



TRANSPORTATION
ENERGY INSTITUTE

Back to the Future:

10 YEARS OF LESSONS LEARNED ABOUT
THE VEHICLE MARKET

AUGUST 2023



About Guidehouse Insights

Guidehouse Insights, the dedicated market intelligence arm of Guidehouse, provides research, data, and benchmarking services for today's rapidly changing and highly regulated industries. Our insights are built on in-depth analysis of global clean technology markets. The team's research methodology combines supply-side industry analysis, end-user primary research, and demand assessment, paired with a deep examination of technology trends, to provide a comprehensive view of emerging resilient infrastructure systems. Additional information about Guidehouse Insights can be found at www.guidehouseinsights.com.

Disclaimer:

This deliverable was prepared by Guidehouse Inc. for the sole use and benefit of, and pursuant to a client relationship exclusively with the Transportation Energy Institute. The work presented in this deliverable represents Guidehouse's professional judgement based on the information available at the time this report was prepared. Guidehouse is not responsible for a third party's use of, or reliance upon, the deliverable, nor any decisions based on the report. Readers of the report are advised that they assume all liabilities incurred by them, or third parties, as a result of their reliance on the report, or the data, information, findings and opinions contained in the report.

© 2023 Transportation Energy Institute

Disclaimer: The opinions and views expressed herein do not necessarily state or reflect those of the individuals on the Transportation Energy Institute Board of Directors and Board of Advisors or any contributing organization to the Transportation Energy Institute. The Transportation Energy Institute makes no warranty, express or implied, nor does it assume any legal liability or responsibility for the use of the report or any product or process described in these materials.

About the Transportation Energy Institute

The Transportation Energy Institute (formerly Fuels Institute), founded by NACS in 2013, is a 501(c)(4) non-profit research-oriented think tank dedicated to evaluating the market issues related to vehicles and the energy that powers them. By bringing together diverse stakeholders of the transportation and energy markets, the Institute helps to identify opportunities and challenges associated with new technologies and to facilitate industry coordination to help ensure that consumers derive the greatest benefit.

The Transportation Energy Institute commissions and publishes comprehensive, fact-based research projects that address the interests of the affected stakeholders. Such publications help to inform both business owners considering long-term investment decisions and policymakers considering legislation and regulations affecting the market. Research is independent, peer reviewed and unbiased, designed to answer questions, not advocate a specific outcome. Participants in the Transportation Energy Institute are dedicated to promoting facts and providing decision makers with the most credible information possible so that the market can deliver the best in vehicle and energy options to the consumer.

For more about the Transportation Energy Institute, visit transportationenergy.org

Transportation Energy Institute Staff

John Eichberger | Executive Director

jeichberger@transportationenergy.org | (703) 518-7971

Jeff Hove | Vice President

jhove@transportationenergy.org | (703) 518-7972

Marjorie Kass | Director, Marketing & Communications

mkass@transportationenergy.org | (703) 518-7973

Amanda Patterson | Coordinator, Communications & Projects

apatterson@transportationenergy.org | (703) 518-7975

Contents

EXECUTIVE SUMMARY.....	05
INTRODUCTION.....	06
THE 2013 PREDICTIONS.....	07
WHAT HAPPENED?.....	08
There's Oil in Them Shales!.....	09
Not So Clean Diesel.....	10
Tesla Beat Expectations.....	11
The End of the ICE Age.....	13
The Worst Happens.....	15
WHAT DO THESE EVENTS TELL US ABOUT FORECASTING?.....	17
WILL EV'S DOMINATE?.....	18
WHAT OF MEDIUM AND HEAVY DUTY FLEETS?.....	19
KEY TAKEAWAYS.....	20

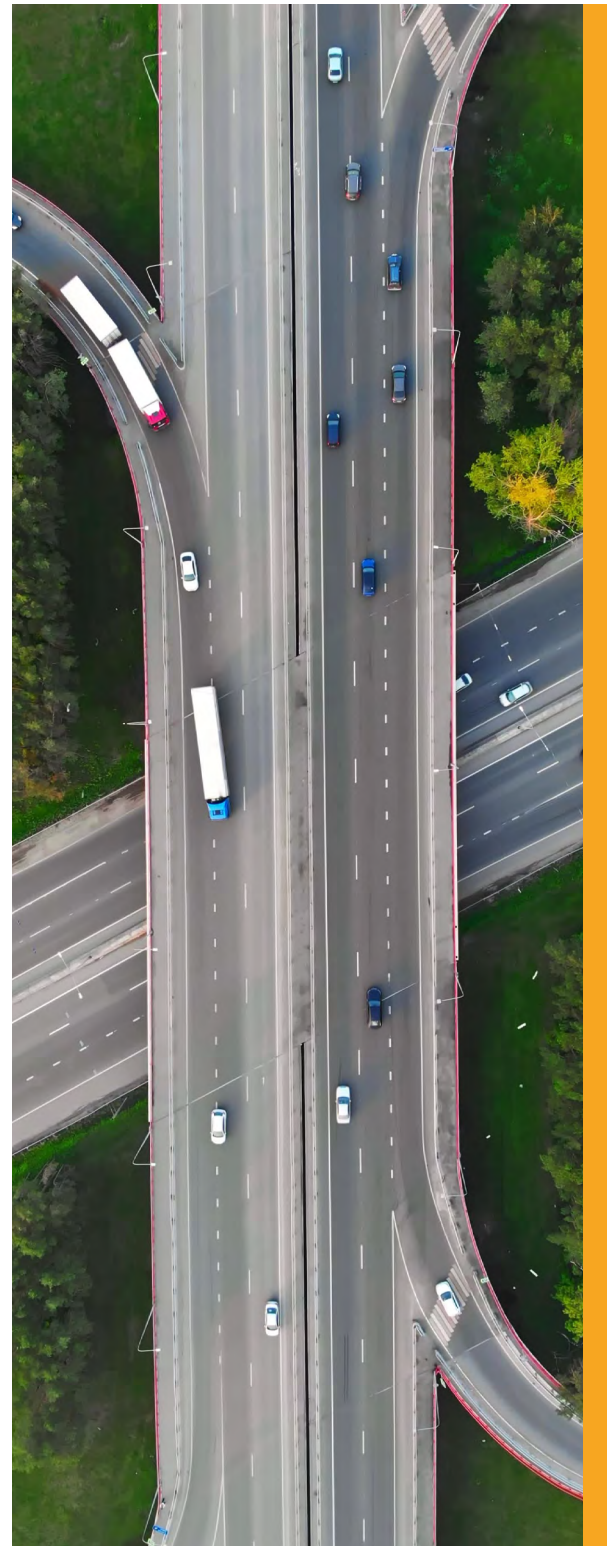
Executive Summary

Ten years ago, the Fuels Institute (now Transportation Energy Institute) and Navigant Research (now Guidehouse Insights) published 10-year forecasts of light, medium, and heavy-duty vehicle markets by fuel type in North America. Now that 10 years have passed, we have looked back to see how the forecasts shaped up to reality. In doing so we have attempted to understand what the difference between what was predicted and what happened means as we look ahead to the next 10 years.

