American Iron and Steel Institute

STEEL INDUSTRY ROLE IN THE FUTURE OF ELECTRIFIED VEHICLES

Executive Summary

As manufacturing industries continue to look at ways to respond to climate change, automakers in the U.S. and around the world have taken the lead by implementing vehicle electrification strategies to achieve substantial CO_2 emissions reductions. The American steel industry plays a critical role in achieving those reductions.

Automakers are ramping up production of Mild-hybrid (MHEV), Plug-in Hybrid (PHEV) and Battery Electric Vehicles (BEV) as integral parts of their product portfolios. The focus on these platforms suggests a deliberate and systematic migration toward product portfolios dominated by BEVs in an effort to become carbon neutral within the next two to three decades. This migration is also being reinforced by governments worldwide which are either providing incentives for BEV use or mandating their use in the near future. Automakers are now competing to develop affordable BEVs that offer drivers an acceptable travel range without compromising the functionality and features available to them in current internal combustion engine (ICE) vehicles.

An increase in BEV range is sensitive to both onboard battery capacity and vehicle efficiency, including mass. As battery technologies continue to evolve over the next decade, their energy density will increase while their cost is expected to decrease. Consequently, automakers are expected to develop cost-effective lightweight steel BEV architectures, using the broad spectrum of steel grades available, instead of using higher-cost alternatives such as aluminum, magnesium and composites. Cost-savings achieved from using steel can be leveraged to maximize the onboard battery capacity. Meanwhile, increased proliferation of BEVs will be accompanied by additional crash requirements over and above the existing standards to minimize intrusion into the battery pack, maintain pack structural integrity and ensure occupant safety. These requirements are expected to make steel the material of choice for future BEV designs worldwide.

Introduction: The Electric Vehicle Landscape

Figure 1 is a snapshot of the full spectrum of BEVs offered worldwide as of 2020. The landscape may slightly change over the next few years; however, one thing remains clear: the move to BEVs will continue.

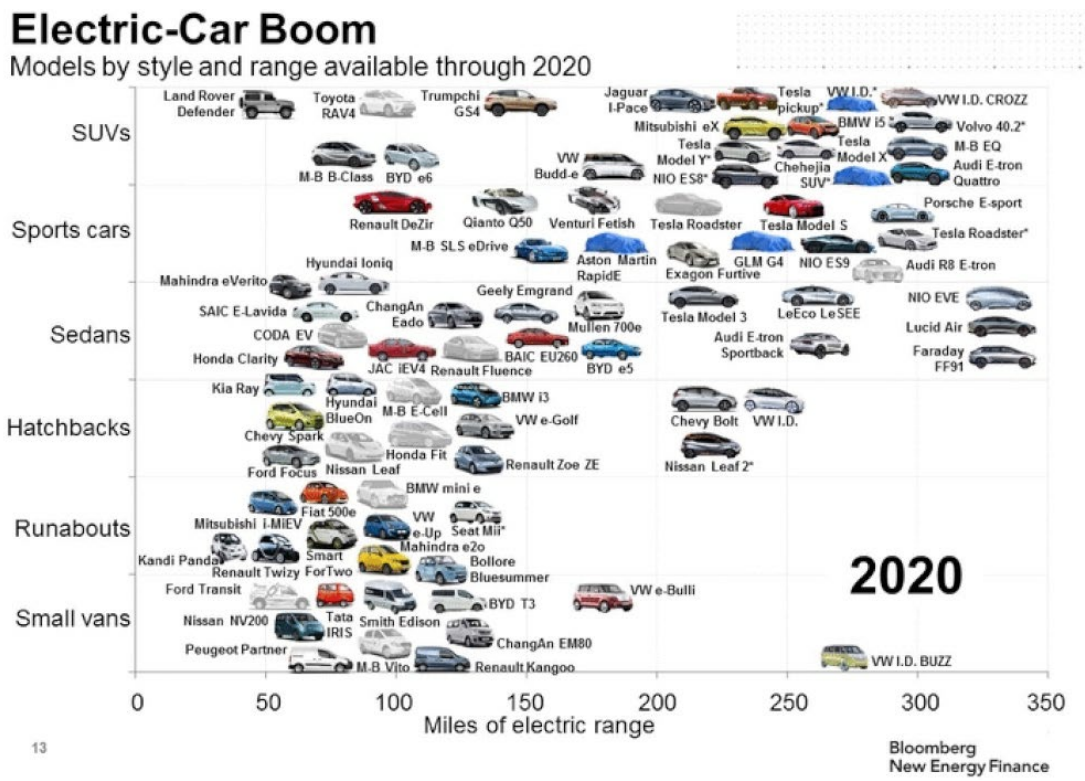

Figure 1: 2020 BEV Landscape Worldwide

According to *Canalys.com*, the global sales of BEVs in 2020 increased by almost 39 percent year-over-year to more than three million units. The site, Figure 2, forecasts that by 2028 the volume of BEVs sold will reach 30 million units worldwide and their sales will further increase to represent nearly half of the total passenger vehicles sold by 2030.

