BUSINESS SWEDEN

U.S. AUTOMOTIVE MARKET STUDY

REPORT FOR THE SWEDISH ENERGY AGENCY

JULY 2019

An assignment from the Swedish Energy Agency
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Disclaimer: This report reflects the view of the consultant (Business Sweden) and is not an official standpoint of the agency.

EXECUTIVE SUMMARY

The U.S. automotive market, like the overall global market, is truly in a transition phase. As production levels slow from recent highs in the car market and levels steady in the heavy vehicle market, automakers are investing in different visions of the future. Many OEMs are still focusing on enhancing traditional internal combustion engine-based vehicles, with some adjusting their product mix and hedging towards hybrid platforms given the uncertainties around further technological and cost-reducing developments. Still, others are truly committing to electrification via battery and fuel cell technologies with dedicated platforms, albeit to a less aggressive degree than in much of Asia and Europe. While the local political and regulatory forces pushing companies to innovate to cleaner technologies are in place to some degree, the consumer appetite and openness to new technology adoption are still in early stages due primarily to infrastructure and technological deficiencies and cost reasons. While difficult to predict with precision, it is clear that a mix of powertrain technologies will be competing within automotive fleets in the medium-term and likely still in the next ten to fifteen years as expected by the majority of the U.S. automotive executives.

The electrification market continues to gain traction locally especially in certain regions of the U.S., primarily along the West Coast. There are still various challenges to mass adoption across the country, and growth forecasts range widely. While still at very low levels, fuel cell technologies are also being deployed and there is a comparable amount of interest among passenger car OEMs to electrification, however interest is particularly strong from the heavy vehicle customers with some new entrants in the field. Driven both by customer and regulatory demands, automakers will continue to invest in optimizing ICE technologies in the short-term as part of the trends towards more hybrid platforms and flexibility that consumers appreciate to help meet regulatory goals. Lastly, lightweighting will continue to be a key part of ICE and electrification strategies with companies and their customers having strong incentives to reduce overall weight on across vehicle types.

Considering the overall attractiveness in the short-term or long-term when considering investment patterns, segment forecasts and the perceived technological stages along their development curve, Business Sweden investigated more specific opportunities within the prioritized areas of lightweighting, battery technology for passenger cars and fuel cell technology for heavy vehicles. Based on in-depth interviews and market feedback, the most relevant opportunity areas include those with technical expertise in lightweighting for seating suppliers and sub-suppliers, as well as heavy powertrain components such as engine and battery enclosures. More generally, companies with expertise for weight-reduction for interior and powertrain components are in high demand.

Within electric battery and related systems, much of the short-term focus is based upon enhancing the efficiency of lithium-ion batteries for which OEMs and battery companies are focusing their commercial strategies. However long-term, vast funding is being deployed for solid-state lithium batteries which are an eventually more sustainable and efficient solution.

Within the fuel cell segment, there are opportunities for technical and engineering services companies with expertise in fuel cell stack design and manufacturing processes, as well as fuel tank design and compressed gas expertise. Many of the companies working on the challenges in this emerging area are from non-automotive areas.

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BACKGROUND AND INTRODUCTION

MOTIVATION AND OBJECTIVE

To help support a greater awareness of opportunities for companies in the U.S. automotive market, Business Sweden is supporting the Swedish Energy Agency by conducting a study to provide an overview of the market and an understanding of key trends and opportunities within the prioritized segments of the automotive industry. The main objective of the research and analysis is to identify business opportunities for which the Swedish Energy Agency will be able to further investigate and pursue with relevant Swedish companies.

The automotive supplier segments of higher priority and interest that Business Sweden has analyzed in this report include the categories of

- Battery Systems and Technology for Electric Vehicles
- Fuel Cell Technology
- Weight-reduction
- Combustion Engine Technology (relevant for alternative fuels and electric hybrid vehicles)

This has resulted in a study aimed at providing an overview of the U.S. automotive market, an analysis of segments of interest and finally identifying specific opportunities for Swedish companies (from both a collaboration and export promotion perspective) in these areas.

INTRODUCTION

As the world's largest consumer market, the U.S. continues to rely heavily on the automotive industry for the transports of people and goods. The overall economy and the automotive market have a strong interdependent relationship, and the U.S. remains a major automotive market for the world's leading players throughout the value chain. In fact, the automotive industry is the country's largest manufacturing sector and is responsible for approximately three percent of the country's overall output.[1] The automotive market is also the country's third largest investor in R&D processes as the U.S. industry invested approximately 21 BUSD in 2017 within this area, of which about 40 percent was conducted by suppliers. The industry consists of more than 5,600 suppliers producing parts throughout the value chain.[2] As new technologies are integrated, non-traditional automotive companies are becoming part of the ecosystem. Today, there are roughly 36 OEMs in the light and heavyoduty markets with additional startups coming to market in recent years.

A downside to the U.S. market's reliance on the industry and automotive transport is the overall environmental impact. In fact, light and heavy-vehicles account for 82 percent of the country's transportation fuel usage.[3] As the heavy majority of vehicles are still powered by petroleum-based fuels, their usage is closely tied to the country's overall emissions and is an established focus area for environmental initiatives among federal and state regulators. Still, the politics within the U.S. remain divided on the topic with vast differences between the republican and democratic parties.

The primary mechanism through which the federal government encourages automakers to promote developing and manufacturing lower efficiency vehicles are the Corporate Average Fuel Economy (CAFE) regulations, first introduced in 1975. The National Highway Traffic Safety Administration (NHTSA) has authority to set CAFE standards for cars and for light vehicles and sets fuel consumption standards for medium- and heavy-duty trucks and engines. The EPA measures vehicle fuel efficiency as well as engine emissions as part of their activities. In addition, California and its California Air Resources Board (CARB) have driven technological change by incentivizing lower emission levels for vehicles as it has been exempted to set its own rules since 1968. Its requirements are among the strictest in the world for automakers.

The power and role of the federal and state authorities with regards to influencing the industry has been divided, however the Trump Administration is pushing towards the federal government assuming the exclusive role in regulating fuel economy and is currently negotiating with California on this matter. In parallel they are also pushing for less ambitious annual decreases in fuel economy for automakers from nearly 50 miles per gallon on average to just 37 mpg by 2026 as set under the Obama administration. The uncertainty regarding the future direction of the standards and geographical acceptance of their vehicles has created a troubling situation for OEMs as they work with their strategies regarding vehicle platforms and investments towards electrification, fuel cells, internal combustion engines, and other areas.[4]

Other major trends shaping the overall U.S. economy and automotive industry includes the ongoing uncertainty around U.S. protectionism towards traditional trade partners Canada and Mexico, as well as the EU and China. The automotive industry has been a major target of tariff threats in negotiations with the European Union and other markets, and slight changes to the automotive sector requirements were a major component of the U.S. Mexico Canada Agreement (USMCA) agreement that was negotiated to supersede the North American Free Trade Agreement (NAFTA). This was a positive development as automotive supply chains are highly integrated within North America.

To date, the overall uncertainty has caused some automakers to postpone or redirect investment decisions to other regions and shift their automotive footprints to help insulate them in the event of sustained high tariffs. Still, there is a climate of optimism today that the trade situation will be resolved between the U.S. and China in the near future, as well as that between the U.S. and EU where steel tariffs remain in place. With a high degree of uncertainty still in the U.S. economy and a slowing overall growth rate consensus prediction of 2.4 percent in 2019 (down from 3.1 percent in 2018), there is an increased risk of a recession facing the U.S. and global economy with a potentially major impact on the domestic automotive market.[5] A brief summary of some of the key initiatives that have impacted the U.S. automotive industry under Trump are below -

Policy Area	Trump Administration's Stance	Status Update
 NAFTA* Renegotiations	Trump blamed NAFTA for the loss of US manufacturing jobs and initiated a renegotiation of the 24 year old trade agreement	United States Mexico Canada Agreement (USMCA) was drafted in October 2018 but still needs to be ratified by each country to take effect
 Increased Protectionism	Reducing the U.S. trade deficit is one of the main economic goals of the Trump administration	Trump introduced tariffs on imported steel and aluminum and hefty tariffs on Chinese imported goods. Has threatened to impose tariffs on EU passenger cars. There is optimism of an agreement with China
 Climate Change	Trump administration finds the Paris Climate Accord to be unfair for American businesses and workers. The administration continues to take a passive view on existence of climate change	Trump withdrew the U.S. from the Paris Agreement in June 2017. The president is now looking to relax automotive emission requirements

Figure 1. Summary of Political Trends Impacting Manufacturers under the Trump Administration

As the U.S. automotive market continues to shift, it is important to analyze and isolate the different segments. The report first analyzes the dynamics of the Passenger Car and Commercial Vehicle markets with an overview of the industry and then examines more carefully the key sustainable technology segments. The report continues with a comparison of the segments for their potential relevance for suppliers. After evaluating the segment potential in the medium and long-term, the report analyzes lightweighting, electric vehicle technology for the passenger car segment, and fuel cell technology for heavy vehicles for specific opportunity areas. The report concludes with guidance and overall recommendations to companies looking to enter the U.S. market within specific identified opportunity areas

MARKET OVERVIEW

PASSENGER CAR MARKET AND TRENDS

In terms of its global importance, the U.S. auto market has been in a steady decline since the 1990s. Both the volume of domestic production and sales have declined significantly during the last 20 years.[6] Currently, the U.S. is the sixth-largest maker of passenger vehicle, such as sedans, compacts, and SUVs, making almost 2,800,000 in 2018 as visible in Figure 2. The drop in new vehicle purchases and production volumes can be partially explained by a strong resale market which negatively impacts new car sales, and partially due to a gradual growth in imported vehicles which negatively impacts U.S. production. Countries such as Mexico have experienced a growth in vehicle production as several car companies including Ford and General Motors have sought the cheap labor force available there, while being able to access the U.S. market through the NAFTA free trade agreement. Between 1999 and 2018 the number of vehicles rose from 990,000 to 1,570,000.[7] However, and perhaps most importantly, China has experienced the most rapid growth. The country, which manufactured just above 500,000 vehicles in 1999, manufactured more than 23,000,000 in 2018 making China the leading auto manufacturer. Sweden, by comparison, increased their vehicle production from 213,000 to 226,000 during those years.[8]

Figure 2. Vehicles Manufactured by Country in 1999[9]

Country	Cars	Commercial vehicles	Total
Japan	8,100,169	1,795,307	9,895,476
USA	5,637,949	7,387,029	13,024,978
Germany	5,309,524	378,168	5,687,692
France	2,784,469	395,724	3,180,193
South Korea	2,361,735	481,379	2,843,114
Spain	2,281,617	570,772	2,852,389
UK	1,786,624	186,895	1,973,519
Canada	1,626,316	1,432,497	3,058,813
Italy	1,410,459	290,797	1,701,256
Brazil	1,107,751	243,077	1,350,828

Figure 3. Vehicles Manufactured by Country in 2018[10]

Country	Cars	Commercial vehicles	Total
China	23,529,423	4,279,773	27,809,196
Japan	8,358,220	1,370,308	9,728,528
Germany	5,120,409	N/A	5,120,409
India	4,064,774	1,109,871	5,174,645
South Korea	3,661,730	367,104	4,028,834
USA	2,795,971	8,518,734	11,314,705
Brazil	2,386,758	493,051	2,879,809
Spain	2,267,396	552,169	2,819,565
France	1,763,000	507,000	2,270,000
Mexico	1,575,808	2,524,717	4,100,525

Though U.S. import levels have plateaued since the 90s, the rise of China and other economies since have undoubtedly hit U.S. vehicle exports. This trend is unlikely to be reversed according to projections produced from Fitch Solutions in Figure 4. These projections suggest that annual production levels will likely remain between 2.5 million and 3 million until 2025. Even though the number of vehicles being sold has decreased,

Americans still buy more vehicles per average household than their European counterparts, and they replace them more frequently as well.

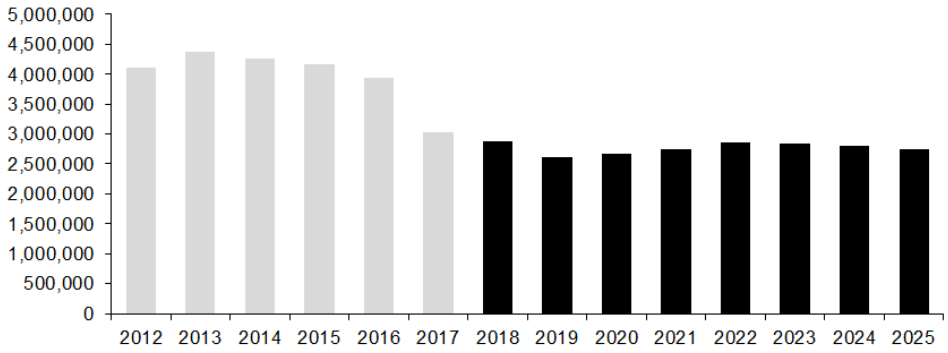


Figure 4. U.S. Domestic Passenger Car Production, Forecast to 2025[11]

Another distinguishing factor of the U.S market is the size of the vehicles. SUVs, Pickups, and Crossovers have remained popular throughout the U.S. even as the general environmental awareness has increased, and as other alternatives have become available. In fact, Ford, one of the largest vehicle manufacturers in the U.S. recently announced plans to remove all their sedans from their North American vehicle lineup to instead focus strictly on the larger vehicles following the success of its Ford F-series pickup and the disappointing sedan sales in the U.S. These sedans, however, will continue to be sold in foreign markets where sales have been better.[12] As the market evolves in the short-term, there is some belief that GM, FCA and Ford will increasingly focus on the larger vehicle models in their lineups, while foreign-based OEMs will focus on sedans either through local production or imports.

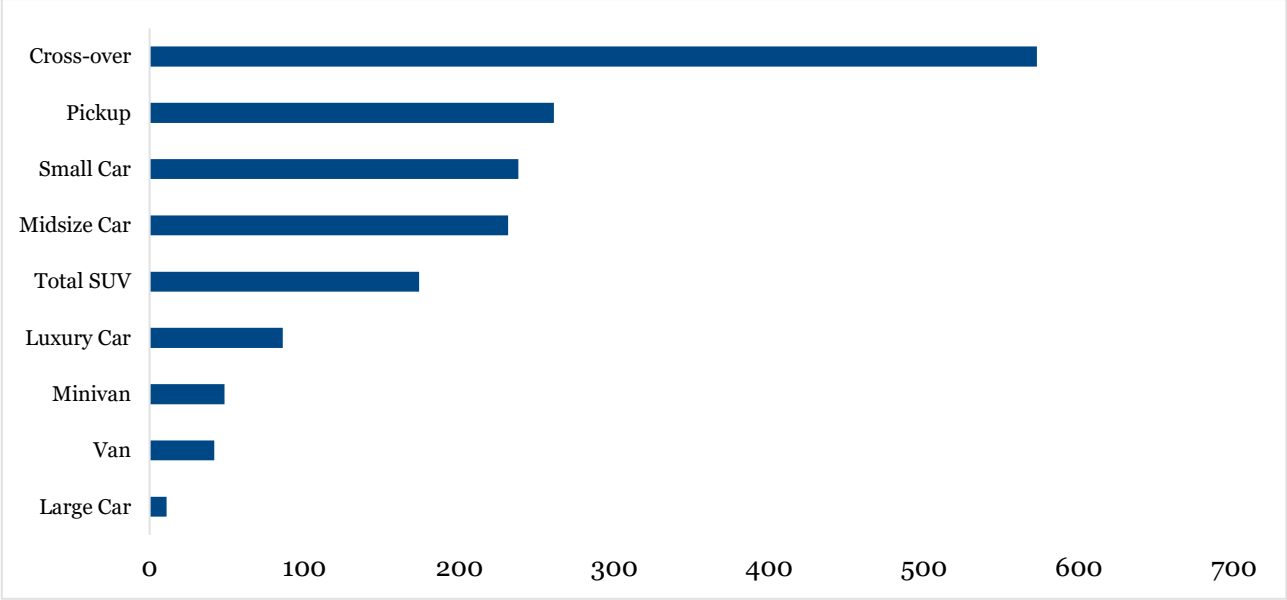


Figure 5. U.S. Car Sales in March 2018 by Type (1000s)[13]

As seen in Figure 6 the primary automotive clusters can be found around the midwestern states of Ohio, Michigan and Illinois with Kentucky and Tennessee also having prominent manufacturing clusters particularly among the traditional American car giants such as General Motors and Ford. There are also additional vehicle clusters in the southern states of Alabama, Mississippi and South Carolina where Asian car brands such as Toyota, Honda, along with European brands such as Mercedes, BMW and, as of recently, Volvo have a strong presence. With the introduction of Tesla and Karma Motors (Luxury EV vehicles) in California, this area has

also become an automotive cluster, albeit, smaller than the aforementioned states. One new entrant, Rivian, is disrupting the traditional automotive market with the development of all-electric trucks and SUVs to rival traditional OEMs in the Midwest.

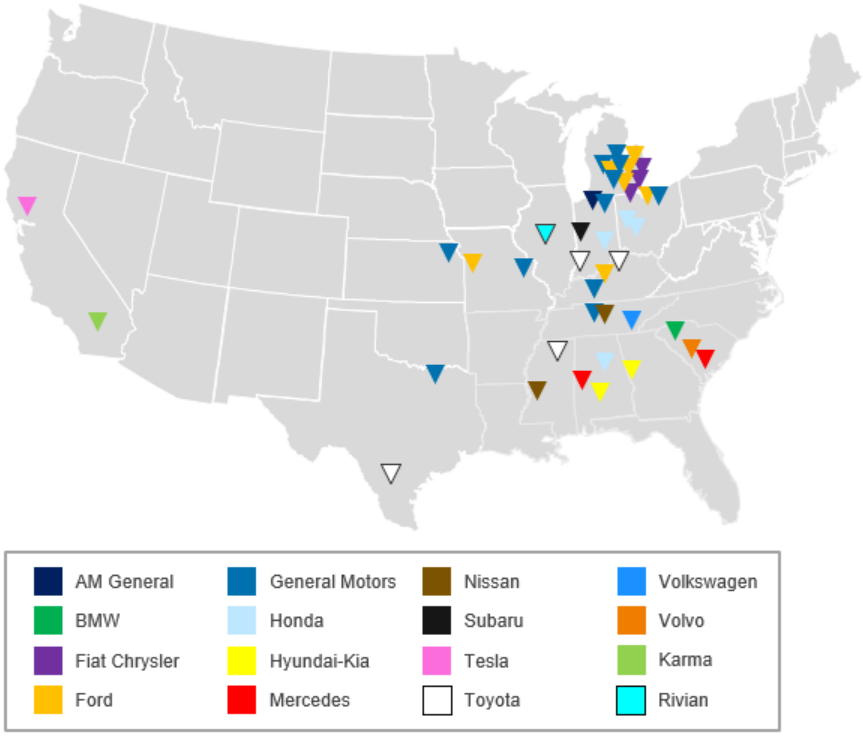


Figure 6. Major Passenger Car Assembly Plants[14]

TREND HIGHLIGHT - ELECTRICAL VEHICLES AND CONSUMER INCENTIVES

In addition to regulatory pushing automakers to achieve fuel economy levels for their fleets, there are multiple political factors that impact consumer behavior in the automotive industry. Regarding the sales of more environmentally friendly options, it is important to look at how different states incentivize consumers. Whereas States like California and New York have comparatively generous tax incentives for EVs there are a wide array of states that do not have any tax incentives for this vehicles type. These incentives largely corelate with the individual state's emission goals and strategies which vary significantly across the country. Currently, only 10 states are promoting traditional EVs on the state level whereas the federal incentives for EVs have largely been eliminated.[15]

This applies similarly to vehicles powered by hydrogen fuel cells. While interest in this technology has been ongoing for years with several large automotive companies developing different versions of the vehicle, the response among consumers has so far been tepid with few sales. Furthermore, the number of states incentivizing the purchase of fuel cell vehicles is limited to a mere handful in the U.S. such as California, or, to a lesser extent, New York.[16] This has made Hybrid Electric Vehicles, which are more competitively priced, a particularly attractive option.

