WORKING PAPER

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Assessment of automotive steel demand in the United States

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INTRODUCTION AND BACKGROUND

To reach international climate targets, it is necessary for the steel industry to decarbonize. Although multiple technologies exist to produce low-emission and fossil fuel-free steel, the vast majority of steel is produced from coal-based technologies (Bui et al., 2024). The transition away from conventional steelmaking pathways to greener alternatives is just beginning in the United States, and large-scale funding opportunities for industrial decarbonization are emerging at the federal level (Gallucci, 2024; Advanced Research Projects Agency-Energy, 2024; Grossman & von dem Hagen, 2024; Industrious Labs & Public Citizen, 2024).

Meanwhile, in the transportation sector, electric vehicle sales continue to increase year-over-year, globally and in the United States (EV Volumes, n.d.; Isenstadt, 2024). In April 2024, the United States finalized new greenhouse gas (GHG) emissions standards that set light- and medium-duty vehicle tailpipe emissions on a path towards zero emissions (Multi-Pollutant Emissions Standards, 2024). As the sales share of new vehicles with zero emissions at the tailpipe increases, the emissions associated with the materials used to manufacture such vehicles will represent a greater share of total life-cycle emissions. In the United States, the automotive industry is the third-largest consumer of steel and, for some steelmakers, represents their largest revenue source (U.S. Geological Survey, 2024; Warrian & Mulhern, 2005). As automakers expand efforts to address emissions embodied within their vehicles, manufacturers are thus well positioned to demand "green" fossil-free steel and spearhead steel decarbonization efforts in the United States.

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In general, there is little public information on the quantities and types of steel in vehicles. Due to steel's importance for vehicle manufacturing—and, by extension, its contribution to emissions embodied within vehicles—improving our understanding of the types and amounts of steel in vehicles is necessary for determining how automakers can begin to transition to green steel.

This paper estimates the quantities of different types of steel used in the production of light-duty vehicles (LDVs) in the United States. It focuses on steel demand at the body-in-white (BiW) stage, at which point all components of the car's frame have been joined together except for moving parts like the motor and chassis; the BiW typically represents around a quarter of the overall vehicle mass (Rowe, 2012). Approximately 40%–70% of the steel used to construct vehicles exists in the body (World Steel Association, n.d.-a). By focusing on the BiW, this study thus assesses the stage of production that offers potential for the largest reductions in embodied emissions from steel and has the largest impact on vehicle steel costs. The paper assesses steel demand on a model-specific basis, focusing on high-volume models, as well as at the vehicle segment, automaker, and light-duty industry levels.

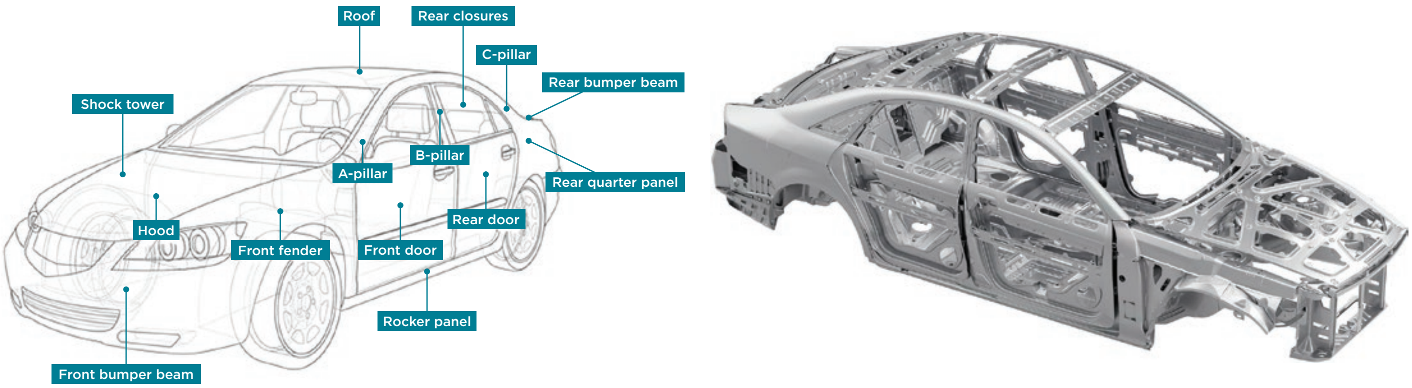
Based on this assessment of steel demand, we also estimate the GHG emissions reduction potential for vehicle segments and the automotive industry more broadly if the industry were to replace today's conventional steel in the BiW with green steel. We also quantify the potential cost increase for individual models, automakers, and the industry as a whole associated with substituting conventional steel with green steel based on a review of the literature and industry announcements as of September 2024.

ASSESSMENT OF BODY-IN-WHITE STEEL USAGE BY VEHICLE TYPE, STEEL TYPE, AUTOMAKER PLANT, AND AUTOMAKER

This section describes the data sources and methodology used to calculate the amounts and types of steel that automakers use to construct their LDVs; it then presents our findings. We examined a dataset from S&P Global Mobility (2024) that provides information on the characteristics of BiW components for LDVs produced around the world. Focusing on the United States, we aggregated the quantities of steel by automaker, vehicle type, and auto manufacturing plant.

Figure 1 depicts the BiW of an LDV. The BiW includes the roof, rear closures, pillars, shock tower, bumpers, hood, fender, and doors, among other components. The data set from S&P Global Mobility (2024) provides information on the characteristics of each BiW component for all LDVs produced globally, including the material group (e.g., steel and aluminum), material type (i.e., the grade or strength characteristics), specific fabrication process, and estimated weight, as well as the volumes of each component corresponding to production volumes of each vehicle manufactured in each market.

Figure 1
Body-in-white structure and components



Notes: This image includes additional components not typically part of the BiW (e.g., steering wheel, seats, and headlights). The labeled components reflect components that comprise the BiW.

Source: S&P Global Mobility, "AutoTechInsight; BiW Forecast April 2024."

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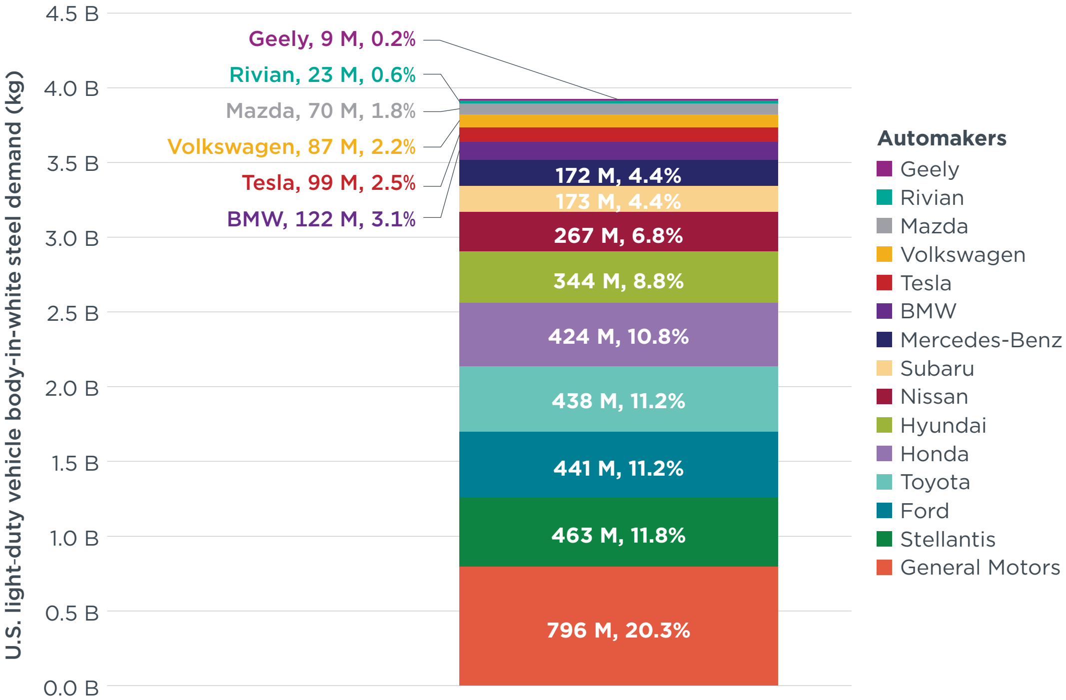
Among LDVs produced in the United States, we found that each vehicle nameplate could have multiple body styles with different compositions of BiW components and thus varying amounts of steel. For example, the Ford F-150 has a 2-door and a 4-door variant. The S&P data set also provides production volumes for each of these body styles. We calculated the 2023 production volume-weighted average of the steel content by type for each nameplate by multiplying the sum of all steel BiW components for each body style of a particular nameplate by its production volume, adding these products together, and then dividing that sum by the cumulative production volume for that nameplate. In this way, we quantified the overall production volume-weighted average of BiW steel by type for each LDV model sold in the United States.

