than their fourfold increase of electric bus stock in 2019. Electric heavy-duty vehicles in Europe increased to about 450 and the U.S. had a total of 240; electric trucks are still below 1% of sales in both regions (see Figure 8).

While buses were the earliest type of heavy-duty electric vehicles, the growing demand for other types of heavy-duty vehicles is driving the development of broader product lines from long-haul freight trucks to garbage collection trucks. China has the widest variety in buses, while the availability of medium-freight trucks is broadest in the U.S., and Europe offers the greatest selection of heavy freight trucks. Truck makers such as Daimler, MAN, Renault, Scania and Volvo have indicated they see an all-electric future.

Figure 8. Electric Bus and Truck Registrations by Region, 2015-2020



Source: International Energy Agency, Global EV Outlook 2023; IEA analysis based on country submissions and data from EV100 and vehicle insurance registration data



Other types of electric powered vehicles

The majority of investments and incentives – and media attention – in the EV expansion thus far has been focused on autos and trucks. This has helped the industry pick up steam, as these are the categories with which the largest number of consumers are familiar. Following is data related to other types of EVs, which are growing in popularity and manufacturer plans around the world.

Daniel Wiegand, CEO of air-mobility company Lilium, believes that electric vertical takeoff and landing (eVTOL) aircraft will be commonplace by 2030. One of more than 250 companies developing these vehicles – including airlines such as United – he’s bullish on the outlook for them. Five times faster than auto travel, many different types of applications are envisioned for them from intercity shuttle routes, which is what many are focused on at this time, to sightseeing, taxis, package and cargo delivery, and more. Since many will be transporting passengers, additional infrastructure is needed to provide the equivalents of train stations, leading to the need for governmental intervention and legislative support. Wiegand anticipates that 2025 will launch the industry, and by 2030 it will experience exponential growth, and become a part of everyday life. (51)

Other rapidly growing segments outside autos and trucks include scooters, motorbikes, e-cycles, and three-wheel vehicles that are widely used throughout Asia.

INTERVENERS WHO CAN SHAPE THE MARKET

Governments at all levels, throughout the globe

Climate-related legislation

Most people are familiar with emissions control regulations, at least on a high level, based on the amount of media coverage for these types of policy decisions by governments around the world working together to improve climate conditions. The decade between 2025 and 2035 will determine whether the vehicle industry can really control emissions from their products to hold an overall global temperature increase to under 1.5 °C. (53)

Worldwide, emissions goals and percentage requirements for EV implementation are gaining significant momentum and passing through governmental bodies at record paces and volumes. Countries are rising to the challenge with substantial – and challenging – emissions goals.

The USA is making strides in accomplishing the necessary transitional activity through such regulatory accomplishments as the Infrastructure Investment and Jobs Act passed by the US Congress in 2021. Since rejoining the Paris Agreement, the Biden administration has set up a National Climate Task Force, with emissions goals as follows (55):

- Reducing U.S. greenhouse gas emissions 50-52% below 2005 levels in 2030
- Reaching 100% carbon pollution-free electricity by 2035
- Achieving a net-zero emissions economy by 2050





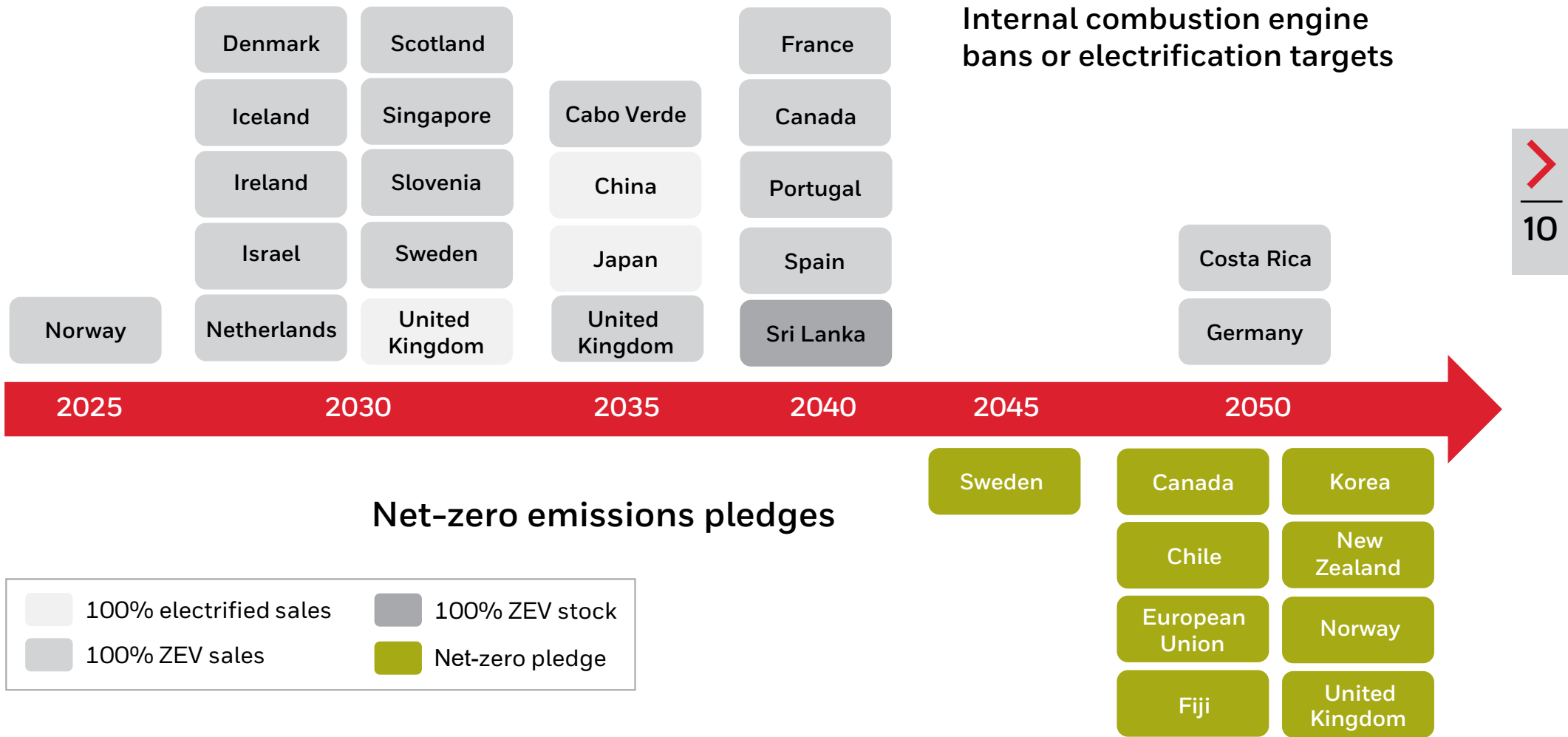
As detailed earlier, the transition of fleets to EVs is one path to super-speeding their widespread usage, and governments can and are playing a key role in that arena. In the U.S., the U.S. Postal Service’s plans for a nationwide fleet of electric vehicles are getting closer to being realized with contracts having been awarded for 9,250 battery electric vehicles and for more than 14,000 charging stations. With a goal of making EVs 75% of its new purchases, USPS will have a fleet of 66,000 electric vehicles deployed by 2028. (56)

In one of the other largest markets in the world for EVs, Asia overall is home to 93 of the 100 most polluted cities in the world and six of the top ten countries most affected by climate risks such as rising water levels and toxic air quality. One of the biggest offenders is also on the leading edge of EV production: China. Looking to become a leader in addressing climate change, China’s government announced in September 2020 that it would aim to reach a peak in its carbon dioxide (CO₂) emissions before 2030 and achieve carbon neutrality by 2060. While that somewhat lags other developed countries, many of the world’s climate control experts believe that the country will overachieve and meet its goals far earlier, with one of the key contributors to that being its aggressive goals for EV production (see Figure 9).

Market growth incentive legislation: cars and trucks

Without governmental regulation for both emissions control and production and sales of EVs, the demand for EVs becomes a chicken-and-egg problem: private companies have diminished incentives to expand their offerings (both the vehicles themselves as well as supporting infrastructure) that have high upfront costs and low initial utilization while consumers and commercial customers are reluctant to purchase vehicles that are not only currently more expensive but may not have the necessary structural infrastructure to support their widespread use.

Figure 9. Policies to Promote Electric Vehicle Deployment



Source: EV Industry Report





In order for countries to meet their emissions goals, it’s widely accepted that incentives for purchases of EVs are needed to speed up their adoption. In the U.S., for example, the Inflation Reduction Act in 2022 includes a tax credit of up to \$7,500 for those buying electric vehicles (both cars and SUVs) priced below \$88,000. Still, the U.S. lags far behind its most aggressive EV manufacturing competitor: China.

China’s electric-vehicle sector is outpacing the U.S. sparking fears that the U.S. has fallen dangerously behind in this crucial future industry. While all governments place their thumb on the scale to favor homegrown firms, China uses its “state capitalism” to bend entire markets to a degree unimaginable in democracies elsewhere. By offering funds as well as revenue protection for high-tech industries such as electric cars (see other studies also on chips, AI development, etc.), the Chinese government could potentially upend the global EV market with subsidized products. In its goal to leapfrog Western powers into the forefront of next-generation technologies, the contest over electric cars represents a market battle of both economic models and political ideologies.

Although Chinese manufacturers have made inroads against their established American, European, and Japanese rivals in auto production, they have never achieved the leading position Beijing desires. The global attention to slowing climate change has offered China a fresh opportunity to begin at a common starting line with the rest of the world’s automakers in producing a new type of product. They enthusiastically leapt to the challenge with a veritable smorgasbord of supportive policies such as subsidies for manufacturers to reduce prices to encourage sales, direct investments including funding for R&D, direct investments into electric-vehicle companies, and charging infrastructure. Consumers received other incentives to encourage their purchases. The Center for Strategic and International Studies estimated that the Chinese government has invested more than \$100 billion in the sector

overall, mostly in subsidies. In 2019 alone, government support was equivalent to almost a third of the sector’s total revenue.

Largely due to a lack of technological advantages over their foreign rivals – as well as poor brand recognition – Beijing’s state program is currently facing headwinds in offering cars the world wants to drive. Recognizing this, though, Chinese automakers are upping their game by working to integrate other nascent technologies, such as AI, into their vehicle plans.

