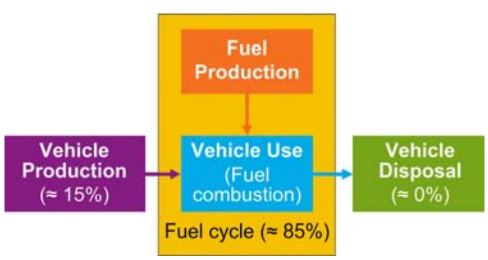
Life Cycle Assessment:
Good for the Planet, Good for the Auto Industry

Cars are an indispensable part of modern life. We depend on them to transport us to work, bring food and goods to our homes and take us where we want, when we want to go there. Cities are planned around them, families budget for them, portions of our days are spent in them, and some of us even give them names. Few other machines inspire such emotional resonance, but our collective love affair with cars has come at a cost.

From the 1960's, most major developed countries began to introduce legislation to reduce automobile emissions in response to growing human health and environmental concerns[1]. Many pollutants were significantly reduced by the removal of lead from gasoline, the addition of catalytic converters, and increased efficiency through advances in power train technology[2].

However, greenhouse gas (GHG) emissions remain a major unresolved issue because of their contribution to climate change[3].

In response to this very real threat, policy makers across the world are implementing regulations in an attempt to curb the GHG emissions released by automobiles into our environment[4].



A Hole in the Tailpipe Regulation

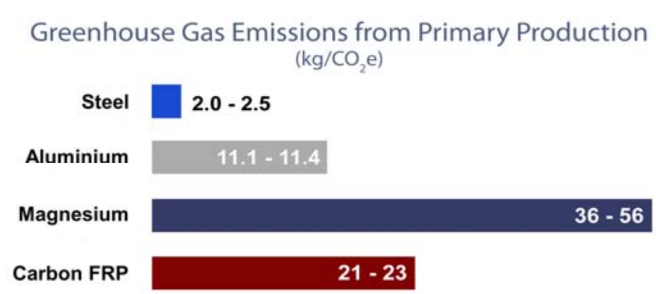
Almost all current legislation focuses exclusively on 'tailpipe' or use-phase emissions. Tailpipe considers the GHG emissions caused solely by the combustion of fuel. Use-phase considers emissions from the entire fuel cycle - both production and consumption of fuel.

Automotive GHG Regulations and Vehicle Lightweighting

For a typical gasoline-powered vehicle roughly 85% of GHG emissions come from the fuel cycle with the remaining 15% caused by vehicle production and disposal[5]. Increasing fuel economy reduces tailpipe emissions and common engineering solutions include more efficient powertrains, better aerodynamics and vehicle light-weighting. Correspondingly the automobile industry is under significant pressure to meet GHG emission standards in Europe, the U.S., and Canada, and fuel economy standards in Japan, China, and South Korea.[6] However, current regulatory approaches are problematic for one important reason:

Unintended Consequences

Light-weighting, for instance, is a costly venture for OEMs. Many low-density materials are expensive and adapting for their use often requires factory retooling - an added financial burden. While the use of light-weight materials reduces use-phase emissions, the primary production of light-weight materials is typically very GHG intensive[7]. If the increase in production emissions is greater than the decrease in use-phase emissions, vehicle light-weighting actually *increases* total emissions - an unintended consequence.



Refer to Annotation #7 for further explanation of comparison on a vehicle component (functional unit) basis.

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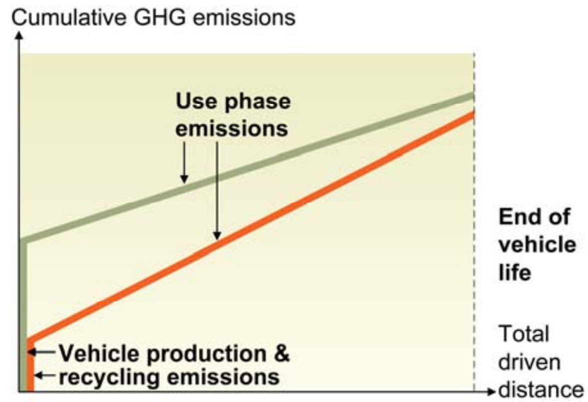
Tailpipe-only regulation may increase vehicle production costs and GHG emissions.