Five unexpected events take center stage in our assessment: the oil price collapse of 2014, dieselgate, Tesla's string of successes from the Model S to the Model 3 debut, emergence of anti-internal combustion engine (ICE) regulation, and the pandemic. These events not only shifted the market trajectory, but also exemplify the limitations of prediction relative to what the narrative suggests is reasonable at any given time.

Looking ahead, the current expectations of the market for light, medium, and heavy-duty vehicles are now very different than they were 10 years ago. Momentum of EVs in the LDV market has made an eventual all-electric transportation model a reasonable afterthought. Meanwhile, in the MHDV market, the future appears to remain diverse with roles for EVs, biofuels, and hydrogen. It would, however, be a mistake to ignore the lessons of the last 10 years.

Reasonable assumptions have a shelf-life, narratives are constantly shifting, and what is known is usually a sliver of what there is to know. Among other yet unexpected possibilities, what is considered reasonable could be disrupted by an EV sustainability issue without a clear resolution, the exploitation of natural hydrogen deposits, or a regulatory pivot more accepting of ICE-based net-zero emissions solutions. As the market continues to move toward net-zero, we can only expect that more of the unknowns will become known and do our best to predict what trends will survive these and which will not.



Introduction

When the Transportation Energy Institute was established in 2013, the outlook for alternative fuels and vehicles was diverse and uncertain. The automotive markets were dominated by gasoline and diesel, but new regulations sought to disrupt ICEV dominance by incentivizing improvements in vehicle energy efficiency, accelerating adoption of zero emission vehicles (ZEVs), and lowering fuel carbon intensity. Besides pushing internal combustion powertrains toward increased efficiency and lower emissions, regulations would also set the stage for greater adoption of alternatives like biofuels and biogases, electricity, compressed or liquified natural gas, hydrogen, and propane autogas. It was clear that the market was going to change in a way that could have significant impacts for all stakeholders, but the direction, timing, and significance of that change was highly uncertain.

Attempting to demystify these uncertainties, Fuels Institute (since renamed Transportation Energy Institute) collaborated with Navigant Research (since renamed Guidehouse Insights) to publish forecasts of what the upcoming fuel diversity in North America could look like in 2023.¹ Now that it is 2023, Transportation Energy Institute is once again collaborating with Guidehouse Insights. This time it is not about forecasting but evaluating our predictions against reality and assessing what the difference between the two means looking forward.

It has been a busy decade. Oil prices collapsed, ride-sharing, micromobility, and the term ‘ICE ban’ emerged, automakers were caught cheating on increasingly stringent emissions tests, and among other things – a pandemic ravaged preconceived notions of supply chain optimization and mobility demands. Some of these things may have been predictable, others, not a chance. Within this context, Guidehouse Insights has taken the opportunity to revisit past predictions and to do so with the help of industry participants who have had unique visibility on the outcomes of these events.

¹ Fuels Institute. [Tomorrow's Vehicles: What will we drive in 2023?](#) November 1, 2013.

The 2013 Predictions

Back in 2013, gasoline was the dominant fuel choice for light-duty vehicles (LDVs) and diesel was for medium-heavy duty vehicles (MHDVs). Following successes in Europe, diesel was also poised to take off in the US LDV market. For example, sales of diesel passenger cars from Volkswagen alone reached over 100,000 in 2013,² more than double the sales of battery electric vehicles (BEVs) that year.³ Meanwhile, alternative fuel vehicle options in either market were limited to a handful of recently deployed EVs (both BEV and plug-in hybrid) from Nissan, Mitsubishi, Chevrolet, and Tesla or to aftermarket retrofits for natural gas or propane autogas. Most alternative fuels adoption was driven by the US Environmental Protection Agency (EPA) Renewable Fuel Standard and the California Air Resources Board (CARB) Low Carbon Fuel Standard and mostly consisted of ethanol (E10) and low-level biodiesel blends (B5).

While options to reduce carbon emissions beyond biofuels were limited, the prospects for a diverse suite of vehicle alternatives looked strong with numerous automakers announcing plans for EVs and fuel cell vehicles, as well as expanded diesel portfolios for the LDV market. In the MHDV market, the emergence of relatively low-cost natural gas compared to diesel generated much interest in increasing use of compressed or liquified natural gas. Added values from renewable natural gas offtake agreements and associated valuable credits under the RFS and LCFS, also increased interests in the natural gas pathway for renewables. Federal and state subsidies for alternative fuel vehicle procurement and infrastructure development were also rife.

Given the trends, Guidehouse Insights predicted that 7-11% of the LDV fleet would shift away from gasoline by 2023. Most of the shift would occur towards diesel and flex fuel vehicles. Meanwhile EVs, fuel cell vehicles, natural gas vehicles, and other alternatives would make up around 1% of the fleet. In the MHDV market Guidehouse Insights predicted diesel would remain dominant, but a modest shift towards natural gas could be expected.



² J Hirsch, "Volkswagen's 2013 diesel-vehicle sales to top 100,000: Why it matters." Los Angeles Times. December 26, 2013.

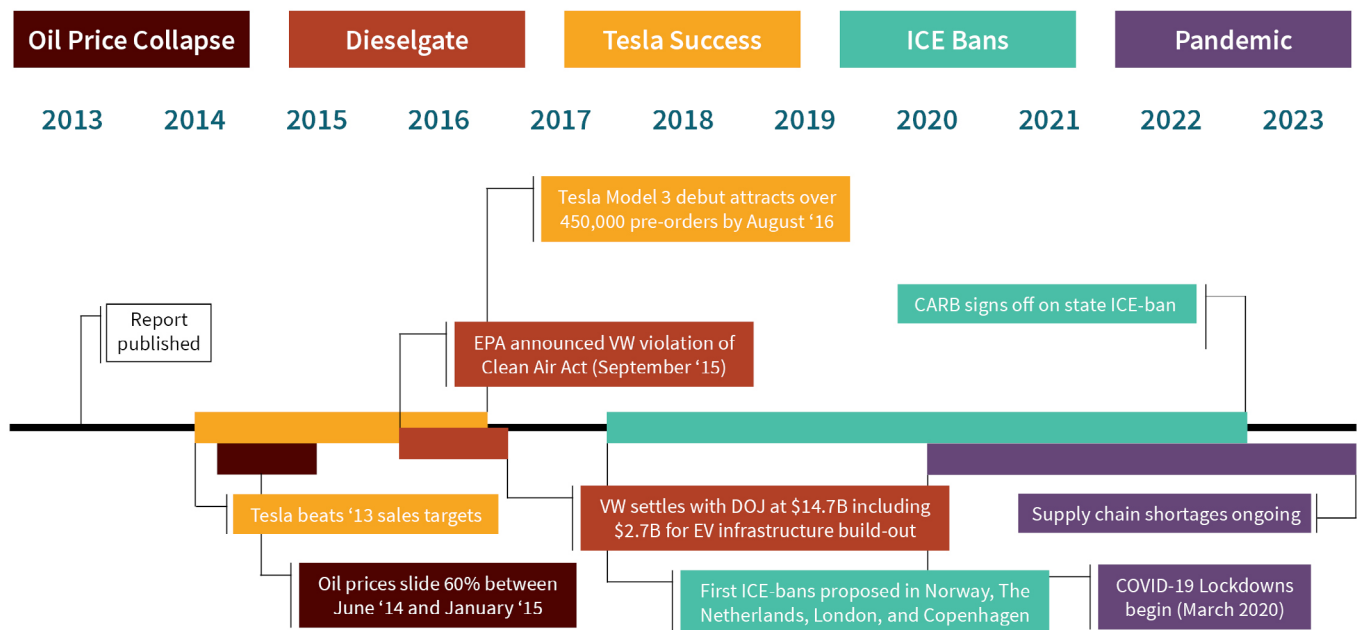
³ U.S. Department of Energy Alternative Fuels Data Center. "U.S. Plug-in Electric Vehicle Sales by Model." Accessed June 2023.

