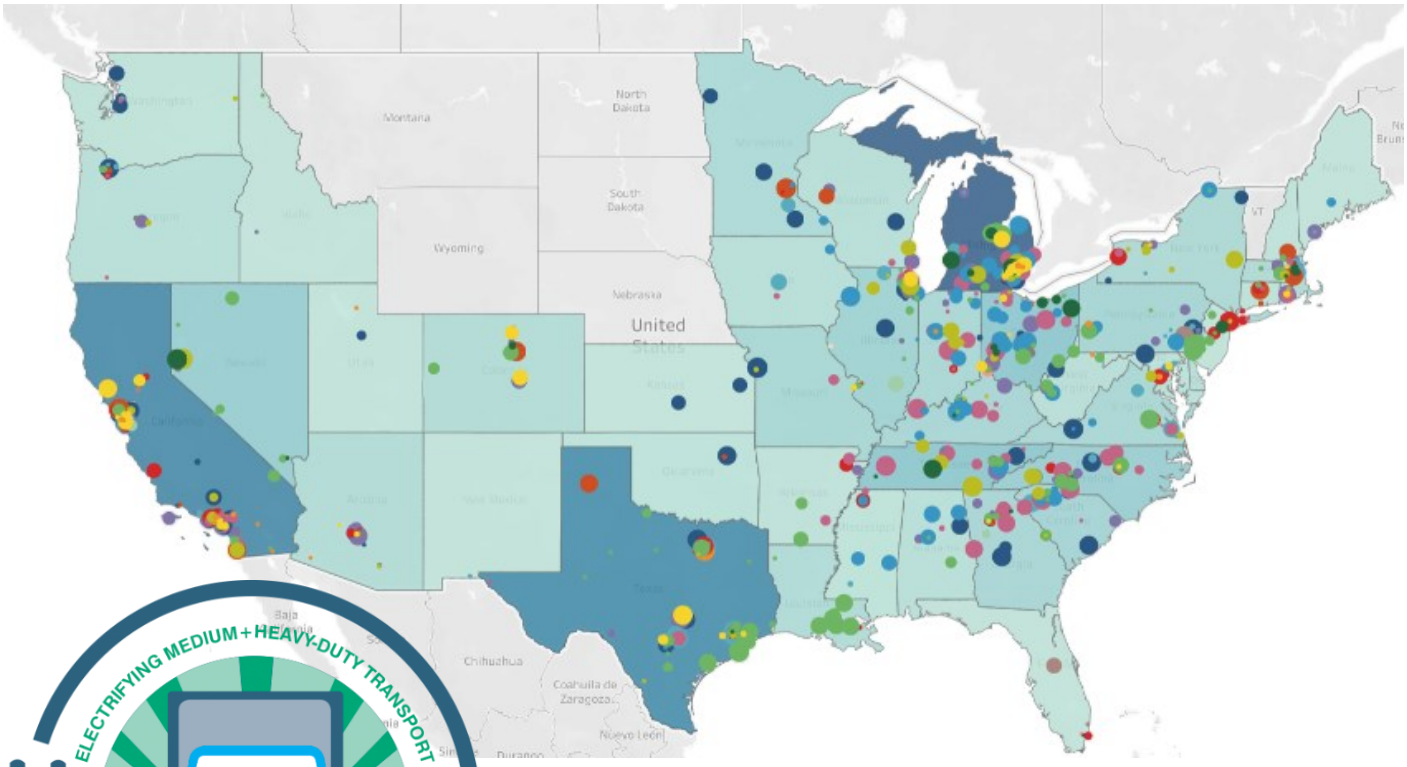
Charged-Up

ANALYSIS OF THE JOBS, INVESTMENTS AND COMPANIES IN THE ZERO EMISSIONS MEDIUM AND HEAVY DUTY VEHICLE SUPPLY-CHAIN ECONOMY

NATIONAL ASSESSMENT



ELECTRIFYING MEDIUM + HEAVY-DUTY TRANSPORT
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October 2021

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Additional information on the national supply-chain analysis is available online at: www.edf.org/mhd_zev_supplychain

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Executive Summary

The United States has been a global center of technological innovation and environmental policy for decades. The convergence of these two ideas have created the conditions where many energy-sector companies have grown into major employers and economic growth drivers. One example is seen in the medium and heavy duty zero emissions vehicle (MHD ZEV) transport industry, where several metrics show both that a vibrant industry has already taken hold and is poised to deliver vast amounts of additional economic investments and job generation.

To better understand the present characteristics and future trends of the burgeoning MHD ZEV industry, Environmental Defense Fund (EDF) compiled a database of companies involved in every segment of its supply chain. After gathering the extensive list of relevant companies with US operations, EDF staff and consultants collected or developed location-specific data, including information on employment, announced investments, and other key attributes. The project team then organized this information by state and city, and congressional district in an effort to demonstrate the geographic distribution of the industry and motivators of present and future growth.

This supply chain study illustrates a robust and rapidly growing industry: as of September 2021, 375 companies were identified across the MHD ZEV supply chain, with about 1000 locations across the country. Those locations collectively employ more than 333,000 people and have announced over $53.7 billion in new EV-related investments. Vehicle assembly boasts the largest number of companies and employees, while the majority of announced investments revolve around the battery, from raw material processing to battery cell and pack production. Since September 2021, additional companies have announced new investments, added employees and opened up new business locations – underscoring the dramatic growth present across industry today and the importance of continued tracking and support.

In leading states like Michigan, Texas and California, the MHD ZEV industry is far-reaching and can deliver economic and employment benefits as the transition to zero-emissions vehicles continues to occur. Auto industry incumbents are adapting their businesses to provide MHD ZEV products, and new entrants are arriving on the scene to take advantage of the emerging market. State level analysis on companies operating, employees at in-state locations, and announced corporate investments in manufacturing, infrastructure, research and training can all be derived from the national dataset.

There are likely several reasons why some states are leading the nation in several metrics associated with the MHD ZEV industry. Existence of auto manufacturers able to make a transition to ZEVs and continued policy and economic support of the MHD ZEV industry are likely two major factors, as is the supportive business environment. As additional transportation policies are developed at the national and state level, consideration of the economic and employment benefits that a growing MHD ZEV supply chain can provide should be taken into account.

Introduction

While medium and heavy-duty vehicles (MHD) today are primarily fueled by polluting fuels such as diesel and natural gas, the transition to MHD Zero Emission Vehicles (ZEVs) is well underway. Over the past several years, investments in MHD ZEVs have made them a financially and environmentally sound choice moving forward. By 2050, climate and public health concerns, along with technological and manufacturing advancements, will likely compel all MHD truck and bus fleets to abandon fossil fuels entirely.

Nevertheless, the transition to a zero emissions MHD fleet will require significant growth up and down the vehicle manufacturing and infrastructure supply chain. This growth will also need to be matched by maintenance and resale (also known as midlife) companies, research and development institutions, and training organizations. Many elected officials and policy makers have recognized the opportunity ahead and are acting now to promote a zero-emissions future.

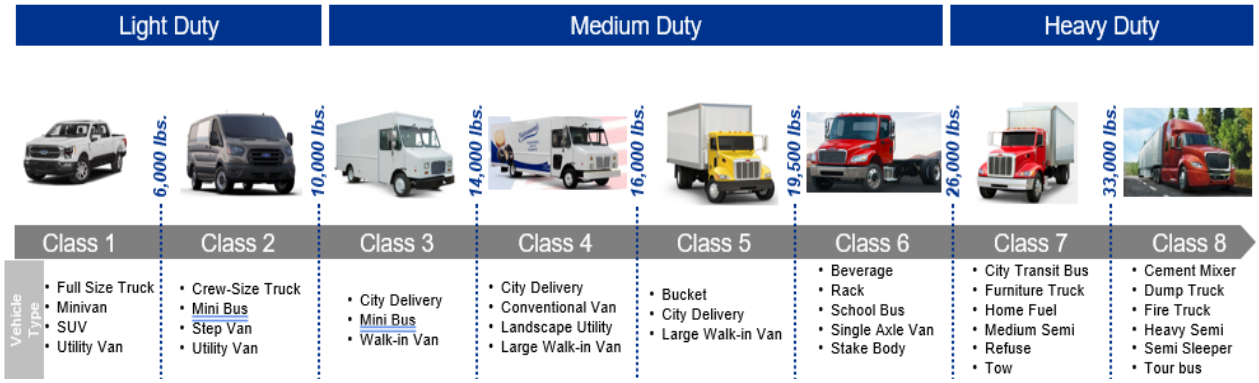
A review of the national MHD ZEV vehicle supply chain shows that with investment in a transition to MHD ZEVs comes the potential for new economic and employment growth, and several states have already begun to experience it. This report details the current footprint of the MHD ZEV supply chain across the United States.

Background

What are Medium- and Heavy-Duty Vehicles?

Medium- and heavy-duty (MHD) vehicles are those that weigh over 10,000 pounds; the category ranges from vehicles as small as local delivery truck to vehicles as large as an eighteen-wheeler (class 3 and class 7 respectively). These vehicles are at least tangentially involved in all aspects of commercial activity—parcel and goods delivery, public transportation, utility and government services, long distance shipping, construction and more all rely on MHD vehicles.