Figure 7 below details the sales trends in the U.S. for Hybrid Electric Vehicles (HEVs), Plug in Hybrids, and regular EVs. Though there has been a rise of interest in electric vehicles in recent years they remain low compared to the number of Hybrid Electrical Vehicles.

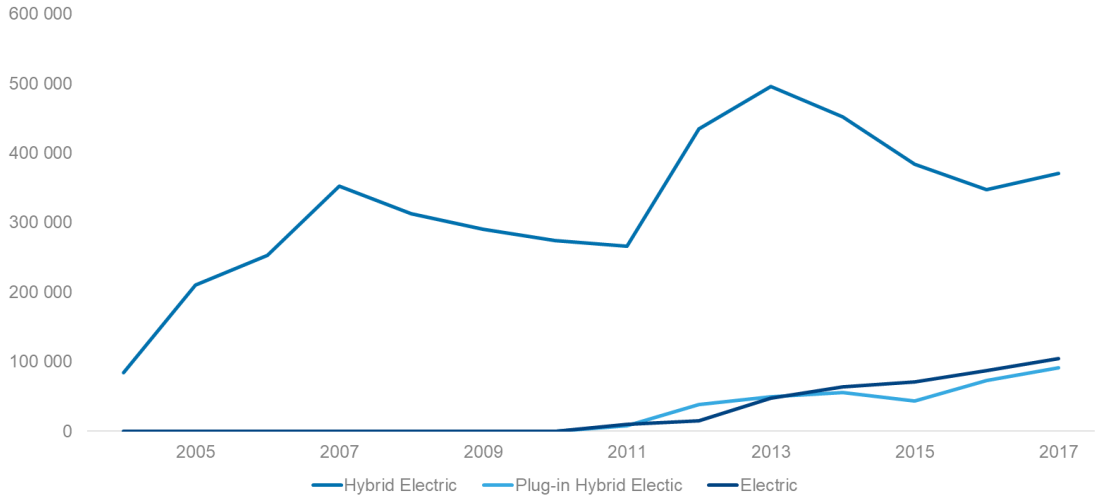


Figure 7. Purchasing Trends of EVs and HEV[17]

A survey of automotive executives produced by KPMG in 2019 confirmed similar trends citing the lack of supporting infrastructure to be one of the main factors limiting EV growth. The numbers of HEVs or EVs sold in the U.S. market pale in comparison to the number of regular vehicles sold in the U.S. In 2016 the total number of passenger vehicles sold in the U.S. was at 7,000,000 of which just about 400,000 (roughly 5% of the market) were hybrids. It should be noted that during this same period total U.S. vehicle sales dropped from 8,7 million in the year 2000. [18]

One important factor that has impacted the development of the EV and hybrid markets that is the uncertainty and fluctuation of oil prices in recent years. Typically, there is a correlation between rising gas prices and the rise in EV sales. This is logical as an EV becomes more competitive in the long run if fuel prices remain high. This is especially true in the U.S. where the average commuter travels 18 000 km a year.[19] Reverting to figure 7 there is a clear drop in EV and hybrid sales after 2008 (due to the financial crisis) and again after 2013 as gas prices began to drop once more.

TREND HIGHLIGHT - RIDE SHARING & AUTONOMOUS VEHICLES

Several recent technological breakthroughs have greatly impacted the American auto industry. While developments for EVs have certainly made headlines, ridesharing apps such as Uber and Lyft have also changed the landscape. With the increased ease and decreased cost of using such services the number of people using apps for personal transport has rapidly increased. In fact, between 2013 and 2018 the number of people using some form of taxi service (which includes Uber and Lyft) to get to work nearly doubled (The Bureau of Transport Statistics, 2018). Even though the percentage of total commuters using these services is still a low portion of the total, this trend has caused some concern among analysts with some suggesting that it would cause a decrease of car ownership. This view is not shared among all however, as some analysts argue that the net impact would be neutral, as cars being used for ridesharing purposes would need to be replaced more frequently.[20]

Similarly, with respect to the development of Autonomous Vehicles (AVs) there have been substantial developments in recent years. With many large traditional automotive companies including GM, Ford and Tesla, as well as traditional tech companies including Google and Uber currently developing alternatives. However, here too, there are few national standards that apply to this industry segment which has resulted in differing regulations. While several states have allowed AV testing, the extent of this testing and what qualifications are required varies significantly. Florida, for instance, now permits drivers to become involved in the testing of AVs as long as the driver has a valid driver's license whereas several states such as Kentucky only allow AVs that are commercial vehicles in so called "platoons" to operate within the state. To date, 29 states have signed new laws in relation to AV testing.[21]

While companies compete in developing their technologies and working with regulators, there remain major hurdles to eventual market acceptance among U.S. consumers. Autonomous vehicle development remains highly controversial among many U.S. consumers from both a safety, consumer cost, and privacy standpoint. Following a couple highly publicized car accidents involving autonomous vehicles, polls showed that less than half of U.S. consumers believe that AV vehicles are safe. In addition, recent studies also show that the majority of U.S. consumer are suspicious of using automated vehicles due to the consumer data that may potentially be shared with external parties. This reflects a growing resistance among the U.S. population towards major tech companies collecting personal data. In fact, according to a study produced by Deloitte, U.S. consumers are the most resistant to having their personal data collected out of the studied countries.[22]

SUMMARY OF POLITICAL, ECONOMIC, SOCIAL AND TECHNOLOGICAL (PEST) FORCES SHAPING THE PASSENGER CAR MARKET

Given the size of the passenger car market and its strong correlation with the overall U.S. economy, there are countless factors affecting its development. The below factors presented within the PEST context provide insight into several additional factors that will be closely tied to its development in the next few years.

The U.S. remains among the world's most important consumer markets for passenger car producers and suppliers. Interestingly, regional political and social factors are driving changes within the automotive industry along different paths as the federal government has been reluctant to take an active role in many areas. As an example, California has actively supported the development of low emission vehicles, through its environmental regulations, and the establishment of electric vehicle supply equipment infrastructure. In addition, California has developed frameworks for pilot testing of autonomous vehicles.

A growing number of alternative passenger vehicle manufacturers and suppliers are locating in California, however the Midwest and Southeast are also large production bases for such vehicles. In most states, however, consumers still prefer larger vehicles. The recent period low oil prices have supported consumers to continue purchasing larger SUVs, pickup trucks and crossover vehicles where U.S. consumers prioritize safety and comfort. Social adoption to electric vehicle routines has been relatively slow, especially in colder climates however different versions of hybrid vehicles are accelerating. On the positive side for the industry's development, recent studies have shown that the supposed aversion of millennials to purchase cars has been overstated and that lower generational ownership rates have been mainly due to the impact of the financial crisis and student debt causes.[23]

Vehicle sales have begun to slow despite the overall economy displaying historically low levels of unemployment, high levels of consumer automotive debt and positive overall economic growth. As the U.S. economy's risk of a downturn increases, some OEMs and suppliers may slow some of their R&D spending in the development of some technologies. Many analysts are bracing for the impact of a potential economic downturn within the next couple of years.

From a technology perspective, OEMs and Tier-1 suppliers are actively partnering with leading ride-sharing and traditional tech companies to develop the next generations of autonomous technologies as regional regulators allow for certain pilot testing on public roads. There is a broad recognition that challenges in the areas of autonomous, connectivity and electrification will require companies to strategically partner, rather than rely solely on internal innovation to gain a competitive advantage.

The various factors point to a continued strong demand within the U.S. market for passenger vehicles overall, but the composition of the types of vehicles will shift in the coming years through the interaction of consumer preferences and producer offerings. Nearly all OEMs are moving towards electrification however some are still focused on larger vehicle models, in high demand today, and hybrid offerings given the lack of clarity on the current administration's plan around vehicle emissions. In the long-term, producers may increasingly import smaller sedan models from lower cost countries where demand is higher for such vehicles and locally produce larger vehicles such as SUVs and pickup trucks and their hybrid and electric variants.

COMMERCIAL VEHICLE MARKET AND TRENDS

The U.S. commercial vehicle market includes a diverse range of vehicles as it includes any type of motor vehicle that transports goods of passengers for commercial purposes such as trucks, vans, buses or coaches. In 2018, 8.4 million total commercial vehicles were produced in the United States alone. Since the 2008 economic crisis, the U.S. commercial vehicle industry has seen gradual growth, with production levels increasing at about an average of 5% per year from 2012 to 2018.[24] As seen in Figure 8 below, when comparing commercial vehicle registrations and sales on a global level, the Americas region is the largest market with U.S. accounting for the highest figures in the region and globally.[25]

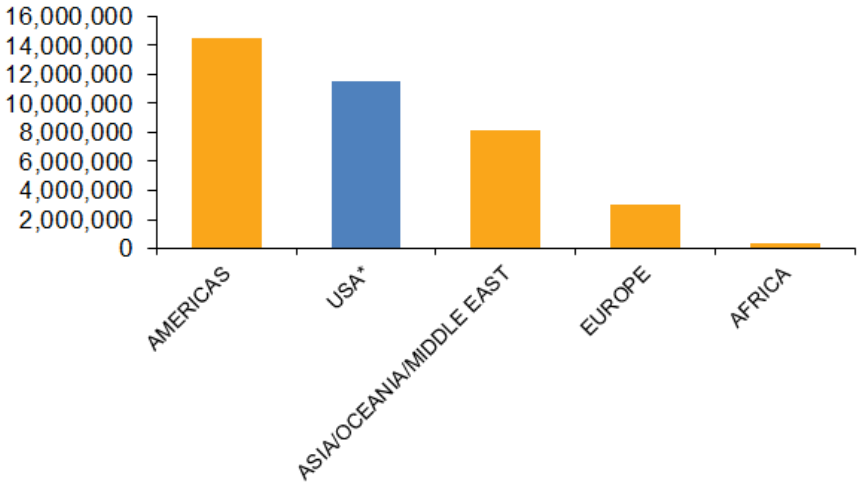


Figure 8. 2017 Provisional New Commercial Vehicle Registrations and Sales[26]
*USA includes in Americas Figures

U.S. HEAVY TRUCK MARKET

For the U.S. heavy truck market (Class 7, 8 and 9 vehicles), 2018 was a strong year with high build rates from truck OEMs on the trailer side. In 2019, production and order deliveries are expected to be at a record high, as previous orders begin to be delivered to fleets and other customers. The forecast for heavy truck production, however, shows a leveling off and stabilization of production up through the year 2025, as shown in Figure 9.[27] Although 2019 is forecasted to be another strong year, many in the industry feel as though it is not as impactful as 2017 and 2018, which were extremely good years, with 2018 setting all-time records for trailer orders.[28] Additionally, concerns about the economy and risks associated with trade issues between the U.S. and China have also added to the more conservative forecast for 2020 and beyond.[29]

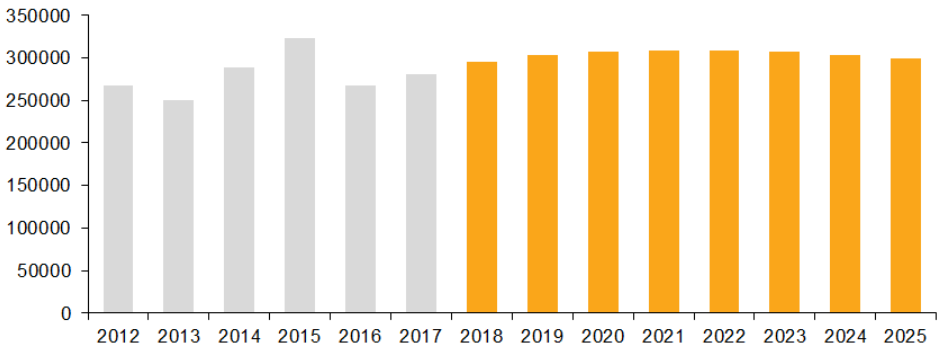


Figure 9. U.S. Domestic Heavy Truck Production, Forecast to 2025[30]

In the U.S., the heavy truck market is dominated by a few players including Daimler Trucks (Freightliner, Western Star), Paccar (Peterbilt, Kenworth), Navistar (International), and Volvo (Volvo/Mack). Overall, Daimler trucks main Class 8 vehicle "Freightliner" holds more than 37% of the overall market share in terms of sales in 2017, with the remaining share being split by domestic manufacturers at 42%, and Volvo/Mack at 18% respectively.[31] There has been a long-standing history of established international heavy vehicle manufacturers in the U.S., with Volvo Trucks and Daimler both acquiring local companies to capture a larger part of the market share and to increase production capacity. In the 1980's Mercedes-Benz took over Freightliner and Volvo acquired White Motor Corporation.[32] Most OEM assembly and production facilities can be found in the same geographic region as the typical automotive (passenger vehicle) manufacturing sector as seen in Figure 10 below.

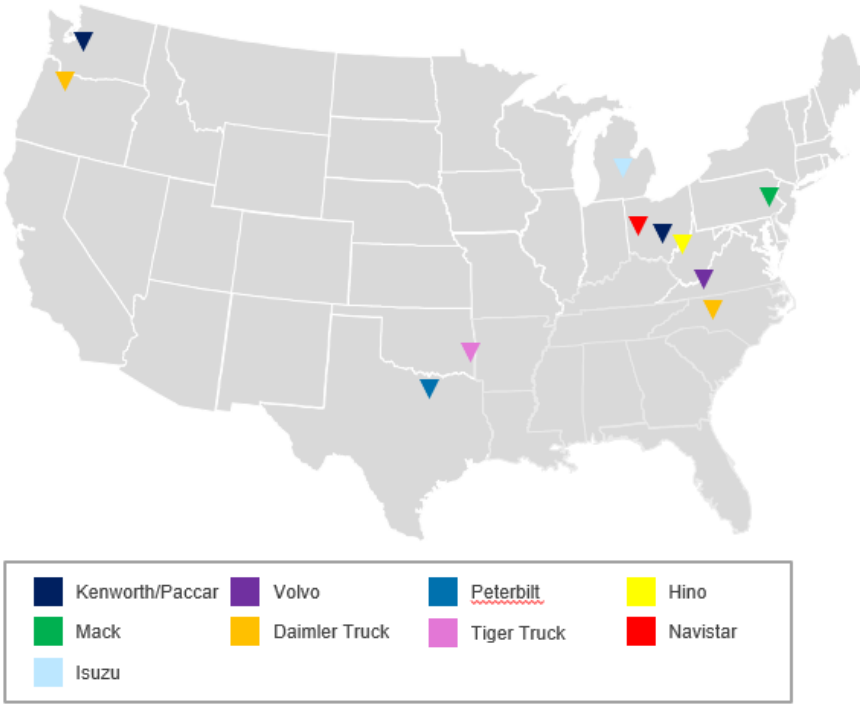


Figure 10. Major Heavy Truck Assembly Plants[33]

When compared to Europe and the rest of the global market, the heavy trucking industry in the U.S. is much more complex and highly customized. The U.S. truck market operates differently from the European market as the higher diversification in climate, terrain, distance and road quality calls for a higher degree of specification of the vehicles. Due to the diverse use cases of different trucks, fleet managers have a high level of control regarding what features will be part of the truck specification in order to maximize performance on a particular route.[34]

Trucking plays a crucial role within the U.S. transportation industry considering almost 70% of the US domestic freight is moved by truck with rail, water, pipeline, and other modes making up the remainder.[35] With the continued growth of the U.S. economy, along and with major increases in e-commerce shipments, the trucking industry is seeing some of the highest levels of shipments and overall movement of truck tonnage since 1998.[36] However, there is a downside to these record-breaking trends in freight transport, as the U.S. transportation sector is also a major consumer of petroleum products, relying on this fuel source for over 92% of its energy requirements. In 2016 and 2017, transportation was also the main contributing factor of carbon dioxide emissions for the nation.[37] This fact has not gone unnoticed, as a recent study by the logistics, shipping and delivery company UPS notes that 83% of respondents including large corporations and government agencies' primary driver for transitioning to commercial fleet electrification is to meet sustainability and environmental goals such as their greenhouse gas emission targets.[38]

TREND HIGHLIGHT - TRUCK AUTOMATION AND PLATOONING

Autonomous trucking in gaining a lot of attention in the trucking industry as supporters believe it will help to increase productivity, reduce costs and could also help to reduce accidents.[39] One trend that is also driving the development of autonomous trucking is that industry experts believe there will be a significant truck driver shortage in the future, as freight volumes will only continue to increase over time. According to the American Trucking Association (ATA), the U.S. will be short approximately 175,000 drivers by the year 2026.[40] While this has been a considerable threat and worrying trend for the industry, the U.S. Department of Labor recently countered this argument with their own study, stating that with the fluctuations in supply and demand for truck driver positions, that they do not see evidence of a shortage as the ATA as forecasted.[41]

While industry experts and government agencies consider the impact to drivers, on the technological side there is a lot of activity and excitement surrounding this topic, with current testing and demonstrations of "truck platooning." Platooning involves the partial automation of trucks that allows a single person to be in control of several vehicles at the same time, typically in a row or so-called platoon. Several companies such as platooning technology company Peloton and Class 8 manufacturers such as Volvo and Daimler are testing platooning in states including Michigan, Florida, Oregon, Nevada and California.[42] According to a recent study by McKinsey, the company believes that by 2027 trucks will be fully autonomous on all highways.[43] While this is a very aggressive timeline for adoption of these technologies, government and industry organizations like the National Highway Traffic Safety Administration (NHTSA) and the ATA believe that it will take many additional years, up to 30, before autonomous trucking becomes commercially viable, particularly in the case of fully autonomous trucks where no human driver would be present.[44]

U.S. LIGHT COMMERCIAL VEHICLE MARKET

The light commercial vehicle segment includes a diverse offering of vehicle types, from light duty trucks (Class 1-4), routinely used as passenger vehicles in the U.S., to commercial vans, and medium duty trucks and transport vehicles utilized by mail, freight, and waste management industries. These types of commercial vehicles are often manufactured by the same OEMs (E.g. Ford, Toyota, GM) in the passenger vehicle segment within the traditional automotive geographic clusters.[45] Furthermore, the Tier 1 supply chain would also be concentrated around the same regions in the U.S. The light and medium truck market is seeing high growth with light truck sales increasing by over 7.7% in 2018 alone. Overall, according to Figure 11 below production of commercial vehicles will continue to gradually increase year over year until 2025.

