Motor Vehicle Electrification: Implications for Iowa

Report submitted to:

Center for Industrial Research and Service (CIRAS)

Project submitted by:

Center for Automotive Research

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Acknowledgments

The successful completion of this research was the result of many individuals contributing to and supporting the project. The Center for Automotive Research would like to thank CIRAS for funding this project. CAR also thanks our industry partners, who provide insights and thoughtful commentary that helps the research team better understand the industry's supply chain and technology dynamics.

Michael Schultz, Industry Economist

Kristin Dziczek, Senior Vice President

Edgar Faler, Senior Industry Analyst

Bernard Swiecki, Research Director

CENTER FOR AUTOMOTIVE RESEARCH

880 Technology Drive, Suite C
Ann Arbor, MI 48108
www.cargroup.org

CAR's mission is to conduct independent research and analysis to educate, inform and advise stakeholders, policymakers, and the general public on critical issues facing the automotive industry and the industry's impact on the U.S. economy and society.

Introduction and Summary of Findings

The Center for Industrial Research and Service (CIRAS) contracted the Center for Automotive Research (CAR) to perform a comprehensive review of risks and opportunities to Iowa's motor vehicle products industry stemming from motor vehicle electrification. CAR staff compiled a database of unique business locations in Iowa from governmental industry data, several subscription databases, and CIRAS's business data to establish these risks and opportunities. The comprehensive database review identified approximately 37 percent more locations than were listed in the North American Industry Classification System (NAICS)-based governmental data (179 vs. 131), and almost 92 percent greater related employment (20,377 vs. 10,619). This discrepancy stems from NAICS-based data classifying business establishments by their primary activity, while the comprehensive database review allows the incorporation of locations with secondary or tertiary products in the motor vehicle product space.

Records for each business location were verified and assigned to a technology category based upon available information on each location's products and services. CAR staff then applied an internally developed risk model for motor vehicle and electrification technologies to these business records. Applying the risk model to NAICS data indicates that 10 percent of motor vehicle product establishments and 7 percent of related employment in Iowa are at risk from electrification, while 8 percent of establishments accounting for 6 percent of employment have new business opportunities. In contrast, applying the risk model to the comprehensive business location database found that 23 percent of Iowa's motor vehicle product establishments and 21 percent of employment are at risk, while 14 percent of establishments and 8 percent of employment may enjoy new opportunities.

For the nation as a whole, a review of NAICS data suggests 19 percent of all motor vehicle product establishments and employment are at risk from electrification. The share of motor vehicle product establishments at risk nationwide is nearly twice the share at risk in Iowa, and the share of motor vehicle product employment at risk nationwide is nearly three times the share of employment at risk in Iowa. Opportunities from electrification are available for only for 10 percent of motor vehicle product establishments nationwide, impacting 9 percent of motor vehicle product employment.

CAR staff also reviewed manufacturing and production and research, development, and engineering certification, training, and education programs in Iowa related to motor vehicle products and vehicle electrification. Through its community colleges, Iowa's manufacturing and production programs are already well-positioned for the technology transition.

Throughout the country, state governments and their economic development offices are primarily competing over vehicle assembly and battery cell and pack production in the transition to electrified and wholly electric vehicle propulsion systems. In addition to these key products, however, electrification will also substantially expand the need for domestic refining, processing, and recycling of battery materials—all areas for which Iowa is particularly well-positioned due to its existing chemical, pharmaceutical, metals, and recycling industries.

Iowa also enjoys relative strengths in electrical equipment, appliance, motor, generators, switchgear, and switchboard apparatus manufacturing. To attract electric vehicle supply equipment (charging systems and stations) manufacturing, Iowa can leverage this endowment.

Section 1: Characterizing Iowa's Motor Vehicle Products Industry

Determining the potential impacts of motor vehicle electrification on Iowa's motor vehicle products industry requires first identifying Iowa's current production and research and development footprint. This section uses governmental data, subscription databases, and CIRAS' data to identify and describe the extent and composition of Iowa's existing motor vehicle products industry. CAR described research, development, design, and engineering activities using occupational employment data and the consolidated business directories and databases. Please note that CAR regularly utilizes data for 2019 to avoid emphasizing the dramatic adjustments effects of the COVID-19 pandemic present in the 2020 data.

Iowa's Motor Vehicle Products Industry: Government Data

Pre-pandemic manufacturing of motor vehicle parts, bodies, chassis, trailers, and motor homes provided 10,619 jobs across 131 establishments, with an average annual wage of USD 50,387 in 2019. In 2020 employment totaled 9,658 jobs across 138 establishments, with average annual wages of USD 51,309 (U.S. Bureau of Labor Statistics, 2021a). Total revenue for these manufacturing operations was approximately USD 3.4 billion and contributed USD 1.4 billion of value-added to Iowa's GDP in 2019 (U.S. Census Bureau, 2020). Table 1 provides a high-level summary of the motor vehicle product industry in Iowa, per governmental data.

Table 1: Iowa's Motor Vehicle Products Industry per Governmental Data

	2019	2020
Total Employment	**10,619**	**9,658**
Bodies and Trailers	6,523	6,226
Vehicle Parts	4,096	3,432
Total Establishments	**131**	**138**
Bodies and Trailers	70	72
Vehicle Parts	60	66
Average annual wage	**USD 50,387**	**USD 51,309**
Total Revenue	**USD 3.4 billion**	***Not Available***
Total Value Added	**USD 1.4 billion**	***Not Available***

Sources: (U.S. Bureau of Labor Statistics, 2021a) (U.S. Census Bureau, 2020)

Most of Iowa's motor vehicle supply base operates in body and trailer manufacturing. In 2020, this industry accounted for 72 establishments and provided 6,226 jobs. Within Iowa's motor vehicle body and trailer manufacturing industry, the primary product focus is travel and camper trailers, which accounted for 29 establishments, followed by motor vehicle bodies (26), truck trailers (13), and motor homes (4) (U.S. Bureau of Labor Statistics, 2021a).

Government data do not disclose employment figures for some smaller specific product areas, but among the sectors with available data, motor vehicle body manufacturing accounted for the most significant amount of employment, with 2,209 employees. Travel trailer and camper manufacturing account for an additional 1,377 jobs. The remaining 2,640 jobs are split across truck trailer manufacturing and motor home manufacturing activities (U.S. Bureau of Labor Statistics, 2021a).

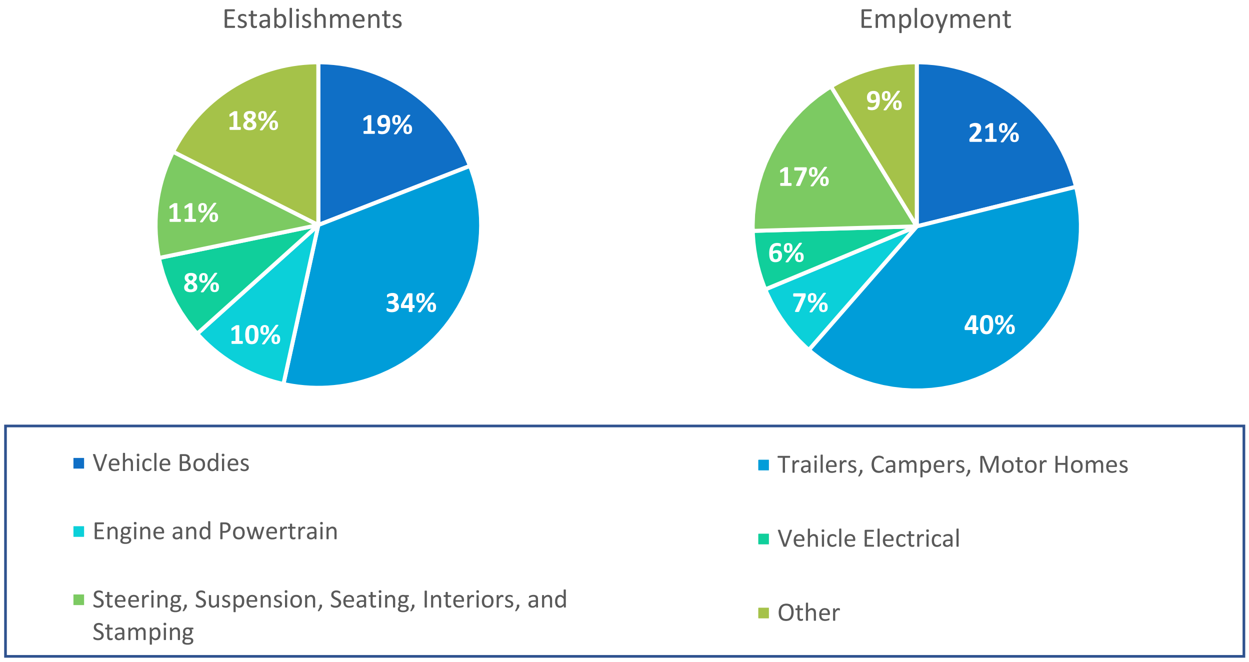
There were 60 motor vehicle parts manufacturing establishments in Iowa in 2019 and 66 in 2020. More than one-third of these establishments operate in the "Other motor vehicle parts" industry, with 23 Iowa facilities in 2019 and 24 in 2020 (QCEW). These companies produce various products, including airbag systems and components, mirrors, bumpers, HVAC and thermal management parts, exhaust systems, luggage racks, trailer hitches, and myriad more (Census NAICS). Motor vehicle electrical equipment manufacturing is the next-largest, with 11 locations in 2019 and 12 in 2020, followed by motor vehicle metal stamping with 10 establishments in 2019 and 2020. The remaining parts categories, by the number of establishments in Iowa, are gasoline engine parts manufacturing (8 in 2019 and 2020), powertrain parts manufacturing (5 in 2019, 6 in 2020), steering systems and parts (2 in 2019, 5 in 2020), seating systems and parts (2 in 2019 and 2020) (U.S. Bureau of Labor Statistics, 2021a).