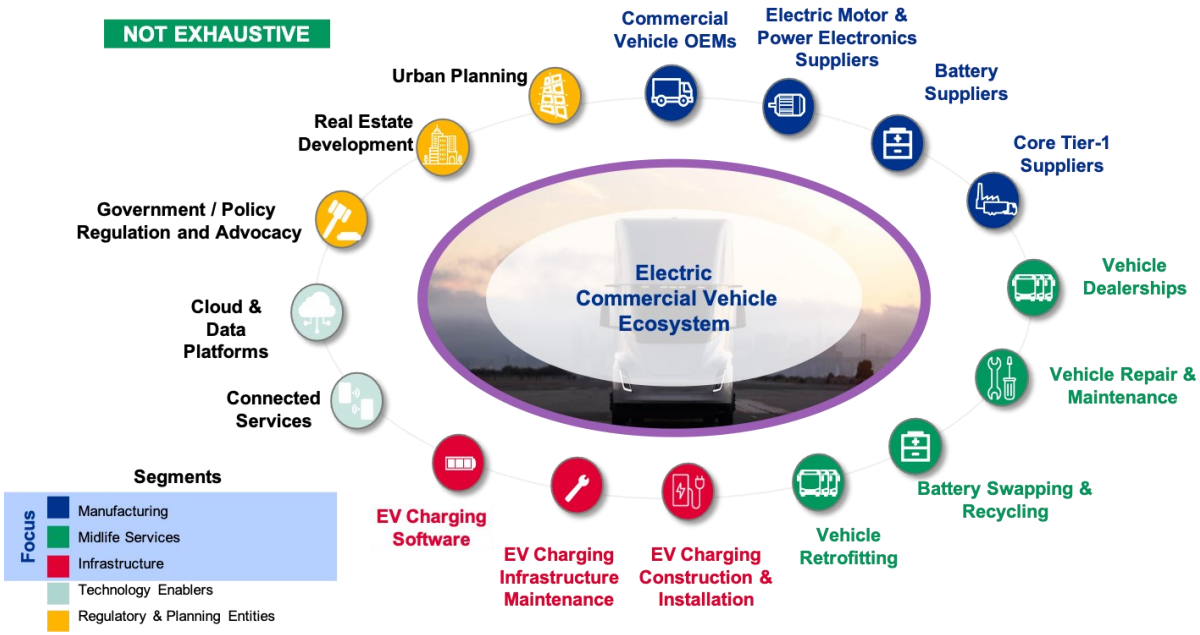
Figure 1: Vehicle Classification and Common Type



Source: Alternative Fuels Data Center

Medium and heavy-duty zero emission vehicles have major cost, operations, and emissions benefits that their fossil fuel-burning, internal combustion engine counterparts do not. That has led vehicle manufacturers, information technology companies, governmental organizations, private fleets, and many more to invest in the transition to zero emission vehicles.

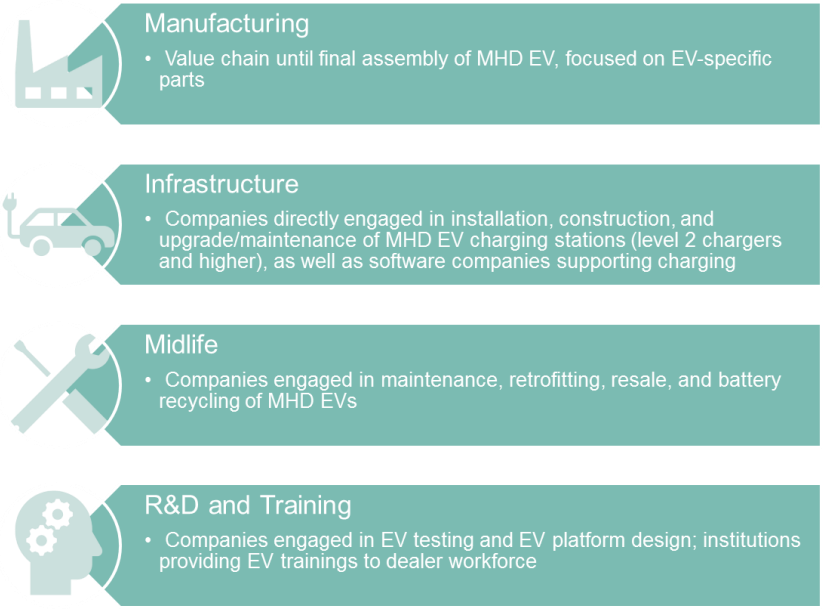
Figure 2: Zero Emissions Vehicle Supply Chain (Market, Regulatory and Development) Segments



Methodology for this study

This industry assessment is based on a literature search and data compilation of various companies across the MHD ZEV supply chain segments in the United States. This study is limited to only a certain portion of the ecosystem of activity relevant to the MHD ZEV vehicle supply chain, and evaluates businesses involved in electrification.

With contracted assistance from the consulting firm PwC, EDF compiled a database of incumbent and new entrant companies operating nationwide that are purposefully involved in the manufacturing, infrastructure, midlife, and R&D and training segments of the MHD electric vehicle supply chain.



Definitions of each of these segments are as follows:

This analysis only includes companies that devote a portion of their capacity specifically to MHD ZEVs. In other words, the analysis considers companies that offer at least some products or services that pertain only to MHD ZEVs.

This assessment also identifies each company's specific sub-segment based on the products and services it offers. This study collected general company-wide information, such as financials, announced investments, and ZEV-related announcements from an array of sources (see Appendix 1 for a data source list). Subsequently, the study team gathered specific data for each company, including location/address, number of employees, union information, state agreements, and other key attributes. If not stated publicly, the study team estimated location level data based on a percentage ZEV share of production volumes, percentage share of ZEV products of total portfolio, or by applying a percentage of MHD-vehicle-based revenue or number of employees to each location. If too little information was available to make a reasonable estimate, the field was left blank and was not included it in the overall summation. The resulting tool paints a detailed picture of the domestic MHD electric vehicle industry, including its regional variability.

Limitations of this study

This study focuses only on a portion of the overall ecosystem of activity involved in the zero-emissions transportation transition. Furthermore, this study does not capture companies whose products may incidentally end up in MHD ZEVs but who have not made it their business to do so. This means that companies in adjacent vehicle manufacturing industries or companies that manufacture non-ZEV-specific parts (i.e., bolts, steering wheels, chassis, etc.) were not included in the database if they do not also produce ZEV-specific parts. Additionally, this database and associated economic assessment does not include information of the effects of indirect or induced growth from investment in the zero emissions industries (e.g. effect of having additional money circulating in the economy). Finally, due to limitations inherent to industry-wide data collection, the study does not purport to provide an exhaustive census of all companies, workers, and investments involved in the evaluated industry segments, but rather offer an illustrative survey of those locations to convey a clear impression of the industry at large.

Due to the restrictive criteria and limitations described above, this study presents a conservative assessment of the overall industry.

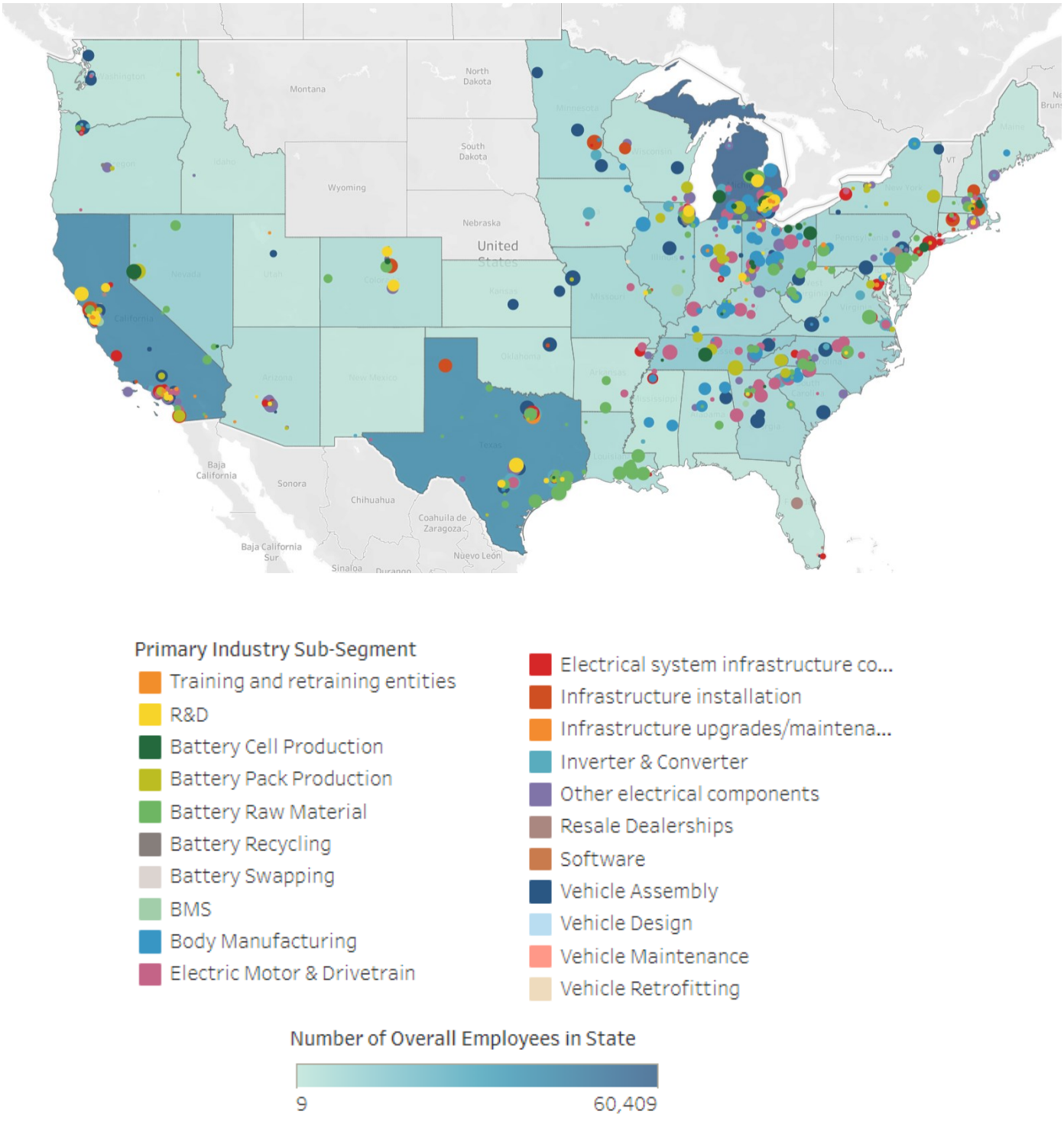
State of the National Market

This study provides evidence that significant investment and growth in the MHD ZEV industry is already taking place. New entrant companies are materializing and competing with incumbents, who are also shifting their manufacturing priorities to focus on ZEVs. As the data captured herein on investments, employment, and corporate locations is viewed alongside the regular release of information announcing rapid technological developments and commitments to electrify major fleets, the pace of change in the industry must be viewed as dramatic, with a large potential for economic gain across the landscape.