What Happened?

The predictions were off, as all predictions are bound to be. However, where predictions diverged from reality most significantly focuses on MHD NGV sales, LD diesel sales, and LD BEV sales. Natural gas failed to materialize in the MHDV market while diesel retracted from the LDV market. Contrarily, EVs did far better than expected.

With ten years of 20/20 hindsight now available, Guidehouse Insights identified five key unanticipated developments that best account for the major differences between our predictions and reality. These are as follows: the 2014 oil price collapse, dieselpgate, Tesla’s market success, a strong regulatory shift against ICE vehicles, and the pandemic.

THE KEY EVENTS

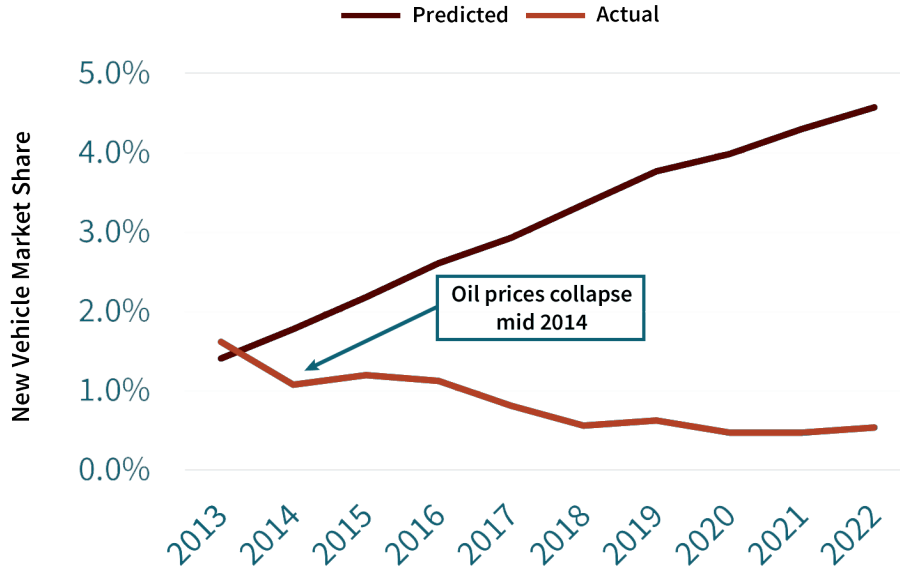


THERE'S OIL IN THEM SHALES!

Predicting oil price movements is an industry unto itself. At the report's publication, oil prices had been on the rise since the early 2000's, and from 2011 had hovered around \$100/barrel. Expectations for much of the industry were that the high oil price environment would persist, and potentially move upward as supply would become increasingly strained by motorization of markets like China and India. High oil prices made all alternative fuels more economically attractive, but this paradigm was not to last.

In mid-2014 oil prices dropped dramatically as North American oil shale production ramped and OPEC decided to forego production cutbacks. Except for pandemic induced volatility, oil prices have generally remained far below \$100/barrel. The impacts of this new environment on the fleet were many. Trends toward larger, less efficient vehicles accelerated. The economics of all alternative fuel options suffered, but some more than others. Observing diminished alternative fuel vehicle demands, automakers and infrastructure developers alike saw little reason to make significant investments in new vehicles or publicly accessible infrastructure networks. For example, the number of CNG and LNG stations has declined by 20% since 2016. As such, demonstrated in the figure below, NGV penetration in the MHD market diverged significantly from our predictions.

PREDICTED MHD NGV SALES VS. ACTUAL, UNITED STATES 2013-2022



Source: Guidehouse Insights

⁴ Energy Information Administration. [Petroleum & Other Liquids, Spot Prices](#). Accessed April 2023.

⁵ D Mead & P Stiger, [The 2014 Plunge in Import Petroleum Prices: What happened?](#) Bureau of Labor Statistics. May 2015. Vol. 4 / No. 9

⁶ Energy Information Administration. [Petroleum & Other Liquids, Spot Prices](#). Accessed April 2023.

⁷ International Energy Association. [New registrations of SUVs in key car markets, 2010-2021](#). Accessed April 2023

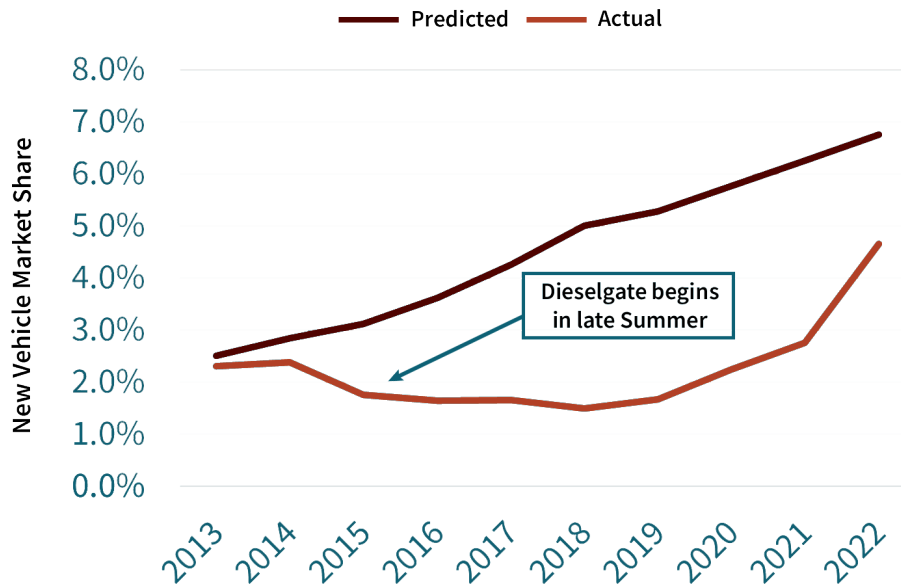
⁸ Alternative Fuels Data Center. [US Public and Private Alternative Fueling Stations by Fuel Type](#). Accessed April 2023.

