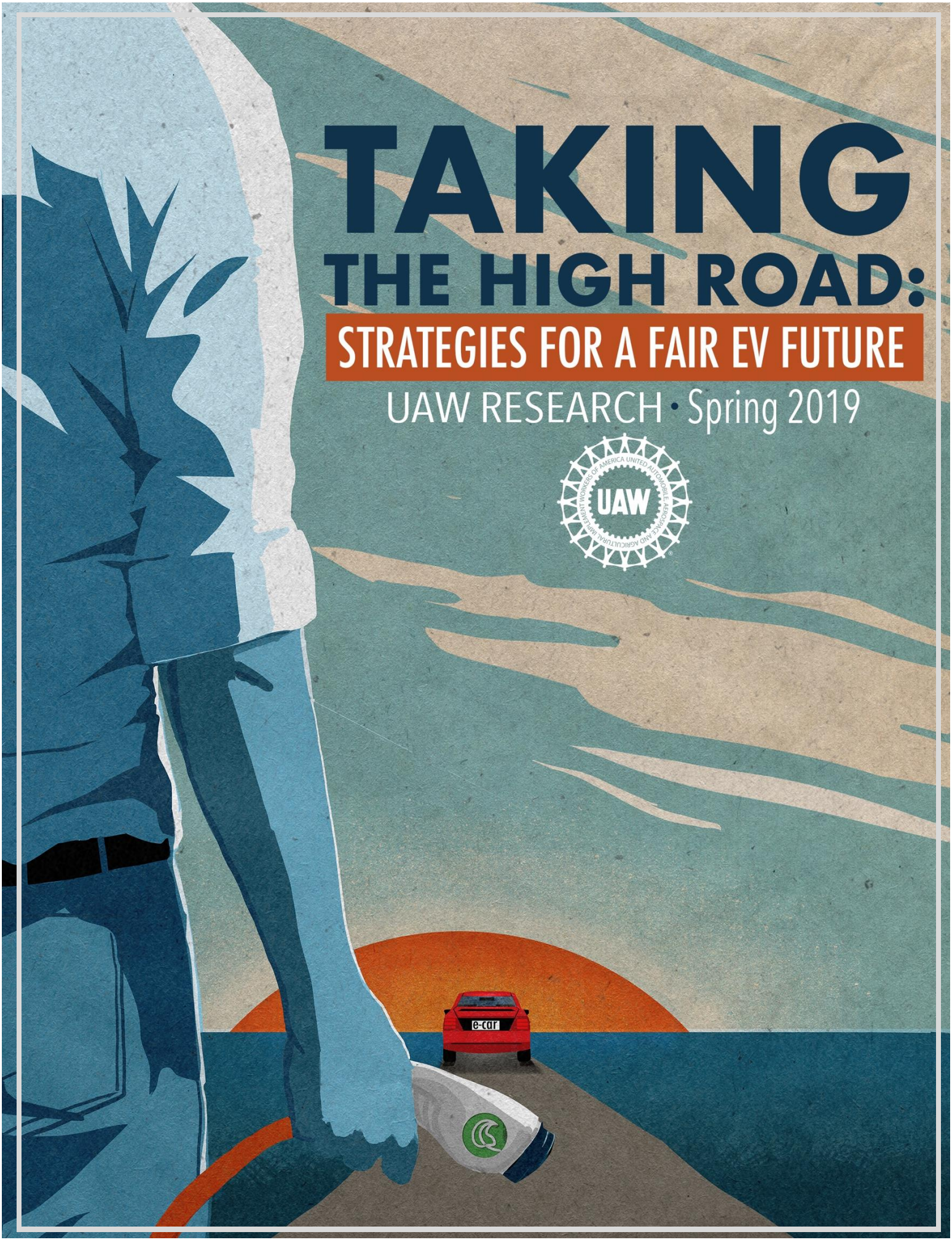
TAKING THE HIGH ROAD:

STRATEGIES FOR A FAIR EV FUTURE

UAW RESEARCH • Spring 2019



Executive Summary: Strategies for a Fair EV Future

The American automotive industry is constantly evolving and, throughout the union's history, the United Auto Workers (UAW) has fought to ensure industry changes result in quality jobs that benefit workers and the economy.

The auto industry is facing a new shift in technology with the proliferation of electric vehicles (EVs). This shift is an opportunity to re-invest in U.S. manufacturing. But this opportunity will be lost if EVs or their components are imported or made by low-road suppliers who underpay workers. In order to preserve American jobs and work standards, what is needed is a proactive industrial policy that creates high-quality manufacturing jobs making EVs and their components.

Coming Shift To EVs

While EVs are only 1% of the U.S. market, there is industry consensus that EVs will increase their market share, it is just a matter of how quickly this will happen. *Bloomberg New Energy Finance* projects EVs will be around 10% of the global market in the mid-2020s and over 50% 2040. EV growth will be driven by a variety of factors.

Cost Competitiveness: Cost is one of the biggest hurdles for EVs. Analysts project this disadvantage will disappear as the price of batteries declines. By 2030, EV powertrains are expected to reach price parity with internal combustion engine (ICE) powertrains. EVs become even more price competitive when fuel and maintenance savings are considered.

Major Actors Investing in EVs: It is not just industry analysts who are projecting a shift to EVs. Automotive companies, suppliers, governments and investors all see EVs as an opportunity. Key stakeholders are setting ambitious EV targets and backing them up with pledges of massive investments. As of January 2019, global automakers have pledged over $300 billion in spending on electrification.[1]

Complements Mobility Trends: EVs will be aided by the growth of ride hailing and autonomous vehicles (AVs). EV fuel and maintenance savings are best realized with highly utilized fleet vehicles and EVs provide the greater power and energy storage necessary for AVs.

Government Mandates: EV growth will likely be boosted by government support, such as consumer subsidies or infrastructure investment. Global governments have set ambitious goals to cut emissions and transition to EVs. Some have even proposed phasing out ICE vehicles entirely.

Disruptive Implications of EVs

EVs are not simply a shift in consumer preference. They are a fundamental shift in the way we power vehicles. This could have disruptive implications for where and under what conditions vehicles are made.

Lower Complexity, Less Labor, Displaced Workers: EV powertrains are mechanically simpler than ICE powertrains. This simplicity could reduce the amount of labor, and thus jobs, associated with vehicle production. EVs could also erode employment in ICE engines, transmissions, exhaust systems, and fuel systems, but could create employment in batteries, electric motors, electronics, thermal systems, braking systems, and semiconductors.

New industry Actors: The production of new EV components could shift business and employment to non-auto companies that lack a large U.S. manufacturing base. This could undermine auto job quality by shifting work to employers with a poor history of labor relations or companies that are more likely to import components.

Will the U.S. Fall Behind?

Automakers, governments, and other key stakeholders have shown a commitment to develop and produce EVs. Where those vehicles and components will be made remains an open question.

China in the Lead: China is promoting domestic production of EVs and EV components by favoring domestic firms and subsidizing its domestic EV market. Because of these policies, automakers are orienting their EV strategies toward China. China is also expected to be home to 62% of global lithium-ion battery manufacturing capacity by 2023.[2]

Europe Recognizes Battery Threat: The EU has recognized that EVs could lead to key vehicle components being imported. The European Commission created the European Battery Alliance to create a "complete value-chain" for batteries in Europe[3] by coordinating with governments and Europe's largest chemical, automotive, and engineering companies.[4]

Creating an Industrial Policy to Lead

A strong, forward-looking industrial policy is needed to use the EV disruption as an opportunity to create high-quality manufacturing jobs making the vehicles of the future.

Infrastructure: Vehicle electrification requires building a charging infrastructure for drivers. It also means upgrading our energy infrastructure to meet electricity demand and ensure electricity production is as green as the EVs themselves. This is an opportunity to create quality jobs to build, install, and maintain EV infrastructure.

Training: Workers will need new skills and displaced workers will need re-training programs. Strong industrial policies should include every effort to re-train and place workers in quality jobs, provide strong economic support for workers during transition periods, and create robust government jobs programs to guarantee quality jobs for all those seeking work.

Trade Policy: The economic potential of EVs will be lost if their components are imported. Advanced vehicle technology should be treated as a strategic sector to be protected and built in the U.S.

Investment Supports: Government incentives can promote production of EVs and EV components in the U.S. Incentives should be used in a targeted way to promote a domestic EV supply chain and enforce high-road manufacturing practices.

Government Procurement: Government EV fleet purchases, from cars to public transportation, can be a tool to spur demand and create cleaner transportation. Such purchases should promote high-road jobs by considering assembly location, origin of content, and labor conditions.

Consumer Incentives: Consumer incentives are a tool to create a robust domestic EV market. This will encourage companies to orient their EV strategies toward the U.S. market. Consumer incentives should also be used to promote high-road domestic EV production. Incentives should be based on where the vehicle and its contents were produced and under what labor conditions.

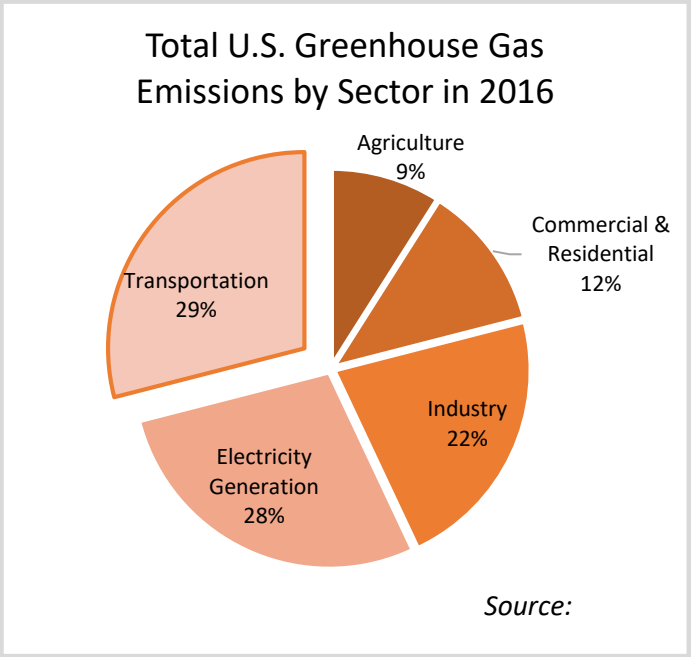
Environmental Policy: Strong environmental standards can be structured as a win-win for the environment, workers, and the economy. Environmental policy should be used to address climate change while also promoting investment in future technologies that create quality jobs in the process.

WHAT IS AN EV? WHY EVS?

Environmental Concerns: To address global warming and climate change, consumers and governments worldwide expect greener products. Transportation accounts for over a quarter of all U.S. greenhouse gas emissions per year[5] and EVs present a way to drastically reduce those emissions.

New Way to Power Vehicles: So, how are EVs and internal combustion engine (ICE) vehicles different? While the cabins of the vehicles are similar, under the hood – and floorboards – they are completely different. In the simplest terms, the ICE vehicle's fuel tank is replaced by a battery pack and its internal combustion engine is replaced with an electric motor.