National assessment of companies and locations

At least forty-four states have companies involved in the MHD ZEV market. This analysis identifies at least 375 distinct companies linked to commercial MHD ZEV manufacturing, infrastructure, and midlife operating at over 996 locations nationwide. Of the 375 companies identified, 232 (62%) percent are involved in manufacturing, 90 (24%) percent in infrastructure, 29 (8%) percent in R&D and training, and 24 (6%) percent offer midlife services such as maintenance and recycling. The largest sub-segment of companies is those involved in vehicle assembly, an arena equally crowded by incumbents and new entrants.

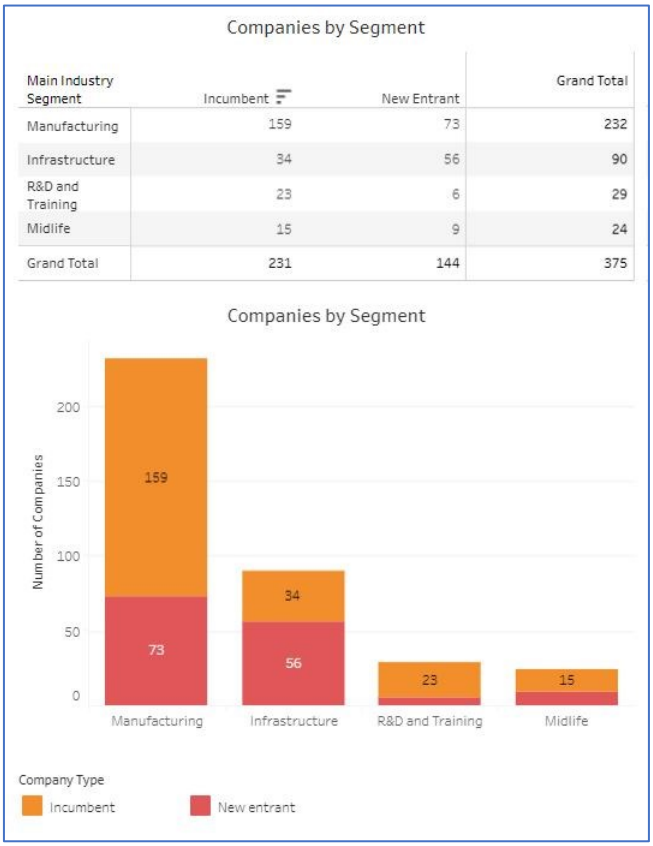
Figure 3: Map of all companies found in the study

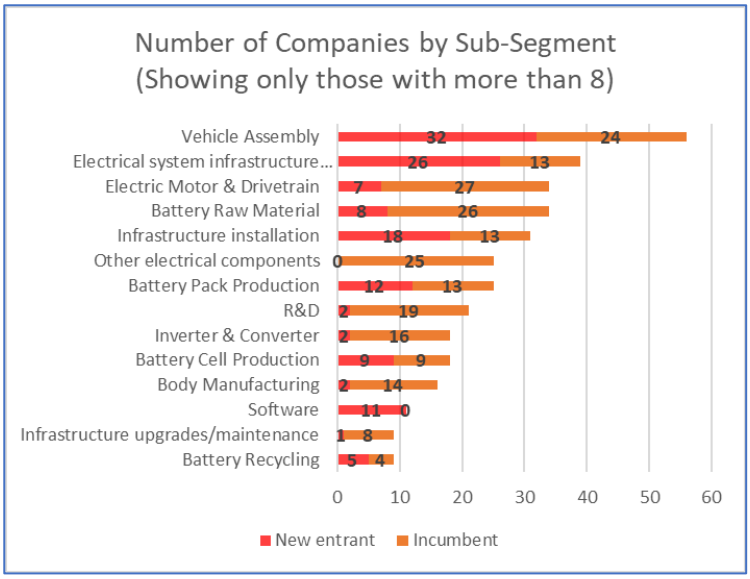


Figures 4 and 5: Nationwide Number of Companies in Each Segment (left) and Each Sub-segment with 8 or more companies(right)

Companies by Segment

Main Industry Segment	Incumbent	New Entrant	Grand Total
Manufacturing	159	73	232
Infrastructure	34	56	90
R&D and Training	23	6	29
Midlife	15	9	24
Grand Total	231	144	375





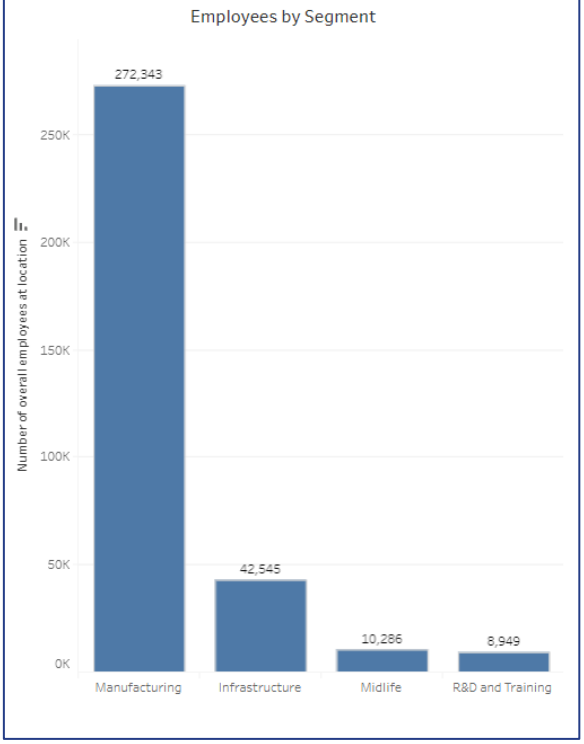
Assessment of MHD ZEV Employees Throughout the Supply Chain

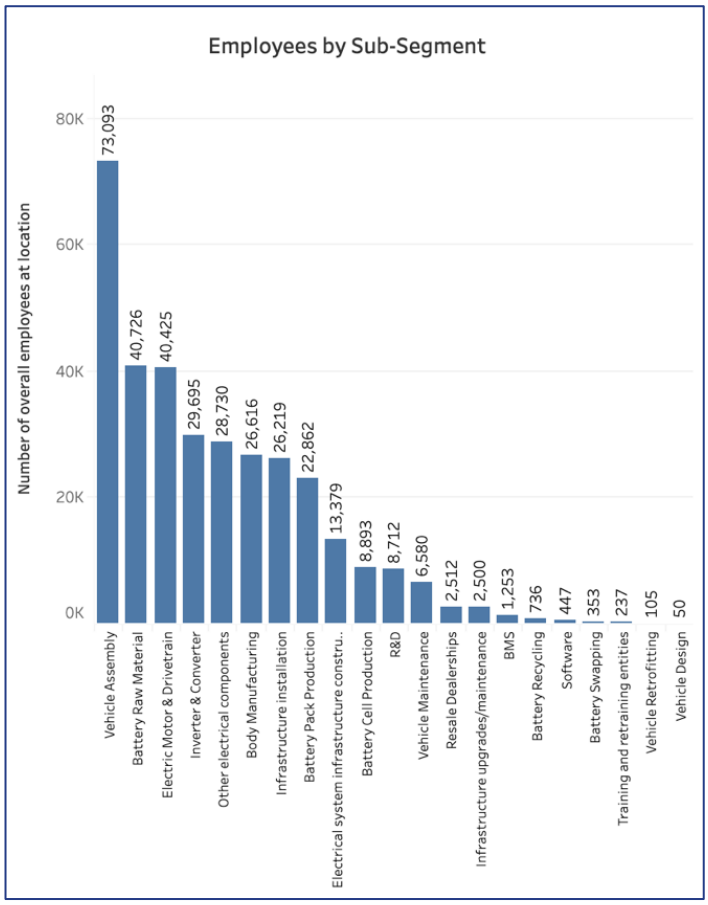
Companies operating in the MHD ZEV supply chain currently support a large number of jobs, many of which are well-paying, and that number is expected to rise. Nationwide, this study found over 334,000 employees working at US locations involved in the MHD ZEV supply chain. Most employees work at companies involved in manufacturing. Once again, vehicle assembly holds the largest share of employees of any sub-segment.

