Lightweighting as a Measure to Reduce GHG Emissions

ICCT International Workshop on greenhouse gas reduction potential and costs of light-duty vehicle technologies

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Brussels

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Outline

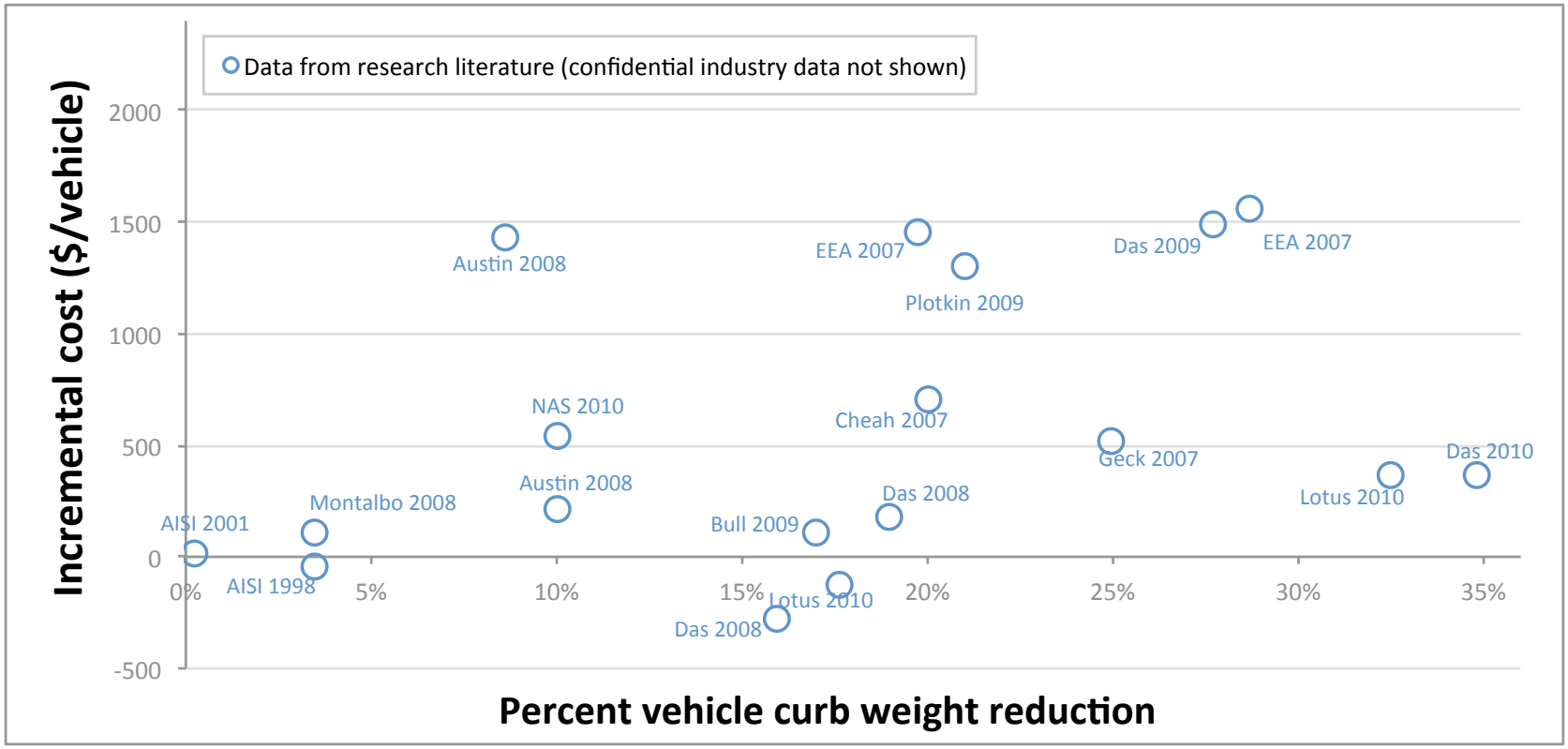
- Existing studies of mass reduction
  - Mass-reduction assessment in US 2017-2025 proposed GHG standards – used for ICCT's current EU cost curves
- Lightweight material potential
- Ongoing state-of-the-art mass reduction studies
  - Major projects underway that are likely to yield lower cost estimates for mass reduction
- Policy implications