Figure 2 shows the estimated light-duty BiW steel demand by automaker in the United States. This demand represents only steel used in the U.S. production of vehicles in 2023 and does not include any steel that automakers may use in factories outside of the United States. The steel is assumed to be sourced from U.S. steel mills given that most steel used for automotive manufacturing is sourced from the same country in which it is produced (Negri et al., 2024). Across the 15 automakers shown, about 3.9 million tonnes (Mt) of steel was used to construct the BiWs of all LDVs produced in the United States. This value represents only the steel that ends up in the final assembly of the BiW and does not account for leftover scrap from cutting components out of sheet steel. Automakers are ordered from bottom to top based on annual steel demand.

Figure 2

Estimated U.S. light-duty body-in-white steel demand by automaker



Source: S&P Global Mobility, "AutoTechInsight; BiW Forecast April 2024."

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General Motors accounted for the greatest demand for BiW steel with about 796 million kg, or around 20% of steel used for LDV BiWs in the United States. Stellantis (463 million kg), Ford (441 million kg), Toyota (438 million kg), and Honda (424 million kg) round out the top 5 automakers, each representing around 11% to 12% of U.S. LDV BiW steel demand. Together, the top 5 automakers account for about 65% of all LDV BiW steel used in the United States. The 10 remaining automakers accounted for the other 35% of U.S. LDV BiW steel demand. Lucid, not shown above, is the only automaker identified that used no steel in the BiW, instead using primarily aluminum. Automakers' respective shares of BiW steel demand somewhat align with their U.S. LDV market shares, with 4 of the top 5 steel consumers ranking in the top 5 manufacturers by market share: General Motors (17%), Toyota (14.5%), Ford (13%), Hyundai (11%), and Stellantis (10%) (VinAudit, n.d.). Honda is just outside of the top 5, with an 8.5% market share.

The production of green steel, defined in this report as steel produced using green hydrogen (i.e., hydrogen produced using 100% renewable electricity), is currently limited in the United States.[1] If U.S. automakers were to shift to green steel for LDV BiWs, this 3.9 Mt demand could be met by two new fully operational green steel plants or two existing steel plants retrofitted to produce green steel. Additionally, there is potential for even more of the steel used in the automotive sector to be decarbonized (World Steel

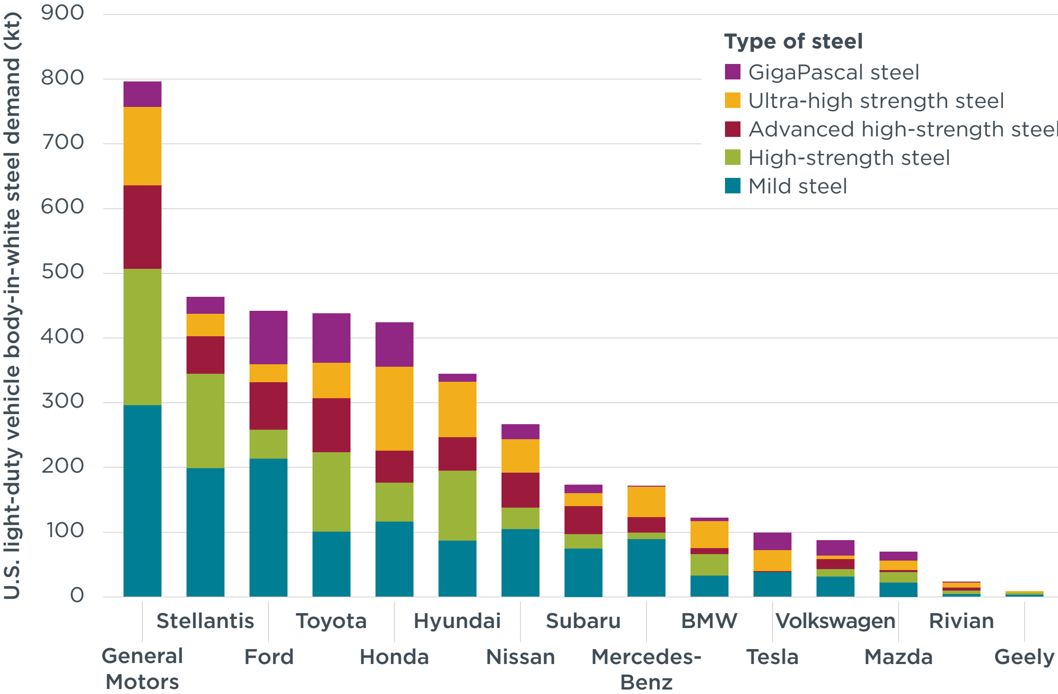
1 Specifically, in this paper, "green steel" refers to steel produced via the hydrogen-direct reduced iron-electric arc furnace (H2-DRI-EAF) steelmaking pathway. This pathway uses green hydrogen as a reducing gas to create direct reduced iron from iron ore, which is then processed in an electric arc furnace to create steel (Basirat, 2024).

Association, n.d.-a; Bui et al., 2024). In 2023, U.S. manufacturers of LDVs, medium-duty vehicles, heavy-duty vehicles, and two-wheelers collectively used about 11 Mt or 14% of domestically produced steel, meaning at least an additional 7 Mt of automotive steel could possibly be decarbonized beyond what is estimated for only LDV BiWs (U.S. Geological Survey, 2024).

Figure 3 details the steel demand by type for major automakers with operations in the United States. The different colors on the stacked bar charts show the quantities of different types of steels used in BiW manufacturing by tensile strength, which refers to the maximum stress a material can withstand without failure under load and is measured in megapascals (MPa). This is an important property for selecting steel used in automotive manufacturing to ensure the structural stability of the vehicle. The steels used in BiW manufacturing include mild steel (<300 MPa), high-strength steel (HSS; 300–549 MPa), advanced high-strength steel (AHSS; 550–779 MPa), ultra-high strength steel (UHSS; 780–999 MPa), and GigaPascal steel (1,000+ MPa).

Figure 3

Estimated U.S. light-duty body-in-white steel demand by type, by automaker



Source: S&P Global Mobility, “AutoTechInsight; BiW Forecast April 2024.”