Figures 6 and 7: Nationwide Number of Employees by Segment (Left) and Sub-segment (Right)

Employees by Segment

Main Industry Segment (Companies)	Number of overall employees at location
Manufacturing	272,343
Infrastructure	42,545
Midlife	10,286
R&D and Training	8,949
Grand Total	334,123





Assessment of Announced Investments in MHD ZEVs

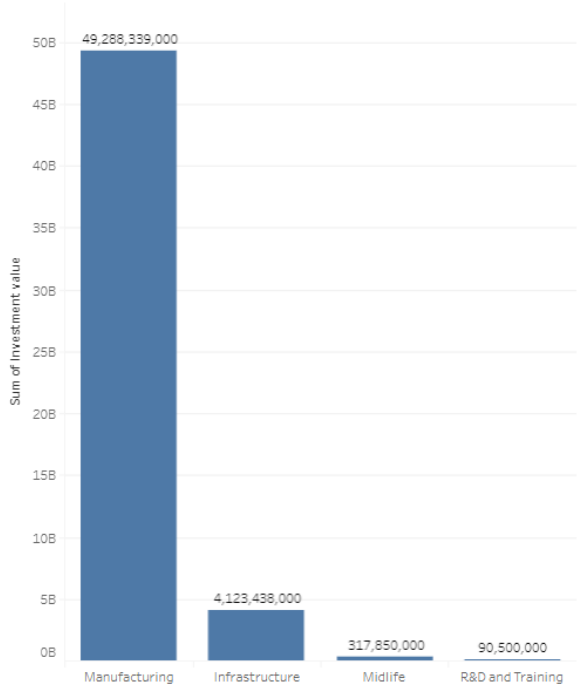
Across the sectors evaluated, this study found the transition to MHD ZEV, primarily associated with electrification of the MHD market, has come by way of 53.8 billion in announced investments, with likely much more being made without announcements.

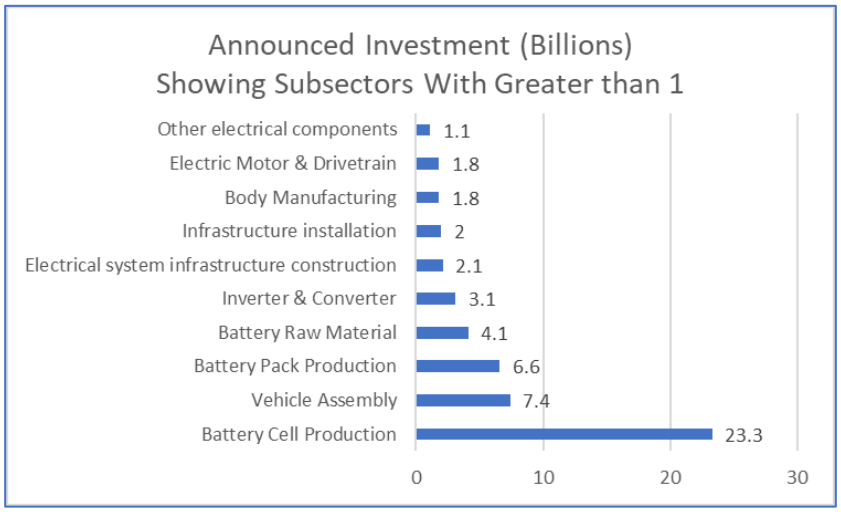
The manufacturing segment leads all others in investment value by far, with over $ 49 billion announced. Most investment is related to battery manufacturing and vehicle assembly. 22 of the 44 total states identified as having companies in the MDV ZEV supply chain feature over 100 million in announced corporate investments.

Figures 8 and 9: Nationwide Announced Investments by Segment (Left) and Sub-segment For Those With Greater Than $1 billion (Right)

Investment by Segment

Main Industry Segment..	Total Announced Investment
Manufacturing	49,288,339,000
Infrastructure	4,123,438,000
Midlife	317,850,000
R&D and Training	90,500,000
Grand Total	53,820,127,000





National Supply Chain Profiles

The segments of the supply chain on which this analysis focuses are manufacturing, infrastructure, midlife, and research and development (R&D) and employee training (see definitions below). These segments are broken down further into sub-segments wherein companies are identified and employee numbers and investments are quantified across the states.

Manufacturing: companies responsible for creating various components of a MHD ZEV.

Infrastructure: companies that not only create ZEV charging infrastructure, but also directly engage in installation, construction, and upgrade/maintenance of MHD ZEV charging stations (level 2 chargers and higher), as well as software companies supporting charging.

Midlife: companies that engage in maintenance, retrofitting, resale, and battery recycling of MHD ZEVs.

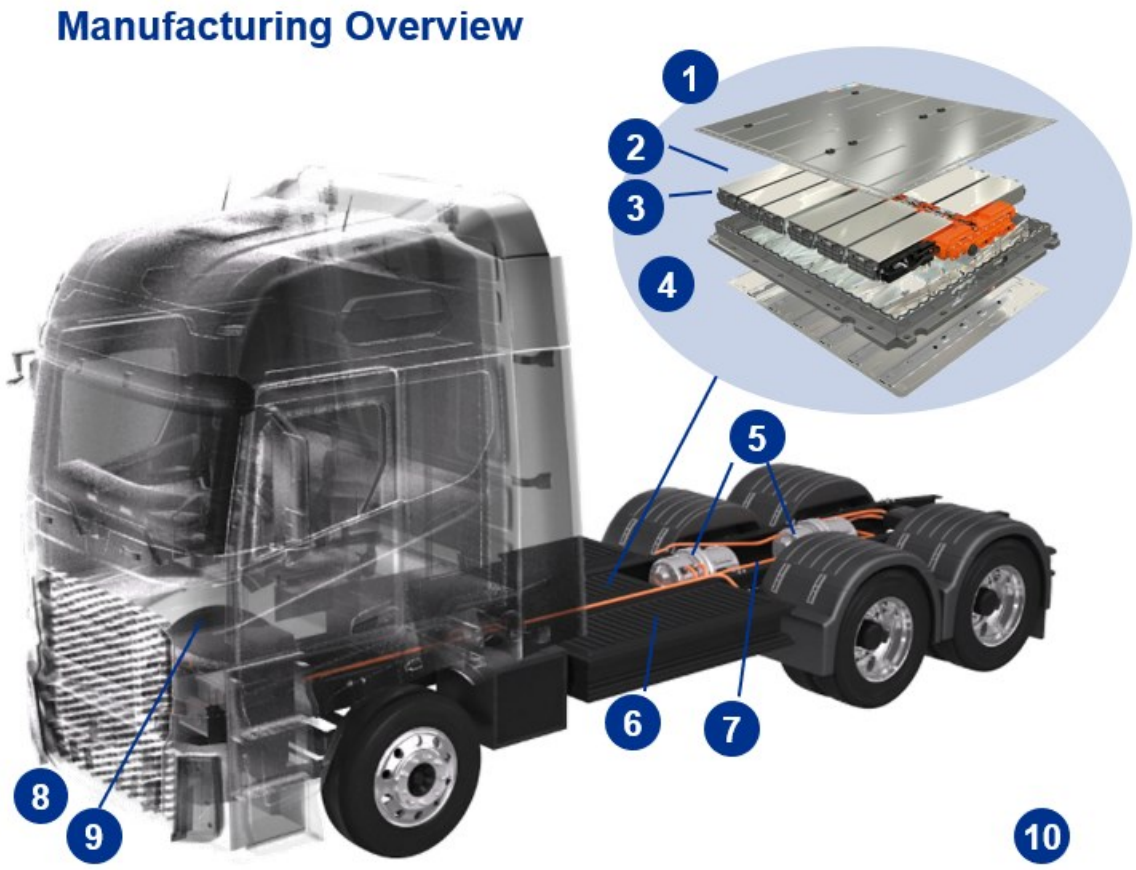
R&D: companies engage in ZEV testing and EV platform design.

Training: institutions that provide EV job manufacturing trainings to dealer workforce

Manufacturing

Many of the components that make up an MHD internal combustion engine (ICE) vehicle are the same as a ZEV. However, the key components that differentiate a ZEV that uses electric drive technology are the battery packs, the electric motor, the inverters and converters, along with other electrical parts. These various components make up the long list of sub-segments within the ZEV manufacturing segment of the supply chain.

