## F. Additional Comments to the World Steel Association/WorldAutoSteel Contribution to 'Consultation on reducing $CO_2$ emissions from road vehicles'

### Towards an LCA-based automotive GHG Regulation

This paper contains thorough explanations of the meaning of a Life Cycle Assessment (LCA) approach to vehicle emissions and addresses the feasibility of Life-cycle-based automotive GHG regulations. The US is currently addressing this issue in the process of regulating $CO_2$ emissions from cars and light duty vehicles over the period 2017-2025. Some of these developments, alongside relevant case studies that back scientifically the importance of LCA for effectively reducing environmental impacts in the car industry, are described below. This data could prove useful for the European Commission ahead of the mid-term review of Regulation 443/2009 on emission performance standards for new passenger cars. The paper is, at the same time, providing further comments on questions B3, B4, C1, E3 and E4 of the Commission's consultation document.

### I. What is LCA

Climate change concerns have placed a focus on reduction of $CO_2$ emissions associated with vehicles resulting in regulations addressing driving phase greenhouse gas (GHG) emissions. However, a vehicle's carbon footprint is more than the driving phase or tailpipe emissions. All phases of a vehicle's life need to be considered.

Regulations that address the fuel cycle already exist in the world or are under consideration and comprehend the emissions associated with fuel production and use only. For example, a battery electric or fuel cell vehicle has no tailpipe GHG emissions, but there are GHG emissions associated with production of electricity to charge the batteries and hydrogen for the fuel cells.

In the same way, it is necessary to also consider the emissions associated with the vehicle manufacturing stage, materials production and end-of-life recycling or disposal. Looking at all of the vehicle's attributes that contribute to its carbon footprint is accomplished with a life cycle assessment (LCA) methodology.

LCA is a technique compiling an inventory of relevant inputs and outputs of a product system, evaluating the potential environmental impacts associated with those inputs and outputs, and interpreting the results of the inventory and impact phases in relation to the goal and scope of a study. It is not just vehicle use that causes GHG emissions, but all of its life cycle stages, from material production and vehicle manufacturing, fuel production to vehicle end-of-life management.

Emissions associated with materials production is important to consider because there is order of magnitude emission differences in the $CO_2$ equivalent ($CO_2e$)[i] emissions associated with the production of the structural materials considered for lightweighting vehicles.

An LCA approach therefore assists automakers in evaluating and reducing the total energy consumed and the life cycle GHG emissions of their products. If only the vehicle use phase, or tailpipe, emissions are considered, it can encourage use of low-density; GHG-intensive materials that may, in some applications, provide lighter weight components that improve fuel economy and tailpipe emissions. However, this may have the unintended consequence of increasing GHG emissions during the vehicle's total life cycle.

A proper assessment encompasses the entire vehicle life including the fuels that power it and the materials from which it is made.

## II. Scientific proof for the relevance of LCA in the automotive industry

Several recent studies illustrate the need for and the usability of an LCA approach to measure $CO_2$ emissions from cars.

Table 1 shows the results of three independent studies on driving phase emissions and demonstrates that:

- Current Vehicle $CO_2$ emissions are dominated by the driving phase at 85 to 90%.
- Looking to the future, many technologies that reduce driving phase emissions will increase emissions associated with vehicle manufacturing.

***Table 1: Study Results on Driving Phase Emissions***

| **Studies on Vehicle LCA** | | **% Driving Phase Emissions** | |
|---|---|---|---|
| | | **Current Vehicle** | **Future Vehicle** |
| Mercedes Vehicle: ISO-Environmental Certificate[ii] | C-Class-ICE | 87% | |
| | S-Class-ICE | 86% | |
| Toyota Data (June 2011) | ICE | 71% | |
| | PHEV-20 | | 59% |
| | EV-40 | | 54% |
| Low Carbon Vehicle Partnership UK (LCVP) Ricardo Study (May 2011)[iii] | ICE | 75% | |
| | Extended Range EV | | 62% |
| | EV | | 40% |
| University of California at Davis, Kendall, et al. 2011[iv] | HEV (Ferrous Intensive) | 85% | |
| | HEV (Magnesium & Aluminium Intensive) | | 70% |
| University of California at Santa Barbara, Geyer et al. (2011) study on Sun to Wheels energy[v] | Gasoline ICE | 85% | |
| | Switch EthOH Ice | | 50% |
| | Switch Electric BEV | | 20% |
| | CdTEPV + BEV | | 10% |