Technical Literature on Mass-Reduction

- Technical assessments on mass-reduction involve major studies by national US energy laboratories, OEM steel suppliers, OEMs with universities, etc
- Studies demonstrate diverse options for mass-reduction
  - Part-specific design or material change (e.g., hood, B-pillar)
  - Material specific alternatives (e.g., aluminum-only, HSS-only focused)
  - System level changes (e.g., entire body-in-white)
  - Full vehicle redesign and material substitution (e.g., body plus secondary effects)
- Studies have differing value for regulatory assessment in terms of technical rigor, data/method transparency, comprehensiveness, crashworthiness validation

Vehicle Mass-Reduction Cost

- Technical assessments on mass-reduction from major studies by national US laboratories, OEM steel suppliers, OEMs with universities, etc
  - Mass-cost data plotted as cost versus percent of vehicle mass reduced
  - Each data point represents a different material/design approach to mass reduction
    - Many studies only address portions of the vehicle, such as the body-in-white

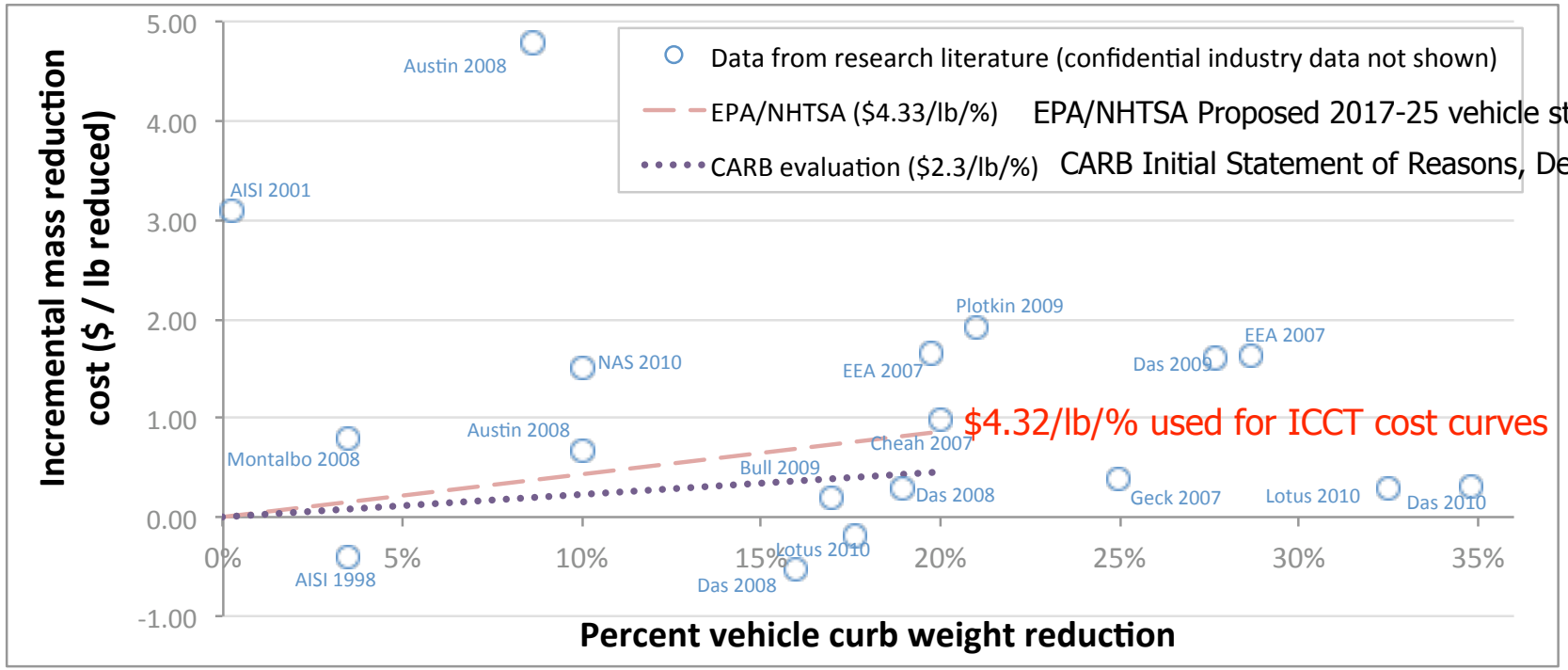


Mass-Reduction in US/CARB Regulation

- Mass-reduction assessment in US regulations involves technical contractor work, confidential business information from OEMs, and fleet safety analysis
- Technical basis, assumptions available in documents at agency websites
- US Environmental Protection Agency (USEPA) and National Highway Traffic Safety Administration (NHTSA):
  - Notice of Proposed Rulemaking (NPRM): Pages 74947 - 74962
  - Joint Technical Support Document (TSD): Pages 3-204 - 3-212
  - Documents at *http://www.epa.gov/otaq/climate/regulations.htm*
- California Air Resources Board
  - Technical Appendix Q: pages 6-20
  - Document at *http://www.arb.ca.gov/regact/2012/leviiighg2012/leviiighg2012.htm*

Vehicle Mass-Reduction Cost

- US agencies collaborated to assess available studies and model costs associated with vehicle mass-reduction
  - Agencies assessed and weighted the available mass-reduction studies for redesign of vehicle models in the 2017-2025 timeframe
  - Regulation analyses apply *cost-per-pound-reduced* vs percent mass reduction
  - Agencies projected average vehicle mass would decrease by 8-12% by 2025



Lightweight Material Potential

- Historically, interactions between the thousands of parts on the vehicles and their impacts on safety, ride, noise, and vibration were impossible to predict
  - Material optimization was a long, slow process of gradually changing a few parts at a time to avoid unanticipated problems
  - Secondary weight reductions were similarly difficult to achieve
- Development of sophisticated and accurate vehicle simulations is changing vehicle design
  - Initial use has been to improve safety design
  - Simulations are continuing to rapidly improve and are starting to be used to simultaneously optimize the material composition, shape, and thickness of every individual part, including secondary weight reductions