Over a century ago, as people switched from the horse drawn carriage to the automobile, it was not clear how these new vehicles would be powered. Both electric and ICE vehicles were on the road, and electric cars had some advantages – they were quiet and did not produce exhaust. However, electric cars could only operate where there was an electrical infrastructure, and electricity was only readily available in the cities, making rural usage or trips nearly impossible (the original range anxiety). It was not until the invention of Ford's assembly line and the mass-produced Model T, as well as the electric starter, that the ICE came out the clear winner.[6]



CLIMATE CONCERNS POINT TO EVS

Despite nearly disappearing from America's roads for nearly half a century, electric vehicles kept coming back as a potentially viable solution to some of our most vexing environmental problems. In the 1970s and 1980s, in response to the smog epidemic, and more recently to address excess carbon dioxide in the earth's atmosphere causing climate change, EVs have held a promise of a cleaner future.

With the invention of lithium-ion batteries in the 1980s, EVs started taking baby steps to compete with ICEs, in terms of price and range. Today, EVs can travel over 300 miles on a charge, and take an 80% charge in a half an hour. According to the Union of Concerned Scientists, an average EV produces less than half the global warming emissions of comparable ICEs.[7] This is especially significant considering transportation accounts for over a quarter of all U.S. greenhouse gas emissions per year.[8]

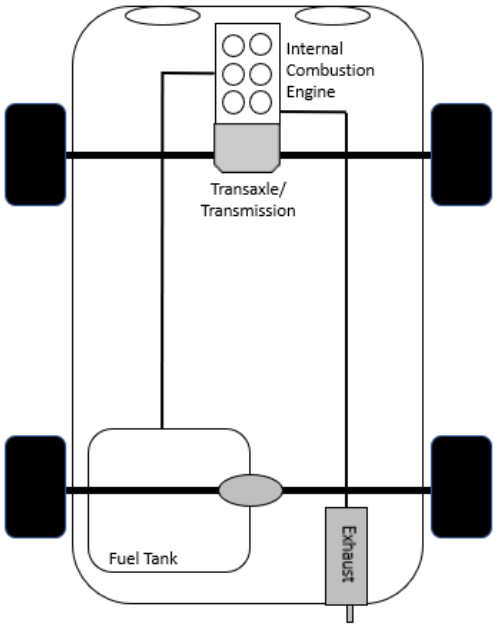
It is important to note that while EVs produce no emission out of the tail pipe – propelling them down the road does take electricity and generating that electricity may cause emissions. Still, when taking into consideration power generation mix (solar, wind, hydro, natural gas, coal) and the ability to add additional emission scrubbers on a stationary power generator that are not feasible on a mobile unit, the average EV in the U.S. is roughly twice as clean as an ICE.[9]

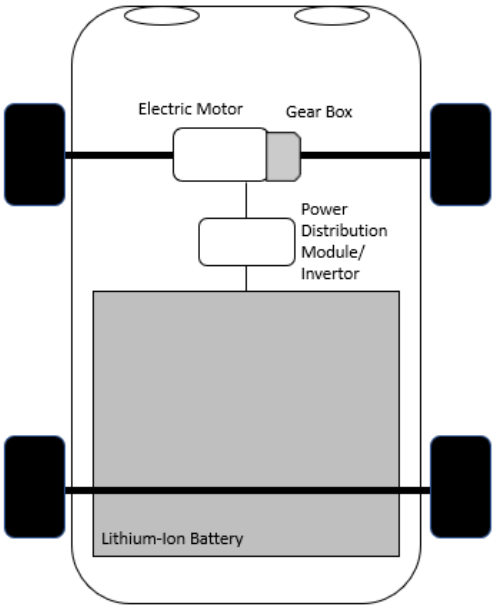
Differences Between EVs and ICEs

So, how are EVs and ICEs different? For starters, while the cabins of the vehicles are similar, under the hood – and floorboards – they are completely different. The ICE's fuel tank is replaced by a battery pack. An internal combustion engine is replaced with an electric motor (or two).

The multi-geared transmission and clutch is replaced with a fixed, single-gear gearbox. Both vehicles require thermal control, but while a radiator manages the heat in an ICE, the EV's thermal management system regulates against both hot and cold temperatures in the battery. Further, an EV has no exhaust or emissions controls because it does not produce any localized carbon emissions.

For a more in-depth look at EV powertrain components, see Appendix A.





The Coming EV Powertrain Disruption

Growing Market Share: EVs make up just 1% of the U.S. market, but industry consensus expects EVs to increase their market share. The debate is over how quickly this will happen. *Bloomberg New Energy Finance* projects EVs will account for around 10% of the global market in the mid-2020s and over 50% by 2040.[10]

Cost Competitiveness: Cost is one of the biggest hurdles for EVs. Analysts project this disadvantage will disappear as the price of batteries declines. By 2030, EV powertrains are expected to reach price parity with ICE powertrains.

Ownership Savings: Besides purchase price, EVs provide savings on fuel and maintenance costs because they do not require regular fluid changes and have fewer moving and wearing parts that may require replacement.

Complements Mobility Trends: EVs will be aided by the growth of ride hailing and autonomous vehicles. EV fuel and maintenance savings are greatest for highly utilized fleet vehicles and EVs provide the higher power and greater energy storage necessary for AVs.

Government Mandates: EV growth will likely be boosted by government support, such as consumer subsidies or infrastructure investment. Governments have set ambitious goals to cut emissions and transition to EVs. Some have even proposed phasing out ICE vehicles entirely.

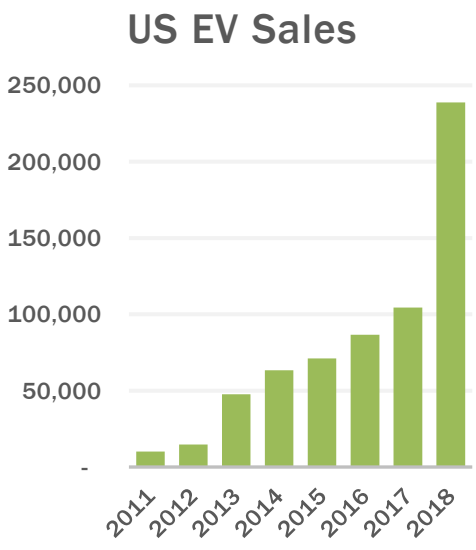
In 2018, EVs and hybrids combined made up just 2% of market share in the U.S.[11] To date, EV sales remain highly dependent upon public policy support for consumers and producers.[12] This small, subsidy dependent segment of the market may seem an unlikely contender to disrupt one of the global economy's most important manufacturing industries.

Yet, there is consensus that electrification will play an ever-greater role in the auto industry, with industry observers only debating how quickly the EV market will grow.

EV sales have shown strong growth since 2010. Globally, new EV registrations were only a few thousand units prior to 2010. By 2017, annual EV sales reached over 750,000 globally and the global vehicle stock for EVs approached 2 million, in addition to over 1 million plug-in hybrids.[13]

Additionally, consumer receptiveness to EVs points to further growth. One survey found that when asked what type of vehicle they would acquire next, 10% of U.S. consumers and 16% of global consumers said they would choose an EV or plug-in hybrid.[14]

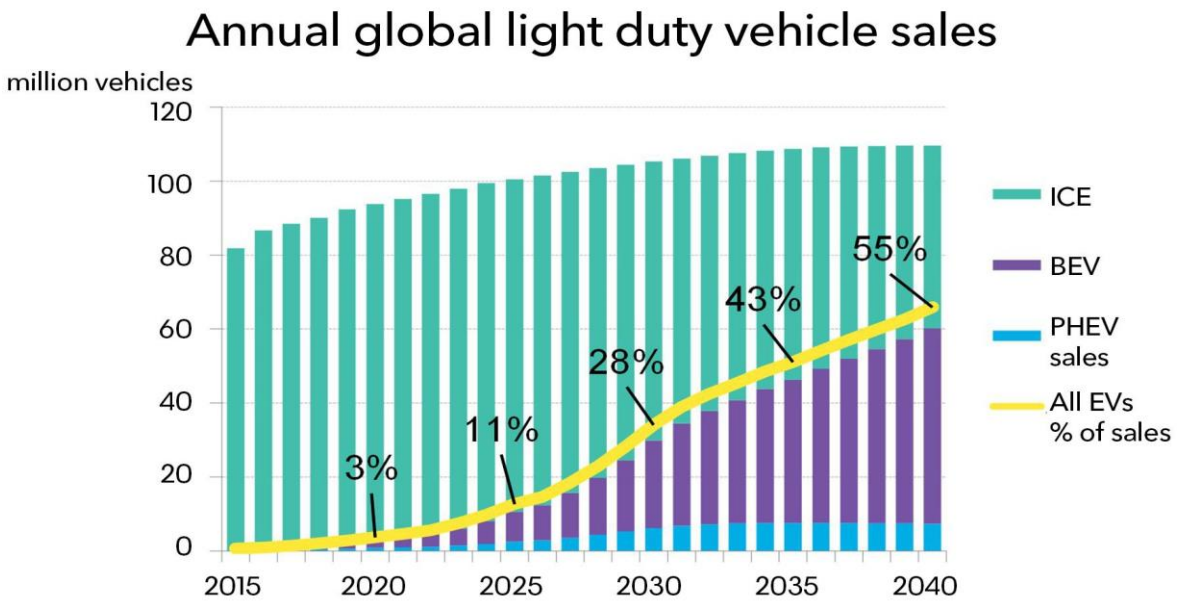
Moderate EV sales growth is expected to continue in the short-term, with the potential for even more rapid growth in the long-term. This growth will be driven by a variety of factors, including declining battery prices, increased vehicle range, stronger government mandates in response to climate change, increased EV charging infrastructure, and wider consumer



Source: U.S. Department of Energy Altenrative Fuels Data Center; InsideEVs

acceptance. Price parity represents a tipping point in many analysts' projections, where EV sales go from slow but steady growth to more rapidly capturing market share.

For example, *Bloomberg New Energy Finance* has projected that EVs and plug-in hybrids will be around 10% of the global market in the mid-2020s and by 2040 will represent over 50% of new vehicle sales.[15]



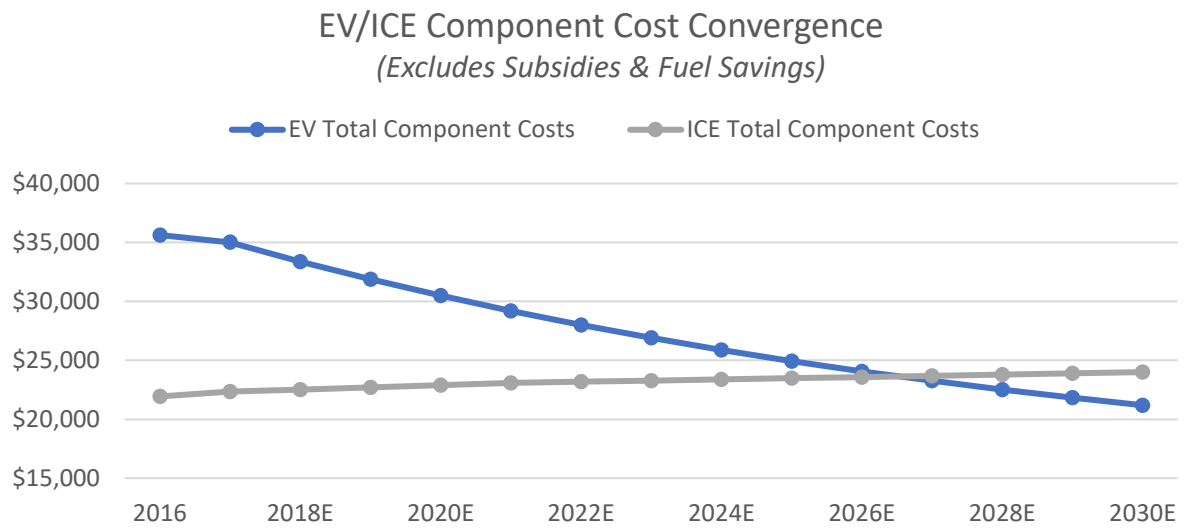
Source: Bloomberg New Energy Finance

Electric Vehicle Prices To Become Competitive

Cost is one of the biggest hurdles for EVs, but one that analysts believe will disappear in the future. One of the drivers of EV costs is the lithium-ion batteries and associated EV powertrain components, which are more expensive than the ICE powertrain components they replace.

