Automotive LCA Case Studies

2009

WorldAutoSteel has released a 2^{nd} iteration of the automotive materials parametric Life Cycle Assessment (LCA) model, which allows for broader evaluations of automotive materials, powertrains, fuels and vehicle total energy consumed. Automakers can now evaluate more comprehensively material selections decisions and their affect on green house gas emissions, with additional options for materials, emerging powertrains and fuel sources. The Phase 2 model was developed under the leadership of Dr. Roland Geyer of the University of California's Bren School for Environmental Science.

The LCA approach assists automakers in evaluating and reducing the total energy consumed and the lifetime GHG emissions of their products. Regulations that consider only the vehicle use phase, or tailpipe emissions, can encourage use of low-density, GHG-intensive materials that provide somewhat lighter weight components. However, this may have the unexpected result of increasing GHG emissions during the vehicle's total life cycle. Thus, the Phase 2 model calculates environmental impacts from vehicle life cycles in three distinct parts, which are:

1. Automotive material production and finishing
2. Vehicle use
3. Scrap use and generation by the vehicle life cycle

WorldAutoSteel - LCA Automotive Case Studies were recently developed using the Phase 2 UCSB Green House Gas Comparison Model to demonstrate the effects of changing body structure materials, powertrains and fuel sources on life cycle emissions. These are real engineering considerations in today's climate challenged world. The alternative lightweight materials covered by the model are Advanced High-Strength Steel (AHSS), aluminium, fibre reinforced composites, and magnesium. The replacement coefficients of these materials relative to mild steel denote the amount of lightweight material required to replace the removed mild steel (in kg lightweight material / kg mild steel). AHSS, aluminium sheet, and sheet molding composite (SMC) were selected for these case studies.

The Phase 2 model is highly parameterized, requiring significant amounts of data from the end-user. The typical variables manipulated during these studies:

- **Vehicle Size (class):** the model allows for three default settings: compact, 5-passenger C-class vehicle; mid-size, D-class vehicle; and large SUV. In keeping with automotive trends and past automotive emissions studies, we selected a compact C-class vehicle, largely modeled after the VW golf in size and weight for the purpose of this case study.

- **Body-in-white mass (without closures):** Today's engineering mass reduction is targeted at the vehicle body structure, or body-in-white. The Phase 2 model is constructed to allow for a certain percentage of mild steel removed from the body structure and replaced with the alternative materials being evaluated. There are default settings which allocate a certain mass reduction coefficient to each material substituted for conventional mild steel, and this determines the total mass reduction for the body structure. The coefficients can be altered, along with the BIW mass default settings.

- **Secondary mass reduction savings:** Papers and modeling have shown a range of values for secondary mass savings, which is the amount of additional savings attributed to taking primary weight out of the vehicle. In our case studies, we follow a default setting of 30% additional savings due to body structure mass reduction efforts.

- **Vehicle Life:** To evaluate lifetime vehicle emissions, we must allocate a certain life for the vehicle, in terms of driving distance. In all WorldAutoSteel case studies, we assign a vehicle life of 200,000 km, which is an industry standard vehicle lifetime expectation.

- **Power train selection:** Modeling capability now includes gasoline- and diesel-based pure internal combustion engine vehicles (ICEV-G and ICEV-D), gasoline-based hybrid electric vehicles (HEV), and fuel cell vehicles (FCV). The power train choice impacts mass and fuel economy of the baseline vehicle, as well as the fuel energy savings per mass savings, i.e. the relationship between mass reduction and fuel economy improvement.

  Note: the mass of the benchmark vehicle depends not only on the size of the vehicle, but also on the selected power train type. Vehicle size and powertrain selection ultimately determine the curb weight assigned to the vehicle.

- **Powertrain re-sizing:** The engine size of the mass-reduced vehicles may be assigned the same as that of the benchmark vehicle, or may be reduced to match the acceleration of the baseline vehicle, i.e. to achieve comparable performance to the benchmark. In all cases, we assign the option of powertrain re-sizing to further achieve reduced emissions.

- **Driving cycle simulation:** there are many driving cycles which are available to modeling, but two are consistently benchmarked: the Hyzem driving cycle and the New European Driving Cycle (NEDC). The latter mixes urban and rural driving in a challenging pattern, and has been selected for these case studies.