The current view is that the driving phase dominates the $CO_2$e emissions for vehicles, representing 85 to 90% of a vehicle's carbon footprint, and therefore, regulating other phases of a vehicle's life is not warranted. This is an accurate assessment for ***current vehicles*** since they:

1. Use carbon intensive fuels (petroleum) and thermally inefficient powertrains (internal combustion engines with <35% efficiency) that result in large driving phase emissions.
2. Are comprised mainly of low carbon intensive materials (65% steel and iron) that result in low manufacturing emissions. (source: Ducker Worldwide GDIS 2011)[vi]

These studies demonstrate that technologies focused at reducing driving phase emissions will change this paradigm because such technologies:

1. Use low carbon intensive fuels (ethanol and clean electricity) and efficient powertrains (electric motors with >90% efficiency) that reduce emissions associated with the driving phase.

2. May use carbon intensive materials such as Li-ion batteries for energy storage and carbon intensive lightweighting materials such as aluminum, magnesium, and carbon fiber that will increase the emissions associated with manufacturing considerably.

Life Cycle Assessment is required to ensure that technology decisions made to achieve lightweighting goals are adequately compensated by driving phase emissions reductions, such that the net result is lower ***total lifetime emissions***.

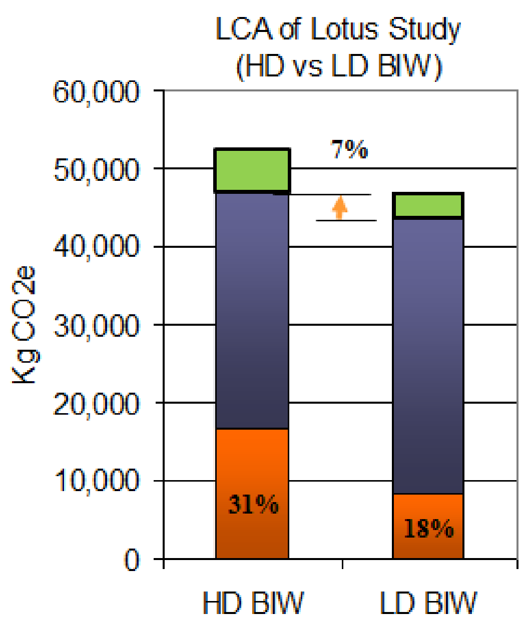
To illustrate this point, a Life Cycle Assessment is conducted on the subject vehicles of a 2010 Lotus Engineering Inc. study[vii], a Toyota Venza (similar to a Toyota Verso). This study was prepared for the International Council on Clean Transportation. It considers two vehicle scenarios:

a) A Low Development (LD) body structure dominated by high strength steel

b) A High Development (HD) body structure dominated by magnesium and aluminum that is 104kg lighter than the LD body structure.

This study predicts that the lighter weight HD body improves fuel economy and tailpipe emissions by 6 percent (Figure 1). However, the high GHG emissions associated with the manufacturing of magnesium and aluminum in the HD body are not offset with the saving in the driving phase, resulting in the HD scenario having 7 percent higher life cycle emissions than the LD scenario.