NOT SO CLEAN DIESEL

The term “clean diesel” refers to use of emission control devices that greatly reduce NOx and particulate matter emissions, not GHG emissions. Given the improved energy efficiency of diesel-powered engines relative to gasoline-powered engines, clean diesel was perceived as a strong GHG reduction strategy for the LDV market. This was reflected in the 2013 report with diesel share in the new LDV market projected to grow from less than 2% to nearly 7% in the US by 2023. However, the US EPA issued a notice of violation of the Clean Air Act to Volkswagen Group in September 2015, sparking what became commonly referred to as “dieselgate.”

VW and its suppliers had devised a method by which NOx emissions were only compliant with regulations when the vehicle was undergoing testing but were significantly higher when the vehicle was operating in real world conditions. The cheat enabled better fuel efficiency at the cost of more NOx emissions. Ultimately, VW had to buy back nearly 400,000 vehicles from customers and others required extensive modification. Other automakers including Mercedes-Benz, BMW, and the Chrysler Group were also using similar technologies to meet the new standards, but VW Group brands sold in the highest volume and were heavily promoted. Thus, diesel vehicle sales in LD passenger car segments evaporated and overall LD diesel sales (inclusive of full-size pick-ups) departed from our prediction as shown in the figure below.

PREDICTED LD DIESEL VEHICLE SALES VS. ACTUAL, UNITED STATES 2013-2022



Source: Guidehouse Insights

TESLA BEAT EXPECTATIONS

In 2013, modern EVs had only been in use for a few years. Battery cost, energy density, and charging rates were so limiting that the cheapest EVs from established OEMs carried significant premiums over similarly classed vehicles, had ranges of around 100 miles or significantly less,¹² and few places to recharge beyond the home garage. These limitations placed the technology within a specific market: relatively wealthy single-family households with two cars, one of which could easily be displaced for an EV to satisfy moderate daily commuting demands. Though the market criteria are somewhat narrow, it proved large enough (in combination with revenue derived from sales of regulatory credits¹³) to in some cases sustain a profitable EV program as evidenced by Tesla's successes, which started with the Model S.

“I famously had a boss at Ford that would say that this car doesn't have 100-mile range. It has 700 miles in a week.”

— Mujeeb Ijaz, CEO of Our Next Energy



While the company established that EVs could be appealing with the Roadster in 2008, it was not until monthly sales figures for the Model S began beating targets¹⁴ that the world understood how revolutionary an EV could be. Then, in 2016, Tesla unveiled the Model 3 and garnered over 450,000 pre-orders.¹⁵ In combination with the Supercharger network, the Tesla business model set the standard for the modern EV market and most automakers are still trying to catch-up.

Massive and broad private sector investment in EV technologies followed accelerating an innovation cycle that was expected to take much longer. From 2013 to 2023, battery costs halved, then halved again.¹⁶ Combined with a tripling of energy density,¹⁷ range grew tremendously such that RAM Trucks is planning to deploy a 500-mile electric truck in 2024.¹⁸ Meanwhile, the definition of fast charging got faster by 3X, and new mega-watt levels of charging are being introduced to support electrification of MHDVs¹⁹ and “extreme fast charging” charge points are now being deployed under the watchful eye of the Department of Energy’s (DOE) Vehicle Technologies Office (VTO).

¹² IEA. [Evolution of average range of electric vehicles by powertrain, 2010-2021](#). October 2022.

¹³ Automakers that are in over-compliance with federal or state-level regulations can sell credits to out-of-compliance automakers competing. Credits can be highly lucrative as demonstrated by [Tesla's reported 2022 credit sales amounting to \\$1.78 billion](#).

¹⁴ Tesla Motors, Inc. [Fourth Quarter & Full Year 2013 Shareholder Letter](#). February 19, 2014.

¹⁵ J Bhuiyan. [“Tesla saw about 63,000 cancellations of Model 3 pre-orders.”](#) CNBC. August 3, 2017.

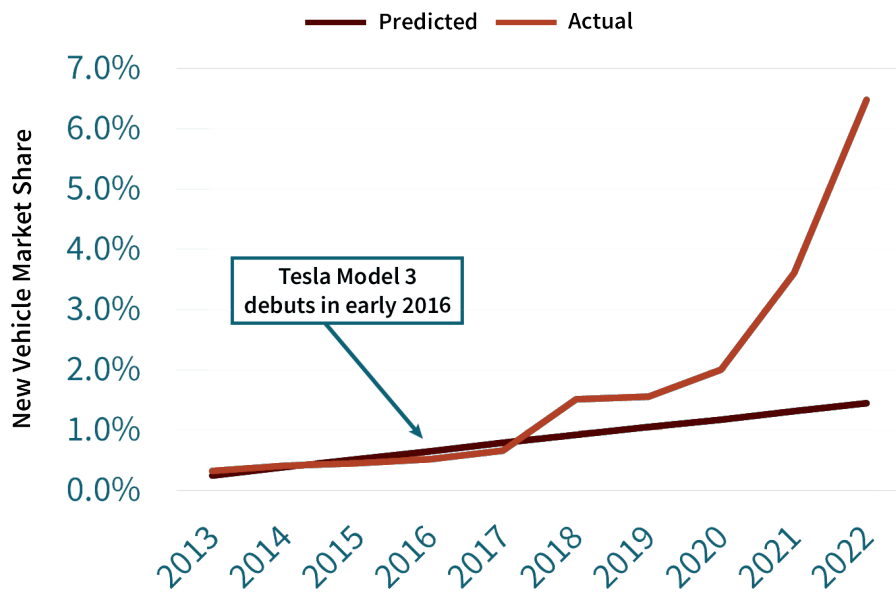
¹⁶ [Estimated Electric Vehicle Lithium-ion Battery Pack Cost, 2008-2022](#). DOE VTO. January 9, 2023.

¹⁷ N Muralidharan, E C Self, M Dixit, Z Du, R Essehli, R Amin, J Nanda, I Belharouak. [Next-Generation Cobalt-Free Cathodes – A Prospective Solution to the Battery Industry's Cobalt Problem](#). *Advanced Energy Materials*. January 2022.

¹⁸ Stellantis. [“All-new, All-electric 2025 Ram 1500 REV Unveiled at New York International Auto Show with Targeted Range of up to an Unsurpassed 500 Miles.”](#) April 5, 2023.

¹⁹ CHARIN. [“CharIN e. V. officially launches the Megawatt Charging System \(MCS\) at EVS35 in Oslo, Norway.”](#) June 14, 2022.