The U.S. could benefit not only from seeing how China’s highly subsidized EV industry involvement plays out, but not at the exclusion of also investing in building infrastructure such as charging stations. Perhaps the most important lesson, though, is geopolitical: The Chinese won’t give up. U.S. and European manufacturers will need to remember that China has no intention of throwing in the towel in the EV race. (58)

EV goals and incentives are not just national either: many cities and regions are implementing their own strategies, as shown in Table 3.

TABLE 3. EXAMPLES OF CITY ELECTRIC VEHICLE GOALS AND STRATEGIES			
City	Goal	Strategy	Strategy Details
Boston	23% of new vehicle purchased are electric by 2025. Deploy 1,055 Level 2 and 320 DC fast chargers by 2025. 100% LDV municipal fleet electric by 2035	2020 zero-emission vehicle roadmap	Established 13 future actions to support widespread electrification and ensure affordable and convenient access to infrastructure
Columbus	1.8% ownership by 2020. Deploy 900 public charging stations	Publicly available ongoing and completed projects	Published playbooks identifying success and lessons learned from projects
Denver	15% of total registration by 2025, 30% by 2030, and 100% by 2050. 100% in-city fleet by 2020	Opportunities for vehicle electrification in Denver Metro area and across Colorado	Discusses steps to address DC fast charging availability and multi-family housing charging access barriers
Houston	30% of new vehicle sales by 2030	Evolve Houston electric vehicle roadmap	Outlines awareness, affordability, and availability actions, with suggested key stakeholders
Los Angeles	25% of total registrations are ZEVs by 2025, 80% by 2035, and 100% by 2050. Deploy 10,000 public chargers by 2022; 28,000 chargers by 2028	L.A.’s Green New Deal	Establishes targets with initiatives from 2021 to 2030
Memphis	5% of vehicle travel by 2025, 30% by 2035, and 50% by 2050	None identified	None identified
New York	20% of new registrations electric by 2025. Deploy 50 DC fast chargers citywide by 2020	\$10 billion to install fast charging stations	None identified
Portland	Replace at least 10,000 vehicles. Double public Level 2 and DCFC. 30% in city fleet by 2020	2017 City of Portland electric vehicle strategy	Details 49 unique actions with lead bureaus
Sacramento	35% of total registrations are ZEVs by 2025	Electric vehicle strategy	Outlines 8 core performance targets with lead department and entities
San Francisco	50% of new registrations by 2025 and 100% by 2030	Proposed electric vehicle roadmap for San Francisco	Establishes 6 main strategies with lead and support authorities
Seattle	30% total registrations by 2030	Drive Clean Seattle Implementation Strategy	Coordinates 5 implementation actions with lead departments

Source: The International Council on Clean Transportation, Evaluating Electric Vehicle Market Growth Across U.S. Cities, Sep 2021



Market growth incentive legislation: other forms of EV transport

Even modest-size electric cars are not a climate panacea, nor are they viable for consumers in many parts of the world. A 2020 study by University of Toronto scholars found that electrification of automobiles cannot prevent a global temperature rise of 2 °C by 2100 without countries also working to shift their populations toward cleaner travel modes such as public transportation and bicycles.

Aware of that need, Norway, perhaps the planet’s most advanced nation in electric-vehicle adoption (they anticipate that their last gas-powered car will be sold in 2025), is replacing most of its EV subsidies with incentives and support for people walking and biking, while also considering a car-weight tax to nudge purchasers away from the bulkiest electric cars. (Norway’s EV leadership is not without cost: it should be noted that the Norwegian government is currently exploring ways to replace government revenue from annual taxes of emission-creating vehicles since that will not be possible to apply to electric vehicles.)

Many other countries are not as farsighted. In the U.S., the Inflation Reduction Act that Biden signed in August includes a tax credit of up to \$7,500 for those buying electric cars priced below \$55,000 but in an implicit incentive to buy larger vehicles as well, eligible SUVs costing as much as \$88,000 still qualify. The new law offers nothing for buyers of e-bikes, e-cargo bikes, e-scooters, or other smaller vehicles which of course do not produce as many emissions but are viable alternatives to cars or trucks in many environments. Their more widespread use can thus completely replace those larger vehicles while reducing the need for their more complex supply chains, which in themselves cannot help but produce climate pollutants. Climate experts have urged more promotion of these options but so far, most legislation has not included their advancement.

Electric-powered public transportation such as buses, light rail, and fast trains are not far behind in coming to the table with electric alternatives; their manufacturers should be closely watched for opportunities for their supply chain partners. (59)

Sales channels

Another area ripe for legislation is the vehicle sales channel, which so far is completely different for EVs than what has been in place for decades for traditional vehicles.

Take the Rivian R1T, the \$75,000 debut pickup from America’s newest electric-truck maker. It’s hard for buyers to appreciate its many benefits, or the benefits of any EV for that matter, without a test drive to experience the smooth ride, unbelievably fast acceleration, and passenger amenities. However, a test drive of the R1T is illegal in more than half of the United States because for as many as 200 million Americans, local antitrust laws meant to protect car dealers from unfair competition forbid automakers such as Rivian from selling directly to customers. Since literally the introduction of gas-powered vehicles, this has just been the way things worked. But now these dealer-protection laws have become a major impediment to decarbonizing the American economy.

When you want to buy clothes, you have choices: you can go to a department store that sells lots of brands or to store that only sells its own brand, like J. Crew or an Oshkosh outlet. Same with furniture, appliances, and most other consumer products. But that’s not how it works for vehicles. While dealers may sell more than one type of vehicle, it’s almost always because the brands are related in some way: if you want to buy a Ford truck, you can’t go to a Chevrolet dealer, you need to go to a Ford dealership owned by a third-party company.



Most Americans cannot buy a car directly from the automaker, and in the rare cases where that's possible, it's pretty limited. In 17 states, including Texas, Wisconsin, and Connecticut, automakers are prohibited to open stores to sell directly to customers and another 11 states, including New York, New Jersey, and Georgia, allow only one automaker, Tesla, to operate stores for direct sales. The vehicle sales channel, then, shapes the market for EVs more than one might think. A quick example illustrates this well: New York and Florida.

By most objective indications, New York should sell more EVs than nearly any other state with their many incentives, including up to \$2,000 of the cost of a new EV. The state also pays companies up to \$5,000 to build an EV charger in their parking lot and they have installed the largest non-Tesla charging hub in the country. EVs can use the carpooling lane on state highways, even if the driver is the only person in the car.

Florida, meanwhile, with close enough to the same population as New York for comparison purposes, has only recently begun expanding chargers on its highways. It has no statewide EV-incentive program (although it also lets EV drivers use the HOV lane). Yet for the past three years, Floridians have bought more than 60 % more electric vehicles than New Yorkers: from 2019 to the middle of last year, Florida residents bought nearly 59,000 new EVs while New Yorkers bought only about 35,000.

The difference? Floridians do drive more than New Yorkers, but the clearest difference is that Tesla, which sells more EVs than any other automaker, has 17 stores in Florida and only five in New York, where it also prohibited by law from opening more. This scales to the national level quite well. Across the country, three out of four EVs sold since 2019 have been sold by a direct-to-consumer automaker—which is to say, Tesla. The most striking pattern is geographic: a wide segment of states running down the middle of

the country block direct sales, while most states in the Mountain West and West Coast permit them.

It is not just the unavailability of stores either – traditional vehicle salespeople are almost completely uneducated on EV features and benefits, and therefore unprepared to sell them. First-time EV shoppers have lots of questions about everything from battery range and long-term upkeep to whether they need to do anything different at the DMV, and salespeople need to have answers at the ready.

To tackle this, Rivian has teamed up with Tesla and Lucid, another up-and-coming electric-car maker, to get laws changed on a state-by-state basis. Their biggest challenge is the revenue model for today's traditional vehicle dealers. EVs, with their lower upkeep costs, can't provide the cash flow that dealers need to survive. Dealers' current business model is to make all their money on service as they have an average of a 30 % margin on service, but only a 5 % margin on sales.

When vehicle sales laws were first put into effect in the 1940s, they were meant to protect dealers from having to compete directly with automakers, which could presumably undercut them on price. In some states, that still very much applies: California, for instance, prevents automakers from opening a location within 10 miles of one of their franchise dealers. So far, while it seems that consumers aren't picky about buying directly from an automaker as opposed to buying through a dealer, legislation involving incentives for consumers and/or dealers could change that. Just because the majority of Teslas have been bought direct really proves nothing: the company just never gave their customers any other choice.

The political power of both dealers and automakers is impressively large and the laws are entrenched. Changes will be necessary if the EV market is expected to flourish. (60)



TRANSITION OF VEHICLE PLAYERS

The financial investments vehicle manufacturers are undertaking to gear up for the transition to EVs was covered in the Financial section. However, there are implications for EV production that go well beyond reconfiguring the physical manufacturing elements such as facilities and equipment. In this section, we'll review a few key focus areas for three of the primary organizations involved in EV manufacturing – the vehicle manufacturers themselves, battery production companies, and battery recyclers – as well as some of the key safety concerns for each, which have many different requirements for EV production as compared to gas-powered vehicle manufacturing.

Vehicle producers

To become strong players in the EV market, vehicle producers have many challenges ahead of them beyond “just” standing up whole new manufacturing operations. For example, while customers won't purchase their own batteries or ensure they are recycled, they certainly want to know plenty of details about them, which entails vehicle makers' knowledge, if not actual involvement, with the battery producers who are scaling up rapidly to meet their needs. As the customer-facing element for EV sales, vehicle producers, then, need to reimagine their supply chains to include battery suppliers and recyclers, which is addressed further in this section. Within their own walls, recruiting and training the workforce who will design and produce EVs is a competitive priority for vehicle

manufacturers. Let's take a look at those workforce implications, as well as the important safety measures that are involved.

Workforce implications

As the EV industry gears up as quickly as possible to be able to affect climate change and transition away from fossil-fuel-powered vehicles, sustainability is critical. Adoption of techniques and careers associated with the circular economy are not only key but expected to move the mobility of people and goods towards net-zero emissions. This opens up a host of new career opportunities and job possibilities over the next several decades.