In an EV, major ICE components such as exhaust, fuel systems, engines, and transmissions are replaced by batteries, electric motors, and power electronics. A 2018 Bank of America Merrill Lynch analysis estimated that in a $35,000 car, the EV powertrain components make up nearly $18,000 in content costs, while the ICE components that they replace cost around $7,000.[16] The cost gap is largely due to the lithium-ion battery cells and battery pack, which make up nearly two-thirds of EV powertrain costs.

However, the cost of EV powertrains is expected to drop as the costs of batteries decrease, making EVs cost competitive with ICE vehicles. The cost of lithium-ion batteries has declined around 75% since 2010 and prices are expected to continue to decline, due to technology improvements and increased production capacity.[17] With this trend continuing, analysts project that EV powertrains and components will become price competitive without subsidies with ICE powertrains between 2025 and 2030.



Source: Bank of America Merrill Lynch[18]

EV Total Cost of Ownership Advantages

In addition to the improved cost competitiveness at the point of purchase, EV cost competitiveness can also improve when the total cost of ownership over the life of the car is considered. EVs have lower maintenance costs because they do not require regular fluid changes and have fewer moving and wearing parts that may require replacement. And EV owners also save on fuel cost by charging their cars rather than purchasing gas.

Like purchase price competitiveness, there is reason to believe that EVs can reach total cost of ownership parity in the coming years, though how quick this happens will vary by region. For example, the investment bank UBS released a research report comparing the total cost of ownership of the Chevy Bolt with a similar ICE vehicle, the VW Golf. UBS projects that in the U.S., a vehicle like the Bolt would reach total cost of ownership parity excluding subsidies and incentives by 2025, with an OEM making profits comparable to an ICE sale by 2028. Total cost of ownership parity could happen in Europe as soon as 2018, with comparable OEM profits by 2023.[19]

Total cost of ownership parity could be met sooner depending on how owners use the vehicle. EV savings from fuel and maintenance will be greater and total cost parity will be reached sooner over longer periods of ownership or at higher levels of utilization. The UBS analysis used modest assumptions of three years owned and 27,000 miles driven.

EVs Complementary to Other Mobility Trends

In addition to greater price competitiveness and consumer adoption, EV sales will be boosted by the fact that EVs are complementary with other trends in the mobility sector: ride hailing and autonomous vehicles.

The growth of ride hailing services means that a greater share of transportation will occur under highly-utilized, continuously circulating fleet vehicles. The operating cost savings of EVs, both in terms of fuel and maintenance, can be realized more quickly under such high-utilization conditions and point to EVs as the choice of future fleet services.[20]

EVs are complementary to another potentially disruptive force in the future of the auto industry: autonomous vehicles (AVs). The higher power and greater energy storage of EV systems is a better fit with AVs, which place greater demands on the vehicle's electrical system for its computing hardware and software. For example, GM's

autonomous Cruise protypes require three to four kW of electricity to operate the autonomous system.[21] In turn, the EV's simpler powertrain system is easier for computers to control.[22] Additionally, AVs are expected to be introduced initially as fleet vehicles, whether they are used for deliveries, industrial applications, transport in controlled areas or ride hailing.

Government Mandates on EVs

In response to climate change and air quality issues, governments around the globe have set ambitious goals to cut emissions and put millions of EVs on the road, with some going as far as proposing the phase out of ICE vehicles entirely.

To meet these goals, governments have used a variety of state supports to promote EVs, including funding for research and development, investment in charging infrastructure, subsidies for consumer purchases, procurement of EVs for government fleets, sales quotas for manufacturers, and preferential access to parking and traffic lanes.[23] If governments choose to stick to their ambitious targets and continue to support EVs, it will give EVs a distinct advantage over ICEs.

Future Uncertainty

Analysts and OEM projections represent the best estimates of key experts and stakeholders. There is a complex set of factors that will determine future EV and AV adoption.

- Gas prices
- Infrastructure development
- Speed of technology advances
- Changes in regulatory policy
- Levels of government subsidies
- Health of overall auto market
- Price of key natural resources, such as cobalt or lithium
- Consumer acceptance
- Battery prices

EVs Have Disruptive Implications

Fundamental Shift: EVs are not simply a shift in consumer preference. They are a complete shift in the way we power vehicles. This could have disruptive implications for where and under what conditions vehicles are made.

Lower Complexity, Less Labor: EV powertrains have much less mechanical complexity than ICE powertrains. This simplicity could reduce the amount of labor, and thus jobs, associated with vehicle production.

Displaced Workers: EVs could erode employment in engines, transmissions, exhaust systems, and fuel systems, but create employment in batteries, electric motors, electronics, thermal systems, braking systems, and semiconductors. Employers and policymakers must commit to re-tool plants, re-train workers, and produce new components in the U.S.

New industry Actors: The production of new EV components could shift business and employment to non-auto companies that lack a large U.S. manufacturing base. This could undermine auto job quality by shifting work to employers with no history of manufacturing labor relations or to companies more likely to import components.

Turn Disruptions into Opportunities: EVs are an opportunity to reinvest in U.S. manufacturing and create new advanced manufacturing jobs. This opportunity will be lost if EV components are imported or made by low-road suppliers. What is needed is a proactive industrial policy to ensure a high-road approach to EVs.

Major Actors Investing in EVs: Automotive OEMs, suppliers, governments and investors all see EVs as an opportunity. Key stakeholders are setting ambitious EV targets and backing them up with pledges of massive investments.

The auto industry has seen many changes in the types of vehicles it sells. But the shift to EVs is not simply a change in consumer preference. It is a more fundamental shift in the way we power vehicles that could have disruptive implications effecting where and under what conditions vehicles are produced.

EV powertrains are simpler and require less labor than ICE powertrains, which could have a negative impact on auto employment levels, while new technologies could shift the auto value chain to companies outside traditional manufacturing or outside the country.

These issues will be of concern to all communities in the U.S. that rely on the auto industry for economic activity and jobs. But they can also be turned into an economic opportunity to reinvest in the U.S. manufacturing sector and create jobs building the vehicles of the future. This will require a coordinated, forward looking industrial policy that invests in U.S. workers and manufacturers promoting high-road practices, ensuring these new jobs are quality jobs.

Lower Complexity, Labor Hours

Electrification presents an opportunity to create innovative products, but the nature of EV production could also threaten employment levels in the automotive industry. This is due to the much lower mechanical complexity of EV powertrains. A UBS-commissioned teardown of a Chevy Bolt found that the EV powertrain had over 80% fewer

moving parts than a comparable ICE powertrain[24] and improved technology and design will allow for greater EV powertrain integration, leading to even fewer parts.[25]

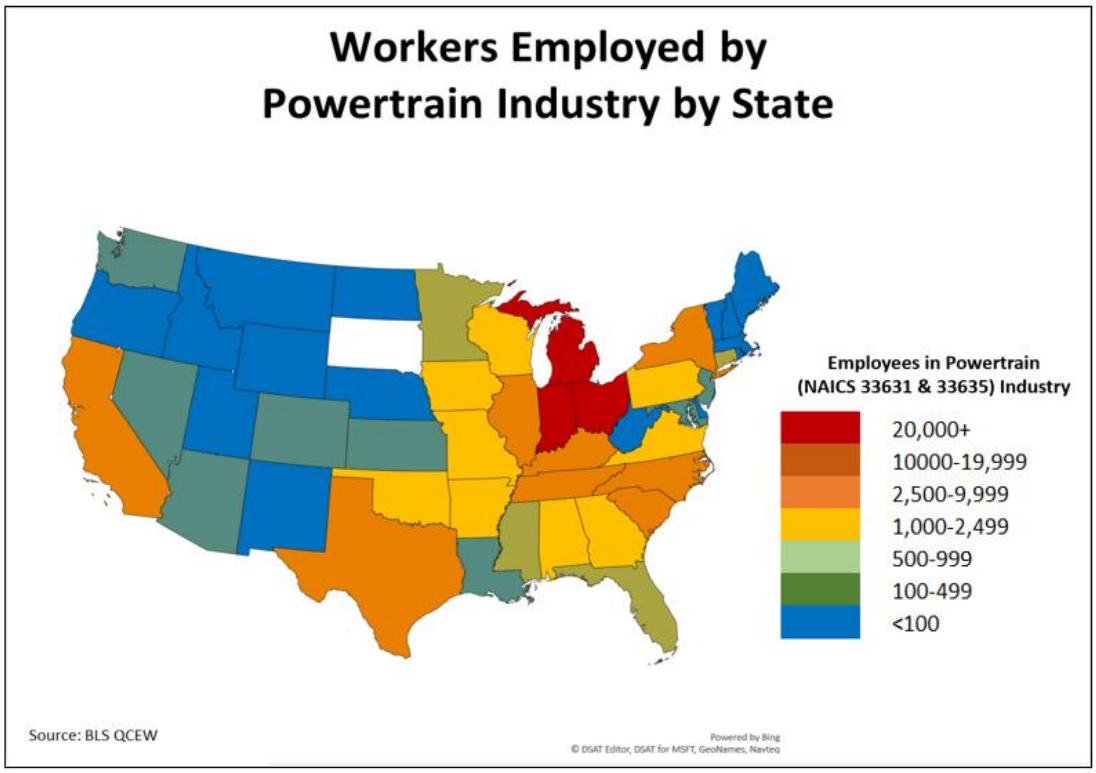
This simplicity could reduce the amount of labor, and thus jobs, associated with vehicle production. Even if OEMs choose to produce EV powertrains in-house, which remains an open question, there could still be a reduction in employment at automakers.[26] Ford has acknowledged this, telling its investors that the product simplification that comes from EVs can lead to a 50% reduction in capital investment and a 30% reduction in labor hours per unit compared to ICE production.[27] Similarly, Volkswagen CEO Herbert Diess has said that "The reality is that building an electric car involves some 30% less effort than one powered by an [internal combustion engine]. That means we will need to make job cuts."[28]

The impact could be even worse if the mechanical simplicity of the components leads OEMs to outsource the work to low-road suppliers that compete primarily on cost-reductions. This would reduce the quality of jobs in the value chain and the positive impact that auto employment has on the rest of the economy.

