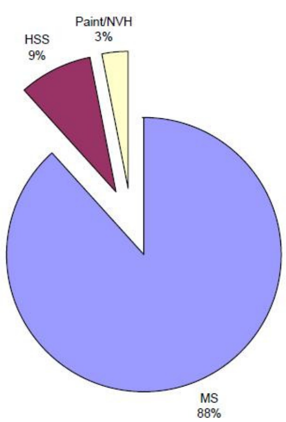
BACKGROUND

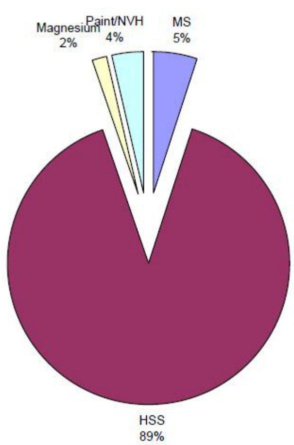
This study, conducted by Lotus Engineering under funding by the U.S. Energy Foundation, aimed to identify potential mass reduction opportunities for a selected baseline vehicle representing the crossover utility segment. The study selected the 2009 Toyota Venza as the baseline vehicle for evaluation and encompassed all vehicle systems, sub-systems and components in an analysis of two distinct vehicle architectures.

The first vehicle architecture, titled the "Low Development" vehicle, targeted a 20% vehicle mass reduction (less powertrain), utilised technologies feasible by year 2014 for inclusion into a 2017 production vehicle. The low development vehicle focused on competitive benchmarking, applied industry leading mass reducing technologies, improved materials, component integration, and planned for vehicle assembly in existing facilities.

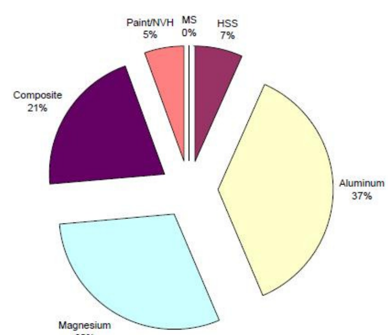
The second vehicle architecture, titled the "High Development" vehicle, targeted a 40% vehicle mass reduction (less powertrain), 2017 technology readiness and 2020 production. It utilised primarily non-ferrous materials and specified a high degree of component integration with advanced joining and assembly methodologies. The study included a cost analysis but did not include a life cycle assessment (LCA). As well, the analysis did not include any considerations for the powertrain. Material usage for each is shown in the following figures:



Baseline 2009 Venza



Lotus - Low Dev Venza



Lotus – High Dev Venza

Mass reductions were accomplished through increased modularisation, inclusion of low-density materials and the application of emergent design concepts. Individual parts were often eliminated through design integration. The Low Development vehicle adopted the footprint of the present vehicle and the body structure used primarily mild and Advanced High-Strength Steels (AHSS), while the High Development vehicle, a multi-material approach, used an increased wheel base and track for additional mass reduction and cost savings opportunities.

LIFE CYCLE ASSESSMENT PARAMETERS

WorldAutoSteel used the UCSB Advanced Powertrain GHG Materials Comparison model (February 4, 2011) to assess the impact of low and high development materials decisions on lifetime vehicle emissions. We modeled parameters provided in the Lotus Engineering report. For most accurate results, mass reduction pertaining to material changes and mass reduction in the Venza body structure, closures and fenders were included in this study. Key model parameters are shown below.