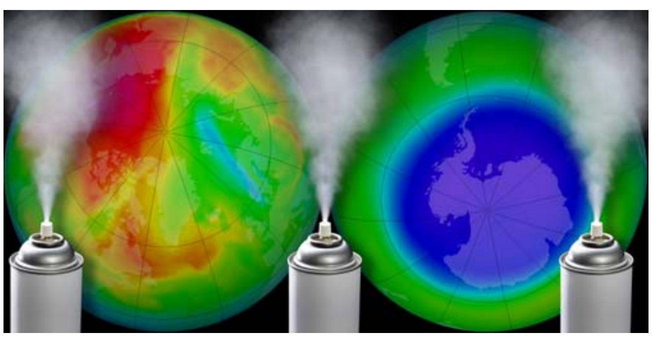


Unintended Consequences are more common than you think.

Corporate Action:
In the 1920s, Tetra-Ethyl Lead (TEL) started being used as anti-knock, which enabled the design of more powerful and fuel-efficient engines.

Unintended consequence: Catastrophic levels of atmospheric lead pollution.

Public Policy Response: Ban leaded automotive fuels.



Corporate Action:
In the 1930s, Chlorofluorocarbons (CFCs) started being used as non-toxic, non-reactive alternatives to toxic and flammable refrigerants and propellants, such as ammonia, chloromethane, and sulfur dioxide.

Unintended consequence:
Dramatic depletion of the stratospheric ozone layer.

Public Policy Response:
Phase out CFCs through the Montreal Protocol.

Public Policy Decision:
In 2005 the USA created a Renewable Fuel Standard (RFS) as part of its Energy Policy Act (EPAct).

Potential unintended consequence:
In some cases biofuel production and use might have higher fossil energy demand and GHG emissions than fossil fuels.

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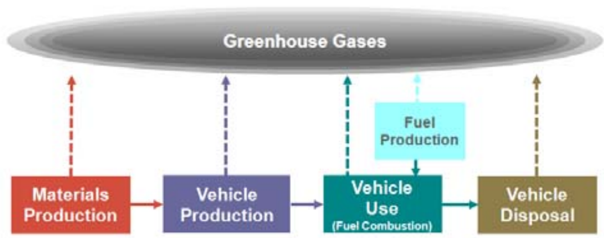
A Better Way – LCA

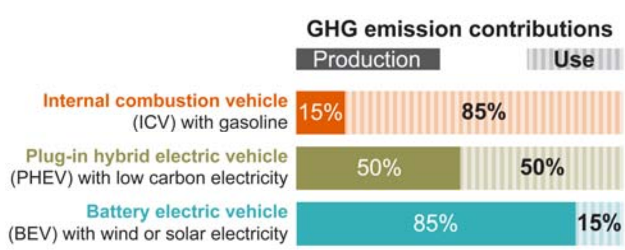
A better way of measuring automotive GHG emissions is by using life-cycle assessment (LCA), which takes into account all of the emissions created during the life of a product from raw material production to product end-of-life.



Only when a vehicle's total life cycle emissions are accounted for can a true picture of its environmental impact emerge. An LCA approach allows manufacturers to make design choices based on true environmental impact and economic value.

A primary driver of vehicle costs are materials, and a primary cost of materials is the energy is takes to make them. Energy is closely correlated with CO_2 emissions, so from an LCA perspective the lower cost solution is frequently the lower CO_2 solution. Low-carbon fuels and innovations in drive-train technology are changing the ratio between emissions created during vehicle production and use.

While a typical gasoline-powered vehicle currently emits only around 15% of its GHG in production, the use of cellulosic ethanol or a shift towards battery or hybrid electric vehicles would dramatically increase the share of vehicle production emissions[8]. For a battery electric vehicle powered entirely by renewable electricity, vehicle production emissions could account for as much as 85% - a complete reversal of the current figures[9].



Tailpipe-only regulation will become increasingly inadequate as the auto industry moves forward, limiting design choices and increasing production costs for OEMs whilst failing to fully account for automotive GHG emissions.

Tailpipe-only regulation will limit design choices and increase production costs for OEMs.

The Auto Industry Is Already Utilizing LCA

LCA is not news to the auto industry. Independent of legislation many manufacturers are already using life cycle thinking and LCA, recognizing its importance and effectiveness in product and process design.