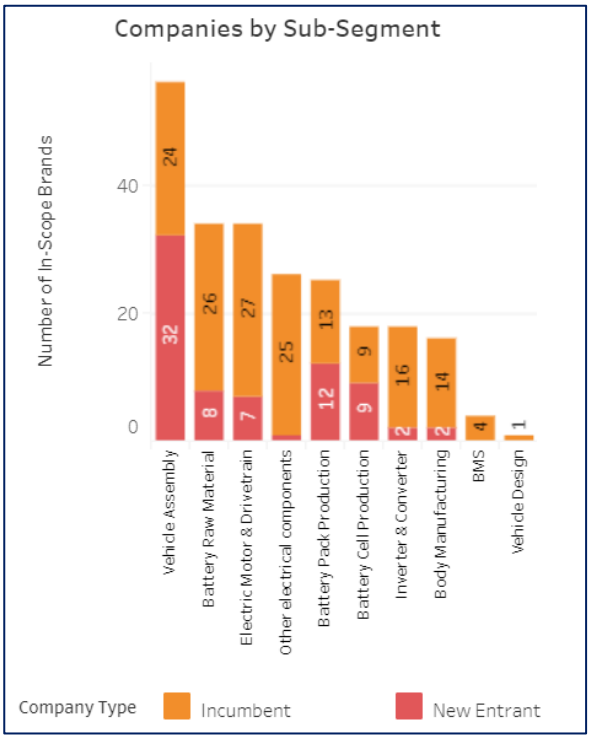
Figure 19: Key Elements of an Electric Truck

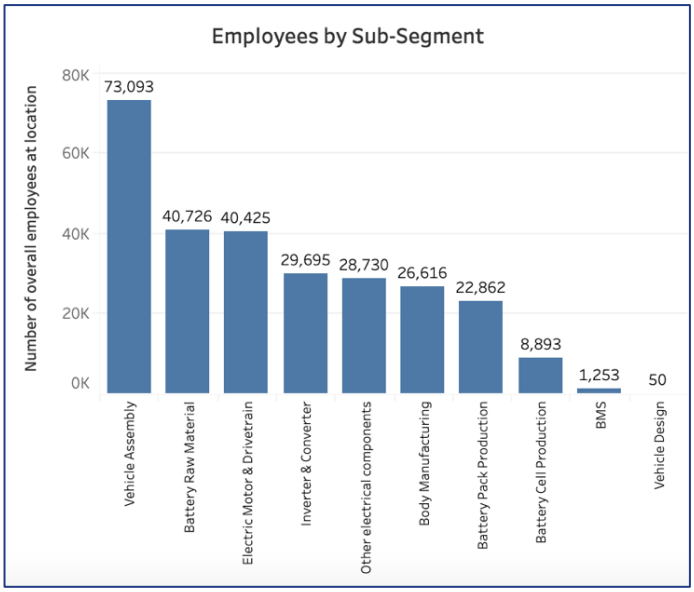


	Sub-Segment	Description
1	Battery Packs	Battery pack through sorting of cells, assembly of modules and pack and BMS integration
2	Battery Raw Materials	Base materials for cathodes, anodes and other components and refined metal chemicals
3	Battery Cells	Cells made from manufacturing electrodes, assembling and finishing cells
4	BMS	Battery management system – controls battery and optimizes performance (circuit board, I/O software, control algorithms)
5	Electric motor	Electric traction motor or powertrain (incl. axles) for propulsion as well as regeneration (while breaking)
6	Inverters/ Converters	Inverters for DC to AC (for electric motor) and AC to DC for regenerative braking, Converters convert high-voltage DC power to lower voltage for other vehicle systems
7	Other electrical	Controllers (regulating energy and thereby speed), onboard computers, chips, and high voltage harnesses
8	Vehicle Design	Commercial ZEV design
9	Body Manufacturing	Body structures and assemblies (e.g. frames, cab, hood, side rails, cross-members)
10	Vehicle Assembly	Commercial ZEV assembly combining all systems

The MHD ZEV manufacturing segment is growing rapidly with 231 companies driven by 73 new entrants. These companies are estimated to employ approximately 272,000 employees to work on the manufacturing of MHD ZEVs. Most of this growth is occurring in the vehicle assembly, battery cell, and battery pack subsegments.

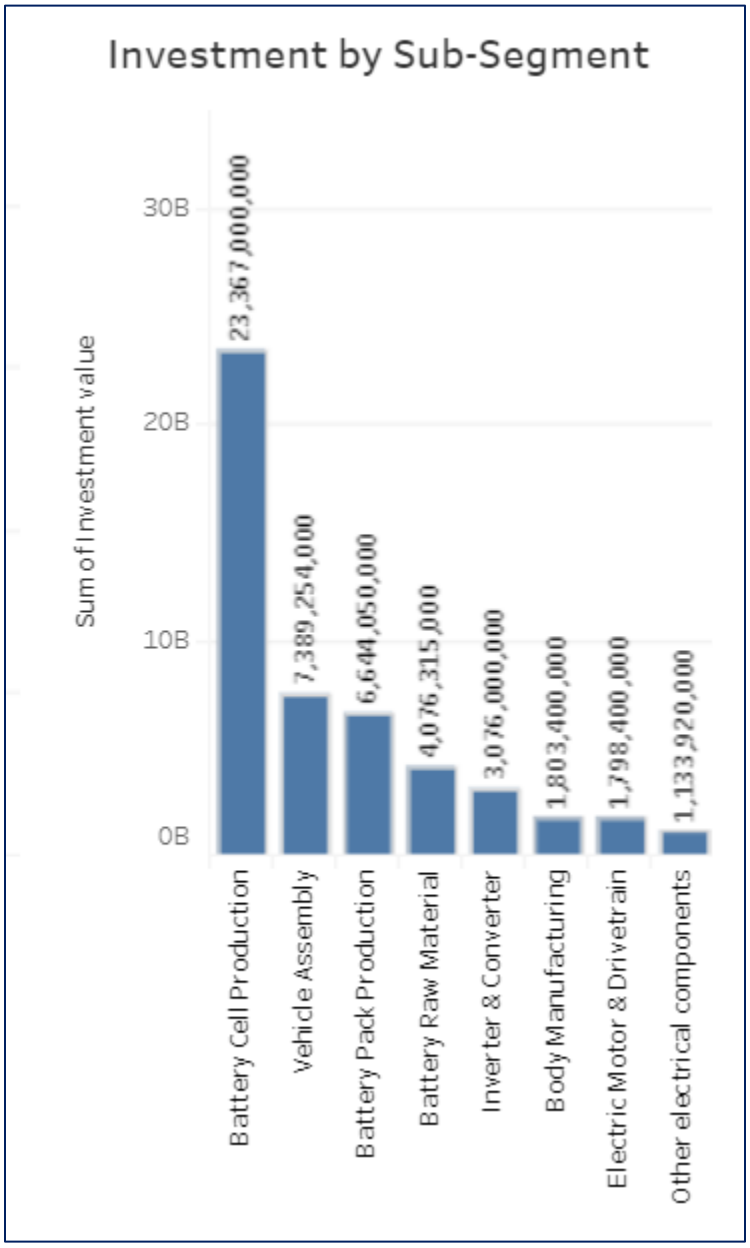
Figures 10 and 11: Companies in Each Manufacturing Sub-segment (left) and Associated Employees (right)





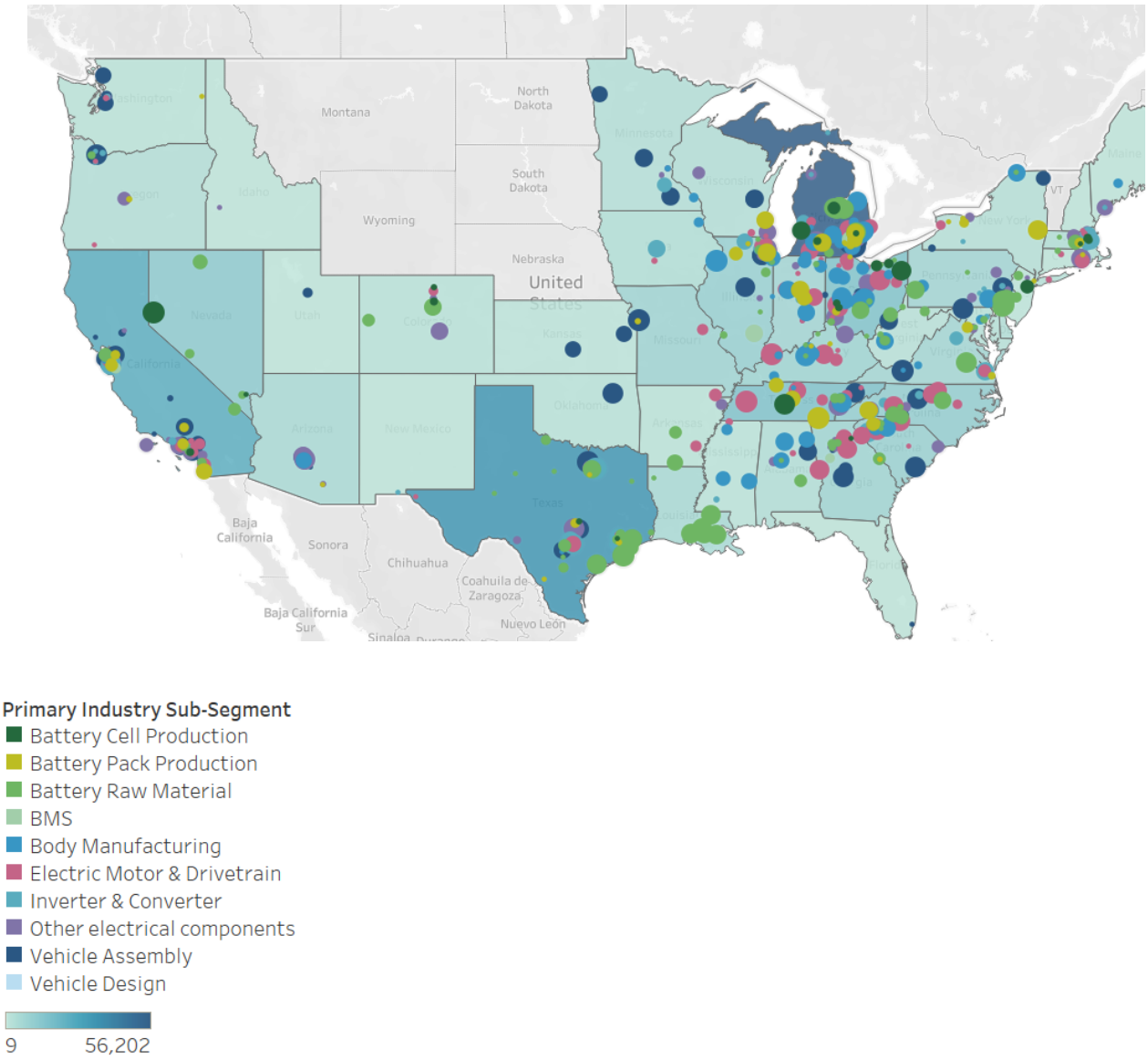
Driven by the companies involved in the sector, investments are taking place mainly in battery cell production at a level of $23.3 billion, vehicle assembly at a level of $7.4 billion, and battery pack production at a level of $6.6 billion.