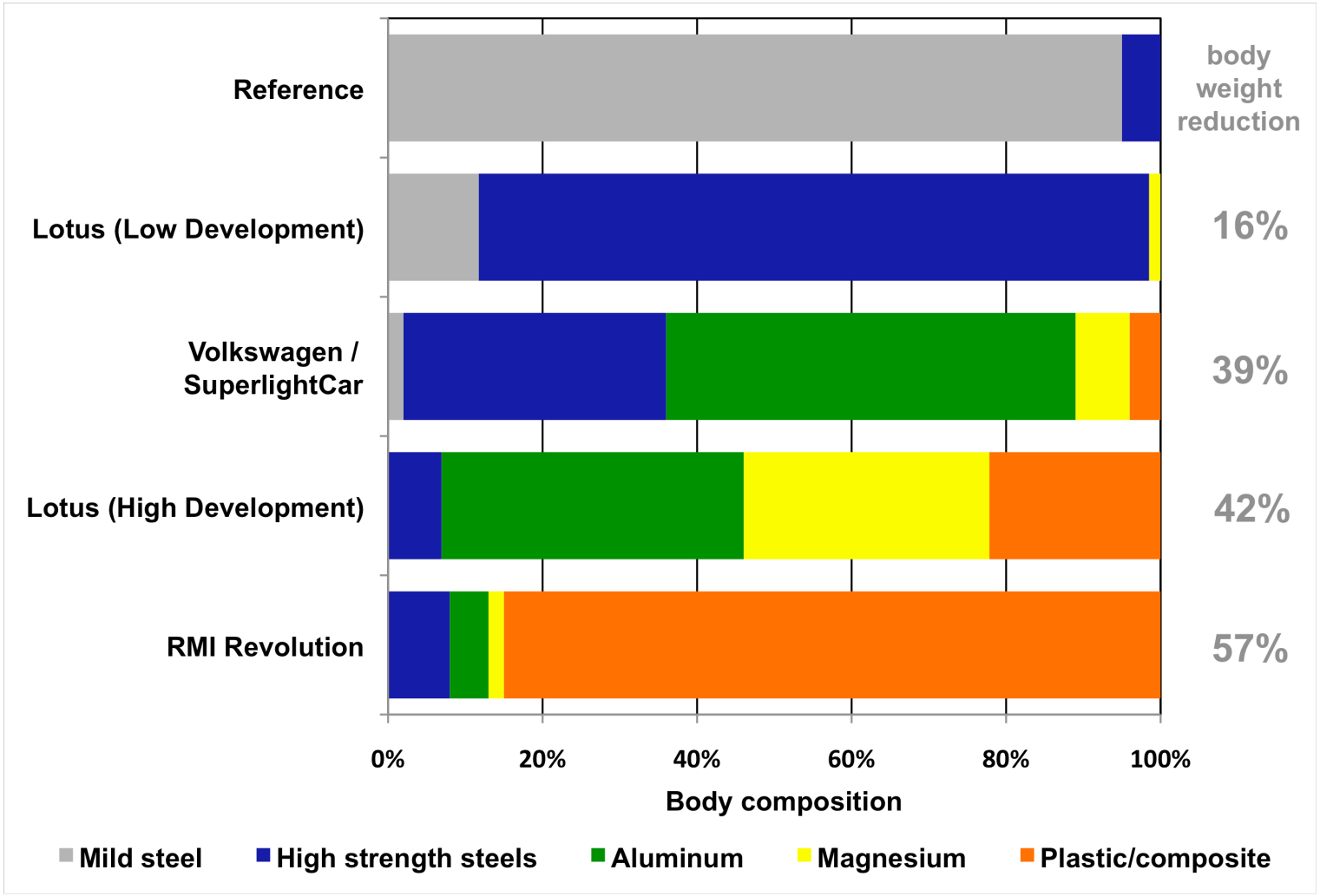
Mass-Reduction: Automaker Plans

- Mass reduction is expected from every automaker
- Below are public statements, anecdotes, quotes…

Company	Quote, statement, or commitment
Ford	• From 2011 to 2020: "Full implementation of known technology… weight reduction of 250-750 lbs" • "The use of advanced materials such as magnesium, aluminum and ultra high-strength boron steel offers automakers structural strength at a reduced weight to help improve fuel economy and meet safety and durability requirements
Toyota	• 10-30% weight reduction for small to mid-size vehicles
Volkswagen	• "Automotive light weight solutions are necessary more than ever to reduce CO_2 emissions " • "Multi-Material Concepts promise cost effective light weight solutions "
GM	• "We… are likely to use more lightweight materials in the future" • "One trend is clear - vehicles will consist of a more balanced use of many materials in the future, incorporating more lightweight materials such as nanocomposites and aluminum and magnesium."
Mazda	• Reduce each model by 220 lb by 2015; another 220 lb by 2020
Nissan	• Average 15% weight reduction by 2015 • "We are… expanding the use of aluminum and other lightweight materials, and reducing vehicle weight by rationalizing vehicle body structure