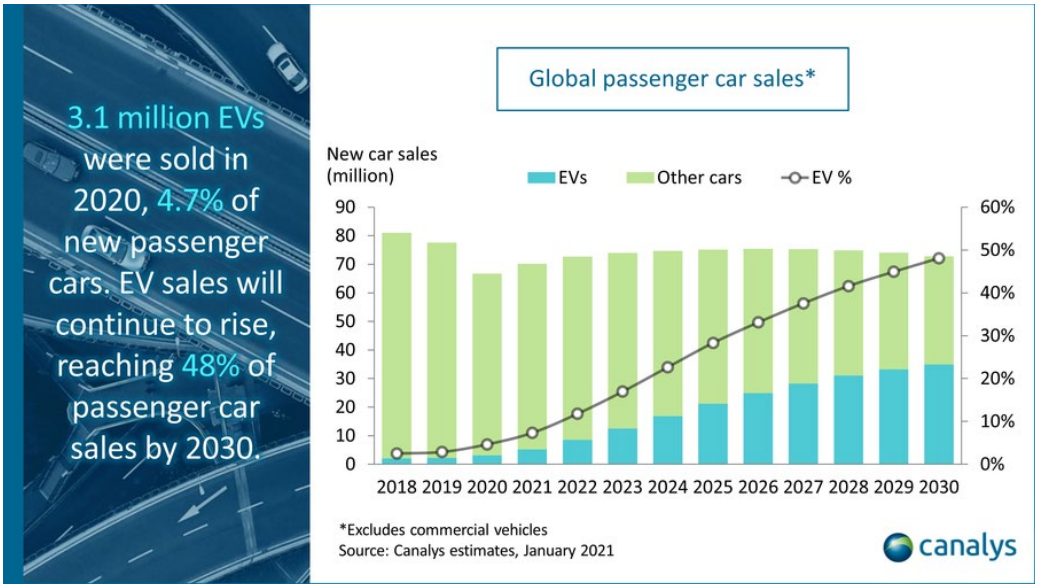

Figure 2: Battery Electric Vehicle Sales Growth

This rapid growth in BEV sales will be fueled by major advances in battery technologies which will lead to higher energy density and lower cost. Government policies and actions aimed at a significant reduction in CO_2 emissions, expansion of BEV charging infrastructure and improvements in charging times will boost BEVs by incentivizing their sales and reducing consumers' anxiety about range.

The U.S. has reinvigorated the demand for BEVs. As the focus shifts toward clean energy, the Biden administration has proposed to replace the entire U.S. government fleet of roughly 645,000 vehicles with electrified vehicles manufactured in the U.S. and is also considering continuation of current incentives. The Biden plan, if enacted as proposed, is expected to boost the total number of BEVs by at least 40 percent above the 1.6 million vehicles, including government and privately owned vehicles, that are currently in service in the U.S.

General Motors (GM) recently announced its intention to offer 30 battery electric vehicle models by 2025 in all four of its main brands. The GMC Hummer EV in 2022 and the Cadillac Lyric in 2023 will be leading the way to GM's ultimate pledge to be 100 percent electric capable by 2035.

Other automakers are also making significant strides toward the introduction of electric vehicles. Ford Motor Company just announced a sweeping transition to electrified vehicles in Europe by 2030. For the U.S. market, Ford plans to introduce the Mustang Mach-E in 2021, followed by the Ford E-Transit and an all-electric F-150 in 2022.

The Value Proposition of Steel

The steel industry's history of responsiveness to the needs of the automotive industry, with a continuously expanding portfolio of grades as seen in Figure 3, indicates that it is well-positioned to play a major role in the future transition toward full electrification. High-strength steel (HSS), advanced high-strength steel (AHSS)* and ultra high-strength steel (UHSS)* grades have been the dominant materials of choice for automakers over the past three decades. This section reviews the value steel continues to offer to multiple facets of a BEV program and the opportunities open for steel to solidify its dominance.

