EconomicPerspectives

Number 4, 2024

https://doi.org/10.21033/ep-2024-4

The emerging geography of electric vehicle production in North America: Revolution or evolution?

Thomas H. Klier, senior economist and economic advisor, and James M. Rubenstein, professor emeritus of geography, Miami University, Ohio

Introduction and summary

The automotive industry has embarked on a major transition from manufacturing gas-powered vehicles to producing electric vehicles (EVs).[1] In this article, we parse out the implications of this shift for the industry's production footprint across North America, comprising Canada, Mexico, and the United States, between 2023 and 2029. We compare the emerging geography of battery electric vehicle (BEV) production facilities with the existing distribution of internal combustion engine (ICE) vehicle production facilities across the region. Two other types of vehicles—hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs)—are also included in our analysis here because they are forecasted to account for significant shares of production in the years ahead.

With this article, we build on our 2022 *Economic Perspectives* article (Klier and Rubenstein, 2022a), which was devoted primarily to background materials related to electric vehicle development. Our earlier article explained that agglomeration economics and economies of scale are shaping the geography of BEV production; these two key factors also underlie the location decisions for ICE vehicle production. It included a detailed description of the differences among the various propulsion systems; a brief history of the regulatory environment that is encouraging the development of EVs; and the principal obstacles to consumer adoption of BEVs. Here we complement our previous analysis by drawing on extensive forecasts for the production of light vehicles (that is, cars and light trucks), as well as their propulsion systems (gas engines, batteries, or a combination of them). These forecasts allow us to discuss changes in the industry footprint at a much richer level of detail than before, including our being able to distinguish between light vehicle production by all major propulsion systems.[2]

In this article, we are concerned with possible changes to the footprint of the automobile industry in North America over the medium term—that is, over the next five to seven years. To guide our analysis, we rely on comprehensive production forecasts by S&P Global Mobility, a well-respected provider of such data.[3] S&P Global Mobility utilizes deep industry expertise to allocate industry production of light vehicles to specific assembly plants, as well as to forecast the sourcing of key vehicle systems, such as engines and batteries. We utilize economic geography concepts to analyze S&P Global Mobility's detailed production forecasts for individual factories in the United States, Canada, and Mexico (all three countries that make up North America produce light vehicles). The figures provided in this article are derived from a careful parsing of current and forecast data provided by S&P Global Mobility.

The time horizon of the S&P Global Mobility forecasts allows us to look ahead along an expected path for the auto industry's transition toward electrification over the medium term. Naturally, there is some uncertainty around the pace of this transition for the industry (it's difficult to estimate when the vast majority of new vehicles will be EVs). Some of this uncertainty stems from the fact that incumbent light vehicle producers, on the one hand, and start-up pure-EV producers, on the other, are facing the transition differently. Incumbent producers need to accommodate a switch from one type of product to a different type of product in the context of mass production; during the transition toward electrification, funding for the emerging side of the business (EV production) will likely be generated by the declining side of the business (ICE vehicle production). The new entrants to the auto sector, however, face a different challenge: These pure-EV manufacturers must cover the high start-up costs in this capital-intensive industry and survive until profitability is reached.

In the next section of this article, we briefly review the current geography of light vehicle production in North America. More than 90% of light vehicles produced in the region in 2023 included a gasoline engine (see figure 3). In 2023, most vehicle assembly plants producing those vehicles (namely, ICE vehicles, HEVs, and PHEVs) and the accompanying engine plants within North America were located in a corridor between southwestern Ontario, Canada, and the Gulf of Mexico, known as "auto alley," plus in a second cluster in central Mexico. As part of this analysis, we map out and describe the locations of assembly plants for the specific types of vehicles (with different propulsion systems)—that is, BEVs, PHEVs, HEVs, and ICE vehicles—as of 2023.

After that, we describe the future geography of light vehicle production across North America, based on forecast data from S&P Global Mobility for 2029. We analyze how the anticipated shifts in product mix between 2023 and 2029 are expected to affect the locations of light vehicle assembly plants over this span. It turns out not very much, at least when considering the production footprint across North America from a broad regional perspective (which we elaborate on later).

Next, we compare the emerging distribution of battery plants with the distribution of engine plants.[4] Since the publication of our 2022 *Economic Perspectives* article, we have obtained much more detailed information on the location decisions made by the manufacturers of EV battery components, such as battery cells and battery packs.

Finally, we conclude the article with a discussion about the emerging footprint of electric vehicle production across North America. We find that despite the massive changes expected in the mix of vehicle types produced, the emerging spatial pattern of BEV assembly and battery production is strikingly similar to the existing pattern for ICE vehicle assembly and engine production across the broader region. That said, we recognize that new battery plants have been (and likely will be) constructed in different communities than those that are home to existing engine plants. Thus, at the local scale of individual cities and towns, the opening of battery plants—as well as the possible closure of engine plants or reduced production activity at them—can portend changes in local economic fortunes.

We ended our 2022 *Economic Perspectives* article with a tentative suggestion that the footprint of BEV production across North America might not be much different from the prevailing footprint of ICE vehicle production in the region. In this article, we reinforce that conclusion, using data that are much richer in detail than those we'd used for our 2022 article. Indeed, our findings based on the S&P Global Mobility data in this article are more refined and nuanced than those discussed in that previous work. For example, it is important to note that the two "intermediate" technologies that power HEVs and PHEVs are playing important roles in the emerging geography of light vehicle production—at least through the end of the current decade—in part because both of these types of vehicles still require an internal combustion engine.

Current footprint of light vehicle assembly plants

Most assembly plants are located in an area within North America known as auto alley—a corridor chiefly within the United States between the Great Lakes and the Gulf of Mexico, with an extension at its northern end into southwestern Ontario, Canada (Klier and Rubenstein, 2022a). It became the principal location for auto production beginning in the 1980s in order to minimize distribution of assembled vehicles to consumers throughout the United States (Rubenstein, 1992). Early in the twenty-first century, a second center of agglomeration for auto production emerged in central Mexico (Klier and Rubenstein, 2017).

The two key factors shaping the geography of ICE vehicle production have been agglomeration economics and economies of scale (for a more detailed explanation of these factors, see Klier and Rubenstein, 2015). Agglomeration refers to the association of productive activities in proximity to one another (Gregory et al., 2009, p. 14). According to Ellison, Glaeser, and Kerr (2010, p. 1195), "the benefits of agglomeration ultimately reflect gains that occur when proximity reduces transport costs." The motor vehicle industry is considered one of the most highly agglomerated manufacturing industries (Ellison and Glaeser, 1997). Economies of scale refer to the fact that the volume of output can influence the per-unit cost of production (Cedillo-Campos, Sanchez-Garza, and Sanchez Ramirez, 2006; Klier and Rubenstein, 2015, p. 105; Lung, 2004; Truett and Truett, 1996, 2001, 2003; and Wynn-Williams, 2009). Note that the different steps in the production process of a light vehicle feature different economies of scale. In the case of ICE vehicle production, engine plants tend to operate at significantly higher volumes than final assembly plants. For example, in North America mean output in 2016 was 281,000 vehicles at ICE assembly plants and 421,000 engines at engine plants (Klier and Rubenstein, 2022b, p. 9). As electrification of the auto industry expands, early evidence suggests that the economies of scale in battery production are comparable to those in engine production (see ahead to figures 22 and 23). We also know that engine plants and final assembly plants for ICE vehicle production tend to co-locate—that is, these two types of plants tend to be located close to each other (Klier and Rubenstein, 2021). Early indications are that a similar pattern of co-location is emerging for battery plants and final assembly plants for EVs.

1. Light vehicle production in North America, by subregion, 2023

Subregion	Production volume	Production share
	(*thousands of units*)	(*percent*)
Canada	1,533	9.8
Mexico	3,804	24.3
United States	10,311	65.9
Auto alley north	4,245	27.1
Auto alley south	4,096	26.2
Outside auto alley	1,970	12.6
Total in North America	15,648	100.0

Notes: U.S. auto alley north consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

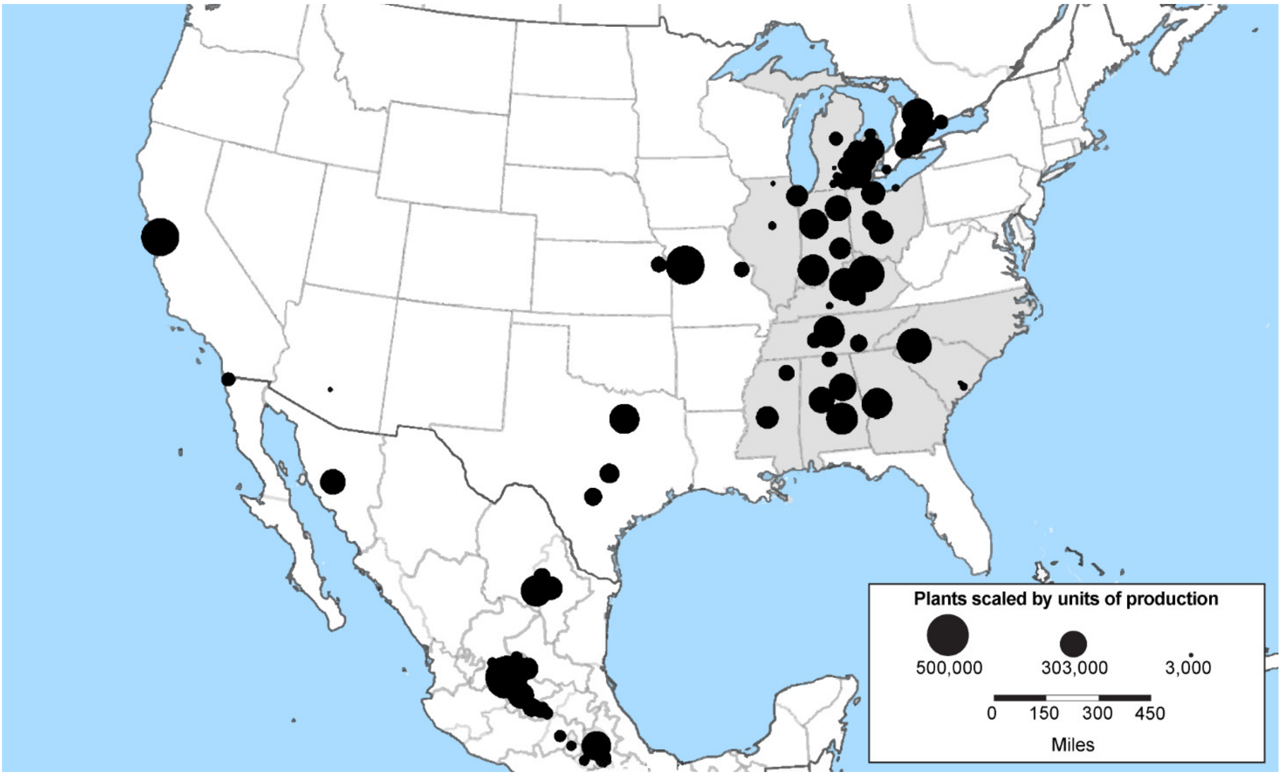
Source: Authors' calculations based on data from S&P Global Mobility as of January 2024.

In 2023, more than one-half of all light vehicles produced in North America were assembled in auto alley, almost equally divided between states north and south of the Ohio River.[5] About one-fourth of these vehicles were assembled in Mexico (see figure 1). The remainder was divided between the Canadian portion of auto alley and locations in the United States outside of auto alley (see figures 1 and 2).

Light vehicles with four types of propulsion systems are currently produced in North America (see Klier and Rubenstein, 2022a, and the U.S. Department of Energy's Alternative Fuels Data Center for more details):

- Internal combustion engine vehicles, powered exclusively by a gasoline or diesel engine;

2. Locations of light vehicle assembly plants in North America, by production volume, 2023



Notes: The black dots represent all assembly plants for light vehicles (including those for internal combustion engine vehicles and electric vehicles) across North America. The black dots are scaled by annual output. Some dots overlap others in this map. Auto alley in the United States consists of the following states (in light gray): Illinois, Indiana, Michigan, Ohio, Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. For further details on auto alley, see the text, in particular note 5.