The move to EVs will generate requirements for new/increased employment in at least three broad areas:

- Design and development of EVs
- Design and innovation of batteries
- Installation and maintenance of charging infrastructure

The U.S. public and private sector is currently lagging behind other countries in all three areas, especially China, threatening both our ability to reach climate goals and the long-term competitiveness of our domestic automobile industry, which has long been a source of high-quality, unionized jobs that support a strong middle class. With fewer parts and lower mechanical complexity, EVs will significantly erode employment in the production of engines, transmissions, exhaust, and conventional fuel systems. For example, Ford estimates that simplification in the assembly of EVs could lead to a 50% reduction in capital investments and a 30% reduction in labor hours compared with ICE vehicle manufacturing. (71)



The International Labour Organization (ILO) points out the expectation that productivity will increase as EVs are less complicated to assemble and therefore can be completed for delivery in far less time (31):

ICE vehicle	6.2 hours
Hybrid vehicle	9.2 hours
EV	3.7 hours

However, there is also good news for employment resulting from the transition to EVs to balance out the potentially negative workforce impacts. According to the US Bureau of Labor Statistics (Beyond the Numbers), projections for a number of engineering fields are quite positive (see Table 4). Engineers aren’t the only ones, though, who will benefit at automobile manufacturers (refer to Table 5). Beyond automobile manufacturing in the overall EV ecosystem, many other areas are also projected to enjoy employment booms (see Table 6).

The International Labour Organization agrees

Potential impact of green transport and electric vehicles on employment

The ILO has developed several scenarios to estimate the potential economy-wide employment implications of an accelerated shift to greener land transport in the region of the United Nations Economic Commission for Europe (UNECE). One of the scenarios explores the employment implications of introducing a voluntary or mandated target that 50 % of vehicles produced across all Member States of the UNECE should be fully electric by 2030.

The result of this modelling, which is based on a macroeconomic multiregional input–output model, is that net employment will increase in the automotive industry and other sectors related to green transport. Net job creation worldwide would be close to 10 million jobs, which is 0.2 per cent greater than the jobs that would be created in a business-as-usual scenario. Some 2.9 million of these jobs would be generated in the UNECE region and some 7 million jobs in other regions.

Source: ILO and UNECE, *Jobs in Green and Healthy Transport: Making the Green Shift*, forthcoming

TABLE 4. EMPLOYMENT PROJECTIONS, 2021–31, AND WORKER CHARACTERISTICS, 2021, FOR SELECT ELECTRIC VEHICLE-RELATED OCCUPATIONS (EMPLOYMENT NUMBERS IN THOUSANDS)							
Occupation title	Employment, 2021	Employment, 2031	Employment change, 2021–31	Percent employment change, 2021–31	Occupational openings, 2021–31 annual average	Median annual wage, 2021¹	Typical education needed for entry
Total, all occupations	158,134.7	166,452.1	8,317.4	5.3	19,532.5	\$45,760	²
Software developers	1,425.9	1,796.5	370.6	26.0	143.4	\$120,730	Bachelor’s degree
Electrical engineers	192.4	195.5	3.1	1.6	12.3	\$100,420	Bachelor’s degree
Electronics engineers, except computer	111.4	118.0	6.7	6.0	7.8	\$104,820	Bachelor’s degree
Chemical engineers	26.9	30.7	3.7	13.9	2.0	\$105,550	Bachelor’s degree

TABLE 5. EMPLOYMENT PROJECTIONS, 2021–31, AND WORKER CHARACTERISTICS, 2021, FOR SELECT ELECTRIC VEHICLE-RELATED OCCUPATIONS (EMPLOYMENT NUMBERS IN THOUSANDS)							
Occupation title	Employment, 2021	Employment, 2031	Employment change, 2021–31	Percent employment change, 2021–31	Occupational openings, 2021–31 annual average	Median annual wage, 2021¹	Typical education needed for entry
Total, all occupations	158,134.7	166,452.1	8,317.4	5.3	19,532.5	\$45,760	²
Electrical, electronic, and electromechanical assemblers, except coil winders, tapers, and finishers	279.5	285.5	6.0	2.2	32.8	\$37,460	High school diploma or equivalent
Miscellaneous assemblers and fabricators	1,367.1	1,270.7	-96.4	-7.1	142.7	\$36,590	High school diploma or equivalent

TABLE 6. EMPLOYMENT PROJECTIONS, 2021–31, AND WORKER CHARACTERISTICS, 2021, FOR SELECT ELECTRIC VEHICLE-RELATED OCCUPATIONS (EMPLOYMENT NUMBERS IN THOUSANDS)							
Occupation title	Employment, 2021	Employment, 2031	Employment change, 2021–31	Percent employment change, 2021–31	Occupational openings, 2021–31 annual average	Median annual wage, 2021¹	Typical education needed for entry
Total, all occupations	158,134.7	166,452.1	8,317.4	5.3	19,532.5	\$45,760	²
Urban and regional planners	41.9	43.5	1.6	3.8	3.8	\$78,500	Master’s degree
Electricians	711.2	761.4	50.2	7.1	79.9	\$60,040	High school diploma or equivalent
Electrical power-line installers and repairers	126.6	130.7	4.0	3.2	11.1	\$78,310	High school diploma or equivalent
Construction laborers	1,358.4	1,430.3	71.9	5.3	143.2	\$37,770	No formal educational credential

Data are from the Occupational Employment and Wage Statistics (OEWS) program, U.S. Bureau of Labor Statistics. Wage data cover non-farm wage and salary workers and do not cover the self-employed, owners and partners in unincorporated firms, or household workers.

2. Not applicable.

Source: U.S. Bureau of Labor Statistics



Safety

Safety and training regulations for production vary widely in different parts of the world, presenting both challenges and opportunities for providers of tools and equipment for vehicle manufacturing. The importance of meeting these needs effectively cannot be overstated as manufacturers push to move to the head of the class competitively, it's tempting to overlook process quality. While a model employer in many ways as regards benefits and social policies, in 2021 Tesla also reported injury rates at its plants that were 31% higher than the U.S. auto industry average. (61).

So, all of this new employment will require substantial volumes of training ranging from sophisticated to less complex. U.S. automotive OEMs are currently looking at training in three buckets:

TABLE 7. SAFETY TRAINING BUCKETS	
Stage	Description
1	Non-electrical work – bodywork, wheels, test driving
2	Electrical work in non-live state – replacement of high voltage components
3	Live work in proximity of live parts – troubleshooting, replacing live parts

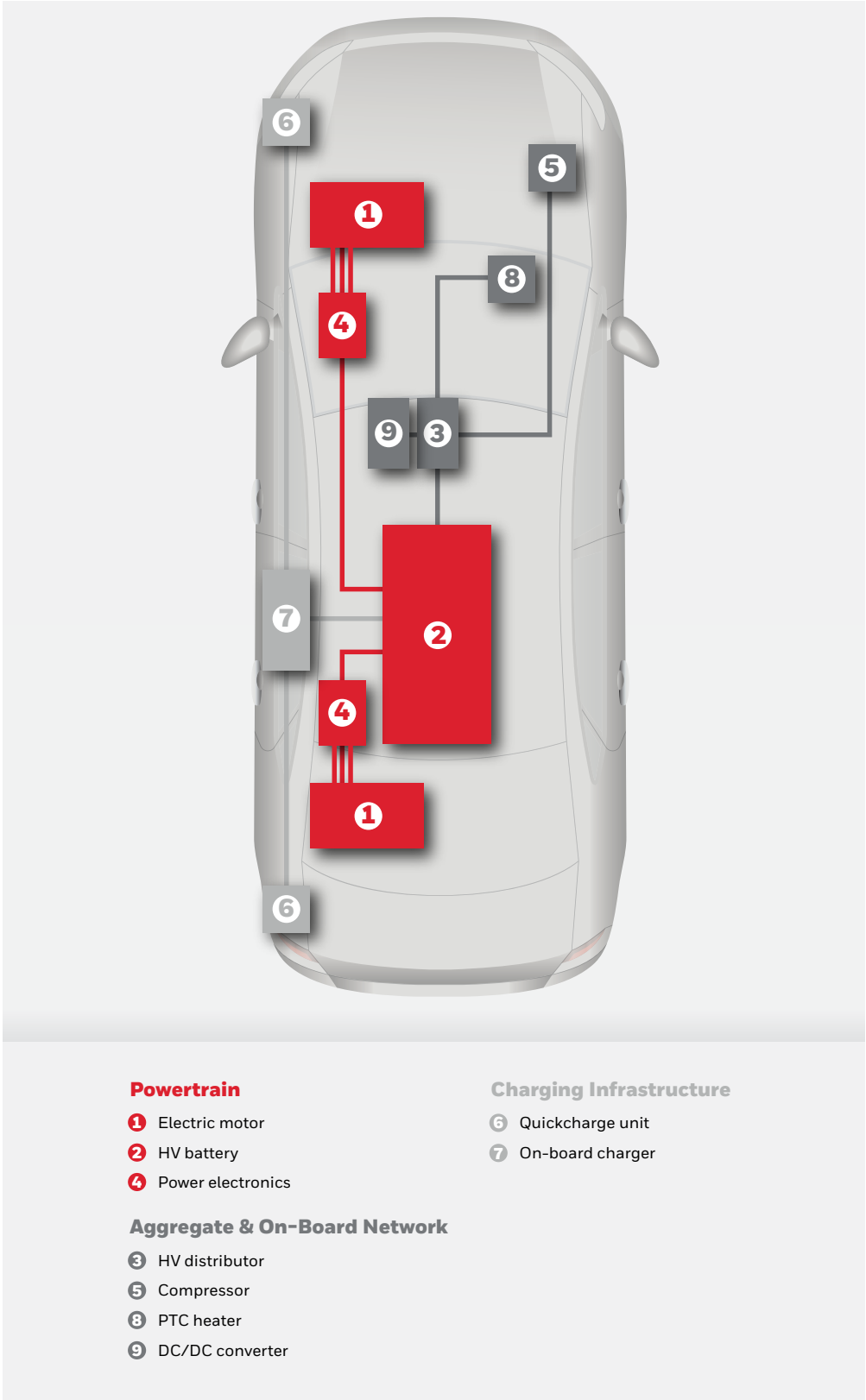
While the number of parts required for EVs is considerably less than those required to manufacture gas-powered vehicles, some of their components – notably those associated with electrical voltage – necessitate the implementation of new types of personal protective equipment (PPE). The different parts of an EV that represent OSHA 1910-132 safety hazards during production – which may be of impact to workers in a variety of positions, including not only engineers, technicians, and testing professionals at vehicle manufacturing facilities but also automotive service technicians and researchers or students working on EV projects – are shown in this graphic from EV Reporter (See Figure 10).

