Aluminum-Intensive Vehicles: Fuel Efficient, Safe and Affordable

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ALCOA

Aluminum Association's Auto and Light Truck Group

AUTOMOTIVE ALUMINUM The Performance Advantage™

The Aluminum Association, Inc.

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Aluminum-Intensive Vehicles: Fuel Efficient, Safe and Affordable

Topics:

Reducing CO_2 Emissions

Performance Advantages

Impact On Fuel Efficiency

Building Safer Vehicles

Aluminum's Performance Advantages

Mass Reduction

Better Fuel Economy

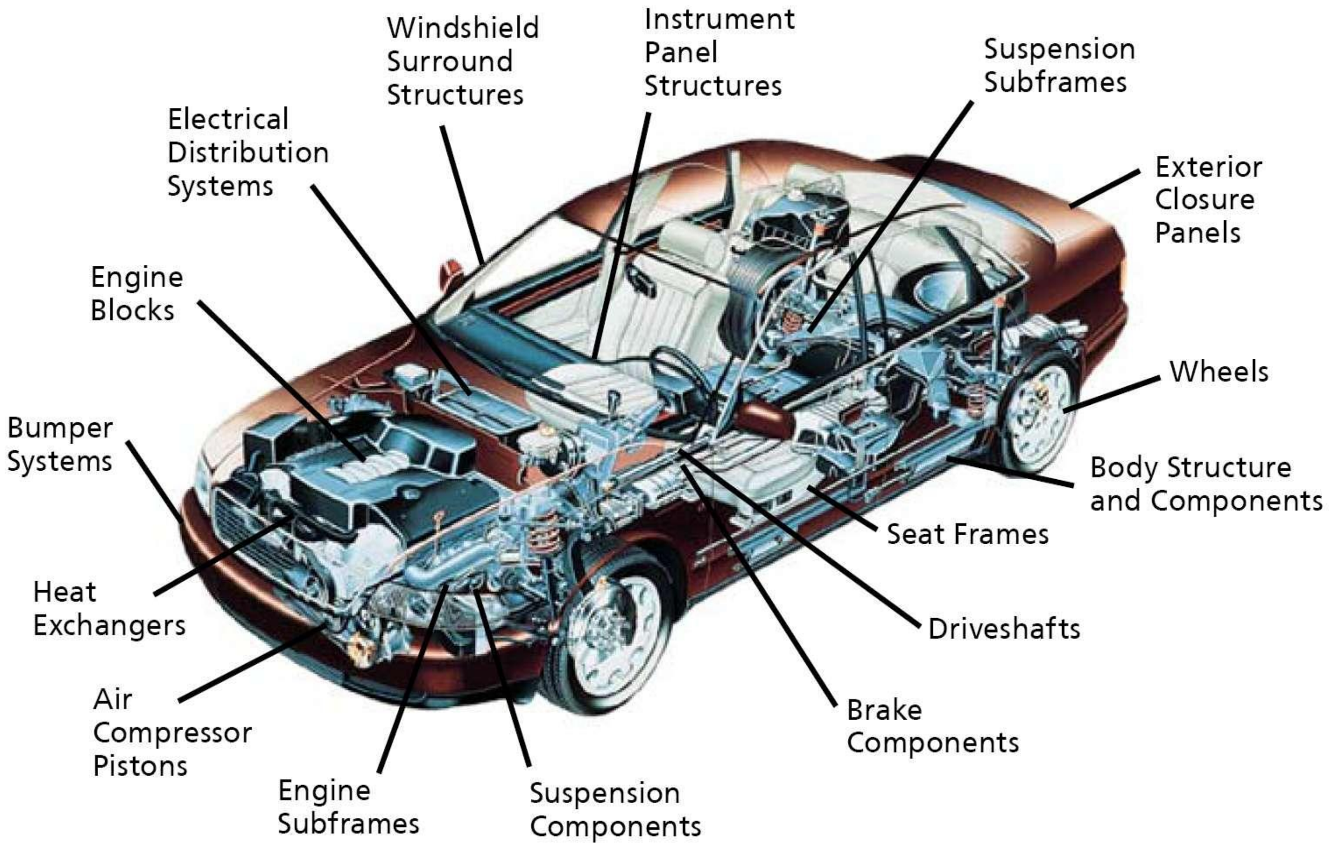
Reduced Emissions

Improved Safety

Enhanced Performance

Infinitely Recyclable

Automotive Aluminum Is Everywhere



Aluminum growth has risen for nearly four decades.