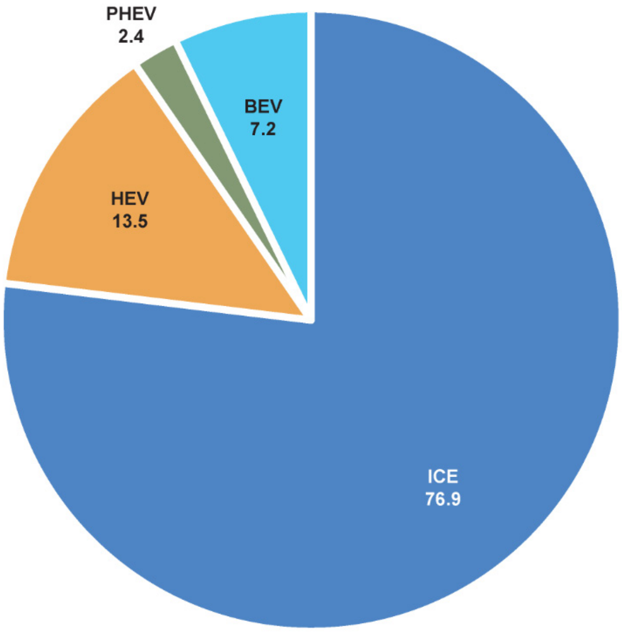
Sources: Authors' adaptation of data from S&P Global Mobility as of January 2024 and Maptitude.

- Hybrid electric vehicles, powered primarily by a gasoline engine and by a small battery that may propel them in some circumstances, such as when starting up from a complete stop;
- Plug-in hybrid electric vehicles, powered by an electric motor connected to a battery, as well as an internal combustion engine; and
- Battery electric vehicles (also known as all-electric vehicles), powered exclusively by an electric battery.

In addition to these four types of vehicles, fuel cell electric vehicles (FCEVs) constitute a fifth type. FCEVs use a propulsion system similar to that of electric vehicles. The fuel cell converts energy stored as hydrogen (stored in a tank on the vehicle) to electricity. No light FCEVs were built in North America in 2023. Around 14,400 were expected to be built in North America in 2029, according to the S&P Global Mobility forecast data. We exclude them from our analysis because their share of total production in 2029 was expected to make up only 0.09%.

BEVs and PHEVs are commonly combined under the label "EV." The terminology matters because these two types of vehicles (along with FCEVs) are the ones classified as clean vehicles by the U.S. federal government, and consequently, they may qualify for clean vehicle tax credits under the Inflation

3. Share of total light vehicle production in North America for each vehicle type, 2023



Notes: All values are in percent. ICE vehicle stands for internal combustion engine vehicle; HEV stands for hybrid electric vehicle; PHEV stands for plug-in hybrid electric vehicle; and BEV stands for battery electric vehicle.

Source: Authors' calculations based on data from S&P Global Mobility as of January 2024.

Reduction Act of 2022 (Pub. L. No. 117-169).[6] PHEVs, HEVs, and ICE vehicles all contain gasoline or diesel engines and, therefore, are sometimes grouped together as gas-powered vehicles. Thus, within this article, depending on the information being conveyed, PHEVs are included along with BEVs as EVs *or* along with ICE vehicles and HEVs as gas-powered vehicles.

In 2023, ICE vehicles made up 76.9% of the roughly 15.6 million light vehicles assembled in North America; HEVs were second in terms of the share of total volume assembled, at 13.5%—followed by BEVs, at 7.2%, and PHEVs, at 2.4% (see figure 3).

What do we know about the production footprints for each of the four vehicle types across the subregions of production within North America? It turns out that the footprints vary by vehicle type (as shown in figure 4): In 2023, the United States had disproportionately large shares of BEV, HEV, and PHEV production in North America, compared with its share of ICE vehicle production. In contrast, Canada and Mexico had larger shares of ICE vehicle production in North America, compared with their shares of production of the other vehicle types. So, for instance, assembly plants located in the United States were responsible for 89.9% of BEVs produced in North America, compared with only 61.5% of ICE vehicles. Conversely, Mexico's assembly plants were responsible for 27.6% of ICE vehicles produced in the region, but only 9.9% of BEVs.[7]

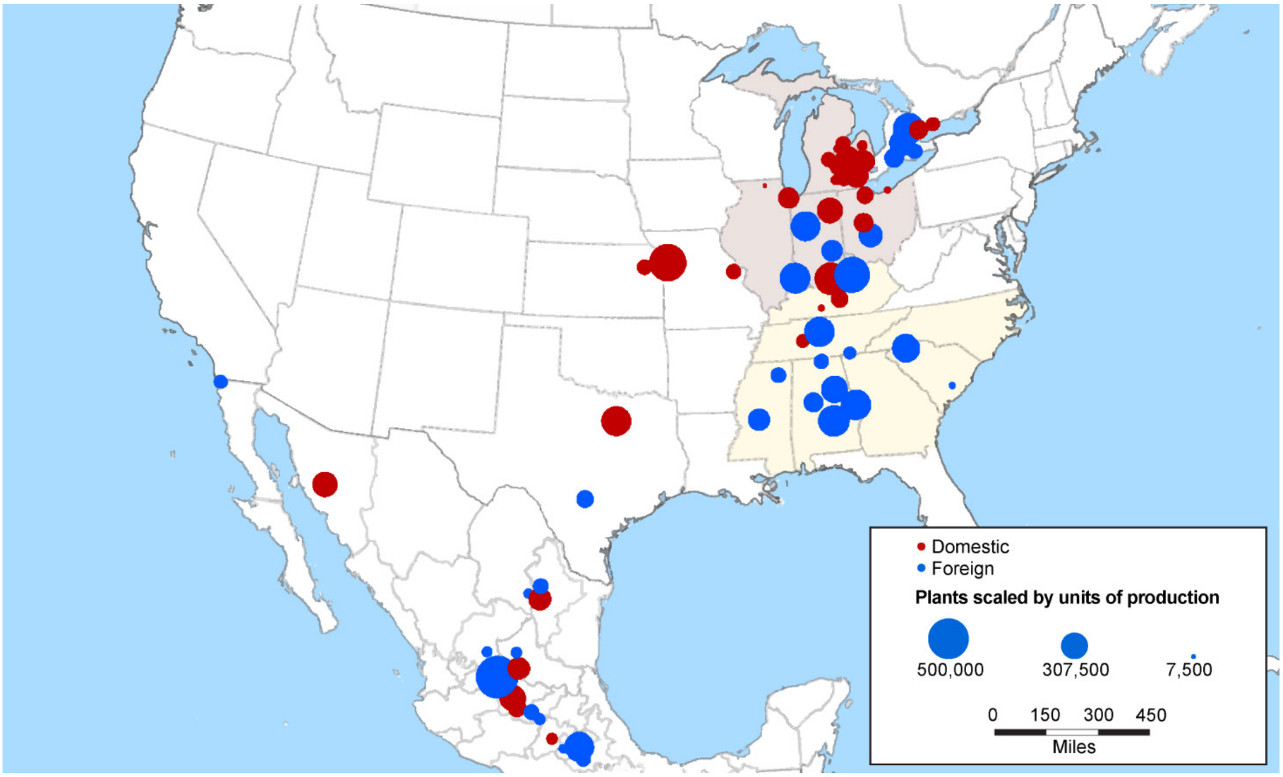
4. Volume and share of light vehicle production in North America, by subregion and vehicle type, 2023

Subregion	Total production volume	Total vehicles	BEV	PHEV	HEV	ICE vehicle
	(*thousands of units*)	(- - - - - - - -	- - - - - - - -	*percent*	- - - - - - - -	- - - - - - - -)
Canada	1,533	9.8	0.2	10.5	8.3	10.9
Mexico	3,804	24.3	9.9	12.0	15.7	27.6
United States	10,311	65.9	89.9	77.6	76.0	61.5
Auto alley north	4,245	27.1	15.9	44.2	39.2	25.5
Auto alley south	4,096	26.2	12.9	33.4	33.6	25.9
Outside auto alley	1,970	12.6	61.1	0.0	3.2	10.1
Total	15,648	100.0	7.2	4.1	13.5	75.1

Notes: U.S. auto alley north consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. BEV stands for battery electric vehicle; PHEV stands for plug-in hybrid electric vehicle; HEV stands for hybrid electric vehicle; and ICE vehicle stands for internal combustion engine vehicle. The final five columns of data may not total to 100% because of rounding. The values in the final four cells of the bottom row represent the shares of total light vehicle production in North America for the four vehicle types; these four values do not total to 100% because of rounding.

Source: Authors' calculations based on data from S&P Global Mobility as of January 2024.

5. Locations of ICE vehicle and HEV assembly plants in North America for domestic versus foreign automakers, by production volume, 2023



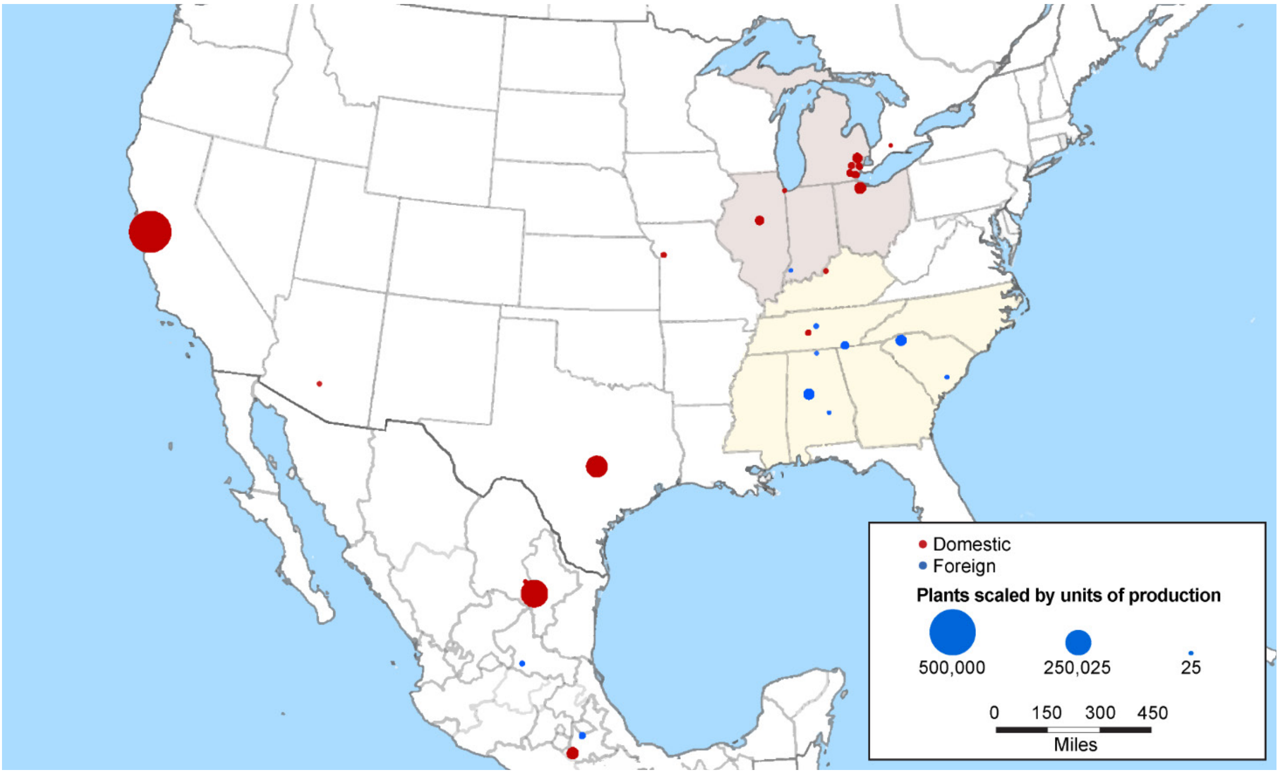
Notes: The dots representing plants are scaled by annual output. Some dots overlap others in this map. ICE vehicle stands for internal combustion engine vehicle; HEV stands for hybrid electric vehicle. Domestic automakers consist of the historically Detroit-based producers—Ford, General Motors, and Stellantis (see note 8)—as well as U.S.-headquartered startups, such as Tesla and Rivian. Foreign automakers consist of producers that are headquartered overseas, such as Toyota and Volkswagen. U.S. auto alley north (in light brown) consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south (in light yellow) consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

Sources: Authors' adaptation of data from S&P Global Mobility as of January 2024 and Maptitude.

Figures 5 and 6 show the distribution of assembly plants in North America by volume of production in 2023. Figure 5 displays the distribution of ICE vehicle and HEV production (the two types of vehicles powered exclusively or primarily by a gas engine). In 2023, assembly plants in the U.S. portion of auto alley produced 51.4% of North America's ICE vehicles, as well as 72.8% of the entire region's HEVs. Similarly, U.S. auto alley assembly plants were responsible for 77.6% of North America's PHEV production in 2023. However, U.S. auto alley assembly plants produced only 28.8% of North America's BEVs (all the percentages in this paragraph are from figure 4). Most BEVs were made outside of auto alley, primarily in California (see figure 6). This pattern reflects Tesla's large share of North America's total BEV production in 2023.