Displaced Workers

The shift to EV powertrains also presents a challenge to the employment of workers currently making ICE engines, transmissions, exhaust systems, and fuel systems. Tens of thousands of UAW members have high quality union jobs producing such components. If an increasing number of vehicles do not require these components, it could have a negative impact on employment levels at plants making these components.

What is required is commitments from employers to re-tool plants and re-train workers to maintain employment levels and allow American workers to make advanced technology vehicles. Policymakers should support reinvestment in these workforces and plants. Such support should be conditioned on employers maintaining employment levels, job quality standards, and freedom of association.



Additionally, the EV shift will bring new types of jobs building electric powertrains and advanced technology components. EVs could lead to growth in the production of batteries, electric motors, automotive electronics, thermal systems, advanced braking systems, and semiconductors. These new components represent a significant economic opportunity in advanced manufacturing. Industrial policy should be used to promote production of these components in the U.S. to offset any job loss in the ICE powertrain sector.

With the production of new components, it is possible that jobs will shift to new companies and regions. This will require policy support for workers that makes every effort to re-train and place workers in quality jobs, provide strong support during transition periods, and create robust government jobs programs to guarantee quality jobs for all those seeking work.

New Industry Actors

The shift to EVs could mean not just new components, but also new corporate actors. The importance of the production of batteries, power electronics, sensors, or semiconductors could shift business and employment from OEMs and Tier-1 suppliers to companies traditionally outside auto manufacturing and without a large U.S. manufacturing base. Such a shift could undermine job quality and the economic benefits that come with auto manufacturing.

Manufacturing jobs, particularly automotive manufacturing jobs, have provided premium wages and benefits compared to the rest of the private sector.[29] But there is nothing inevitable about the manufacturing sector providing quality jobs, since much of the manufacturing wage premium is due to higher union density and strong collective bargaining agreements in manufacturing.

This wage premium can be eroded by outsourcing and low-road practices.[30] If EV components are made by new actors without a developed U.S. manufacturing base, it could lead to more components being imported from overseas. And if these new employers have a poor history of manufacturing labor relations, or if they treat EV components as low-value commodity products, it could result in more production under low-road conditions, undermining job quality in the auto sector.

Turning Disruptions Into Opportunities

The shift to EVs represents a significant economic opportunity to reinvest in the U.S. manufacturing sector and create new advanced manufacturing jobs. The value of this economic opportunity will depend on where these components are made and under what conditions.

If the production of these components is primarily abroad, it will represent a significant shift of the automotive value chain outside the U.S. and a decline in job quality in the automotive industry, particularly if these components are imported from countries with low labor standards. Similarly, if automotive OEMs choose to outsource EV components to low-road suppliers who focus on cost reduction at the expense of wages, working conditions, safety, and quality, it will represent a decline in the quality of automotive employment and a reduction in the positive economic impact that manufacturing can have on the rest of the economy.

Instead, what is needed is a high-road transition to EV production that takes full advantage of this economic opportunity by ensuring that the shift results in quality automotive jobs and the positive economic benefits that manufacturing provides the rest of the economy.

Such a high-road approach would support research and development, as well as capital investment in the infrastructure and manufacturing capacity necessary to make sure EVs and EV components are produced in the U.S.

It would require commitments from automakers, perhaps with government support, to re-tool their facilities and train their workers to produce new energy vehicles and maintain employment levels as the industry shifts to new products. And it would require policies that promote higher wages, health and safety, and unionization, that ensure that autoworkers have quality jobs no matter how the components of a vehicle change, or which employer makes them.

Key Stakeholders See Opportunity

Automakers

Major automakers are setting ambitious EV product and sales targets and they are backing up those targets with billions in investment commitments. By January 2019, global automakers had pledged over $300 billion in spending on electrification.[31] Automakers have also set ambitious goals to introduce new EV models, the impacts of which will be in seen in the near future. Just through model year 2022, it is estimated that the U.S. market will see the launch of 53 new EV models and 150 models with some form of hybrid powertrain.[32]

- **General Motors** announced that it will begin making a profit on EVs by 2021,[33] introduce 20 new electric and fuel cell vehicles globally by 2023,[34] and sell 1 million EVs globally by 2026.[35]
- **Ford** announced it will spend over $11 billion by 2022 on electrification of its fleet and introduce 40 electrified vehicles and 16 full electric vehicles globally.[36]
- **Fiat Chrysler** announced it will invest $10.5 billion on electrification of its fleet through 2022[37] and introduce EV or hybrid versions of more than 30 models through 2022.[38]
- **Volvo** announced that starting in 2019 all new models will be EVs, plug-in hybrids, regular hybrids, or mild hybrids, including five new fully electric models between 2019 and 2021. Volvo has targeted 1 million electrified car sales by 2025.[39]
- **Volkswagen** announced it will spend $50 billion on EVs, AVs, and mobility services by the end of 2023[40], produce EVs at 16 production sites by 2022,[41] sell 1 million EVs by 2025,[42] and offer an electric version of all its models by 2030.[43]
- **Toyota** announced plans to introduce 10 new EVs globally by the early-2020s, offer an EV or hybrid version of every Toyota and Lexus model by 2025, and sell over 1 million EVs and hydrogen fuel cell vehicles by 2030.[44]
- **Daimler** announced it will spend $11 billion on electric vehicle development and develop 10 EVs by 2025.[45]
- **Nissan** announced plans to develop 8 EVs,[46] sell 1 million EVs and hybrids annually by 2022,[47] and have 20%-30% of its U.S. sales in EVs and hybrids by 2025.[48]
- **Changan** announced a $15 billion plan to launch 21 EVs and 12 plug-in hybrids by 2025 and phase out its production of gasoline engine vehicles.[49]
- **Great Wall Motor** plans to spend between $2 and $8 billion over the next 10 years on new EV models.[50]

Auto Suppliers

Automotive suppliers see significant business opportunities in the EV shift and are determined to demonstrate to investors that they will be ready for it with investments in new EV components.

- **American Axle** estimates it has over $2,500 in content opportunity per vehicle in hybrids and EVs for its powertrain and driveline components and will sell up to $200 million in EV components by 2021.[51]
- **BorgWarner** projects that by 2023 the company will have $3.8 billion in revenue from powertrain components for EVs and hybrids.[52]
- **Magna** estimates there is $2,300 in per vehicle content opportunity in EVs and $2,900 in per vehicle content for hybrids for the company's products.[53]

- **Delphi** estimates there is around $1,500 in content opportunity per vehicle for the company in EVs and $1,800 in content opportunity per vehicle for plug-in hybrids.[54]
- **Continental** projects that the company's addressable market in vehicle electrification will be worth €100 billion by 2025.[55]
- **Panasonic** projects that its automotive battery and power supply sales will increase by 88% between 2017 and 2019, up to nearly $7 billion dollars.[56]

GOVERNMENTS

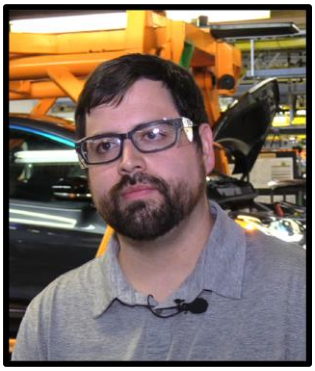
Governments around the world are mandating a transition to greener cars to help address climate change and have introduced a variety of EV targets that they hope to meet in the coming decades.

- **China** has set a target of seven million EV sales by 2025[57] and has discussed developing a timeline for banning gasoline and diesel-powered vehicles.[58]
- **European Union** has set the goal of halving the use of ICE vehicles in cities by 2030 and phasing them out of cities entirely by 2050.[59]
- **France** aims to end the sale of gas and diesel-powered vehicles by 2040.[60]
- **Germany** has set a target of 1 million EVs on the road by 2020[61] and is spending over $300 million to support the installation of 15,000 charging points by 2020.[62]
- **Norway's** Parliament has set a nonbinding goal that by 2025 all new cars should be EV, hydrogen fuel cell, or plug-in hybrids.[63]
- **India's** National Electric Mobility Mission Plan has set the goal of selling 6 to 7 million hybrids and EVs by 2020 and India's Minister of State for Power and Renewable Energy has set the goal of selling only EVs in India by 2030.[64]
- **California** has set the goal of 5 million zero-emission vehicles on its roads by 2030 and 250,000 charging stations by 2025.[65]
- **Colorado** has set the goal of having nearly 1 million EVs on the roads in Colorado by 2030.[66]

INVESTORS

- Venture capital investment has turned its sights, and its investment dollars, toward the shift to EVs. According to a January 2019 *Reuters* analysis, venture capital has invested over $20 billion in 250 start-ups related to vehicle electrification.[67]

A View from GM Orion, Home of the Chevy Bolt



Quentin Perea, Team Leader, Chassis, UAW Local 5960 - GM Orion Assembly

Role of workers in the shift to EVs

Everything is run down the same line, AV, EV, Sonic. In the beginning, we had issues that we had work through and overcome. But the workforce here is very experienced, and we are used to change, we were able to adapt to it pretty quickly… Any changes that needed to happen went through a plan for change process where the engineers, team and group leaders – everyone works together. We try to come up with the best solution, the most effective way to ensure quality, safety and protect the customer.

Importance of EVs to the plant

It's the most important thing, it gets talked about daily. We all recognize the industry is changing. More in the next five years, than the last 100 years, and we want to be a part of that.

Ethical Supply Chains

Make EV Supply Chains Right from the Start: Just because EVs help solve our environmental problems, does not mean we should excuse labor and ethical problems in the supply chain. EVs should be a win-win for workers and the environment all along the supply chain.

While the impact of the internal combustion engine on the environment has been well documented, the labor and environmental challenges associated with the electric powertrain are only starting to come into focus. Many of the essential minerals in long-range lithium-ion batteries are in limited supply and are often mined under inhumane conditions. The auto industry has a responsibility to ensure that it is not solving one problem by creating a new one. Therefore, there should be full transparency in every step of the supply chain, from when the minerals are mined, to the processing, installation in a vehicle, and finally to their recycling. Considering the disruptive nature of EVs, and the hopes pinned to the new technology, society has an opportunity to get it right this time.

Mining & Child Labor

The conditions in which cobalt and lithium are mined highlight the need for early and continued oversight and intervention. These elements are already being mined in mass quantities for the electronics industry – and the results are troubling. The growth of EVs will exponentially increase the demand for these elements.