Across all products, motor vehicle parts manufacturing employed 4,096 workers in 2019 and 3,432 in 2020. Greater levels of detail characterize less than 60 percent of employment by product area. Within the detailed areas for which employment figures are available, "Other motor vehicle parts" is again the largest, having had 929 employees in Iowa in 2019 and 834 in 2020. The second-largest remains motor vehicle electrical equipment, with 620 employees in 2019 and 519 in 2020. Gasoline engine parts manufacturing had 516 employees in Iowa in 2019 and 380 in 2020. Powertrain parts manufacturing provided 259 jobs in 2019 and 220 in 2020. The smallest employment size among detailed areas is steering systems and parts, with 37 employed in Iowa in 2020; 2019 employment is unavailable. The remaining positions are spread across brake system manufacturing, seating systems and parts, and motor vehicle metal stamping (U.S. Bureau of Labor Statistics, 2021a).

The two charts in

Figure 1 provide a visual summary of the distribution of establishments and employment across NAICS industries in Iowa’s motor vehicle products industry.

Figure 1: The Distribution of Establishments and Employment in Iowa’s Motor Vehicle Products Industry, per Governmental Data



Source: (U.S. Bureau of Labor Statistics, 2021a)

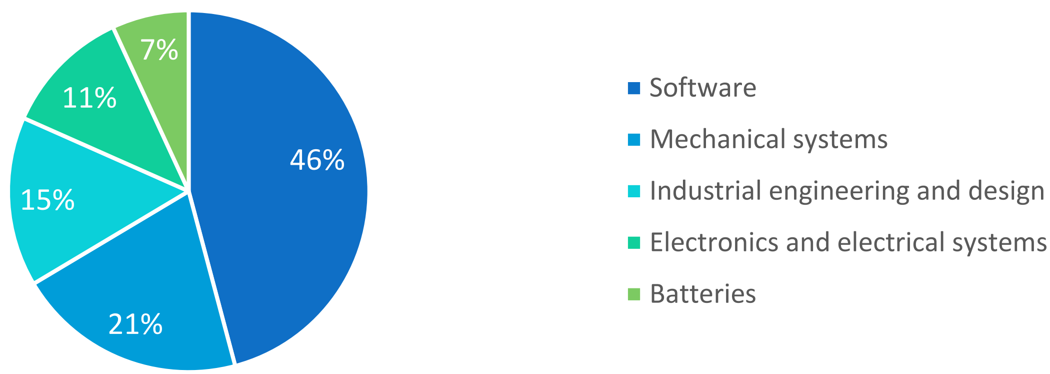
Research, Development, Design, and Engineering Occupational Employment

As no comprehensive data covers research, development, design, and engineering activities by industry and state, CAR researchers relied upon occupational employment data from the U.S. Bureau of Labor Statistics to characterize Iowa’s footprint. Iowa employment in occupations relevant to “motor vehicle products industry”[1] research, development, design, and engineering activities totals 24,230 (U.S. Bureau of Labor Statistics, 2019).

[1] “Motor vehicle products industry” is used as short-hand to reference all of the following:
light-, medium-, and heavy-duty vehicle assembly; vehicle bodies, chassis, and trailers, inclusive of recreational vehicles; traditional motor vehicle parts; and vehicle electrification components and systems.

Figure 2 provides an overview of how this employment is distributed across occupational groupings.

Figure 2: Research, Development, Design, and Employment by Occupational Grouping[2]



Source: (U.S. Bureau of Labor Statistics, 2021a)

Iowa hosts substantial employment in occupations that are relevant to future automotive research and development activities. However, note that these individuals by and large are not presently in the motor vehicle products space. Data on occupational employment by industry and state is very limited, but what data is available suggests that of the more than 24,230 workers in these fields between 360 and 700 currently work in the motor vehicle product space (U.S. Bureau of Labor Statistics, 2019b).

By far, the greatest share of employment is in software development and testing occupations, which account for 11,110 (46 percent) of employment in related motor vehicle industry-related occupations (U.S. Bureau of Labor Statistics, 2019). Historically, this skillset was relatively unimportant to the motor vehicle industry, but myriad factors have driven a long-term trend towards the elevation of software as key to motor vehicles. Fuel economy and tailpipe emissions regulations long ago necessitated the incorporation of computer-controlled powertrains and software development to optimize engine performance. The rise of built-in navigation and infotainment systems further elevated the importance of software. Electrification and vehicle automation will only accelerate this transformation.

The next-largest occupational group is mechanical systems R&D, totaling 4,990 (21 percent) of jobs (U.S. Bureau of Labor Statistics, 2019). Within the motor vehicle industry, these roles most often design and develop internal combustion engines, transmissions, and parts thereof. Electrification already sees automakers phasing out these positions via a combination of targeted retirement incentives and reduced hiring of these skillsets. However, while these roles may substantially diminish, they will not disappear from the motor vehicle industry. Mechanical systems occupations also engineer vehicle body structures and assist in developing hybrid or partially-electrified powertrain systems.

[2] The occupational groupings are defined as follows:
Batteries: Chemical Engineers, Chemical Technicians, Chemists, Materials Engineers, Materials Scientists, and Physicists
Electronics and electrical systems: Electrical and Electronic Engineering Technologists and Technicians, Electrical Engineers, and Electronics Engineers, Except Computer
Mechanical systems: Mechanical Drafters, Mechanical Engineering Technologists and Technicians, Mechanical Engineers
Industrial engineering and design: Commercial and Industrial Designers, Industrial Engineers
Software: Software Developers and Software Quality Assurance Analysts and Testers

The third-largest grouping is industrial engineering and design, accounting for 3,680 jobs in Iowa (U.S. Bureau of Labor Statistics, 2019). These roles pertain to factory design, manufacturing process development, and product design. CAR does not anticipate significant changes to these roles in the motor vehicle industry. As electrification sees new companies enter the motor vehicle industry, and these companies both often evaluate non-traditional manufacturing processes and need to differentiate their products from those offered by the established industry and the other new entrants, it is easy to imagine a boost in the motor vehicle industry's industrial engineering and design employment. Any such increase will likely prove temporary. The scale usually required to operate profitably in the industry suggests extensive future consolidation among new entrants and existing companies, most notably between new and extant automakers.

Occupations in the remaining two groupings, batteries and electronics and electrical systems, currently account for a total of 4,450 jobs in Iowa, respectively providing 1,670 (7 percent) and 2,780 (11 percent) of employment in motor vehicle industry-related research, development, design, and engineering (U.S. Bureau of Labor Statistics, 2019). As a result of electrification trends, these occupational groupings are expected to grow substantially in their importance to and their scope of employment in the motor vehicle industry.

The View from Business Databases

Governmental data provides a near-census of employment, establishments, wages, and revenue for manufacturing activities, by NAICS classification. However, these may understate the true scope of manufacturing activities for a given product space, as NAICS code assignments are determined by the primary activity of a given establishment. Additionally, service sector activities such as research, design, and engineering related to trailer manufacturing are not clearly captured in NAICS-based data.