While studying auto alley within the United States, we elected to distinguish between assembly plants located north of the Ohio River and those located south of it. The three automakers with roots in the Detroit area dating back more than a century—Ford, General Motors, and Stellantis[8]—have most of their auto alley assembly plants located in the northern part of auto alley, whereas international automakers—rooted in Germany, Sweden, Japan, or South Korea—have most of their assembly plants in the southern part of auto alley. Total production in 2023 amounted to 4.2 million light vehicles in the northern portion of U.S. auto alley and 4.1 million vehicles in the southern portion (see figure 1).

6. Locations of BEV and PHEV assembly plants in North America for domestic versus foreign automakers, by production volume, 2023



Notes: The dots representing plants are scaled by annual output. Some dots overlap others in this map. BEV stands for battery electric vehicle; PHEV stands for plug-in hybrid electric vehicle. Domestic automakers consist of the historically Detroit-based producers—Ford, General Motors, and Stellantis (see note 8)—as well as U.S.-headquartered startups, such as Tesla and Rivian. Foreign automakers consist of producers that are headquartered overseas, such as Toyota and Volkswagen. U.S. auto alley north (in light brown) consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south (in light yellow) consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

Sources: Authors' adaptation of data from S&P Global Mobility as of January 2024 and Maptitude.

The northern and southern portions of U.S. auto alley (see note 5) both produced nearly identical shares of ICE vehicles manufactured in North America in 2023, corresponding to about 3 million vehicles each (see figure 4 for the exact percentages). Within the United States, assembly plants in auto alley north accounted for a higher share of North America's HEVs (39.2%) than the assembly plants in auto alley south did (33.6%) in 2023. That year the northern portion of U.S. auto alley was responsible for slightly more production of two types of EVs (BEVs and PHEVs) than the southern portion: At this early point in the industry's shift toward electrification, assembly plants in auto alley north produced 15.9% of North America's total BEV production and 44.2% of its total PHEV production, while plants in auto alley south produced 12.9% and 33.4%, respectively (see figure 4).

Future locations of ICE vehicle and BEV assembly plants

In this section, we describe the location of assembly plants for ICE vehicles and for BEVs (along with those for HEVs and for PHEVs) as forecasted through 2029. The data are based on forecasts developed by S&P Global Mobility for the assembly of light vehicles.[9] The data are available to us at the level of individual vehicle models produced at each assembly plant; we can distinguish propulsion systems by vehicle model. We recognize that specific numbers in the forecast can change over time. But here we are examining broad patterns concerning the auto industry's transition toward electrification—as well as what they imply for its production footprint across North America.

7. Change in the volume and share of light vehicle production in North America, by vehicle type, 2023–29

Vehicle type	Production volume 2023	Production volume 2029	Production share 2023	Production share 2029	2023–29 change	
	(*thousands of units*)		(- - - - *percent* - - - -)		(*thousands of units*)	(*percent*)
BEV	1,133	7,287	7.2	44.4	6,154	543.2
PHEV	371	539	2.4	3.3	168	45.3
HEV	2,118	3,404	13.5	20.7	1,286	60.7
ICE vehicle	12,025	5,165	76.9	31.5	–6,860	–57.0
Total	15,648	16,395	100.0	100.0	747	4.8

Notes: BEV stands for battery electric vehicle; PHEV stands for plug-in hybrid electric vehicle; HEV stands for hybrid electric vehicle; and ICE vehicle stands for internal combustion engine vehicle. The first five columns of data may not total because of rounding.

Source: Authors' calculations based on data from S&P Global Mobility as of January 2024 (for 2023 data) and as of December 2023 (for 2029 data).

As of December 2023, S&P Global Mobility forecasted an increase of 4.8% in overall light vehicle assembly across North America over the next six years—from 15.6 million vehicles in 2023 to 16.4 million in 2029. The four vehicle types were expected by S&P Global Mobility to display different growth patterns between 2023 and 2029. Assembly of ICE vehicles was forecasted to decline by more than one-half, from 12 million to 5.2 million. In contrast, BEV assembly during those six years was projected to increase more than sixfold, from 1.1 million to 7.3 million (see figure 7). As a result, the share of total light vehicle production in North America accounted for by ICE vehicles was anticipated to decline from around three-fourths in 2023 to less than one-third in 2029; in contrast, the share accounted for by BEVs was anticipated to increase from 7.2% in 2023 to 44.4% in 2029, surpassing ICE vehicle output by the end of the decade. The share of production of HEVs was also expected to grow substantially from 2023, representing 20.7% of total light vehicle production by 2029 (again, see figure 7).

The mix of light vehicle types (by propulsion systems) in 2029 was forecasted by S&P Global Mobility to vary across subregions within North America (figure 8). As in 2023, the United States was expected to account for a relatively high share of North America's total BEV assembly in 2029, although Canada and Mexico were expected to have gained shares of BEV production since 2023. In 2029, Mexico was expected to account for an even larger share of North America's ICE vehicle production than in 2023, and Canada for relatively larger shares of the region's PHEV and HEV production (compare the subregions' production share data in figures 4 and 8).

Within North America, U.S. auto alley was expected to account for the same share of overall light vehicle production in 2029 as it did in 2023 (53.3%), according to our calculations using S&P Global Mobility data (again, compare figures 4 and 8). However, both the northern and southern portions of auto alley were expected to increase their respective shares of the region's BEV production between 2023 and 2029; the share was forecasted to increase slightly more rapidly in auto alley south (from 12.9% in 2023 to 25.3% in 2029) than in auto alley north (from 15.9% in 2023 to 25.3% in 2029). Note that in 2029, North America's BEV production was expected to be allocated almost evenly among auto alley north, auto alley south, and the rest of the United States (each of these three subregions was forecasted to account for a little over one-quarter of BEV production in North America).

8. Volume and share of light vehicle production in North America, by subregion and vehicle type, 2029

Subregion	Total production volume	Total vehicles	BEV	PHEV	HEV	ICE vehicle
	(*thousands of units*)	(- - - - - - - -	- - - -	*percent*	- - - -	- - - - - - - -)
Canada	1,295	7.9	4.9	17.0	18.4	4.2
Mexico	3,903	23.8	18.9	11.7	14.4	38.2
United States	11,197	68.3	76.1	71.3	67.3	57.6
Auto alley north	4,525	27.6	25.3	31.8	29.0	29.5
Auto alley south	4,209	25.7	25.3	39.5	36.6	17.5
Outside auto alley	2,463	15.0	25.5	0.0	1.7	10.6
Total	16,396	100.0	44.4	3.3	20.7	31.5

Notes: U.S. auto alley north consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. BEV stands for battery electric vehicle; PHEV stands for plug-in hybrid electric vehicle; HEV stands for hybrid electric vehicle; and ICE vehicle stands for internal combustion engine vehicle. The six columns of data may not total (the final five to 100%) because of rounding. The values in the final four cells of the bottom row represent the shares of total light vehicle production in North America for the four vehicle types; these four values do not total to 100% because of rounding.

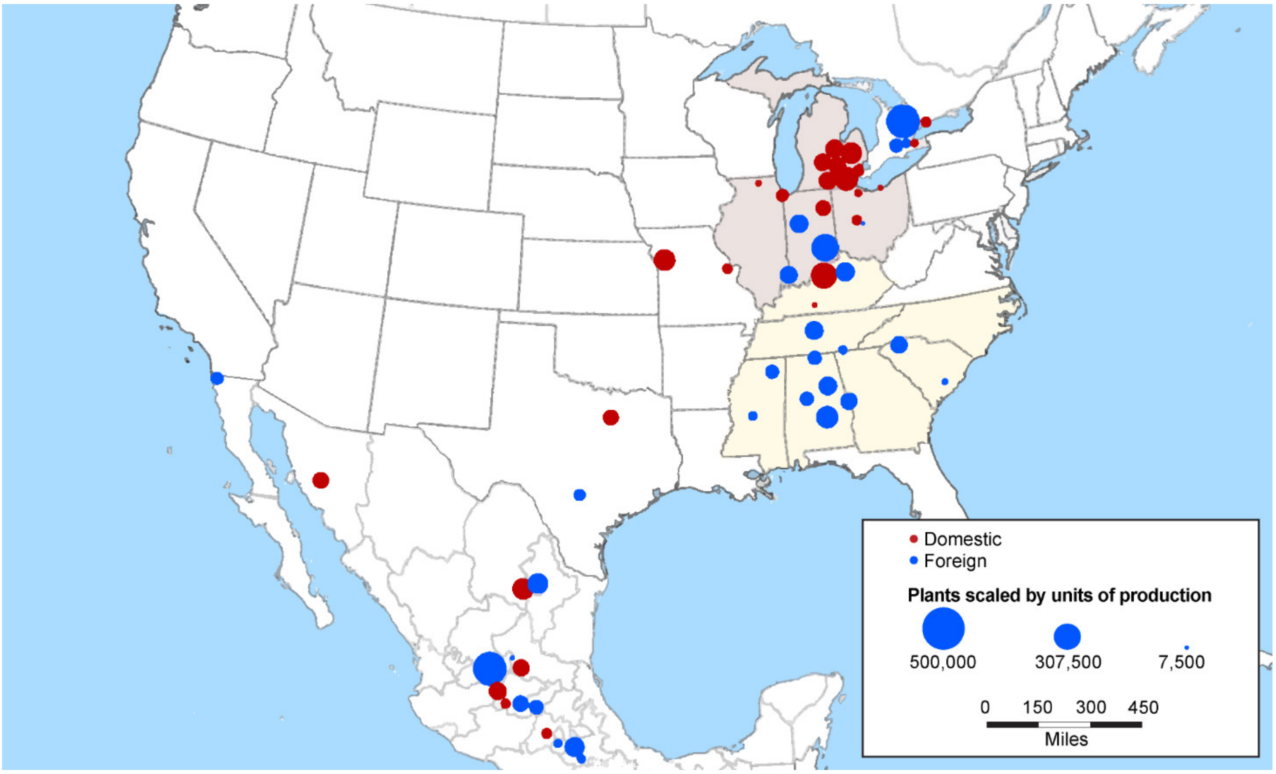
Source: Authors' calculations based on data from S&P Global Mobility as of December 2023.

Figures 9 and 10 show the distribution of assembly plants across North America by the forecasted 2029 volumes of ICE vehicle and HEV production and of BEV and PHEV production, respectively. Comparing figures 5 and 9 shows how the geography of ICE vehicle and HEV production—along with the output of these vehicle types at specific assembly plants—is expected to change for domestic and international automakers between 2023 and 2029. Meanwhile, comparing figures 6 and 10 shows the same for BEV and PHEV production.

The change in light vehicle production between 2023 and 2029 was not expected to be distributed evenly across the subregions of North America (see figure 11). Over this span, light vehicle production was expected to increase by 4.8% for the entire region. Only production in the United States was expected to grow more rapidly than that: Light vehicle output in the United States was anticipated to rise by 8.6% between 2023 and 2029. Production in Mexico was expected to grow modestly over this time, while production in Canada was expected to decline by more than 15%. Within the United States, production in auto alley as a whole was forecasted to grow by 4.7%,[10] with the northern half increasing more rapidly than the southern half (6.6% versus 2.8%). Light vehicle production within the United States outside of auto alley was forecasted to grow substantially between 2023 and 2029 (25.2%), almost all on account of the expected increase in production at Tesla's facility in Austin, Texas.

Breaking down the data by vehicle type (that is, by propulsion technology), we note that the production of BEVs, PHEVs, and HEVs was forecasted to increase in all three North American countries in terms of vehicle units, whereas ICE vehicle assembly was forecasted to decline in all three countries (figure 12). In U.S. auto alley, the expected increase in BEV production was almost the same as the expected decrease in ICE vehicle production. The increase in BEV assembly was forecasted to nearly make up for the decrease in ICE vehicle production in Mexico, but not in Canada. Overall, Canada was the only one of the three North American countries expected to show a decline in light vehicle production between 2023 and 2029.