Figure 1 following shows the results of a study comparing different production materials for a specific car body and their GHG reduction potential.




| Vehicle Description | Curb Wt | GHG Emissions ($CO_2e$) Production | Use | Recycling | Total Veh Life |
|---|---|---|---|---|---|
| Lotus HD Body | 1214 kg | 16,524 | 36,288 | (5,508) | 47,304 |
| Lotus LD Body | 1324 kg | 8,428 | 38,556 | (3078) | 43,902 |

***Figure 1: Lotus Engineering - Toyota Venza/Toyota Verso Mass Reduction Study.***
***UCSB GHG Materials Comparison Model[viii] Life Cycle Emissions of LD and HD Vehicle Concepts***

The results show that the use of ultra lightweight materials does not provide a reduction in the total GHG emission when all stages of the life of a vehicle are taken into account.

There are many stakeholders that highlight the importance of LCA. Mercedes issues environmental certificates in accordance with ISO-standards for new vehicles that make use of LCA calculations. Ford has begun to work with suppliers on requiring carbon footprint data as a requirement of its suppliers.

Volkswagen also issue Environmental Commendations which are based on ISO conformant LCA studies and cover not only the service life of the vehicle i.e. the time it actually spends on the road, but its entire life cycle from production through use to disposal.

The U.S. Automotive Industry Action Group (A IAG) is developing carbon footprinting requirements in the automotive industry as part of its supply chain objectives. Automakers, as a matter of course, push their own requirements down the supply chain to all those contributing to the vehicle manufacturing mix. In a regulation environment that includes a life cycle assessment approach would instill the entire supply chain to evaluate their products' life cycle emissions.

In addition, several organizations are starting to promote the LCA approach. The World Resources Institute (WRI) has written a standard[ix] for product-based carbon footprinting. The automotive consultancy Ricardo issued a recent study[iii], conducted for the U.K.'s Low Carbon Vehicle Partnership, describing the importance of LCA in determining total vehicle emissions. The United Nations Environmental Program (UNEP) is developing a global standard for product life cycle assessment.

The growing number of scientific studies indicates that LCA is becoming acknowledged as the holistic approach for evaluating a product's impact on the environment, including vehicles.

While LCA may not be necessary for today's vehicles to avoid unintended consequences, the direction of future regulations will make it imperative in order to comply with the **intent** of the regulation.

### III. Towards an LCA regulatory approach

Life-cycle-based automotive GHG regulation is perfectly feasible and can be achieved by amending rather than replacing current standards. The following is a proposed framework for an LCA regulatory approach (Figure 2).

**• Driving Phase Emissions only (current regulations)**

Equation 1) $$\frac{gCO_2e}{km} = \left(\frac{1}{\text{lifetime km}}\right) x \left(gCO_2\ (use)\right)$$

**• Proposed approach to extend the current methodology to include LCA**

Equation 2) $$\frac{gCO_2e}{km} = \left(\frac{1}{\text{lifetime km}}\right) x \left(gCO_2e\ (prod) + gCO_2e\ (use) + gCO_2e\ (EOL)\right)$$

***Figure 2: An approach to incorporating LCA in vehicle emission regulations, referencing UC Davis Kendall study[iv]***

The current regulatory approach is to measure the $CO_2$ emissions at the tailpipe, which only addresses the driving phase of the vehicle, and is represented by equation 1 with the total tailpipe emissions divided by the total kilometers driven over its life.

This approach can readily be extended to total life cycle emissions by including the emissions associated with manufacturing and end of life as shown in equation 2. Under this proposed approach, the current $gCO_2$ /km environmental metric can be extended from the driving only phase to the entire LCA of the vehicle.

Figure 3 below illustrates this calculation for two compact class vehicles with different material compositions.