Table 1: UCSB Model Parameters Used

2009 Toyota Venza	Lotus - Low Development Venza	Lotus - High Development Venza
Vehicle Curb Weight – 1705 kg	1428 kg	1210 kg
Body Structure Mass - 370.5 kg	313 kg	209 kg
Closures, Fenders Mass – 143.2 kg	108 kg	143 kg
Body Structure & Closures/Fenders Mass Reduction	58 kg body structure, 35 kg closures and fenders	161 kg body structure, 59 kg closures and fenders
Powertrain – ICE-g 410.4 kg		
Powertrain Resizing?	Yes – 356 kg	Yes – 356 kg
Secondary Mass Reduction	187 %	125 %
Total Mass Reduction	277kg	495 kg
Fuel Consumption – 25.4 mpg		
Driving Cycle	NEDC	NEDC
Lifetime Driving Distance	200,000 km / 124,321 miles	200,000 km / 124,321 miles
Steel Composition	75% hot-dip galvanized, 25% CR	75% hot-dip galvanized, 25% CR
Recycling Treatment – alpha value	Alpha = 0.1	Alpha = 0.1
SRI Recycling Rates:		
Steel (conv. and AHSS)	97% collection, 98% shredder efficiency, 95% collection	97% collection, 98% shredder efficiency, 95% collection
Aluminium	97% collection, 90% shredder efficiency, 90% collection	97% collection, 90% shredder efficiency, 90% collection
Magnesium	97% collection, 90% shredder efficiency, 90% collection	97% collection, 90% shredder efficiency, 90% collection
Manufacturing Yields:		
Steel (conv. and AHSS)	60% stamping	60% stamping
Aluminium	55% stamping, 80% extrusion and casting	55% stamping, 80% extrusion and casting
Magnesium	55% casting	55% casting
Composites	50%	50%

AHSS Mass Reduction Potential. The UltraLight Family of Research (www.worldautosteel.org), as well as industry practice, shows that a 25% mass reduction can be achieved with AHSS compared to conventional mild steel. Optimisation techniques have yielded even greater light weighting potential. In the Lotus Venza low development engineering solution, body structure mass reduction potential utilizing advanced high strength steels was ~16%, consistent with late models that already use a moderate amount of these materials.

Table 1 (below shows the results of the UCSB modeling . We've added another vehicle concept, a hybrid between the Low Development and High Development Lotus vehicles. In this case, we've combined the steel-intensive body structure, closures and fenders with the vehicle systems mass reduction achieved in the High Development vehicle. The result is a steel-intensive vehicle with a curb weight between the LD and HD concepts, but absent the use of cost-prohibitive materials such as aluminium, magnesium and composites.

Table 1: Lotus Engineering - Toyota Venza Mass Reduction Study.
UCSB GHG Materials Comparison Model Life Cycle Emissions of LD and HD Vehicle Concepts

Vehicle Description	Mass (kg)	Body Structure Materials	Production GHG's (kg)	Use Phase GHGs (kg)	Recycling Credit (kg)	Life Cycle GHGs (kg)
Baseline – 2009 Venza	1705 kg	Steel	3,922	55,356	(1,667)	3,931
Low Development (2017 Venza)	1428 kg	AHSS	2,946	47,740	(1,148)	49,538
High Development (2020 Venza)	1210 kg	Multi-Material	13,162	41,714	(5,379)	49,498
Low Dev, High Dev Hybrid MR Concept	*1336 kg*	*AHSS*	*2,405*	*45,207*	*(896)*	*46,715*

CONCLUSIONS:

1. Contrary to the misperception that material production emissions are insignificant, the High Development (multi-material) vehicle's production emissions account for ~27% of its lifetime emissions, and thus cannot be ignored when considering environmental impacts. As the use of advanced powertrains (such as hybrids) and improved driving cycles (such as the implementation of timed lights and roundabouts) accelerate, dramatic reductions in use phase GHG emissions occur, and **material production emissions will become much more relevant.**

2. Whereas the High Development, multi-material vehicle shows the lowest tailpipe emissions attributable to its low mass, the Low Development and High Development vehicles show virtually the same lifetime vehicle emissions, as shown in Figure 2. despite the use of costly alternative materials for lightweighting. The analysis shows the extreme production emissions penalty associated with a multi-material approach. Conversely, the "hybrid" vehicle shows a significant reduction in material production and vehicle life cycle emissions.