9. Locations of ICE vehicle and HEV assembly plants in North America for domestic versus foreign automakers, by production volume, 2029



Notes: The dots representing plants are scaled by annual output. Some dots overlap others in this map. ICE vehicle stands for internal combustion engine vehicle; HEV stands for hybrid electric vehicle. Domestic automakers consist of the historically Detroit-based producers—Ford, General Motors, and Stellantis (see note 8)—as well as U.S.-headquartered startups, such as Tesla and Rivian. Foreign automakers consist of producers that are headquartered overseas, such as Toyota and Volkswagen. U.S. auto alley north (in light brown) consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south (in light yellow) consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

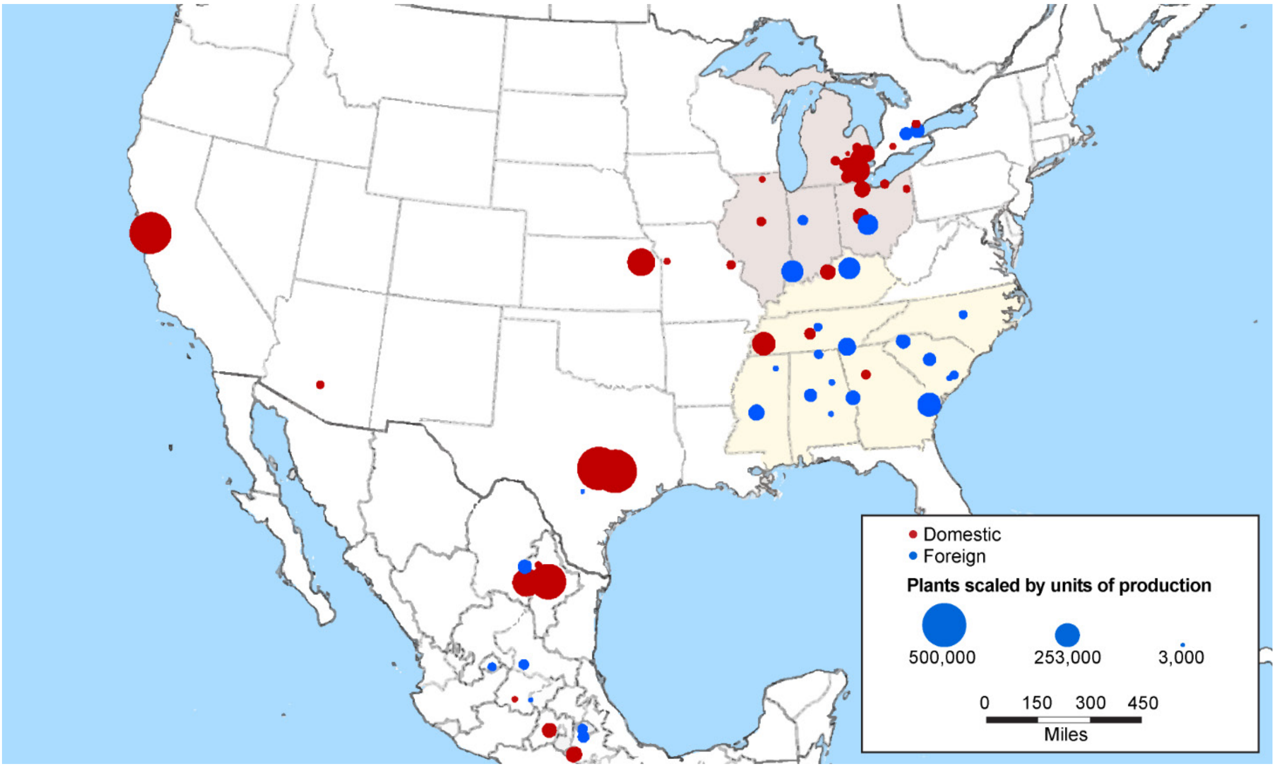
Sources: Authors' adaptation of data from S&P Global Mobility as of December 2023 and Maptitude.

Within the United States, 74% of the increase in BEV production between 2023 and 2029 was expected to be clustered in auto alley. Both halves of auto alley were expected to attract the same share of the growth in BEV assembly. BEV production outside of auto alley was forecasted to account for 26% of the increase.[11]

Figure 12 suggests a massive change is expected in the mix of vehicle types produced in North America between 2023 and 2029. If final assembly plants were limited to producing vehicles with only one type of propulsion technology, the shift from ICE vehicle to BEV production indicated in figure 12 would require a substantial change in the industry: Automakers would have to add many new assembly plants that manufacture BEVs (around 25 plants) and close many assembly plants that manufacture ICE vehicles (around 26 plants).[12]

Yet, despite the expected substantial shift from ICE vehicle to BEV production, the footprint of assembly plants across North America was anticipated to remain virtually unchanged. Why? According to S&P Global Mobility, the production of BEVs was projected to take place—with a few exceptions—at existing light vehicle assembly plants that were previously producing ICE vehicles. Hence, at the scale of North America as a whole, the transition from ICE vehicle to BEV production was expected to have a relatively minor impact on the industry's vehicle assembly footprint.

10. Locations of BEV and PHEV assembly plants in North America for domestic versus foreign automakers, by production volume, 2029



Notes: The dots representing plants are scaled by annual output. Some dots overlap others in this map. BEV stands for battery electric vehicle; PHEV stands for plug-in hybrid electric vehicle. Domestic automakers consist of the historically Detroit-based producers—Ford, General Motors, and Stellantis (see note 8)—as well as U.S.-headquartered startups, such as Tesla and Rivian. Foreign automakers consist of producers that are headquartered overseas, such as Toyota and Volkswagen. U.S. auto alley north (in light brown) consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south (in light yellow) consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

Sources: Authors' adaptation of data from S&P Global Mobility as of December 2023 and Maptitude.

11. Change in light vehicle production in North America, by subregion, 2023–29

Subregion	2023 production volume	2029 production volume	2023–29 change
	(- - - - - - - - - - - - - *thousands of units*	- - - - - - - - - - - - -)	(*percent*)
Canada	1,533	1,295	–15.5
Mexico	3,804	3,903	2.6
United States	10,311	11,197	8.6
Auto alley north	4,245	4,525	6.6
Auto alley south	4,096	4,209	2.8
Outside auto alley	1,970	2,463	25.2
Total	15,648	16,396	4.8

Notes: U.S. auto alley north consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. The first two columns of data may not total because of rounding.

Source: Authors' calculations based on data from S&P Global Mobility as of December 2023 (for 2029 data) and as of January 2024 (for 2023 data).

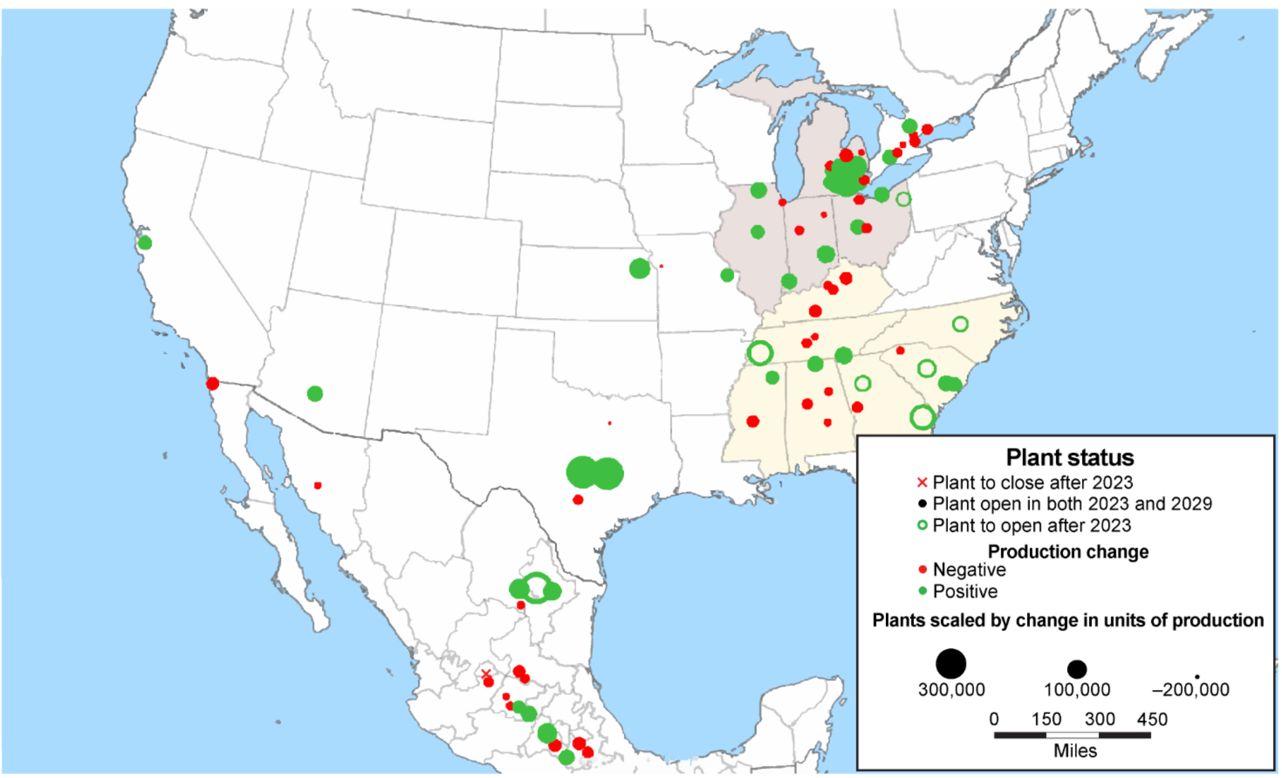
12. Change in light vehicle production in North America, by subregion and vehicle type, 2023–29

Subregion	Total	BEV	PHEV	HEV	ICE vehicle
	(- -	- - - - - thousands of units	- - - - - - - - - - - - - - -	- - - - - - - -	- - - - - - - - - -)
Canada	–238	357	53	449	–1,096
Mexico	99	1,268	19	155	–1,343
United States	887	4,529	96	682	–4,421
Auto alley north	280	1,665	7	155	–1,547
Auto alley south	113	1,698	89	534	–2,209
Outside auto alley	493	1,166	0	–8	–664
Total	748	6,154	168	1,286	–6,860

Notes: U.S. auto alley north consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. BEV stands for battery electric vehicle; PHEV stands for plug-in hybrid electric vehicle; HEV stands for hybrid electric vehicle; and ICE vehicle stands for internal combustion engine vehicle. The columns of data may not total (or the U.S. values may not subtotal) because of rounding. The rows of data may not total because of rounding.

Source: Authors' calculations based on data from S&P Global Mobility as of December 2023 (for 2029 data) and as of January 2024 (for 2023 data).

13. Locations of light vehicle assembly plants in North America, by change in production volume, 2023–29



Notes: The dots representing plants are scaled by the change in annual production volume between 2023 and 2029. Some dots overlap others in this map. U.S. auto alley north (in light brown) consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south (in light yellow) consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

Sources: Authors' adaptation of data from S&P Global Mobility as of December 2023 (for 2029 data) and as of January 2024 (for 2023 data) and Maptitude.

14. Change in status of light vehicle assembly plants with an annual production volume of at least 25,000 units in North America, by subregion, 2023–29

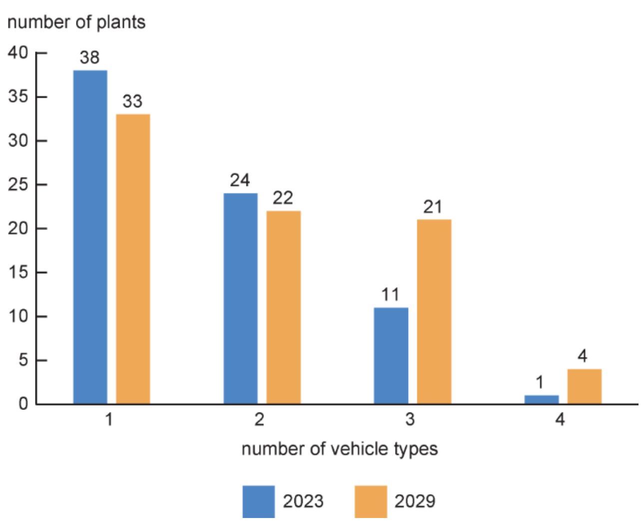
	Production change at existing plants, 2023–29[a]						
Subregion	Higher	Little change	Lower	Open in 2023	Closed 2024–28	Opened 2024–28	Open in 2029
Canada	2	1	5	8	0	0	8
Mexico	5	3	9	18	1	1	18
United States	19	7	22	48	0	6	54
Auto alley north	12	3	8	23	0	1	24
Auto alley south	4	2	11	17	0	5	22
Outside auto alley	3	2	3	8	0	0	8
Total	26	11	36	74	1	7	80

[a] "Higher" indicates producing at least 10% more vehicles in 2029 than in 2023, "lower" indicates producing at least 10% fewer vehicles, and "little change" indicates producing less than 10% more or fewer vehicles. Only plants existing in both 2023 and 2029 are analyzed.

Notes: In our analysis, there are 74 assembly plants in 2023 and 80 in 2029. We excluded nine assembly plants that were forecasted to produce fewer than 25,000 units annually through 2029. U.S. auto alley north consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

Source: Authors' calculations based on data from S&P Global Mobility as of December 2023 (for 2029 data) and as of January 2024 (for 2023 data).