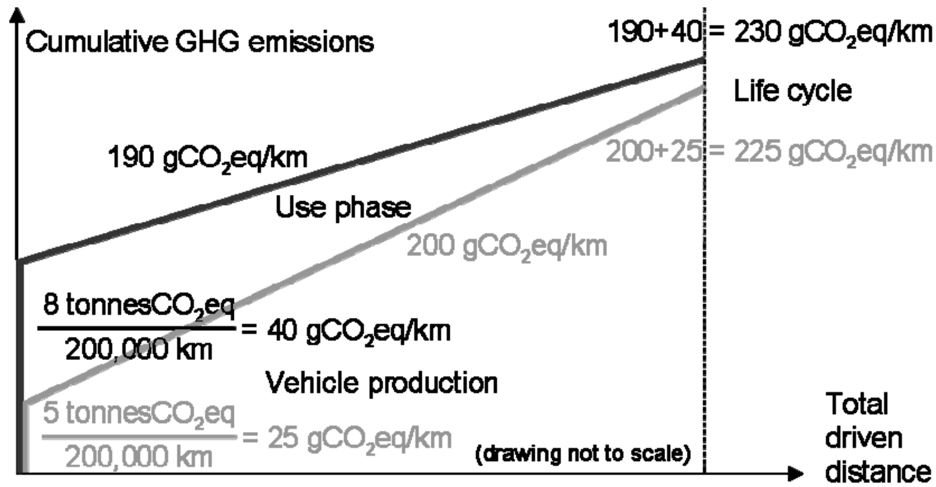



***Figure 3: LCA GHG emissions calculation (recycling calculated as a part of vehicle production emissions (Source: Dr. Roland Geyer, University of California-Santa Barbara, used by permission)***

An automotive life cycle GHG emission standard accounts for the joint emissions from fuel combustion, fuel production, and vehicle production.

- Fuel production emissions need to be included so that driving fuel cell or battery electric vehicles do not appear emission free, even though hydrogen and electricity production can be fairly GHG-intensive.
- Emissions from vehicle production need to be measured by science-based rules. A good starting point is to multiply the material composition of a vehicle, which is readily available, with the GHG intensity of each material. This would cover the majority of vehicle production emissions. Dividing the emissions from vehicle production by total driven distance yields a measure in grams of $CO_2$equivalent per km ($CO_2$e/km) and can be readily added to the fuel cycle measure ( as figure shows).

This example shows that automotive life cycle GHG emission standards are feasible and will benefit the climate.

**IV. The US case and other examples**

The main task of accounting for vehicle production is to avoid unintended consequences as the ones mentioned earlier.

In the U.S., for example, the emissions associated with manufacturing and end of life can be obtained from the Bill of Materials (BOM) that is developed with every vehicle. The BOM can be translated into equivalent emissions by using life cycle inventory (LCI) databases, such the Argonne National Lab GREET model[x] or PE International's GaBi Software and LCI database[xi].The use of the BOM addresses the concern or need to track and define the manufacturing emissions on a part by part and supplier by supplier basis. This approach will allow the vast majority of manufacturing emissions to be accounted for with data already available. The use of an established LCI database, such as GaBi provides a standard reference point for materials related emissions. A vehicle's total miles driven can be obtained from sources such as the Oak Ridge National Lab "Transportation Energy Data Book" published annually.

An example of applying this approach is conducted on the Mercedes C-Class using the data available in the C-Class Environmental Certificate[ii]. Figure 3-1 of the report describes the Bill of Materials (BOM) for the car, which is used to calculate the production $CO_2e$ emission of 6.4 tones/vehicle and the recycling emissions of 0.3 tonnes/vehicle with material LCI data obtained from the GaBi database[xii] as shown in Figure 4-2 of the Certificate.

Mercedes assigns a total lifetime driving distance of 200,000 km applicable to European vehicles. Continuing with the example of the C-Class Mercedes (refer to Figure 4), a $CO_2e$ value is calculated for both tailpipe and life cycle emissions. As anticipated, the LCA approach results in LCA vehicle emissions per mile that are 15% higher than the tailpipe emissions. However, this is for today's vehicles using GHG-intensive petroleum fuel and internal combustion engines resulting in high driving phase emissions, while the manufacturing phase emissions are represented by 65% steel materials resulting in low manufacturing emissions.