- In 2002, Honda implemented LCA Data and Management Systems, since it regards "LCA as a vital tool for environmental impact assessment."[10]
- Toyota actively carries out LCA in the development stage of new technology and has made the decision not to use carbon fiber because the high GHG emissions released during its production outweigh the GHG savings from mass reduction.[11]
- Volkswagen and Mercedes use LCA for environmental product design and issue environmental certificates or commendations in accordance with the relevant ISO-standards.[12]
- Ford routinely uses LCA and has begun to require carbon footprint data from its suppliers.[13]
- Nissan's 2010 green initiative incorporates LCA for all new models.[14]
- AIAG (Automotive Industry Action Group) has developed carbon footprinting requirements in the automotive industry as part of its supply chain objectives.[15]
- Ricardo issued a recent study emphasizing the shortcomings of regulating tailpipe CO2 and the importance of LCA in determining automotive GHG emissions.[16]

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In short, LCA-based regulation will help to:

- Truly decrease GHG emissions and other environmental impacts across the entire vehicle life cycle without the risk of unintended consequences.
- Keep costs down for OEMs by allowing them greatest flexibility in designing lowest-cost, lowest-emission vehicles.
- Make sure that GHG regulation is consistent with the way the car industry thinks about environmental management and product design.

LCA-based regulation is better for the environment, and better for the auto industry.

Environmental Regulatory Agencies Support Life Cycle Thinking

Many environmental agencies around the world support life cycle assessment, including the European Commission which calls it "the best framework for assessing the potential environmental impacts of products currently available."[17] Today, LCA and life-cycle-based GHG accounting are mature assessment tools with global standards.[18] Nonetheless, life-cycle-based environmental regulation is in its infancy and not without significant challenges. There are some examples of legislation with a life cycle perspective, such as California's Low Carbon Fuel Standard[19], but environmental regulators and policy makers need more encouragement to pursue this more frequently and consistently.

The Road to LCA-Based Regulation – What You Can Do

The support of the auto industry will be critical in bringing about the required legislative changes. There is varying awareness of LCA amongst lawmakers but regulations using this approach are yet to be adopted. Some regulatory bodies may already be aware of LCA, but daunted by the task of switching from use-phase-only to LCA-based regulation. In order to be influential, there is a need to:

Substantiate that use-phase-only legislation is creating an unforeseen problem

Explain how LCA-based regulation can solve this problem

Demonstrate how it is feasible to create LCA-based regulation

Communicating with Policy Makers

Effective engagement of governmental bodies requires careful planning and strong, persuasive communications. Legislators will have specific concerns that need to be addressed, and the right information needs to be available and accessible in order to make a compelling case for including LCA in future regulations.

An automotive LCA strategy folder containing key presentations, case studies and interactive tools are available to all OEM's to assist in this endeavor. Please contact Kate Hickey at khickey@worldautosteel.org to obtain a copy.

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Annotations

[1] A good overview and further literature is given in "The Automobile and the Environment in American History" by Martin V. Melosi (http://www.autolife.umd.umich.edu/Environment.htm)

[2] Air Quality Trends – Lead (available on http://www.epa.gov/air/airtrends/lead.html); Air Quality Trends – Ozone (available on http://www.epa.gov/airtrends/ozone.html); Air Quality Trends – NO2 (available on http://www.epa.gov/airtrends/nitrogen.html); Automobiles and Carbon Monoxide, U.S. EPA, Fact Sheet OMS-3, January, 1993

[3] Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2010, EPA-420-S-10-002, November 2010

[4] Regulation (EC) No 443/2009 in the European Union, the new Codes of Federal Regulation 40 CFR Parts 85, 86, and 600; 49 CFR Parts 531, 533, 536, 537 and 538 in the United States

[5] Life cycle assessments of passenger vehicles consistently find that vehicle production, including all upstream processes, makes up 10-20% of life cycle GHG emissions. Due to their better fuel economy, diesel versions of a given model have higher contributions of vehicle production than gasoline versions. The other main factors that decide whether vehicle production contributes closer to 10% or 20% to life cycle GHG emissions are vehicle class, material composition of the vehicle, and the assumed total driven life time distance. For an unspecified gasoline-powered light duty vehicle, 15% vehicle production contribution is the most likely value. Here are a few example calculations from literature:

Samaras & Meisterling (2008) EST 42, 3170-3176:
Vehicle production: 8,500 kgCO2eq ($13,500 1997 producer price of a Toyota Corolla in the CMU EIO-LCA model)

Fuel cycle: $$(2.3+0.67)\frac{kgCO_2eq}{liter}\cdot 0.08\frac{liter}{km}\cdot 240{,}000km = 57{,}025kgCO_2eq$$ (87% of total)

$$(2.3+0.67)\frac{kgCO_2eq}{liter}\cdot 0.08\frac{liter}{km}\cdot 200{,}000km = 47{,}520kgCO_2eq$$ (85% of total)

Environmental Certificate Mercedes-Benz C-Class (2007):
Vehicle production and recycling (no recycling credits): (6,400+300) kgCO2 = 6,700 kgCO2
Fuel cycle: 43,800 kgCO2 (86.7% of total)

Passat: Environmental Commendation – Detailed Version (2009):
Vehicle production contribution of the diesel models varies from 18% to 21%.
Vehicle production contribution of the gasoline models varies between 13% and 18%.
Assumed total driven life time distance is 150,000 km.