15. Light vehicle assembly plants in North America, by number of vehicle types produced, 2023 and 2029



Notes: A plant is considered to produce a vehicle type (BEV, PHEV, HEV, or ICE vehicle) if it produces at least 1,000 units of that type. BEV stands for battery electric vehicle; PHEV stands for plug-in hybrid electric vehicle; HEV stands for hybrid electric vehicle; and ICE vehicle stands for internal combustion engine vehicle.

Source: Authors' calculations based on data from S&P Global Mobility as of December 2023 (for 2029 data) and as of January 2024 (for 2023 data).

We explore this aspect of S&P Global Mobility's auto outlook in more detail: Only seven new light vehicle assembly plants had been under construction or announced as of late 2023, and these were forecasted by S&P Global Mobility to open over the next six years from that point in time. The seven new plants will open in the following locations: two in Georgia (by Hyundai and Rivian) and one each in North Carolina (by VinFast), Ohio (by Fisker), South Carolina (by Volkswagen), Tennessee (by Ford), and Mexico (by Tesla) (see the green circles in figure 13). All seven were forecasted to be utilized exclusively for BEV assembly. Only one assembly plant was forecasted to be shuttered by 2029—a joint venture plant by Mercedes-Benz and Nissan in Mexico (see the red x in figure 13).

What about the fortunes of continuing assembly facilities across North America? According to our detailed analysis, of the 73 assembly plants open in 2023 *and* forecasted to still be open in 2029, 26 assembly plants were expected to produce at least 10% more vehicles in 2029 than in 2023, 36 were expected to produce at least 10% fewer vehicles, and 11 were expected to experience little change, defined as producing less than 10% more or fewer vehicles (figure 14).

16. Number of light vehicle assembly plants producing at least 1,000 units of each vehicle type in North America and mean production at these plants, by vehicle type, 2023 and 2029

	Number of plants making each type		Mean production	
Vehicle type	**2023**	**2029**	**2023**	**2029**
			(- - - - - - - *thousands of units* - - - - - - -)	
BEV	18	58	63	121
PHEV	14	14	26	38
HEV	26	38	81	89
ICE vehicle	65	45	185	119
Total	Total plants = 74	Total plants = 80	Mean of total plants = 211	Mean of total plants = 204

Notes: BEV stands for battery electric vehicle; PHEV stands for plug-in hybrid electric vehicle; HEV stands for hybrid electric vehicle; and ICE vehicle stands for internal combustion engine vehicle. The first two columns of data will not total because some plants produce more than one vehicle type. The final row displays the total number of plants (regardless of the vehicle types produced at the plants) and their mean production in 2023 and 2029.

Source: Authors' calculations based on data from S&P Global Mobility as of December 2023 (for 2029 data) and as of January 2024 (for 2023 data).

How can the rather stable number of assembly plants accommodate the dramatic change in the mix of vehicles produced over the medium term (as shown in figure 12)? S&P Global Mobility forecasted a greater diversity in the product mix among existing vehicle assembly plants in 2029 relative to 2023. In 2023, 38 of the 74 light vehicle assembly plants operating in North America produced vehicles with only one type of propulsion system, 24 produced vehicles with two types, 11 produced vehicles with three types, and just one produced vehicles with four types. By 2029, the number of assembly plants producing vehicles with four types of propulsion systems was expected to have increased to four and the number of plants producing vehicles with three types was expected to have increased to 21. Moreover, the number of assembly plants producing vehicles with only one type of propulsion system was forecasted to have declined from 38 in 2023 to 33 in 2029 (figure 15).

Complementing figure 15, figure 16 reports the actual and projected numbers of light vehicle assembly plants producing each vehicle type (ICE vehicle, HEV, PHEV, and BEV) in 2023 and 2029, respectively. Here each vehicle assembly plant is counted for each vehicle type it produces. We note that between 2023 and 2029, the number of plants assembling ICE vehicles was expected by S&P Global Mobility to drop from 65 to 45; yet the number of plants assembling BEVs was expected to jump from 18 in 2023 to 58 in 2029, more than offsetting that decline. The number of plants manufacturing HEVs was also projected to rise over this time, albeit more modestly, from 26 to 38. At 14, the number of plants assembling PHEVs was expected to be the same in 2029 as it had been in 2023.

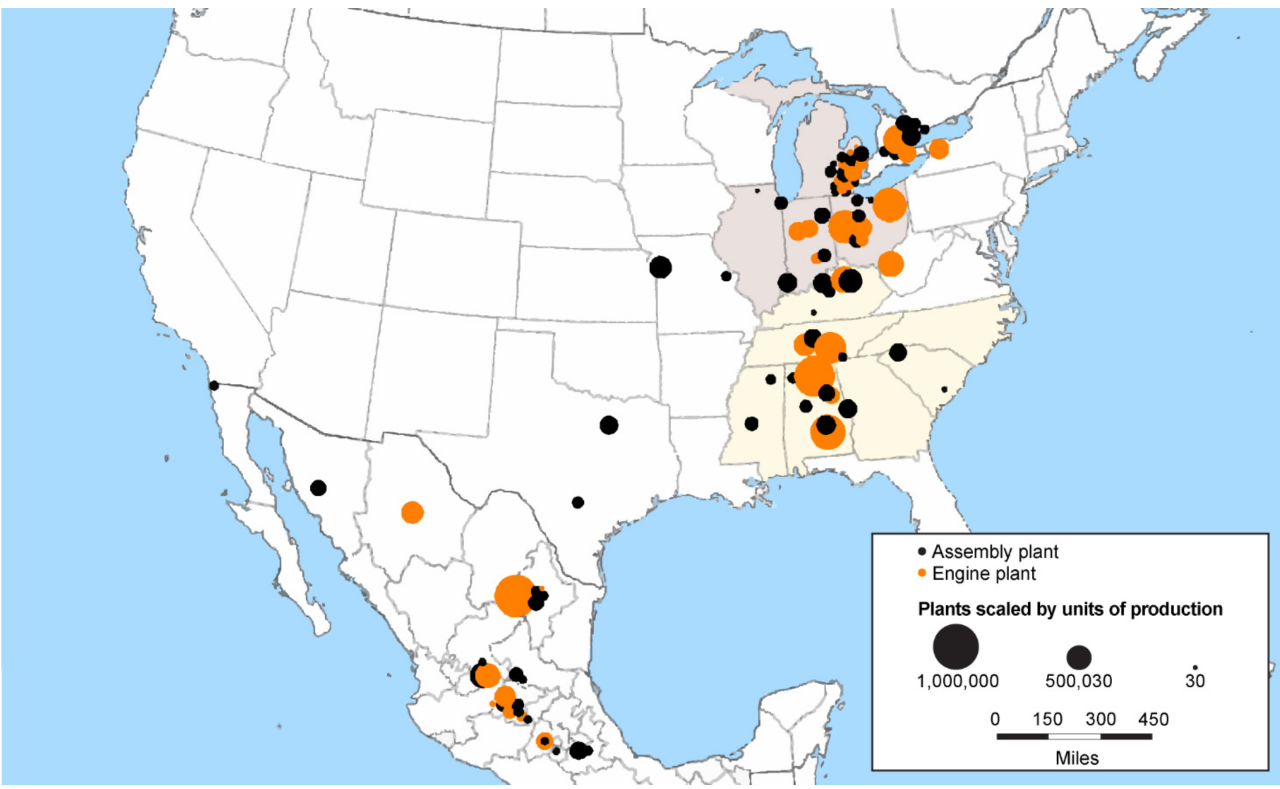
Let us return briefly to light vehicle assembly plants fully specializing in producing just one vehicle type (see again figure 15). Note that in 2023 there were 30 plants in North America that produced only ICE vehicles and eight that produced only BEVs, according to the S&P Global Mobility data; the numbers were expected to be virtually the opposite in 2029, with nine light vehicle assembly plants producing only ICE vehicles and 23 producing only BEVs (one plant was expected in 2029 to specialize in producing only HEVs). As the auto industry's transition toward electrification progresses, it seems like the development and production of BEVs will be based on platforms optimized for electric vehicles. This trend would support the growing number of vehicle assembly plants that produce BEVs only.[13]

Overall, the mean production per light vehicle assembly plant was forecasted to decrease from 211,000 vehicles in 2023 to 204,000 vehicles in 2029, according to our calculations using S&P Global Mobility data. In terms of output by vehicle type, the outlook varied: Consistent with the forecasted change in the product mix (figure 7), mean production was anticipated to decline substantially for ICE vehicles, but increase somewhat for HEVs and PHEVs and substantially for BEVs (figure 16). Notably, the mean output of BEVs was expected to exceed that of ICE vehicles in 2029.

The distribution of engine and battery plants

When ICE vehicles dominated production, strong co-location between engine plants and final assembly plants could be observed (see, for example, Klier and Rubenstein, 2021). Figure 17 shows that in 2023 both engine plants and final assembly plants were clustered in both auto alley and central Mexico. Will such a strong co-location between final assembly and propulsion system plants continue with the growth of electrification? We address this point in two parts: First, we examine whether strong co-location between light vehicle assembly plants and engine plants will continue; and second, we examine whether strong co-location between light vehicle assembly plants and battery plants is likely to emerge over the next few years.[14]

17. Locations of assembly plants producing light vehicles with engines and locations of engine plants in North America, by production volume, 2023



Notes: The dots representing plants are scaled by annual output. Some dots overlap others in this map. The vehicles with engines are internal combustion engine (ICE) vehicles, hybrid electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs). U.S. auto alley north (in light brown) consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south (in light yellow) consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. This figure represents engines produced in North America and installed in light vehicles assembled in the region; it does not represent engines produced in North America and exported to other regions of the world.

Sources: Authors' adaptation of data from S&P Global Mobility as of January 2024 and Maptitude.

Distribution of engine plants and assembly plants for light vehicles with gas engines

The shares of assembly operations for light vehicles with gas engines (ICE vehicles, HEVs, and PHEVs) among Canada, Mexico, and the United States (comprising the two halves of auto alley and the rest of the country) have closely matched the shares of engine production among these subregions (figure 18). For example, plants in Canada assembled 10.6% of North America's total output of light vehicles with engines and produced 9.5% of the engines installed in light vehicles assembled within the region in 2023 (figure 18). That same year, plants in Mexico assembled 25.3% of the light vehicles with engines made in North America and produced 22.1% of the engines installed in light vehicles manufactured within the region. Similarly, the three areas within the United States—auto alley north, auto alley south, and the rest of the nation outside of auto alley—had roughly equivalent shares of North America's production of light vehicles with engines and the region's production of engines installed in such vehicles in 2023. Notably, in our analysis of the production of engines for light vehicles assembled in North America, we do not have access to data about engines produced within North America and exported outside of it (although we do have data on engines produced overseas and imported for installation in light vehicles assembled within the region).

Little change was forecasted for the distribution of production of light vehicles with engines across North America between 2023 and 2029. Similarly, the distribution of engine production across the region was anticipated to not change very much over this span. So, in 2029, the shares of assembly operations for light vehicles with engines among Canada, Mexico, and the United States (comprising auto alley north and south and the rest of the nation) fairly closely match the shares of engine production among these subregions—as they did in 2023. In 2029, Canada was expected to have 10.3% of North America's total assembly of light vehicles with engines and 4.9% of the production of engines installed in light vehicles manufactured in the region; Mexico was forecasted to have 27.6% of North America's assembly of such vehicles and 28.4% of such engine production. U.S. auto alley's share of the assembly of light vehicles with engines in North America and its share of the production of engines installed in light vehicles made