BMW	• "Lightweight construction is a core aspect for sustainable mobility improving both fuel consumption and CO_2 emissions"
Renault	• "To meet commitments on CO_2 emission levels, it is important that we stabilize vehicle weight as from now, and then start bringing it down."

Lightweight materials offer great potential

Material composition of lightweight vehicle body designs:



Also incremental improvements in aerodynamics and tire rolling resistance

2011 Ford Fiesta

- First car in subcompact segment to earn top crash-test ratings in each of the U.S., China and Europe.
- "Top safety pick" from the Insurance Institute for Highway Safety under its new test standards.

- More than 55% of the body structure is made from ultra-high-strength steel
- Extensive use of high-strength, lightweight boron steel to help protect critical occupant safety zones

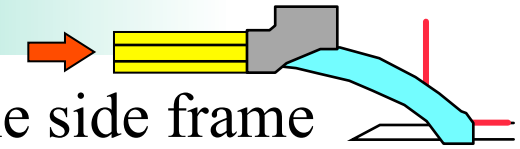
High-strength steel improves safety and reduces weight

Linear Compression of Aluminum

2000 Honda Insight

Side frame structure to control frontal crash energy

First stage



Front end area of the side frame

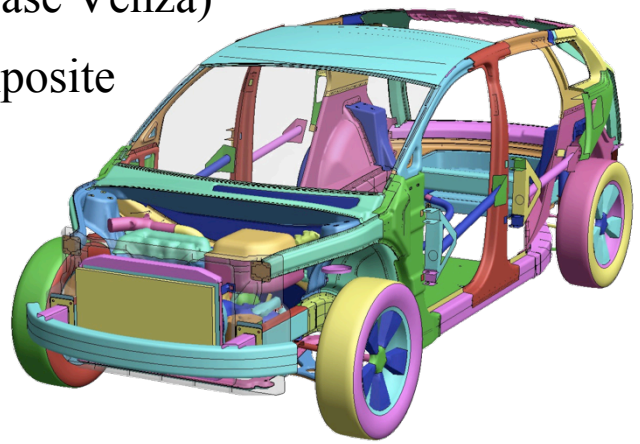
The hexagonal cross section member is compressed for efficient absorption of impact energy.