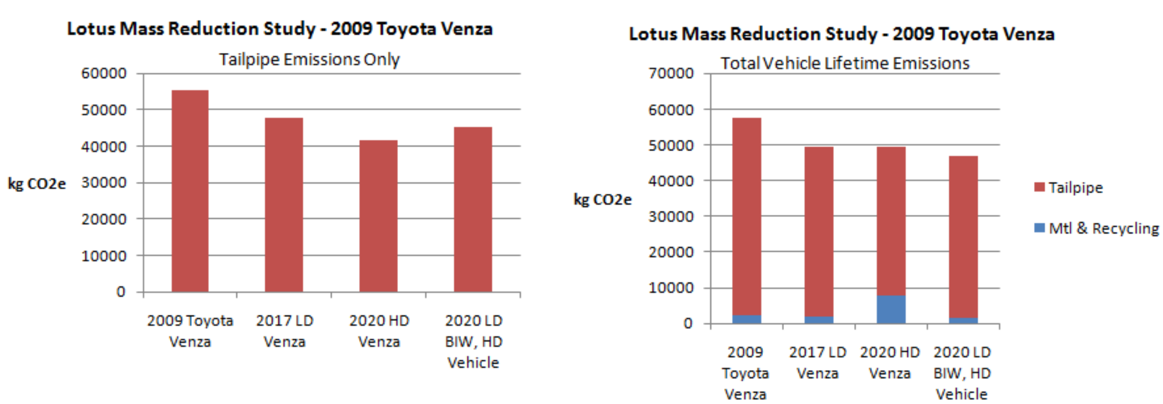


Figure 2: Tailpipe Emissions and Total Vehicle Lifetime Emissions based on LCA.

3. The Low Development and hybrid vehicles, which represent AHSS-intensive solutions, achieve reductions in mass, and emissions in ***all*** life cycle phases.

4. The High Development concept, or multi-material vehicle, results in more than 4 TIMES the material production emissions compared to the Low Development, steel-intensive vehicle. Accumulative emissions are thus significantly greater until recycling occurs at vehicle end-of-life. Due to concerns regarding the infrastructure for recycled content of GHG-intensive materials, the benefits from recycling of these materials is at minimum one vehicle life cycle, or 12 years, into the future. It's important to note that a high percentage of recycling is a fundamental requirement of energy-intensive materials (magnesium and aluminium), in order to offset their production emissions. Small changes in their recycling rates will have a large impact on GHG emissions.

5. A more realistic comparison of emissions performance for these vehicles would be to discount recycling credits altogether, until these vehicles actually demonstrate recycling behavior that match recycling assumptions. In this scenario, the Low Development vehicle shows 4.3 tons **fewer** CO2e per vehicle compared to the High Development, multi-material vehicle. With an assumption of 15 million vehicle production by 2015, this accounts for 64.5 million additional tons of CO2e annual emissions, or over half of the steel industry's entire annual emissions for its highest production year this decade (2007). Interestingly, investing in cost reduction of other vehicle systems (our hybrid vehicle) results in the lowest emissions solution, one that would save 7.3 tons CO2e per vehicle compared to the High Development vehicle.

6. Research studies argue that upfront emissions cause greater damage to the environment due to Cumulative Radiative Forcing (CRF) and propose the application of a Time Correction Factor (TCF) to account for such temporal effects. AISI and UC-Davis are collaborating on a study that will provide data to legislators, emphasizing the need for LCA and CRF cumulative effects to prevent tailpipe emissions legislation that cause unintended consequences. To demonstrate the effect, Figure 3 is a chart with TCF's applied to the material production and recycling phases of the total vehicle life cycle. The results demonstrate the alarming environmental impact of the multi-material approach.

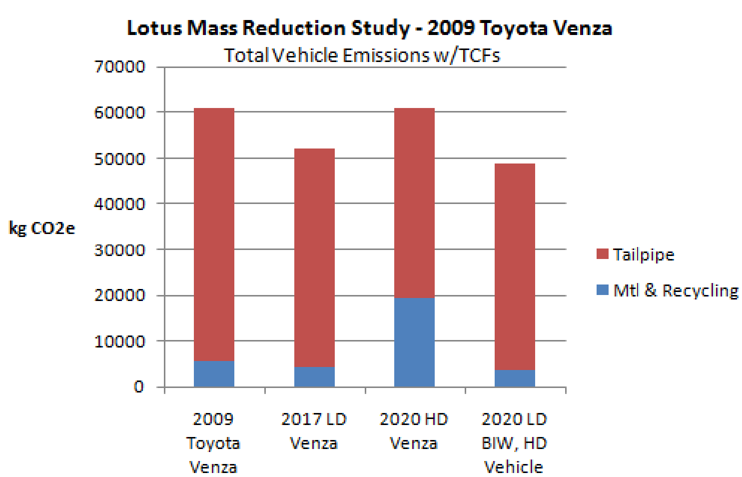


Figure 3: The Application of Time Correction Factors to Production Emissions.

Source: Lotus Engineering, Inc., 2010, ***An Assessment of Mass Reduction Opportunities for a 2017 – 2020 Model Year Vehicle Program***