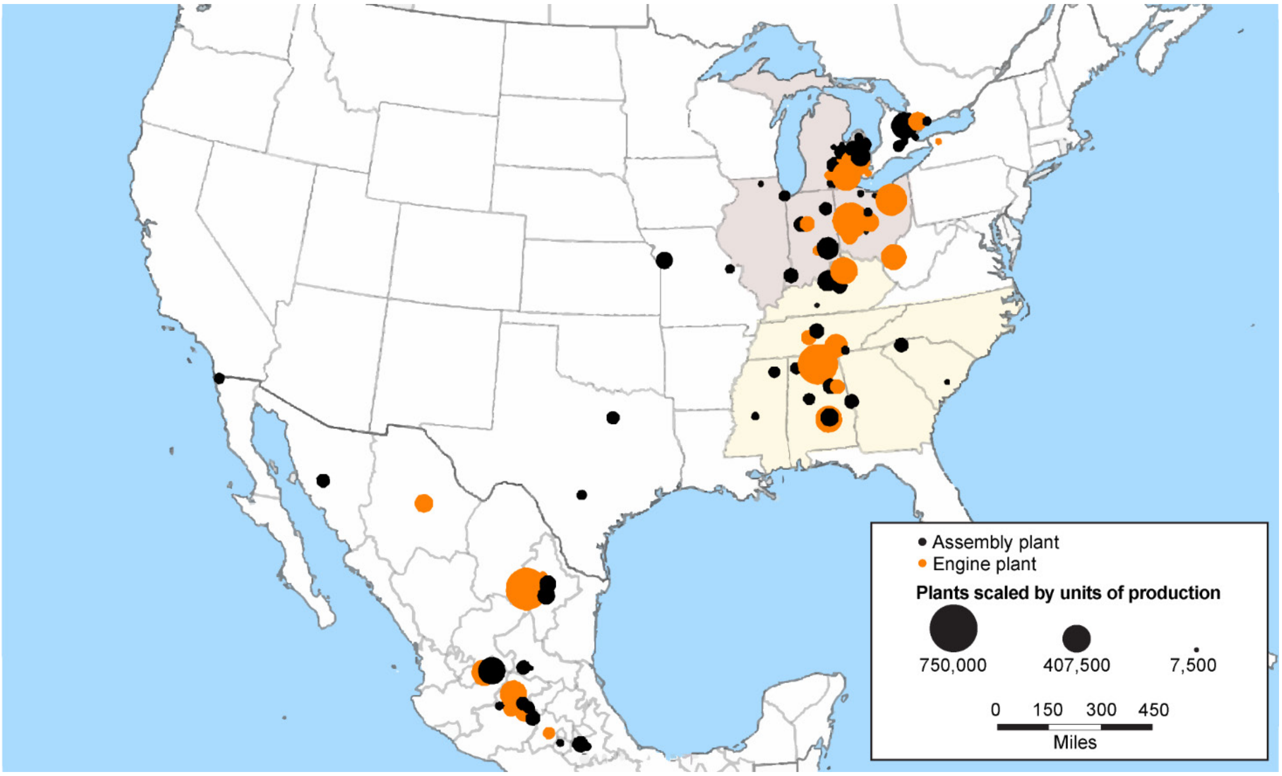
18. Share of production of light vehicles with engines in North America and of engine production, by subregion, 2023 and 2029

	Vehicles with engines		Engines	
Subregion	**2023**	**2029**	**2023**	**2029**
Canada	10.6	10.3	9.5	4.9
Mexico	25.3	27.6	22.1	28.4
United States	64.1	62.1	58.2	59.3
Auto alley north	28.0	29.5	26.7	30.5
Auto alley south	27.3	26.0	25.2	24.0
Outside auto alley	8.8	6.6	6.3	4.7
Imported from outside North America	n.a.	n.a.	10.1	7.5
Total (*thousands of units*)	14,515	9,108	14,515	9,108

Notes: All values are in percent except for those in the final row. U.S. auto alley north consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. The vehicles with engines are internal combustion engine (ICE) vehicles, hybrid electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs). Note that n.a. means not applicable. The columns of data may not total (or the U.S. values may not subtotal) because of rounding. The engine output data are for engines produced in North America or imported from outside the region and installed in light vehicles assembled in the region; these data exclude engines produced in North America and exported to other regions of the world.

Source: Authors' calculations based on data from S&P Global Mobility as of December 2023 (for 2029 data) and as of January 2024 (for 2023 data).

19. Locations of assembly plants producing light vehicles with engines and locations of engine plants in North America, by production volume, 2029



Notes: The dots representing plants are scaled by annual output. Some dots overlap others in this map. The vehicles with engines are internal combustion engine (ICE) vehicles, hybrid electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs). U.S. auto alley north (in light brown) consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south (in light yellow) consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. This figure represents engines produced in North America and installed in light vehicles assembled in the region; it does not represent engines produced in North America and exported to other regions of the world.

Sources: Authors' adaptation of data from S&P Global Mobility as of December 2023 and Maptitude.

within the region were forecasted to be 55.5% and 54.5% in 2029, respectively. Most vehicles with engines and most engines produced in North America were expected to continue to be made in U.S. auto alley—with the shares located in the northern half of auto alley running slightly ahead of the shares located in the southern half. For U.S. auto alley as a whole, its share of the assembly of light vehicles with engines in North America and its share of the engines produced for light vehicles made within the region were both expected to be slightly higher in 2029 than in 2023 (see figure 18 and also compare figures 17 and 19).

How many engine plants are expected to be shut down as the production of ICE vehicles declines? At first glance, the projected steep decrease in ICE vehicle production from 12 million vehicles in 2023 to 5.2 million in 2029 (figure 7) would suggest a drop in the need for engines equivalent to around ten fewer engine plants.[15] However, S&P Global Mobility forecasted the closure of only five of the 34 full-sized engine plants in North America between 2023 and 2029—one each in Canada and Mexico and three in the northern portion of auto alley (see figure 20).

20. Number of engine plants in North America and mean production at these plants, by subregion, 2023 and 2029

Subregion	Number of engine plants		Mean output	
	2023	2029	2023	2029
Canada	4	3	343,749	147,492
Mexico	10	9	321,394	287,485
United States	20	17	422,607	317,507
Auto alley north	12	9	322,700	308,798
Auto alley south	6	6	610,315	364,735
Outside auto alley	2	2	458,926	215,010
Total	34	29	383,561	290,602

Notes: U.S. auto alley north consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. The output data are for engines produced in North America and installed in light vehicles assembled in the region; these data exclude engines produced in North America and exported to other regions of the world.

Source: Authors' calculations based on data from S&P Global Mobility as of December 2023 (for 2029 data) and as of January 2024 (for 2023 data).

At the same time, mean output at engine plants in North America was forecasted to decline by 24%—from about 384,000 in 2023 to about 291,000 units in 2029 (figure 20)—representing a much smaller drop (less than half) than the 57% decline anticipated in ICE vehicle production over this span (figure 7).[16] The principal reason for this relatively modest decline in the volume of engine production is the projected 61% increase in the volume of HEV production between 2023 and 2029 (see figure 7).

Emerging distribution of battery plants

Lithium-ion battery production for EVs involves three main stages of manufacturing: cell, module, and pack. Several cells are put together into a module, with the number varying by individual manufacturer and automaker. Similarly, a pack contains a number of modules, which also vary by individual manufacturer and automaker (Klier and Rubenstein, 2022a). Cells and packs may be manufactured in the same factory or in different factories, but typically, according to S&P Global Mobility, modules are produced in the same plants as cells and/or packs, rather than at a different set of plants. Therefore, we focus on cells and packs in this article.[17]

In 2023, nearly one-half of all battery *cells* installed in BEVs and PHEVs assembled in North America were imported from other regions (that is, Europe and Asia), according to our analysis of the S&P Global Mobility data.[18] Only 10.3% of cells installed in BEVs and PHEVs assembled in North America in 2029 were expected to be imported from outside the region (see figure 21).

Given the imported share of battery cells in 2023 just discussed, that means that 54.2% of cells installed in BEVs and PHEVs assembled in North America that year were made within the region. Of all the cells installed in BEVs and PHEVs assembled in North America in 2023, 44.8% were manufactured at supplier-owned factories within the region, 3.1% were manufactured at joint ventures in North America between suppliers and automakers, and 6.3% were manufactured directly by an automaker from the region (Tesla). Three suppliers accounted for around three-fourths of all cells installed in BEVs and PHEVs manufactured in North America in 2023: 32.2% by Panasonic, 23.9% by Samsung SDI, and 17.5% by LG Energy Solution (Panasonic and LG Energy Solution produced some of their cells in North America and some of them outside the region) (figure 21).

21. Production share of battery cells installed in BEVs and PHEVs assembled in North America, by geography and type of manufacturer, 2023 and 2029

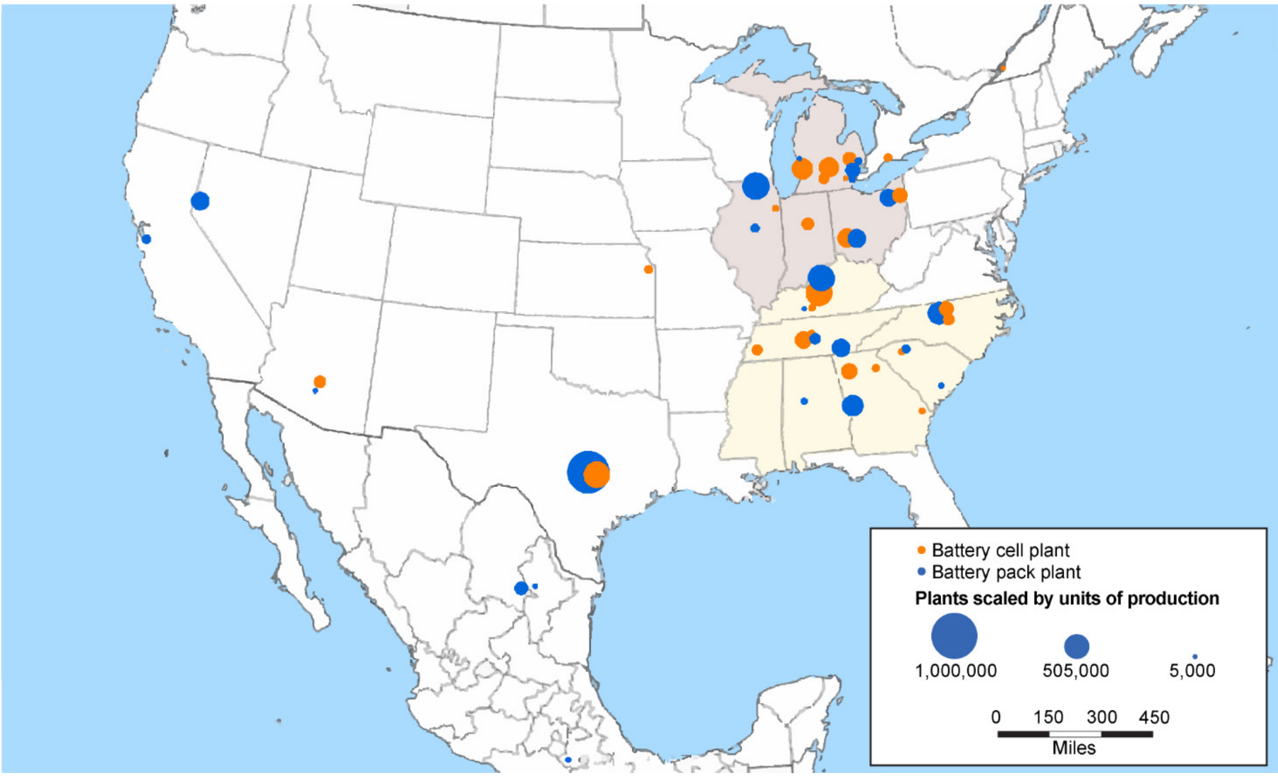
	2023	2029
	(- - - - - - - *percent* - - - - - - -)	
North America production	**54.2**	**89.6**
Suppliers alone	***44.8***	***32.1***
LG Energy Solution	10.2	8.0
SK On	6.6	1.3
Samsung SDI	0.0	0.6
CATL	0.0	11.4
Panasonic	27.2	6.2
Envision AESC	0.8	3.3
Other suppliers	0.0	1.3
Automakers alone	***6.3***	***14.5***
Tesla	6.3	7.0
Toyota	0.0	5.9
Volkswagen	0.0	1.6
Joint ventures between automakers and suppliers	***3.1***	***43.0***
LG Energy Solution	3.1	21.4
SK On	0.0	13.1
Samsung SDI	0.0	6.4
CATL	0.0	2.1
Imports	**45.8**	**10.3**
Suppliers alone	***45.8***	***8.9***
LG Energy Solution	4.2	0.7
SK On	1.6	0.8
Samsung SDI	23.9	2.3
CATL	9.6	1.8
Panasonic	5.0	1.0
Envision AESC	0.0	0.7
Other suppliers	1.4	1.6
Automakers alone	***0.0***	***1.4***
Toyota	0.0	0.7
Volkswagen	0.0	0.7

Notes: This figure accounts only for battery cells produced in North America or imported from outside the region and installed in battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) assembled in North America; it excludes the production of battery cells installed in hybrid electric vehicles (HEVs) assembled in the region (see note 14 for further details). It also excludes battery cells produced in North America and exported to other regions of the world. CATL refers to Contemporary Amperex Technology Co., Limited; Envision AESC refers to Envision Automotive Energy Supply Corporation. The columns of data may not total (or subtotal) because of rounding.

Source: Authors' calculations based on data from S&P Global Mobility as of December 2023 (for 2029 data) and as of January 2024 (for 2023 data).