PREDICTED LD BEV VEHICLE SALES VS. ACTUAL, UNITED STATES 2013-2022



Source: Guidehouse Insights



THE END OF THE ICE AGE

In late 2019, a few months before publicly unveiling the brand’s first full EV, then president of Cadillac, Steve Carlisle declared it “the end of the ICE age.”²⁰ While Carlisle was almost certainly not the first to use that phrase, the timing fit with a broad industry move to EVs alongside a growing sense among policymakers that 1.) the most sensible path to achieving net-zero emissions targets was to abandon the ICE, and 2.) zero-emission-vehicle (ZEV) trends indicated this was possible.

Driven in part by the 2015 Paris Agreement which mandates significant action on climate change across various industrial sectors, the ICE ban policy trend started in Europe where significant subsidization of EVs had transformed the automotive markets of Norway and the Netherlands in a few years. Policymakers in these countries proposed banning ICE vehicles from new vehicle markets as soon as 2025.²¹ Larger European countries, like the UK, and France, and then even the EU itself,²² followed, proposing the bans in 2035.

“Advocacy groups have latched on to the idea that electric is the only clean way and natural gas is now a dirty fuel.”

***— Lisa Jerram,
Former Navigant Research Analyst***

While this might seem ambitious, policies at the local level were far more so where cities like London, Paris, Oslo, and Amsterdam targeted bans of ICE vehicles within city centers.²³ China, the largest automotive market, joined the trend mandating all new vehicles be ‘new energy’ by 2035.²⁴ The US has been a late comer to this concept, but it is not wholly foreign as California adopted its 2035 new vehicle ICE ban in 2022.²⁵ More states aligned with California’s environmental regulations are expected to follow. While an ICE ban at the national

level is unlikely, the policy direction is similar. EPA’s latest proposed GHG emissions standards for model year 2032 target a 56% GHG emissions reduction from 2026, achieving 82 g/mile by 2032.²⁶ EPA estimates the regulations will result in two-thirds of the new vehicle market being battery electric by 2032.²⁷ The targets are supported by significant federal level investments in infrastructure and vehicle purchase incentives via the Bipartisan Infrastructure Law and Inflation Reduction Act passed in 2021 and 2022 respectively.

²⁰ J LaReau. “Cadillac has big changes ahead for its lineup and manufacturing.” Detroit Free Press. December 12, 2019.

²¹ I Burch & J Gilchrist. Survey of Global Activity to Phase Out Internal Combustion Engine Vehicles. The Climate Center. February 2018, Revised March 2020.

²² M Eddy. “European Union to Ban Gas-Powered Cars by 2035.” NYTimes. February 14, 2023.

²³ S Wappelhorst. The end of the road? An overview of combustion-engine car phase-out announcements across Europe. May 2020.

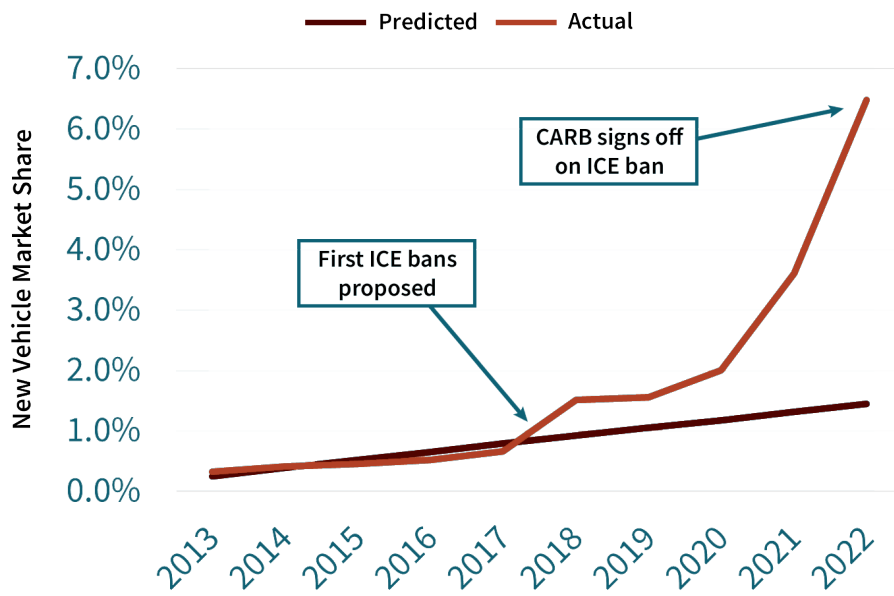
²⁴ S Ibold, X Yun, & X Shuyue. NEV Development Plan 2035. GIZ. 2021

²⁵ California Air Resources Board. California moves to accelerate to 100% new zero-emission vehicle sales by 2035. August 25, 2022.

²⁶ EPA. Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles. April 2023

²⁷ Ibid

PREDICTED LD BEV VEHICLE SALES VS. ACTUAL, UNITED STATES 2013-2022



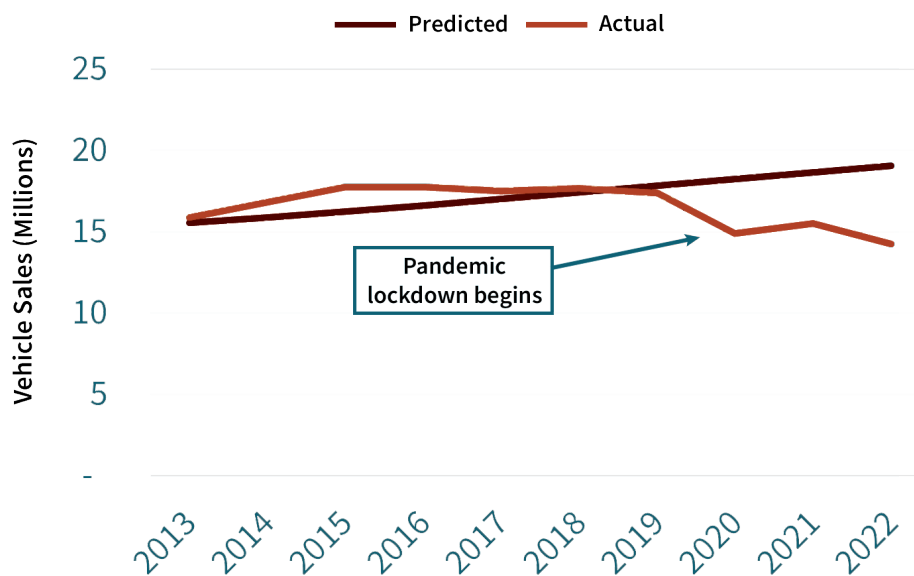
Source: Guidehouse Insights



THE WORST HAPPENS

Pandemics are not new, nor are they frequent; or at least pandemics on the scale of COVID-19—the last similarly sized pandemic was 100 years ago. The global event, now over three years-old appears to finally be winding down. Impacts on the automotive industry are, however, ongoing as demonstrated in the figure below. It is yet too soon to fully understand how the pandemic has shifted the automotive sector’s trajectory. Given that, there are two fundamental assumptions within automotive market forecasting that were significantly disrupted by the pandemic worthy of early assessment – globalism and multi-modality.