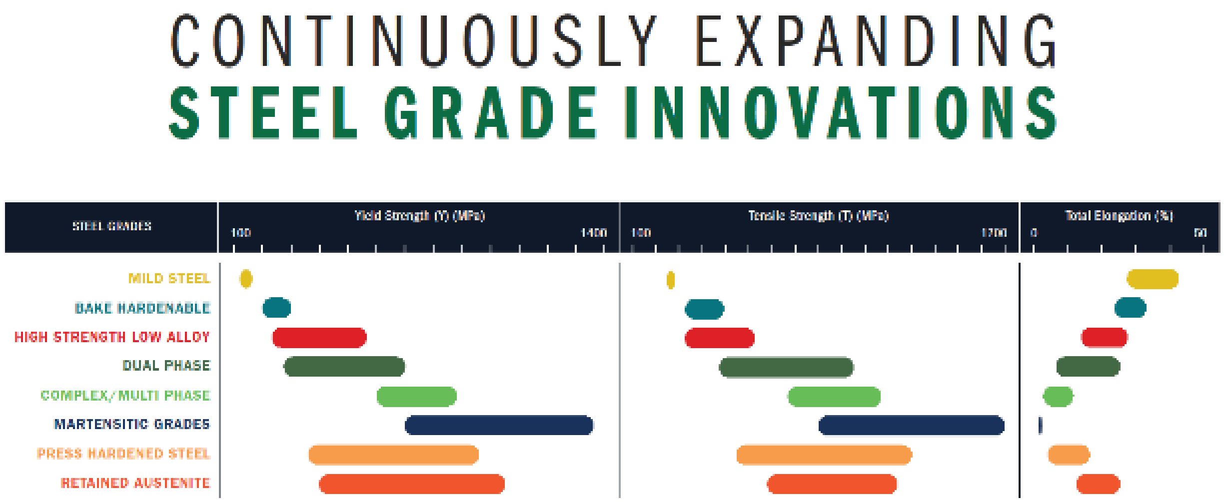

Figure 3: Steel Grade Innovation

** In this document, AHSS refers to all steel products with a tensile strength equal to or greater than 590 MPa including those UHSS products with a tensile strength at or above 1000 MPa.*

Architecture Design

The most significant architectural feature of BEVs will be the integration of the battery enclosure into the underbody structure, often referred to as skateboard by new BEV manufacturers. It is important to focus on promoting efficient steel enclosures that are developed in unison with the full body structure and contribute to enhancing both vehicle crashworthiness and its noise, vibration and harshness characteristics.

Steel is superior in enabling key vehicle attributes that may be difficult to attain with other materials. For example, vehicle body sides are being engineered without a center pillar for ease of entry and exit. Additionally, mass efficient side doors consistent with the pillarless themes and lightweight multi-functional rear closures can help solidify steel's dominance in BEV body designs. It should be noted that BEV architectures are still evolving and not all automakers have accepted alternate materials for the body or battery enclosure structure. Therefore, efficient design demonstrators using steel, coupled with credible and creative manufacturing technologies, will sustain the confidence of automakers in continuing to maintain steel as the material of choice in their future BEVs.

It should also be noted that highly efficient electrical motors utilized in BEVs require a specialty iron-silicon alloy steel called non-oriented electrical steel (NOES). This steel has magnetic properties that are practically the same in any direction in the plane of the material. It has superior permeability at high inductions, low average core loss and good gauge uniformity. Produced by the American steel industry, NOES will be critical to further enhancing the efficiency and range of BEVs.

Business Case

Cost remains a key decision driver in any vehicle program. For ICE vehicles, the cost of lightweighting with alternative premium materials is usually justified by the need to achieve the necessary fleet fuel economy targets. For BEVs, the objective will be increasing vehicle range which is a function of both onboard energy capacity and the rate of energy consumption. Studies have indicated that, unlike ICE vehicles, energy consumption in BEVs is less sensitive to increased vehicle mass due in some part to brake energy regeneration. Consequently, for increased range it may be more beneficial to add battery capacity than reduce vehicle mass using high-cost premium materials.