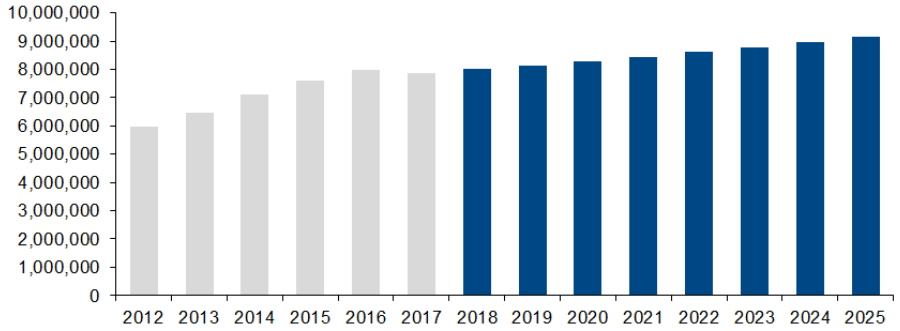


Figure 11. Light Commercial Vehicle Production and Forecast to 2025[46]

One reason why the light commercial industry is so strong in the U.S. is due to long-standing, and often controversial, tariffs of 25% on these types of vehicles into the U.S. This regulation established in 1969, referred to as the "Chicken Tax", was originally a retaliatory tax placed on foreign pickup trucks and commercial vans in response to a European tariff placed on U.S. Chicken.[47] This tariff is still in place in the U.S. and continues to drive local production of these vehicles. Furthermore, light duty trucks are beginning to be more a more popular choice for family vehicles than smaller cars and SUVs, as reflected in the shifting sales trends where light trucks made up almost 70% of sales, and passenger cars 30% in 2018.[48] The van market in the U.S. tends to fluctuate form year to year, with sales falling slightly for the past two years. Overall, the van market is dominated by Ford van models which made up approximately 50% of the share of sales figures in 2018.[49]

U.S. BUS MARKET

The U.S. bus market is a much smaller segment of the overall commercial vehicle industry. This market can be classified into three specific areas including transit buses, motor coaches, and school buses. While Figure 12 below shows steady growth of production levels in the bus market in the U.S. over time, the overall market size is quite limited when compared to passenger cars, and light commercial vehicles such as trucks and vans. This is reflected by the fact that in the U.S., the main mode of transportation for both local and long-distance travel is by car, contributing to about 70% of all person-miles of travel (PMT) in 2016. Travel by bus consists of about 6% of PMT, trailing both domestic and international air travel figures.[50]

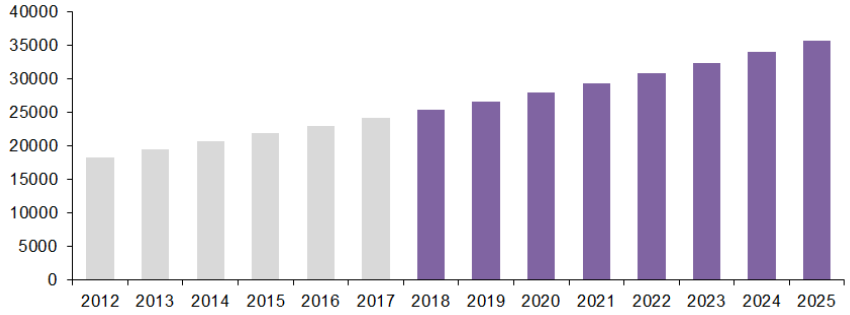


Figure 12. U.S. Domestic Bus/Coach Production and Forecast to 2025[51]

Perhaps not surprisingly, in the U.S. market, the school bus segment is the largest, when considering the number of vehicles out on the roads daily. On a given day there are over 480,000 school buses on the roads with over 25 million riders.[52] The overall growth within the market as reflected above can be contributed to specific positive trends in the industry overall. With transit buses, demand will continue to grow, especially for production of new alternative fuel and electric buses as local governments and transit agencies in places like California push for more zero-emission buses.[53] Additionally, school bus sales are seeing healthy sales numbers as funds allocated from sales taxes are increasing due to strong economy. Additionally, at least 30% of the U.S. school bus fleet is over fifteen years old and will need replacement in the near future.[54] Finally, within the coach bus segment, there is an increasing interest and demand for "inter-city" buses to fill the gap of recent service cuts from regional rail providers such as Amtrak, who is struggling to keep operations running with threats of a 24% budget reduction by the Trump administration for 2020.[55]

Compared to other types of vehicle production, the bus OEMs are much more widely dispersed within the continental U.S., with additional clusters centered around the South and Western regions as seen in Figure 13 below.

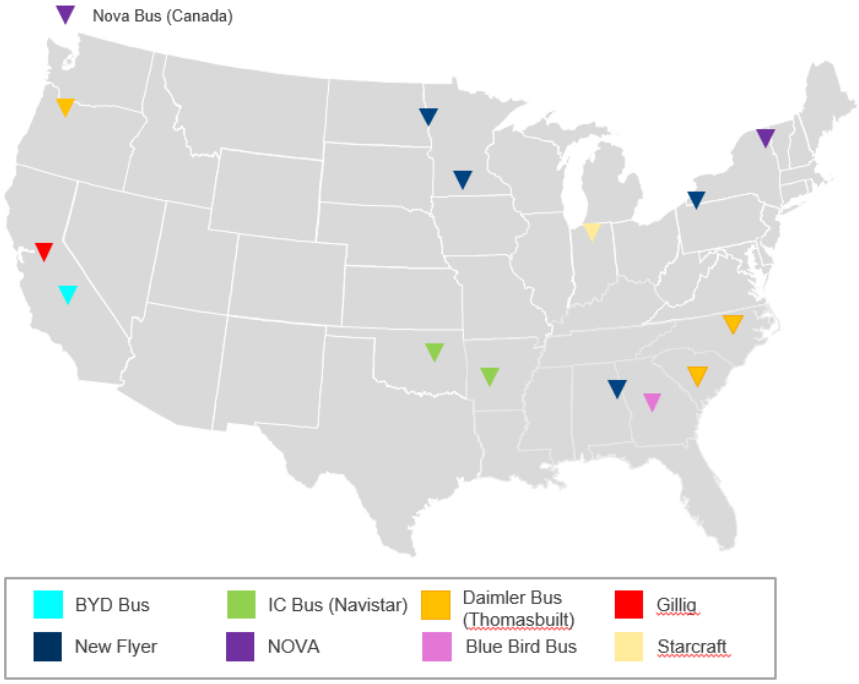


Figure 13. Major Bus Assembly Plants (School, Motorcoach, and Transit)[56]

Within the U.S. heavy-duty transit bus segment, only three major manufacturers remain including Gillig, Nova Bus, and New Flyer. This is primarily due to the volatile demand and spending trends in this small market, where many players have gone through bankruptcy, acquisition or have left the market altogether.[57]

The overall transit industry in the U.S. including rail and bus market is also seeing increased threats by the entry and growth of ride-sharing companies into major cities. While some experts feel the U.S. transit industry is being affected by factors such as low gas prices, reductions in service, and maintenance problems, not all these issues could explain the significant decreases in transit ridership.[58] A recent study by the University of Kentucky found that when ride-sharing companies entered specific markets, rail ridership decreased by 1.29% and bus by 1.7%, with some figures as high as 12.7% overall in San Francisco since initial entry approximately ten years ago.[59]

Like the passenger vehicle market, automation is also a key point of interest for the transit industry, where there have been several testing sites and demonstrations for autonomous bus systems in Minnesota, California, Oregon, Nevada, and Florida among others.[60] Overall adoption has been slow for this technology as local transit agencies are risk-averse and federal investment would be required in order to accelerate development in this area.[61]

INDUSTRY HIGHLIGHT – NEW FORMATION OF ZERO-EMISSION HUB FOR COMMERCIAL VEHICLES

A new trend in company localization is emerging, with an increasing number of "zero-emission" commercial vehicle manufacturers establishing on the West Coast. With this new hub developing, the market is seeing an increased influx of both investments and movement of EV and other zero-emission component suppliers to the area. The main states where OEMs have established, or are planning to establish, are centered around California, Nevada and Arizona as show in Figure 14 below. New entrants such as Nikola, BYD, and Proterra are establishing facilities on the West Coast focusing on electrification of commercial vehicles such as electric battery and hydrogen-powered buses and class 8 trucks.

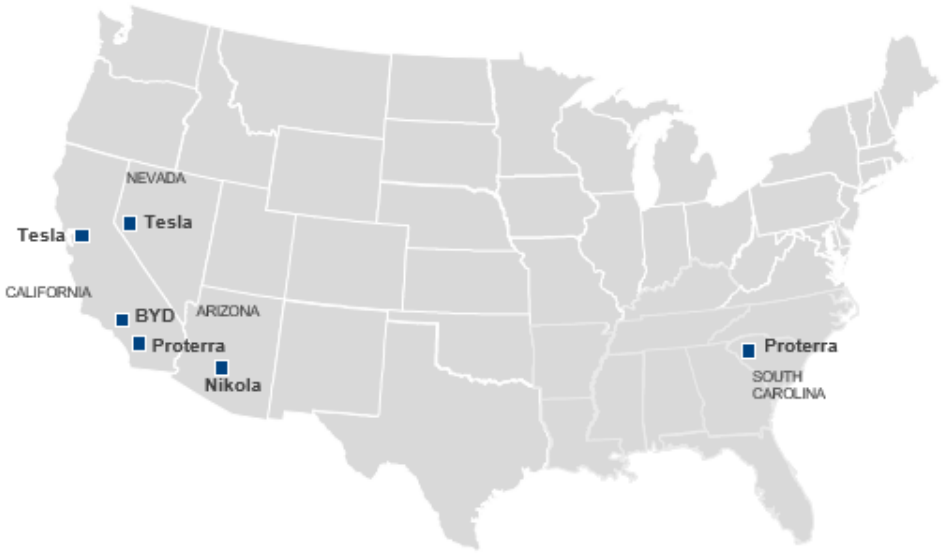


Figure 14. West Coast Zero-Emission CV Manufacturing Plants[62]

SUMMARY OF POLITICAL, ECONOMIC, SOCIAL AND TECHNOLOGICAL (PEST) FORCES SHAPING THE COMMERCIAL VEHICLE MARKET

The heavy truck market is the largest commercial vehicle segment in the U.S. and among the most mature in the world. Given its primary usage in domestic goods transport, its performance is closely tied to the conditions of the overall economy to a similar degree as the passenger vehicle market. As a highly mature market, political interests are well-entrenched in representing vehicle manufacturers, operators and private infrastructure stakeholders.

There is some debate that political forces and special interests may delay the adoption of certain technologies including autonomous and green technologies within the commercial vehicle market. As with other automation processes, there is public concern around the displacement of many individuals over time and the overall safety risks of deploying such systems. As oil prices have remained low in recent years, EPA regulations will continue with its phased in plan requiring more fuel-efficient engines for on-road heavy vehicles placing a greater emphasis on R&D and investments in emission reductions, primarily for diesel fuel but also further incentivizing electrification and other alternative fuel technologies. Given their prevalence of U.S. roadways, heavy trucks have been a focus emission target for regulators.

The U.S. light commercial vehicle remains politically protected by high tariffs on pickup truck imports and is also closely tied to the health of the U.S. economy as well as strong consumer appetites for home-work vehicles. Despite the large size of these vehicles, automakers are increasingly offering hybrid models to help comply with the CAFE requirements. Technological advancements in autonomous and alternative-fuel vehicle technologies are being adopted to different degrees among heavy vehicle manufacturers with the smaller bus market outpacing in electrification development. Social forces are also pushing some private fleet owners and cities to lead in the areas of sustainable technology development to support their brand in the eyes of consumers.

As U.S. urbanization increases particularly in suburbs where some bus services may be present (compared to rural areas), commuter bus demand has some untapped potential. Spending in this area is difficult to project as state and city funding challenges facing many cities will impact the potential for such investments. Generally, ridesharing technologies have impacted public bus ridership, but there remain questions on the long-term sustainability of price levels and company profitability. Despite ridesharing technologies offering low-priced alternatives, commuter transit will continue to be counter-cyclical as individuals shift to public transport options during downturns.

The U.S. economy will continue to remain highly dependent on the use of heavy vehicles for the transport of goods, and the extra demands of profitability and vehicle uptimes from private owners present additional challenges to the adoption of new technologies. Demand is expected to remain strong in the coming years for heavy trucks as manufacturers continue to fill their order backlogs. While cities will continue to invest in new bus fleets and have been quicker to adopt new technologies, the heavy vehicle market will likely continue to be more conservative in its adoption of innovations until a clear ROI is demonstrated. Although the U.S. market is behind the passenger car market in the adoption of new clean technologies, long-term regulatory pressures will continue to incentivize operators to transition to new technologies as fuel cell and battery costs decrease to make such investments realistic.

SEGMENT ANALYSIS AND EVALUATION

BATTERY ELECTRIC VEHICLE SEGMENT

The future role of EVs within the automotive industry is among the key megatrends discussed today. There are several theories each with differing predictions. In a recently released report, the Edison Electric Institute and the Institute for Electric Innovation developed a consensus forecast from various thought leaders in the space. The report forecasts that in the year 2030 about 7 percent of all vehicles on the road, and 22 percent of all new vehicles sold (approximately 3.5 million vehicles), will be either battery electric (BEV) or Plug-in hybrid electric vehicles (PHEV).[63] Though these consensus-estimate figures may seem ambitious, it is not unreasonable if one considers the rate of technological development that occurred in the early 2010s and recent growth rates. EVs were not available at a scalable level until the early 2010s. In 2015, 75,000 were sold in the U.S. and by 2018 this number had jumped to over 360,000 showing the rapid adoption period occurring at present.[64]

These predictions are consistent with the survey carried out by KPMG in 2019 which predicted that the EVs would account for 30% of global car production volume by 2040. However, according to the same survey, one of the main constraints limiting the consumer adoption of EV vehicles is the overall price and access to charging stations. As mentioned previously, different U.S. states have different environmental goals and therefore, different incentives for their populations. Many states do not provide any incentives which significantly increases the cost of an EV especially as federal incentives are reduced or eliminated. The uneven political support leads to a situation where EVs that were affordable due to certain tax credits can suddenly become more expensive the next year (Fitch Solutions, 2018). Hybrid vehicles, by comparison, are less susceptible to these changes as they are more competitively priced from the onset, which is one reason why hybrids have been selling more. Another widely shared critique is the amount of time it can takes to fully charge an EV.[65] This is especially important to note in the American market where the average commute is longer than that in many other countries. Slower recharging limits the usability of the vehicle which is not an option for many consumers.

INVESTMENT AND R&D

Passenger Vehicles
There has been a rising interest in EV development with many of the leading Car Brands investing heavily in this area. In the chart below the investment flows by country of origin of the car maker can be seen. As visible Chinese and German automakers lead the investments, with China receiving the bulk of investments. Even though the U.S. ranks third in this pie chart U.S. based automakers are still investing 34 Billion USD in EV development.

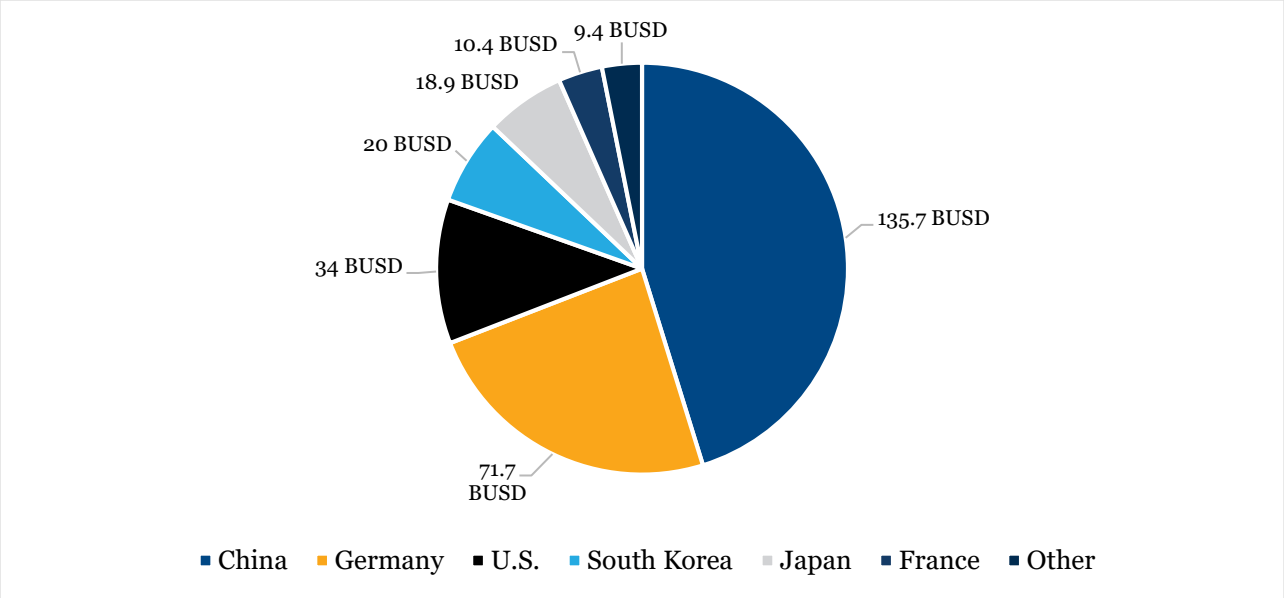


Figure 15. Foreign EV Investment Flows (announced for next 10 years) by Origin Country and Destination[66]

There has also been a focus on reducing the weight and size of the batteries to make them easier to replace and less expensive. This was one of the major developments in Tesla's new model and the goal was that the new batteries would be easier to manufacture. This has been a key topic as Tesla aims to ramp up production.[67] According to Bloomberg, there has been some success especially in relation to costs. Though the average EV battery made up for half the car's total cost in 2015 it made up for only 33% in 2019 due to technological advancements as well as growing production volumes.[68] The emphasis on production costs cannot be stressed enough as most automakers make consistent losses from their EV models. According to a report by McKinsey EVs cost an average of 12,000 USD more to make than regular Internal Combustion Engine cars.[69]

The high energy requirements pose an additional challenge for auto manufacturers such as Tesla who has tried to combine autonomous technology with their EVs. Not only is it crucial to extend the range for electric car batteries, the additional hardware and software components such as radar, sensors, cameras and lasers also require massive amounts of energy. If batteries become more efficient, more energy will be able to be used to run the systems in autonomous vehicles. However, in the current state, the range is greatly reduced when the battery also powers other autonomous technologies. This in turn risks reducing the overall competitiveness of these EVs.[70]

Similar challenges have also been faced by other U.S.-based car companies such as Ford and GM. The Ford Focus Electric was initially heavily criticized due to the large battery which decreased the storage space of the vehicle. The model was later discontinued due to low sales in both the U.S. and Europe. Nonetheless, most automakers now offer both HEV and EVs as part of their vehicle portfolio, even though they often account for a rather small percentage of total vehicle sales. As visible in figure 16, Toyota and Kia are the car brands that have the highest percentage of HEV or EV vehicles in their portfolio out of the major car brands.