To flesh out the details of Iowa's motor vehicle products industry, inclusive of related services and secondary and tertiary products, CAR performed a comprehensive database review incorporating business records from several subscription databases, as well as CIRAS's internal records. CAR staff reviewed each business location covered in these records to populate location-specific product information further where possible (company-wide product information, where location-specific is not available) and classified locations by their level of exposure to the motor vehicle electrification revolution.

Whereas NAICS-based data finds a total of 10,619 jobs and 131 establishments in the motor vehicle products industry in Iowa, this more-expansive review of businesses identifies 20,377 employees and 179 establishments. These results from the database review indicate that Iowa has up to 92 percent greater employment and 38 percent more establishments tied to motor vehicle products than are captured by the primary activity-focused NAICS-based governmental data.

The distribution of employment and establishments also differs between our database review and the governmental data. Unlike the governmental data, this more expansive approach finds that body and chassis manufacturing is the single largest contributor to employment in Iowa's motor vehicle products industry, with 4,236 employees or 15 percent of Iowa's total motor vehicle product industry employment. The second-largest segment is trailer manufacturing with 3,067 employees (15 percent); motor home, RV, and camper manufacturing are the third-largest, with 2,718 employees (13 percent). Establishment counts find trailer manufacturing has the greatest number of business locations at 34 (19 percent), followed by body and chassis manufacturing with 33 locations (18 percent). Aftermarket products account for the third-largest number of locations, with 18 (10 percent). Table 2 provides the full details of employment and establishments in Iowa's motor vehicle product industry from our review of business details in subscription databases and CIRAS' internal data.

Table 2: Iowa's Motor Vehicle Products Industry per Private Data

Category	Employment	Establishments
Aftermarket Products	1,051	18
Bodies, Chassis	4,236	33
Electric Motors	737	9
Electrical and Electronic Parts	827	15
Exhaust and Emissions	90	4
Fuel Systems	270	3
ICE Powertrain Parts	1,726	9
Interior Parts	2,011	13
Lead Acid Batteries	1,019	4
Motor homes, RVs, Campers	2,718	4
Suspension Systems	249	3
Thermal Management	740	7
Trailers	3,067	34
Wheels, Tires	789	7
Other	847	16

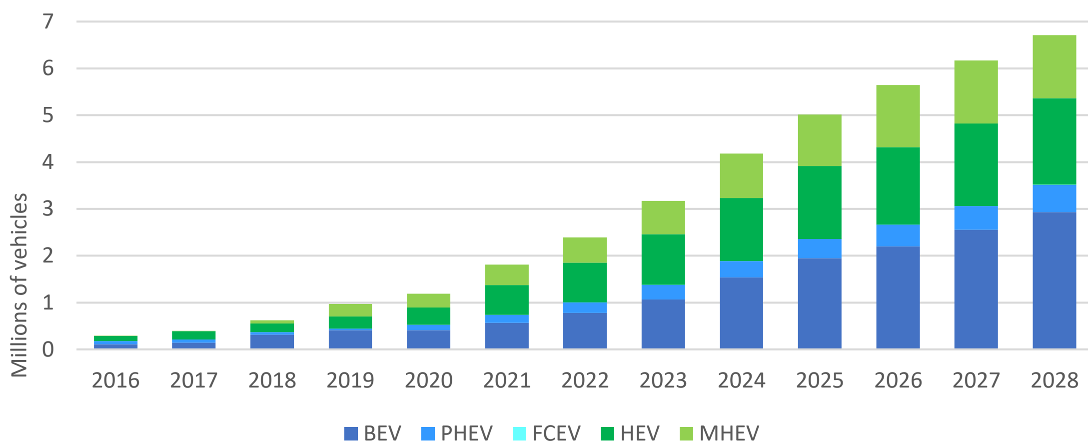
Source: (Center for Automotive Research, 2021-2022)

Section 2: Motor Vehicle Industry Technology Trends

Production of electrified vehicles—mild hybrids, full hybrids, plug-in hybrids (PHEV), battery electric (BEV), and hydrogen fuel cell (FCEV) vehicles—is forecast to grow significantly in the coming years, as illustrated below in Figure 3. Electrified vehicles will grow from approximately 1.2 million units in 2020, or 10 percent of total light-duty vehicles produced in North America, to 6.7 million units by 2028, accounting for a 39 percent share (LMC, 2021). Focusing on only electrified vehicle technologies that do not include internal combustion engine (ICE) powertrain components—FCEVs and BEVs—the share of production in 2020 was 3 percent, with the 2028 production share expected to be 17 percent, with BEVs accounting for 99.8 percent of the combined volume of BEVs and FCEVs (LMC, 2021). Other electrified vehicles maintain the ICE powertrain: even in 2028, 83 percent of North American light vehicle production is forecast to have an ICE still.

Similarly, the production of medium- and heavy-duty truck electrified vehicles is forecast to grow meaningfully, although not reaching comparable share levels until much later. For example, medium-duty electrified vehicles are estimated to achieve 38 percent share in 2030, at roughly 200,000 units, up from essentially none to speak of in 2020. In contrast, heavy-duty electrified vehicles are forecast to only reach a 22 percent share by 2020, at 300,000 units, up from none currently, due to lagging charging infrastructure development at a substantially higher cost than electrified light-duty vehicles (Dana, 2021).

Figure 3: North American Electrified Light Vehicle Production

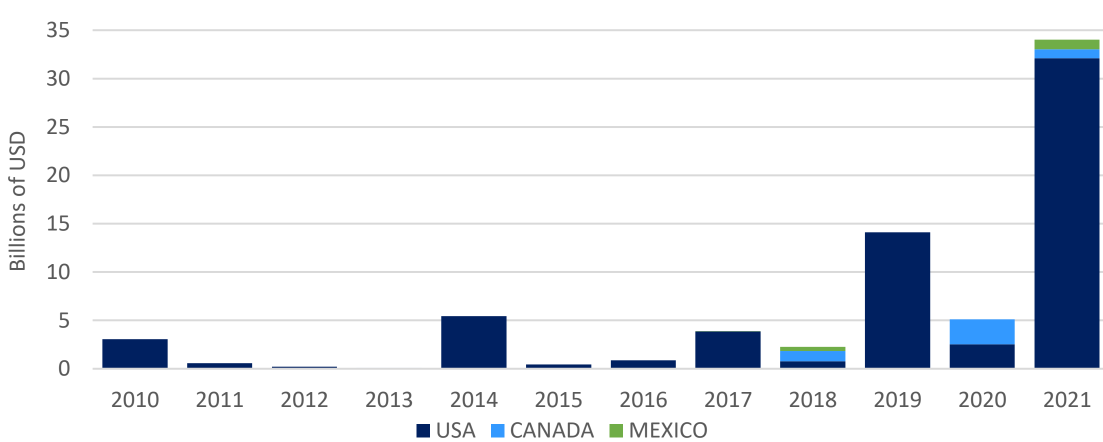


Source: (LMC, 2021) *and CAR analysis*

To support strong forecast electrified vehicle demand, vehicle manufacturers have begun investing heavily to convert existing assembly plants and construct new ones to produce newly developed (and planned) dedicated electric vehicles, as illustrated below in

Figure 4. Such investments are not likely to come online until 2024-2025, however, given traditional long lead times for property development and plant construction.