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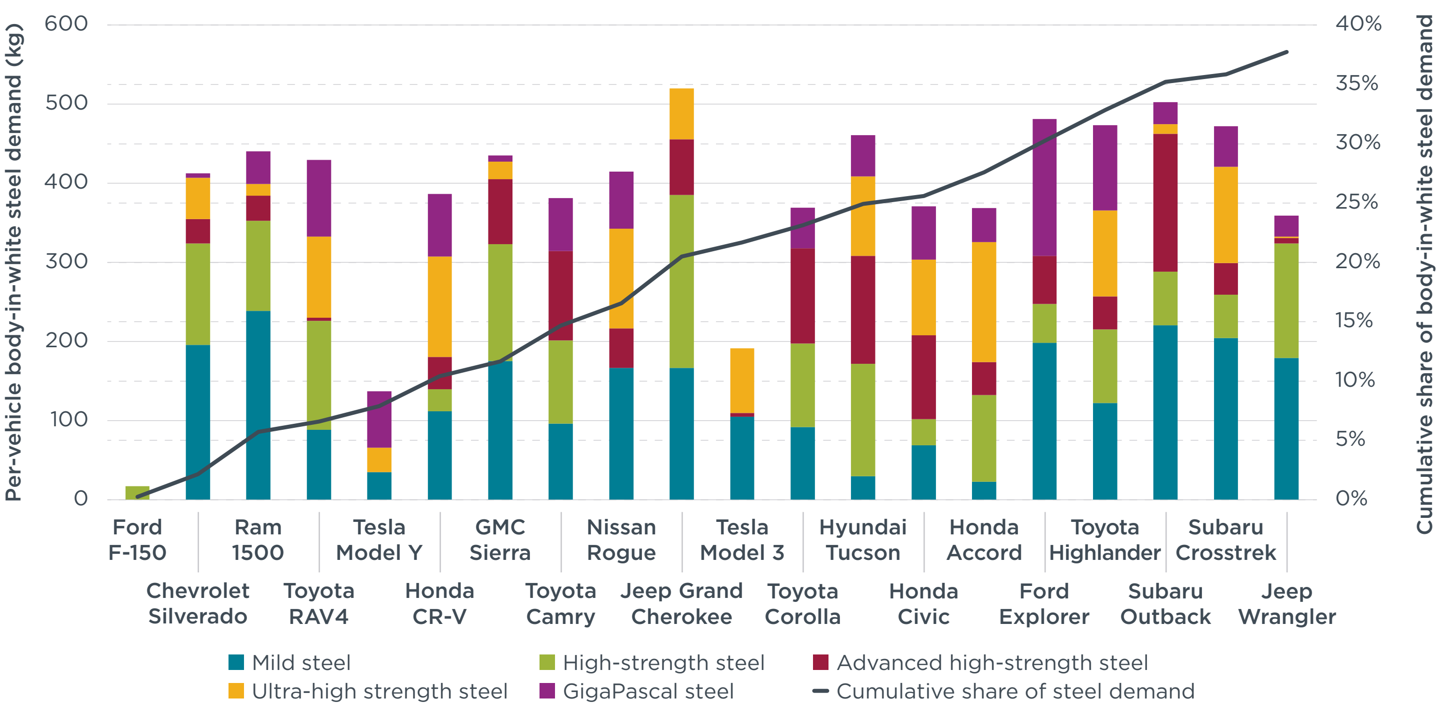
Several automakers use relatively more mild steel in the BiW than any other type of steel, while GigaPascal steel has the lowest demand among all steel types used in LDV BiW manufacturing. Generally, the quantity of steel needed decreases as its strength increases. This suggests that using higher strength steels could reduce overall steel demand in the automotive industry, given the greater strength-to-weight ratio (International Refining and Manufacturing Company, n.d.). However, automakers balance several needs when selecting materials for the BiW, including costs, safety, weight, and formability. At the industry level, 36% of BiW steel demand in 2023 was for mild steel (1.4 Mt), 21% for HSS (0.8 Mt), 17% for UHSS (0.7 Mt), 15% for AHSS (0.6 Mt), and 10% for GigaPascal (0.4 Mt).

The steel demand for each automaker shown reflects the aggregates for the types of steel used to construct BiWs for all vehicle models an automaker produces in the United States. Different models from the same automaker can have different steel compositions and may not contain all the types of steel that automakers use. The distribution of the automaker's steel demand corresponds to which factories produce which vehicles, as shown later in this section.

Figure 4 shows the 20 highest-selling LDVs produced and sold in the United States and their per-vehicle BiW steel use by steel type. Models are presented in descending order of 2023 U.S. sales as reported by Car and Driver (Capparella, 2023), beginning with the highest-selling vehicle on the left. The black line indicates the cumulative share of total U.S. BiW steel demand these 20 models collectively make up, progressing from left to right.

Figure 4

Per-vehicle body-in-white steel demand, by type, for the 20 highest-selling light-duty vehicles produced and sold in the United States



Source: S&P Global Mobility, "AutoTechInsight; BiW Forecast April 2024," and Capparella (2023).

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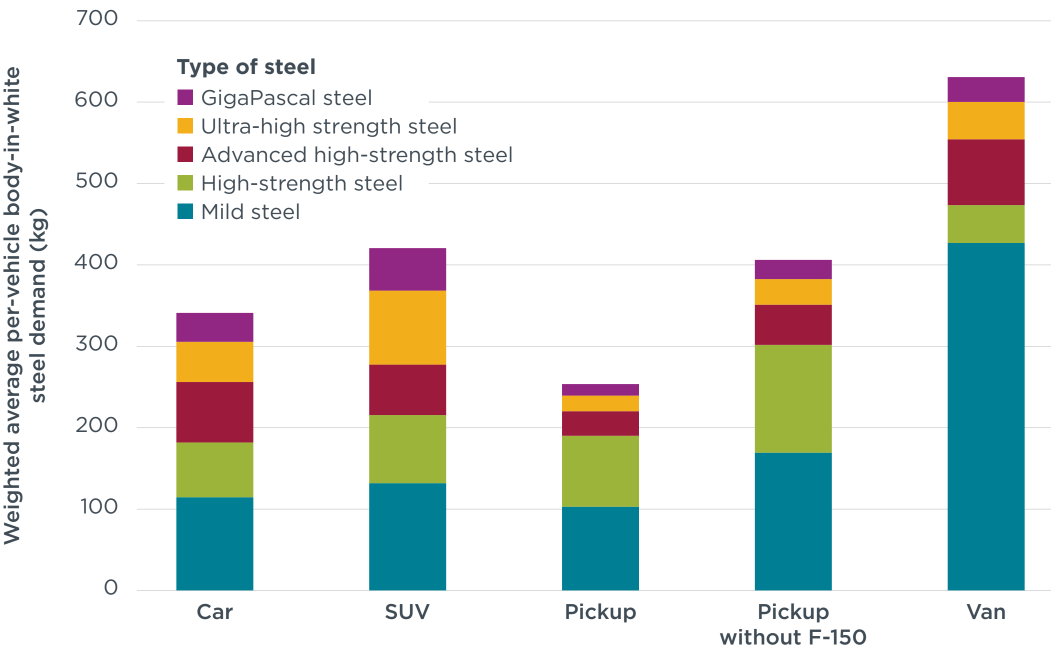
The BiWs for most of the models shown require approximately 400 to 500 kg of steel, although there is not a clear trend in terms of the types of steel used. The Ford F-150, the Tesla Model Y, and the Tesla Model 3 contain significantly less steel in the BiW than any other of the top-selling models. A detailed examination of these models reveals that much of the mass of steel in the BiW is substituted with aluminum, particularly for the F-150. It still could be the case that components not included in the BiWs of these vehicles have steel content that is similar to most other models shown. Aluminum is a common material used for lightweighting vehicles, with approximately 0.8 Mt of aluminum used in LDV BiWs according to the S&P data set. Though aluminum tends to have higher embodied emissions than steel, its use in lightweighting can improve a vehicle's fuel efficiency (Bui et al., 2024). Automakers may also use a mix of steel, aluminum, composite materials, and magnesium in their BiWs, which leads to the variability in BiW composition. The cumulative steel demand of the 20 highest-selling models represented about 38% of all BiW steel demand in 2023. With aggregate sales of more than 5.9 million, these top 20 models also represented about 38% of all LDVs sold the same year (Manzi, 2023).

The per-vehicle steel content for the top models shown above represents the production-weighted steel content of different body styles of the same vehicle nameplate. By grouping these together, we can provide an average steel content by type for different nameplates, though no individual nameplate would have the precise steel composition shown in Figure 4.

Figure 5 shows the production-weighted average BiW steel content by type of steel and vehicle class. Steel content is weighted by production volumes of vehicles in each class. The S&P Global Mobility data set includes more granular vehicle classifications than what is shown here. Our "Car" class includes vehicles classified as coupes, convertibles, roadsters, hatchbacks, and sedans. Our "SUV" class includes sport-utility vehicles (SUVs) and wagons. The "Pickup" class includes pickups; an additional column shows the production-weighted steel content for pickups when F-150s are omitted because this model has a uniquely low steel content and high annual sales. The "Van" class includes chassis-cabs, multi-purpose vehicles, and vans.

Figure 5

Production-weighted average body-in-white steel demand, by type and vehicle class



Source: S&P Global Mobility, "AutoTechInsight; BiW Forecast April 2024."