PREDICTED OVERALL VEHICLE SALES VS. ACTUAL, UNITED STATES 2013-2022



Source: Guidehouse Insights

Globalism

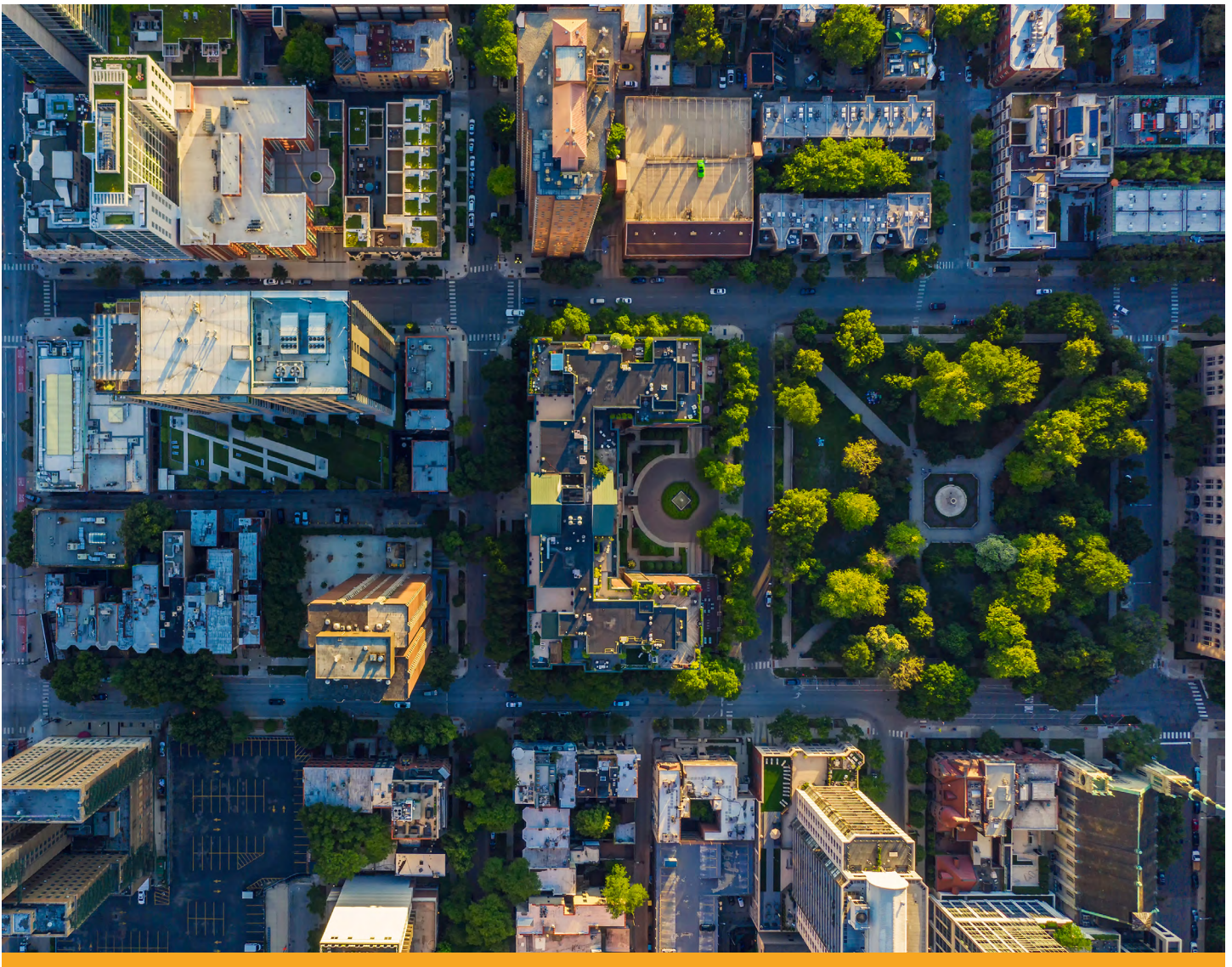
As governments attempted to manage the pandemic, various components of the global supply chain stopped functioning across all sectors and have yet to recover. The most critical shortage in the automotive sector has been microchips.²⁸ This shortage was further impacted by the Russian invasion of Ukraine, the leading global supplier of neon which is used to operate lasers used in microchip production.²⁹ Shortages, like that of microchips, highlighted the costs of a globalized supply chain and thus the supply chain is re-orienting towards greater localization. When everything is working, costs can be significantly reduced, but the pandemic highlighted the brittleness of this global strategy. How this will impact the future automotive market is to be determined but it is not unreasonable to assume it may add direct costs as well as controversy regarding land use and resource access while at the same time making the entire value chain more resilient.

²⁸ JP Morgan. “Supply chain issues and autos: When will the chip shortage end?” Updated: April 18, 2023.

²⁹ A Alper. “Exclusive: Russia’s attack on Ukraine halts half of world’s neon output for chips.” Reuters. March 11, 2022.

Multi-Modality

In the years leading up to the pandemic, urbanization and communications connectivity were driving trends toward use of shared mobility assets rather than the individual owned car.³⁰ Alongside developments in vehicle sensors, compute platforms, and artificial intelligence, the future appeared headed toward vehicle ownership as a luxury rather than the norm. “Shelter-in-place,” “social distancing,” and more-so “work from home” disrupted the trend with likely long-lasting consequences. Demand of some forms of mobility may return to pre-pandemic levels as the kinetic component of the pandemic abates; however, the value of the individually owned vehicle to the market has been refreshed and it is unlikely to fade away anytime soon.