With the size of individual cells being small, long-distance shipment of them might in principle be cost effective, as is the case with many engine parts. Most cell plants are owned either by independent suppliers—all of which are based in East Asia—or by joint ventures between cell makers and automakers—in contrast with engine plants, which tend to be owned by automakers.[19] These qualities of EV battery

22. Locations of battery cell and pack plants in North America, by production volume, 2029



Notes: The dots representing plants are scaled by annual output. Some dots overlap others in this map. U.S. auto alley north (in light brown) consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south (in light yellow) consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. This figure represents battery cells and packs produced in North America and installed in battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) assembled in the region; it does not represent the production of battery cells and packs installed in hybrid electric vehicles (HEVs) assembled in the region (see note 14 for further details). It also does not represent battery cells and packs produced in North America and exported to other regions of the world. Note that the units of cells (and packs) we report have been normalized to the number of BEVs and PHEVs; that is, we count the multitude of cells (or typically one pack) installed in a single BEV or PHEV as one unit of cell (or pack) production and report the total cell (or pack) production volumes accordingly.

Sources: Authors' adaptation of data from S&P Global Mobility as of December 2023 and Maptitude.

cell manufacturing raise the question of whether the emerging footprint of battery production will differ from the existing footprint of engine production, which is clustered in auto alley and central Mexico.

Of the eight plants in North America providing lithium-ion cells for BEVs and PHEVs assembled in the region in 2023, four were in the southern portion of U.S. auto alley, two in the northern portion of U.S. auto alley, two elsewhere in the United States, and none in Canada or Mexico. Whereas most automakers appear to be in the process of converting existing assembly plants from ICE vehicle production to BEV production, we do not find examples of plants currently producing gasoline engines being converted for EV battery cell production. Rather, cells are produced in newly constructed factories.[20]

S&P Global Mobility forecasted battery cell production from 28 factories in North America in 2029 (see figures 22 and 23)—with some cells coming from overseas—for the 7.8 million BEVs and PHEVs to be assembled in the region that year (figure 7). Three cell plants were expected to be operating in Canada in 2029 and 24 in the United States (ten in auto alley south, eight in auto alley north, four elsewhere in the country, and two in locations yet to be specified); Mexico was projected to have one cell plant in 2029 (see figure 23). Thus, cell plants were forecasted to reinforce the existing geography of light vehicle production clustered in auto alley. Note that auto alley's shares in 2029 of cell production (55.7%) and

23. Distribution of battery cell and pack plants in North America, by subregion, 2029

Subregion	Number of plants: Cell	Number of plants: Pack	Share of production: Cell	Share of production: Pack
			(- - - - - - - - - *percent*	- - - - - - - -)
Canada	3	0	5.0	0.0
Mexico	1	4	11.4	9.5
United States	24	24	73.3	84.7
Auto alley north	8	9	27.0	29.5
Auto alley south	10	10	28.7	35.6
Outside auto alley	4	5	15.9	19.5
Location unknown	2	0	1.7	0.1
Imported	n.a.	n.a.	10.3	5.7
Total percentage	–	–	100.0	100.0
Total count	28	28	7,826,409	7,826,409

Notes: This figure accounts only for battery cells and packs produced in North America or imported from outside the region and installed in battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) assembled in the region; it excludes the production of battery cells and packs installed in hybrid electric vehicles (HEVs) assembled in the region (see note 14 for further details). It also excludes battery cells and packs produced in North America and exported to other regions of the world. The units of cells (and packs) we report have been normalized to the number of BEVs and PHEVs; that is, we count the multitude of cells (or typically one pack) installed in a single BEV or PHEV as one unit of cell (or pack) production and report the total cell (or pack) production volumes accordingly; this is why the production volumes for both cells and packs are identical. Note that n.a. means not applicable. All values are in percent in the final two columns of data except for those in the bottom row; these columns may not total because of rounding.

Source: Authors' calculations based on data from S&P Global Mobility as of December 2023.

of pack production (65.1%) were both expected to be above its share of overall light vehicle production (53.3%, as shown in figure 8). Furthermore, U.S. auto alley's share of pack production was anticipated to be noticeably higher than its share of engine production (54.5%, as shown in figure 18). Plants in the United States outside of auto alley were expected to have greater shares of total cell and pack production for BEVs and HEVs assembled in North America than plants in either Canada or Mexico in 2029 (see figure 23); in addition, these plants in the United States were also projected to have a higher share of pack production (19.5%) than their share of engine production (4.7%, as shown in figure 18) that year.

Also, note that when it comes to cell and pack production, the southern portion of U.S. auto alley was expected to lead the northern portion in 2029 both in terms of plant count and production share (figure 23). Finally, note that U.S. auto alley's share of battery cell production (55.7%) was anticipated to be higher than its share of BEV production (50.6%, as shown in figure 8).

Meanwhile, the share of imported cells was forecasted to decline from 45.8% in 2023 to 10.3% in 2029 (figure 21). Imports from both Europe and Asia were expected to decline considerably as a share of the total cell production volume used for BEVs and PHEVs assembled in North America between 2023 and 2029, according to our calculations using S&P Global Mobility data.

LG Energy Solution was forecasted to become the largest supplier of EV battery cells in North America, with 30% of the market in 2029, primarily through a series of joint ventures with automakers. SK On was forecasted to increase its share of the EV battery cell market from 8% in 2023 to 15% in 2029, again primarily through joint ventures with automakers. In contrast, Samsung SDI and Panasonic were forecasted to have reduced market shares in 2029—down to 9% and 7%, respectively. Three automakers—Tesla, Toyota, and Volkswagen—were forecasted to produce 16% of cells themselves rather than rely on joint ventures, as other automakers were expected to. Tesla has relied primarily on Panasonic cells; the decrease in

Panasonic's market share reflects an expectation that Tesla will increase production of its own cells in the same locations as its final assembly plants (see figure 21).

As S&P Global Mobility data show, 20 *pack plants* were already in operation in North America in 2023: eight in the northern portion of U.S. auto alley, seven in the southern portion of U.S. auto alley, four elsewhere in the United States, and one in Mexico. According to our calculations using these data, only 14% of packs were imported into North America in 2023, compared with 46% of cells. The earlier arrival of pack plants in North America relative to cell plants is a reflection of how packs are manufactured. For the most part, packs are typically part of the chassis or undercarriage, now widely referred to as the vehicle's platform. Consequently, packs are manufactured in or near final assembly plants, as is the longstanding practice with ICE vehicle chassis.

Of the total number of packs forecasted to be installed in BEVs and PHEVs assembled in North America in 2029, 95% of those packs were expected to be put together by automakers alone, according to our calculations using S&P Global Mobility data. For the most part, these packs are manufactured in or near the automakers' final assembly plants. Given that final assembly plants are clustered in auto alley, pack production will likely have a similar geographical distribution in North America. S&P Global Mobility forecasted 28 plants to be producing battery packs in 2029: ten in the southern portion of U.S. auto alley, nine in the northern portion of U.S. auto alley, five elsewhere in the United States, and four in Mexico (refer to figure 23). Note that the concentration of battery pack production in auto alley (65.1%) is significantly higher than that of BEV assembly in 2029 (50.6%, as shown in figure 8).

Co-location of propulsion system plants and final assembly plants

For each light vehicle assembly plant, S&P Global Mobility estimates the number of engines or batteries (cells and packs) anticipated to be shipped from each propulsion system factory (that is, engine or battery plant). We can therefore calculate the median distance that each propulsion system travels between the location of its production and the final assembly plant where it is installed in a vehicle.

Many light vehicle assembly plants receive engines and/or batteries from more than one factory; in those cases, the median distance is weighted by the share of engines and/or batteries an assembly plant is anticipated to receive from the various propulsion system plants. The median provides a more meaningful measure of distance than the mean because a relatively small number of engines or batteries shipped from other regions of the world would inflate the mean much more than the median and consequently result in a less accurate measure of the geographic relationship between propulsion system plants and final assembly plants.

In a previous study based on 2017 data (Klier and Rubenstein, 2021, p. 333), we calculated that in North America the median distance between the places of production of engines and the final assembly plants where they are installed in vehicles was 376 miles (605 kilometers).[21] We reported that this distance, which is less than a one-day's drive, represented a high degree of co-location. For this article, we have calculated that the median distance between engine production and final assembly was 272 miles (438 kilometers) in 2023 and is expected to be 222 miles (357 kilometers) in 2029, using data from S&P Global Mobility. Thus, on average, the spatial relationship between engine plants and final vehicle assembly plants is even closer than what we found a few years ago—and this spatial relationship is expected to be closer still in 2029.

For EVs (BEVs and PHEVs) assembled in North America, we have calculated two median distances for 2029: 1) between the cell plants and the pack plants to which the cells are expected to be sent and 2) between the pack plants and the final assembly plants to which the packs are expected to be sent.

We calculate that in 2029 the median distance between pack plants and final assembly plants in North America is expected to be 284 miles (457 kilometers). In other words, the median distance forecasted between battery pack plants and final assembly operations is rather similar to the median distance between engine plants and final assembly plants. Our analysis of S&P Global Mobility's forecast data for 2029 indicates 56.0% of packs are expected to be made in final assembly plants and 36.1% in cell plants. We calculated the median distance between cell plants and pack plants to be only 40 miles (64 kilometers), dramatically lower than the median distance between pack plants or engine plants and final assembly plants.

Thus, the footprints of cell and pack production are expected to align remarkably closely with the distribution of final assembly plants forecasted to produce electrified vehicles (in particular, BEVs and PHEVs). U.S. auto alley was forecasted to have the bulk of the new EV production in 2029, whereas Canada and Mexico were expected to have relatively small shares.

Discussion

In this article, we compare the geographic footprint of the auto industry across North America in 2023 and 2029, using actual and forecast data from S&P Global Mobility. At the scale of the integrated three-country region, we find surprisingly little change is expected in the geography of light vehicle production. Most BEVs are forecasted to be assembled in existing plants after they have been converted from ICE vehicle production. And most new battery (cell and pack) plants are being situated in auto alley, where engine plants have long been clustered.

This is partly explained by the fact that the underlying economic geography principles of motor vehicle production—agglomeration economics and economies of scale—continue to influence location decisions for production even as the auto industry shifts toward electrification. The majority of plants assemble large volumes of light vehicles and are located within auto alley and central Mexico, resulting in a highly agglomerated industry footprint. Battery cell plants, even though typically based in greenfield locations (that is, undeveloped areas in and around cities), tend to be located reasonably close to battery pack plants, which are situated for the most part close to final assembly plants. The most significant outlier from the clustering in auto alley—Tesla's choice of California for its first BEV assembly plant—is still consistent with the broader auto industry's goal of minimizing the shipping distances of assembled vehicles to consumers (and, therefore, the associated costs of doing so) because more than one-third of North America's BEV sales through 2021 were in California (Klier and Rubenstein, 2015, 2022a).

Three factors are especially important in reaching the conclusion that only modest and selective changes are likely to occur in the distribution of light vehicle production within North America, at least through the end of the 2020s. First, very few final assembly plants are forecasted to open or close in the years ahead, despite the expectation that annual production in North America will increase by more than 6 million BEVs and decrease by more than 6 million ICE vehicles (see figure 7). The reason is that with only a few exceptions, automakers have begun converting existing final assembly plants to accommodate BEV production. With very few plant openings and closures, the overall footprint of assembly operations in North America is therefore unlikely to change.

Second, although propulsion system plants are typically not being converted from engine to battery production, new battery plants are being constructed in similar locations as those of existing engine plants. The location of battery plants—like that of engine plants—is strongly influenced by the desire for co-location with light vehicle assembly plants. Thus, if the distribution of assembly plants is not changing, new battery plants are likely to exhibit a similar spatial pattern as that of the existing engine plants.

Third, the growth of hybrid vehicles also suggests that there will be rather minor differences between the footprints of BEV and ICE vehicle assembly and between the distribution of battery and internal combustion engine production. S&P Global Mobility forecasted HEVs and PHEVs jointly to account for 24.0% of North America's total vehicle output in 2029 (see figure 7). Furthermore, 47 of the 80 assembly plants in operation in 2029 were expected to be producing vehicles with more than one of the four main propulsion systems and the number of assembly plants producing vehicles with at least three different types of propulsion systems was forecasted to increase from 12 in 2023 to 25 in 2029 (see figure 15). The ability to produce vehicles with a variety of propulsion systems at a single assembly plant reinforces the forecast that few assembly plants will be opened or closed in the years ahead. At the same time, it is expected that by 2029 a much larger number of assembly plants (nearly a third) will be specializing in the production of electric vehicles (as we mentioned earlier, 23 of the 80 final assembly plants in 2029 were projected to produce only BEVs).