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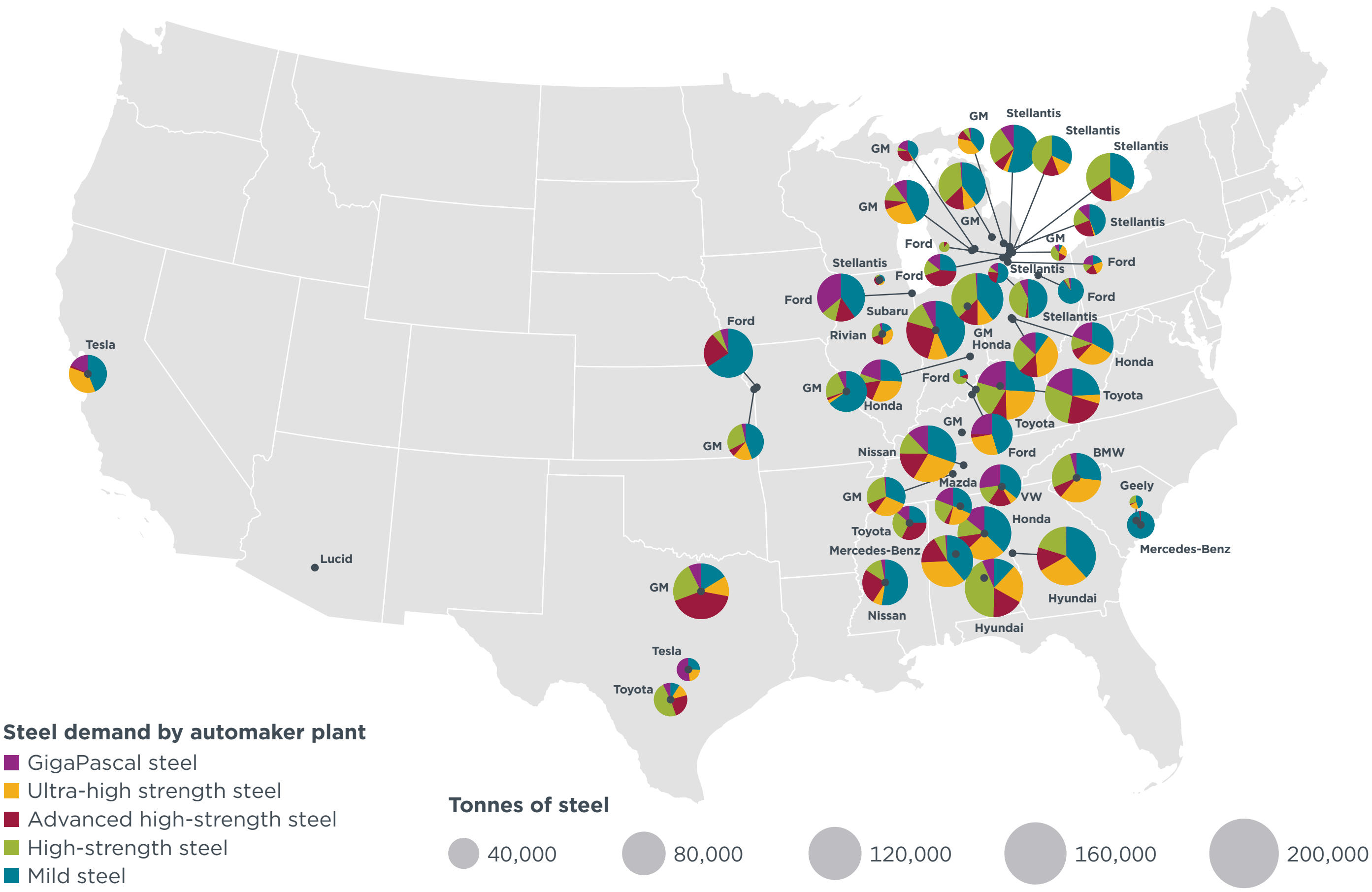
Overall, pickup trucks are shown to have less steel demand on average than the other vehicle classes. After omitting F-150s, however, the average BiW steel content of pickup trucks is around 400 kg, which is closer in line with SUVs. The average steel content for LDVs in the United States is about 411 kg.

Using 2023 production volumes for each light-duty auto plant in the United States obtained from Automotive News Research & Data Center (2023), we then multiplied the per-vehicle production volume-weighted average steel content of each nameplate by their production volume at each plant to determine the total steel demanded at each plant by type. Figure 6 depicts the location of LDV manufacturing plants in the United States and the relative shares of different types of estimated steel demanded at each plant. The pie charts are sized according to the estimated annual tonnes of LDV BiW steel used in 2023. The majority of LDV manufacturing plants are clustered in the Midwest and in the South, and most plants use several different types of steel. For example, 46 of the 50 plants use four to five types of steel, whereas only three plants use three or fewer types of steel. Lucid's manufacturing plant does not use any steel.

Figure 6

U.S. automaker plants by amount of light-duty body-in-white steel demand and relative share of steel, by type



Source: S&P Global Mobility, "AutoTechInsight; BiW Forecast April 2024," and Automotive News Research & Data Center (2023).

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The shares of steel types used at each plant vary depending on which vehicles are built at each plant and their material composition. For example, Tesla generally uses very little AHSS or HSS in its vehicles, except limited amounts of both in the Cybertruck and some AHSS in the Model 3. Tesla produced a negligible number of Cybertrucks at its Austin, Texas plant in 2023, such that the AHSS and HSS portions of that facility's pie chart are imperceivably small. Tesla's factory in Fremont, California, which produces the Model 3, shows a small sliver of AHSS but no HSS. Likewise, the Ford plant in Kansas City, Missouri produces F-150s and Ford Transits, neither of which contain UHSS, which therefore does not appear in the factory's chart. The largest auto manufacturing plants in terms of LDV BiW steel demand tend to be those in which multiple vehicle models are produced and those that produce the most popular vehicle models. Table A1 in the appendix shows a detailed breakdown of each plant with the amount and types of steel used to construct BiWs and the models and quantities produced.

ASSESSMENT OF GREENHOUSE GAS EMISSIONS AND COSTS OF SWITCHING TO GREEN STEEL

This section calculates the GHG emissions and cost impact of substituting green steel in the manufacturing of LDV BiWs in the United States. First, we apply findings on the carbon intensity of green steelmaking to our findings of BiW steel demand to calculate the cumulative GHG emissions reductions should the entire automotive industry substitute green steel in place of conventional steel for the construction of LDV BiWs. We next summarize the results of a detailed literature review of the manufacturing costs of conventional steel and green steel and apply the relative cost findings to the BiW demand to assess the cost difference of replacing conventional steel with green steel on a per-vehicle basis.

IMPACT OF GREEN STEEL ON BODY-IN-WHITE GREENHOUSE GAS EMISSIONS

To assess the possible GHG emissions reductions of using green steel in BiWs for LDVs, we combine our automakers' BiW steel demand estimates with the estimated carbon intensities of conventional steel versus green steel. We adopt steel carbon intensity values from ICCT's analysis of several steel decarbonization pathways and their impact on life-cycle GHG emissions from LDVs (Bui et al., 2024). For conventional primary steel, we apply a carbon intensity of 2.27 t of carbon dioxide equivalent (CO_2e) emissions per tonne of steel based on the Baseline blast furnace-basic oxygen furnace (BF-BOF) steelmaking pathway in the United States in Bui et al. (2024). For green primary steel, we apply a carbon intensity of 0.1 t CO_2e per tonne of steel based on the Best Possible (i.e., 100% green hydrogen) hydrogen-direct reduced iron-electric arc furnace (H2-DRI-EAF) steelmaking pathway in the United States in the same study.[2] We assume that 25% of BiW steel is secondary steel (World Steel Association, n.d.-b; Bridgewater Recycling Inc., n.d.; Gardner Metal Recycling, n.d.; Buckingham, 2005), for which we apply a carbon intensity of 0.97 t CO_2e per tonne of steel based on the Baseline scrap EAF steelmaking pathway in the United States in Bui et al. (2024). These carbon intensities include a broader scope of emissions beyond Scope 1 and Scope 2, including certain process emissions, such as from iron ore mining and final stamping.