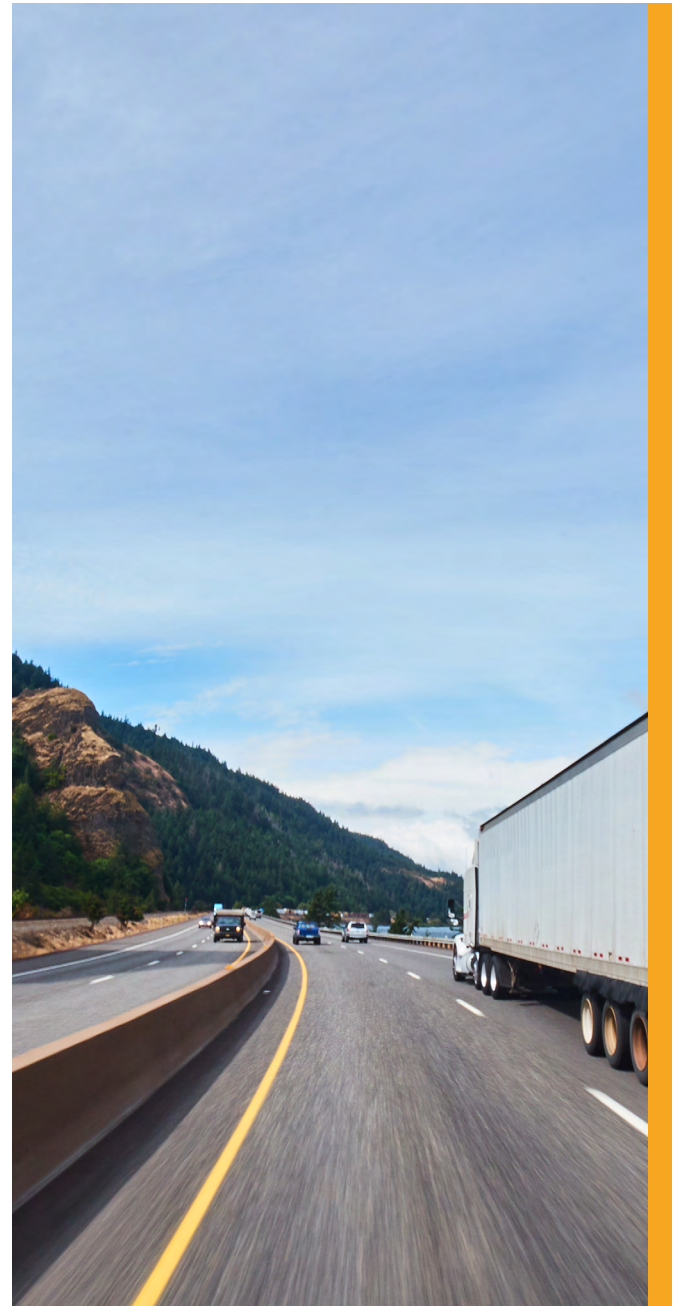


³⁰ M Sivak & B Schoettle. *Recent Decreases in the Proportion of Persons with a Driver's License across All Age Groups*. University of Michigan Transportation Research Institute. January 2016.

What do these events tell us about forecasting?

Forecasts are typically designed to be sensitive to specific, uncertain, market forces. Typically, the assumptions about these uncertainties are framed within a range of reason by a scenario analysis. Reality, however, often falls outside the range as demonstrated by these five events. That oil prices might fall would have seemed reasonable, but by more than half, unreasonable. That market players would break laws in such a blatant way, unreasonable. That Tesla would become valued by an order of magnitude over Ford and GM while selling a fraction the number of vehicles, unreasonable. That regulators would consider, propose, and pass ICE-ban legislation, unreasonable. The emergence of a pandemic, unreasonable. Thus, our ability to determine what may be reasonable in the future is severely limited.

Now what seems reasonable is defined by a new paradigm. One highly sensitive to an ecosystem of issues surrounding climate stability such as land-use, natural disasters, human rights, outsourcing, waste-stream management, and so on. It is strongly influenced by the shift in government regulations to the benefit of ZEV technologies. It, however, also draws support from major corporate interests that are driven by trends to prioritize environmental, social, and governance (ESG) factors in investment decisions. Momentum of EVs in the LDV market has made an eventual all-electric transportation model a reasonable afterthought, whereas powertrain diversity in the MHDV market remains reasonably uncertain.



Will EVs Dominate?

Trends would suggest the future LDV market is not to be as diverse as predicted in 2013. Government and private investors firmly back EVs. It is challenging to see a path by which an alternative powertrain would be able to catch-up. The uncertainty has appeared to shift from not if, but when. Thus, predictions across the industry of forecasters, Guidehouse Insights included, have adoption curves for EVs heading towards saturation of new vehicle markets in major regions in the 2030s and 2040s.³¹

Implicit in this prediction is that the EV industry overcomes a suite of challenges inhibiting adoption among all vehicle applications by the time ICE-bans are implemented. Such as and among others, the development of:

1. Sufficient public charging infrastructure to support adoption among consumers without a garage or access to private, dedicated parking structures,
2. Affordable ZEVs across all market classes,
3. Sufficient identification, extraction, and production of EV technology material resources,
4. Sufficient grid distribution infrastructure, and
5. A profitable model for battery reuse and recycling.

That each of these developments may be addressed by industry within the timeline may be a stretch if not a leap but may not be wholly unreasonable. There are private investment streams attached to solving each of these challenges. For example, the development of vehicle-to-everything technologies has the potential to transform EVs from a grid liability to a grid asset.

However, given the learnings of this study, it is also reasonable that these developments may not be addressed and require a rethink of the proposed anti-ICE regulations. For example, perceived or actual weakness in the industry to make ZEVs accessible to all consumer classes could translate to regulatory revisions that become more inclusive of net-zero emissions solutions from ICE-based technologies like e-fuels. This pivot was recently demonstrated in Europe where the EU commission announced ICE vehicles could still be sold after 2035 if they use net-zero fuels like e-fuels.³²

“We’re talking about gigawatts of batteries on wheels that could mean we don’t have to build as much standalone storage to integrate renewables.”

***— Ed Burgess, Policy Director,
Vehicle Grid Integration Council***

³¹ BNEF. *The Road to Electric Car Supremacy in Five Charts*. August 30, 2022; IEA. *Global EV Outlook 2023*. April 2023.

³² R Perkins. “German car makers welcome EU deal to allow e-fuels in new ICE cars after 2035.” S&P Global. March 27, 2023.

What of Medium and Heavy Duty Fleets?

As predicted in 2013, the MHDV fleet remains highly dependent on diesel.³³ With natural gas and propane autogas not gaining significant momentum in the new vehicle market, the remaining alternatives have focused on renewable diesel, hydrogen, and electricity. While renewable diesel is having a moment, it is largely seen as a bridge fuel to both hydrogen and electricity because it is highly questionable that sufficient

“Renewable diesel works well as a drop-in for conventional diesel... As the supply increases to match that demand, it’s possible it may also offer a stably-priced alternative to diesel.”

— Alissa Recker, Product Regulatory Affairs Engineer, DTNA

feedstock capacity exists to power all trucks and support the maritimeshipping and commercial aviation markets.³⁴ Thus, regulators and the MHDV market are preparing for ZEV options.