Figure 12: Announced Investment by Manufacturing Sub-segment



Most manufacturing employment is currently in California, Texas, and Michigan, with these three states covering 65 percent of the total manufacturing workforce. Based on the data collected, the high number of employees in the Midwest is driven by incumbents shifting their portfolio to support MHD ZEVs.

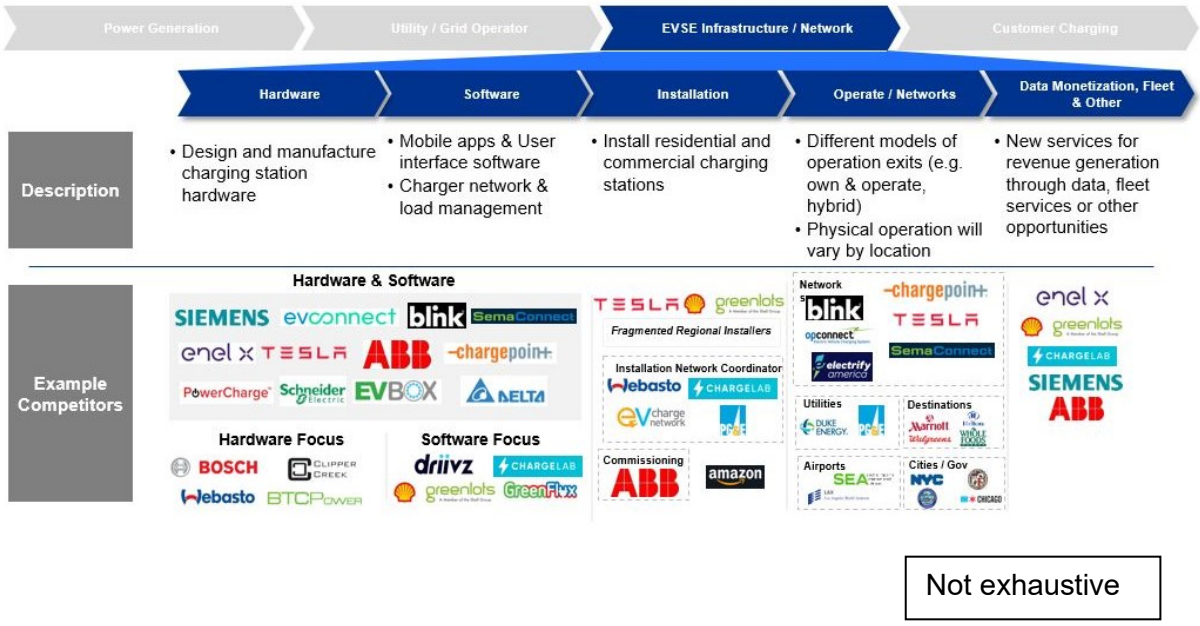
Figure 13: Manufacturing Employment by State



Infrastructure

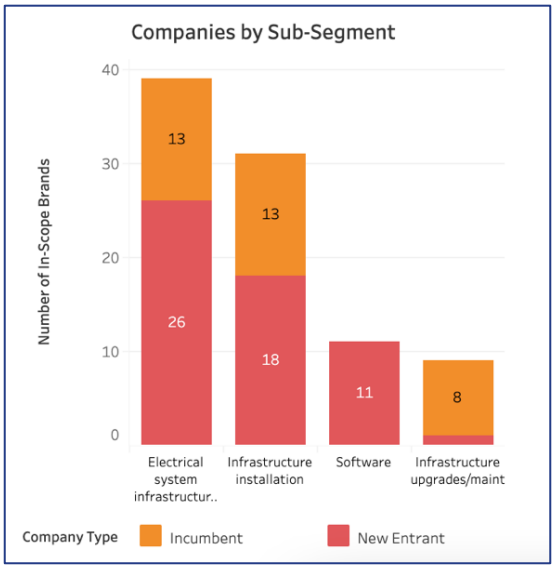
The MHD ZEV market cannot thrive without a robust infrastructure ecosystem to support electrification, and a spectrum of entities have been investing in the charging network. The electric vehicle supply equipment (EVSE) infrastructure can be broken down into five value chain segments, including hardware, software, installation, network operation, and new services (e.g., data monetization and fleet services).

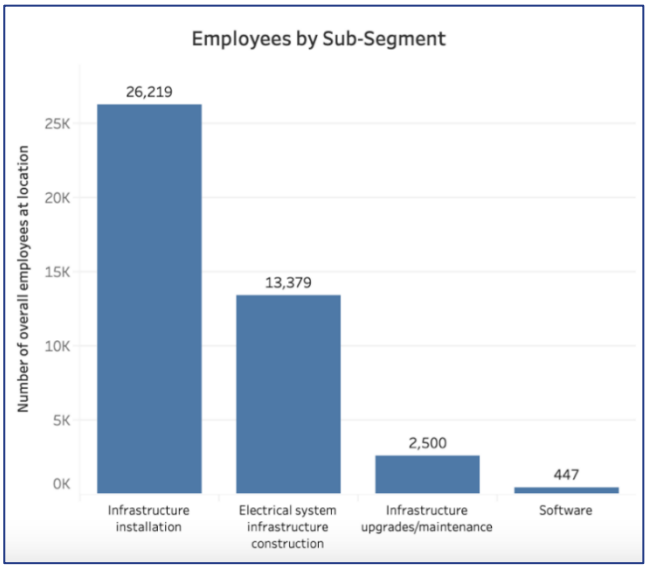
Figure 14: EVSE Industry Description



Although the ZEV infrastructure segment is still in nascent stages, 90 companies are already participating in the space with a majority classified as new entrants - indicating that a widening array of companies are bringing new investments and solutions to charging to market at a quickening pace. Both utilities and electronics companies are some of the entities that are emerging as new entrants in the space. Overall, the study found employment of over 42,000 people in the U.S across the sector.

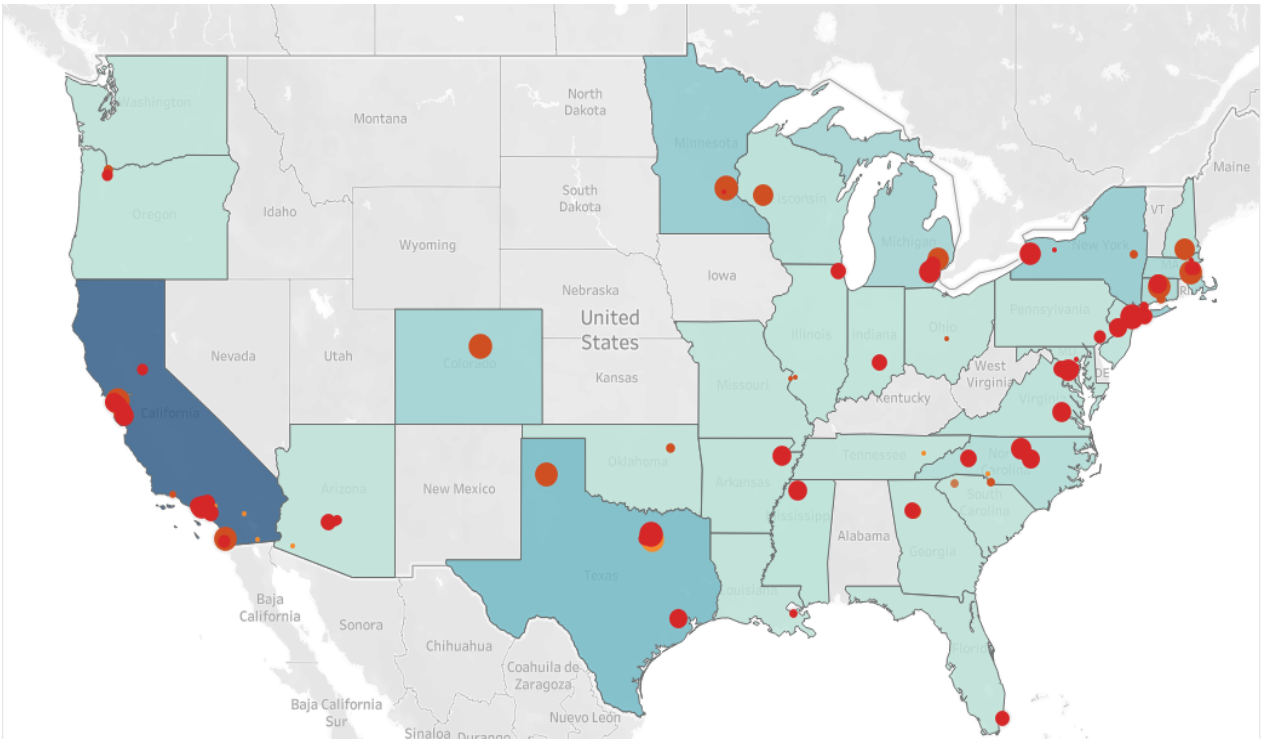
Figures 15 and 16: Infrastructure Companies in Each Sub-Segment (left) and Associated Employees (right)





Approximately 80 percent of entities in the space are domestic to the U.S., with the majority of employment located in California, and an array of companies along the Eastern Coast and Texas.