Major New Mass-Reduction Studies

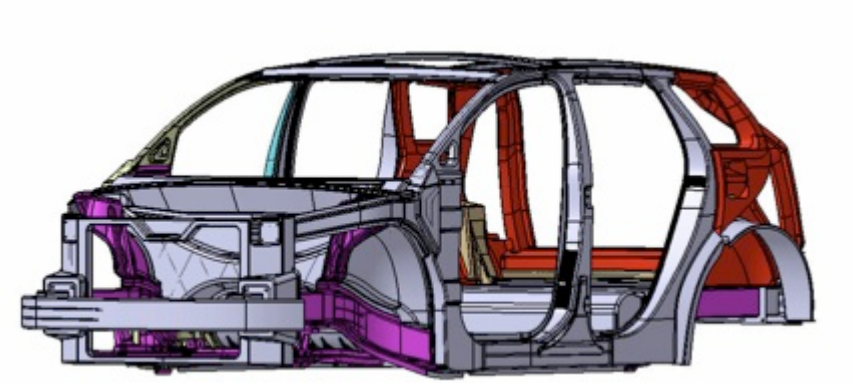
- Lotus Engineering (contracted by CARB)
  - Continuation of earlier 2010 Lotus work (20% and 33% mass-reduced Toyota Venza crossover)
    - See: *http://www.theicct.org/lotus-lightweighting-study*
  - On-going work includes crashworthiness/NHTSA/NCAP validation of 33%-mass-reduced vehicle (primarily aluminum)
- FEV / EDAG (contracted by US EPA, ICCT)
  - Involves development, validation, cost assessment of 20%-mass-reduced Venza
- EDAG / Electricore (contracted by NHTSA)
  - Mass-reduced mid-size vehicle (Honda Accord) ≤10% vehicle cost premium
- WorldAutoSteel "Future Steel Vehicle" (with AISI, EDAG)
  - High-Strength Steel (HSS): 18%+ mass reduction at no additional system cost
    - See: *http://www.worldautosteel.org/Environment/Future-Steel-Vehicle.aspx*

Lotus Mass-Reduction Project

- Contracted by CARB
  - Continuation of 2010 study (*http://www.theicct.org/lotus-lightweighting-study)*
- Crashworthiness, validation:
  - Front (FMVSS 208; IIHS 3/6 mph); Side (FMVSS 214); Rear (FMVSS 301, IIHS 3/5 mph); Roof (FMVSS 216); Seat belt/restraint (FMVSS 210/213)
  - Additional 35mph car-to-car crash with NHTSA (vs. Ford Taurus and Explorer)
  - Torsional stiffness: ~33,000 Nm/deg
- Engineering design:
  - Mass reduction: 242 kg body-in-white (-37% from base Venza)
  - Material: 75% alum., 12% magn., 8% steel, 5% composite
  - Parts count ~170 (base: >400 parts)
  - Cost increase: TBD
- Peer review process: On-going



Lotus Phase 2 Status – Sept. 2011



Body in White CAD Model

	New BIW Status	Venza
Mass:	241 kg (-37%)	383 kg
Materials:		
Aluminum:	75%	Steel: 100%
Magnesium:	12%	HSS: 49%
Steel:	8%	
Composite:	5%	
Parts Count:	<170	>400

Cost Status

Piece Cost: +60% (+$730/unit)
Part tooling: -60% (-$233/ unit)Assembly: -37% (-$251/ unit)

Assembled BIW : +$250 vs. Venza (60,000/yr)

Cost Factor: 108%"(> 5 years) (Assembled BIW)