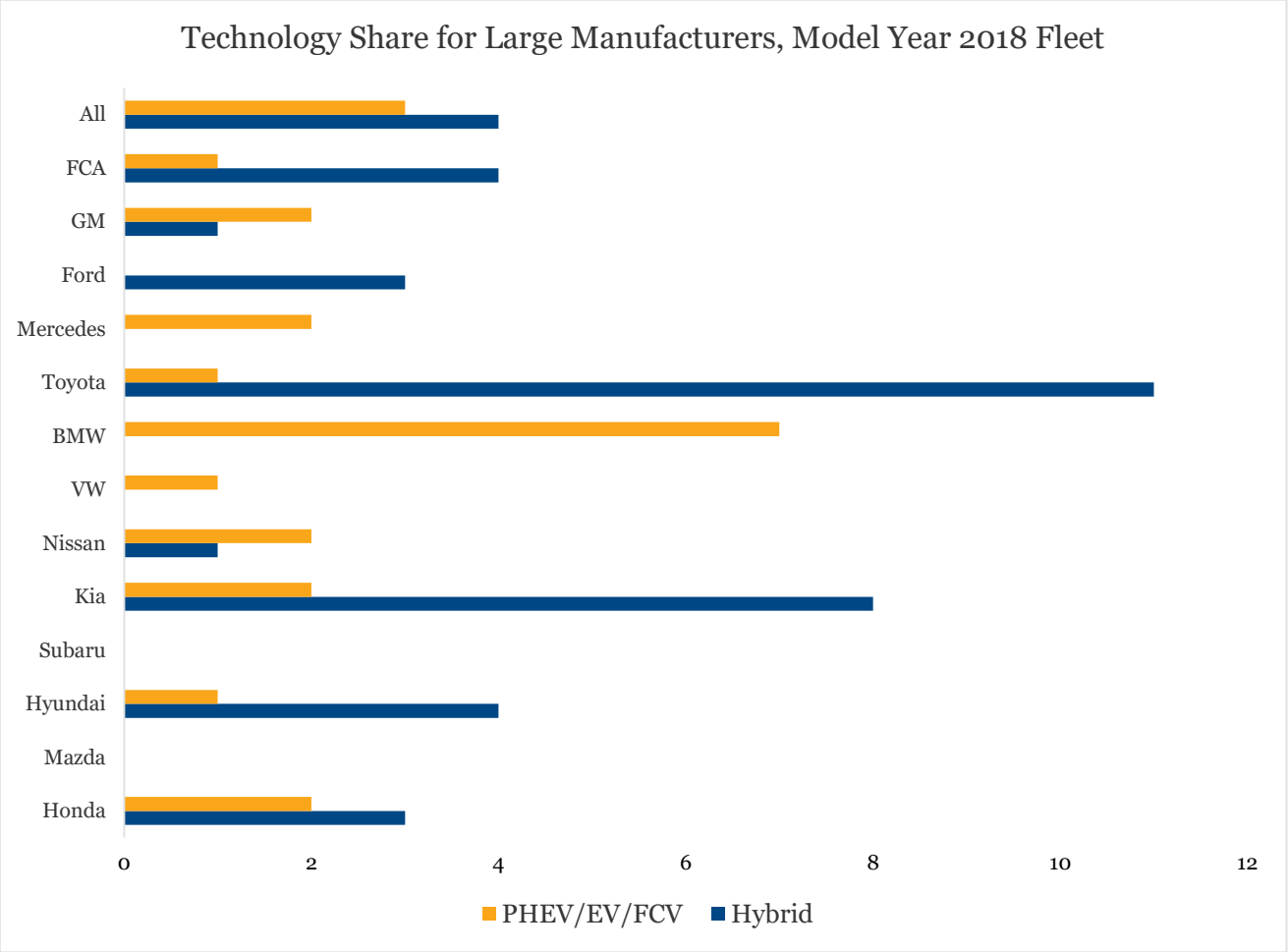


Figure 16. Vehicle Portfolio of Largest Carmakers in U.S.[71]

Another development within battery systems that has received ample attention among business leaders and the scientific community alike is the supercapacitor. One drawback of the existing supercapacitors is the fact that they discharge rather rapidly. A car with a supercapacitor could hypothetically discharge in a matter of weeks if left idle. The rapid discharge also makes it less suitable to sustain prolonged energy consumption and more suitable for short bursts, such as when a car is accelerating or braking. Ideally a supercapacitor could be combined with a smaller battery to combine the benefits of both, however such aspirations have yet to be fully realized. Nonetheless, auto manufacturers Tesla and Lamborghini have made significant investments in this area with the former purchasing the supercapacitor Maxwell Technologies for $200 million in 2019.[72]

Commercial & Public Sectors

The challenges for EVs are particularly limiting for the U.S. commercial segment which is very reliant on vehicles that can travel great distances with minimal downtime. Every time that a truck must stop represents a sunk cost for the transport company as the driver still has to be paid. If the truck then must stop for several hours each time it refuels, the profit margins for any transport company vanish as argued in a report produced by the North American Council for Freight Efficiency (NACFE) in 2018.[73]

Nonetheless there are still several truck manufacturers that are developing their versions of electric trucks. Companies such as Daimler and Volvo are investing heavily in this area with the latter recently receiving a nearly 45 Million USD grant from the California Air Resources Board (CARB). One of the major areas of investment for this money is fast chargers.[74] Another recipient of the funding was NFI, a 3PL based in New Jersey with more than four thousand trucks. announcements reflect the broader effort by CARB to curb commercial vehicle emissions. Similarly, EV-focused OEMs, such as Tesla, are also developing commercial electrified trucks, however like other U.S. truck manufacturers such as Paccar, which owns Peterbilt and Kenworth, these are only in the early development fazes. [75]

Various local governments have also shown interest in electric busses as an alternative for public transport needs. In the recently approved federal budget the U.S. recently approved 84,000,000 USD to be invested in expanding the current U.S. electric bus fleet which currently stands at 300.[76] While this may not sound particularly substantial it is also important to keep in mind the current state of public transport of the U.S. Very few cities have a well-developed public transport infrastructure to begin with. New York, which has the most well-developed public transit by far, had a total of 5,710 busses as of 2016.[77] Bearing this in mind, if New York is excluded not only is 300 busses a substantial number so too is the 84,000,000 USD investment.

OPPORTUNITIES AND GROWTH

While EVs are still in relatively early stages of market adoption through the U.S., hybrid models are a priority area in the short-term for many automakers. Due to the wide variety of support towards full EVs and the fluctuating tax incentives there has been a continuous interest in Hybrid vehicles among consumers. These partially electrified alternatives primarily exist in two variants, the Hybrid Electric Vehicles (HEV) and Plug in Hybrid Electric Vehicles. The main difference between the two is that the PHEV (PHEV) has a battery that can be recharged by connecting it to an external source of power.

The regular HEVs came to prominence during the early 2000s and the most popular brand was the Toyota Prius which accounted for 47% of all hybrids sold in the U.S. in 2015[78].Regarding the PHEV, much like regular electric vehicles, substantial efforts have been dedicated to reducing the charging time, increasing the range and thereby improving the mileage of the vehicle while maintaining the same size and similar performance that the U.S. customer base has grown accustomed to. The SUV standard has proven resilient in the American market with multiple car brands, such as Toyota, Mercedes, and Range Rover releasing Plug-in Hybrid versions of their vehicles this year.

An additional factor that impacts the popularity of the HEV is their price competitiveness when compared to EVs. This is especially true as government subsidies for EVs have reduced rapidly under the current administration. The rising prices will likely cause more price sensitive consumers to shift to Hybrid options[79].

RISKS AND THREATS

In terms of industry risks and threats it is once again important to note the impact that changing governmental regulations can have on the development of the industry. Changes in tax incentives can make a previously competitively priced EV suddenly unobtainable for the majority of American consumers. Furthermore, if there are no tax incentives it is also going to be difficult for EV manufacturers to achieve sufficient production volumes to make the car profitable.[80] In addition there is a risk that developing shorter charging times can take longer than initially anticipated. If that is the case, there may be a loss of buyers who simply grow impatient with the current technology standards.

It is also worth mentioning that one reason the introduction of fully electric buses has been slow is partially related to challenges related to Federal Transit Authority (FTA) regulations. As outlined by the Buy America act public transit agencies must follow specific regulations for public procurement. Within this Act, the FTA requires that at least 65% of the cost of a bus must be of domestic origin as measured by the specific components that make up the bus. Currently, the law is interpreted differently among different branches of the Department of Transportation which can cause confusion in the market especially for new technologies (APTA, 2017). It is also worth noting the lack of charging infrastructure, not many cities have the infrastructure to support fully electric busses. This limitation also means that there are a limited number of cities where the approved 84,000,000 can be efficiently spent.

Within the commercial transport segment there are also limited options that are currently available. The Tesla Semi truck, for instance, is only available to preorder, this is also true for many vehicles using Fuel Cells. This means that it can be difficult to maintain interest and early investments if there are additional delays, much like Tesla has experienced.81

SUMMARY

While full EV passenger vehicles have garnered ample attention during the last couple of years U.S. consumers still prefer partial electrified options, particularly Hybrids, to a far greater extent. Still, EVs have had a period of rapid growth and many analysts predict that it will continue to grow even though many states have a lackluster charging infrastructure, and few offer any tax incentives. Within the commercial and public

transport segments several large truck manufacturers have developed prototypes however few are available for purchase whereas in the bus segment there has been some favorable developments recently. In the 2018 federal budget 84 million was set aside to help cities around the U.S. invest in electrical buss fleets.

FUEL CELL ELECTRIC VEHICLE SEGMENT

Fuel cells, and most commonly hydrogen fuel cells, is another technology area that has experienced increasing attention among OEMs and consumers over the past years but has experienced a slower development than battery EV segment. In terms of research and future development most states do have research facilities that are studying various aspects of fuel cells however, the number of facilities varies significantly. States such as Alabama and Arizona only have one program studying fuel cells while the frontrunners California and Colorado have dozens of programs each.[82]

INVESTMENT AND R&D

Passenger Vehicles
In terms of sales, the number of Fuel cell electric vehicles (FCEV) leased and purchased rose to a high of 3,800 as of 2018. However, it is important to note that this number was only at 1,500 in 2017, which was a record-breaking year.[83] Even more striking, the U.S. accounts for more than half of the world's FCEV vehicles in 2018 at less than 6,500. The low sales are partially due to the fact that there are a very limited number of manufacturers pursuing the technology, with Honda, Hyundai and Toyota leading the pack.[84]

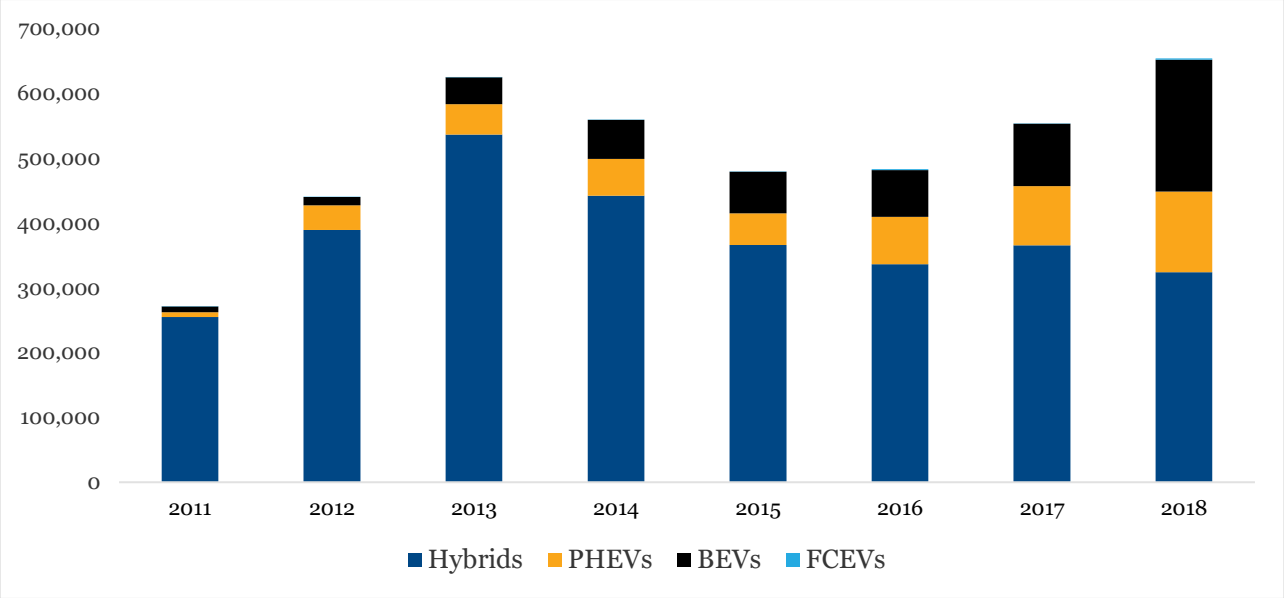


Figure 17. US EV and Hybrid Sales, 2011-2018[85]

Though the rapid increase in fuel cell vehicles is interesting, the overall sales number remain very low compared to the HEV and other EVs. One reason for this limitation is that the number of publicly available refueling stations remains very low throughout the U.S. In California, which is the leading state by far, there are only approximately 30 refueling stations whereas the remaining can be found in Michigan and Massachusetts, which only have a single charging station in each state.[86] Another challenge for the passenger car segment is the fact that the actual fuel cells are very heavy. This is because the hydrogen needs to be pressurized and thus, also needs to have a thicker shell to maintain that pressure and reduce the chances of being pierced. This heavy weight is a challenge for smaller, lighter passenger cars.[87]

Commercial and Public Transport
Due to the more rigid routes used by public transport and trucking industries, both have been investing in hydrogen fuel cells, even if it is to differing degrees. The application in buses has been of particular interest due to the fact that they typically have a longer range and are faster to refuel compared to their battery EV counterparts. These factors are very important for vehicles in public transport which typically travel great distances daily. The lack of stations and weight of the fuel cell are less of a restriction for busses that use fuel cells. Out of the total 32 fuel cell buses being used in the U.S. 25 are in California, 6 are in Ohio and 1 is in

Illinois as of August 2018. In the near future California will add another 27 fuel cell buses while Ohio plans to purchase an additional six.[88]

OPPORTUNITIES AND GROWTH

Though companies such as Toyota, Hyundai and Honda have invested in FCEVs for several years, much of the recent attention has been placed on the heavier vehicles. Though the investments in hydrogen fuel cell buses have been rather low there appears to be a surge of investments in trucking segment. One company that has received significant attention in recent years is the vehicle manufacturer Nikola, based in Arizona, which has secured an order of 800 fuel cell trucks from Anheuser-Busch, the maker of Budweiser.[89] Currently the company has started an investment drive of over 1.5 billion USD to help further the development of their fuel-cell vehicles and for their hydrogen fueling infrastructure plans. The U.S. company has been collaborating with renowned suppliers in the heavy trucking industry including Meritor, Bosch, and Wabco among others. Furthermore, a major fleet management company Ryder, has already made the decision to move forward with Nikola trucks as their primary maintenance partner for the trucks in the future.[90] Nikola plans to address the shortage of charging stations by building the stations themselves along specific trucking routes. Through careful planning and routing the company is in theory able to secure high service levels while also limiting the number of stations that are needed to be built.[91] Toyota and Kenworth have also been developing heavy FCEV trucks during the past couple years.[92] Even in the parcel delivery sector major companies such as UPS and FedEx have also unveiled their alternatives which has garnered significant attention.[93]

RISKS AND THREATS

There are multiple risks that can slow the development of fuel cell powered electric vehicles. This combined with the lack of charging stations could stall future developments and investments unless there is development soon. The number of states that are incentivizing fuel cells also remains rather limited meaning that this industry will likely rely heavily on the performance of individual private companies. There is also significant competition from the LNG segment which have also been racing to develop trucks and charging stations. These players have the additional benefit that the general infrastructure is much more developed after decades of investment. As visible in Figure 18 below the number of LNG stations has significantly outpaced their hydrogen counterparts. Similarly, Compressed Natural Gas (CNG) has also seen a rapid expansion ever since the early 90s though there have been some fluctuations.[94]

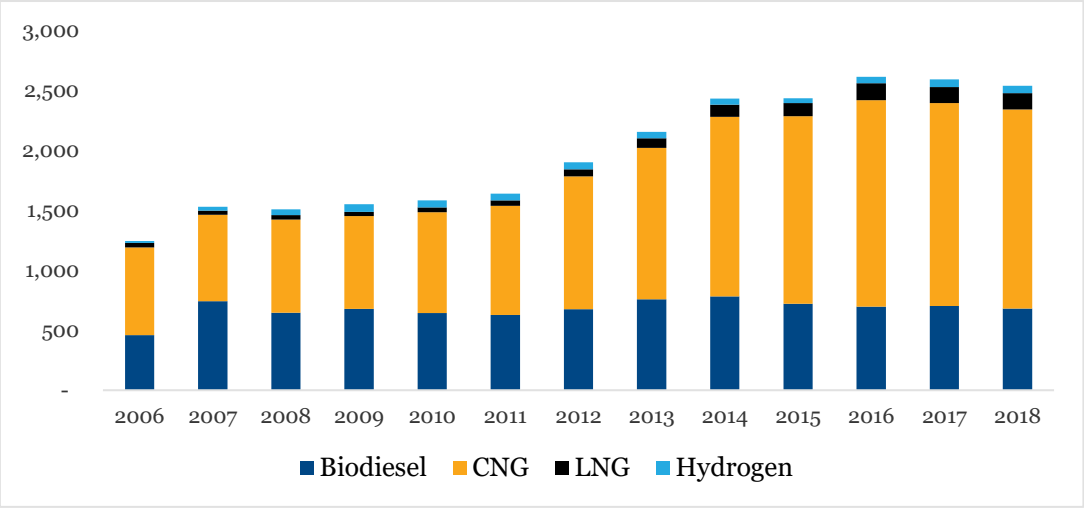


Figure 18. Number of Alternative Fueling Stations by Type, 2016-2018[95]

Many players who are prominent on the American market such as Daimler, Kenworth and Peterbilt have already developed prototypes that boast impressive figures, such as emitting 1/20 the amount of nitrogen oxides that diesel trucks do.[96] This is particularly important to note as the private sector will likely lead the development, based on the low number of buses purchased as well as an overall lack of government incentives, barring a handful of states. The development of this technology and the market adoption's reliance on the private sector is a major risk. Investors are not known to be the most patient and proponents to clean energy argue that government subsidies are necessary to push the development of cleaner sources that may not be financially viable in the short term but may pay off in the long term. It should also be mentioned though, that one large reason many local governments have not been investing in either electric or fuel cell technology is

due to a lack of government funding for infrastructure. This has been an ongoing challenge in the American market. According to a report published by the Center for American Progress at least 3 trillion U.S. dollars needs to be invested in this sector.[97] This is a very substantial figure that almost equals the total annual U.S. tax revenue.