Up to 70% of these new positions over just the next three years will require education and use of PPE ranging from body safety to respiratory protection, depending on the size of the operation. In India, for example, EV Reporter lists these types of PPE as minimum requirements for worker safety in addition to clear safety signage:

- Insulated gloves
- Goggles
- Non-slipping insulated boots
- Hot sticks (a long, insulated pole to separate a person under electric shock conditions from contact)



Figure 10. High Voltage Components of an EV



Frost and Sullivan prepared an exhaustive global report on the need for personal protective equipment (PPE) in the worldwide EV industry, based on three strategic imperatives:

TABLE 8. THE IMPACT OF THE TOP THREE STRATEGIC IMPERATIVES ON PERSONAL PROTECTIVE EQUIPMENT (PPE) IN THE ELECTRIC VEHICLES (EVS) INDUSTRY			
	Transformative Mega Trends	Disruptive Technologies	Geopolitical Chaos
Why	The penetration of EVs in the overall global vehicle parc is on the rise. Ever-tightening emission standards, coupled with government policies that incentivize EV production, are increasingly driving multi-billion-dollar investments in automotive electrification infrastructure, and, in turn, creating significant growth avenues for PPE suppliers. The rising demand for EVs will result in unprecedented demand for batteries alike. Moreover, the inherent safety risks associated with specific operations across the value chain entail the need for value-added PPE products that act as safeguards against thermal, electrical, and chemical hazards.	With tightening regulatory requirements and rising consumer acceptance, the industry majors are increasingly shifting toward vehicle electrification. As such, the need for sustainability across the value chain will result in an urgent need for sustainable solutions. Considering the rate of growth and overall scale, the problem of battery waste and scrap accumulation requires action. Accordingly, participants across the value chain are increasingly strengthening infrastructure for recycling and end-of-life (EOL) management of EV batteries.	While China remains the early mover in the global EV market, a rapid surge in demand has occurred in other regions, especially in Europe, in the recent past. Automotive manufacturers, particularly in Europe, have been expediting EV development and transitioning toward battery and EV manufacturing to strengthen their competitive position. Furthermore, government incentives and investment-friendly policies will drive a regional capacity re-balancing effort across the industry. Similarly, the US government is poised to roll out policies that augur well for localized production of batteries.
Perspective	Frost & Sullivan expects revenues from PPE used in the EV value chain to register substantial growth through 2026, underpinned by increasing employment, especially in battery manufacturing; rising compliance levels; and higher PPE spending per employee owing to the need for value-added PPE products, such as insulating gloves.	Incumbents will benefit from the ever-increasing focus on EOL management of EV batteries. The average life of an EV battery is 8 to 10 years. Accordingly, the industry will witness a surge in demand for EOL management services in 2 to 3 years, thereby driving the demand for PPE used therein. Similarly, the need for using sustainable, greener materials will gather pace the next 1 to 2 years.	Frost & Sullivan believes that with concerted efforts toward re-balancing the EV value chain, the industry could witness a surge in investments toward capacity building as well as ramp-ups, thereby driving growth in employment and hence the demand for PPE in the next 3 years.

In the study, Frost & Sullivan is expecting revenues to register substantial growth through 2026, by which time it is anticipated that it will have grown to three times its current level, reaching a point where it is generating incremental annual revenue growth representing over \$530 million (PPE in the EV industry today is valued at around \$260 million). PPE reviewed in the study include above-the-neck protection, respiratory protection, protective clothing, hand protection, foot protection, fall protection, and gas detection.

Battery Production

As noted earlier, the EV market is not just about investments in manufacturing vehicles themselves but also the batteries that power them. With its own supply chain – and the challenges that go with it – this is proving to be a very large, fast-growing market globally.

Lithium-ion batteries are currently the battery of choice for EVs, but according to the IEEE Spectrum, the lithium battery market – while not going anywhere for the next few years – is exceptionally ripe for disruption. Battery innovators from Tesla to start-ups around the world are in major competition to reduce the amount of natural resource elements necessary for lithium battery production to help offset the challenge of needing to purchase those materials from geopolitically dicey governments.

Ensuring that batteries are up to the challenge of keeping people on the road, with stable chemistry and the ability to endure thousands of cycles of charging and discharging over the life of a vehicle, is driving innovation in this field too. The cost-effective production of batteries using completely different technologies like hydrogen can help reduce the need for extensive recycling capabilities. Solid-state batteries and sodium-ion batteries are also being imagined or reimaged for EV purposes. Not only could these technologies



radically simplify the necessary electrical infrastructure for EVs, but also may help drastically reduce weight (a key factor in increasing driving range) and vehicle maintenance, lower prices (the battery in current models accounts for one third of the price), and improve interior space and cargo volume. (63)

These innovations in batteries will be going head-to-head in a race to outpace lithium batteries just as battery volume requirements are anticipated to ramp up by more than 15 times by 2030, setting up what could potentially become one of the fastest-to-market major technology shifts in recent years. This will also represent a challenge for major new battery manufacturers making large investments in lithium production facilities for whom new technologies would mount pressure to transition those facilities for new types of batteries. (64)

As the EV market hits its stride, the growth of battery production facilities is slated for exponential growth. In 2022, production was estimated at \$73 billion and Benchmark Mineral Intelligence, a data and market intelligence provider, expects U.S. capacity to expand fivefold by 2026 and another 86% by 2031.

Almost all of these are gigafactories, defined as exceeding 1 GWh of capacity, although the majority exceed 10 GWh and the largest exceeds 40 GWh. New gigafactories are clustering in several geographic areas (see Figure 11).

Geopolitical Concerns

EV batteries require a lot of elements not needed for traditional gas-powered vehicles, and that presents supply chain challenges. EVs require roughly six times more minerals than ICE vehicles, which makes one of the most challenging aspects of meeting demand the global geopolitical environment for a number of natural resources required for the manufacture of EV batteries, namely lithium, cobalt, and high-grade nickel, many of which come from countries without

democratic governments. Addressing this represents a combination of governmental diplomacy levels in negotiating trade protocols and treaties as well as manufacturers themselves building and maintaining strategic alliances.

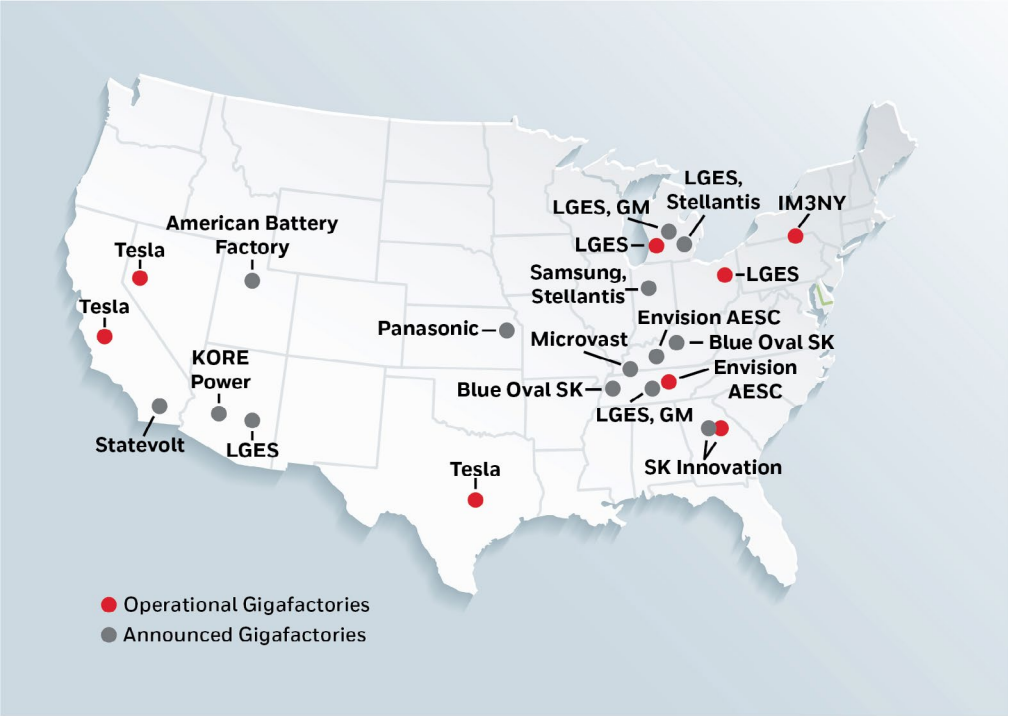
These can be time-consuming and also may conflict with human rights policies in some cases. For example, the Democratic Republic of the Congo (DRC) produces over 70% of the world’s cobalt, much of it mined by thousands of children working in hazardous conditions. China, which provided over 40% of the world’s lithium batteries in 2020, used cobalt imported from the DRC in nearly 90% of its batteries (78).

The U.S. EV industry, however, is not wholly dependent on politically dubious sources of battery materials. A parallel supply chain is being created across North America that includes the mining of critical minerals. The United States-Mexico-Canada Agreement (USMCA, formerly known as NAFTA or the North America Free Trade Agreement) can provide the certainty companies expect in order to invest billions into the EV transformation in Canada, Mexico, and the U.S., the scale of which is enormous: EVs and battery storage demand for mineral inputs in North America alone are expected to grow by at least 30 times to 2040.

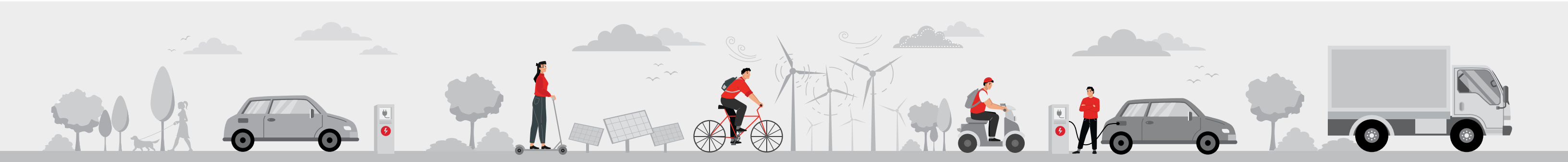
Fortunately for North America, Canada is in the top five countries producing cobalt, copper, graphite, precious metals, nickel, and uranium, and also has the potential to expand in lithium, magnesium, and rare earths production. It is the only nation in the Western Hemisphere with deposits of the complete set of minerals required to make EV batteries.