[6] Passenger Vehicle Greenhouse Gas and Fuel Economy Standards: A Global Update, An F, Gordon D, He H, Kodjak D, Rutherford D, International Council on Clean Transportation (ICCT), 2007. Global Vehicle Fuel Economy and GHG emissions Regulations for Light- and Heavy-duty Vehicles, German J, ICCT, Presentation at MIIT Workshop, Beijing, China, April 14, 2011.

[7] The sources for the cradle-to-gate GHG emission data for primary material production are: The 2010 inventory data from the World Steel Association; Life Cycle Assessment of Aluminium: Inventory Data for the Primary Aluminium Industry, Year 2005 Update, 2007, International Aluminium Association; Tharumarajah A & Koltun P (2007) Is there an environmental advantage of using magnesium components for light-weighting cars?, Journal of Cleaner Production, 15(1007-1013); Ramakrishnan S & Koltun P (2004) Global warming impact of the magnesium produced in China using the Pidgeon process, Resources Conservation & Recycling, 42(49-64); *Materials Selection in Mechanical Design*, M. F. Asby, 2005, Third Edition, Elsevier; Eco-profiles of the European Plastics Industry, 2005, Boustead I for Plastics Europe. For the GHG implications of automotive material substitution see, for example, Geyer R (2008) Parametric assessment of climate change impacts of automotive material substitution, EST, 42(18) 6973-6979.

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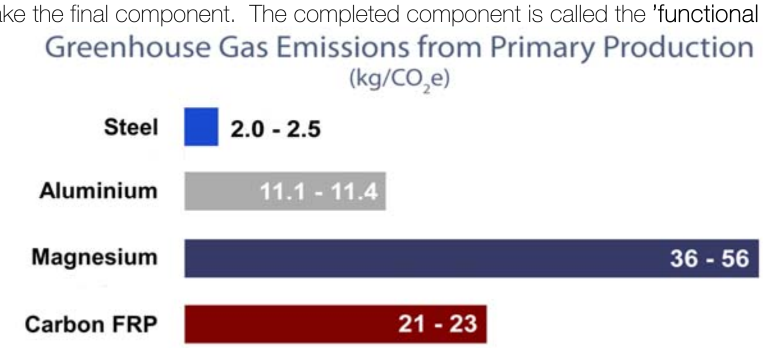
Different density of materials is taken into consideration and is included in the mass of the component. Then, CO2 emissions are calculated on the basis of the amount of material used to produce the part.

Refer to "Example Illustration" in this footnote for an explanation of how 'functional unit' values are calculated. However, GHG emissions measurement of a product that is produced from these materials must account for the actual total amount of material used to make the final component. The completed component is called the 'functional unit'.



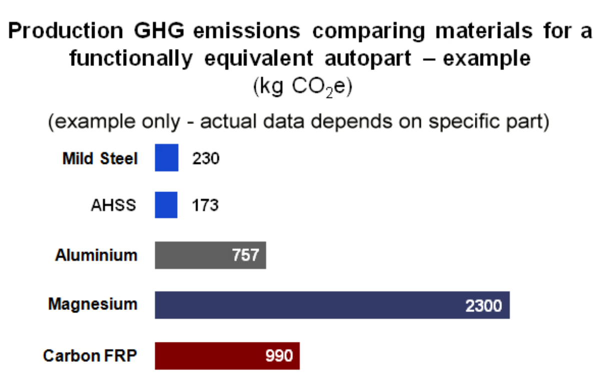
The functional unit (component) must have the same performance characteristics (strength, stiffness, crash energy absorption, etc.) no matter from which material it is made. The 'material' GHG emissions for the component are then calculated by multiplying the value for the CO_2e/kg (previous chart) times the actual weight of material to make the part.

CO_2 in material production should be compared not by material weight (kg) but by parts with taking different material density into consideration.