Summary

In short, while the commitment among vehicle OEMs and adoption of fuel cell cars and buses has been slow, the market has seen renewed interest and investments in the commercial truck sector for this technology. Due to the more rigid nature of the trucking routes it has also been argued that building the supporting infrastructure would be easier. However significant challenges remain. As the technology continues to develop so do competing alternatives, several of which have a more developed infrastructure and advantageous position.

VEHICLE LIGHTWEIGHTING

Lightweighting has already been a major focus area for the passenger vehicle market for the past 25 years, most often taken into consideration when designing sports cars with lightweight materials to increase vehicle speed.[98] In the current market, however, the main driver for increased interest in lightweighting is related to improving fuel economy to meet the 2025 CAFE standards. To address this challenge, OEMs are turning to lightweighting, where a reduction of weight by 10% can help increase fuel economy by up to 8%.[99]

INVESTMENT AND R&D

Passenger Vehicles
While fuel economy is currently driving incremental innovation in lightweight technologies, a more recent focus on the development electric and autonomous vehicles is now creating a need for disruptive changes.[100] Lightweighting is crucial to address when considering the heavy weight of batteries and the addition autonomous technology features, which alone are estimated to add up to 300 pounds.[101] This would be in addition to the typical features OEMs add annually to each new vehicle model to meet changing demands related to safety, performance, comfort.[102]

Globally, OEMs and suppliers continue to make large investments into lightweighting where the industry is forecasted to grow at a CAGR of 13.1% between 2016 and 2025.[103] In the passenger vehicle segment, General Motors is investing millions into lightweight materials, joining forces with Teijin, a Japanese composite company, to co-develop carbon fibre technologies. Furthermore, General Motors is also putting over $1.2 billion dollars' worth of investments into one of their assembly plants to make new pickup trucks with a carbon fibre bed.[104] In the U.S. two major industry institutions, the Institute for Advanced Composites Manufacturing Innovation (IACMI) and Lightweight Innovations for Tomorrow (LIFT) have invested over $50 million into a new R&D and testing facility, the Institute for lightweight and composite materials.[105]

Commercial Vehicles
For light and medium commercial vehicles in local metro areas or short-distance hauling, the need for lightweighting is critical in this segment as the economic benefits are more quickly realized by heavy vehicles where stopping and starting multiple times per day can result in high fuel usage.[106] For example, electric bus company Proterra has developed a carbon fibre body structure for the CATALYST bus which is already selling to local transit agencies in California.[107] Furthermore, heavy vehicles benefit from lightweighting not only decreasing emissions or power requirements, it also affects the bottom line of freight carriers as additional cargo or materials can replace the structural weight of the vehicle.[108] One interesting factor that is unique to the trucking industry is that OEMs such as Navistar are allowing fleet managers to choose their components and feature from a wide variety of options, bypassing the need for standard packages where additional weight and costs are often not something that is necessary or useful for the fleet.[109] With the trend of electrification in the heavy vehicle segment, lightweighting will end up being a critical component to the success and viability of both electric battery and fuel celled vehicle development.

OPPORTUNITIES AND GROWTH

One of the major opportunity areas within lightweighting is the usage of alternative materials. is most commonly related to material replacement is the use of aluminum components in place of steel, as it can contribute up to a 40% weight reduction in vehicles.[110] This was demonstrated in the light commercial vehicle market with the recent launch of the 2015 Ford F-150, where the use of aluminum as the major structural material contributed to a reduction of over 700 pounds in weight.[111] General Motors and FCA have also introduced similar light trucks utilizing aluminum structures in reaction to Ford's release of the modified F-150.[112] Other alternative materials such as plastics and carbon fibre have also been found to contribute to a significant amount of weight reduction.[113] According to the Center for Automotive Research, between the year 2010 and 2040 there will be a significant shift in the material distribution per vehicle where new materials such as high strength steels, boron, martensite, aluminum and carbon fibre are expected to make up a much larger percentage of vehicle composition as shown in Figure 19 below.

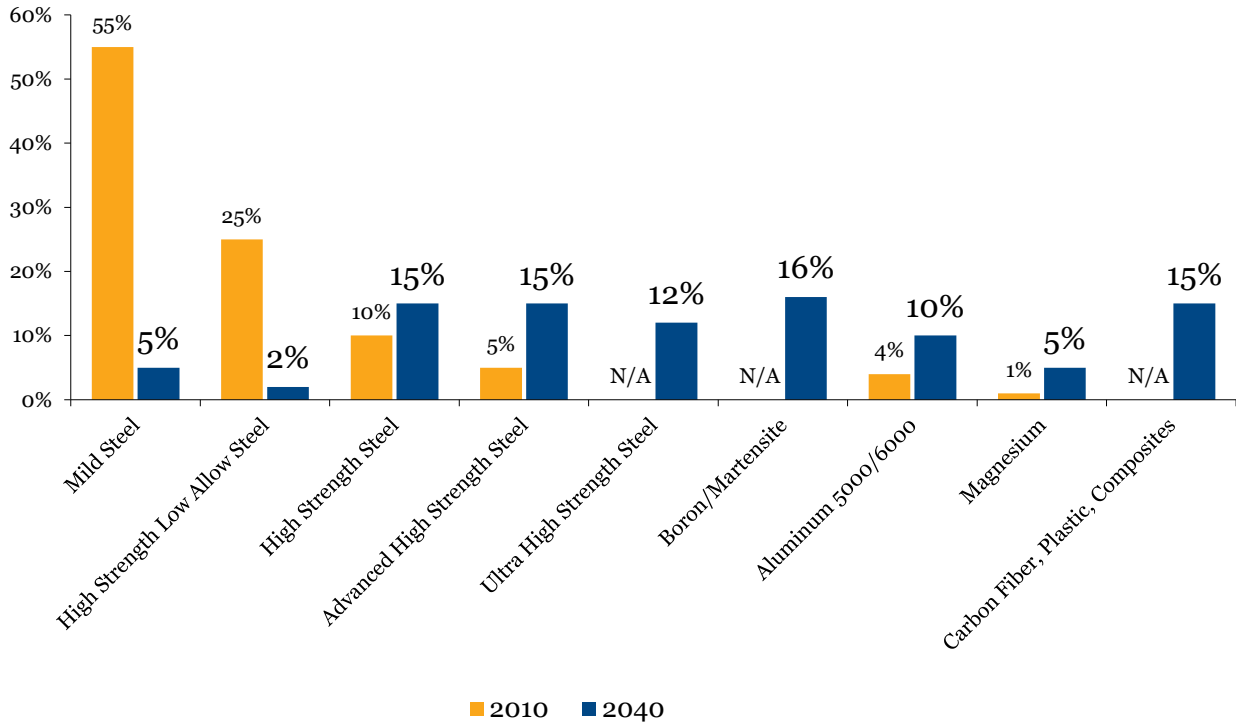


Figure 19. Material Distribution in U.S. Fleet[114]

There are a few specific structures that are the primary focus of vehicle lightweighting, including the power train, chassis, and more recently, the interior of the vehicle.[115] A study carried out by Penton Research shown in Figure 20 below, shows an increase in importance of Powertrain systems from 2016 to 2017. While all other vehicle areas have decreased as a primary target area for companies within the past year, the interior of the vehicle stands out with the largest jump in growth. Increased attention has been on reducing weight of the interior seating and instrument panels.[116]

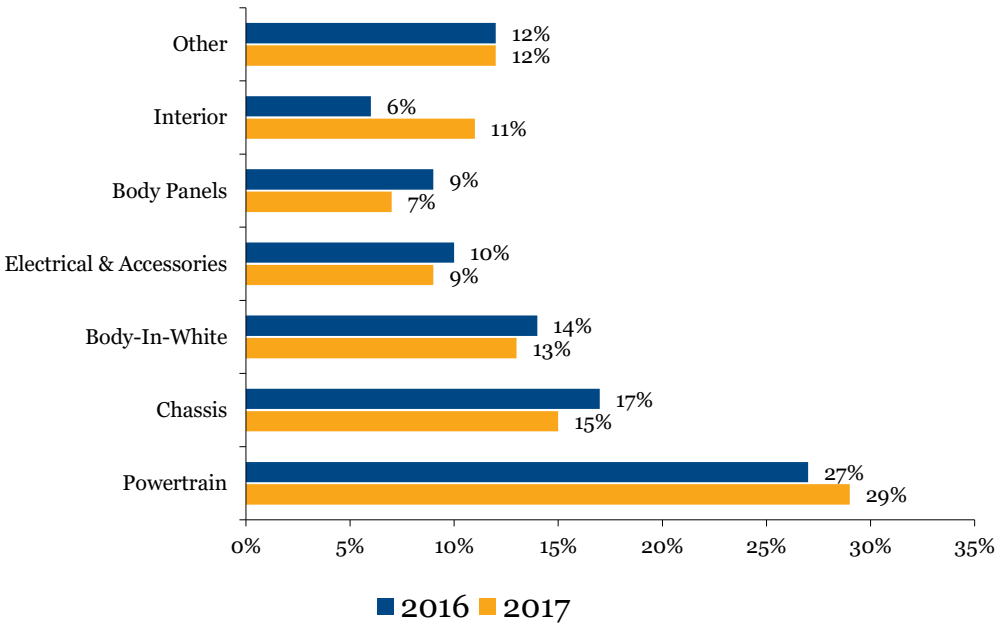


Figure 20. Vehicle Areas Targeted for Lightweighting[117]

OEMs are also looking beyond materials and components and are focusing on the way that they manufacture project to reduce weight. For example, General Motors is evaluating current manufacturing processes and trying to understand if there are different ways to design and produce products using a new 3D printing software solution.[118]

RISKS AND THREATS

Challenges for passenger cars include the fact that automakers have come to a point where it is becoming harder to reduce the weight of the vehicle through improving conventional materials such as steel, which currently contributes to over 95% of vehicle structural composition.[119] This roadblock related to conventional materials is driving innovations in new materials technologies, metallurgy and alternative manufacturing and production processes as mentioned previously. While carbon fibre has the highest potential weight reduction when compared to other alternative materials, the prohibitive costs related to processing and producing the materials are currently slowing the overall adoption and implementation of this material on a larger scale.[120] The same issues relate to aluminum, as the overall cost per pound is more than double that of steel. While these materials are cost prohibitive in the passenger car market, carbon fiber has been more broadly adopted in the aerospace industry as well as the sports car racing industry, where performance is valued over price.[121] Potential advancements in these industries could be transferred over to the passenger vehicle market if major improvements are made in the future.[122]

Apart from the challenges related to individual materials like manufacturing costs and product availability, there are also various challenges when working with multiple materials in one vehicle, such as joining issues (putting dissimilar materials together) and those related to corrosion, forming, noise, vibration and temperature control for different types of materials. Furthermore, new manufacturing processes including 3D printing and new novel molding and casting processes still have issues that need to be resolved before they are ready to handle mass production capabilities.[123]

SUMMARY

Vehicle lightweighting is an area that already has a long history of development in the U.S. market. This area is poised to continue to be on OEMs and suppliers' radars in the short term since it has such a distinct interrelation to different types of drivetrain technologies and their functionality and performance. While other technologies such as battery vehicles or fuel cells have direct threats, where one technology could overtake the other, this type of scenario does not apply to lightweighting where challenges are more related to the technology itself. The main threats in the near term are high costs and making new novel manufacturing processes more viable for lightweighting to become a more integral part of every-day vehicle design and manufacturing activities.

INTERNAL COMBUSTION ENGINE (ICE) TECHNOLOGIES

Given the current political and regulatory situation in the U.S. along with hurdles associated with electric vehicles and fuel cells, incremental innovation of internal combustion engine (ICE) technologies will likely continue in the automotive industry at least in the short term.[124] Specific impact and influence from the oil industry can also be seen in the U.S. automotive market industry where large oil companies are working with local U.S. OEMs to make traditional engines more efficient. Just this year, a large international oil company set up a research facility in Detroit to develop fuel efficiency of ICE vehicles.[125]

The overall market acceptance with consumers is also likely to continue as low gas prices, familiarity, and an overall lack of infrastructure for alternative vehicles, will make it an easy choice for consumers to continue to drive vehicles powered by combustion engines.[126] Currently, the combustion engine, or gasoline powered engine accounts for 97% of vehicle sales in the U.S., and it is expected that even by 2030 that at least 7 out of every 10 cars will be internal combustion vehicles.[127]

INVESTMENT & R&D

Both industry experts as well as major powertrain technology suppliers expect that ICE technologies will be a major part of the drivetrain volume in the U.S. fleet until at least 2025, primarily due to cost competitiveness (Car research). General Motors, when compared to new entrants like Tesla, is facing challenging decisions as the company must not only continue to fund development of incremental changes to ICE but must also put heavy investments into alternative drivetrains to stay competitive.[128] Investment trends tend to be OEM-specific as each company has their own plans on how they will tackle the move to electrification. Ford, for example, made an announcement in 2017 that it would be shifting approximately one-third of their R&D funding dedicated to internal combustion engines over to electrification.[129]

While it may seem that the market is quickly moving in the direction of electrification, the overall patent count, which is a good indicator of R&D investment, shows that currently there are still more patents filed for ICE technologies than for electric and hybrid technologies. This is particularly true for the American OEMs where ICE patents make up the highest amount, while on the other hand Japanese OEMs have moved ahead quite significantly on the electric side with Electric-related patents almost doubling the number of ICE patents.[130]

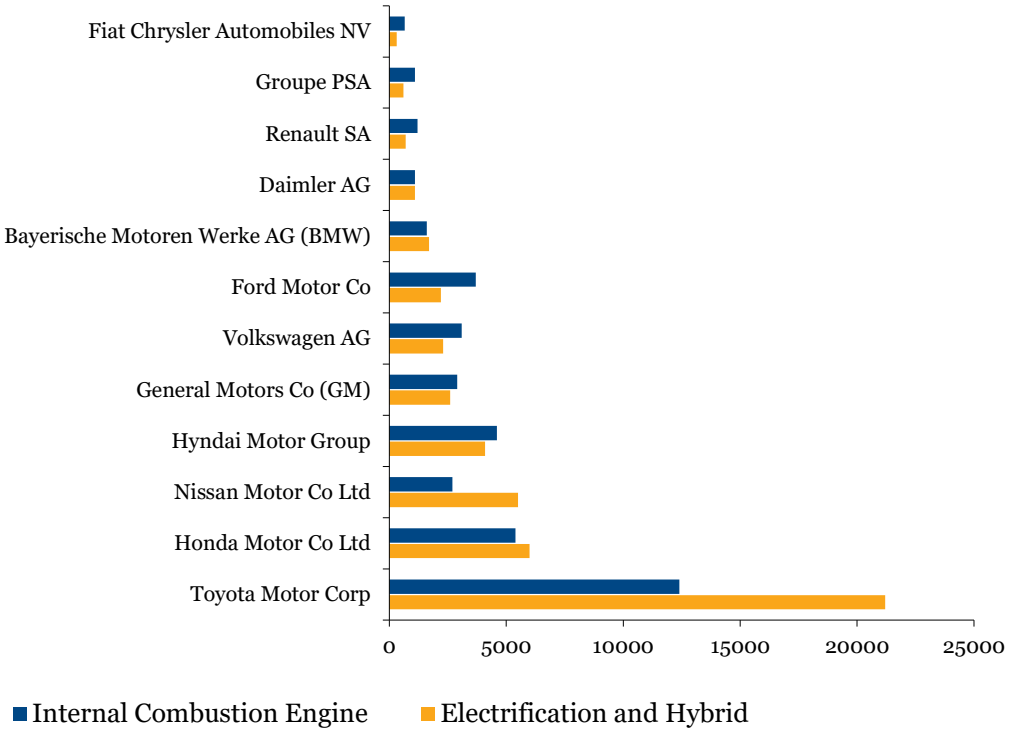


Figure 21. Number of Patents in engine technologies per OEM[131]

Alternative fuel considerations are also affecting the type of research and investment into combustion engine modification and optimization for these types of fuels. In the U.S., alternative fuels are not very commonly used in passenger vehicles, with only some engines running on a mix of gasoline and ethanol.[132] Most of the major OEMs are supplying vehicles that run on alternative fuels with flex-fuel which is a combination of E85 and gasoline, being the most common version of vehicle. American OEMs, specifically GM, FCA and Ford, have been front-runners in this area of flex fuel vehicles for cars and light trucks. In 2016, there were a total of 66 model vehicles with flex fuel options, partly due to a credit offered through the CAFE program.[133]