Figure 17 Infrastructure Employment by State

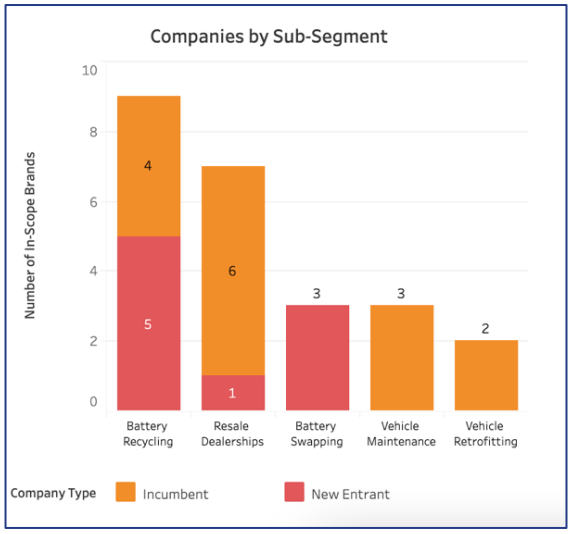


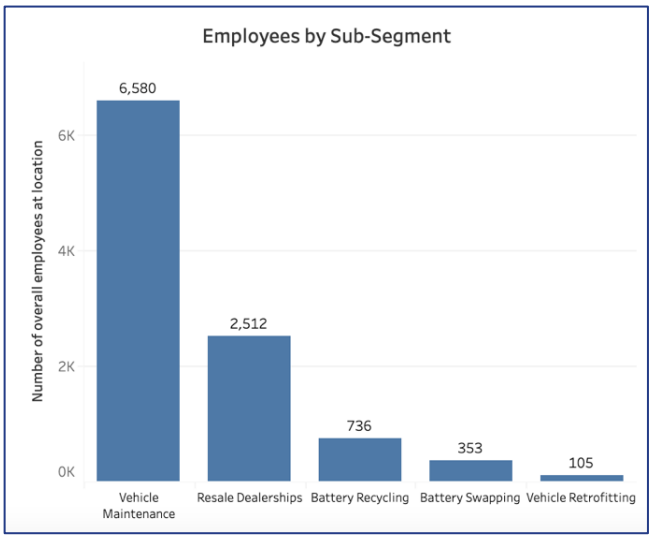
Midlife

The midlife segment of the supply chain is comprised of companies engaged in maintenance, retrofitting, resale, and battery recycling of MHD ZEVs. As commercial ZEVs are just starting to enter the market, limited dedicated midlife locations exist, but major players including truck leasing companies are building up capabilities.

In addition to established battery manufacturers advancing their recycling capabilities (e.g. LG Chem, BASF, SK Innovation, Tesla, CATL), this segment includes major US recycling incumbent Retriev Technologies and a few startups like Redwood Materials and Li-Cycle. Over 10,000 people are employed in this field in the U.S., and that number is expected rise as the ZEV industry grows.

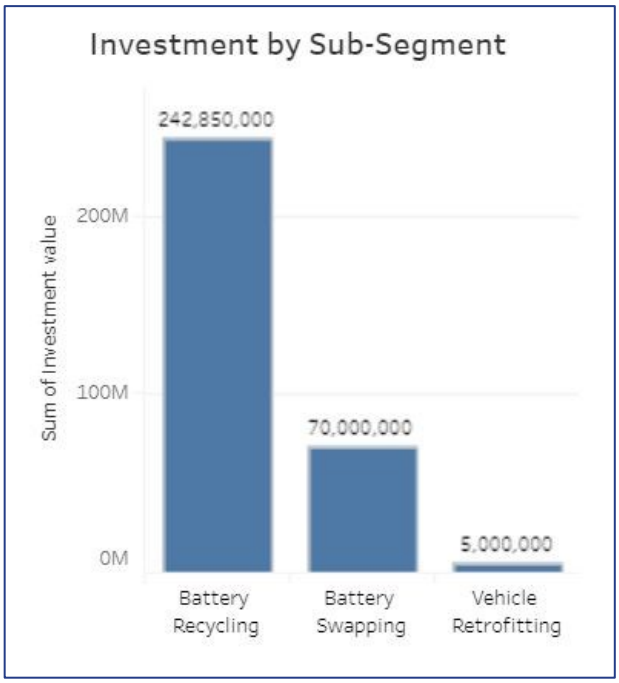
Figures 18 and 19: Midlife Companies in Each Sub-Segment (left) and Associated Employees (right)





As more ZEVs hit the road, more investments will be made by dealers/OEMs and fleet managers, therefore improving the capabilities and possibilities for midlife, resale, and recycling. Major known investments currently total over $267 million.

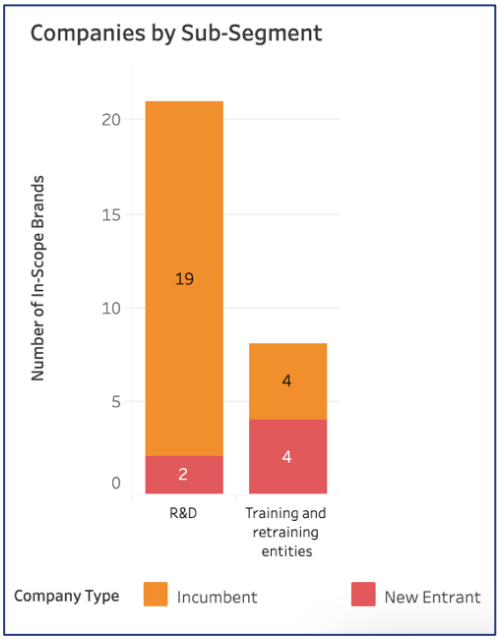
Figure 20: Midlife Investment by Sub-segment

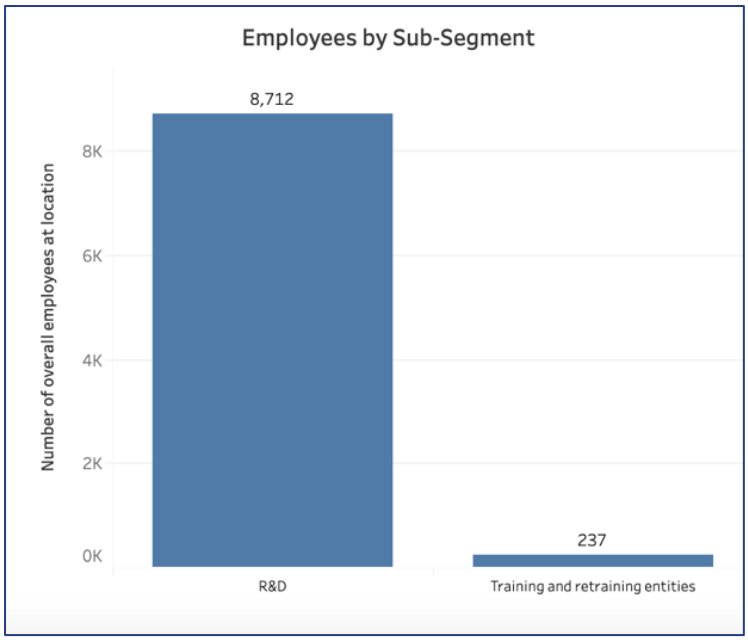


R&D and Employee Training

R&D companies are the behind-the-scenes innovators quietly leading the charge on vehicle electrification. These companies, many of them engineering firms, are engaged in EV testing (electric motor testing, battery testing, charging simulation, EMC, etc.) and ZEV platform design. Employee training companies are the entities ensuring that the transition happens as smoothly as possible, providing ZEV trainings to the dealer workforce. These trainings equip technicians with the skills to repair and maintain EVs and focus heavily on technology. There are almost 9,000 currently employed in the space in the U.S at 29 companies.