Cost savings are possible from other parts of the vehicle

Light-Weighting Options for Vehicle Structures for Model Year 2020

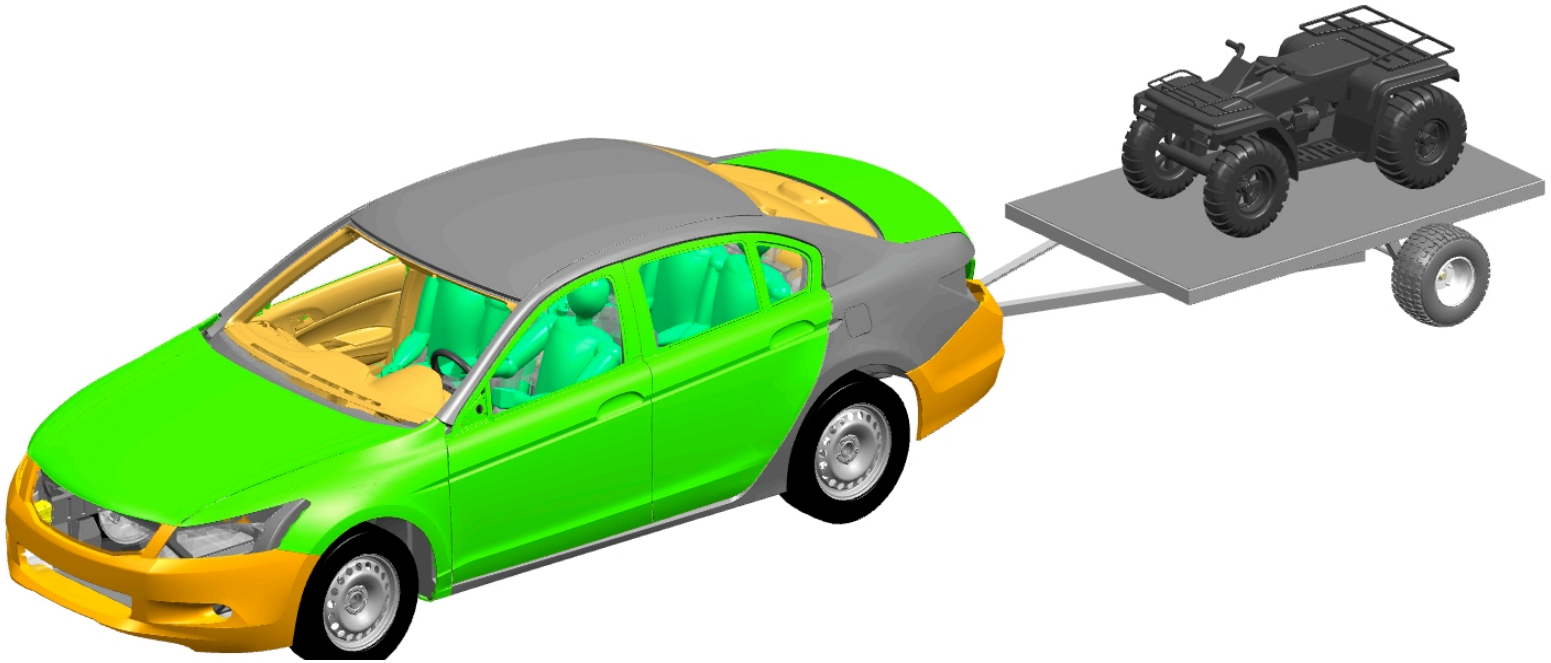
H. Singh – January 27th, 2012

NHTSA
www.nhtsa.gov

How Much Mass Reduction is Feasible for a Midsize Sedan for Model Years 2017-2025?

1. Baseline vehicle 2011 Honda Accord
2. Identify light weighting technologies for 2020 model year vehicle
3. **Cost no higher than 10% of current baseline vehicle's MSRP**
4. Same vehicle performance and functionality
5. All recommended technologies to be suitable for 200,000 annual production, 1 Million vehicles over 5 years
6. Deliver a detailed CAE model to NHTSA suitable for further safety related work

LWV – Mass Saving Summary



Mass (kg)	Pay-load	Non Structural	Body Structure	Chassis	Power train	GVW	CVW	MSRP
Honda Accord - 2011	385	465.1	343.8	287.8	383.3	1865	1480	$22,730
LWV	385	366.5	261.1	206.1	311.7	1530	1145	
Mass Reduction		-21%	-24%	-28%	-19%	-18%	-23%	

WorldAutoSteel "Future Steel Vehicle"

- With AISI, EDAG
  - See: *http://www.worldautosteel.org/Environment/Future-Steel-Vehicle.aspx*
- Body only
- Cost matched the cost of a baseline 1994 vehicle (at 225k vehicles/year)
- Body weight of 188 kg
  - 18% reduction compared to 230 kg for a highly efficient current production A/B class vehicle
  - 30% reduction compared to 270 kg for a baseline 1994 vehicle