Such a tradeoff will be self-evident as battery system costs decrease over the next decade while battery energy density increases. Figure 4 shows that, as the battery system cost drops below $100/kWh, steel intensive designs would be the preferred approach when cost is the main driver. In December 2020, BloombergNEF (BNEF) reported that the average price per kilowatt-hour for a lithium-ion battery pack has fallen to $137, down 13 percent from $157 in 2019. In the report, BNEF analysts indicated that they expect battery makers to achieve $101/kWh in 2023. At that time, it will no longer be a matter of taking weight out of the vehicle at any cost, but instead about getting more energy onboard. Automakers will continually reassess their priorities in an effort to align vehicle costs with their overall business strategy. This approach could favor steel, with only selective application of alternate materials depending on vehicle segment and need.

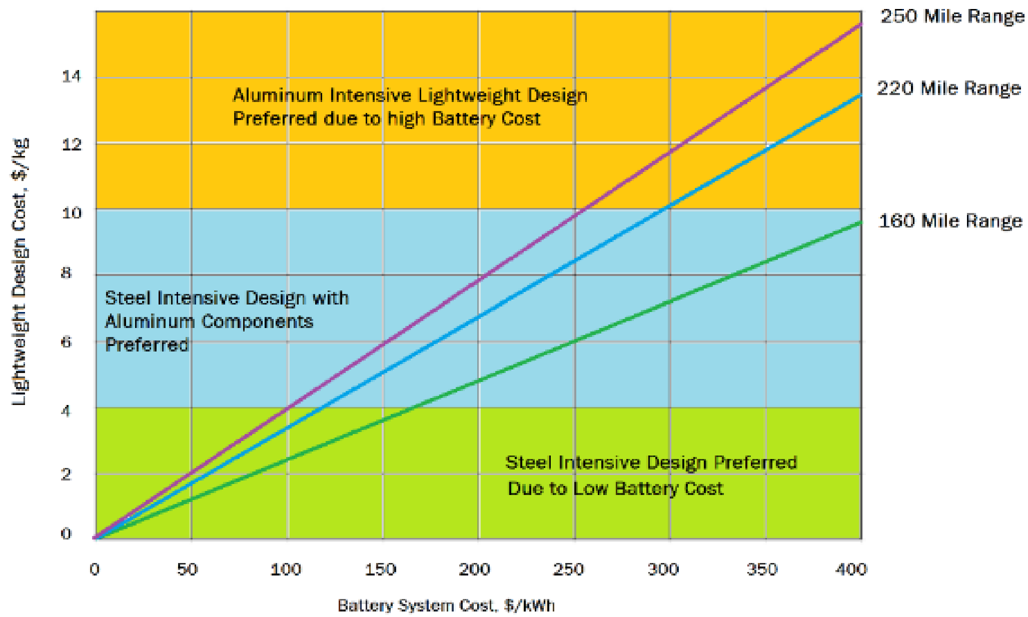

Figure 4: Battery System Cost vs. Cost of Lightweighting
Source: Nucor presentation at BEVA conference, Sept. 2018

Manufacturing Infrastructure

Automakers seek to maximize return on investment in their manufacturing infrastructure. While they have been adopting newer technologies over time, their manufacturing infrastructure remains largely dominated by sheet metal stampings and fusion welding. This may seem to present automakers with the challenge of introducing dedicated BEV platforms. However, the steel industry has been continually broadening its global portfolio to offer grades with strength and ductility combinations that were unthinkable just a decade ago (e.g., 3rd Gen 980 and 1180 with more than 20 percent elongation, and 2 GPa Press Hardened Steels). With such a wide choice of grades coupled with innovative technologies such as tailor rolled blanks (TRB) and tailor welded blanks (TWB), roll forming, hydroforming, adhesive bonding and laser welding, among others, automakers will be able to develop innovative structural solutions with only incremental updates to their existing fabrication and assembly facilities and avoid a large capital expenditure.

Sustainability

The climate change narrative is shifting toward a focus on total life cycle vehicle emissions versus emissions from only the driving phase, which would be eliminated for BEVs.

The life cycle assessment (LCA) methodology looks at the total greenhouse gas emissions (GHGs) from all phases of a vehicle's life — from its manufacture through its disposal and/or recycling— and can help automakers make better decisions in the selection of materials for future cars and trucks. Past LCA studies focused on ICE vehicles have shown that lightweighting a vehicle fleet with AHSS versus aluminum results in cumulative net savings of more than 300 million metric tons of GHG emissions by 2038 — the equivalent of the emissions resulting from combustion of 45 billion gallons of gasoline. By 2053, an additional 100 million metric tons would be saved, totaling more than 400 million metric tons of GHG emissions savings. Consequently, if one considers the total vehicle life cycle, it becomes evident that steel is the most environmentally effective choice due to its relatively lower energy intensity and emissions during the manufacturing phase, significant mass reduction during the driving phase and full recyclability at the end of the vehicle's life.