On the other hand, within the heavy vehicle segment, a few alternative fuels have been gaining increased traction including liquified natural gas, hydrogen and propane.[134] Natural gas is already a popular choice of fuel for major Class 8 truck OEMs as the price of diesel fuel continues to climb in the U.S.[135] A lot of activity is surrounding this area as the U.S. Department of Energy's National Renewable Energy Laboratory has selected nine projects related to natural gas vehicle development to receive up to 18 MUSD, with recipients including Cummins, GTI, Isuzu, Argonne National Laboratory and the University of Alabama.[136]

Major heavy vehicle operators' interest in alternative fuels is driving increased partnerships and investments within the industry. One of the largest U.S. trucking fleet owners, Penske, has made recent efforts to get away from diesel fuel and switch to liquified natural gas as a major source for its trucking fleet. As diesel prices move higher and natural gas prices decrease, this is a clear driver for the switch to natural gas as a fuel source.[137] While natural gas is a growing fuel in the heavy vehicle segment, major trucking sales and servicing company Rush Enterprises notes that they do not expect natural gas to replace diesel fuel. However, they do expect moderate growth in the demand for natural gas vehicles. As a result, they are working with engine manufacturers to ensure that their CNG fueling system is well integrated into current systems.[138] For the foreseeable future, fleet owners and trucking companies will continue to work with natural gas and biodiesel until battery technologies and related maintenance issues improve.[139]

OPPORTUNITIES AND GROWTH

Some technologies that have been of particular interest for further development within the ICE segment are gasoline direct injection (GDI), turbocharging, stop/start and compression-ignition technologies, and Atkinson cycle engines are promising for hybrid vehicle applications (Automotive World, CAR research, EPA below).[140] In the current market of 2018 model year vehicles, as reflected in Figure 22, the most widely adopted technology by all major OEMS is GDI. Turbocharging also seems to be gaining ground with OEMs, while concepts such as StopStart technologies have made traction in European and US models but is not as prevalent in the manufacturing lineup of Japanese OEMs. A study by the Center for Automotive Research complements these findings with data showing that GDI, turbocharging and StopStart technologies are expected to reach at least 50% market penetration in the U.S. by the year 2025.[141]

Figure 22. Technology Share for Large Manufacturers, Model Year 2018[142]

RISKS AND THREATS

Although Hybrid and Electric vehicle technologies currently do not make up a large part of the market, industry players expect that some form of hybridization will be needed to meet both increasing regulations but also to prepare for electrification. Patrick Lindemann, the President Transmission Systems & E-Mobility from Schaeffler in Ohio predicts that by 2035, a mix of HEVS and ICE vehicles will make up at least 70% of vehicles, thus further confirming that the combustion engine will not be going away any time soon.[143]

The main threat for ICE will be encountered farther in the future when battery or other alternative propulsion technologies achieve market viability, where these alternatives must first overcome their own challenges related to cost, technology and infrastructure. In the meantime, OEMs will continue to try to optimize combustion engines as much as possible to gain efficiency in the short term and to meet the 2025 CAFE standards.

SUMMARY

The Internal Combustion Engine is still very relevant in the U.S. market when considering the current political situation and overall consumer acceptance levels for this type of vehicle. While OEMs are jumping head first into EV investments, they will still have to juggle a balance of also investing in making ICE vehicles more efficient. This specific area of propulsion technologies will continue to be dominant in the U.S. market until one of the other alternative technologies are fully realized in a commercial setting.

SEGMENT COMPARATIVE ANALYSIS AND PRIORITIZATION

Based on the previous analysis of four technology areas related to sustainable and fuel-efficient vehicles, it is evident that lightweighting is an integral component to drivetrain technologies no matter if they are conventional, hybrid, electrical or other. Therefore, **it is recommended that lightweighting be one prioritized area that should be further investigated**. The remaining three technologies related to the vehicle powertrain have been evaluated according to four key scoring criteria to determine the most relevant areas for investigating potential business opportunities in the U.S. Each type of technology (EV, Fuel cell and ICE) have been evaluated with an assigned score of 1-3 (with 3 representing favorable segment attractiveness and 1 representing unfavorable attractiveness) for the following criteria both in the short, and medium to long-term:

- The relevance of the technology for both the light and heavy-duty vehicle segments
- The investment focus of U.S. OEMs towards each drivetrain segment
- The openness of OEMS and local suppliers in these areas in terms of the stage of technology development and local internalization of projects, which may involve proprietary IP
- Overall consumer views and rate of adoption of the types of drivetrain technologies

When looking at the short-term relevance of these technologies, it is recommended to investigate further opportunities in the battery electric vehicle segment when considering both hybrids and purely battery-electric vehicles. In fact, among U.S. executives participating in KPMG's 2019 Global Automotive Executive Survey, hybrid and battery powertrains were the areas of most investment. Other major studies find similar results in increased investment towards electric drivetrain compared to ICE projects where investment levels are expected to relatively decline in the coming years. There is an increasingly high interest in fuel cell electric vehicle investments, but it is still lower than battery electric and hybrid projects. Consumers are adopting hybrid and electric vehicles at an increasing rate as well far beyond that of Fuel Cell EVs. Based on the research and current market, Business Sweden proposes to **focus on identifying business opportunities within the active battery electric space primarily for passenger vehicles**. A summary of our short-term evaluation is presented below and accords with feedback received from local industry experts in addition to various external studies.

SHORT-TERM PERSPECTIVE (up to 2025)	Battery EVs (incl Hybrid)	Fuel Cell EVs	Internal Combustion Engine Technologies
1 Relevance for both Light and Heavy-Duty Vehicles	2	3	3
2 Investment Focus for U.S. OEMs	3	1	1
3 Openness of Suppliers and Collaborators	2	3	1
4 Consumer Views/Rate of Adoption	2	1	3
Total	9	8	8

Figure 23 Business Opportunities by Segment (Short Term)

In the longer-term, with greater uncertainty, industry forecasts become less reliable. The Battery EV segment will be increasingly relevant in the long-term; however, Fuel Cell vehicles are a highly interesting segment given their various advantages over competing technologies and their relatively earlier stage of their development cycle. As such, projects in this space represent a potentially more attractive opportunity area for new suppliers and collaborators. While consumer adoption rates are highly uncertain in this segment and will have a significant lag, there are several prominent heavy vehicle manufacturers already placing orders for fuel cell heavy trucks. Business Sweden proposes to **investigate the potential opportunities for suppliers and collaborators in the Fuel Cell EV segment with a focus on heavy vehicle opportunities**.

MED - LONG TERM PERSPECTIVE (2025 and beyond)	Battery EVs (incl Hybrid)	Fuel Cell EVs	Internal Combustion Engine Technologies
1 Relevance for both Light and Heavy-Duty Vehicles	2	3	2
2 Investment Focus for U.S. OEMs*	3	2	1
3 Openness of Suppliers and Collaborators	2	3	1
4 Consumer Views/Rate of Adoption*	2	2	2
Total	9	10	6

*Very high degree of uncertainty given varying forecasts and lack of consensus

Figure 24 Business Opportunities by Segment (Long Term)

MARKET AND BUSINESS OPPORTUNITIES IN KEY SEGMENTS

VEHICLE LIGHTWEIGHTING

As reflected in the previous sections of this report, lightweighting can have a significant impact, not only on alternative fuel vehicles such as battery electric vehicles, but also on conventional cars and trucks. Lightweighting activities within the automotive industry revolve around design and material development, cost analysis, prototyping, certification, and testing. Given the many drivers encouraging further advancements here, there is widespread activity and research for all levels of the automotive supply chain, as well as non-traditional automotive sub-suppliers.

Additionally, many non-profit, governmental, and industry organizations are actively collaborating with industry leaders to further innovate. Most organizations are open to working with international companies for research and development such as the Lightweight Innovations for Tomorrow (LIFT) organization. LIFT works with multiple stakeholders both in automotive and aerospace including OEMs Volkswagen and Boeing and supports small innovative startups. For international companies, it is often more common for organizations such as LIFT to collaborate with those that have an existing stake in the local market. Other major research institutions related to lightweighting include the Center for Automotive Research (CAR) and their associated collaboration with the Coalition for Automotive Lightweighting Materials (CALM) in Detroit. CALM works with some of the Tier 1 companies highlighted in the subsequent sections including Faurecia, Magna, and Martinrea.[144]

AREAS OF OPPORTUNITY AND MAJOR PLAYERS

Within lightweighting, much progress has already been achieved, stemming from the first attempts by automakers in the 1990s to reduce weight driven by the addition of new features such as infotainment and speakers, to new innovations for carbon fibre to reduce structural and body weight of the vehicle.[145] Currently, the vehicle body is the main focus of lightweighting activities as it makes up as much as 25% of the vehicle mass and plays an important part in meeting targets for safety, strength and noise control.[146] While this specific area will continue to be a relevant area for the automotive sector, companies are also beginning to explore new areas for lightweighting such as the powertrain, interior structures, and other key components such as electrical and lighting. As shown in Figure 25 below, primary structural features of a vehicle such as body, suspension and chassis make up a majority of the weight, however, other areas such as powertrain and interior have gained more recent interest in the lightweighting arena.[147]

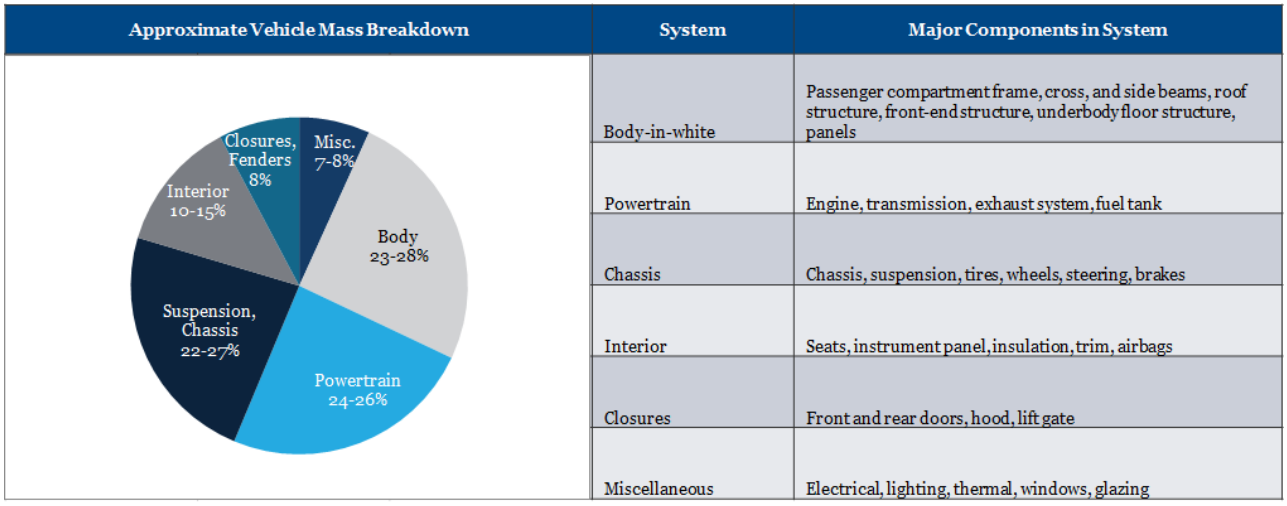


Figure 25. Vehicle mass breakdown by automotive system and major components[148]

Seating and Interiors

When addressing specific interior assemblies for lightweighting, the overall weight is one of many factors to consider, with safety, comfort, and consumer preferences adding additional layers of complexity. For example, due the addition of new technologies such as sensors and cameras in autonomous vehicles, weight reduction is being sought by vehicle and component manufacturers in the U.S. In terms of prioritization areas for lightweighting, most vehicle manufacturers in the U.S. will prioritize the most cost-effective option, whereas in Europe, environmental regulations and engineering considerations are a larger driver of lightweighting efforts.[149] Many non-structural components such as seating, instrument panels, airbags, and restraints come at a high cost and heavy relative weight. According to industry experts in lightweighting, seating is one area that is on many automotive companies' radars, as there has been a great focus by manufacturers to come up with new seating configurations. Seats overall are important for lightweighting as they are expensive, heavy and take up a lot of space in the vehicle.[150]

Given the high prioritization of cost savings, coupled with continued aggressive goals of weight reduction, it is easy to see why seating has become such an important focal point for lightweighing activities in the U.S., and therefore, also a potential opportunity area for Swedish companies. According to a study by the Idaho National Laboratory (within the Department of Energy), seating and restraints account for the second most expensive and fifth heaviest major component within a typical mid-size passenger vehicle.[151]

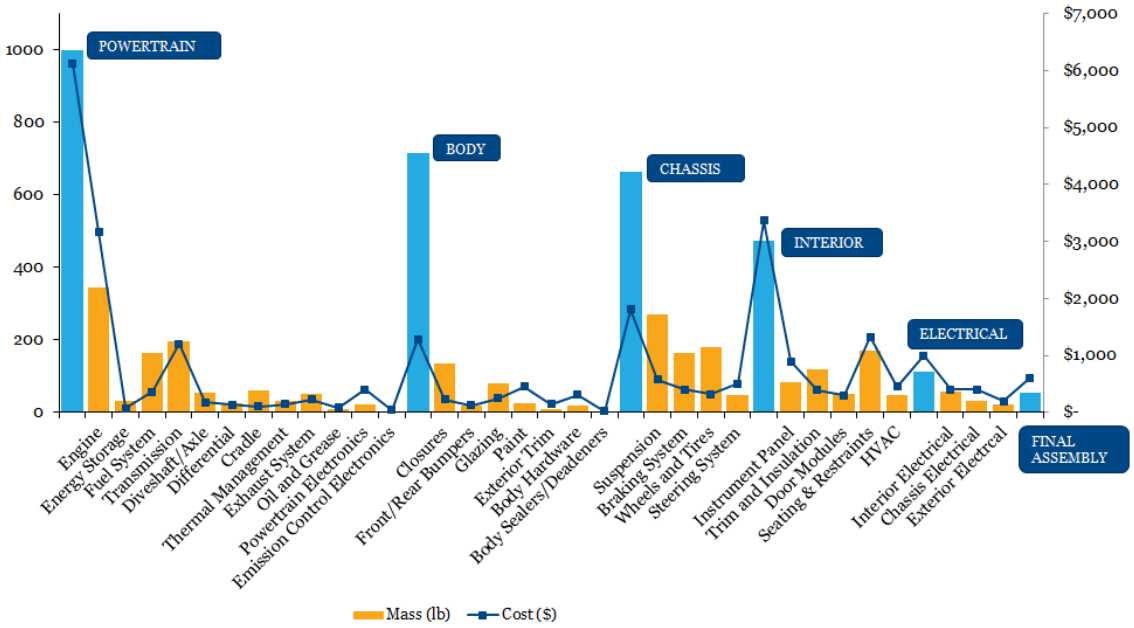


Figure 26. Weight and cost of typical components in a baseline midsize vehicle, before lightweighting[152]

As reflected in Figure 26 above, interior systems including seating and instrument panels have a much higher cost per weight ratio when compared to other major systems such as the body and chassis. Therefore, there are major opportunities for improvement for both weight reduction and cost reduction of these components. For example, one of the more complex proposals of implementing carbon fiber in instrument panels and seat structures, could result in an overall weight reduction of 39 and 41% respectively.[153] However, these types of weight reduction strategies also bring high risks when considering material and processing challenges, and the prohibitive cost involved.[154] Thus, the main opportunity for suppliers will be to offer solutions that help to commercialize new innovations that combine weight reduction, cost effectiveness, while retaining system safety and functionality.[155] While full commercialization of carbon fiber substitutions is still far off, companies like Faurecia have been working on making new seating structures from magnesium alloys. Their competitor, Adient, is taking a multi-material approach to seating combining magnesium, glass fiber-reinforced plastic, and aluminum and high tensile steel in their seating design.[156]

The U.S. automotive seating market can be considered an oligopoly with a few major players making up the majority of market share. Adient, a spinoff of Johnson Controls, and other major Tier 1s including Magna Seating, Lear Corporation, and Faurecia make up over 78% of the global market share.[157] These larger companies can be seen as clear leaders in seating solutions and are implementing some of the newest lightweighting innovations in the market.

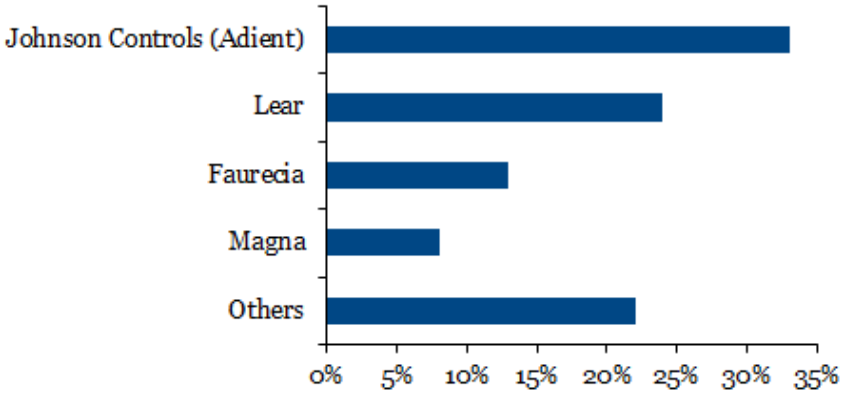


Figure 27. Global passenger car and light vehicle seating market share in 2017 by manufacturer [158]

While each of these four companies has a local presence in the U.S., with Lear and Adient being headquartered in the U.S., they also have global presence and satellite locations in Sweden, providing opportunities for local accessibility. The types of sub-suppliers for these Tier 1 seating companies vary widely by type of component and include both U.S. based and international suppliers. For example, Adient already works collaboratively with the Swedish company Autoliv to ensure both comfort and safety.[159] Some smaller and more local seating manufacturers in the U.S. include Tachi-S, NHK Seating, and TS Tech Americas.[160]

Although all these companies are officially Tier 1s, one could consider them more as seating OEMs due to their overall size and complex product offering, and thus entry and collaboration within this market may be more accessible to market newcomers at the tier 2 or 3 level. For example, companies focusing on sub-assemblies or specific materials may be more easily accessible for collaboration or business opportunities. Within seating, areas such as structural components including the seat frame or base, as well as fabric, closures and electrical or thermal-related products may provide more clear opportunities for Swedish suppliers. For structural seating components, innovative companies in the U.S. market include suppliers such as Meridian Lightweight technologies who is working on magnesium seating structures and Rifast who produces lightweight fasteners used in seat rails and seat tracks.[161] Additional examples of leading players in the seating industry that could be potential targets for partnerships are listed in Appendix A.