Roughly 60% of the world's cobalt is mined in the Democratic Republic of Congo (DRC), where child labor and other labor abuses are prevalent, and injury and death are common. Approximately 40,000 children work as "artisanal" miners, working 10-12 hours a day, earning $1-2/day.[68] An estimated 100,000 cobalt miners use hand tools to dig hundreds of feet underground with few safety measures. Injury and death are common.[69] Chronic exposure to dust containing cobalt can result in "hard metal lung disease."[70] Wastewater has contaminated waterways, making them unfit for human consumption.[71]

In December 2016, the *Washington Post* highlighted the ethical and environmental problems associated with lithium mining in Argentina. The rich lithium deposits are located under indigenous lands and, not surprisingly, the people living there are not receiving proper compensation for the mining operations. Inhabitants have traded water shortages and environmental degradation for small investments and a few new jobs.[72]

Many automakers have stepped forward and pledged to keep child labor out of their vehicles. We must ensure that the whole industry takes this pledge, so a greener future is not built on the backs of children. Considering the enormous shifts in demand for minerals essential to EVs, the industry should anticipate those seeking to turn a quick profit at the expense of workers and the environment and enforce an ethical supply chain. Every element in a lithium-ion battery should be treated as a conflict mineral for disclosure purposes.

Recycling Batteries

Even with disclosure, countries with weak environmental and labor laws or non-existent whistleblower laws are bound to cheat the system. This why it is so important that the U.S. actively capture the U.S. battery aftermarket. Spent EV batteries can be repurposed for the home, the electrical grid and other uses. The processing of these batteries should be done in workplaces that protect both workers and the environment. If the government does nothing to promote and protect this burgeoning industry, it will move offshore – just as the lead battery recycling industry chased lax environmental regulations to Mexico.

Will U.S. Fall Behind in the EV Race?

OEM Investments: Automakers have pledged over $300 billion of investment in vehicle electrification, but where will this investment occur? For the U.S. economy to capture the economic potential of EVs, these investments must be made in the U.S.

China in the Lead: China is promoting domestic production of EVs and EV components by favoring domestic firms and using subsidies to create a strong domestic EV market. Because of these policies, the world's largest automakers are orienting their EV strategies toward China. China is positioned to dominate the lithium-ion battery market. 62% of battery manufacturing capacity is projected to be in China in 2023.[73]

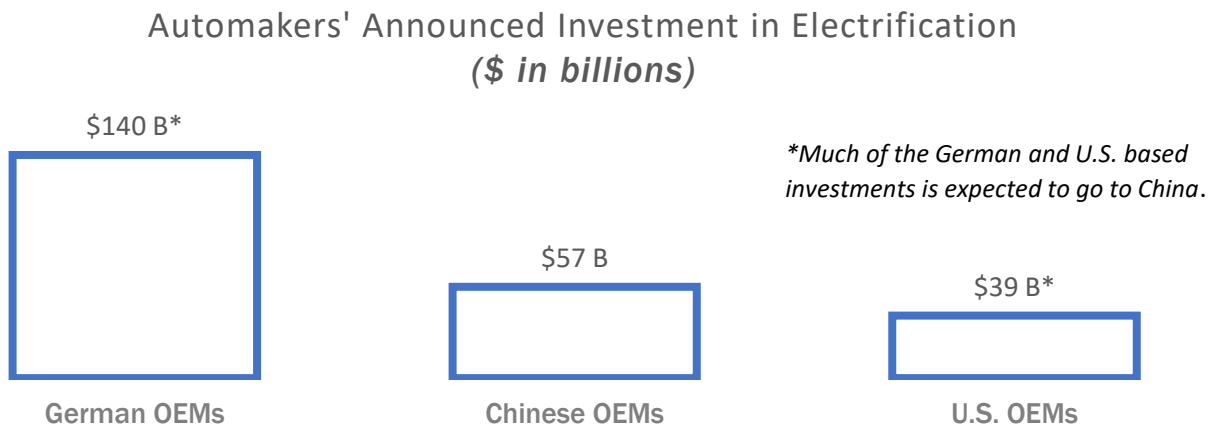
Europe Recognizes Battery Threat: The EU has recognized that EVs could lead to key vehicle components being imported. The European Commission created the European Battery Alliance to create a "complete value-chain" for batteries in Europe[74] by coordinating with governments and Europe's largest chemical, automotive, and engineering companies.[75]

Patchwork EV Policy in U.S.: U.S. policy has been a patchwork of federal and state policies, primarily focused on consumer incentives. What is needed is a comprehensive EV policy that supports consumer purchases and ensures that the EV manufacturing supply chain is in the U.S.

The massive investments pledged by automakers represents a strong commitment to the development and eventual mass production of EVs. But where those vehicles and components will be made remains an open question and will determine which economies benefit from the EV shift.

OEM Investment

A January 2019 *Reuters* analysis of automaker investment announcements found over $300 billion in pledged investment for vehicle electrification, with $39 billion announced by U.S.-based automakers, $139.5 billion from Germany-based automakers and $57 billion from China-based automakers. However, the report also found a large portion of those investments from U.S. and German automakers are destined for China to address the country's tightening EV regulations.[76]

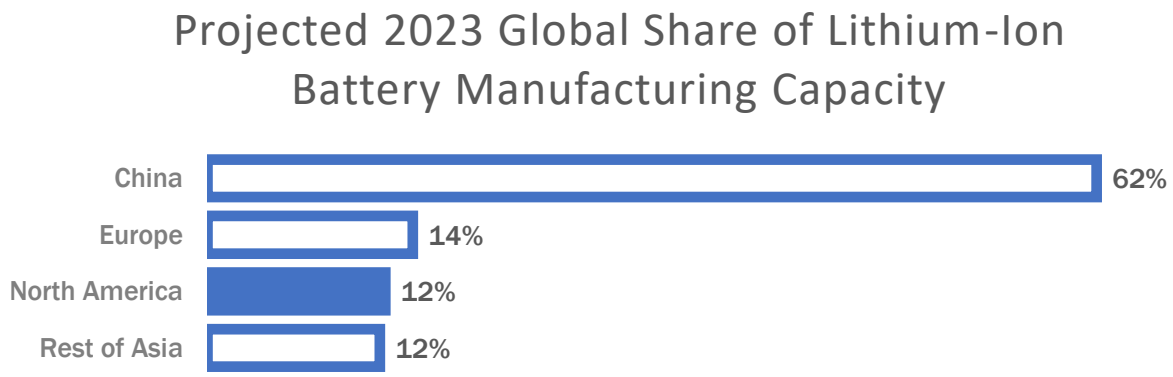


Source: Reuters[77]

Supply Chain Investment

Besides competition over where EVs will be assembled, there is a global competition for control of the new EV value-chain. The prime example of this race is lithium-ion batteries. Lithium-ion batteries are the most valuable component in EVs. With the growth of demand from EVs, global lithium-ion battery production capacity is expected to grow by 73%between 2017 and 2021[78] and the EV battery market could become over an $80 billion market by 2025.[79] This has sparked a race to develop the production capacity to meet growing battery demand and it is this race that will determine the geography of much of the EV value chain.

Based on developments so far, the U.S. is falling behind Asian and European countries in lithium-ion battery capacity. It is projected by 2023, 62% of battery manufacturing capacity will be in China and another 14% will be in Europe. North America will only have 12% of global battery production capacity and this production will be highly dependent on the success of one plant, the Tesla-Panasonic Gigafactory in Nevada.[80] Three of the top five battery companies will be based in China, along with LG Chem in South Korea and Tesla-Panasonic in the U.S.[81]



Source: Benchmark Minerals[82]

The EV value chain is not just battery mega-factories, it is an entire supply chain of associated battery and EV components that will determine which countries will benefit from the shift to EVs. To take just one example, battery separators are a component that prevents short-circuits by creating a barrier between the anode and cathode materials in a lithium-ion battery. The battery separator market is projected to be worth $2.7 billion by 2025, its growth driven by EV battery demand.[83] Nearly all the global manufacturing capacity for battery separators is in China, Japan, and South Korea.[84]

Falling behind on EV components and other advanced technology can shift the value chain out of the U.S. in ways that reduce the positive impacts of EVs produced in the United States. For example, the UAW-assembled Chevy Bolt made in Orion Township, Michigan, marked an important industry milestone by introducing a long-range, mass-market EV made in the U.S. Yet, a UBS-commissioned tear-down of the Bolt found that 56% of the value of the vehicle was produced by LG,[85] with much of these components produced overseas.

Will Industrial Policy Determine Winners And Losers?

How has China gotten out ahead on the battery arms race? China has developed an industrial policy that uses targeted, proactive policies to increase demand for EV batteries and channel that demand toward the purchase of domestic products.

Made in China 2025 Automotive Goals

- 1 million EVs and plug-in hybrids sold by 2020 and 3 million sold by 2025
- Chinese auto models to reach top 10 in global sales by 2020
- 2 Chinese OEMs to reach top 10 in global sales by 2025
- Reach 80% global market share in key EV systems, including batteries and electric motors
- 1,000 fuel cell vehicles produced by 2020
- 30% reduction in traffic accidents and 10% reduction in traffic fatalities through active safety and autonomous vehicles

Source: *The State Council of the People's Republic of China*

Made in China 2025 set ambitious targets for the new energy auto industry. This includes a sales target of 1 million EVs and plug-in hybrids in 2020 and 3 million in 2025. It calls for 80% global market share in EV batteries and electric motors by 2020, and to have two Chinese OEMs enter the global top 10 in sales by 2025.[86]

China has increased demand from consumers by offering a variety of purchase subsidies, tax breaks, and in-kind benefits to EV buyers. China has also stimulated demand through government procurement policies that mandate a portion of vehicle purchases are EVs or hybrids. As a result, China is leveraging its position as the world's largest automotive market and leading the world's largest automakers to orient their EV strategies toward China.

China has structured these incentives to support domestic production. For example, consumer subsidies are only applied to cars with government-approved batteries that favor Chinese-made batteries [87] and government procurement is directed toward domestically produced vehicles.[88]

To promote domestic supply of EVs, China has supported domestic EV production, domestic OEMs and required foreign OEMs to create 50-50 joint ventures with domestic OEMs. Beginning in 2019, China will set EV and plug-in hybrid production mandates for automakers. This will be based on a credit trading system where automakers earn credits through the production of qualifying vehicles or purchase such credits from EV producers.[89]

China's support of battery and EV manufacturing through industrial policy is part of a wider policy program to promote not just Chinese EV production, but also a wide range of domestic manufacturing sectors.[90]

It is not just China that sees the importance of the new EV value chain. The European Union has recognized that the lack of a domestic battery manufacturing base will undermine the region's competitiveness,[91] especially if the growth of EVs leads to key vehicle components being imported from elsewhere. The European Commission estimates that that the European battery market could be worth €250 billion by 2025.[92]

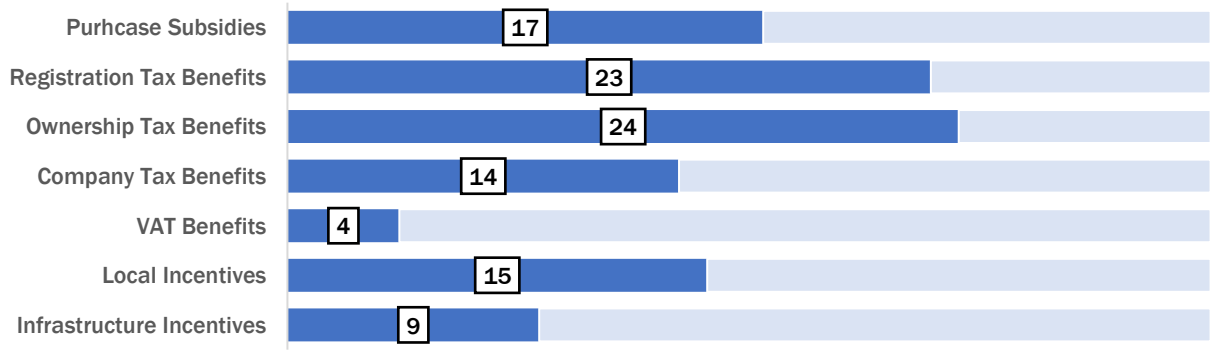
In a speech to the EU Members of Parliament, Vice President of the European Commission Maroš Šefčovič put the issue in stark terms. "*The European battery market is expected to create four to five million new jobs. These can be jobs here in Europe or somewhere else*".[93]

"So, either we create this [battery] market here or we import the batteries from somewhere else. I think we all agree that our own industry should benefit from our market. The European battery market is expected to create four to five million new jobs. These can be jobs here in Europe or somewhere else. I think we can all agree we could use these jobs here in Europe."
- Maroš Šefčovič, Vice President of the European Commission (2/20/18)

To address this concern, in October 2017, the European Commission announced the creation of the European Battery Alliance. The goal of the alliance is to develop a "complete value-chain" for manufacturing batteries in Europe [94] by coordinating with governments and stakeholders throughout the battery supply chain, including major European companies in the chemical, automotive, and engineering sectors.[95] The EU could support the alliance with up to 2.2 billion euros.