Example illustration:
To illustrate the Life Cycle Assessment (LCA) calculation of the 'material' portion of a typical automotive component, let us use the mid-range CO_2e values for the materials in the above chart and then multiply those CO_2eq values by the actual weight of material that is required to make the component. The amount (weight) of each different material needed for a component with the same performance is, of course, determined by the design of the component. For this illustration we use example assumptions about the weight of each material required to make components with different material and the same performance. See table:

			Functional Unit		
Material used	CO2e/kg		(kg)		CO2eq
Conventional (mild) steel	2.3	x	100	=	230
Advanced High Strength Steels (AHSS)	2.3	x	75	=	173
Aluminium	11.3	x	67	=	757
Magnesium	46.0	x	50	=	2300
Carbon FRP	22.0	x	45	=	990

This functional unit comparison can be illustrated in the following chart:



Data source: UCSB Greenhouse Gas Materials Comparison Model 2012

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[8] See for example Samaras C & Meisterling K (2008) EST 42(9) 3170-3176.
See also Nissan's life cycle CO2 emission calculations for its LEAF (verified by Japan Environmental Management Association for Industry (JEMAI)): Using a total driven distance of 100,000km, roughly one third of total life cycle emissions are from the fuel cycle, i.e. electricity production, delivery and use. For a total driven distance of 200,000km, the fuel cycle would thus make up 50% of total emissions. (information can be found at http://www.nissan-global.com/EN/ENVIRONMENT/CAR/LCA/)

[9] Geyer R, Stoms D, Kallaos J, Photovoltaics offer Land-efficient Low-Carbon Sun-to-Wheels Transportation, unpublished.
[10] In 2002, Honda implemented LCA Data and Management Systems, since it regards "LCA as a vital tool for environmental impact assessment." (Honda Corporate News Release, June 12, 2002, available at http://world.honda.com/news/2002/c020612.html)

[11] Toyota's Eco-Vehicle Assessment System (Eco-VAS), its main tool to assess environmental impacts from vehicles, is based on LCA. (see, e.g., http://www.toyota-global.com/sustainability/environmental_responsibility/)

[12] VW's environmental management and strategy is based on a life cycle perspective, and LCAs plays a "key role in reliably achieving the objectives of Volkswagen's Environmental Policy." Volkswagen also issues LCA-based environmental commendations of its cars in accordance with the relevant ISO-standards (VW Sustainability Report 2010 pp.44/45)
According to its 2011 Sustainability Report, environmentally responsible product development at Daimler is based on a life cycle perspective and comprehensive LCA. Mercedes also issues LCA-based environmental commendations of its cars in accordance with the relevant ISO-standards (Daimler Sustainability Report 2011 pp.52/53)

[13] According to Ford's Sustainability Report 2010/11, Ford's main tool for environmental assessments is called Product Sustainability Index (PSI) and is based on LCA.

[14] Nissan states that "to effectively cope with today's environmental challenges, we need comprehensive assessments of the actual impact of Nissan vehicles on the global environment. We have adopted an LCA method […]". (quote is from http://www.nissan-global.com/EN/ENVIRONMENT/CAR/LCA/)

[15] AIAG Supplier Guidance for Estimating GHG emissions for OEMs, Version 1.4, OHS-11, 2010, available on http://www.aiag.org.

[16] Preparing for a Life Cycle CO2 Measure, Ricardo Report RD.11/124801.4 for Low Carbon Vehicle Partnership, 20 May 2011.

[17] Quote from "Integrated Product Policy: Building on Environmental Life-Cycle Thinking", COM(2003) 302 final, Brussels, 18.6.2003, p.10.

[18] ISO 14040 Environmental management -- Life cycle assessment -- Principles and framework (Revision of ISO 14040:1997, ISO 14041:1998, ISO 14042:2000 and ISO 14043:2000) ISO 14044 Environmental management -- Life cycle assessment -- Requirements and guidelines (Revision of ISO 14040:1997, ISO 14041:1998, ISO 14042:2000 and ISO 14043:2000)
PAS 2050:2011, Specification for the assessment of the life cycle greenhouse gas emissions of goods and services, The British Standards Institution (BSI), London, UK. Greenhouse Gas Protocol: Product Life Cycle Accounting and Reporting Standard, World Resources Institute (WRI) and World Business Council on Sustainable Development (WBCSD), September 2011.

[19] Quote from paragraph 4. of California's Executive Order S-01-07: "The LCFS […] shall be measured on a full fuels cycle basis […]". LCFS stands for Low Carbon Fuel Standard.

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