Brookings notes that increasing and diversifying Canadian production of critical minerals will enhance North American security and increase trilateral trade. Building North American supply chains starting with mineral exploration to mining presents an important

Figure 11. New Gigafactories Cluster in the Midwest, South, and Near Tesla Facilities



Notes: We define a gigafactory as having capacity of 1 gigawatt or greater. Map does not include announcements missing a location or capacity estimate.
Source: Electrek, Here’s Where the New US EV ‘Battery Belt’ Is Forming – and why, Oct 2022



opportunity for job creation and economic growth while ensuring responsible mining practices. (65)

While responsible acquisition of EV mineral elements has been identified as an area for further improvement it may also be able to benefit from creative ways of recycling the materials that exist in vehicles on the road. Recycling is covered in more detail further in this report.

Safety

The battery industry has many of the same safety challenges as those identified earlier for vehicle manufacturers, such as protection from chemical and thermal exposure. There are unique safety issues in this industry too, with one of the most serious being exposure to lead. As has been shown in other industries for many decades, lead can impact the brain, digestive system, nervous system, and reproductive system, as well as the heart and kidneys.

Lead compounds present during several stages of production create lead dust as a byproduct. It is important that workers do not breathe this dust into their lungs but they also don't carry it on their clothing or hands. OSHA has mandated a number of safety practices that are required when lead is present, as it is in these steps of battery production ranging from maintenance to repair/reclaim.

The mining industry referenced above also represents significant opportunities for PPE providers, including (66):

- Hard hats: different classes depending on the conditions of the mine site
- Safety glasses: usually standard but sometimes incorporated with a full respirator; if welding or cutting is occurring, a full-face shield may be required

- Mask/respiratory protection: dust exposure poses a huge risk to workers; protection ranges from nose/mouth covers with replaceable filters to powered air-purifying respiratory gear
- Hearing protection: loud sounds in confined spaces mandate the wearing of ear muffs or plugs
- Reflective clothing: due to sight challenges in tight spaces, workers should be outfitted in reflective jackets or shirts as well as reflective pants
- Personal fall protection equipment: especially important in elevators and mine shafts, should include anchors, body supports, and connectors
- Hand and foot protections: durable boots of differing levels of classification; standard work gloves are generally sufficient

Battery Recycling

The EV battery recycling industry is just getting started, but the implications for the future are tremendous. The challenges faced by the industry can be addressed through a variety of programs and incentives.

Since many battery elements are highly re-usable, Redwood, a recycler in California, is working to deconstruct used batteries to recoup their natural resource elements for use in new batteries (77) and exploring the idea of using batteries past their vehicle's lifespan but still operable to store wind and solar energy. Batteries are commonly expected to last 15+ years, but as the recycling industry gets off the ground it is still proving profitable for at least some recyclers as they concentrate on smaller batteries from cell phones, computers, and production waste from EV battery production.





The EU has mandated that vehicle manufacturers seek out and accept used batteries at the end of a vehicle’s life; EV auto manufacturer Renault currently recycles not only all their own batteries but all batteries in their supply chain, including production waste from battery manufacturing plants (16). Another option along these lines would be to offer rebates on new vehicles when batteries from previous vehicles are returned to dealers. Other vehicle manufacturers are finding ways to re-use batteries, in applications such as in-factory parts delivery systems.

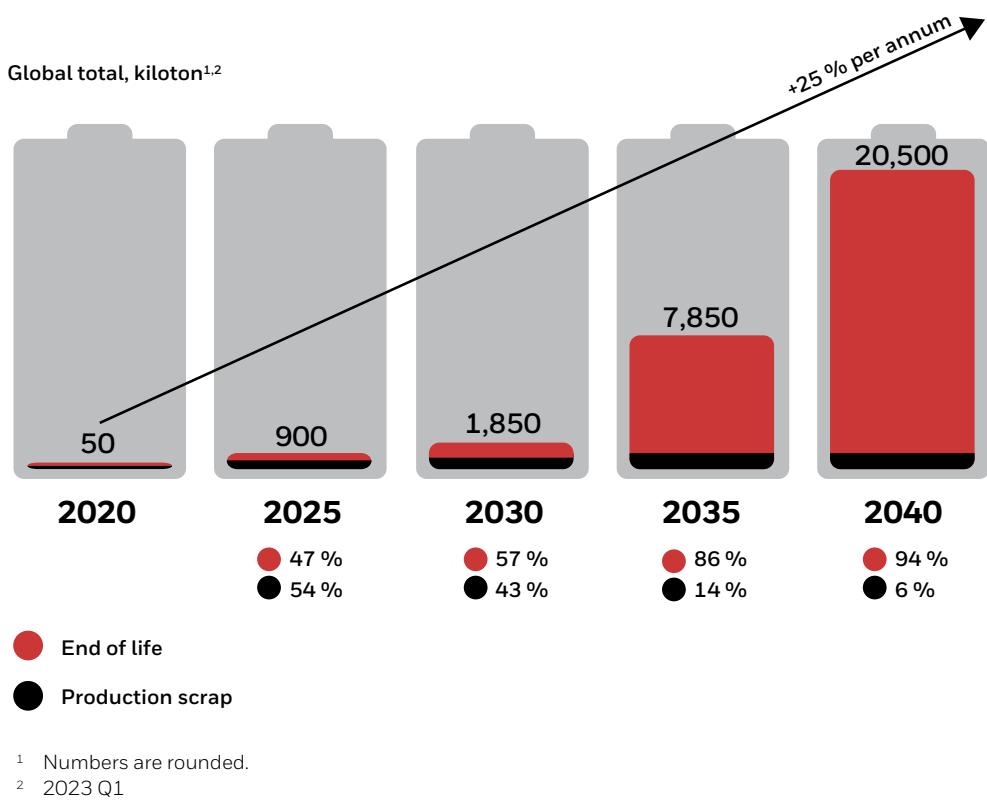
McKinsey estimates that battery recovery revenues are expected to grow to more than \$95 billion per year by 2040 through a combination of vertically integrated battery lifecycle recyclers, specialized battery recyclers, and in-house OEM recyclers. Prior to 2030, the majority of recycling is expected to be mostly production scrap, but after that time it will be made up primarily of end-of-life batteries (see Figure 12).

They further note that recycling battery materials can significantly reduce the carbon footprint of EVs (see Figure 13).

Safety

As might be expected, the safety requirements for the recycling industry are largely the same as those for the battery production industry, minus most of the requirements for live voltage protection. Because of the significant weight of EV batteries, additional protection is necessary for handling heavy loads, both by humans and equipment such as skid loaders and forklifts.

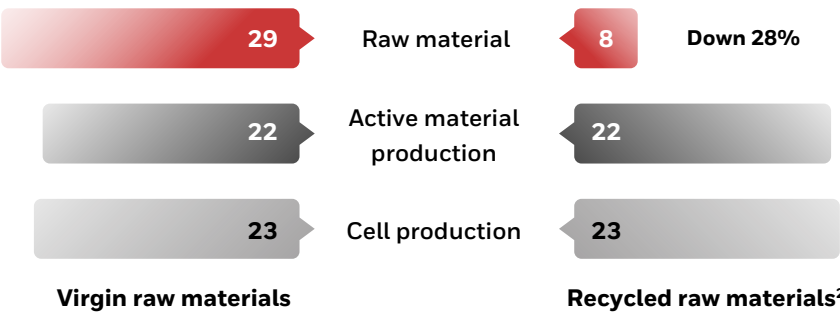
Figure 12. The Global Supply of EV Batteries for Recycling



Source: McKinsey & Company: Battery recycling takes the driver's seat

Figure 13. CO₂E Battery Cell Production Emissions

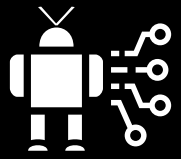
Total CO₂e battery cell production emissions from a nickel-based lithium-ion battery with virgin versus recycled materials,¹ kgCO₂e per kWh



¹ United States, 2023 Q1.
² Assuming mechanical pre-treatment and hydrometallurgical recycling.

Source: McKinsey & Company: Battery recycling takes the driver's seat





TECH GIANTS

Tech giants, including digital communications channels, are a more recent but increasingly significant player in EV adaptation. Included in this section is information on the inclusion of these types of technologies both in electric vehicles themselves as well as in supporting their sale and widespread adaptation by the buying public.

Vehicle components/user data

One of the most interesting aspects of the technological disruption that’s in play with EVs is that by 2025, “tech giant” corporations – data, AI, facial recognition, and so on – will literally own a not-insignificant percentage of the operating system of the vast majority of the new cars in the future. The consumer expectation that their driving experience be equally as technologically advanced as their smart phones or digitally integrated homes is already commonplace. From optic systems that alert drivers to potential obstacles or hazards and automatic route mapping to advanced entertainment options and seamless ways to connect vehicles to personal digital assistants like Siri™ or Alexa™ to accomplish a wide variety of tasks, the transition to digitally sophisticated vehicles is well underway.

Gartner analysts estimate that by 2025, the giant companies of data and other intellectual property types of information will own a part of those operating systems for 95 % of new cars on the road. They have already begun to displace established automotive in-vehicle software providers (e.g., Google Automotive Services and CarPlay), and are also using their ecosystems to claim a larger

share of the vehicle operating system territory (e.g., Renault’s partnership with Google and VW’s partnership with Microsoft). Other tech giants working directly with vehicle manufacturers include Foxconn, Huawei, Alibaba, Xiaomi, Tencent, and Sony are all examples of this trend.