- **Driving Phase Emissions only (current regulations)**

Equation 1)

$$\frac{gCO_2e}{km} = \left(\frac{1}{\text{lifetime km}}\right) x \left(gCO_2e\ (use)\right)$$

$$= \left(\frac{1}{200{,}000\ km}\right) x \left(43{,}800{,}000\ gCO_2e\right) = \quad 219\ gCO_2e/km$$

- **Proposed approach to extend the current methodology to include LCA**

Equation 2)

$$\frac{gCO_2e}{km} = \left(\frac{1}{\text{lifetime km}}\right) x \left(gCO_2e\ (prod) + gCO_2e\ (use) + gCO_2e\ (EOL)\right)$$

$$= \left(\frac{1}{200{,}000\ km.}\right) x \left(6{,}400{,}000 + 43{,}800{,}000 + 300{,}000\right) = \quad 251\ gCO_2e/km$$

**(115% of tailpipe only emissions)**

***Figure 4: UC Davis Kendall study[iv] calculation adjusted to kilometers to demonstrate the Mercedes example***

A second example is conducted using data from the Lotus Engineering Toyota Venza/Verso study, representing a future concept. The comparison is again conducted between the HD body using GHG-intensive materials and the LD body using low GHG-intensive materials. Since this is a North American example, it uses North American sources and values. The BOM is used to establish the material content for each vehicle case, which is translated into $CO_2e$ values using Argonne's National Labs GREET 2.7 model. Total miles over the vehicle's life are obtained from the 2010 ORNL "Transportation Energy Data Book" at 162,000 miles for a typical vehicle. The tailpipe and LCA emissions are calculated using fuel economy targets of 56 mpg as one scenario anticipated for 2025. The LD Body variant is 104 kg heavier, resulting in a lower fuel economy performance of 52.9 mpg. The results show (Figure 5) that while the lighter weight HD body sees a 6 percent advantage in fuel economy and tailpipe emissions, the total LCA emissions are 10 percent higher than the LD body case.

| Lotus Venza Study | Tail Pipe Emission Regulation: Fuel Econ. (mpg) | Tail Pipe Emission Regulation: Tailpipe Emissons (gCO2e/mi.) | LCA Approach: LCA Emissions (gCO2e/mi.) |
|---|---|---|---|
| HD Body in HD Venza | 56.3 mpg | 193 | 261 |
| LD Body in HD Venza | 52.9 mpg | 205 | 238 |
| | | 94% | 110% |

***Figure 5: Applied to Lotus Venza Study (Example of Future Concept)***

Tailpipe emissions regulations would support the deployment of the HD body structure with its advantages in fuel economy, but would result in the unintended consequence of increasing the total emissions associated with this vehicle relative to the LD body structure.

The U.S. is currently shaping the new regulation for fuel economy and emissions for passenger cars and light trucks that will raise the industry average to 54.5 miles-per-gallon (mpg) from 2017 to 2025. On 16 November, the US National Highway Traffic Safety Administration (NHTSA) and the US Environmental Protection Agency (EPA) issued a Notice of Proposed Rulemaking that seeks input concerning the use of LCA. According to the rulemaking, the EPA is asking for comments on studies and research regarding information on lifecycle impacts of future advanced technologies that could ultimately assist in the introduction of LCA in vehicle regulations.

Within this process, the automotive steel industry is proposing a framework for incorporating LCA into US regulations by establishing a reference point that dovetails with the existing regulation, based on a tailpipe approach, running from 2012 to 2016. In summary, the 2016 tailpipe regulation could be adjusted to reflect the additional manufacturing and end-of-life associated emissions and serve as the reference point for the future 2017-2025 regulations (more details could be provided upon request).