While it is still in the early stages, the EU's attempt at an ambitious, coordinated policy may be what is necessary to ensure that changes in the auto industry result in job creation domestically.

EU Member Country Incentive Policies



As of April 2018; Source: European Alternative Fuels Observatory[96]

In the U.S., the federal government and states have adopted policies to promote EVs. However, what is lacking is a comprehensive EV policy that not only supports consumer purchases, but also ensures that the EV manufacturing supply chain is in the U.S.

The federal government offers tax credits of $2,500 to $7,500 for the purchase of EVs and plug-in hybrids, with credits gradually phasing out for each manufacturer after they have sold over 200,000 qualifying vehicles.[97] GM and Tesla will be the first two automakers to hit the 200,000 qualifying vehicles milestone, after which both companies will see their EV incentives reduced over the following year, at which point they are no longer eligible.[98]

The federal government has also offered funding for EV and plug-in hybrid purchases to local governments through the Federal Transit Administration's Low or No Emission Vehicle Program.[99] And the 2009 American Recovery and Reinvestment Act provided grants and tax credits for EV and EV component manufacturing, as well as funds to make federal fleets more fuel efficient.[100]

Leadership on EV policy has often been fostered by the states. California has been a clear leader on the issue. The state has set a goal of 1.5 million EVs, plug-in hybrids, and hydrogen fuel cell vehicles on California roads by 2025.

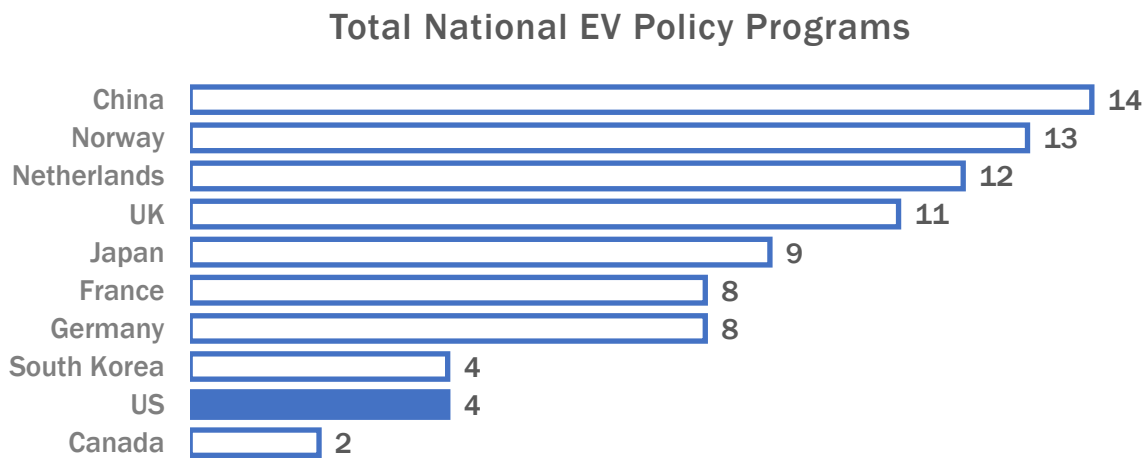
The governor has since added to that goal, calling for 5 million zero-emission vehicles on its roads by 2030 and 250,000 charging stations by 2025.[101]

California has pursued these goals by setting up a credit-based EV sales quota system for manufacturers, as well as consumer rebates, charging stations grants, utility time-of-use rate reductions, EV access to carpool lanes, consumer awareness campaigns, building code policies that promote EV charging infrastructure, and EV public fleet purchase mandates.[102]

The largest program aimed at influencing manufacturers rather than consumers is the Zero Emission Vehicle (ZEV) credit regulations adopted by 10 states. The ZEV regulations were established by California and followed by nine other states that are allowed by Section 177 of the Clean Air Act to adopt California regulations. These states are Connecticut, Massachusetts, Maryland, Maine, New Jersey, New York, Oregon, Rhode Island, and Vermont.

The regulations are aimed at vehicle manufacturers who must generate a minimum number of ZEV credits in proportion to their total sales. ZEV credits are generated through the sale of EVs, plug-in hybrids, or fuel cell vehicles, with credits varying by vehicle type and range. To create flexibility for manufacturers, they can obtain credits through the sale of vehicles or the purchase of credits from manufacturers who have over-complied with the ZEV sales quota. By 2025, this system will require automakers to generate credits equivalent to around 8% of sales.[103]

While select states have introduced a range of policies to promote EVs, the U.S. lags behind other countries on implementing comprehensive nationwide policies. In 2018, the International Council on Clean Transportation looked at 24 policy actions to promote EVs through industrial policy, regulatory policy, consumer support, and charging infrastructure. They found that when it comes to nationwide EV policy programs, the U.S. lags behind many leading countries in Europe and Asia.



Source: International Council on Clean Transportation[104]

NEW TECH WORKERS *ARE* WORKERS

New Technology Cannot Be an Excuse to Impose Outdated Working Conditions: We strongly believe that jobs in the auto industry must remain pathways to the middle class, with safe workplaces and good wages and benefits.

As the automotive and tech companies begin to transform the automotive industry, it is important to ensure that companies do not use this shift as an opportunity to turn its back on workers. While everyone is familiar with the high paid leaders in the tech industry – the vast majority of tech workers face a different reality. Electronics manufacturing is generally pushed to low-cost countries, where workers have few rights, while white collar jobs in developed countries are often staffed by temporary or contract workers.

We strongly believe that jobs in the auto industry must remain pathways to the middle class, with safe workplaces and good wages and benefits. Auto jobs must remain good jobs. Whatever the product, workers create value through their labor and that must continue to be respected and fairly compensated.

ENGINEERS AND PROGRAMMERS

Electrified powertrains require greater amounts of computer programming. This will only be amplified when coupled with autonomous technology, requiring hundreds, if not thousands, of programmers and engineers.

As the auto industry looks to optimize powertrain, battery and autonomous technology, that additional value will often be created by low-to-mid level programmers and engineers. These workers will often be asked to work as independent contractors with no job stability and limited to no benefits. UAW high-tech engineers and researchers have firsthand experience improving their workplaces – leading to better worker satisfaction and retention.

Currently though, in the tech industry, contingent employment relationships make it difficult, if not impossible to organize in the industry. Going forward, pressure must be put on these tech and auto companies to ensure that tech workers are afforded the same rights to good pay, benefits, stability and the right to organize as other workers.

INDUSTRIAL POLICY: CREATING A ROADMAP TO LEAD

Infrastructure: Vehicle electrification requires building a charging infrastructure for drivers and upgrading our energy infrastructure to meet electricity demand while ensuring electricity production is as green as the EVs themselves. This is an opportunity to create quality jobs to build, install, and maintain EV infrastructure.

Training: Workers will need new skills and displaced workers will need re-training programs. Strong industrial policy should include every effort to re-train and place workers in quality jobs, provide strong economic support for workers during transition periods, and create robust government jobs programs to guarantee quality jobs for all those seeking work.

Trade Policy: The economic potential of EVs will be lost if their components are imported. Advanced vehicle technology should be treated as a strategic sector to be protected and built in the U.S.

Investment Supports: Government incentives promote production of EVs and EV components in the U.S. Incentives should be used in a targeted way to promote a domestic EV supply chain and enforce high-road manufacturing practices.

Government Procurement: Government EV fleet purchases, from cars to public transportation, can be a tool to spur demand and create cleaner transportation. Such purchases should be used to promote high-road jobs by considering where vehicles are assembled, their level of domestic content, and the labor conditions under which they were produced.

Consumer Incentives: Consumer incentives are a tool to create a robust domestic EV market. This will encourage companies to orient their EV strategies toward the U.S. market. Consumer incentives should also be used to promote high-road domestic EV production. Incentives should be based on where the vehicle and its contents were produced and under what labor conditions.

Environmental Policy: Strong environmental standards can be structured as a win-win for the environment, workers, and the economy. Environmental policy should be used to address climate change while also promoting investment in future technologies that create quality jobs in the process.

What we are faced with is the potential for a significant long-term shift in the auto industry that could have implications for where and how vehicles are manufactured. This disruption could be an economic opportunity to create jobs in advanced vehicle technology. However, it could also result in a shift in jobs from high-road domestic manufacturing to low-road manufacturing here or abroad. To put the nation on a path to a high-road transition to EVs, what is needed is a proactive and forward-looking industrial policy.

Industrial policy helps to shape the economy to achieve stronger growth, compete globally and deliver higher living standards for its citizens. These policies can cover taxes, trade, labor law, wages, research and development, education, health care, infrastructure, monetary policy, and a host of other issues. In the case of the transition to EVs, the U.S. economy will be at risk of falling behind other nations if there is not a coordinated industrial policy to prepare for the shift.

INFRASTRUCTURE

The shift to EVs will require greater charging infrastructure. In January 2019, the International Council on Clean Transportation estimated that to meet 2025 targets, public and workplace charging infrastructure deployment will need to grow by 20% per year.[105]

Building out the U.S. charging network represents a significant opportunity to create quality jobs to domestically produce, install, and maintain this infrastructure, while also creating the infrastructure necessary to develop a robust EV market. If the U.S. is to effectively incentivize companies to locate the EV supply chain in the U.S., it will have to provide the infrastructure that will make the U.S. an attractive market for EV sales and production.

Thus far, the development of the EV infrastructure in the U.S. has been a patchwork, with investments coming from a variety of actors: automakers, governments, third-party providers and commercial and residential property owners. However, to mobilize the resources needed to create enough EV infrastructure, the government will have to play an active role in investment and coordination. Government involvement will be necessary to provide the 'patient capital' that is willing to invest in infrastructure that will provide benefits in the long term and to coordinate the various stakeholders with an interest in EV infrastructure. Government investment in EV infrastructure can also be used to ensure EV infrastructure development takes a high-road approach, creating good-paying jobs for American workers and ensuring that any employers receiving government support meet standards of compensation, health and safety, and freedom of association.