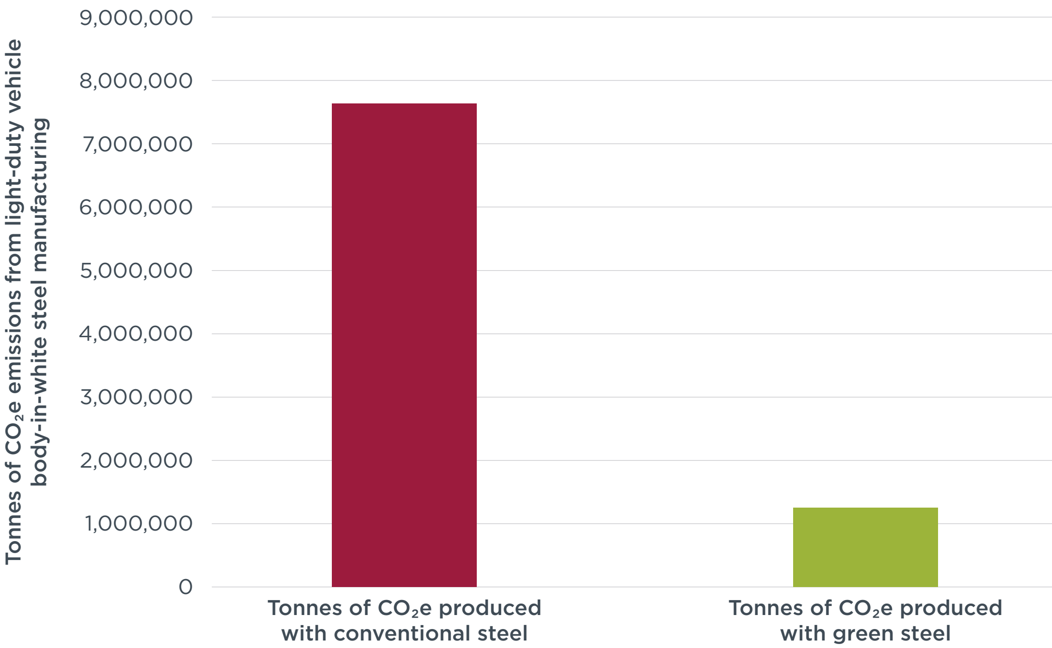
Based on these emissions factors, we determine that conventional BiW steel has a carbon intensity of 1.945 t CO_2e per tonne of steel, whereas green BiW steel has a carbon intensity of 0.3175 t CO_2e per tonne of steel. Therefore, we find that switching to green steel could offer an 84% reduction in per-tonne CO_2e emissions compared with using conventional steel. It is unclear if steelmakers would explicitly source renewable electricity to power secondary steel production, but as the U.S. grid becomes less reliant on fossil fuels and incorporates more renewable electricity sources, the emissions from secondary steel production would decrease.

2 Primary steel is new steel created from iron ore and other reducing agents, whereas secondary steel is made from recycled scrap steel.

Applying these carbon intensities to the estimated 3.9 Mt of steel used by automakers for BiWs in 2023 in the United States, we find that approximately 7.6 Mt of CO_2e emissions are produced industry-wide with conventional steel versus about 1.2 Mt of CO_2e emissions if automakers were to use green steel. Figure 7 depicts the industry-wide, annual CO_2e emissions for LDV BiW manufacturing in the United States, comparing conventional and green steel.

Figure 7

Estimated U.S. industry-wide, annual CO_2e emissions for light-duty body-in-white production using conventional and green steel



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Assuming the same carbon intensity for all types of steel used in the BiW, the GHG emissions reduction potential of substituting green steel in the manufacturing of BiWs for LDVs could thus allow for an additional 6.4 Mt of embodied CO_2e emissions to be avoided annually.[3] For context, the U.S. Environmental Protection Agency (EPA) estimates that approximately 39 Mt of cumulative tailpipe CO_2e emissions will be avoided by 2030 under the new multi-pollutant rule for light-duty and medium-duty vehicles (Multi-Pollutant Emissions Standards, 2024). If green steel was widely available and automakers were to switch to green steel to construct BiWs starting in 2025, an additional ~38 Mt of CO_2e could be avoided by 2030, nearly matching the expected CO_2e emissions reductions from EPA's rule.

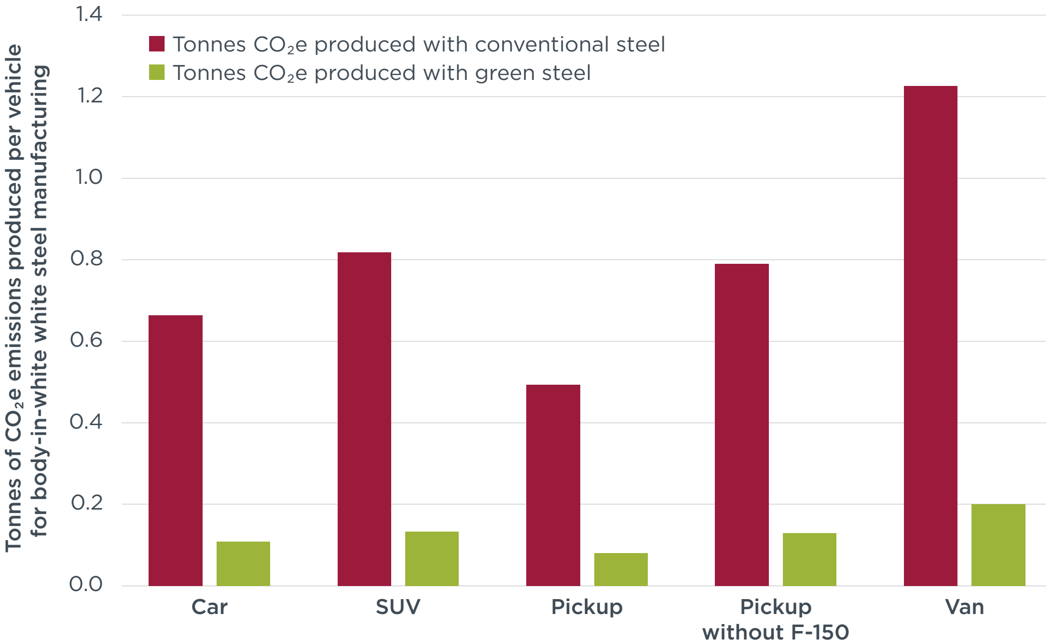
Figure 8 shows the per-vehicle BiW CO_2e emissions for different LDV classes when using either conventional steel or green steel. To estimate these results, we applied the carbon intensity of conventional and green steel to the total production-weighted steel content per vehicle, shown in Figure 5. Irrespective of the total amount of steel, substituting green steel leads to an 84% reduction in CO_2e emissions for each vehicle class. For vehicles with BiWs produced using conventional steel, CO_2e emissions range

3 There are likely relative differences in carbon intensities for different types of steel, but there is limited information to establish these specific differences.

from approximately 0.5–1.2 t CO_2e per vehicle. If automakers switched to green steel, emissions would be reduced to 0.08–0.2 t CO_2e per vehicle.

Figure 8

Per-vehicle body-in-white steel greenhouse gas emissions by vehicle class



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IMPACT OF GREEN STEEL ON BODY-IN-WHITE COSTS

To estimate the costs for automakers to substitute green steel in the manufacturing of LDV BiWs, we reviewed the literature investigating the cost of manufacturing green steel compared with conventional steel pathways and of announced green steel contracts. Table 1 presents the findings of this review. The table includes the source, the green steel cost compared with that of conventional BF-BOF steel, and any notes on the source or the underlying methodology.