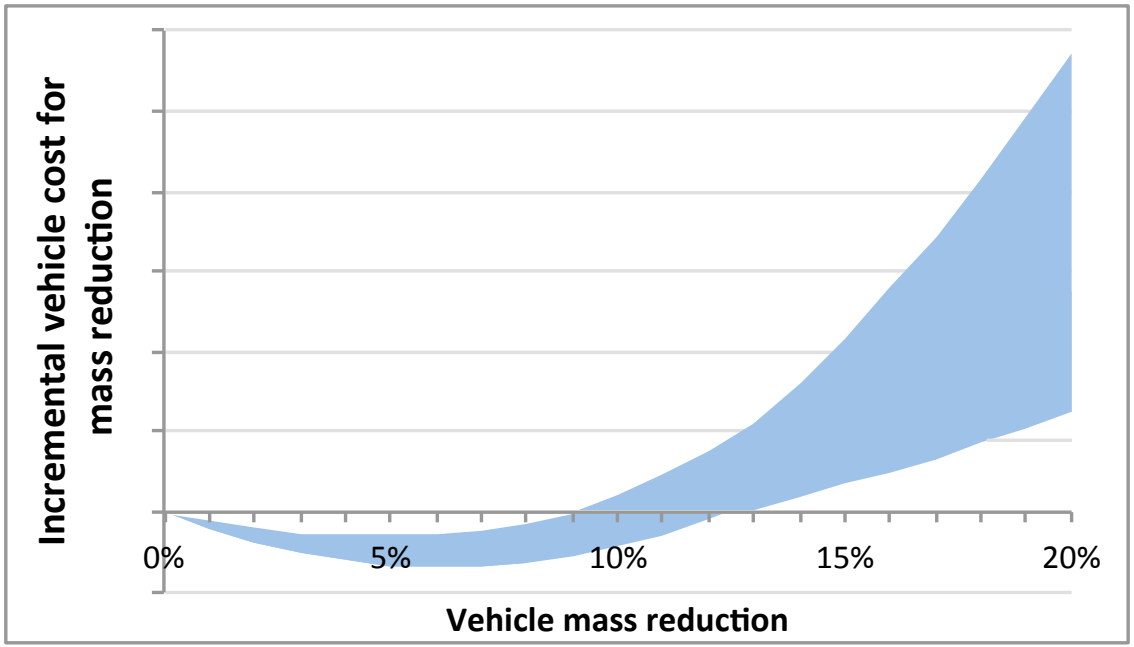
FutureSteelVehic

FEV Assessment of HSS Design

- EPA and ICCT have funded FEV to assess the crashworthiness and cost of the advanced (primarily) high strength steel Toyota Venza design
  - Very similar in scope to the NHTSA project and will include CAD and crash models
  - Vehicle design has met all major safety test requirements
  - Completion: Draft April 2012, release August 2012
- Most important of the new studies, due to transparency and thoroughness of FEV tear-down cost assessments

