Cars are changing the climate

Legislators Would Like To Change This

There is overwhelming scientific evidence that anthropogenic climate change is real and is a threat to our welfare.

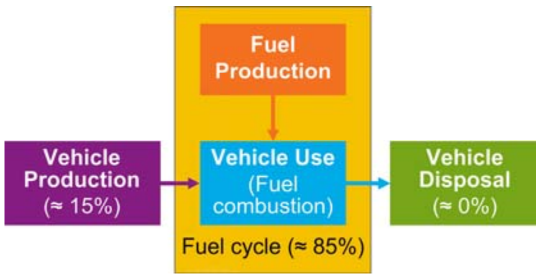
"Scientists know with virtual certainty that human activities are changing the composition of Earth's atmosphere" and "increasing greenhouse gas (GHG) concentrations tend to warm the planet."[1]

The U.S. Environmental Protection Agency (US EPA)

"In particular, transport remains a sector where emission reductions are urgently required but seem to be especially difficult to achieve. Emissions from transportation grew by 23.9 per cent from 1990 to 2004."[2]

U.N. Framework Convention on Climate Change (UNFCCC)

Cars are a significant source of GHG emissions. Tailpipe emissions of light duty vehicles alone are estimated to account for 10% of global CO_2 emissions[3]. Legislators around the world are addressing this challenge by setting progressive automotive GHG emission limits, fuel economy standards or a combination of both[4].



A Hole in the Tailpipe Regulations

All significant 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.

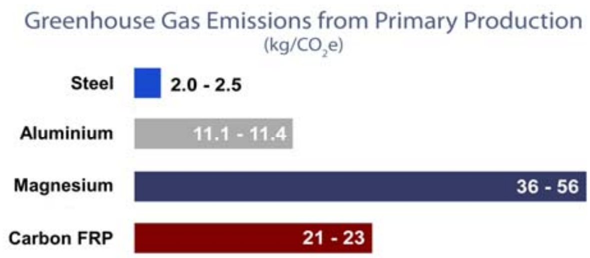
For a typical gasoline-powered vehicle roughly 85% of GHG emissions come from the fuel cycle with the remaining 15% caused by vehicle production and disposal[5].

Increasing fuel economy reduces fuel cycle emissions and one important way to achieve this is by reducing vehicle mass. Correspondingly the automobile industry is under significant pressure to light-weight vehicles in order to meet GHG emission standards in Europe and Canada, fuel economy standards in Japan and China, and a mix of both in the U.S. and South Korea.

While policy makers should be commended for their resolve, all current regulatory approaches are problematic for one important reason: The possibility of unintended consequences.

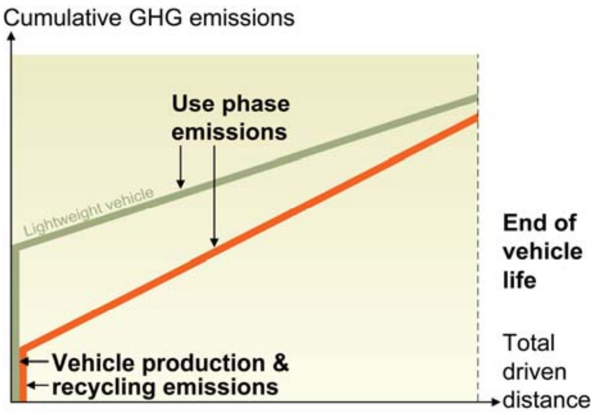
Unintended Consequences

Regulating only tailpipe or use phase emissions could lead to industry responses that actually make things worse. Consider the use of light-weight materials to reduce vehicle mass: It does decrease use-phase emissions, but since the production of light-weight materials is typically GHG intensive[6], the emissions during vehicle production are likely to increase significantly[7].



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

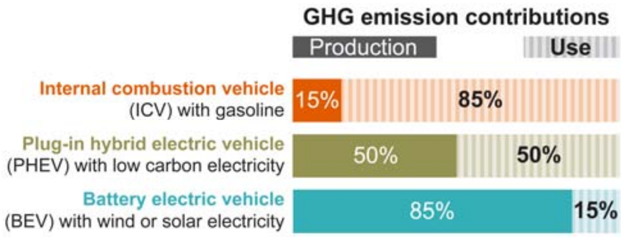
If the increase in production emissions is greater than the decrease in use-phase emissions, vehicle light-weighting actually *increases* total emissions - an unintended consequence.



Vehicle light-weighting is also costly, since it typically relies on expensive materials and requires retooling of manufacturing lines. There is evidence that redesigning power trains offers a better environmental return on investment than light-weighting.

The problems created by ignoring emissions from vehicle production will be further aggravated by future low-carbon fuels and drive-train technologies. While a typical gasoline-powered vehicle currently emits only around 15% of its GHG during 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].