**V. Conclusions**

Studies have demonstrated that a tailpipe emissions regulatory basis can result in vehicle makers deploying technologies that improve the $CO_2$ tailpipe emissions performance of their products in order to comply with the regulations while achieving the unintended consequence of increasing the total LCA emissions associated with their product. With the increasing use of advanced powertrains and advanced materials, the $CO_2$ emissions related to manufacture and disposal of vehicles is becoming a more significant component of the total life-cycle emissions of a vehicle increasing the magnitude of the unintended consequence of increased LCA $CO_2$ emissions. To ensure that legislation targets genuine cuts in $CO_2$ emissions and to avoid unintended consequences, it is essential that legislation for emissions from vehicles moves to an LCA basis in the near future. We believe that this is entirely feasible within the time frame foreseen in the EU (upcoming review of Regulation 443/2009 on emission performance standards for new passenger cars and the analysis of post 2020 targets) and would have the following benefits:

- An LCA approach, within the regulation, would serve to incentivize the supply chain to reduce the carbon intensity of their products. This is due to the commercial advantage this may provide the supplier in helping his customer reduce the carbon footprint of the vehicle.

- Applies sound science in an integrated systems approach to reduce energy use and greenhouse gas emissions associates with passenger vehicle by addressing all phases of a vehicle's life. This would also provide a more rigorous definition of a zero carbon vehicle and avoid burden shifting.

- Europe is already leading the world in the development of a new generation of clean cars with a more effective regulatory approach.

- Enhances energy security by reducing energy consumption in all phases of a vehicle's life and placing value on technologies with the lowest embodied energy.

- Spurs economic growth enabling lowest cost clean cars by providing OEMs greatest design flexibility in achieving clean cars.

The automotive steel industry believes it is clear that life cycle emissions need to be considered. Initial research by the University of California-Davis[iv] indicates this can be done in a simpler manner than originally thought, as explained earlier in this document's Section III.

Initial research by other organizations such as the Low Carbon Vehicle Partnership supports the principles of a life cycle approach. Development of a final methodology will still take extensive discussion among experts so a timetable for developing such an approach needs to be put in place sooner rather than later.

WorldAutoSteel requests the European Commission identify life cycle emissions as an important consideration in the mid-term review of Regulation (EC) No 443/2009 on emission performance standards for new passenger cars. The review will look at the modalities of reaching the 2020 target of 95 g/km for passenger cars and the long-term (2030) perspective, while building on the experience gained from implementing the short term targets.

Recent developments in the US could be useful within this process. The automotive steel industry is proposing a framework for incorporating LCA into US regulations by establishing a reference point that dovetails with the existing regulation, based on a tailpipe approach, and which can serve as the reference point for the future regulations. WorldAutoSteel believes that this proposed model could prove useful to the European analysis on the current review of the 2009 emissions regulation, and remains available for providing further technical details.

## VII. References

[i] Carbon dioxide equivalents (CO2e) represent a measure of all greenhouse gases attributable to a product that affect global warming potential and include gases other than CO2.

[ii] Mercedes Vehicle: ISO-Environmental Certificate, 2007, http://media.daimler.com/dcmedia/0-921-658895-1-827628-1-0-0-0-0-0-11701-614316-0-1-0-0-0-0-0.html.

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[v] Geyer, Stoms, Kallaos, 2011, Photovoltaics Offer Land-Efficient and Low-Carbon Sun-to-Wheels Transportation.

[vi] Ducker Worldwide, 2011, Future of AHSS Growth, Presentation at Steel Market Development Institute's Great Designs In Steel.

[vii] Lotus Engineering Study for the International Council on Clean Transportation, 2010, An Assessment of Mass Reduction Opportunities for a 2017 – 2020 Model Year Vehicle Program, Available from http://www.theicct.org/documents/0000/1430/Mass_reduction_final_2010.pdf.

[viii] Geyer, R., (2010). *UCSB Greenhouse Gas Materials Comparison Model – June 2010*, Available from http://www.worldautosteel.org/Projects/LCA-Study/2010-UCSB-model.aspx

[ix] World Resource Institute, GHG Protocol Initiative, GHG Protocol Product Life Cycle Standard, 2011, Available from http://www.ghgprotocol.org/feature/download-new-ghg-protocol-product-life-cycle-standard

[x] Argonne National Lab Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model (GREET) model, Available from http://greet.es.anl.gov/.

[xi] PE International, GaBi Software, Available from http://www.pe-international.com/gabi/.