Succeeding without collaborating with these digital giants will not be possible for a traditional OEM or supplier; partnerships will become battlegrounds for OEMs wishing to remain profitable and competitive in the industry. (8)

Influencers

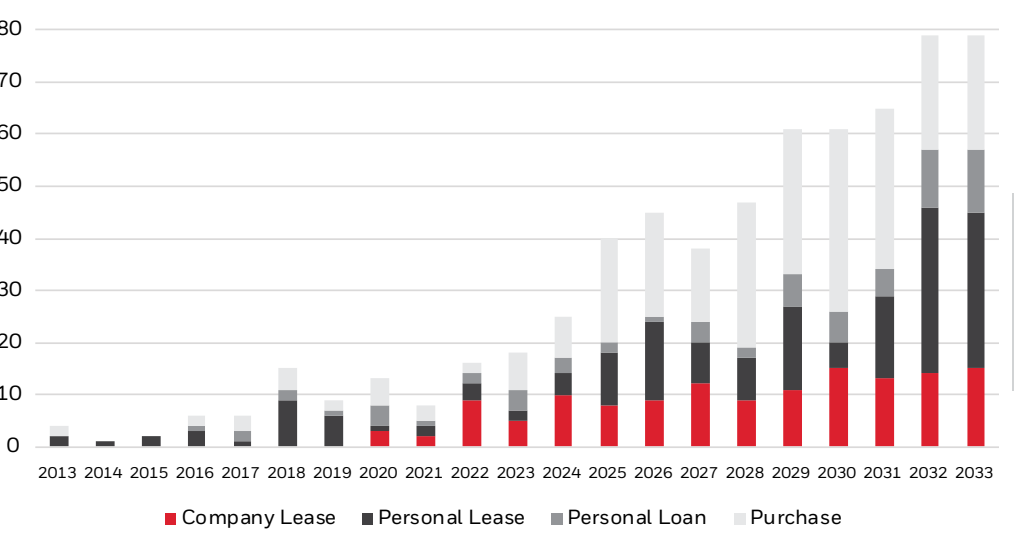
One of the first and most trusted influences for EV adaptation is first-hand experience with people who already have them and digital media is ideal to accomplish this task. To that end, the types of current buyers make up an important group in reaching future buyers, and those current buyers represent a variety of types of purchasers (see Figure 14).

Furthering that observation, new digital options including social media and streaming services like YouTube™ are playing a significant role in reaching new buyers. During the pandemic, for example, global English-language conversations about EVs grew a staggering 238% on Facebook. But while the conversation trended upward, it was found that more than half of auto intenders surveyed weren’t actively considering electric vehicles.

This was found through a study commissioned by Meta™ (formerly Facebook™) of 10,000 people to get their thoughts on electric vehicles and understand their hesitations in buying. First, it was found that some 42% are at least looking into electric cars. With actual EV purchases far lower than this, what’s stopping them?

While transportation remains the largest source of climate pollution in the U.S., and vehicle-related pollution continues to cause higher

Figure 14. BEV Buyer Purchase Types



Source: National Library of Medicine at the National Center for Biotechnology Information, Aug 2021





rates of asthma, cancer, and other illnesses, according to the data – and contrary to what some might believe about climate concerns being a primary buying indicator – the barriers for converting potential EV buyers are largely practical. Consumers are concerned about battery life-span, travel range, charging infrastructure and cost. That suggests that messaging around these aspects is not getting through, and Meta says that sellers of EVs need to do better at communicating the benefits around maintenance, performance and the development of infrastructure to support charging needs.

In this sense, practical messaging works best, as opposed to idealism, or sometimes puzzling tech speak, and it also won't hurt to find ways to get potential buyers to experience EVs firsthand – the majority of those responding report having never even been in an electric car (79). Once potential buyers indicate interest, social media can play another role in tipping them into actual purchasing. An example was provided dating back many decades, when the adoption of tractors in Saskatchewan and hybrid corn in Iowa was proving problematic for the sellers.

The University of Saskatchewan conducted “tractor schools” during the 1920s, where farmers would gather at a local farm and agriculture instructors would provide hands-on instruction, including discussions of the economics of horses and power-farming. These were both popular and successful because farmers could quiz the experts and discuss among themselves.

Similarly, during the late 1930s, the University of Iowa would find an influential, trusted farmer to host a hybrid corn “school” to encourage less innovative farmers to try the new corn that produced higher yields but did not reproduce so was more expensive up-front.

The modern equivalents of these schools are Meta, Twitter™, LinkedIn®, Instagram™ and other digital platforms where EV owners and enthusiasts can share information with prospective buyers. (68)

Buyer behaviors

As outlined above, digital/social media plays an important role in EV buying behavior. Certainly many of these observations apply to traditional types of advertising and promotion as well, but as the marketing industry in general transitions to more digital formats, it's important to see how buyer behaviors may be able to be better, or at least additionally, addressed through social media.

One example lies in the time-honored strategy of product placement – it just now applies not only for traditional media but new digital media as well. If you tune in to Queer Eye in 2023 you may find the “Fab Five” talking about the transformative power of an interior refresh of a zero-emissions Hummer™ pickup truck. The placement is part of a new deal between Netflix® and General Motors to feature electric vehicles on the streaming service, a deal that both companies are promoting as a step toward “creating a better, more sustainable future for our world.” Queer Eye debuted in 2003, which indicates that EV promotions may be trending less towards first adopters and more towards the general market, which of course is exactly where the market wants them to go. (69)

Buyer behavior begins with customer education, which is a substantial challenge for the EV industry overall and digital media, including social media and a variety of streaming services is well suited to this purpose. As essentially “a completely new technology,” customers have questions – detailed questions – about almost every aspect of owning an EV. As an example, many consumers don't know enough, in their estimation, about EV batteries, including safety aspects such as chemicals and overheating. Just look at the types of questions and concerns from several countries regarding EV batteries (see Figure 15).



One significant piece of information that has not been promoted widely enough to make a strong impact on EV sales is total cost of ownership of an EV, which can be surprising.

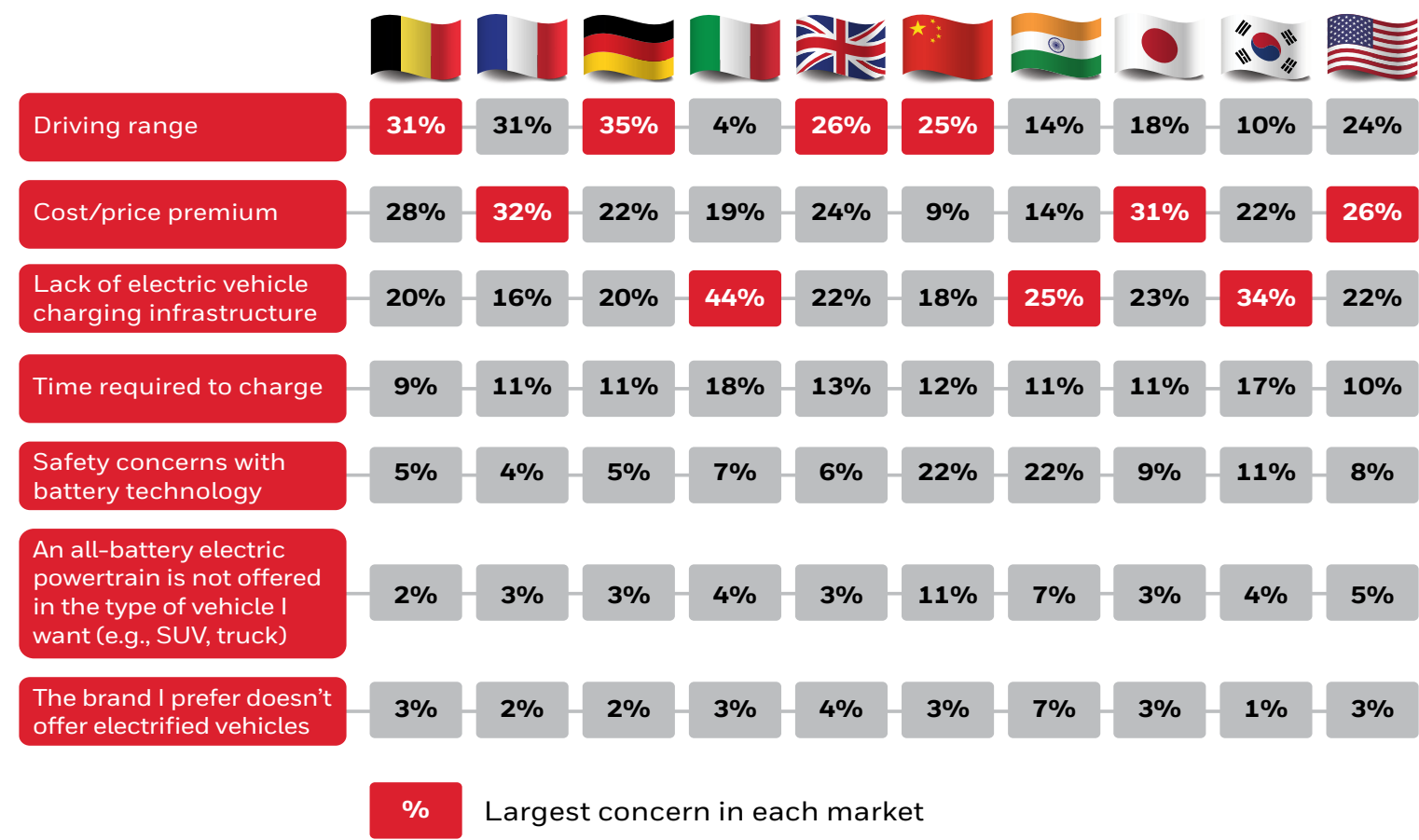
New analysis from Atlas Public Policy finds electric cars and trucks can cost less than some of the most popular vehicles in the U.S., including the Ford F-150 described earlier. Their comprehensive analysis includes the latest data on vehicle purchase price, maintenance and fuel costs, taxes, fees, and depreciation in order to create a total cost of ownership comparison between electric and gas-powered vehicles across four vehicle classes; SUVs, pickups, low-cost sedans, and mid-cost sedans.