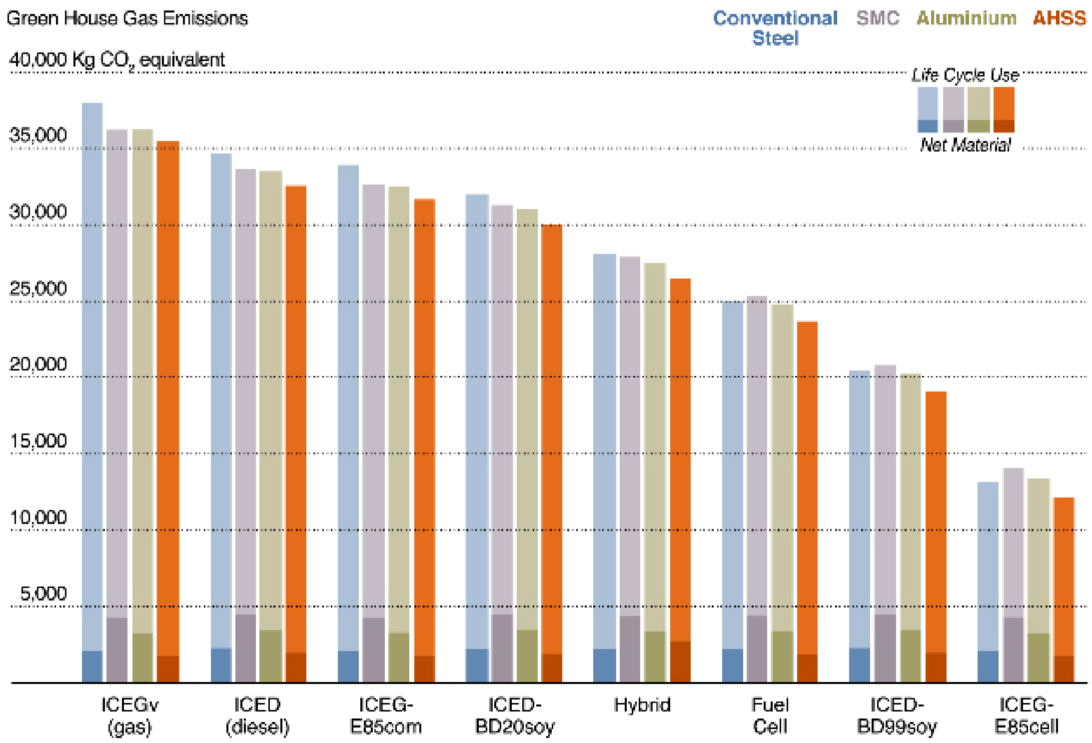
- **Fuel Source:** The last step in variable input selection is to further specify the fuel used by the chosen powertrain. Currently, the only fuel characteristics that can be varied are biofuel content and fuel crop, in the case that a gasoline/bioethanol or diesel/biodiesel blend is used. We specify the volumetric biofuel content of the used fuel blend, which can be anywhere between 0% and 100%.

Results of these inputs

In selecting materials for automotive vehicle mass reduction, life cycle assessment (LCA) methodologies should be incorporated to assess the full impact of these materials decisions, and the Geyer Phase 2 model allows such comparisons, summarized in Figure 1, Page 2. When we compare AHSS, aluminium and SMC, we observe that material production emissions create a life cycle disadvantage for the low density materials, one that cannot be erased during the vehicle use phase or with recycling credits. This is true because new AHSS products have narrowed the gap in mass reduction potential compared to alternative low-density body structure materials candidates.

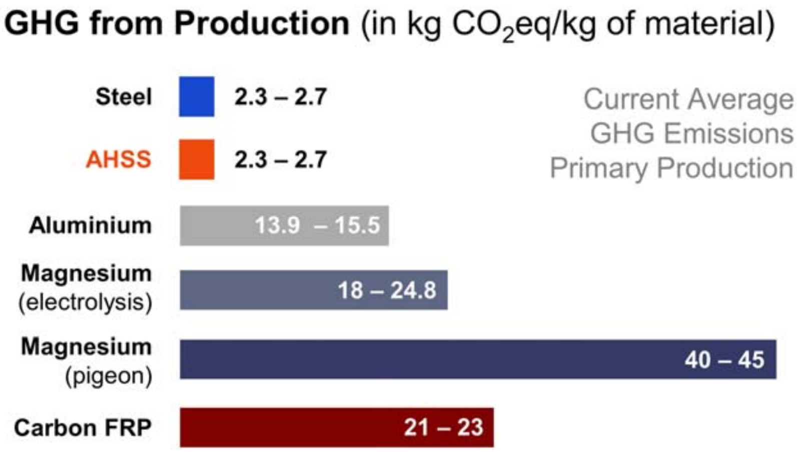
As we explore advanced powertrains and fuel sources (move to the right in our summary figure), total life cycle emissions decrease, meaning material production emissions contribute a greater percentage to the whole. Thus as these technologies are implemented in mainstream vehicle designs, the emissions from material production becomes relatively more important in the total life cycle. This figure also clearly shows that significant improvements in reducing automotive GHG emissions will not be made by material substitution alone, however. Investment in new powertrains and fuels contribute to the greatest reductions in vehicle emissions, and may represent the best investment opportunity for the automotive engineering community.

Figure 1: Life Cycle GHG's, Varying By Materials, Powertrains and Fuel Sources



Conclusion

Figure 2: Material production GHG emissions



Materials that compete with AHSS for automotive light-weighting are costly to the environment. This is especially important, since many of the most harmful gasses are present in the production of competitive materials. For example, aluminium, contributes high levels of perfluorocarbons, and magnesium is responsible for the emission of sulfur hexafluoride. GHG emissions from steel production **consist of only carbon dioxide**. Figure 2 below illustrates the drastically different levels of GHG emissions from the material production stage of competing automotive materials. Please notice that all of the GHG data is shown in Carbon Dioxide Equivalents (CO_2eq), which includes carbon dioxide plus the carbon dioxide equivalent of other emissions such as PFCs.

Material production for alternative material vehicles will load the environment with significantly more GHG emissions than that of a steel vehicle and these override any benefits that may be gained through fuel efficiency improvements.

LCA captures these environmental costs, and thus **is the responsible approach to measuring environmental impact over a vehicle's lifetime, and implementing effective, global solutions**.