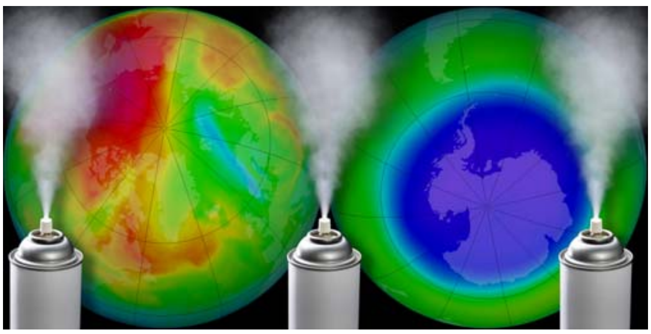
Fuel economy or tailpipe emissions standards are not enough to ensure overall reductions in automotive GHG emissions.

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.

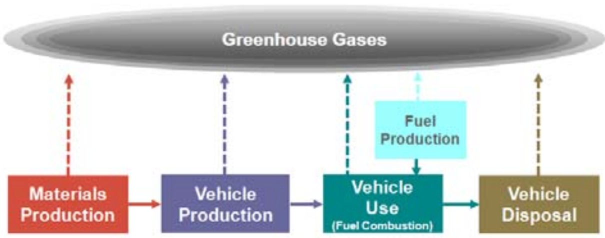
Public Policy Response:
Phase out CFCs through the Montreal Protocol.

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.

Avoiding Unintended Consequences with Life Cycle Assessment (LCA)

A more thorough 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 the net environmental impact of different designs be compared.



Production of lightweight materials such as aluminum, magnesium and carbon fiber are typically GHG-intensive and may offset or even outweigh the emission savings due to fuel economy improvements.

How Widespread And Accepted Is LCA?

LCA methodology and practice have been developing since the early 1970s. Today, it is a mature assessment tool with global standards.[10] Independent of legislation, many car 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."[11]
- 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.[12]
- Volkswagen and Mercedes use LCA for environmental product design and issue environmental certificates or commendations in accordance with the relevant ISO-standards.[13]
- Ford routinely uses LCA and has begun to require carbon footprint data from its suppliers.[14]
- Nissan's 2010 green initiative incorporates LCA for all new models.[15]
- AIAG (Automotive Industry Action Group) has developed carbon footprinting requirements in the automotive industry as part of its supply chain objectives.[16]
- Ricardo issued a recent study emphasizing the shortcomings of regulating tailpipe CO2 and the importance of LCA in determining automotive GHG emissions.[17]

LCA is equally accepted and used by material producers. In fact, together with many of their member companies, the trade associations of the steel, aluminium, and plastic industries are among the most active members of the global LCA community[18].

LCA and Public Policy

Many environmental agencies around the world support life cycle assessment, including the European

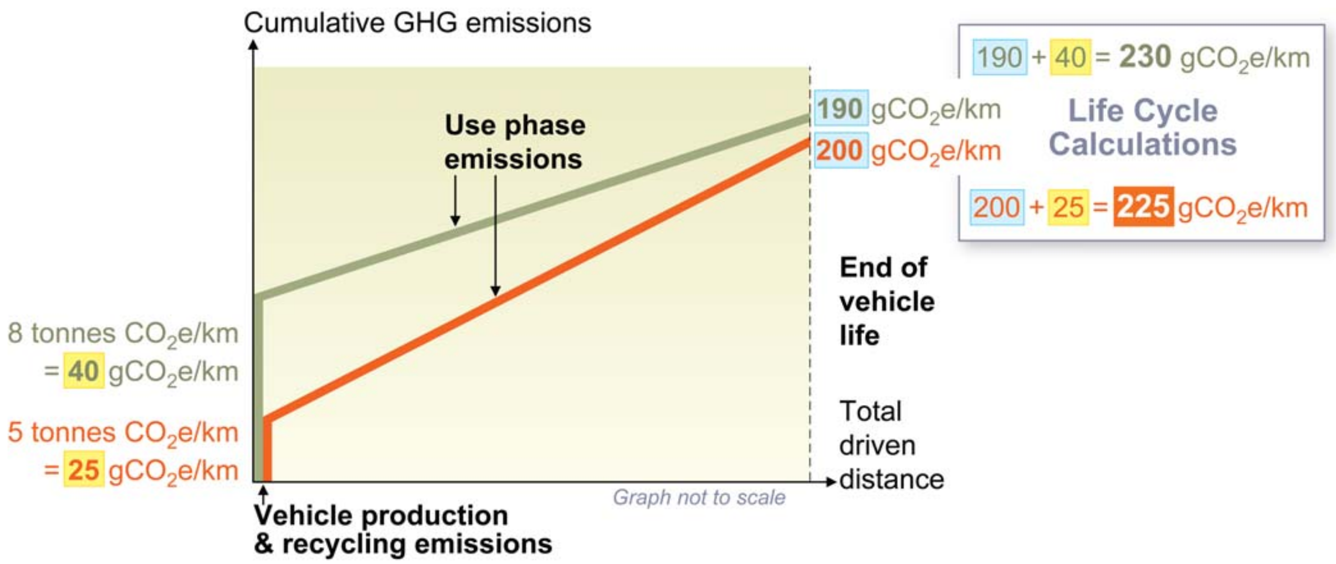
Commission which calls it "the best framework for assessing the potential environmental impacts of products currently available."[19] Environmental regulators and policy makers have begun to draft legislation with a life cycle perspective, such as California's Low Carbon Fuel Standard[20], but need to do so more frequently and consistently. Life-cycle-based environmental regulation is in its infancy and not without significant challenges. Nevertheless, the regulation of automotive GHG emissions provides a unique opportunity to align regulatory practice with the state of the art in environmental product policy and launch a new area of enlightened and successful environmental legislation.