The ZEV solutions pose significant complications. Upfront costs are high, some performance and operational sacrifices are required, infrastructure solutions are complex, and technology familiarity is low. Of the two options, electricity and hydrogen, the foundations for electricity are stronger having commercial options in the market, an established energy infrastructure system, and a reliable investment pipeline driven by the prospects of LDV market electrification. Hydrogen is behind as solutions

remain pre-commercialization, and energy infrastructure is scant. However, once available, hydrogen promises to meet performance requirements of which it is unclear electricity could attain. As such, general expectations are that the market will eventually move to a combination of electricity and hydrogen, with electricity supporting MHDVs with lesser energy intense duty cycles and hydrogen supporting those with the most energy intense duty cycles. Implicit in this prediction is that the hydrogen vehicle industry overcomes the following challenges:

1. Commercialization of low carbon intensity hydrogen solutions (green³⁵ or blue³⁶) with sufficient distribution infrastructure to support energy intense duty cycles occurs before an electric solution is ready.
2. Costs and risks will be less than the those of adapting operations to enable a less ready electric solution, or to extend ICE use leveraging a near-to or net zero emissions strategy with renewable diesel or another alternative like e-fuels.

³³ S Davis & R Boundy. *Transportation Energy Data Book – Edition 40*. Oak Ridge National Laboratory. 2022. Table 5.4

³⁴ IEA. *Is the biofuel industry approaching a feedstock crunch?* December 2022.

³⁵ World Economic Forum *What is green hydrogen and why do we need it? An expert explains*. December 21, 2021.

³⁶ MIT News *3 Questions: Blue hydrogen and the world’s energy systems*. October 17, 2022.

That these challenges may be overcome is reasonable to assume. Equally so is the possibility that they may not. The pace of EV innovation is a threat to hydrogen investments. If it continues at the current pace it makes hydrogen riskier, slowing investments and the innovation cycle thereof. The longer hydrogen is delayed, the more likely the market leans toward renewable diesel until electrification or an ICE-based long-term net-zero emissions solution like e-fuels is established.



Key Takeaways

As was true in 2013 and is still true today, the impact of alternative fuel vehicle adoption on the overall fleet, and therein, on fuels consumption, is gradual. According to the National Highway Traffic Safety Administration's Fatality Analysis Reporting System there were nearly 300 million vehicles in the US in 2020.³⁷ Annual new vehicle sales roughly account for 5% of the overall fleet which means turning it over should take roughly 20 years. The turnover timeline is likely growing as evidenced by the average vehicle age now surpassing 12 years.³⁸ This means that vehicle service providers have time to adapt to shifts in the new vehicle market – even sudden ones. Given that, barring a significant market shift against the current trends it is likely that peak gasoline has passed,³⁹ and it is possible that peak diesel has as well.⁴⁰

The descent from the peak is likely long and gradual. However, per Amara's law "We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run."⁴¹ As such, it is reasonable to begin thinking about adaptation and in this regard, it is hard to argue that planning for electrification is premature.

³⁷ NHTSA. *Fatality Analysis Reporting System*. Accessed: April 2023.

³⁸ BTS. *Average Age of Automobiles and Trucks in Operation in the United States*. Accessed: April 2023.

³⁹ EIA. *US Product Supplied of Finished Motor Gasoline*. Accessed: April 2023.

⁴⁰ EIA. *US No 2 Diesel Adj Sales/Deliveries to On-Highway Consumers*. Accessed: April 2023.

⁴¹ AFP. *AFP Jargon Watch: Amara's Law*. September 2018

Though the challenges for electrification are significant, the drivers for innovation investment that can overcome the challenges are equally so. Ultimately the question of which alternative fuel vehicle will win is a distraction; it is clear that EVs will have a significant presence in the market and they will demand a greater volume of services moving forward. This is a function of the number of EVs registered, but also of who owns them. As first and second generation EVs are resold, and as the technology ecosystem improves, more EVs will likely be owned by consumers that do not have a dedicated charging location and are therein probably going to rely more on public services than current EV owners.

That demand will grow is thus not in question, however, how it will be supplied profitably is. Every aspect of the EV services supply chain is evolving—charging technologies, site designs, business models, utility rate structures and so on. Accessibility is a key area of concern and may present an opportunity for fuel retailers given that on-site staff can assist drivers that need support and retail sites are inherently designed to support a wide range of vehicle types. Current fast charging services are often located in remote corners of parking lots, often fully exposed to the elements. Placement, relative to the parking spot also often makes chargers unusable for various EV drivers or vehicle types.⁴² Much can be learned by the EV industry regarding the ways in which existing retail fuel services have been designed to provide services for most to all vehicle users and types.

While electrification has a strong lead, it is not unreasonable that the current predictions and expectations are overstated, or that an EV sustainability issue without a clear resolution is exposed or seriously aggravated. Perhaps the single largest challenge will be access to an affordable supply of critical minerals for cell production. While dozens of new cell factories are under construction globally, the raw material supply is not expanding as quickly.

“The diesel engine has a lot of room of improvement... we see the diesel engine can be one of many solutions to realize a carbon neutral future.”

— Mazda Motor Corporation

As of mid-2023, more than 800 GWh of lithium ion cell production capacity has been announced just for North America with more announcements expected in the next year or two. All these plants need raw materials and while recycled materials are expected to play a major role from the 2030s onward, the supply of end-of-life batteries will be limited until then. Localization of material production is important to both sustainability and resilience. Mining lithium in South America or Australia, shipping it to China for processing and then on to North America for cell production adds cost, time, and substantial GHG emissions to the EV lifecycle. However, establishing new mines or other extraction facilities requires years of permitting and environmental approvals before construction. This process has lagged well behind the construction of the cell plants which may require use of materials sourced overseas through at least the remainder of the 2020s.

⁴² EV Pulse EVs and towing: [It's not the range, it's where to charge with a trailer](#). May 21, 2021.

It is possible that within the time it take for the EV supply chain to materialize conditions for renewable diesel and/or hydrogen might improve significantly. Such developments might come from multiple angles, like, for example exploitation of natural hydrogen deposits⁴³ or a regulatory pivot more accepting of ICE-based net-zero solutions.



Developments in transportation beyond the road have impacts as well. For example, investments in decarbonization solutions for shipping and aviation may accelerate innovation cycles for renewable diesel and hydrogen that make these technologies more competitive against an all-electric future. At the same time, the current post-pandemic induced predictions about mobility patterns and assets could be overstated and therein diminishing the disruptive potential that could come from a return to pre-pandemic interests in automated vehicles. Alternatively, pandemic memories may accelerate interests in alternative forms of transportation that are less public, like micro- and/or urban-air mobility systems, or infrastructure that is more restrictive to LDVs and MHDVs and more friendly to pedestrians, bicycles, and scooters.

There is little doubt that events we cannot anticipate will shift the course of the future in ways that seem unreasonable now. In many ways, we are still trying to understand how the events that have already happened will shape the future. Geopolitics, biology, technology, economics, social trends and new business innovations impact the transportation markets in ways that are challenging to anticipate. As such, we can only anticipate that there are unknown unknowns and do our best to predict what trends will survive these and which will not.

⁴³ E Hand. "Hidden Hydrogen." Science. February 16, 2023.



(703) 518-7970
TRANSPORTATIONENERGY.ORG

1600 DUKE STREET
SUIT 700
ALEXANDRIA, VA 22314