There is a move to require automakers in Europe to report life cycle CO_2 emissions of all new cars based on a harmonized methodology by 2025. Material production alone can account for up to 30 percent of the total GHG emissions in ICE vehicles and as much as 47 percent in BEVs. This type of LCA discipline within the automotive industry can ensure that automakers will take appropriate and adequate steps toward reducing emissions and slowing down climate change. Currently, steelmakers are exploring means of lowering their carbon footprint and operating cost. While this drives capital investment in the short term, in the long term it will increase steelmaking efficiency and make steel an excellent contributor to achieving overall CO_2 emissions reduction goals.

Global automakers are mandating reductions in CO_2 emissions of their raw materials in the next several decades. This is a challenge for all body materials due to the high energy requirements of production. The manufacture of steel produces an order of magnitude less CO_2 emissions than other body materials such as aluminum, magnesium and carbon reinforced plastic. All body material manufacturers are striving to reduce emissions; however, the steel industry will be able to significantly reduce the carbon footprint of its products more efficiently and cost-effectively compared to other materials. As a result, the cost to produce alternate materials will increase, versus the cost to produce steel, if the target is an equivalent amount of CO_2 emissions.

The increased efficiency of the BEV propulsion systems and advancements in battery technology will temper the environmental benefits of lightweighting. As automakers learn more about the impact of material selection decisions on overall vehicle emissions, it is expected that they will eventually view requirements for "lower embodied emissions" in a manner similar to what is happening in the construction market. For example, the catalysts for lower CO_2 solutions will be coming from several sources including cities, states, NGOs and end users more so than from federal regulations. The steel industry will continue to support automakers by assisting the shift toward cleaner and more energy-efficient vehicles.

Summary of Steel's Attributes

The value proposition of steel-intensive solutions compared to other materials include:

- Exceptional strength and ductility combinations to ensure occupant safety, maintain the integrity of the battery system and protect vital vehicle components such as sensors and control modules.
- Cost-effective lightweight structural solutions that allow automakers to redirect the cost savings to add energy capacity for more vehicle range or add other customer facing technologies.
- Exceptional stiffness to achieve world-class noise, vibration and harshness performance.
- Excellent formability to deliver desirable styling themes and innovative designs.
- Compact structural section designs for enhanced interior spaciousness and component packaging.
- Solutions aligned with the automakers' existing manufacturing infrastructure, yet flexible enough to allow architectural innovations.
- An environmentally responsible material, which will be critical as the global narrative shifts toward lowering GHG emissions from the entire life cycle of the vehicle.
- Enhanced cost of ownership to the consumer, including cost of purchase and repair.
- Continuously improving and expanding supply chain infrastructure.

Steel E-Motive Program

On November 12, 2020, WorldAutoSteel announced a new engineering program to demonstrate steel architectures for Mobility as a Service (MaaS) vehicles. The program, Steel E-Motive, will establish the benefits of steel for global MaaS architectures characterized by fully connected and autonomous electric vehicles.

Although the program assumes a fully autonomous vehicle without a steering wheel, it is essentially focused on the development of a highly efficient steel body structure with an integrated steel battery enclosure. The design calls for no center pillar and a consistent steel side closure design concept to enhance entry and exit. The program will leverage a broad portfolio of steel grades and manufacturing technologies (forming, joining and assembly) to produce a credible steel intensive solution within the framework of vehicle technical specifications consistent with contemporary BEV performance requirements.

The intent is to provide automakers with steel concepts and solutions they can draw upon for their existing clean sheet BEV development. The final concept design for the full vehicle will be revealed in late 2022 including manufacturing assessments, LCA and a comprehensive technical cost analysis. It is expected that Steel E-Motive will deliver new, exciting innovations for steel vehicle architectures that will shape the future of sustainable mobility.

AISI's Automotive Program assisted in drafting the vehicle technical specifications for the Steel E-Motive program and continues to be fully engaged in defining the structural architecture and developing the design concept for the program.

Conclusion

As the move toward electric vehicles continues to be part of many automakers' future sustainability plans, steel will remain the preferred material for body structures, closures and battery enclosures. Electric vehicles' structural performance and battery packaging requirements favor the use of steel with its inherent strength and ductility. Automakers will likely choose steel to develop cost-effective lightweight BEV architectures and leverage the cost savings to increase the onboard battery capacity and maximize vehicle driving range on a single charge.