LCA-based automotive GHG Regulation

Life-cycle-based automotive GHG regulation is feasible and can be achieved by amending rather than replacing current standards. An automotive life cycle GHG emission standard accounts for the joint emissions from fuel combustion, fuel production, and vehicle production and recycling. 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.

The main task of accounting for vehicle production is to avoid unintended consequences such as the one discussed earlier. Science-based rules need to be established about how to measure emissions from vehicle production. A good starting point would be to multiply the material composition of a vehicle, which is readily available, with the GHG intensity of each material. (see figure below).

The figure below illustrates this for two compact class vehicles with different material compositions. Automotive life cycle GHG emission standards are feasible and will benefit the climate.



Annotations

[1] Quote is from http://www.epa.gov/climatechange/science/stateofknowledge.html

[2] Quote is from the UNFCCC press release “2006 UNFCCC greenhouse gas data report points to rising emission trends”, Bonn, 30 October 2006. The data can be found in “GHG Data 2006: Highlights from Greenhouse Gas (GHG) Emissions Data for 1990-2004 for Annex I Parties”, submitted under the United Nations Framework Convention on Climate Change (UNFCCC).

[3] Global Warming on the Road: The climate impact of America’s automobiles, DeCicco J and Fung F, Environmental Defense Fund, 2006.

[4] 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.

[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)

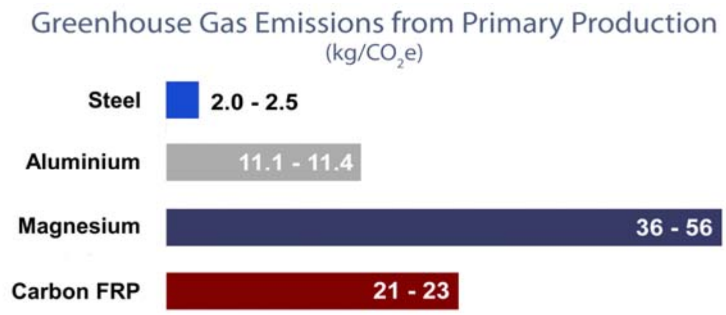
Environmental Certificate Mercedes-Benz C-Class (2007):
Vehicle production and recycling (no recycling credits): (6,400+300) kgCO2 = 6,700 kgCO2
Fuel cycle: 43,800 kgCO2 (86.7% of total)

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] 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.

[7] Explanation of ‘Functional Unit.’ 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’.



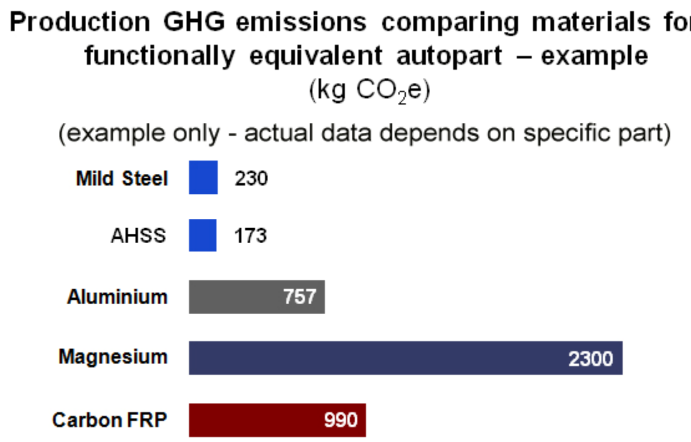
The functional unit (component) must have the same performance characteristics (strength, stiffness, crash energy absorption, etc.) no matter from which material it is made. The 'material' GHG emissions for the component are then calculated by multiplying the value for the CO_2eq/kg (previous chart) 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

[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 taken from 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] 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)
[11] 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)

[12] 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/)

[13] 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)

[14] 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.

[15] 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/)

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

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

[18] The World Steel Association, the International Aluminium Institute, and Plastics Europe are global leaders in the provision of life cycle inventory data and are equally involved in the methodological development of LCA. More details are available on the following web pages:
http://www.worldsteel.org/steel-by-topic/life-cycle-assessment.html
http://www.world-aluminium.org/Sustainability/Environmental+Issues
http://www.plasticseurope.org/plastics-sustainability/life-cycle-thinking-1746.aspx

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

[20] 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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