These policies should be a part of a wider infrastructure initiative, that includes repairing old roads, updating our water systems, electrical grid, mass transit, high-speed internet, bridges and high-speed rail. These improvements will put millions of Americans to work in good-paying jobs, reduce our environmental impact, improve Americans' health and quality of life, as well as make the U.S. an attractive place to invest.

TRAINING

The shift to EVs will also require an investment in the U.S. workforce. Skilled workers will be needed to compete in making the vehicles of the future and comprehensive re-training programs will be needed to prepare displaced workers for this shift to new technology.

Federal and state governments must invest in improving and expanding vocational training and apprenticeship programs, with an active role for unions to ensure quality training and high-road working conditions. These programs must provide workers not only with the skills to make EV vehicles and components, but also prepare them for the changing nature of manufacturing work, as automation and other new technologies change the production process. The government should also incentivize the development of joint training and apprenticeship programs between employers and unions and push employers to commit to re-training workers displaced by new technology.

TRADE POLICY

Trade policy will be important in determining the role that the U.S. economy will play in the EV industry. While the shift to EVs represents an economic opportunity to reinvest in U.S. manufacturing, that opportunity will be lost if EVs and EV components are imported from other markets. This would represent a significant shift of the automotive value chain outside the U.S. and a decline in the job quality in the automotive industry, particularly if these components are imported from countries with low labor standards. Trade policy that enforces protections for workers, consumers, and the environment keeps the U.S. economy from being undercut by countries using low-road methods to produce vehicles or components.

Trade policy should be used to create trade agreements that include strong, enforceable language to discourage outsourcing and protect workers, consumers, and the environment. We need to establish and enforce meaningful labor standards because it is the right thing to do from a human rights perspective but also from an economic one. Poor labor standards in foreign nations have a real impact on the U.S. When companies relocate to take advantage of workers who lack basic rights and are underpaid, it leaves manufacturing communities devastated and puts downward pressure on U.S. wages, benefits and working conditions. If companies locate EV production in low-cost countries, U.S. workers will be hurt, and the U.S. economy will be behind the curve on future automotive technology.

To that end, the U.S. should amend current trade pacts and only enter into new pacts that require: independent democratic unions; strong environmental and health and safety standards; balanced trade; and protection for strategic industries. The pacts should also include language stating that if any of these standards are violated, punitive tariffs will be imposed.

Finally, advanced vehicle products developed through U.S.-based research and development and governmental support should be manufactured in the U.S. as well. This will help ensure U.S. manufacturers remain industry leaders and American workers will share in that prosperity. Specifically, we believe the following manufacturing sectors should be protected within our trade policy:

- Advanced powertrain vehicles
- Automotive semiconductors and computers
- Advanced battery technologies
- EV battery thermal control systems
- Electric motors, drives, axles and related components

Investment Supports

Government incentives in support of EVs should be broad based and include both consumer incentives that support the EV market and incentives to expand domestic production of EVs and EV components.

Incentives to companies, whether in the form of grants, loans, or investment tax breaks, should be used in a targeted way that rewards companies for re-tooling production facilities to maintain employment levels, re-training workers for new products, establishing or expanding EV production facilities, and developing domestic supply chains. Such incentives can be used to promote domestic EV manufacturing while also enforcing high-road corporate practices by making incentives conditional on labor peace, wage and benefit standards, health and safety requirements, and environmental standards.

Taxpayer incentives should not simply be used as tools for states to compete over attracting or retaining individual high-profile plants. That approach simply pits states against each other, creates a race to the bottom that hurts taxpayers, and results in a patchwork of inefficiently used incentive funds. What is required is a coordinated, long-term approach to investing that pushes manufacturers to invest in domestic production and component sourcing.

Incentives should also be used in a coordinated way that commits manufacturers to developing the domestic supply chain. Too often pricing and capital spending pressure is pushed down the supply chain to smaller domestic suppliers, hurting the U.S.-based supply base and encouraging larger firms to import components.[106] This will be particularly true if the U.S. supply base is not prepared to produce the new components used in EVs. A coordinated manufacturing investment policy should help increase the domestic content of EVs by supporting supplier capital investment to produce new components and pushing larger firms to commit to domestic supply chains.

Germany offers an example of how industrial policy support that develops the entire supply chain is crucial to manufacturing success. Germany may be well known for the success of its large manufacturers, such as BMW, Volkswagen, or Siemens, but midsized German companies play an import role in the country's manufacturing success. Germany's federal government has programs dedicated to supporting the country's small and medium-sized companies, known as the *Mittelstand*, the majority of which are suppliers to other firms. These programs help firms secure access to capital and technology, work with unions to provide vocational training, and help domestic firms seek export markets.[107]

Government support for research and development will also be important to U.S. competitiveness. However, the economic benefits of this research must translate into good jobs for workers. If research and development is done domestically, but mass production is done abroad, then the U.S. economy will only capture a small portion of the economic benefits of the EV revolution and few U.S. workers will benefit. Research and development support should promote domestic commercial production.

Procurement Policy

Government EV fleet purchases, whether it is cars or public transportation, can be a tool for spurring demand and creating cleaner transportation. And EVs are well-suited for fleet purchases due to their operating cost advantages.[108]

These purchases can also be a tool to push EV production toward a high-road path, by conditioning such purchases upon standards of social responsibility. Such purchasing programs can encourage domestic high-road production of EVs by adopting purchasing policies that consider where the vehicle was assembled, the level of the vehicle's domestic content, and the conditions under which the vehicle and components were produced, including wages, benefits, health and safety, and freedom of association. Such purchase policies would incentivize manufacturers to establish a production footprint in the U.S. and ensure that production has the positive economic impacts that come with quality manufacturing jobs.

There is already a model for these types of policies that is being promoted by Jobs to Move America (JMA). JMA is a national organization that promotes tying public transportation procurement to job creation and high road employment practices. More information on JMA can be found at *jobstomoveamerica.org*.

Consumer Incentives

Similarly, consumer incentives for vehicle purchases or residential charging installations are a policy tool that can increase the adoption of cleaner vehicles and nurture this new market. Consumer incentives should also be used to promote domestic high-road production of EVs by considering where the vehicle was assembled, the level of the vehicle's domestic content, and the conditions under which the vehicle and components were produced, including wages, benefits, health and safety, and freedom of association.

Policies To Protect Displaced Workers

The shift to EV powertrains also presents a challenge to the employment of workers currently making ICE engines, transmissions, exhaust systems, and fuel systems. If an increasing number of vehicles do not require these components, it could have a negative impact on employment levels at plants making these components.

What is required is commitments from employers to re-tool plants and re-train workers to maintain employment levels and allow American workers to make advanced technology vehicles. Policymakers should support

reinvestment in these workforces and plants. Such support should be conditioned on employers maintaining employment levels, job quality standards, and freedom of association.

With the production of new components, it is possible that jobs will shift to new companies and regions. This will require policy support for workers that makes every effort to re-train and place workers in quality jobs, provide strong support during transition periods, and create robust government jobs programs to guarantee quality jobs for all those seeking work.

Environmental Policy

As a North American union with hundreds of thousands of members in manufacturing, we have a responsibility to address global warming and climate change. Consumers and governments worldwide expect greener products. They will be made somewhere. Europe and China are already developing advanced green technologies through strategic policymaking. The U.S. must be a producer and exporter of advanced technology products, not jobs. We must act to safeguard the future of our jobs, families, communities, and our planet.

The UAW rejects the idea promoted by climate change deniers that fuel efficiency and environmental regulations lead to closed plants and lost jobs. Fuel-efficient vehicles, clean energy, clean manufacturing, renewable energy and other advanced technologies are an opportunity to create new middle-class jobs with good pay, good benefits, and economic security. Our economy is changing in real time and UAW members already design and build advanced cars and trucks; advanced engines and transmissions, lighter materials and other advanced, green products.

Policies that promote higher environmental standards are good for the environment and for our economy. By pushing companies to invest in new technologies to meet more stringent environmental standards, regulations ensure the companies in the U.S. are keeping up with global competitors. This can create an economy that is good for the environment, American workers, and U.S. manufacturing and competitiveness.

The 2012 fuel economy standards are evidence that it is possible to balance competing demands and craft smart policy that considers the needs and concerns of all stakeholders. The 2017-2025 CAFE standards have provided regulatory certainty to the automakers and were coupled with loans and grants that helped manufacturers make the necessary investments in advanced vehicles technologies. As a result, today thousands of UAW members are making the vehicles of the future.

A similar approach can be applied to new energy vehicles. Policies that promote the EV market, support domestic EV production, and develop the necessary infrastructure can be implemented in a way that benefits workers, the environment, and the economy.

Conclusion: Will Disruption Be A Threat or An Opportunity?

Industry analysts, investors, and automakers may disagree about the speed and scale of EV adoption, but there is industry consensus that EVs will make up a larger share of the auto market in the coming years. The shift to EVs is different from previous shifts in consumer preference, because it involves a fundamental change in the key components that power the vehicle.

Such a change will have disruptive implications for the auto industry. These could include changes in where and under what condition vehicles and key components are made, employment declines in powertrain manufacturing, and the entrance of new corporate actors without a U.S. manufacturing base.

These disruptions could be an opportunity to re-invest in U.S. manufacturing to produce the vehicles of the future under high-road working conditions. But this opportunity will be lost if components are imported from other economies or shifted to low-road employers that pay wages below U.S. manufacturing standards. U.S. policymakers must be prepared to respond to these changes, to turn the disruptions of electrification into economic opportunities.

What is needed is a proactive industrial policy that promotes the production of EVs and their components in the U.S. under higher road conditions that benefit American workers and the communities that rely on manufacturing jobs.

Infrastructure: Vehicle electrification requires building a charging infrastructure for drivers and upgrading our energy infrastructure to meet electricity demand while ensuring electricity production is as green as the EVs themselves. This is an opportunity to create quality jobs to build, install, and maintain EV infrastructure.

Training: Workers will need new skills and displaced workers will need re-training programs. Strong industrial policy should include every effort to re-train and place workers in quality jobs, provide strong economic support for workers during transition periods, and create robust government jobs programs to guarantee quality jobs for all those seeking work.

Trade Policy: The economic potential of EVs will be lost if their components are imported. Advanced vehicle technology should be treated as a strategic sector to be protected and built in the U.S.

Investment Supports: Government incentives can promote production of EVs and EV components in the U.S. Such incentives should be used in a targeted way to promote a domestic EV supply chain and enforce high-road manufacturing practices.