Powertrain and Propulsion System Structures

Along with interior systems, the powertrain and engine systems areas are also a major lightweighting focus for automotive companies in the U.S. According to leading research engineers, lightweight structures around battery systems and the powertrain is important to consider for gaining as much energy as possible from the batteries. They explain that the powertrain is very important as it is a massive system encompassing the engine, differentials, and transmission. For electric vehicles, it is important to reduce the complexity of the powertrain and reduce the overall size of the battery, while at the same time keeping the same speed and overall power.[162]

For conventional engines, Tier 1 companies are working to reduce the weight of the engine cradle and engine components such as engine block, frame, oil pan and engine cover.[163] Formerly made from steel, companies are looking to use aluminum and now magnesium materials to replace previous structural forms. Companies such as Martinrea produce aluminum engine components for American OEMs such as Ford, GM and FCA.[164] When considering the OEMs themselves, they are also collaborating with suppliers to drive innovation as reflected in the recent announcement by Ford and Magna where they will soon decide upon rolling out a carbon fiber engine subframe in upcoming production.[165]

Another interesting extension of these research activities is overlapping the area of electric battery cages and supporting structures. Currently, most of these structures are made of steel, however, they are also starting to move towards being manufactured out of aluminum, composites and new rigid structural foam materials. Unique challenges exist when working with electric batteries when it comes to considerations for heat, flammability, thermal insulation and overall durability, and therefore, choosing the right design and materials are key.[166] More recently, there has been a significant trend of major OEMs such as Nissan, VW, and Tesla driving the switch from steel to aluminum for battery enclosures.[167] Given this new demand for aluminum and lightweight metals, players with highly diversified product offerings such as industrial aluminum company Novelis are developing new battery enclosure solutions.[168] Tier 1 Faurecia is also active in this space with their development of a composite battery housing cover, providing overall lower weight and cost. Faurecia's goal for 2020 and beyond is to integrate thermal management into the housing to help with cooling challenges for battery powered vehicles.[169]

BATTERY ELECTRIC PASSENGER VEHICLES (BEV/HEV/PHEV)

An ecosystem of suppliers and research organizations are focused on making electric battery systems more efficient, cost-effective and powerful. According to researchers and experts in the field of electric vehicles, traditional lithium-ion batteries still have a lot of potential left in terms of improvement and innovation. According to most conservative estimates, it will be another ten years before any other major technology displaces lithium-ion.[170] Major governmental and research organizations such as Oak Ridge National Laboratory and local players such as the Battery Innovation Center, are dedicated to improving lithium-ion batteries mainly to drive the further commercialization of these new technologies, but also to improve the safety of these current batteries.[171] Furthermore, geopolitical concerns about cobalt and lithium deposits and availability in the U.S. are forming a new interest in new chemical and material compositions for lithium-ion batteries. [172]

AREAS OF OPPORTUNITY AND MAJOR PLAYERS

Lithium-Ion Battery Upgrades

While there are only about five major battery manufacturers (e.g. Tier 1) in the U.S. including XALT, LG Chem, JCI, A123 and Tesla, there is an emerging trend of startups looking to improve upon current technologies instead of competing directly with the manufacturers themselves. Because of this trend, there are several opportunities for Swedish companies to form collaborative relationships with either research organizations, engineering firms, and lower tiered startups that are looking to work on incremental improvements.[173]

One particular component that researchers continue to target are the electrode and active materials within the lithium ion battery (e.g. cathode and anode.) When a battery cell charges and discharges, ions flow between the anode (negative electrode) and the cathode (positive electrode), as depicted in Figure 29 below.[174]

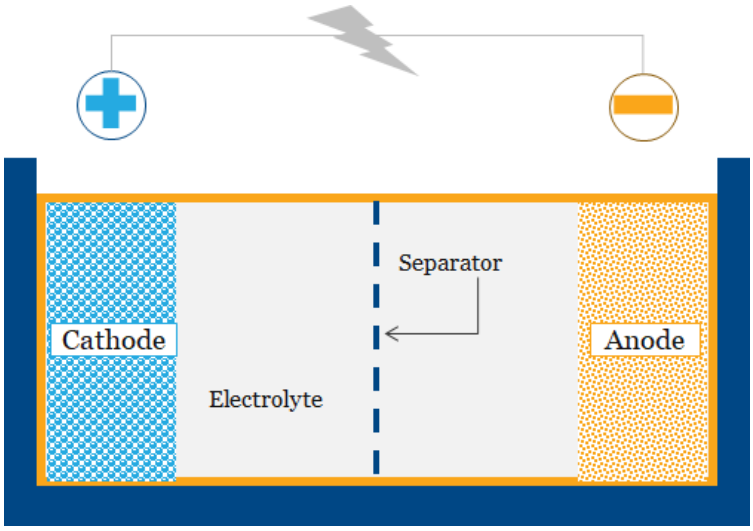


Figure 29. Major components and structure of a typical lithium-ion battery

In the past few years, research institutions have developed new materials and formulations that improve cathode and anode technologies. These specific materials are important, as different types of combinations and material choices can greatly affect multiple aspects of the vehicle battery including cost, power, energy, performance and safety.[175] Currently, the six most common types of lithium-ion batteries are made with anodes consisting of graphite or titanite and cathodes consisting of lithium and metal combinations. Figure 30 below shows the composition of current commercialized versions of lithium-ion batteries and their general market applications[176]

Lithium Cobalt Oxide		Lithium Manganese Oxide		Lithium Nickel Manganese Cobalt Oxide	
Anode	**Cathode**	**Anode**	**Cathode**	**Anode**	**Cathode**
Graphite	$LiCoO_2$	Graphite	$LiMn_2O_4$	Graphite	$LiNiMnCoO_2$
Typical Applications: Mobile phones, tablets		Typical Applications: Power tools, medical devices		Typical Applications: E-bikes, EVs	
Lithium Iron Phosphate		**Lithium Nickel Cobalt Aluminum Oxide**		**Lithium Titanate**	
Anode	**Cathode**	**Anode**	**Cathode**	**Anode**	**Cathode**
Graphite	$LiFePO_4$	Graphite	$LiNiCoAIO_2$	Titanate	$LiMnO_4$ or NMC
Typical Applications: Energy Storage		Typical Applications: Medical Devices, EV's (Tesla)		Typical Applications: EVs (Mitsubishi I-MiEV, Honda Fit EV), solar street lighting	

Figure 30. Six common types of lithium-ion batteries and their composition

On the cathode side, researchers at Rensselaer Polytechnic Institute have improved charging speeds by replacing the cathode cobalt oxide with vanadium disulfide, while researchers at the University of Maryland along with the U.S. Army have developed a new cathode material iron trifluoride which is said to triple the capacity of lithium ion battery electrodes. [177] On the anode side, market newcomer Sila-Nanotechnologies is looking to manufacture lithium ion batteries with a silicon-based powder for the anode, which absorbs lithium faster than graphite.[178]

While new lithium-ion compositions are continually being developed by researchers, the main goal is to make these new innovations a reality on the commercial side. Overall the expenses and technology required to properly scale these innovations is preventing much of these new novel technologies from taking off outside of the scientific and research community.[179] More specifically, when looking beyond the chemical and physical composition and make-up of lithium-ion cells, one practical challenge that comes with these improvements in lithium-ion cells is the overall system constraints involved. This includes issues with manufacturability, processing, quality management and pack designs.[180] Some companies that produce lithium ion material solutions also are working on processing improvements such as OneD Material who has developed a scalable manufacturing process for producing anode materials.[181] For innovations in joining materials, production technology company Trumpf has developed laser welding technologies that help to join complex and sensitive components such as battery cells.[182] Therefore, there is a clear opportunity for Swedish companies to provide enhanced engineering, manufacturing and process-related solutions for the U.S. battery market.

Solid State Lithium Batteries

In part due to the safety concerns of lithium-ion batteries there has been a rising interest in solid state lithium batteries.[183] Solid state lithium batteries are essentially batteries that rely on solid electrodes rather than liquid electrodes which can be found in most conventional batteries. Companies have been investing in this technology as solid-state batteries have the potential to also offer faster recharging, longer range and slower degradation mainly because these batteries can have a much higher energy density than their liquid counterparts. The following illustration demonstrates the energy density by technology:

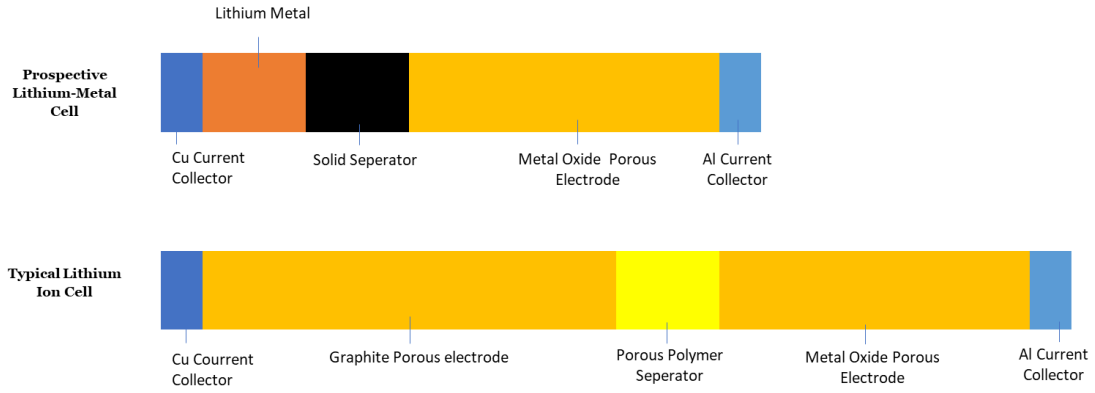


Figure 31 Proportional Representation of Solid-State Battery and Lithium Ion Battery [184]

Several automakers, such as Toyota (working with Panasonic) have been active in this area in a bid to gain a competitive advantage on other electric automakers such as Tesla.[185] Other companies such as A123 and Ionic Materials have also made recent strides in this area, with the pair recently developing a battery that does not use any liquid electrolyte and is thus non-flammable. The two companies also claimed that the new battery design could be manufactured with only minor adjustments to existing manufacturing processes since it uses polymer instead of the more commonly-used lithium metal.[186]

The complications associated with the manufacturing process has otherwise been the source of hesitation for many companies which still recognize the long-term viability of the technology. Auto manufacturer Nissan, for instance, stated that it would probably take another decade before the technology was commercially available. This is particularly interesting to note as Nissan invested 65 MUSD in Ionic Materials in 2018. whereas other companies such as QuantumScape, a California based manufacturer of solid-state batteries which received a 100 MUSD investment from VW, stated that it would not happen before 2025.[187] Other companies have been more optimistic, with Solid Power, a Colorado battery manufacturer, announcing that they would be able to mass produce solid state batteries by 2020. Both Ford and BMW have signed agreements with Solid Power to include the new battery in their EVs.[188]

Meanwhile, the price of the nearest competitor, the lithium ion battery, is expected to continue decreasing. Since 2010 the price of lithium ion batteries has already dropped by 85% and is likely to continue to fall as global production capacity at battery factories is expected to triple in the next 5 years.[189] Therefore, the main challenge for manufacturers of solid-state lithium batteries is to bring down the cost of production to make it competitive. In the meantime, many companies are still eyeing lithium ion batteries. Even though Solid Power has set 2020 as a target launch date the fact that other companies have a much later launch planned would indicate that many companies in this sphere still have significant challenges and needs in this area and may be more approachable by potential partners and collaborators if they have the right talent and technological knowhow.

FUEL CELL TECHNOLOGIES: HEAVY VEHICLES

While fuel cell vehicles have existed for several years, the application for heavy vehicles has seen a recent surge of interest particularly following the development of high profile protypes by Nikola as well as Toyota & Kenworth. Many cities and municipalities have also increased their investments into fuel cell busses as part of an effort to curb vehicle emissions. It is also worth mentioning that due to the ongoing development of the technology many companies in this field have yet to fully develop their supplier base with many OEMs still researching the components or making components either in house or from unconventional suppliers. This also means that there are many new entrants gaining traction as more established OEMs or tier 1 suppliers compete with one another to access the most recent technological development. There are also a variety of research entities that are involved in the development of heavy fuel cell vehicle components who were also able to provide input.

AREAS OF OPPORTUNITY AND MAJOR PLAYERS

Fuel Cell Stack

A fuel cell stack is a central component of fuel cell vehicles. The fuel cell stack is essentially the component that produces electricity from the hydrogen and enables the vehicle to move forward. Though it has been argued that the technology itself is mature and unlikely to have any significant. The main challenge with Fuel Cell stacks is the cost of manufacturing. As one interviewee stated regarding the development of fuel stacks,

> "I don't think there is any major issues, worthy of a Nobel prize. It's mostly about bringing down the cost of the fuel cell [stack]. That's where the challenge lies. Currently they use a lot of platinum and the goal is to eventually use something more affordable to bring down the total cost,"[190]

Both Bosch and Hyundai have also acknowledged the challenge of reducing the amount of platinum in the fuel stacks, with both companies investing in platinum "light" fuel stacks.[191] Currently platinum serves as a key component in a fuel cell vehicle, serving as a catalyst to convert hydrogen into protons and electrons, and breaking oxygen bonds and eventually form water. Essentially, platinum is the key ingredient to transform hydrogen into electricity and water.[192]

An additional challenge facing manufacturers of fuel stacks is the production cost and need to create economies of scale. Toyota has made some strides in making more adaptable stacks that can be used in both the Mirai passenger vehicle and heavy-duty trucks. The only difference would be that the truck would require two instead of one. This opportunity for making adaptable stacks to improve scalability has the potential to bring down manufacturing costs substantially.[193] In similar efforts to improve fuel stacks Bosch recently announced a partnership with the Swedish fuel cell manufacturer Powercell Sweden AB to research and develop polymer-electrolyte membrane (PEM) fuel cells for large scale production.[194] Another large tier 1 supplier in the heavy vehicle segment is the Canadian company Ballard, which is a key supplier of the fuel stacks and engines used in the buses of New Flyer, a prominent fuel cell bus manufacturer active in Canada and the U.S.[195] Much like Bosch, Ballard is a well-established Tier 1 supplier active in the fuel cell vehicle segment that could be a potential collaboration partner for Swedish companies.

Fuel Cell Tanks (Compressed Gas)

As previously mentioned, one of the biggest challenges in terms of reducing vehicle weight, is related to the fuel tanks used by FCEVs. Due to the low energy density of hydrogen, the gas needs to be compressed at 5000-10,000 psi. This is significantly higher than LNG, which only needs to be compressed at 3,000-3,600 psi.196 The thicker fuel tanks also tend to be more expensive and account for a sizeable portion of the vehicle's total cost. Another limitation posed by the high-pressure requirements from a design standpoint is the shape of the fuel tank. To keep the pressure evenly pressurized, the gas tanks need to be cylindrical. Image 32 shows the fuel cell tank of a Toyota Mirai as a demonstrative example. This vehicle has two plastic tanks which are reinforced with carbon fibers. These weigh 88 kg combined.

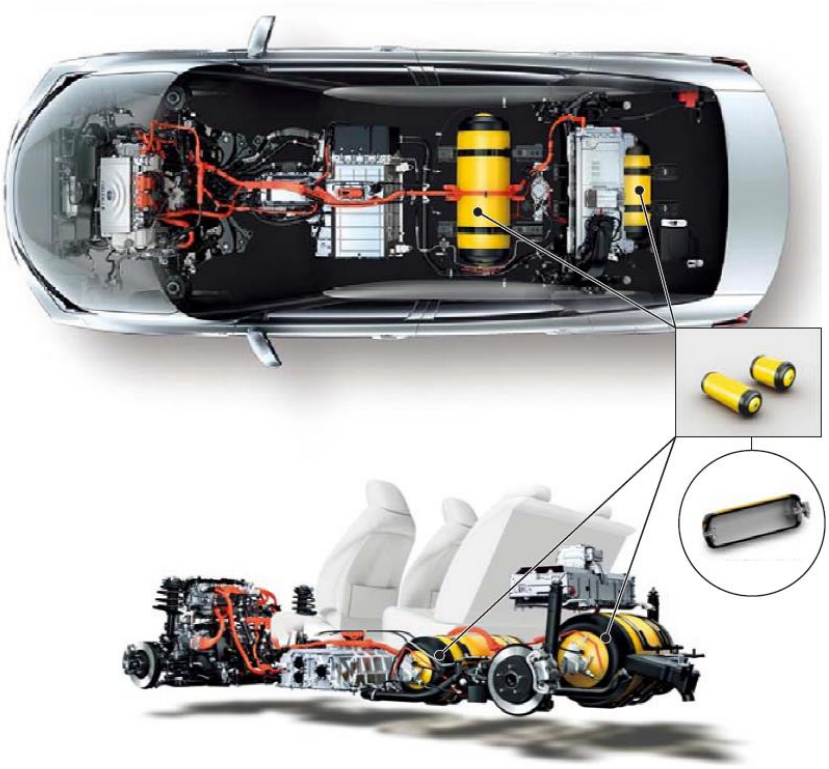
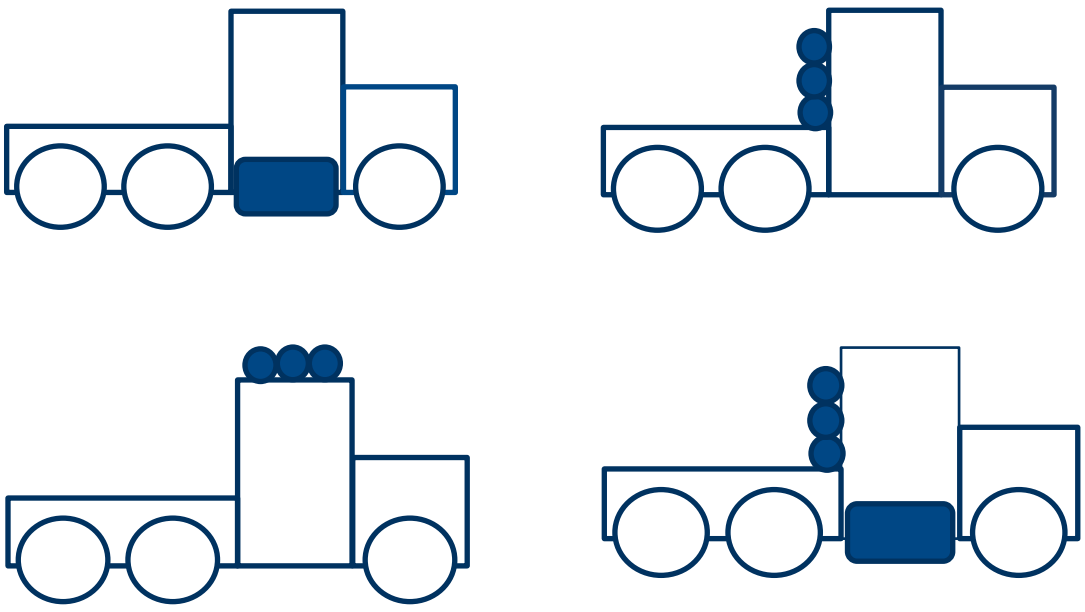


Figure 32 Configurations of the Fuel Tanks on a Toyota Mirai [197]

Other companies have used similar approaches mixing aluminum and carbon however, the shape requirement remains a challenge as it also restricts how other truck components can be designed. This is particularly important to note when discussing heavy trucks as these typically require larger storage fuel tanks due to the heavier loads and need for longer range. While other large vehicles, such as buses have solved this challenge by placing the fuel cell tank on the roof this is less of an option for trucks which have a smaller roof size.[198] Figure 33 below shows different configurations of storage. As shown, unless the truck cab uses a combination of fuel storage systems it will have significantly less storage possibilities than a bus.