The growth of hybrid production is even more significant for reducing the disruption to propulsion system plants over the medium term. The dramatic decrease in the production of ICE vehicles (over 6 million units)—along with the commensurate decline in demand for engines—between 2023 and 2029 is not expected to result in a massive number of engine plant closures. One of the main reasons for this is that HEVs also require engines. Hence, the forecasted decline in demand for engines for ICE vehicles would be offset to a considerable extent by the growth in demand for engines for HEVs, as production of that type of vehicle was also expected to grow (see figure 12).[22]

We started this article with the question of whether the transition to electrified vehicles will result in material changes to the automotive industry's production footprint over the medium term. We had expected to focus on similarities and differences between the longstanding distribution of ICE vehicle production on the one hand and the emerging distribution of BEV production on the other. What we learned suggests that there will be rather minimal changes to the industry's footprint over the medium term. Existing vehicle assembly plants will be able to accommodate the production of vehicles featuring propulsion systems other than the internal combustion engine. Furthermore, increased production of hybrid vehicles containing both gas engines and batteries will likely further limit changes in the geography of motor vehicle production across North America.

It is important to mention, however, that the degree of change in the industry footprint depends on the scale of analysis. Auto alley is expected to see few challenges to its dominant role in light vehicle production, yet at the local scale of specific cities and towns, the opening of battery plants—plus the possible closure of engine plants or reduced production activity at them—may well lead to changes in local economic fortunes.

Notes

[1] The U.S. Department of Energy's Alternative Fuels Data Center states the following: "An EV is defined as a vehicle that can be powered by an electric motor that draws electricity from a battery and is capable of being charged from an external source. An EV includes both a vehicle that can only be powered by an electric motor that draws electricity from a battery (all-electric vehicle) and a vehicle that can be powered by an electric motor that draws electricity from a battery and by an internal combustion engine (plug-in hybrid electric vehicle)."

[2] See also Klier and Rubenstein (2024).

[3] Note that we have used data from the same source in previous work; see, for example, Klier and Rubenstein (2017) and Brincks, Klier, and Rubenstein (2016). In those earlier articles, the data source was listed as IHS Markit Automotive Solutions, but it is now called S&P Global Mobility as a result of the merger of S&P Global and IHS Markit in February 2022.

[4] In this article, we account for only EV batteries and gas engines in our analysis of the anticipated shifts in light vehicle propulsion systems and their impacts on the auto industry footprint across North America. We do not consider transmissions or components of the electrified powertrain in this analysis.

[5] U.S. auto alley north consists of Illinois, Indiana, Michigan, and Ohio. U.S. auto alley south consists of Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. Southwestern Ontario, Canada, is sometimes considered as an extension of auto alley. However, in our analysis (as reflected throughout our figures), southwestern Ontario is treated separately in order to more clearly identify expected changes in production in each of the three light-vehicle-producing countries of North America.

[6] The U.S. Department of Energy provides further details about the clean vehicle tax credits on this Alternative Fuels Data Center webpage and this Office of Energy Saver webpage.

[7] Figure 4—as well as other figures within this article organized by light vehicle type (that is, by the propulsion system for the vehicle)—order the four types of vehicles (noted in the column headings) from electric-only to hybrid to gas-only. That way, readers can group neighboring columns when considering plug-in vehicles as EVs (BEVs and PHEVs) or as vehicles with gas or diesel engines (PHEVs, HEVs, and ICE vehicles).

[8] Stellantis N.V. was formed in 2021 through the merger of Fiat Chrysler Automobiles N.V. (FCA) and Peugeot S.A. FCA operated with two main subsidiaries—FCA Italy (previously Fiat) with headquarters in Italy and FCA US (previously Chrysler, one of the original Big Three automakers) with headquarters in Michigan (Piovaccari, 2021; Bond, 2020; and Vellequette, 2014). We classify Stellantis as a Detroit-based company (that is, a domestic automaker) in this article because all the brands of vehicles it assembles in North America stem from Chrysler.

[9] We base our analysis on a production forecast issued by S&P Global Mobility. This outlook extended through 2029 at the time of our research; it is updated at a monthly frequency. Specific quantities and product allocations can vary from month to month. After comparing several monthly forecasts from 2023, we found our conclusions to be robust. The forecast data for 2029 represent information issued by S&P Global Mobility in December 2023. (The actual data for 2023 represent information issued by S&P Global Mobility in January 2024.)

[10] This production growth value for auto alley as a whole is not shown in figure 11; it is based on our calculations using the same data source listed in figure 11.

[11] We derived the share of 2023–29 growth in BEV output within the United States for the entirety of auto alley mentioned in this paragraph by using the data for its two halves (north and south), as well as the whole country, reported in figure 12. The share of this growth outside of auto alley was also derived from data reported in figure 12.

[12] The rule of thumb for annual production on a final assembly line is around 250,000 units (which is based on a rate of one vehicle per minute during two eight-hour shifts per day, for five days a week, over 50 weeks per year).

[13] According to an *Automotive News Europe* article summarizing an interview with Pedro Pacheco, vice president of research at Gartner, "dedicated EV platforms have given automakers the freedom to design assembly lines that are suited to their characteristics, including a smaller powertrain and flat battery floor" (Sigal, 2024).

[14] Note that we discuss the location of battery production only for BEVs and PHEVs, that is, vehicle types with a battery that can be charged directly (with a plug). We do not cover the geography of HEV battery production in our analysis. In terms of driving on electricity alone, HEV batteries are designed to provide a shorter range than either BEV or PHEV batteries. HEV batteries are typically much smaller than BEV or PHEV batteries and differ from them in other ways (for details, see Csere, 2021).

[15] This estimate of ten fewer engine plants is based on our calculation for the mean production at engine plants in North America (Klier and Rubenstein, 2022b).

[16] Based on our calculations using data reported in figure 7, the production of vehicles with engines (ICE vehicles, HEVs, and PHEVs) was expected to decline by 37% between 2023 and 2029. Generally speaking, in this article, we discuss engine production during the unfolding transition toward electrification. The first-order relationship we focus on is that for every fully electric vehicle, one fewer internal combustion engine will be needed. Note that there are possible second-order adjustments at play (which are beyond the scope of this article). For example, there could be changes to the engine mix produced at engine plants (as the range delivered by batteries for hybrids increases, the size of the engine might shrink), and these plants might start to produce components of the electrified powertrain.

[17] Note that the majority of electric batteries for vehicles currently follow the cell-module-pack production sequence (and are forecasted to do so in 2029); however, there are alternative approaches, such as skipping the module as a separate production stage or integrating the modules (or cells) into the vehicle body.

[18] Note that the units of cells we report have been normalized to the number of BEVs and PHEVs assembled in North America; that is, we count the multitude of cells installed in a single BEV or PHEV (averaging over 700 cells per light vehicle, according to our calculation based on S&P Global Mobility data) as one unit of cell production and report the total cell production volumes accordingly.

[19] S&P Global Mobility forecasted Toyota and Volkswagen would be producing some of their own cells for EV batteries by 2029, as Tesla had already been doing in 2023, as shown in figure 21.

[20] Plants producing EV batteries, including their cells, have unique requirements regarding “production flow, material handling, environmental control and fire safety”; such factories also need to be able to accommodate very large electrical loads (two to three times the loads of a typical light vehicle assembly plant) (Verner, 2023). On balance, these and other factory design factors suggest that EV battery manufacturing plants are likely to be built on greenfield sites (that is, undeveloped areas in or around cities), in lieu of transforming existing engine plants for EV battery production.

[21] We calculated the distances as straight-line distances.

[22] While the production of PHEVs (which also require engines) was expected to grow between 2023 and 2029 (figure 12), the PHEV share of total light vehicle production in North America was projected to decrease (see figure 4 versus figure 8); thus, PHEVs likely won’t contribute much to helping offset the decrease in demand for engines due to ICE vehicle production reduction. Note also that we did not explore possible changes to engine characteristics, along with related supply chain impacts, during the auto industry’s transition to electrified vehicles—to the extent that hybrid vehicles (HEVs and PHEVs) replace ICE vehicles.

References

Bond, Vince, Jr., 2020, "Newly merged FCA-PSA entity will be called Stellantis," *Automotive News*, July 15, available online by subscription.

Brincks, Corey, Thomas Klier, and James M. Rubenstein, 2016, "The role of national champions in the evolving footprint of vehicle production in Europe—1990–2013," *International Journal of Automotive Technology and Management*, Vol. 16, No. 2, pp. 130–146. Crossref

Cedillo-Campos, Miguel Gaston, Juan Sanchez-Garza, and Cuauhtemoc Sanchez Ramirez, 2006, "The new relational schemas of inter-firms cooperation: The case of the Coahuila automobile cluster in Mexico," *International Journal of Automotive Technology and Management*, Vol. 6, No. 4, pp. 406–418. Crossref

Csere, Csaba, 2021, "Battery taxonomy: The differences between hybrid and EV batteries," *Car and Driver*, August 10, available online.

Ellison, Glenn, and Edward L. Glaeser, 1997, "Geographic concentration in U.S. manufacturing industries: A dartboard approach," *Journal of Political Economy*, Vol. 105, No. 5, October, pp. 889–927. Crossref

Ellison, Glenn, Edward L. Glaeser, and William R. Kerr, 2010, "What causes industry agglomeration? Evidence from coagglomeration patterns," *American Economic Review*, Vol. 100, No. 3, June, pp. 1195–1213. Crossref

Gregory, Derek, Ron Johnston, Geraldine Pratt, Michael J. Watts, and Sarah Whatmore (eds.), 2009, *The Dictionary of Human Geography*, 5th ed., Chichester, UK: Wiley-Blackwell.

Klier, Thomas H., and James M. Rubenstein, 2024, "From ICE to BEV production in Europe: Industry geography in transition," *International Journal of Automotive Technology and Management*, Vol. 24, No. 1, pp. 95–117. Crossref

Klier, Thomas H., and James M. Rubenstein, 2022a, "North America's rapidly growing electric vehicle market: Implications for the geography of automotive production," *Economic Perspectives*, Federal Reserve Bank of Chicago, No. 5. Crossref

Klier, Thomas, and James M. Rubenstein, 2022b, "Trade agreements and the geography of motor vehicle production in North America and Europe," *International Journal of Automotive Technology and Management*, Vol. 22, No. 1, pp. 4–28. Crossref

Klier, Thomas, and James M. Rubenstein, 2021, "ICE age geography: Powertrain sourcing in Europe and North America," *International Journal of Automotive Technology and Management*, Vol. 21, No. 4, pp. 322–342. Crossref

Klier, Thomas H., and James M. Rubenstein, 2017, "Mexico's growing role in the auto industry under NAFTA: Who makes what and what goes where," *Economic Perspectives*, Federal Reserve Bank of Chicago, Vol. 41, No. 6, available online.

Klier, Thomas H., and James M. Rubenstein, 2015, "Auto production footprints: Comparing Europe and North America," *Economic Perspectives*, Federal Reserve Bank of Chicago, Vol. 39, Fourth Quarter, pp. 101–119, available online.

Lung, Yannick, 2004, "The changing geography of the European automobile system," *International Journal of Automotive Technology and Management*, Vol. 4, Nos. 2–3, pp. 137–165. Crossref

Piovaccari, Giulio, 2021, "After long journey, Fiat Chrysler and PSA seal merger to become Stellantis," Reuters, January 16, available online.

Rubenstein, James M., 1992, *The Changing US Auto Industry: A Geographical Analysis*, London and New York: Routledge.

Sigal, Peter, 2024, "EVs will be cheaper to build than ICE cars by 2027, analyst says," *Automotive News Europe,* March 8, available online by subscription.

Truett, Lila J., and Dale B. Truett, 2003, "The Italian automotive industry and economies of scale," *Contemporary Economic Policy*, Vol. 21, No. 3, July, pp. 329–337. Crossref

Truett, Lila J., and Dale B. Truett, 2001, "The Spanish automotive industry: Scale economies and input relationships," *Applied Economics*, Vol. 33, No. 12, pp. 1503–1513. Crossref

Truett, Lila J., and Dale B. Truett, 1996, "Economies of scale in the Mexican automotive sector," *Journal of Productivity Analysis*, Vol. 7, No. 4, October, pp. 429–446. Crossref

Vellequette, Larry P., 2014, "Fiat's European holding company now called FCA Italy," *Automotive News Europe*, December 16, available online by subscription.

Verner, David, 2023, "Battery plant design do's and don'ts," *Assembly Magazine*, September 15, available online by subscription.

Wynn-Williams, Michael S., 2009, "Economies of scale in the automobile industry," in *Surfing the Global Tide: Automotive Giants and How to Survive Them*, Basingstoke, UK: Palgrave Macmillan, pp. 41–71.

Economic Perspectives is published by the Economic Research Department of the Federal Reserve Bank of Chicago. The views expressed are the authors' and do not necessarily reflect the views of the Federal Reserve Bank of Chicago or the Federal Reserve System.

ISSN 0895-0164