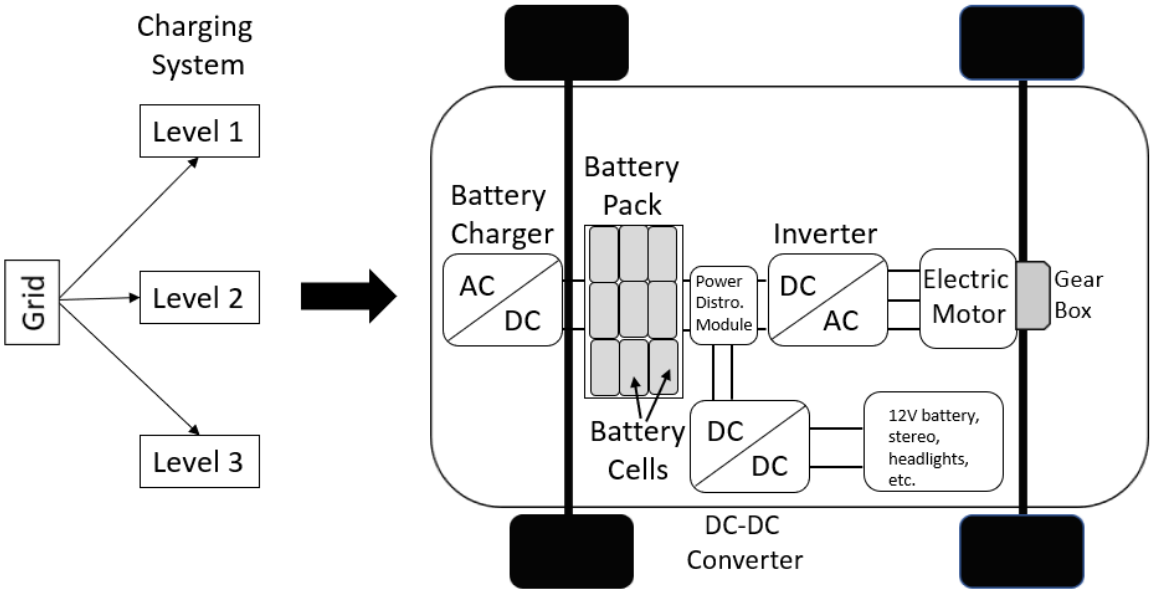
Government Procurement: Government EV fleet purchases, from cars to public transportation, can be a tool to spur demand and create cleaner transportation. Such purchases should be used to promote high-road jobs by considering where vehicles are assembled, their level of domestic content, and the labor conditions under which they were produced.

Consumer Incentives: Consumer incentives are a tool to create a robust domestic EV market. This will encourage companies to orient their EV strategies toward the U.S. market. Consumer incentives should also be used to promote high-road domestic EV production. Incentives should be based on where the vehicle and its contents were produced and under what labor conditions.

Environmental Policy: Strong environmental standards can be structured as a win-win for the environment, workers, and the economy. Environmental policy should be used to address climate change while also promoting investment in future technologies that create quality jobs in the process.

APPENDIX A – IMPORTANT EV COMPONENTS

Each automaker is experimenting with EV design and component integration. These decisions depend on the level of investment, manufacturability, battery technology and chemical makeup, and relationships with suppliers. Despite the differences between EVs, they all share common propulsion components. The following components – either as standalone component or part of an integrated module – are part of every EV currently on the road.



Charging Modules – These are the internal receptacles where the vehicles receive an electric charge from an outside source. Vehicles vary on the charge speed depending on range, battery type and size, and electrical components and materials. All EVs on the road can accept a Level 1 or 2 charge. Level 3 charges, or quick charges, are generally only available on EVs with extended ranges.

Level 1 and 2 charging ports have been standardized across nearly every automaker – except Tesla, who has its own port design, but provides owners an adapter so it can use standard Level 1 and 2 chargers.

There are currently three different port designs for Level 3 chargers: CHAdeMo (Nissan, Mitsubishi and Kia), CCS: Combined Charging Standard (BMW, GM, Ford, Mercedes, and VW), and Tesla's Supercharger. Within Level 3 charging there are still further distinctions based on steps in kWs (50kW, 150kW and 350kW). No cars can currently take a 350kW Level 3 charge, but its anticipated that Porsche, Audi and VW will introduce models that can soon.

Each charging level steps up the voltage, in turn shortening the charging time:

> **Level 1:** Cord connects to regular household outlet of 120V, 15-20A. Charge time can take 7 to 30 hours, depending on the battery size and internal wiring and components in car.
>
> **Level 2:** Found in both residential and commercial applications. Cord comes off a stand-alone charging unit uses two-phase 240V, 30-80A to charge the vehicle. Charges a vehicle in approximately four to five hours.

Level 3: Due to its three-phase electrical requirement, in the U.S. these are only found in commercial spaces. Charges at 400-600V, up to 300A can charge an EV to 80% in about 30 minutes.

The modules also include an AC/DC converter/rectifier which changes the AC power coming from Level 1 and 2 charges and converts it to DC for the battery. Currently, Level 3 power is provided as DC power, so it does not need to be converted.

Battery cells – lithium-ion batteries all share the same basic construct, thin layers of cathode and anode with a separator. How these elements are packaged account for the difference in appearances of EV battery cells. There are currently three different battery cell formats:

Cylinder cells – these cells take cathode and anode layers and roll them into a cylinder. The result is like an elongated C battery used in flashlights. Tesla currently sources these types of cells from Panasonic.

Pouch cells – these cells are like oversized laptop battery packs. They are generally only one or a few stacks high and must be enclosed in a protective case. GM and Nissan use pouch cells in the Volt, Bolt and Leaf. GM sources its cells from LG Chem, while Nissan sources from Automotive Energy Supply Corp (AESC).

Prismatic cells – like pouch cells, but instead fold the stack to fit within a rectangular package. The VW e-Golf and BMW i3 uses this arrangement, sourcing the cells from Samsung.

Each automaker uses its own specific cocktail of elements to address cost, performance, life span and safety. The primary materials used are graphite, nickel, aluminum, copper, lithium, cobalt and manganese. The EV market currently uses five types of lithium-ion batteries:

Lithium manganese oxide (LMO) – Nissan Leaf, Chevy Volt, BMW i3

Lithium iron phosphate (LFP) – Hybrids, plug-in hybrids, BYD electric bus.

Lithium nickel manganese cobalt oxide (NMC) – Chevy Bolt, Tesla Powerwall

Lithium nickel cobalt aluminum oxide (NCA) – Tesla Models S, X, and 3

Lithium titanate (LTO) – Mitsubishi MiEVs, Proterra Electric bus.

Lithium, cobalt and nickel have been experiencing price fluctuations as tech and auto companies compete for the same resources. In the last year, several automakers have attempted to lock down long-term pricing arrangements for lithium and cobalt.

Solid-state lithium-ion batteries – Technology being developed to potentially replace current lithium-ion batteries. The batteries switch out the flammable liquid electrolyte found in today's batteries and replace it with a solid electrolyte reducing the batteries volatility and weight. Several automakers are pursuing the technology, but to date, only small solid-state batteries used in electronics has been possible.

Battery Packs – Battery cells are bundled into modules, and those modules are used as building blocks for the EVs battery. Battery packs are designed for the specific car to match the design structure.

Thermal Management – Battery temperature is important to the safety, performance, reliability and life of the battery. Warm climates diminish the life of the battery, where cold climates decrease the capacity of the battery. Most importantly, active thermal management can limit thermal runaway and potential fires. Automakers have not

come to a common solution, developing their own approach addressing cost, size, weight, reliability, manufacturability and serviceability factors.

Power Distribution Module – As the name implies, takes power from the battery and directs it to the car's different components. Can have the DC-DC converter and/or inverter integrated within.

DC-DC converter – Steps down high voltage battery charge to 12v to charge separate 12v battery that powers headlights, stereo, seat heaters, etc. Replaces ICE's alternator.

Inverter – Converts DC battery power to AC power. Providing power and control to the electric motor – as well as other ancillary AC needs. The inverter replaces the Engine Management System in ICEs.

Electric Motor – An electric motor is a far simpler motor than a traditional internal combustion engine – both in terms of manufacturability and operation. According to UBS, the Chevy Bolt's e-motor has three moving parts, while a VW Golf's combustion engine has 113.[109] Modern brushless electric motors are free from the periodic maintenance required of ICEs, as there is no oil or spark plugs to change.

There are two types electric motors used in EVs: AC induction and permanent magnet synchronous AC induction motors use electricity to generate magnetic currents inside the motor, where permanent magnet motors do not. Rather they use rare earth magnets, creating a magnet current that is always on. AC induction motors are generally only found in performance vehicles, since they can create greater power. Whereas the Tesla Model S uses AC induction, the Chevy Bolt, Nissan Leaf and Tesla 3 all have permanent magnet motors, where the Tesla Model S uses AC induction.

Despite the electric motor being simpler than ICEs, there is still plenty of room for improvements. Automakers are experimenting with light weighting, improved performance of different rare-earth magnets, manufacturability, and integration. For example, e-axles integrate the electric motor, the gear box, the differential, suspension and an axle into one unit.

Gearbox – EV gearboxes are far simpler than an ICEs multi-geared transmission. An EV gearbox is a simple single-speed fixed gear used to translate rotational speed down to the final drive ratio. Since it is only one fixed gear, there is no need for a clutch, greatly reducing the wear and tear on the unit.

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ABOUT THE UAW

The International Union, United Automobile, Aerospace and Agricultural Implement Workers of America (UAW) is one of the largest and most diverse unions in North America, with members in virtually every sector of the economy.

UAW-represented workplaces range from multinational corporations, small manufacturers and state and local governments to colleges and universities, hospitals and private non-profit organizations.

The UAW has more than 400,000 active members and more than 580,000 retired members in the United States, Canada and Puerto Rico.

There are more than 600 local unions in the UAW. The UAW currently has 1,600 contracts with some 1,000 employers in the United States, Canada and Puerto Rico.

A unique strength of the UAW is the solidarity between its active and retired members. A solid majority of the union's retirees stay actively involved in the life of their union, participating in retiree chapters and playing a vital role in the UAW's community action program.

Since its founding in 1935, the UAW has consistently developed innovative partnerships with employers and negotiated industry-leading wages and benefits for its members. UAW members have benefited from a number of collective bargaining breakthroughs, including:

- The first employer-paid health insurance plan for industrial workers.
- The first cost-of-living allowances.
- A pioneering role in product quality improvements.
- Landmark job and income security provisions.
- Comprehensive training and educational programs.

A Voice For All

As impressive as it is, the UAW's success record at the bargaining table is only part of the story. From our earliest days, the UAW has been a leader in the struggle to secure economic and social justice for all people. The UAW has been actively involved in every civil rights legislative battle since the 1950s, including the campaigns to pass the Civil Rights Act of 1964, the Voting Rights Act of 1965, the Fair Housing Act, the Civil Rights Restoration Act of 1988 and legislation to prohibit discrimination against women, the elderly and people with disabilities.

The UAW also has played a vital role in passing such landmark legislation as Medicare and Medicaid, the Occupational Safety and Health Act, the Employee Retirement Act and the Family and Medical Leave Act. In Washington and state capitols, the UAW is fighting for better schools for kids, secure health care and pensions for retirees, clean air and water, tougher workplace health and safety standards, stronger worker's compensation and unemployment insurance laws and fairer taxes.

The UAW's commitment to improve the lives of working men and women extends beyond our borders to encompass people around the globe. Through vigilant political involvement and coordination with world labor organizations, we continue to fight for enforcement of trade agreement provisions on human and worker rights, fair labor standards and a new approach to international trade — one that raises the quality of life for working people worldwide.

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