Table 1

Sources informing the green steel cost assumptions used in this analysis

Source	Green steel cost findings	Notes
Assessment of Hydrogen Direct Reduction for Fossil-Free Steelmaking (Vogl et al., 2018)	€361–€640/t for H2-DRI-EAF versus €318/t for BF-BOF; 14% to 101% cost premium	Electricity prices range from €20–€100 Euro/MWh; 51 kg H_2/t steel
Industrial Transformation 2050: Pathways to Net-Zero Emissions From EU Heavy Industry (Material Economics, 2019)	€578–€645/t green steel via H2-DRI-EAF versus €547/t BF-BOF; ~6%–18% cost premium	Upper and bottom bounds are both H2-DRI-EAF with electricity cost of either €40/MWh or €60/MWh
Forging Ahead: A Materials Roadmap for the Zero-Carbon Car (World Economic Forum & McKinsey & Company, 2020)	$420–$450/t steel from H2-DRI-EAF versus $310–$320/t steel from BF-BOF in 2030; 31%–45% cost premium	Uses hydrogen cost of $22/GJ in 2030
Road Map to a US Hydrogen Economy (Fuel Cell & Hydrogen Energy Association, 2020)	$1270/ton for BF-BOF, 100% H2-DRI-EAF breakeven at $2.89/kg H_2; -26%–63% cost premium	H2-DRI-EAF ranges from $942/ton to $2066/ton for H_2 prices range from $0/kg to $10/kg
Net Zero Steel: Global Facility Level Net-Zero Steel Pathways (Bataille et al., 2021)	~$450/t steel from BF-BOF without carbon capture and storage in 2030 versus ~$530/t from H2-DRI-EAF in 2030; ~18% cost premium	Assumes no change in operating costs other than electricity
Steeling Demand: Mobilising Buyers to Bring Net-Zero Steel to Market Before 2030 (Energy Transitions Commission & Material Economics, 2021)	15%–40% cost premium to produce green steel	$35/MWh for hydrogen
ArcelorMittal CEO Says Decarbonization Would Drive Steel Prices up 10%-20% (ArcelorMittal CEO says," 2023)	10%–20% cost premium for green steel ($100–$200 price increase per car)	From remarks at World Trade Organization forum on decarbonization based on internal study
Forging a Clean Steel Economy in the United States (Gamage et al., 2023)[a]	$717/t for hot rolled coil from H2-DRI-EAF versus $678/t for BF-BOF without carbon capture and storage; ~6% cost premium	BF-BOF costs based on recent market highs for fossil-fuels; does not include production tax credit for hydrogen
The World's Largest Low-Carbon Steel Plant Moves Closer to Completion (St. John, 2023)	H2 Green Steel secured 20%–30% price premium for automakers' contracts	
Unlocking the First Wave of Breakthrough Steel Investments in the United States (Terry et al., 2023)	$635/ton green steel H2-DRI-EAF versus $647/ton historical hot-rolled coil (both 20-year levelized cost); ~2% cost saving	Includes $3/kg tax credit for hydrogen production
15 Insights on the Global Steel Transformation (Witecka et al., 2023)	$1492/t BF-BOF versus $1559/t–$1725/t from H2-DRI-EAF; 4%–16% cost premium	Converted 2010 capital expenditures to 2023 dollars; hydrogen prices range from $1.50/kg to $3.50/kg
The Roosevelt Project: Iron and Steel Decarbonization by 2050: An Opportunity for Workers and Communities (Foster et al., 2024)[a]	$529/t capacity and $395/t in variable costs for BF-BOF versus $808/t capacity and $707 in variable costs for H2-DRI-EAF	H2-DRI-EAF costs decrease by 66% when applying hydrogen tax credit
Green Steel Economics: Comparing Economics of Green H2-DRI and Conventional Steelmaking Around the World (Hasanbeigi et al., 2024)[a]	$543/t–$790/t for H2-DRI-EAF versus $563/t for BF-BOF; 4% cost saving to a 40% cost premium	Hydrogen prices range from $1/kg to $5/kg

[a] Values in these studies were used to estimate the green steel premium in 2024.

This literature review identified a wide range of green steel premiums over the cost of conventional steel, and in some cases found minor cost savings. The varied results reflect different assumptions concerning such factors as the per-unit cost to produce green hydrogen, the geographic region of steel production, the year of the cost projection, the amounts of scrap steel used alongside direct reduced iron in the electric arc furnace, and the inclusion of any policy interventions that might increase or decrease the cost of conventional and green steel.

To estimate the green steel premium used in our analysis, we selected a subset of the sources shown in Table 1 that were aligned with key variables in this study, including the region of production (United States), the percentage of scrap (0% scrap), and the impact of policy interventions (full production costs without any subsidies for green steel or penalties for conventional steel). We grouped these studies based on their projection year and used the average premium across the studies for each year. By taking the average of the premiums, rather than the absolute cost of green steel production in each study, we avoided potential minor differences in system boundaries between studies. Due to a limited number of studies projecting green steel costs for 2024, we estimated the green steel premium in 2024 by averaging findings from studies with cost projections between 2022 and 2024.

Based on this subset of studies, we estimated that the green steel premium without subsidies is approximately 42% higher than the cost of conventional steel. We found a similar premium when we averaged the findings for studies projecting green steel costs in 2030. However, we would expect that as renewable electricity becomes more widely available, hydrogen electrolyzer technology becomes more commercialized, and steel producers improve on initial green steel deployments, these costs would decrease (Navarrete & Zhou, 2024; Attwood, 2023).

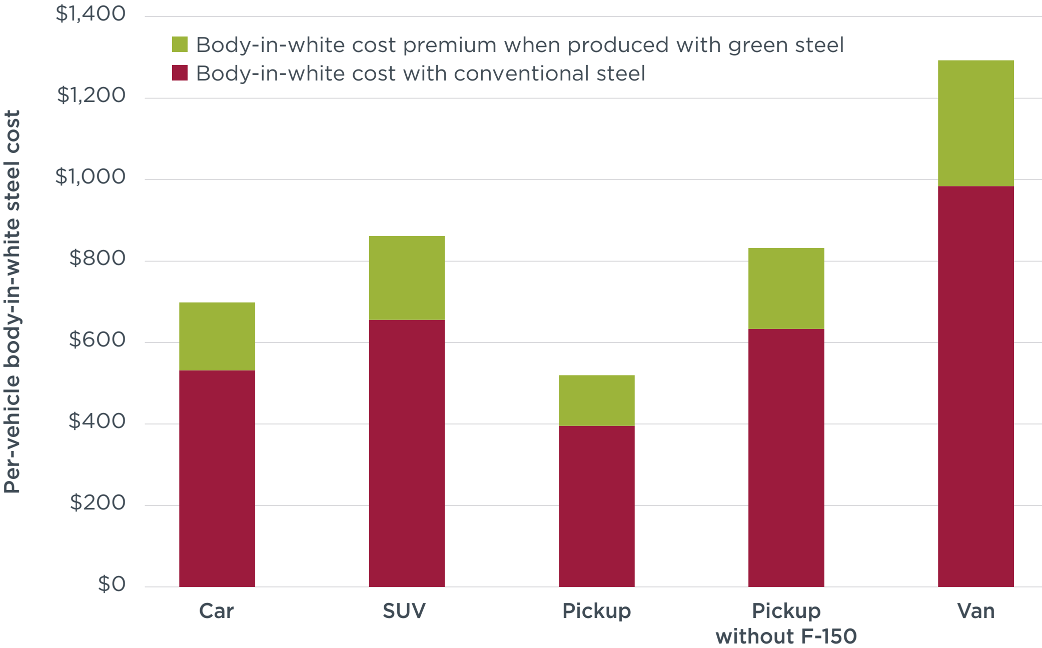
To estimate green steel costs, we applied the estimated 42% premium to the cost of conventional steel, assumed to be $1,560/t based on the cost of automaker steel from Cleveland-Cliffs Inc. (2023). Though there are likely to be different costs for steel with different strengths used in BiW manufacturing, data on these cost differences were unavailable. We then multiplied the assumed conventional steel cost by the tonnes of BiW steel demanded by each automaker to determine the total cost of conventional BiW steel for each automaker. For green BiW steel, we applied the 42% premium to 75% of the BiW steel cost for each automaker to account for only the primary steel being replaced with green steel. We divided the automaker BiW costs by the total number of vehicles each automaker produced to determine a per-vehicle cost of BiW steel for each automaker. Subtracting the per-vehicle costs of BiW steel using conventional steel from the per-vehicle cost of BiW steel using green steel for each automaker, and averaging this across the industry, we found an average cost premium per vehicle of $199, or a 0.66% premium over a $30,000 manufacturer suggested retail price (MSRP).

Our estimated average cost premium of $199 per vehicle is in line with estimated premiums of $100–$200 per vehicle from real-world green steel contracts (Bui et al., 2024). In aggregate, we estimate about $6.1 billion is spent annually on LDV BiW steel across the entire automotive industry, not including leftover scrap. With a 42% green steel premium to replace the primary steel, an additional $1.9 billion would need to be spent annually should the entire industry shift to green steel for LDV BiWs. These estimates represent the green steel cost premium in 2024 if green steel were available, and it is expected that the cost of green steel will fall over time, eventually reaching parity with conventional steel and perhaps offering savings as the prices of hydrogen and renewable electricity decrease (Hill et al., 2024). Ultimately, because LDV BiWs generally contain less than a tonne of steel per vehicle, the overall cost to substitute green steel is small, particularly compared with the overall price of the vehicle.