Figure 4: Automaker Announced Electrification Investments, 2010 – 2021

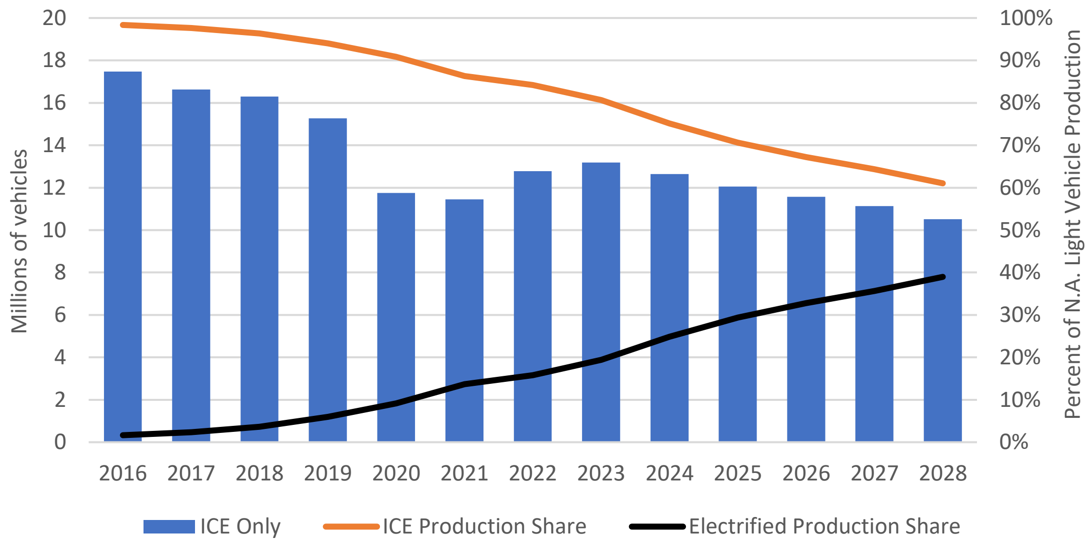


Note: Announcements in 2019 reflect UAW contracts
Source: (Center for Automotive Research, 2022)

At the same time, the electrified vehicle growth opportunity for vehicle manufacturers and suppliers will come at the expense of conventional ICE vehicles, which are forecast to fall from nearly 90 percent of North American light vehicle production in 2020 to roughly 60 percent by 2028, as highlighted below in

Figure 5. However, the outlook for EV vehicle penetration still varies considerably during this timeframe and through 2030, e.g., appearing to range from 20-40 percent, which remains below recently made targets set by automakers to achieve President Biden's goal of 50 percent BEV and PHEV market penetration. Key uncertainties remain concerning widespread customer acceptance, battery performance and cost hurdles, charging infrastructure requirements, as well as sufficient availability of critical raw materials and batteries.

Figure 5: Internal Combustion Engine Vehicle Production and Internal Combustion Engine vs. Electrified Share



Sources: (LMC, 2021) *and CAR analysis*

Regardless, the electrification trend presents significant consequences for suppliers of conventional ICE systems as product volumes eventually decline over time, as illustrated below in

Figure 6.

*Figure 6: Major Systems Affected by Transitioning from a USD 35,000 MSRP ICE Car to a Light-Duty BEV **

Major Systems Affected by Transitioning to BEV	Estimated Dollar Impact per Vehicle
Axles, driveshafts & auxiliary components (Reduced complexity)	↓ 300
Exhaust system (Eliminated)	↓ 400
Fuel system (Eliminated)	↓ 500
Transmission including clutches, planetary gears & torque converter (eliminated & replaced with electric drive unit & electric motors, 2 assumed in the example but up to 4 possible)	↓ 500 net
Engine (Eliminated)	↓ 4,500
Power electronics & high-voltage electrical architecture (Added)	3,000
Battery pack (Added)	10,000
Other systems affected including body structures (increased content), audio/infotainment (upgraded), braking (upgraded), climate control/HVAC (upgraded)	2,000

Sources: ***Invalid source specified.****,* (Wolfe Research, 2020)*, and CAR analysis.*
**Note: For illustrative purposes. Figures rounded to nearest USD 100. Light trucks and performance models could differ significantly.*

As shown above, the most negatively impacted suppliers will be those currently producing sub-assemblies and systems for conventional internal combustion engines, i.e., replaced by batteries and related power electronics, which for typical passenger cars represents approximately USD 4,500 per vehicle (combined) or more for high-performance cars and light trucks. BEVs do not require fuel systems, exhaust, or emissions controls systems either, which altogether eliminates roughly USD 900 content per vehicle for affected suppliers.

Furthermore, BEVs do not necessitate complex transmissions, e.g., 7-9 speed transmissions or continuously variable transmissions, which are replaced by electric transaxles that share common parts at significantly reduced build complexity, providing cost savings and economies of scale for automakers. However, medium- and heavy-duty electrified vehicle transmissions will require more gearing to handle higher electric motor torque requirements, leading to higher content per vehicle—but reducing brake requirements and content per vehicle compared to light vehicles.

Additionally, there will be a long transitional period, wherein half or more of electrified vehicle volumes will be hybrids or plug-in hybrids. Due to their electrified propulsion systems, these vehicles remain mechanically complex, with added complexity compared to traditional ICEs. Plug-in hybrid vehicles are particularly complex products—a significant factor in why the overwhelming majority of plug-in vehicle production is BEVs.

CAR's Product/Technology Risk Ranking Model

CAR applied its proprietary risk scoring model to understand the potential risk to Iowa's motor vehicle products industry. This model considers key risk factors that have historically compelled vehicle manufacturing suppliers to move or consolidate operations. These key factors are identified in

Table 3.

Table 3: Risk Factors and Evaluation Criteria for Product/Technology Category Risk Scoring vis-à-vis Electrification

Risk Factors	Definition	Risk Model Scores		
		-1	0	1
Concentration	Market concentration impacts companies' ability to earn above (or below) "market" profitability. High concentration, e.g., top 5 suppliers > 66% market share = higher economic profits	*Low* concentration (Top 5 suppliers < 66% market share)	*Medium* concentration	*High* concentration (Top 5 suppliers > 66% market share)
Consolidation	Combined industry concentration (BofA analysis) & corresponding consolidation risk, i.e., "low" market concentration of suppliers = "high" consolidation risk if pricing is negative (-1 score)	*Low* concentration = High M&A risk	*Medium* concentration = Moderate M&A risk	*High* concentration = Low M&A risk
Pricing	Content per vehicle (CPV) outlook, i.e., is pricing negative/stable/positive, impacting CPV	*Negative/Declining*	*Stable*	*Positive/Increasing*
Restructuring	Risk associated with restructuring and cost-cutting as a result of declining volume outlook and/or negative pricing	*High*	*Moderate*	*Low*
Total Addressable Market (TAM)	Market opportunity, i.e., combined unit volume & pricing, compared to LVP outlook, i.e., is the market declining/stable/increasing relative to 2028 LVP forecast	*Negative* i.e., <LVP outlook	*Stable* i.e., in-line with LVP (1-2% CAGR baseline)	*Positive* i.e., >LVP outlook
Unit Volume Outlook	Outlook compared to 2028 light vehicle production (LVP) forecast, i.e., are additional units forecast per vehicle	*Negative* i.e., <LVP outlook	*Stable* i.e., in-line with LVP (1-2% CAGR baseline)	*Positive* i.e., >LVP outlook

Source: ***Invalid source specified.*** *and CAR analysis*

CAR's risk scoring model derives inputs from a combination of our in-house expertise, interviews with transportation industry executives, as well as publicly-available secondary sources, such as investor presentations and the BofA Securities "Who Makes the Car of the Future – 2021" report. Our model produces an overall risk ranking by Bill Of Material (BOM) category based on prevailing market trends, i.e., the sum of the six risk factor scores, weighted by average dollar content per light passenger vehicle. CAR believes this model is also a reasonable proxy for medium-duty vehicle suppliers (excluding buses), similarly impacted by electrification trends.

The original risk model developed by CAR considered twenty-one discrete technology categories based upon parts and systems present in light-duty vehicles across diverse traditional, hybrid, and electric powertrains. Given the unique nature of the Iowa motor vehicle product industry vis-à-vis the overall motor vehicle industry in North America, these twenty-one categories were modified to improve relevance for Iowa. CAR researchers consolidated technology categories with little presence in Iowa while adding categories with a meaningful presence in Iowa but not covered by the original twenty-one technology categories. This modification resulted in a fifteen-category risk classification system for the present analysis. Table 4summarizes these categories and the expected primary impact of electrification on each

Table 4 Product Categories Utilized for Evaluating Risks and Opportunities for Iowa's Motor Vehicle Product Industry

Product Category	Primary Expected Impact of Electrification
Aftermarket Products	Unaffected
Bodies, Chassis	Unaffected
Electric Motors	Opportunity
Electrical and Electronic Parts	Opportunity
Exhaust and Emissions	At Risk
Fuel Systems	At Risk
ICE Powertrain Parts	At Risk
Interior Parts	Unaffected
Lead Acid Batteries	At Risk (in the very long term)
Motor homes, RVs, Campers	Unaffected
Suspension Systems	Unaffected
Thermal Management	At Risk
Trailers	Unaffected
Wheels, Tires	Unaffected
Other	Unaffected

Source: CAR analysis

Section 3: Implications for Iowa's Motor Vehicle Products Industry

The potential impacts of motor vehicle electrification on Iowa can be evaluated by applying our risk ranking criteria to the industry details established in Section 1. CAR researchers carried out this application on the governmental data and the business database compiled from subscription databases and data provided by CIRAS. For this second review, CAR researchers verified possible business location-specific products and services to the fullest extent. After verifying location-specific activities, CAR researchers assigned each location a risk ranking based upon these activities. Where a business location has specific products within our categories that are expected to experience impacts separate from their overall category, the risk ranking assignment of that location is assigned separately from the overarching product category.