The analysis finds the total cost of owning the forthcoming electric version the Ford F-150 (the F150 Lightning) is 17 % lower than the gas-powered version; the cost of the electric Volkswagen ID.4, an SUV, is 15 % less than the Honda CRV; a Tesla Model 3 is nearly 5 % less than a similar Lexus; and the Chevy Bolt costs 6 % less than a Toyota Corolla. Data used was from 2021, and was as follows:

- A potential Build Back Better EV tax credit was not factored into the cost. The existing \$7,500 tax credit was factored in where applicable.
- Home charging was assumed to be 88 %, representing the midpoint of a range provided in a report from the National Renewable Energy Laboratory; no charging equipment costs were included.
- Public charging costs drew from Electrify America charging prices.
- The manufacturer’s suggested retail price (MSRP) of vehicles was drawn from FuelEconomy.gov.
- Expected years of use was assumed to be eight years at an average of 15,000 miles per year.
- No climate costs or benefits were factored into the calculation



Figure 15. Customer Concerns Regarding Battery Electric Vehicles



Source: Deloitte Global Automotive Consumer Survey 2018



INFRASTRUCTURE

The infrastructure needed to support the expansion and adaptation of EVs is an entire industry unto itself, and extensive studies and reports on this aspect of the industry alone are readily available. Provided here are short summaries and examples of the important elements of this industry; for more detailed analysis, any of the major market research groups can provide as much information as might be required.

One overarching element common throughout infrastructure activity has been mentioned in all of the previous parts of this report: incentives. Just like incentives to control emissions or encourage EV purchases, incentives – primarily government incentives – apply here as well. The same goes for regulations, which need to adapt quickly to accommodate the transition, as opposed to the lengthy law creation process most often experienced to date. Creating the momentum for infrastructure through incentives is important because because it's a costly proposition until scale is realized.

Europe has a head start in understanding and planning for this. The graphic here shows the relationship between three major parts of the infrastructure (see Figure 16),

Not including 29 million private charging stations that homeowners, apartment building managers, and workplace parking operators would have to install to meet demand by 2030, this more conservative scenario would require an acceleration from about 1,600 new installations per week in 2021 to more than 10,000 per week by 2030 (see Figure 17.)

For information related to finding grants and other funding sources related to infrastructure projects, visit <https://www.grants.gov/web/grants/view-opportunity.html?oppld=34679>.

Energy Grid

As mentioned earlier, the adaptation of fleets is a key area to meet emissions targets more quickly. In the U.S., electrification of the U.S. vehicle fleet is anticipated to be the primary driver of an estimated 38 % increase in electricity demand by 2050 according to a 2018 analysis by the U.S. Department of Energy. This will require major expansion and modernization of the nation's grid, leading to a major source of job creation within the EV ecosystem model

Grid demands vary widely across geographies. In rural environments, for example, driving range becomes more important because at least currently, charging stations are much more widespread. There are different but critical differences in urban grid requirements. Globally, 55 % of the population now live in urban areas and that percentage is expected to increase to 68 % by 2050 with 90 % of that urban population growth in Asia and Africa. In 2015, 64 % of all travel was made in urban environments; by 2050, the total distance of urban kilometers traveled is expected to triple.

Another challenge facing the energy companies responsible for expanding and updating the grid is simply its age and unwieldy operation: a comprehensive audit of the grid and its capabilities is long overdue. The problem of vulnerability to attacks, and therefore disruption of service, is also lagging the necessity of a strong, stable nation- or region-wide grid both here in the U.S. and abroad. (71)

Figure 16. Infrastructure, Grid, and Energy Requirements for Growth of Electric Vehicles (EVs) in Europe

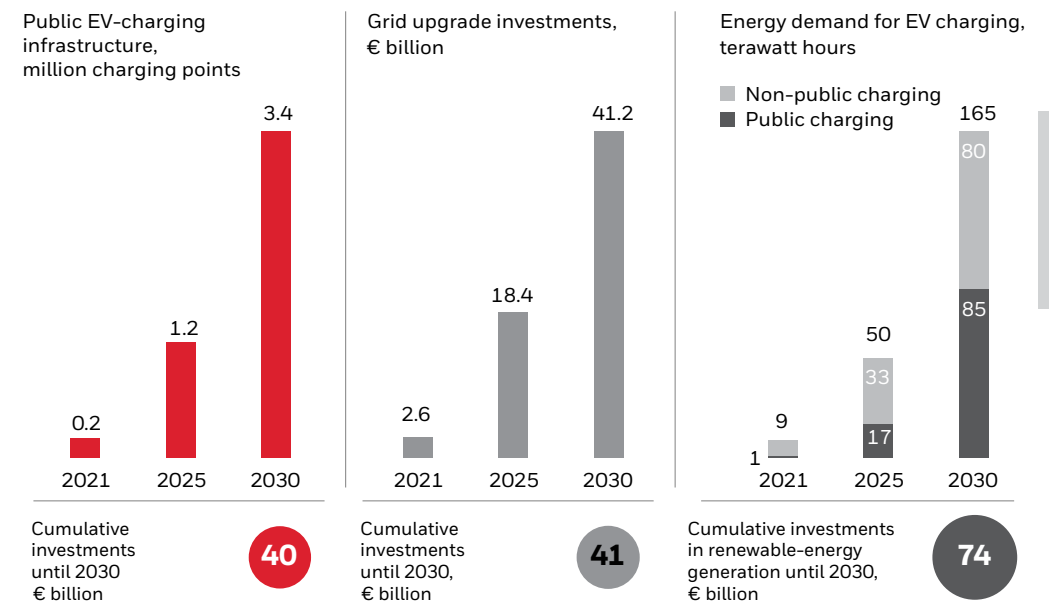
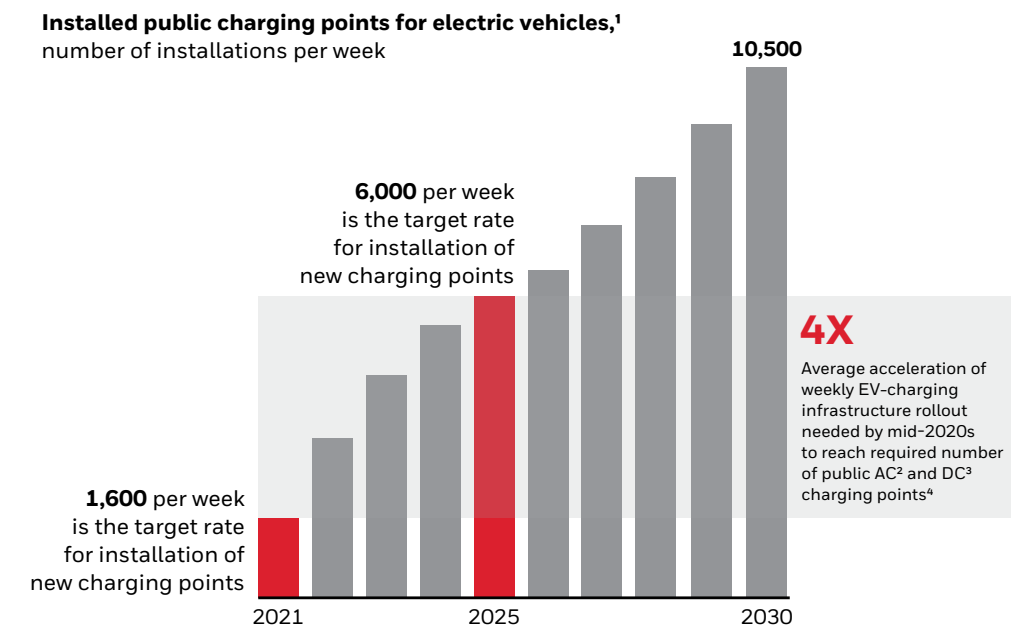


Figure 17. The Pace of Public-Charger Installations in Europe Must Quadruple by 2025



¹Target rate reflects utilization-oriented scenario described in the European Automobile Manufacturer's Association (ACEA) report.
²Alternating current
³Direct current
⁴470 weeks left until end of 2030 and some 3 million public charging points to be installed.

Source: European Alternative Fuels Observatory; national transport and mobility organizations; McKinsey EV charging-infrastructure model.



Charging

As the grid challenges are being addressed, the need for literally thousands of new charging stations must be addressed in tandem so that there is no lag between the two. Charging stations and technologies represent a huge tangential industry that must grow quickly to accommodate the planned sale of millions of new EVs. The U.S., for example, plans to add 500,000 new chargers by 2025 to an existing volume of 100,000. (72)

A robust charging system plays a major role in EV purchasing decisions as renters, for example, may not have the option to install charging infrastructure, and even if they have charging infrastructure now, their next rental may not provide access. Many homeowners don't have off-street parking, and relying entirely on public charging infrastructure will represent a challenge. The charging infrastructure must offer consumer confidence that they can charge at home, at work, or independently, and getting everyone up to speed will require consumer education.

As a result, the rollout of commercial, publicly accessible, cost-effective charging is an area where innovations are highly anticipated. Obstacles must be overcome as cost is not just the time involved and the nuisance of needing to plan ahead: today's public charging is marked up in order to ensure profitability and charging during peak hours adds even more cost. The expansion will require governmental support and insight into factors such as accessibility, convenience, and equity for charger locations. Utilities providing the stations will need to decide on charging speeds and pricing, balancing profitability with consumer expectations. (73)

One alternative in the works is fast-charging, which is currently pretty pricey – as of 2022, the hardware alone can be \$50-100K. However, this is expected to drop at least 40% in the next five-to-seven years as the EV customer base expands.