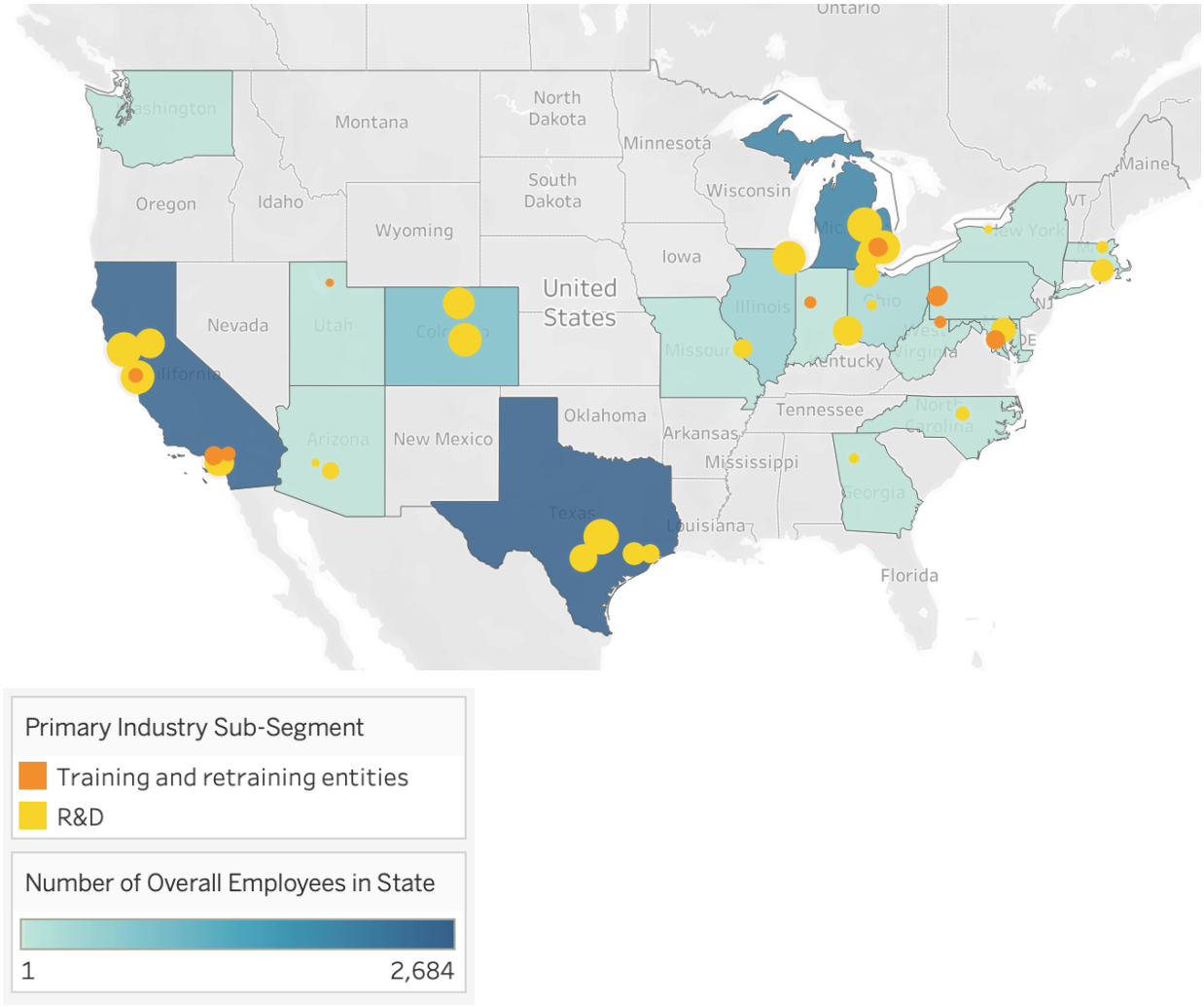
Figures 21 and 22: Number of R&D and Employee Training Companies in Each Sub-Segment (left) and Associated Employees (right)





R&D and testing facilities are located in California, Texas, Colorado, and the Midwest. Dedicated ZEV training and education is limited but gradually growing in California.

Figure 23: R&D and Training Employment by State



The Way Forward

Companies in the zero-emission supply chain are present across the United States, and in over half of the U.S. Congressional Districts. California, a state that has extensive policies on zero emissions vehicle transportation and technological hubs in places like Silicon Valley and Los Angeles is leading in several metrics, such as number of companies and corporate headquarters. Michigan, a state with a robust existing auto manufacturing industry and large employment base is leading in total employment. Texas, with significant polices to attract emerging businesses and an existing manufacturing base is close behind in every category.

To continue this rapid growth, a continued focus on durable public policy signals to

1. promote additional corporate investments,
2. ease the process of buying and operating vehicles, and
3. ensure that infrastructure can support swift development will be crucial for the sector moving forward.

Supply chain businesses were found in 44 separate states, and over $53 billion in announced investments across identified companies. These widespread and sizeable announced investments are a clear signal of where the MHD ZEV industry is heading, and there is more to be gained from a market share and an employment perspective. This industry has the potential to increase both the number and geographical distribution of domestic EV jobs.

Under the umbrella of ZEV manufacturing, there are already many different rapidly growing subfields such as battery cells, vehicle assembly, and vehicle design. Moreover, the jobs are being created across the entire country. As investment into domestic ZEV manufacturing increases, the distribution of these jobs will also spread more widely around the nation, leading to increases in job equity and equality.

In addition to economic and employment benefits, the electrification of MHD vehicles offers a plethora of environmental, public health, and economic benefits. Over their lifetime, ZEVs produce fewer emissions than vehicles powered by internal combustion engines, and as nations worldwide transition their electricity grids from fossil-fuels to renewables, the environmental benefits of ZEVs will only increase.

Appendix

The following is a list of data sources used to assemble and analyze the data for this analysis

Title (Linked if available)	Publisher	Year	Segment(s) Covered	Comment
Automotive Supplier Consolidation Study 2020	PwC (Internal)	2021	Manufacturing	Long list of automotive manufacturing suppliers; key data points (revenue, employees)
Economic potential of growing electric transportation in CA, NY, IL markets	AEE, BW Research	2021	All	Select CA, NY, IL companies from each segment noted
Battery Critical Materials Supply Chain	US DoE	2020	Manufacturing	Sector overview
Next-generation Battery Technology Report	IHS Markit	2020	Manufacturing	Battery cell and battery pack manufacturers
Mineral Commodity Survey 2021	U.S. Geological Survey	2021	Manufacturing	Battery raw materials suppliers
State of the EV lithium-ion battery market	Prescouter	2020	Manufacturing	Battery raw materials suppliers, Battery cell and battery pack manufacturers
EV Powertrain Market Research Report	Market Research Future	2021	Manufacturing	Electric motor and drivetrain players
Electric Motors for Electric Vehicle Market	Mordor Intelligence	2020	Manufacturing	Electric motor players
Electric Vehicle Power Inverter Market	Mordor Intelligence	2020	Manufacturing	EV Inverter players
EV Market Status report	EDF / MJ Bradley	2021	Manufacturing	Vehicle Assembly
Top 71 Electric Car Startups	Energy Startups dot Org	2021	Manufacturing, Infrastructure	Vehicle Assembly, EV Charging infrastructure players
ZEV Bus & Truck Market in US & Canada	ICCT	2021	Manufacturing, Infrastructure	Vehicle Assembly, EV Charging infrastructure players
Top 10 EV Tech Solution Companies	Auto Tech Outlook	2020	Infrastructure	Key EV charging infrastructure players identified

Top 7 EV Stocks and Battery Companies	US News	2021	Manufacturing	Vehicle Assembly
Sustainability Market Assessment	PwC (Internal)	2020	Infrastructure	EV Charging infrastructure players
California Energy Commission announces new incentive program for ZEV truck and bus infra	Charged EV Magazine	2021	Infrastructure	Key investments, state grants in CA EV Infrastructure segment; Key players
San-Francisco EV Infrastructure Working Paper	ICCT	2020	Infrastructure	Sector overview
EV Stations Map by PlugShare	PlugShare	Live	Infrastructure	Key EV charging infrastructure players identified
US EV Infrastructure Market	Grand View Research	2021	Infrastructure	Key EV charging infrastructure players identified
Electric Vehicle Charging Infrastructure Trends	NREL	2020	Infrastructure	Key EV charging infrastructure players identified
PG&E's Approved EV Charge Network vendors	PG&E	Live	Infrastructure	Key EV charging infrastructure players identified
Electric Vehicle Charging Station Market	Research and Markets	2020	Infrastructure	Key EV charging infrastructure players identified
Top 20 electric charging station companies	News article	2019	Infrastructure	Key EV charging infrastructure players identified
Top Electric Vehicle Charging Startups	Tracxn	2021	Infrastructure	Key EV charging infrastructure players identified
EV charging infrastructure: Rising role of utilities	ADI Analytics	-	Infrastructure	Key EV charging infrastructure players identified
Electric Vehicle Battery Swapping Market	Allied Market Research	2021	Midlife	Battery swapping players
Top 10 international truck dealers in US	Fue Loyal	2017	Midlife	Only 1 sells/services EV trucks
Dealers prepping for the inevitable shift toward electric vehicle service	Transport Topics (News)	2021	Midlife	Only 1 sells/services EV trucks
Bus Dealers Distributors & Sales	Metro Online Directory	Live	Midlife	Some EV bus dealers and maintenance players

North American Commercial Vehicle Contract Maintenance Market, 2020	Research and Markets	2020	Midlife	Vehicle Maintenance players (EV specific selected)
EV Test Equipment Market - Forecast to 2026	Research & Markets	2021	R&D and Training	Key EV Testing players; EV Testing equipment manufacturers
EV Charging Systems Testing Market	Allied Market Research	2021	R&D and Training	Report yet to be published; sourced key player names

Generic Sources Used	Publisher	Year	Segment(s) Covered	Comment
Capital IQ (Licensed Database)	S&P Global	Live	All	Key company data (revenues, geography, employees, business description)
Dun & Bradstreet Business Directory	Dun & Bradstreet	Live	All	Key company data (revenues, employees, business description)
LinkedIn	Microsoft	Live	All	Key company data (employees, business description, HQ, geographies)
SEC Edgar	SEC	Live	All	Key company data (revenues, geography, employees, business description)
Monster	-	Live	All	Key company data (employees, business description, jobs, salaries)
Glassdoor	-	Live	All	Key company data (employees, business description, jobs, salaries)
Investor Reports, Annual Reports	Company websites	Live	All	Key company data (revenues, geography, employees, business description)
Misc. News Articles on EV	-	Live	All	Smaller players, JVs, partnerships, etc. (Eg: Volvo & Mack trucks)
Google Ads	-	Live	All	Direct leads on segment players from Google Sponsored Ads