Applying the risk ranking to the NAICS industry-based governmental data indicates that the majority of both establishments and employment in Iowa's motor vehicle products industry is likely unaffected by the transition to hybrid and electric vehicles. Only one NAICS category present in Iowa is clearly at risk: motor vehicle engine and powertrain production. In total, Iowa has 13 establishments in this category, with accompanying employment of 775; this represents 10 percent of establishments and 7 percent of employment within Iowa's motor vehicle products industry (U.S. Bureau of Labor Statistics, 2021a). Similarly, one NAICS category in Iowa may benefit from motor vehicle electrification: vehicle electrical parts production. This category includes 11 establishments with 620 employees, representing 8 percent of Iowa's motor vehicle products establishments and 6 percent of employment (U.S. Bureau of Labor Statistics, 2021a). The 107 establishments and 9,224 jobs remaining in the NAICS categories are expected to remain largely unaffected by motor vehicle electrification.

NAICS data permits contextualizing Iowa's potential risk level against the country as a whole, and each state with motor vehicle product manufacturing activities. At the national level, applying the risk ranking criteria to NAICS data finds that 19 percent of motor vehicle product establishments in the United States are at risk from electrification—nearly double Iowa's 10 percent of motor vehicle product establishments. The share of motor vehicle product employment at risk nationally is also 19 percent, which is almost three times the share of motor vehicle product employment at risk in Iowa (U.S. Bureau of Labor Statistics, 2019).

Reviewing data for each 46 of the states with motor vehicle product manufacturing finds both the average and the median state sees 12 percent of total motor vehicle product employment at risk, compared to 7 percent for Iowa. Ranking states by their individual share of motor vehicle product employment at risk finds North Carolina the most susceptible, as nearly 35 percent of related employment is specifically within engine and transmission manufacturing. While North Carolina ranks 1st, Iowa ranks 32nd for share of motor vehicle product employment at risk.

Contextualizing at-risk employment against total state employment, rather than only motor vehicle product manufacturing employment, changes the rankings of individual states significantly. The average share of total state employment at risk across states is 0.09 percent, with the median at 0.02 percent of employment. Indiana is the most at-risk state, with 0.82 percent of all state employment in an at-risk category, with Michigan second, at 0.73 percent of employment at risk. By this method of contextualization, with 0.05 percent of all employment in Iowa in an at-risk category, Iowa is the 16th most at-risk state among 46 states with motor vehicle product manufacturing activity.

For many of the 46 states with little risk to employment, this stems in part from the diminutive scale of their motor vehicle products footprint. Considering only the 24 states that had at least 5,000 employees in this space in 2019, an average of 15 percent of employment within the motor vehicle product space is at risk (median of 13 percent). Contextualized against total state employment, the average of these 24 states sees 0.16 percent of total statewide employment at risk (median 0.07 percent). Among these states, Iowa ranks 22nd of 24 for share of motor vehicle product employment at risk, and 16th of 24 for share of total statewide employment at risk.

When using governmental data, the inability to differentiate risk levels by specific products or business locations presents a potential source of bias in risk and opportunity exposure. Evaluating individual business locations and determining expected impacts according to location-specific production allows a clearer picture of Iowa's risks and opportunities. Whereas a review of the NAICS categories suggests 10 percent of establishments and 7 percent of employment are at risk, this approach indicates 23 percent of establishments in Iowa's motor vehicle products industry may be at risk of lost business, impacting 21 percent of employment within Iowa's motor vehicle products industry. Table 5 provides the full details of potential risks and opportunities for establishments in Iowa and the related employment scale.

Table 5 Potential Impacts of Motor Vehicle Electrification on Iowa's Motor Vehicle Products Industry, per Private Data

Category	Establishments			Employment		
	At Risk	Unaffected	Opportunity	At Risk	Unaffected	Opportunity
Aftermarket Products	10	8		254	797	
Bodies, Chassis		33			4,236	
Electric Motors			9			737
Electrical and Electronic Parts			15			827
Exhaust and Emissions	4			90		
Fuel Systems	3			270		
ICE Powertrain Parts	9			1,726		
Interior Parts		13			2,011	
Lead Acid Batteries	4			1,019		
Motor homes, RVs, Campers		4			2,718	
Suspension Systems		3			249	
Thermal Management	7			740		
Trailers		34			3,067	
Wheels, Tires		7			789	
Other	5	10	1	98	748	1
Overall	**42**	**112**	**25**	**4,197**	**14,615**	**1,565**

Source: CAR analysis of data from subscription databases and CIRAS' data

Iowa is relatively unimpacted by vehicle electrification as few business activities are directly related to internal combustion engines or motor vehicle transmissions. Instead, nearly half of Iowa's motor vehicle product employment relates to bodies and chassis, trailers, motor homes, RVs, and camper trailers. These products are not subject to the largely regulatory forces driving the shift to electrified vehicle propulsion systems. However, market forces may be a factor as motor home manufacturers are beginning to explore electric models, with Winnebago revealing a battery electric camper van concept vehicle on 18 January 2022 (Winnebago, 2022). Likewise, trailers, whether semi-truck trailers, utility trailers, or camper trailers, may see new pressure for reduced weight so that they have less impact on the effective travel ranges of battery electric vehicles.

Five of the fifteen categories are at risk. Four face near-term pressures (within the next five years), and the possibility their products will significantly decline over the next ten years and eventually wholly disappear perhaps twenty years from now. These four categories are specific to internal combustion engine vehicles: exhaust and emissions control systems, fuel systems, internal combustion engine powertrain (engine and transmission) parts, and thermal management systems.

The fifth product category at risk, lead acid batteries, may, somewhat ironically, enjoy a durable period of increased profitability and a decades-long decline. Manufacturing lead acid batteries for installation in new vehicles at the assembly plant provides meaningfully lower profit margins than selling these batteries for aftermarket use. Production scale will be lost as battery electric vehicles gain production share. However, the nearly 276 million motor vehicles in the United States, almost wholly internal combustion engine-powered, will need replacement batteries for many decades to come (Office of Highway Policy Information, 2021).

Some of the at-risk businesses may transition alongside the overall motor vehicle industry. Current thermal management producers may shift towards battery cooling, passenger cabin heat pumps, or cooling systems for onboard computer and electronic systems. Fuel systems cease to be relevant in a wholly battery electric world, but fuel cell propulsion systems require onboard fuel storage and delivery systems. However, this may prove an exceptionally difficult task. A significant impediment to fuel cell propulsion is hydrogen embrittlement of materials from the hydrogen production stage, to delivery to and dispensing from fuel infrastructure, through to the onboard vehicle fuel system. To date, carbon fiber is the most promising material for addressing hydrogen embrittlement, and full-scale use of carbon fiber has significant production challenges of its own.

For specific engine and transmission parts, such as valves and manifolds, similar to current thermal management solutions, it may be possible to successfully pivot to battery and electronics cooling systems. Transmission parts suppliers may be able to retain some business serving electric vehicle 1-speed transmissions and e-transaxle units, but these are far less complex systems than existing ICE transmissions. Most other parts and components in the ICE powertrain do not align with battery electric vehicle propulsion systems. Rather, these manufacturers should consider pursuing non-motor vehicle applications of their products, such as in industrial equipment. Otherwise, the ICE aftermarket will require repair and replacement parts for decades to come—but volumes may not sustain businesses dependent upon these product lines. However, if significant policy support for electric vehicles does not manifest, or if rosy forecasts of North American battery electric vehicle adoption do not bear out, the existing ICE powertrain, hybrid, and plug-in hybrid propulsion systems will continue to enjoy significant production volumes for decades to come.