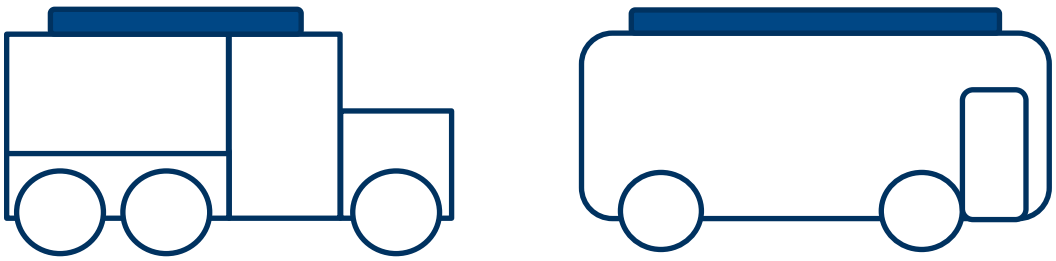


Figure 33 Compressed Gas storage in Various Configurations on Trucks and Buses[199]

In the pursuit of developing lighter and more efficient fuel tanks automotive suppliers have sought expertise from a wide variety of companies. Faurecia, another large automotive supplier in North America, has made recent strides in reducing the weight of the fuel cylinders after forming an agreement with STELIA Aerospace Composites, another French company active in Canada and the U.S.[200] Meanwhile, companies such as Luxfer which traditionally designs and manufactures aluminum cylinders for several industries including medical product manufacturing, have also become increasingly focused on vehicles, such as trucks, buses and even trains as of late.[201] While Luxfer has been active in developing CNG tanks for garbage trucks such as McNelius the company has also made strides within hydrogen, having supplied their hydrogen tanks to Ford, Daimler, Nissan and Hyundai.[202] On the 20th of June it was announced that Luxfer's fuel cylinders had been used for a prototype hydrogen train in London.[203] Similarly, CP Industries also made gas cylinders for other industries before entering the auto market.[204] Sharing the space is also Norwegian based Hexagon Composites, who has a long-term contract with New Flyer to develop gas tanks and fuel systems.[205] These examples show that there are several different companies active in the field and that many North American companies are open to collaborate with Northern European companies.

The extra space requirement for hydrogen is due to the lower energy density when compared to regular gasoline. To address the limitation fuel storage, companies such as BMW have been developing FCEVs that use and store liquified hydrogen at 253 degrees Celsius below zero. At this state the fuel is three times denser than regular gasoline.[206] When hydrogen is in a liquid the tank can take on a greater variety of shapes. The challenge of course is that in order to maintain the hydrogen at that low temperature energy is required, meaning that a vehicle which is left idle for too long may consume its own fuel just to maintain its liquid state.[207] Therefore, ample attention was placed on improving the insolation of the tank. Here, the main challenge is to improve the insolation without substantially increasing the size or weight of the tank. This research, however, had a variety of issues mainly associated with avoiding fuel evaporation or expansion as the liquid tanks were only built to withstand 5 par pressure. [208]

Similarly, there are several research entities conducting tests with cryogenic storage. In this scenario the hydrogen is not cooled down to liquid form, but it is in a colder gas form, making it denser. This decreases the spatial requirement and allows more freedom in terms of design and does not face the same issues as the liquid form. This technology, however, is currently only in early stages of research.209 In these areas there are significant opportunities for Swedish companies and engineers to partake as many of the research institutions are open to collaborate with foreign entities, particularly from Northern Europe.[210]

KEY SUCCESS FACTORS FOR BUSINESS DEVELOPMENT GROWTH INITIATIVES IN THE U.S.

The strong interest and demands among leading players to solve technical challenges for their product development and manufacturing processes presents opportunities for Swedish companies with technical competence and expertise, even from non-traditionally automotive areas. The overall need to reduce weight, from both an emission reduction and cost perspective, has OEMs working with suppliers to innovate with lightweighting solutions in specific areas including seating and interiors as well as powertrain systems including battery enclosures. On the overall battery side, companies with technical expertise in the design and manufacturing processes of lithium-ion and solid-state batteries have broad opportunities in this prioritized investment area. As heavy vehicle manufacturers are beginning to invest in R&D for hydrogen fuel-cell platforms to varying degrees, the high long-term potential provides opportunities for companies with expertise in fuel cell stacks, fuel-cell tanks and gas compression.

There are four main common establishment strategies among Swedish companies supporting the automotive industry ranging from establishing a sales and marketing organization, or local R&D office, to forming a joint venture or operating a full-scale production facility. With a certain level of business in place, companies can look to set up local offices, but a capital-intensive investment requires customer commitment and existing business to drive such a decision. Prior to moving ahead, however, it is crucial to establish a strong level of business in the local market to justify such an establishment. A few guiding principles for any automotive-related newcomer that is exploring opportunities in the U.S. market include the below success factors –

Figure 34 Key Success Factors for U.S. Automotive Business Development

For small and medium-sized Swedish automotive companies, from a sales and business development perspective, it is typically recommended to focus on leveraging existing customer and partnership relationships in Europe for their U.S. counterparts, and to initially drive business development activities from Sweden. Over time, companies may establish their own U.S. entities and small offices to facilitate carrying out consulting and technical services work locally with tier 1 or tier 2 suppliers and OEMs.

As part of the entry strategy, it is highly recommended to focus on building influence through the engineering teams at the different potential automotive partners. From experience, if a technology is relevant enough or in a prioritized area, suppliers and even OEMs will be more responsive at the engineering and development level. As part of a long-term trend, Tier 1 and tier 2 suppliers are continuing to assume more design and R&D responsibilities for OEMs and given the non-traditional challenges at hand, are increasingly open to collaborations with new innovators. Still, companies should be prepared to be persistent and patient when approaching larger suppliers as some will be very cautious about sharing information and may have substantial evaluation periods.

To build relationships and gain acumen about the local automotive market structure in the U.S., it is of utmost importance to start attending tradeshows and conferences in an early stage of a U.S. establishment. Despite the prevalence of formal channels, including supplier portals and vendor registrations, tradeshows and conferences are still important for local decisionmakers to learn about new technologies, meet with industry colleagues and develop relationships with new potential partners and suppliers. Aside from exhibitions, there are various niched technical conferences and seminars through the calendar year. It can be valuable to map out the company representatives serving on different technical committees established by organizations like the Society of Automotive Engineers (SAE). Many of these organizations will accept technical paper submissions for peer-review which can help a company promote its expertise.

Within lightweighting, most events are centered around Detroit and include the Global Automotive Lightweight Materials Conference and the Automotive Composites Conference & Exhibition. For the growing electric battery ecosystem, key events include the Battery Show North America and Electric & Hybrid Vehicle Technology Expo, which bring together many representatives from leading players. As the fuel cell market is still in early stages, two events stand out as most essential, the Hydrogen & Fuel Cells International Fuel Cell Seminar & Energy Exposition. Several of the events provide matchmaking sessions where attendees can have the opportunity to hold one-on-one with different engineers and/or buyers. Visiting events in a company's specific focus area is typically a good starting point for assessing market potential and interest.

APPENDIX A: KEY TIER 1 AND 2 LIGHTWEIGHTING SUPPLIERS

Name	Category	Location	Specialization	Link
Adient	Tier 1	Plymouth, MI	Seating, interiors	https://www.adient.com/
Lear Corporation	Tier 1	Southfield, MI	Seating	https://www.lear.com/
Faurecia	Tier 1	US: Auburn Hills, MI	Seating, Interiors, Structural	https://www.faurecia-us.com/
Magna Seating	Tier 1	Aurora, Canada	Seating, & Exterior Components	https://www.magna.com/home
Grupo Antolin	Tier 1	U.S: Auburn Hills, MI	Doors, Interior lighting	http://www.grupoantolin.com/en
Tachi-S	Tier 1	Farmington Hills, MI	Seating,	https://www.tachi-s.com/
Novares	Tier 2	U.S. Livonia, MI	Interiors	https://www.novaresteam.com/
DURA Automotive	Tier 2	Auburn Hills, MI	Powertrain, Body, Chassis,	https://www.duraauto.com/
Shiloh Industries	Tier 2	Wilmington, DE	Powertrains, Doors, Body,	https://shiloh.com/
Gentherm	Tier, 2	Northville, MI	Seating, Interiors,	www.gentherm.com/
Toyota Boshoku	Tier 1	U.S. Erlanger, KY	Seating, interiors	https://www.toyota-boshoku.com/us/
Woodbridge Group	Tier 2	Mississauga, Canada	Seating, Interiors	https://www.woodbridgegroup.com/
Almag Aluminum	Battery Box Design	Brampton, Canada	Aluminum Extrusions	https://almag.com/
Martinrea	Metal parts	Detroit, MI	Aluminum products	http://www.martinrea.com/
NHK Seating	Tier 1	Frankfort, IN	Seating	http://www.nhkseating.com/
Rifast	Fastners	Lincolnwood, IL	Fasteners	https://www.rifast.com/en/node/103
Novelis	Alumium parts	Atlanta, GA	Aluminum EV battery enclosure	http://novelis.com/
TS Tech Americas	Tier 1	Reynoldsburg, OH	Seating	https://www.tstna.com/
Meridian Lightweight	Magnesium parts	Strathroy, Ontario	Magnesium structural and interior parts	http://www.meridian-mag.com/
Camaco	Tier 2	Farmington Hills, MI	Seating	http://www.camacollc.com/
Gill Industries	Tier 2	Grand Rapids, MI	Seating	https://www.gill-industries.com/

APPENDIX B: CONFERENCES AND EVENTS LIGHTWEIGHTING

Event	Location	Date	Description	Link
Lightweighting World Expo	Novi, MI	Oct 8-9, 2019	Lightweighting World is the only trade publication in the automotive industry exclusively dedicated to lightweighting design, engineering and manufacturing processes. Offering direct access to the designers, engineers, and manufacturers who need your products to succeed.	www.lightweightingworldexpo.com
Global Automotive Lightweight Materials Conference	Detroit, MI	Aug 20 – 22, 2019	North America's Flagship OEM Driven Summit and Technology Innovations Showcase on Automotive Lightweight Materials, Structures and Advanced Manufacturing	http://www.global-automotive-lightweight-materials-detroit.com/
Automotive Composites Conference & Exhibition	Novi, MI	Sep 4 - 7, 2019	This event is designed to educate and update automotive design and production engineers, sales personnel, and management from transportation OEMs and Tier suppliers about the benefits and expanding importance of thermoset and thermoplastic composites in passenger vehicles, light trucks, and other ground transportation applications.	https://www.compositesworld.com/events/details/8a5a42b2-2fe6-454e-9e62-c1da778a8b43
SAE world conference	Detroit, MI	Apr 21-23, 2020	A conference where experts address the latest in Autonomous Driving Systems, IoT, semiconductors, ADAS, Smart Manufacturing, Artificial Intelligence and Smart Transportation	https://www.sae.org/attend/wcx/call-for-papers
Lightweight Next-gen Automotive Seating Technology Congress	Detroit, MI	May 21st, 2019	A one-day workshop sets out to address the technological, material and production challenges of the new frontier of next-generation, lighter, smarter, innovative automotive seating systems; whilst focusing on the core 'today' challenges of mass vs comfort/ durability vs cost.	https://www.automotive-seating-technology.com/wp-content/uploads/2019/05/Lightweight-Automotive-Seating-Technology-2019_V28.pdf

APPENDIX C: KEY TIER 1 AND 2 BATTERY VEHICLE SUPPLIERS

Name	Category	Location	Specialization	Link
A123 Systems	Tier 1	Livonia, MI	Batteries,	http://www.a123systems.com/automotive/products/
XALT	Tier 1	Midland, MI	Batteries	https://www.xaltenergy.com/
JCI	Tier1	Milwaukee, WI	Batteries	https://www.johnsoncontrols.com/suppliers/batteries
Tesla/Panasonic	OEM/Tier1	Sparks, NV	Batteries, Gigafactory	https://www.tesla.com/gigafactory
Trumpf	Tier1	US: Farmington, CT	Manufacturing Solutions	https://www.trumpf.com/en_US/industries/automotive/
LG Chem	Tier 1	U.S.: Holland, MI	Batteries, Semi-Conductors	https://www.lgchem.com/us/main
SK Innovation	Tier	U.S: Houston, TX	Batteries, Electrodes,	http://eng.skinnovation.com/main.asp
Pellion Technologies	Tier 2	Cambridge, MA	Batteries	http://www.pelliontech.com/
Solid Power	Tier 2	Louisville, CO	Solid State Lithium Batteries	http://solidpowerbattery.com/
Sila Nanotechnologies	Tier 1	Alameda, CA	Battery components	https://silanano.com/
QuantumScape	Tier 1	San Jose, CA	Solid State Lithium Batteries	https://www.quantumscape.com/
Ionic Materials	Tier 1	Woburn, MA	Solid State Lithium Batteries	https://ionicmaterials.com/

APPENDIX D: CONFERENCES AND EVENTS FOR BATTERY AND ELECTRIC VEHICLE TECHNOLOGY

Event	Location	Date	Description	Link
Battery Show & Electric and Hybrid Vehicle Technology Expo	Novi, MI	Sep 12-12, 2019	Each year, engineers, innovators, and thought leaders converge in Novi, Michigan, for a conference and expo focused on keeping up with the fast-moving advanced battery and automotive industries.	https://thebatteryshow.com/
2020 NAATBatt Annual Conference	Pasadena, CA	Feb 10-13, 2020	Conference and meeting for members of NAATBatt International Trade Association	https://naatbatt.org/conference-2020-brief/
Advanced Automotive Battery Conferences	San Diego, CA	Jun 24-27, 2019	The AABC 2019 program will uncover the underlying technical and business issues that will impact the pace and path of vehicle electrification worldwide	https://www.advancedautobat.com/home
Annual International Battery Seminar & Exhibit	Ft. Lauderdale, FL	Mar 25-28, 2019	Founded in 1983, the International Battery Seminar & Exhibit has established itself as the premier event showcasing the state of the art of worldwide energy storage technology developments for consumer, automotive, military, and industrial applications.	https://www.internationalbatteryseminar.com/

APPENDIX E: KEY OEMS, TIER 1 AND 2 SUPPLIERS TO FUEL CELL PLAYERS

Name	Category	Location	Specialization	Link
Toyota	OEM	Plano, TX	Vehicle manufacturer	https://www.toyota.com/
Kenworth	OEM	Kirkland, WA	Heavy truck manufacturer	https://www.kenworth.com/
Nikola	OEM	Phoenix, AZ	Heavy truck manufacturer	https://nikolamotor.com/
New Flyer	OEM	Winnipeg, Canada	Bus manufacturer	https://www.newflyer.com/
Bosch	Tier 1	Farmington Hills, MI	Fuel cell stack & other components	https://www.bosch.us/
Meritor	Tier 1	Troy, MI	Propulsion systems	https://www.meritor.com/
Hexagon Composites	Tier 1	Oslo, Norway & Lincoln, NE,	Fuel Tank	https://www.hexagongroup.com/
Luxfer	Tier 1	Riverside, CA,	Fuel tank	https://www.luxfercylinders.com/
CP Industries	Tier 1	McKeesport, PA	Fuel tank and storage	https://www.cp-industries.com/products/applications/alternative-fuels/on-board-vehicle-storage
Ballard	Tier 1	Burnaby, Canada	Fuel cell stack	http://ballard.com/
Powercell Sweden AB	Tier 2	Gothenburg, Sweden	Fuel cell stack	https://www.powercell.se/en/start/
Lawrence Livermore National Laboratory	Research Institute	Livermore, CA	Fuel Tank, Storage,	https://www.llnl.gov/about
Pratt & Miller	Research & Development	Lyon, MI	Exterior components	https://www.prattmiller.com/

APPENDIX F: TRADE SHOWS AND CONFERENCES FOR THE FUEL CELL SEGMENT

Event	Location	Date	Description	Link
Hydrogen & Fuel Cells International	Salt Lake, USA	23-26 Sep 2019	The largest gathering of hydrogen and fuel cells professionals in North America, co-located with Solar Power International and Energy Storage International	https://10times.com/hfcna
Fuel Cell Seminar & Energy Exposition (FCS&EE)	Long Beach, California	November 5 - 7, 2019	The FCS&EE features dynamic keynotes, track sessions, an exhibit hall showcasing the latest technologies from around the world, and networking opportunities.	https://www.fuelcellseminar.com/
Storage Week Plus	San Francisco, CA	July 25 - July 29, 2019	Storage Week Plus brings together a who's who of policymakers, renewable energy and storage developers, utility and corporate customers, and the financiers leading the burgeoning growth of storage.	https://infocastinc.com/special/storage-week-10/?utm_source=fchea&utm_medium=supporting_org&utm_campaign=supporting_org
US Hydrogen & Fuel Cells Energy Summit	Boston, MA	July 10-11, 2019	Representatives from hydrogen producers and suppliers, fuel cell companies, automotive OEMs, will come to discuss perspectives & market opportunities for the hydrogen & fuel cells market.	https://www.wplgroup.com/aci/event/us-hydrogen-and-fuel-cells-energy-summit/

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The Swedish Energy Agency is subordinate to the Ministry of Infrastructure and leading the energy transition into a modern and sustainable, fossil free welfare society.

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