Figure 9 shows the per-vehicle cost of using conventional and green BiW steel by vehicle class. Per-vehicle green steel BiW cost premiums range from about $124 to nearly $310, depending on the vehicle class and the amount of steel contained in the BiW. For instance, the vehicle class with the highest BiW steel content, vans, also has the greatest cost premium. The pickup class is shown in the figure with and without the Ford F-150 to account for the low amount of steel used in this high-selling vehicle.

Figure 9

Per-vehicle body-in-white steel costs and green steel cost premium by vehicle class



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Because total vehicle costs tend to increase at a higher rate than the cost of green steel as vehicles increase in size, the BiW green steel premium does not necessarily make up a larger percentage of the MSRP for larger vehicle classes. Comparing the average January 2024 MSRP by vehicle class with our estimated BiW green steel cost premium, we find that cars have an average MSRP of $35,724 and a cost premium of $167 (0.47%), SUVs have an average MSRP of $43,616 and a cost premium of $206 (0.47%), and trucks have an average MSRP of $50,016 and a cost premium of $124 (0.25%) or $199 (0.4%), depending on whether or not F-150s are considered ("20 New Cars," 2024).

The Inflation Reduction Act of 2022 (IRA) provides tax credits to incentivize the production of green hydrogen and renewable electricity. The H2-DRI-EAF green steel production pathway, in its least carbon-intensive mode, uses renewable electricity to produce green hydrogen via electrolysis, which is then used to reduce iron ore for further processing into steel (World Steel Association, n.d.-b). Therefore, this pathway qualifies for both the clean hydrogen production tax credit and the renewable electricity production tax credit (Alternative Fuels Data Center, n.d.; U.S. Environmental Protection Agency, n.d.).

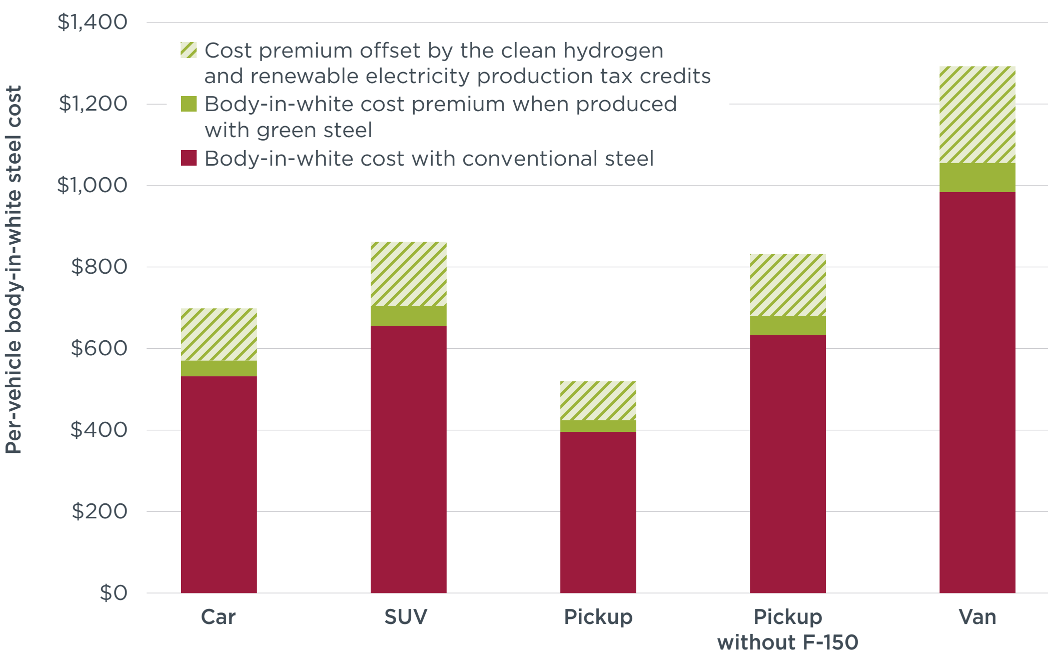
We thus also consider what the BiW green steel cost premium would be if steel producers were able to subsidize production costs by applying the IRA clean hydrogen and renewable electricity production tax credits. To do so, we multiplied estimates of the 10-year average cost savings per kilogram of hydrogen from Slowik et al. (2023)

by the concentration of hydrogen per tonne of steel in the H2-DRI-EAF production pathway. We then subtracted this from the cost per tonne of steel from each of the studies in our literature review to estimate the subsidized green steel premium across all the studies. For the studies that did not incorporate the tax credits, we estimate that green hydrogen costs in 2024 are approximately $5.29 per kilogram of hydrogen without the tax credits and $3.31 per kilogram of hydrogen with the tax credits over an 8-year period between 2024 and 2032, amounting to savings of $1.98 per kilogram of hydrogen (Slowik et al., 2023). It is estimated that approximately 54 kg of hydrogen are required per tonne of steel produced (Capra, 2023), which means the cost of green steel can be reduced by approximately $107 per tonne when the IRA tax credits are applied. Averaged across the studies, we find that applying the tax credits to the price of green hydrogen reduces the green steel premium by about 77%, from 42% to 10%. At 10%, the average BiW green steel cost premium per vehicle is $46, or 0.15% of a $30,000 MSRP, and the additional annual cost to produce green steel for LDV BiWs industry-wide falls from $1.9 billion to about $450 million.

Figure 10 shows the per-vehicle cost of BiW steel by vehicle class and the green steel cost premium when subsidized by the IRA clean hydrogen and renewable electricity production tax credits. Each bar shows the cost to construct the BiW with conventional steel, the additional cost to manufacture the BiW with green steel, and the amount of the green steel premium that is offset when applying the clean hydrogen and renewable electricity production tax credits.

Figure 10

Per-vehicle body-in-white steel costs and subsidized green steel cost premium by vehicle class



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By applying the clean hydrogen production tax credit, per-vehicle BiW green steel cost premiums would range from $29 to $72 depending on the vehicle class and amount of BiW steel contained in the vehicle. Again, comparing the average January 2024 MSRP by vehicle class with this subsidized green steel cost premium, we find that cars would have an average cost premium of $39 (0.11%) for a $35,724 MSRP, SUVs would have an average cost premium of $48 (0.11%) for a $43,616 MSRP, and trucks would have an average cost premium of $29 (0.06%) including F-150s or $46 (0.09%) excluding F-150s for a $50,016 MSRP ("20 New Cars," 2024). It is likely that continued learning, economies of scale, renewable electricity production, commercialization of hydrogen electrolyzers, and other technological advancements will further reduce green steel costs in the years ahead.

CONCLUSIONS

Based on our research into BiW automotive steel in the United States, we draw the following conclusions:

U.S. light-duty BiW automotive steel demand is about 3.9 million tonnes annually. This accounts only for the steel used in the BiW and does not include leftover BiW automotive steel that becomes scrap, steel that is used throughout the rest of the vehicle, or steel that is used to construct other vehicle types. If automakers switch to green steel, this 3.9 Mt demand could be met by two new, fully operational green steel facilities or two retrofitted existing steel facilities. Total U.S. automotive steel demand was estimated to be around 11 Mt in 2023, indicating the considerable decarbonization potential of substituting green steel throughout the automotive sector.

Automakers use a variety of steels with distinct strength characteristics to manufacture the BiW for LDVs. Of the 3.9 Mt of steel used in LDV BiWs in the United States in 2023, 36% (1.4 Mt) was mild steel, 21% (0.8 Mt) was high-strength steel, 17% (0.7 Mt) was ultra-high-strength steel, 15% (0.6 Mt) was advanced high-strength steel, and 10% (0.4 Mt) was GigaPascal steel. Not all vehicles contain every type of steel, so the distribution of the amounts and types of steels at different auto plants around the United States reflects which nameplates are manufactured and the overall production volumes in each facility.

Using green steel to manufacture the BiW for LDVs produced in the United States could save around 6.4 Mt of CO_2e annually. With about 3.9 Mt of steel demanded for LDV BiW manufacturing in the United States annually, assuming a carbon intensity of 1.945 t CO_2e per tonne of conventional BiW steel results in estimated GHG emissions of about 7.6 Mt CO_2e per year. Green BiW steel offers an 84% reduction in CO_2e emissions compared with conventional steel, with an estimated carbon intensity of 0.3175 t CO_2e per tonne of steel. At this carbon intensity, LDV BiW manufacturing in the United States using green steel would result in GHG emissions of 1.2 Mt annually, corresponding to 6.4 Mt of CO_2e emissions avoided per year. Assuming these emissions savings remain constant from 2025 through 2030, about 38 Mt of CO_2e could be avoided by substituting green steel for conventional steel to construct LDV BiWs. This amount of emissions reductions is comparable to the cumulative emissions reductions expected from EPA's multi-pollutant rule for light-duty and medium-duty vehicles through 2030.