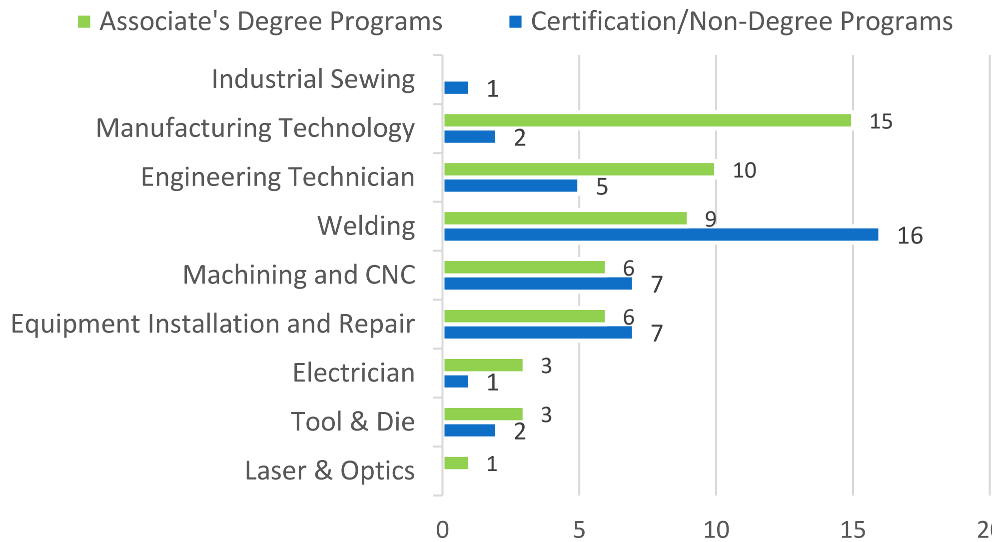
Section 4: Workforce Education and Training in Iowa

To identify potential workforce opportunities from motor vehicle electrification, CAR staff researched existing education and training programs in Iowa. First, CAR staff developed a list of motor vehicle products and motor vehicle electrification occupations. CAR researchers used this list to identify related educational and training requirements. CAR staff then reviewed academic, technical, and trades programs at Iowa's colleges and universities. This process identified 174 programs in related fields, with 94 programs pertinent to manufacturing and production occupations and 80 baccalaureate programs related to research, development, and engineering occupations. For non-degree programs, when a given track at a single institution could end in one of multiple certificates, based upon the final semester's course selection, that was counted as one certification program. When a track combined certification and degree programs, each was counted separately. For example, if an Engineering Technician program could end at 30 credits with a certificate or 60 credits with an associate's degree, that program was counted as both a certification and a degree program.

Existing certification, non-degree, and associate's degree programs in Iowa align well with Iowa's current manufacturing footprint.

Figure 7: summarizes the certification, non-degree, and associate's degree programs at Iowa's community colleges related to the motor vehicle products industry and/or motor vehicle electrification.

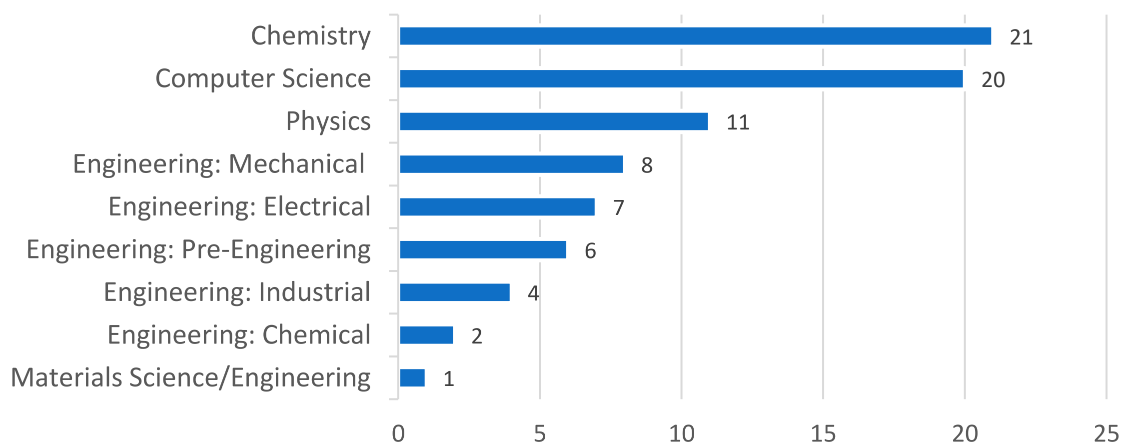
Figure 7: Manufacturing Certifications and Associate's Degrees, Number of Programs by Type and Field



Source: CAR analysis

Chemistry and Computer Science programs comprise more than half of bachelor's degree programs in Iowa relevant to motor vehicle products, as shown in Figure 8. As with the certification, non-degree, and associate's degree programs, the distribution of bachelor's degree programs matches current occupational employment. For example, software development and testing employment was identified in Section 1 as the largest share of motor vehicle product-related employment in Iowa. Chemists did not overtly feature in the occupational grouping data presented in Section 1 but were incorporated within the batteries grouping.

Figure 8: Iowa's Relevant Bachelor's Degree Programs, 2022



Source: CAR analysis

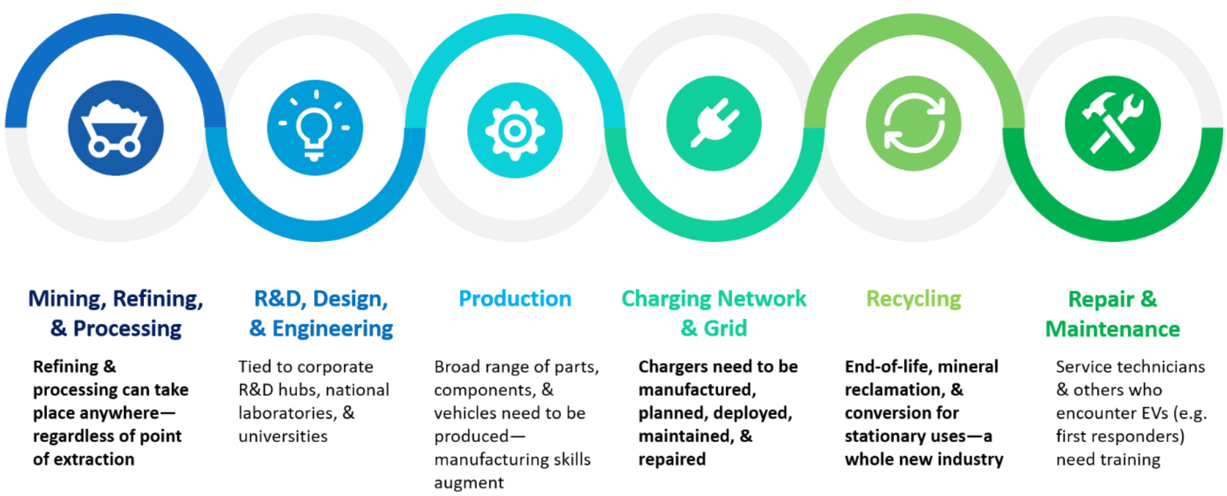
Interviews and discussions with manufacturers indicate little concern with production worker retraining over the long run. Instead, companies are worried about the availability of research, development, and engineering staff. CAR staff also compiled occupational profiles - what skills, education, and training are needed for each impacted occupation and what duties and tasks are involved. A review of these profiles supports manufacturers' comments. Most impacted production roles should need minimal retraining; indeed, several of the specific roles expected to decline are classified within a single occupation as roles anticipated to grow. For example, engine assemblers are classified with coil winders (electric motor manufacturing) as assemblers and fabricators (U.S. Bureau of Labor Statistics, 2021b).

Overall, Iowa has a broad set of manufacturing training programs, many of which already cover aspects of electrification and motor vehicle technology changes. While companies have indicated a general lack of concern concerning production worker retraining as motor vehicles electrify, small manufacturers may face unique difficulty in adjusting their equipment and retraining their workers. Further, companies may require more assistance with their traditional training activities, given the diversion of resources to electrification-related training.

Section 5: Workforce Development Opportunities

Different parts of the electric vehicle value chain require different skillsets and workforce strategies. In consultation with CIRAS, CAR focused on workforce opportunities in mineral refining and processing, recycling, and EV charging station manufacturing.

