The federal government regulates fuel economy and greenhouse gas (GHG) emissions associated with the operation of passenger cars and light trucks. To meet increasingly stringent targets, automakers are implementing new technology in various areas of the vehicle including: improved powertrain systems, increased aerodynamics, reduced rolling resistance and reduced curb weight. The steel industry has worked collaboratively with automakers to help with vehicle lightweighting while achieving the same high vehicle performance and value for the consumers. Lightweighting with steel is possible because of new advanced high-strength steel (AHSS) grades replacing lower strength grades. This higher strength allows for less material (thickness of the sheet metal) to be used to achieve the same or improved performance. The focus on fuel economy and tailpipe emissions only, combined with the significant tightening of these standards is pushing automakers to alternate, high cost materials for incrementally small gains in meeting the standards.

Figure 1 shows a comparison of body structural materials by their relative mass reduction potential and compares this with GHG emissions for material production. This simple comparison raises the question of whether or not replacing steel is the best answer for the environment. To fully evaluate this hypothesis, the Steel Recycling Institute (SRI), a business unit of the American Iron and Steel Institute (AISI), conducted a comprehensive study to assess the total environmental impact of vehicles lightweighted with AHSS and aluminum. The study assesses the GHG emissions and energy consumption associated with the entire life cycle of a vehicle; comprising the vehicle production phase (including materials production), use (driving) phase, and end-of-life phase.

The University of California Santa Barbara Automotive Materials Comparison Model (UCSB Model v5), a peer-reviewed, publicly available model, was used in this study to assess several average MY 2016 vehicle types with different powertrain systems, including a:

- Mid-size sedan with a gasoline internal combustion engine (ICEV-G);
- Sport utility vehicle (ICEV-G);
- Pick-up truck (ICEV-G);
- Mid-size hybrid electric vehicle (HEV); and,
- Compact battery electric vehicle (BEV).
The baseline vehicles were each redesigned separately with aluminum and AHSS to reduce the overall weight of the vehicle while achieving the same general performance. Life cycle GHG emissions total and by individual phase were determined for each vehicle. An example of the model outputs is shown in Figure 2 for the SUV (ICEV-G). As expected by the simple comparison above, the materials production phase shows lightweighting with AHSS clearly has the lowest GHG emissions. Also, as expected, in the use phase with all else equivalent on a vehicle (in other words only changing body and closure mass), the aluminum contender vehicle shows slightly lower emissions, or the equivalent of 0.8 percent or 0.26 mpg increase in fuel economy. Finally in the end-of-life, credits are given to all materials because metals are melted again and put back into use, again aluminum is given a larger credit because it is so energy intensive to produce the primary metal. In total, however, the large increase in the production emissions for aluminum in the first phase of a vehicle’s life is often never fully recovered at the end of life. In fact, the best case scenarios for aluminum shows it breaks even with AHSS, as shown in Figure 3.
Following completion, the study was subjected to a thorough and independent critical review by a panel of automotive life cycle assessment (LCA) experts from Harvard University, Massachusetts Institute of Technology, Argonne National Laboratory, and thinkstep (an LCA consultant). The panel verified the study conforms to the applicable ISO standards for comparative LCAs, thus giving it a third party validation as a scientifically based study.

The details of the study’s methodology, assumptions, results, and multiple sensitivity and uncertainty analyses can be found in the full report, but the key findings and basic conclusions are:

1. Lightweighting with AHSS resulted in equivalent or lower life cycle GHG emissions than the same vehicle lightweighted with aluminum in every instance.

2. The use of aluminum instead of AHSS for lightweighting resulted in a significant increase in materials production GHG emissions and energy consumption for every scenario considered. These emissions occur at the start of (and remain in the atmosphere throughout) the vehicle life cycle.
   - The increase in production emissions ranged from 30 - 60 percent for sedans, pickups, SUVs and HEVs when using aluminum over AHSS for lightweighting.

3. The dramatic increase in production emissions for vehicles lightweighted with aluminum over AHSS is not offset by emission reduction benefits during the use phase until at least the end of the vehicle’s useful lifetime, and in several cases they are never offset.
   - In the SUV example, the difference in life cycle GHG emissions ranged from no difference between the two vehicles to 6 percent higher life cycle emissions for the aluminum vehicle.

4. In some cases, the aluminum vehicles had higher life cycle GHG emissions than even the original (pre-lightweighting) baseline vehicles. In these cases, when focusing only on GHG emissions, it would be better to not lightweight at all than to lightweight with aluminum.

5. To address uncertainty and values used in other studies or industries, Monte Carlo simulations were used to test an expanded range of inputs for several key variables. Even when inputs more favorable to the aluminum vehicles were included, the AHSS vehicles had lower life cycle GHG emissions than the aluminum vehicles in at least 90 percent of the cases.

6. Primary aluminum sourcing has a significant effect on the aluminum vehicle GHG profile.
   - Over the last several years, imports of primary aluminum into North America have increased significantly, reaching 42 percent in 2016.

So what do the results of this study mean in the real world? What does a kg of CO₂ emissions implicate? The model calculates the difference in emissions per vehicle. When this number is multiplied by the number of vehicles produced in a given year of the vehicle type, the amount of GHG emissions becomes significant and representative of the real impact to the environment each year.

- Figure 4 shows lightweighting five 2016 vehicle fleets with AHSS vs. aluminum would result in 12 million tons lower GHG emissions over their lifetime. This is equivalent to the GHGs emitted from the annual electricity production for 1.6 million homes.

- Other equivalents for 12 million tons of CO₂ emissions include:
  - 1.2 billion gallons of gasoline consumed;
  - 26.7 billion miles driven by an average passenger vehicle;
  - 2,757 wind turbines running for an entire year; or,
  - 12.8 million acres of U.S. forests to sequester the CO₂.
What this means for the environment is producing steel still has the lowest greenhouse gas emissions compared to other materials making it the environmentally sound choice for automakers. What this means for the consumer is total cost of ownership, including purchase price, insurance and repair are lower for steel-intensive vehicles than vehicles made from alternative materials.

Figure 4 - Infographic showing the equivalent CO₂ emissions of lightweighting six million vehicles with aluminum instead AHSS.

12 million tons = 1.6 million homes