Another ground-breaking technology is automated charging, where no cords are required and the charging mechanism is built into the underside of the vehicle. This alternative is just in its infancy but expected to reach maturity in some areas by 2025. A more efficient method by at least 1 or 2 % than corded charging, one can imagine grocery store parking lots that are essentially large charging “fields” and as you shop for your groceries, your parked vehicle will be charging up so that you are never caught without energy for your travels. McKinsey provides an example of this in Vienna, Austria, where only electrified taxis will be allowed by 2025. Without automated charging, EVs would not be profitable for taxi providers as they could need to spend an hour or more charging their vehicles for each shift. Automated charging solves this problem by charging taxis as they line up in taxi stands. Similar plans are in place for first-responder vehicles such as ambulances and fire trucks. (29)

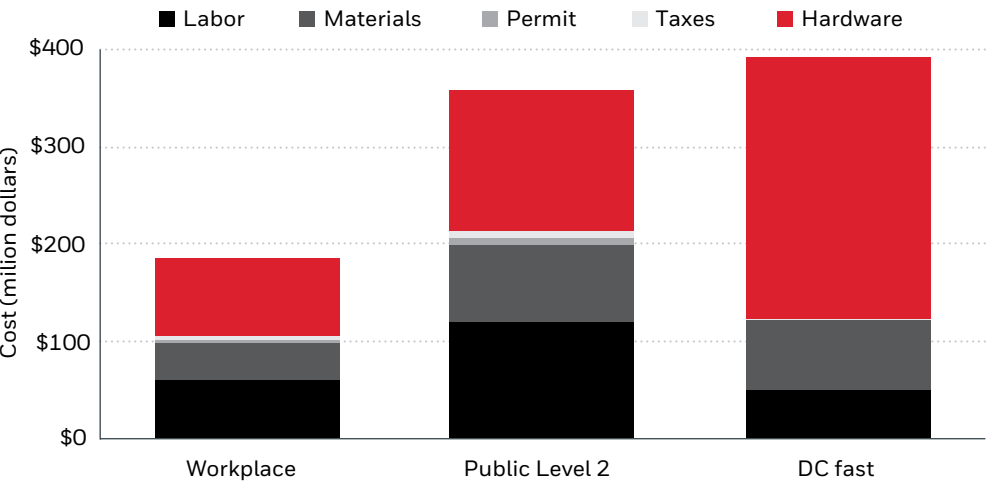
Workforce implications

One of the immediate implications of making infrastructure match requirements for widespread EV expansion is the number of workers who will need to be employed to upgrade the grid and build thousands of charging stations. From architects and software developers to construction workers and electricians, as well as supporting roles in project management and other administration functions throughout the employment process, employment will need to scale up, and scale up fast. It will not be inexpensive either: home charging costs through just 2025 are expected to total \$1.3 billion, whereas new workplace, public Level 2, and DC fast charging is estimated at \$940 million (see Figure 18).

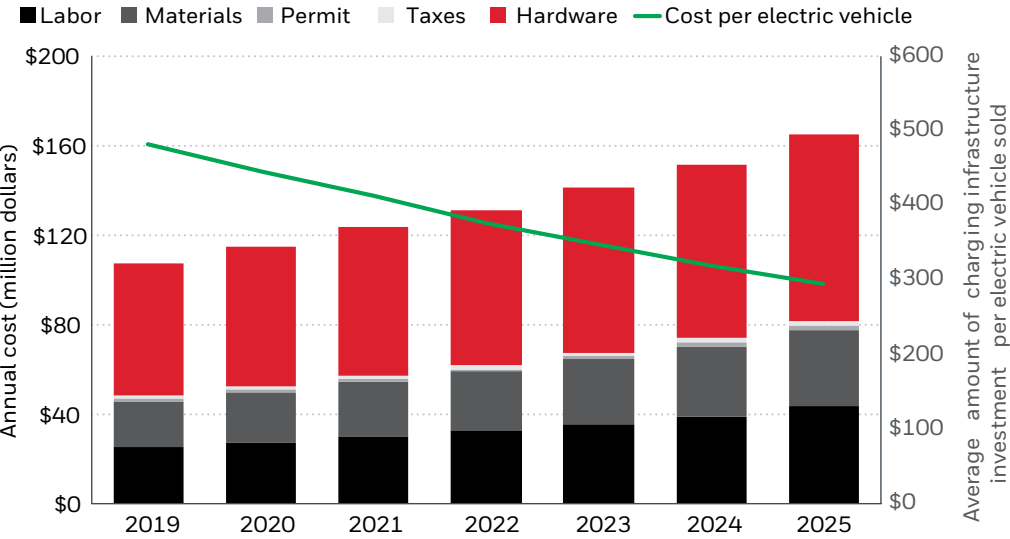
As electric vehicles become more commonplace, a whole new set of protocols will need to be created for workers in some professions, such as first responders; dealing with a road accident involving a gas-powered vehicle is quite different from handling one involving an electric vehicle. Electricians will require training and new PPE

Figure 18. Estimating Electric Vehicle Charging Infrastructure Costs

Workplace, public Level 2, and DC fast charger costs from 2019 through 2025.



Total cost of public and workplace infrastructure and associated average aggregate charger cost per new electric vehicle sold for 2019 through 2025.



Source: The International Council on Clean Transportation



to meet OSHA standards in commercial jobs and even home electricians will need education and potential new PPE to handle electrical upgrades in homes throughout the country.

The importance of ensuring sustainability for the infrastructure is critical to its long-term success, and there are jobs related specifically to ensuring that projects meet expectations in this regard. These range from science and research jobs to materials engineering careers, as well as positions that are construction-specific and for environmental and OSHA testers and inspectors. The EV ecosystem overall is a prime industry for “green jobs” and new training programs and degrees reflect that reality. A new report from Environmental Defense Fund and the consulting firm WSP found that more than 94,000 new EV-related jobs announced have been announced since the passage of the Infrastructure Law in November 2021. (75)

More information on positions related to environmental sustainability can be found at <https://socialimpact.linkedin.com/environmental-sustainability>

In short, the infrastructure to support EV adaptation is likely to be the engine for a significant percentage of job growth throughout the world.

Safety

As EV infrastructure employment increases, the necessity of appropriate PPE does too. In addition to all safety gear required today in construction environments, additional requirements for work on jobs incorporating electrification include:

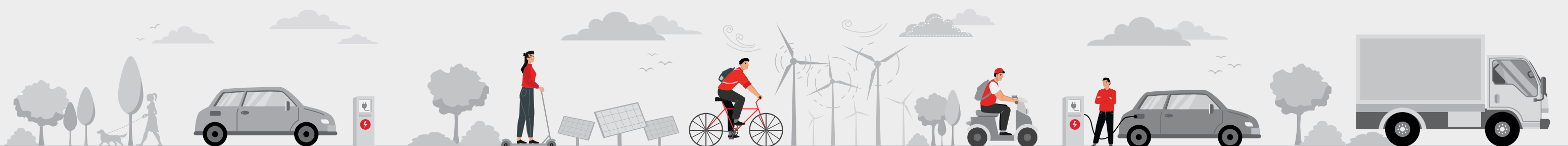
Rubber and leather gloves and rubber sleeves: insulating rubber gloves and insulating rubber sleeves are made of materials that block the transmission of electric charges so that no electricity up to a certain voltage can go through the material; these should be

selected based on the voltage a worker is expected to encounter, among other factors. In addition, a second physical barrier is created by wearing leather gloves to keep workers and their rubber gloves safe from cuts, tears or punctures. Leather glove protectors should never be used alone for protection against electric shock.

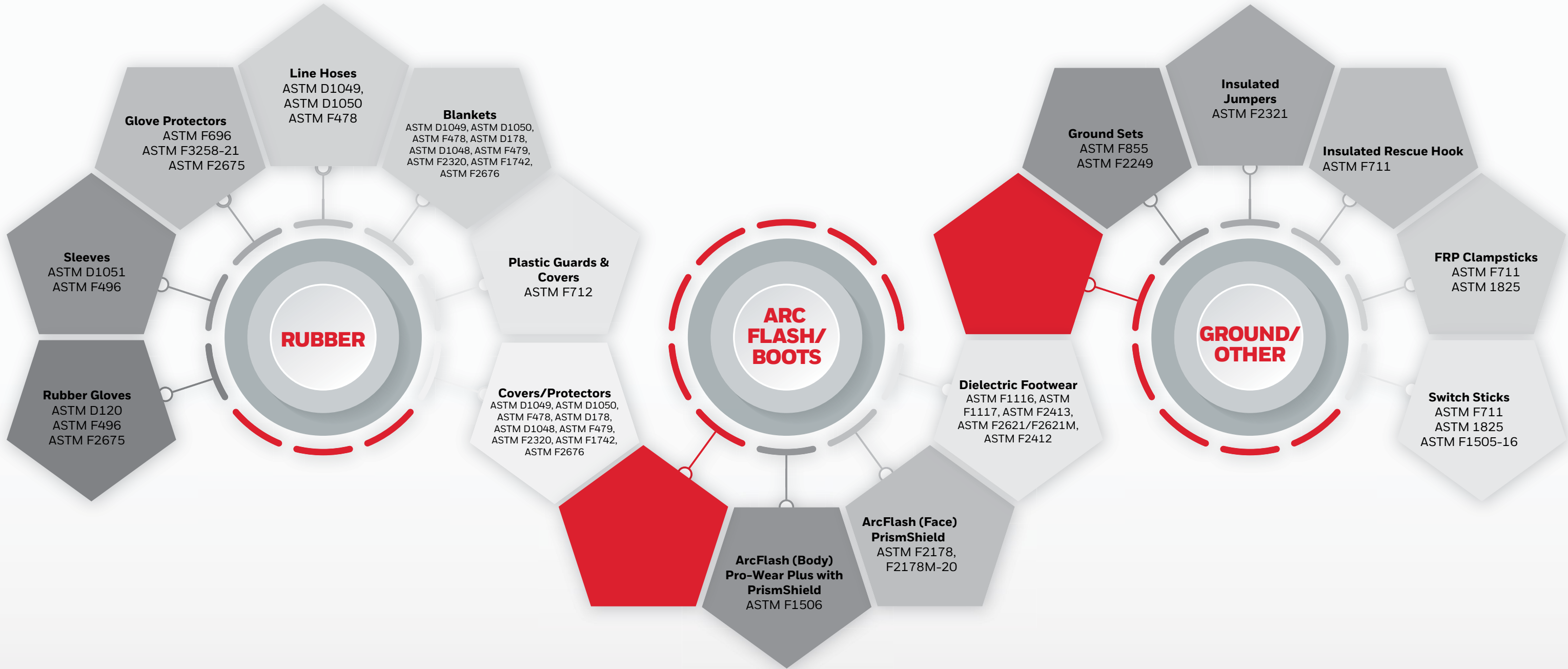
Dielectric boots, overboots, and overshoes: a considerable safety hazard that many electrical workers face is called step potential, where workers could experience an injury or electrocution by stepping near an energized, grounded object without actually touching the exposed power source on the ground. Dielectric footwear provides high-voltage protection and prevent charges from passing through workers’ bodies from the ground.

Arc flash protection: these quick, explosive blasts can cause severe damage, including potential blindness or deafness and other hidden fatal injuries such as internal bleeding. The temperature of an arc flash can reach 35,000 degrees Fahrenheit—which is up to four times hotter than the sun. This means workers in potential arc flash environments need specialized PPE to prevent them from experiencing substantial consequences (76).

Extensive information, including safety risks and best practices, that include both PPE and action protocols specifically for first responders may be found at <https://www.nfpa.org/EV> – there are numerous videos at this site as well as opportunities to register for training programs available throughout the country.



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