Figure 9: Battery-Electric Vehicle Value Chain

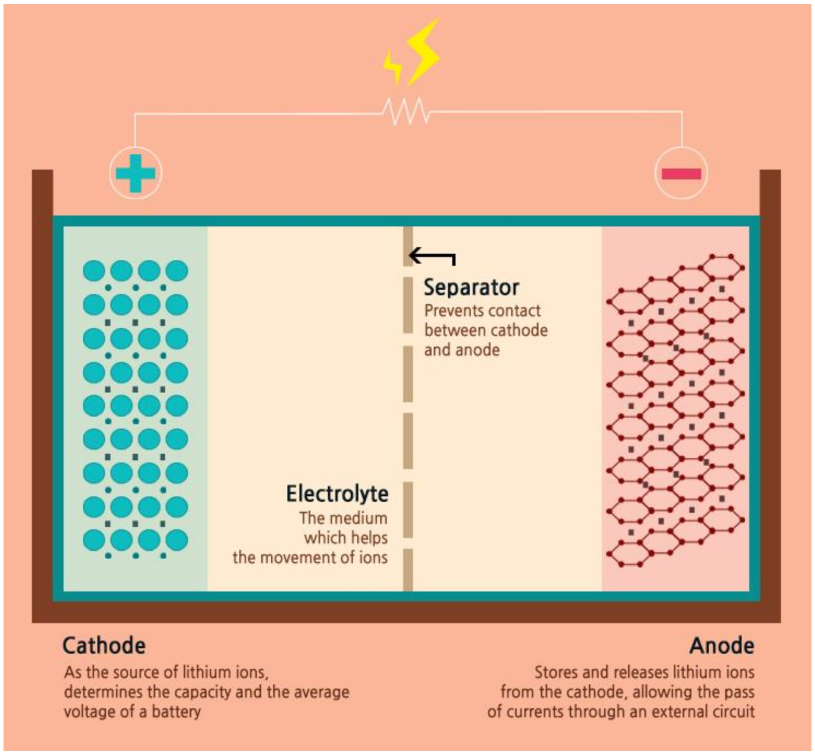


Source: Center for Automotive Research

Opportunities in Materials Refining, Processing, & Recycling

Electric vehicle batteries have four main components: anode, cathode, separator, and electrolyte, as shown in Figure 10. Manufacturers use a range of highly-refined and processed minerals and materials to produce these components—most notably, cobalt, graphite, lithium, nickel, and manganese—the five top minerals required for electric vehicle battery production (Bloomberg New Energy Foundation, 2021). These five materials are critical for current battery production; for example, batteries for all uses (including EVs) currently demand 71 percent of global lithium production (U.S. Geological Survey, 2021). However, battery chemistries are changing rapidly to achieve greater energy density and lower costs—including replacing scarce cobalt with more plentiful materials such as manganese. These new chemistries and materials change the relative demand for cobalt, graphite, lithium, nickel, and manganese and introduce greater reliance on silicon, sulfur, tungsten, and zinc inputs.

Figure 10: Anatomy of a Battery



Source: (Samsung SDI)

The U.S. motor vehicle industry is driving increased demand for batteries, and in turn, increased demand for critical minerals and materials—many of which are either not found in U.S. mineral deposits or are not currently mined in the United States. In its 2021 100-Day Supply Chain Review, the White House emphasized that extracted and recycled materials and minerals for high-capacity batteries will require increased domestic refining and processing capacity (White House, 2021). While many states are competing to attract high-profile BEV and battery cell production, a strategy focused on refining, processing, and recycling battery materials could be a good fit for a state like Iowa.

While geological deposits determine the location of mining operations, refining, processing, and recycling can occur anywhere in the world. Domestic recycling operations reduce the dependence on foreign sources, and expanding domestic refining and processing capacity will similarly increase the United States' mineral independence. The following table shows the United States' dependence on foreign sources for the five critical battery minerals as well as the top foreign and domestic sources:

Table 6: Major Battery Minerals, U.S. Import Dependence, & Top Sources

Mineral	2020 U.S. Import Dependence	Top Import Sources	Top Domestic Sources	Recycling
Aluminum	49%	Canada-50%, UAE-10%, Russia-9%, China-5%, and other-26%	Smelters: Indiana, Kentucky, Missouri, Montana, Texas, New York, Ohio, South Carolina, Washington, West Virginia Alumina refineries: Louisiana	Recycled aluminum is roughly 53% from new (manufacturing) scrap and 47% from old scrap (discarded aluminum products); recycled aluminum from old scrap = 51% of consumption
Cobalt	76%	Norway-20%, Canada-14%, Japan-13%, Finland-10%, other-43%	Michigan (cobalt-bearing nickel concentrate), and Missouri (nickel-copper-cobalt concentrate)	Cobalt in purchased scrap = 29% of consumption
Copper	37%	Refined copper (85% of non-manufactured imports): Chile- 59%, Canada-24%, Mexico-11%, and other-6%.	Arizona (74%), Utah, New Mexico, Nevada, Montana, Michigan, and Missouri	Copper recovered from scrap = 38% of consumption
Graphite	100%	China-33%, Mexico-23%, Canada-17%, India-9%, other-18%	None, but companies in Alabama and Alaska are developing mines	Information not available
Lithium	>50%	Argentina-55%, Chile-36%, China-5%, Russia-2%, other-2%	Operational: Nevada (brine) In development: Arkansas (brine), California (brine), Nevada (clay), North Carolina (ore)	U.S. firm Retriev was the first in North America to recycle lithium metal and lithium-ion batteries in British Columbia and Lancaster, Ohio. Seven companies have or plan to open recycling U.S. operations.
Manganese	100%	Ore: Gabon-69%, South Africa-17%, Mexico-8%, Australia-4%, other-2%	The United States has not produced Manganese ore since 1970.	Manganese reclamation is incidental as part of ferrous and nonferrous metals recycling.
Nickel	50%	Canada-42%, Norway-10%, Finland-9%, Russia-8%, other-31%	Michigan (cobalt-bearing nickel concentrate), Missouri (nickel-copper-cobalt concentrate), Montana (byproduct of smelting and refining platinum).	Recycled nickel=50% of consumption.

Source: (U.S. Geological Survey, 2021)

Iowa is not a top source of any current critical battery minerals. The state ranks 28th in the total value of non-fuel mineral production, with leading products including Portland cement, lime, industrial and construction sand and gravel, and crushed stone (U.S. Geological Survey, 2021). Of the nearby midwestern states:

- Michigan has nickel, copper, cobalt, and gold deposits;
- Missouri has lead, zinc, copper, silver, and historic mine tailings that produce nickel, copper, and cobalt; and
- Minnesota has the most significant identified cobalt resources in the United States but does not currently produce cobalt.

Mining, refining, and processing can be environmentally damaging processes. Investment in new methods and approaches can result in a cleaner supply chain for "clean energy" vehicles. A greater reliance on recycling can also yield environmental benefits and increase U.S. mineral supplies.

Refining and processing minerals removes all undesirable minerals and contaminants, resulting in highly-purified and consistently uniform inputs for battery manufacturing. Battery materials are highly engineered with purity and defects measured to ppm or ppb levels and dimensional targets measured in microns. Refineries and processers must meet very high cleanliness demands, and manufacturers must store the materials at consistent temperatures and humidity levels (Mikolajczak, 2021). The skills required to work to these demanding specifications and tolerances are common in chemistry and pharmaceutical manufacturing—both strengths in Iowa.

One way to measure a state's relative advantage is to examine its location quotients. Location quotients (LQs) measure industry concentration; an LQ greater than one means that the industry is more concentrated in Iowa than nationwide. If the wage LQ is higher than the employment LQ, that means the industry is relatively better paid than expected compared to the nation as a whole.

Iowa has pronounced strengths in organic chemistry, agricultural chemicals, alumina and aluminum production, and foundries (LQs>2). The state is also strong in pharmaceutical and medicine manufacturing, primary metal manufacturing, iron and steel mills and ferroalloy manufacturing, and recyclable material merchants and wholesalers.