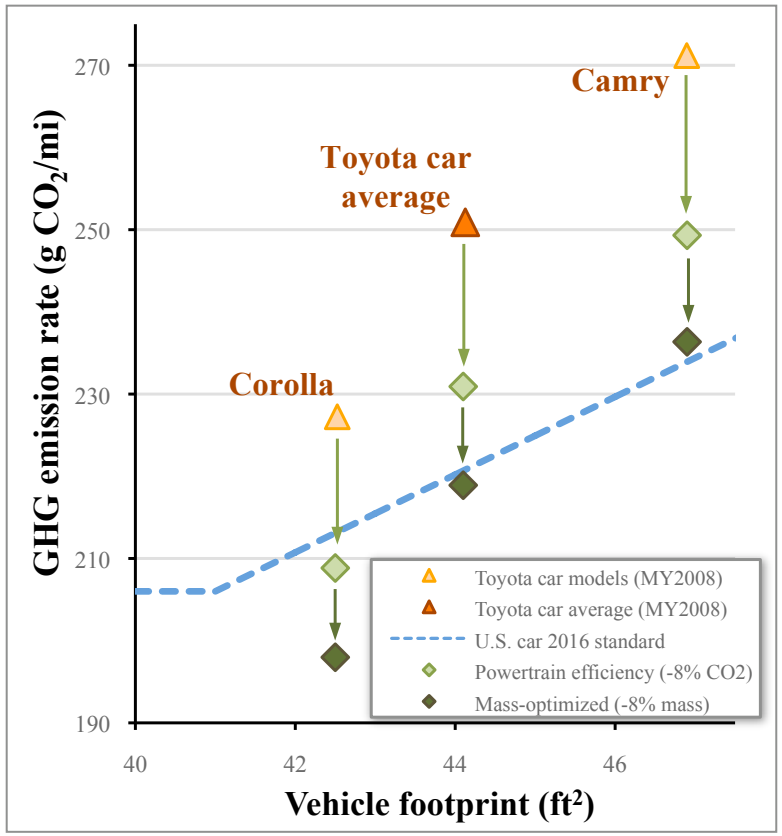
Major On-Going Mass-Reduction Studies

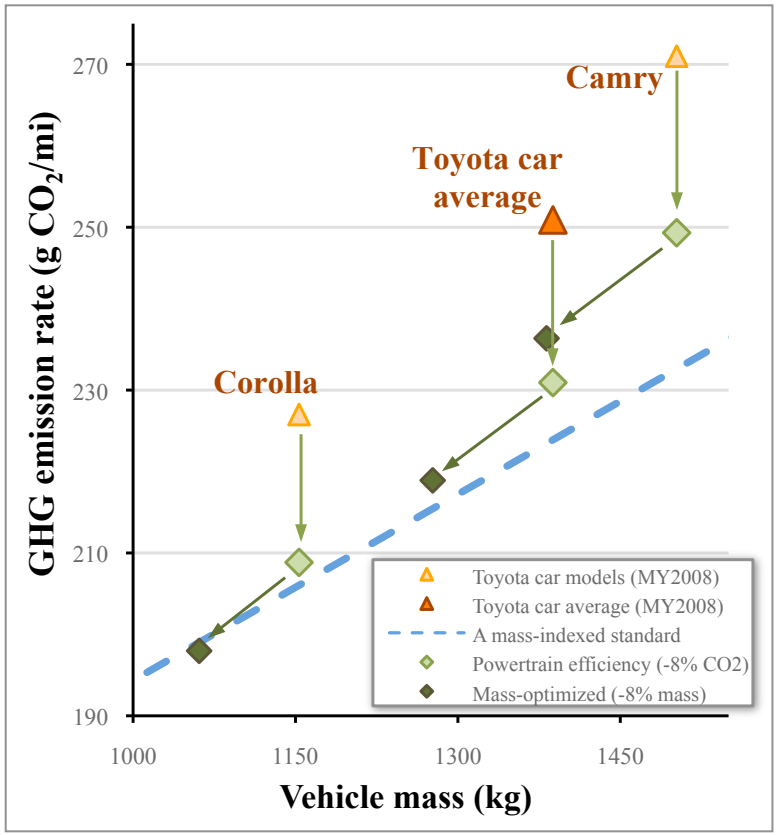
- The three Agency-contracted vehicle mass-reduction studies….
  - Advance the state-of-the-art in modeling technical potential with finite element analysis, CAD/CAE design, crashworthiness, compatibility, and cost assessment
  - Will be peer-reviewed and used for the final US GHG regulations (planned August 2012)



Mass-Reduction Policy Implication

- Some standards incentivize mass reduction more than others
  - Of course, any CO_2 regulation incentivizes improved-efficiency powertrains
  - With *same application* of mass reduction technology, there is far lower value in mass-indexed regulatory systems





Conclusions

- Mass reduction costs likely overstated in ICCT cost curves
  - CARB analyses yielded $2.30/lb, versus $4.32 used by EPA and ICCT
  - WorldAutoSteel study showed 18%+ weight reduction at no cost
  - Three new agency studies available August 2012
- US agencies found strong technical basis for mass-reduction as a prominent technology toward 2017-2025 compliance
  - All automakers intend to utilize mass-reduction to help comply
  - HSS and aluminum have better crash properties than mild steel
- Mass reduction includes a set of diverse technical approaches that can be utilized toward CO_2-reduction goals
  - Different advanced materials/designs are being pursued across OEMs
- The regulatory incentive to deploy the technology is weaker when regulatory standards are mass-indexed

Thank You