Switching to green steel in the BiW would cost about $199 per vehicle on average, which would amount to an increase of about 0.66% in the MSRP of a $30,000 vehicle. Because LDV BiWs generally contain less than one tonne of steel, the cost premium of substituting green steel for conventional steel is low, particularly compared with the total price of a vehicle. Our cost estimate of green steel for the BiW is based on a literature review that found a 42% premium over the cost of conventional steel without accounting for subsidies or other policy levers to reduce costs. It is anticipated that green steel costs will decline over time as the prices of hydrogen and renewable electricity decrease and hydrogen electrolyzers are increasingly commercialized.

Tax credits in the IRA can significantly reduce the cost of green steel production in the United States. Green steel produced using green hydrogen via the H2-DRI-EAF pathway qualifies for the clean hydrogen production tax credit and the renewable electricity production tax credit under the IRA. Based on the average savings per tonne of green steel offered by these credits, the green steel cost premium over conventional steel can be reduced from 42% to 10%—which amounts to an average of $46 per vehicle when green steel is substituted in LDV BiWs.

Steel used in LDV BiWs represents a significant share of automotive steel demand in the United States. The findings of this analysis suggest considerable potential for substituting conventional steel with green steel outside of the BiW, but more research would be required to determine the quantities of steel and the costs that this would entail. Future research could also assess the opportunities for and costs of substituting green steel in other segments, such as medium- and heavy-duty vehicles, as well as the prospects for greener alternatives to non-steel components.

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APPENDIX

Table A1 lists all the auto manufacturing plants in the United States. It provides a summary of the BiW steel demand by type at each plant, as well as the estimated annual vehicle production volume and a list of the vehicle models produced. This table supplements Figure 6 and provides the underlying quantitative findings used to produce the map.

Table A1

Body-in-white steel demand by steel type, vehicle production volume, and models produced for vehicle manufacturers in the United States

OEM	City	State	Total BiW steel demand (kt)	% Mild	% UHSS	% AHSS	% HSS	% GPa	Production volume	Models
BMW	Greer	SC	122	27%	34%	8%	27%	4%	311,978	X3, X4, X5, X6, X7, XM
Ford	Chicago	IL	115	40%	0%	13%	10%	36%	238,658	Explorer, Lincoln Aviator
Ford	Dearborn	MI	5	0%	0%	11%	89%	0%	324,995	F150, F150 Lightning
Ford	Flat Rock	MI	18	20%	23%	19%	14%	23%	61,165	Mustang
Ford	Kansas City	MO	120	66%	0%	23%	6%	5%	462,381	Transit, F150
Ford	Louisville	KY	11	20%	0%	10%	70%	1%	384,029	Super Duty, Expedition, Lincoln Navigator
Ford	Louisville	KY	86	45%	27%	3%	0%	25%	194,018	Escape, Lincoln Corsair
Ford	Wayne	MI	52	26%	0%	44%	16%	14%	157,735	Bronco, Ranger
Ford	Sheffield	OH	34	90%	0%	1%	6%	3%	74,951	E-series, Super Duty
Geely	Ridgeville	SC	9	45%	23%	2%	30%	0%	22,531	60 Series
GM	Arlington	TX	156	16%	12%	41%	23%	7%	346,077	Escalade, Escalade ESV, Suburban, Tahoe, Yukon, Yukon XL
GM	Bowling Green	KY	0						41,499	Corvette Stingray
GM	Detroit	MI	13	7%	26%	17%	41%	9%	28,292	Silverado EV, Hummer EV
GM	Kansas City	KS	66	44%	17%	6%	29%	3%	153,856	Malibu, XT4
GM	Flint	MI	112	40%	9%	14%	36%	1%	217,752	Silverado, Sierra
GM	Roanoke	IN	135	40%	10%	13%	36%	1%	267,828	Silverado, Sierra
GM	Lansing	MI	98	42%	27%	7%	14%	10%	182,321	Enclave, Traverse
GM	Lansing	MI	22	41%	2%	32%	6%	19%	62,897	CT4, CT5, Camaro
GM	Lake Orion	MI	35	39%	39%	11%	8%	3%	77,359	Bolt EV/EUV
GM	Spring Hill	TN	76	31%	28%	9%	30%	1%	150,428	Lyriq, XT5, XT6, Acadia
GM	Wentzville	MO	84	65%	3%	2%	23%	7%	167,646	Colorado, Express, Canyon, Savana
Honda	East Liberty	OH	90	33%	29%	8%	11%	19%	207,022	MDX, RDX, CR-V
Honda	Greensburg	IN	89	26%	31%	16%	8%	20%	234,250	Civic, CR-V
Honda	Lincoln	AL	145	37%	26%	10%	13%	14%	306,787	Odyssey, Passport, Pilot, Ridgeline
Honda	Marysville	OH	100	10%	39%	14%	25%	13%	270,203	Integra, TLX, Accord
Hyundai	Montgomery	AL	171	12%	21%	17%	43%	7%	369,000	Elantra, GV70, Santa Cruz, Santa Fe, Tucson
Hyundai	West Point	GA	173	38%	29%	13%	20%	0%	356,807	K5/Optima, Sorento, Sportage, Telluride
Lucid	Casa Grande	AZ	0						8,428	Lucid Air
Mazda	Madison	AL	70	32%	22%	4%	23%	19%	154,500	CX-50, Corolla Cross
Mercedes-Benz	Ladson	SC	38	98%	0%	2%	0%	0%	47,287	Metris, Sprinter, eSprinter
Mercedes-Benz	Vance	AL	134	39%	36%	17%	7%	1%	294,677	EQE, EQS, GLS, GLE, GLE Coupe
Nissan	Canton	MS	105	53%	6%	25%	13%	3%	283,034	Altima, Frontier, Titan
Nissan	Smyrna	TN	162	30%	28%	17%	13%	12%	359,076	Leaf, Maxima, QX60, Murano, Pathfinder, Rogue
Rivian	Normal	IL	23	17%	31%	21%	27%	4%	57,235	EDV, R1S, R1T
Stellantis	Belvidere	IL	6	30%	22%	33%	16%	0%	11,901	Cherokee
Stellantis	Detroit	MI	116	34%	16%	16%	34%	0%	239,275	Durango, Grand Cherokee
Stellantis	Detroit	MI	81	32%	12%	14%	42%	0%	179,454	Grand Cherokee
Stellantis	Sterling Heights	MI	115	54%	3%	7%	26%	9%	306,078	Ram pickup
Stellantis	Toledo	OH	74	50%	0%	2%	40%	7%	205,496	Jeep Wrangler
Stellantis	Toledo	OH	20	53%	0%	24%	8%	15%	63,951	Jeep Gladiator
Stellantis	Warren	MI	51	44%	2%	23%	19%	12%	124,602	Grand Wagoneer/Wagoneer
Subaru	Lafayette	IN	173	43%	11%	25%	13%	8%	350,820	Impreza, Crosstrek, Legacy, Ascent, Outback
Tesla	Austin	TX	27	25%	23%	0%	0%	52%	157,373	Cybertruck, Model Y
Tesla	Fremont	CA	72	44%	37%	2%	0%	18%	457,062	Model 3, Model S, Model X, Model Y
Toyota	Blue Springs	MS	58	25%	0%	33%	29%	14%	156,219	Corolla
Toyota	Georgetown	KY	152	24%	5%	23%	29%	19%	389,099	ES 300h ES 350, Camry, RAV4
Toyota	Princeton	IN	172	26%	24%	9%	21%	21%	363,060	Lexus TX, Grand Highlander, Highlander, Sienna
Toyota	San Antonio	TX	56	9%	12%	24%	48%	7%	181,812	Sequoia, Tundra
VW	Chattanooga	TN	87	36%	6%	18%	14%	27%	174,024	Atlas, ID4
TOTAL			3,927	36%	17%	15%	21%	10%	10,236,928	

Notes: Values in the table are a combination of data from S&P Global Mobility, "AutoTechInsight; BiW Forecast April 2024," and Automotive News Research & Data Center (2023).

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