Table 7: Iowa Employment & Wage Location Quotients for Refining, Processing, & Recycling Battery Materials, Q2 2021

NAICS/Description	Quarterly Establishments	Employment LQ	Wage LQ
NAICS 325 Chemical manufacturing	248	**1.22**	**1.27**
NAICS 3251 Basic chemical manufacturing	77	**1.79**	**1.66**
NAICS 32518 Other basic inorganic chemical manufacturing	7	0.74	0.83
NAICS 32519 Other basic organic chemical manufacturing	53	**3.86**	**3.78**
NAICS 3252 Resin, rubber, and artificial fibers manufacturing	10	0.55	0.66
NAICS 3253 Agricultural chemical manufacturing	52	**5.42**	**7.22**
NAICS 3254 Pharmaceutical and medicine manufacturing	47	**1.06**	0.98
NAICS 3255 Paint, coating, and adhesive manufacturing	16	0.67	0.63
NAICS 3256 Soap, cleaning compound, and toiletry manufacturing	23	0.96	**1.01**
NAICS 3259 Other chemical product and preparation manufacturing	23	0.46	0.48
NAICS 32599 All other chemical preparation manufacturing	15	0.36	0.40
NAICS 331 Primary metal manufacturing	65	**1.83**	**2.24**
NAICS 3311 Iron and steel mills and ferroalloy manufacturing	11	**1.19**	**1.26**
NAICS 33122 Rolling and drawing of purchased steel	7	0.74	0.70
NAICS 3313 Alumina and aluminum production	8	**4.53**	**6.39**
NAICS 3315 Foundries	32	**2.06**	**2.40**
NAICS 42393 Recyclable material merchant wholesalers	141	**1.46**	**1.67**

Source: (U.S. Department of Labor, Bureau of Labor Statistics, 2021)

Chemistry is not only one of Iowa's industrial strengths; it is also an educational advantage—with 21 bachelor's degree programs. Iowa could leverage the vast array of chemistry programs and Iowa State's materials science/engineering program to support an economic development transition to mineral refining, processing, and recycling.

The occupations needed to refine, process, and recycle battery materials include geosciences and mining, metallurgy, chemistry, and materials engineering. As with most advanced manufacturing industries, the work involves highly automated precision equipment, and battery materials producers employ many scientists, engineers, data analysts, machinists, mechanics/tradespersons, and skilled production workers to design, run, and maintain their manufacturing processes.

Materials Refining, Processing, & Recycling Recommendations

- Align with Iowa's economic development strategy to prioritize mineral refining, processing, and recycling business and attraction and retention efforts;
- Strengthen Iowa State's metallurgy program offerings through partnerships with other universities or national labs;
- Partner with the U.S. Department of Energy's ReCell Center to expand Iowa State's research and development and workforce development opportunities (currently, there are just three educational partners: Michigan Technical University, University of California-San Diego, and Worcester Polytechnic Institute)

Opportunities in Building the U.S. EV Charging Network

Consumers want their electric vehicles to be as convenient as owning gasoline- or diesel-powered vehicles. That means the United States must invest heavily in an expanded vehicle charging network. President Biden has pledged to increase the number of public charging stations ten-fold—from the roughly 46,000 available in 2021 to 500,000 by 2030 (U.S. Department of Energy, Alternative Fuels Data Center, 2022). The recently-passed Infrastructure, Investment, and Jobs Act contains USD 7.5 billion to help build the public EV charging network (U.S. Congress, 2021). However, to reach the President's goal of BEVs and PHEVs making up 50 percent of new light vehicle sales by 2030, the nation will need at least 1 million public chargers.

There are three levels of EV charging:

AC Charging (uses vehicle's onboard charger)	Level 1 uses a standard household 120-volt outlet (no special equipment) to add 3-5 miles of charge per hour to the battery;
	Level 2 uses specialized electric vehicle supply equipment (EVSE) at home or public stations to charge at 208- to 240 volts and add 12-80 miles of charge per hour;
DC Charging (shared infrastructure)	Level 3 uses 400-900 volt EVSE (DC Fast Charge and Tesla Supercharger) to add 3-20 miles of charge per minute (public charging)

The current U.S. public charging network is plagued by poor reliability, which challenges wider EV adoption. Current EV owners often arrive at a public charger only to find the power is out, the data connection is not working, their payment method does not work, the charger is not working (broken) or is inaccessible (location locked or the charger is blocked by ice, snow, or another user) (Sperling, 2021). Building a robust network of reliable public charging equipment is a critical national challenge.

The cost of Level 2 chargers ranges between USD 2,500-4,900 and costs an additional USD 2,500-7,000 to install; Level 3 EVSE costs between USD 20,000-480,000 (depending on the kW size) and costs an additional USD 18,000-175,000 to install (Pournazeri, 2022). The equipment is similar to industrial electrical equipment (Level 3 fast chargers) and home appliances (Level 2 EVSE).

LQs also indicate that Iowa enjoys relative strength in manufacturing electrical equipment, appliances, motors, generators, switchgear, and switchboard apparatus. Strength in these areas can provide a foundation for a burgeoning EVSE manufacturing cluster. Table 8 details the number of establishments and location quotients for Iowa in these fields.

Table 8: Iowa Employment & Wage Location Quotients for EV Supply Equipment, Q2 2021

NAICS/Description	Quarterly Establishments	Employment LQ	Wage LQ
NAICS 335 Electrical equipment and appliance mfg.	63	**1.56**	**1.52**
NAICS 335122 Nonresidential electric lighting fixture mfg.	5	0.27	0.26
NAICS 3353 Electrical equipment manufacturing	20	0.86	0.93
NAICS 33531 Electrical equipment manufacturing	20	0.86	0.93
NAICS 335312 Motor and generator manufacturing	6	**1.46**	**1.52**
NAICS 335313 Switchgear and switchboard apparatus mfg.	4	**1.60**	**2.06**
NAICS 3359 Other electrical equipment and component mfg.	21	0.79	0.78
NAICS 33593 Wiring device manufacturing	4	0.09	0.07
NAICS 335931 Current-carrying wiring device manufacturing	4	0.13	0.10
NAICS 33599 Other electrical equipment and component mfg.	11	0.93	0.83

Source: (U.S. Department of Labor, Bureau of Labor Statistics, 2021)

EV Charging Network Recommendations

- Identify EVSE manufacturers that plan to expand their North American footprint;
- Iowa's economic development strategy should prioritize EVSE manufacturing attraction efforts, as Iowa has existing strengths in related industries and occupations, and other states are not focusing their own efforts in this space;
- Work with the State of Iowa's Electrical Licensing and Inspection Department to require EVSE installers to complete specialized training (such as the Electric Vehicle Infrastructure Training Program https://evitp.org/), to ensure alignment with industry standards and requirements being adopted by state and local governments;
- Convene Iowa's community college network to align electrical apprentice and technician training to the needs of charging infrastructure manufacturing, installation, maintenance, & repair

General EV Workforce Training Recommendations

As EV adoption increases, every state will need more certified EV maintenance and repair technicians, first responders trained to interact safely with EVs in emergencies, and a pipeline of students interested in pursuing green energy careers. In addition to broad STEM-based educational initiatives, CIRAS may want to investigate the following programs:

- Center for Advanced Automotive Technology http://autocaat.org/Resource_Library/ NSF-funded open-access library of EV & related curricula

- Student Energy https://studentenergy.org/program/career-training-program/ 4-month program to engage students in the green energy transition

Conclusion

CAR staff performed a comprehensive review of Iowa's motor vehicle products industry, evaluating potential risks to and opportunities for the state's businesses stemming from the electrification of the motor vehicle industry. Overall, Iowa's existing businesses are largely unaffected by this technology transition, owing to Iowa's concentration of body, chassis, trailer, camper, motor home, and RV manufacturing. These product areas are largely unimpacted by the forces (primarily regulatory) driving motor vehicle electrification in North America.

Five of the fifteen product categories evaluated for Iowa are at risk. Four categories—exhaust and emissions control systems, fuel systems, internal combustion engine powertrain (engine and transmission) parts, and thermal management systems—face near-term pressures, and their products may eventually disappear. Some of these businesses may transition to related products supporting battery electric and fuel cell vehicles.

The fifth at-risk product category is lead acid battery production. While vehicle electrification, broadly defined—inclusive of hybrids, plug-in hybrids (PHEVs), battery electric (BEVs), and fuel cell vehicles (FCEVs)—is expected to rapidly progress, even a decade from now, a majority of newly-produced light vehicles will still have propulsion systems incorporating ICEs and require starter batteries. As BEVs and FCEVs gain share in production and sales, lead acid battery production volumes will decline, but these batteries will enjoy many decades of continued (more profitable) aftermarket sales.

CAR staff reviewed training and education programs at Iowa's colleges and universities to evaluate workforce development needs and opportunities for Iowa that stem from electrification. Through its community colleges, Iowa's manufacturing and production training, certification, and degree programs are already well-positioned for the technology transition. These programs and Iowa's existing electrical equipment, appliance, motor, generators, switchgear, and switchboard apparatus manufacturing industries can be leveraged to attract electric vehicle supply equipment (charging systems and stations) manufacturing. Additionally, due to the concentration of chemistry programs at Iowa's universities and the state's existing chemical, pharmaceutical, metals, and recycling industries, Iowa is well-positioned to pursue opportunities in the refining, processing, and recycling of battery materials.

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