Average vehicle today contains over 320 pounds of aluminum.

Global Megatrends

1 billion global LV population by 2020

Emerging markets growth

Urbanization

Stock of Light -Duty Vehicles

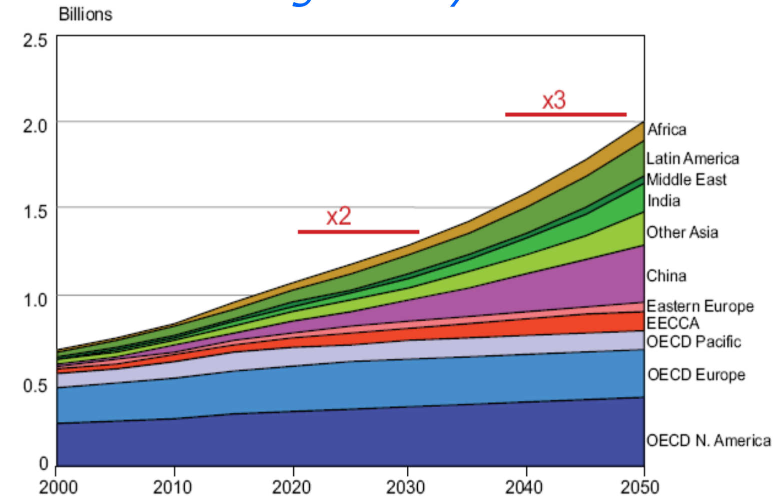


Figure 5.5: *Total stock of light-duty vehicles by region*

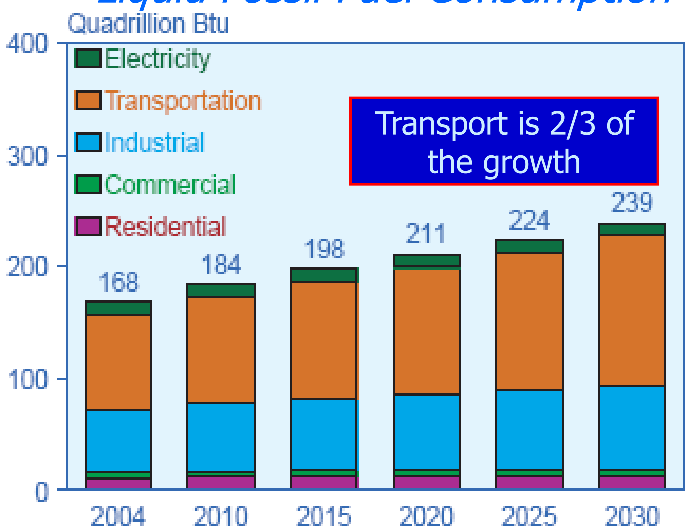
Source: WBCSD, 2004a.

Growing fuel consumption

CO_2 concern

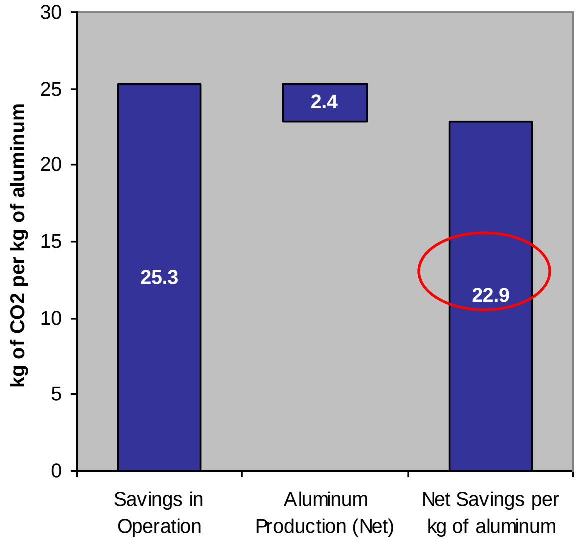
Efficiency of transport must improve

Liquid Fossil Fuel Consumption



Lightweighting With Aluminum Is Part Of Solution

Aluminum saves CO_2 net of its production energy vs. steel

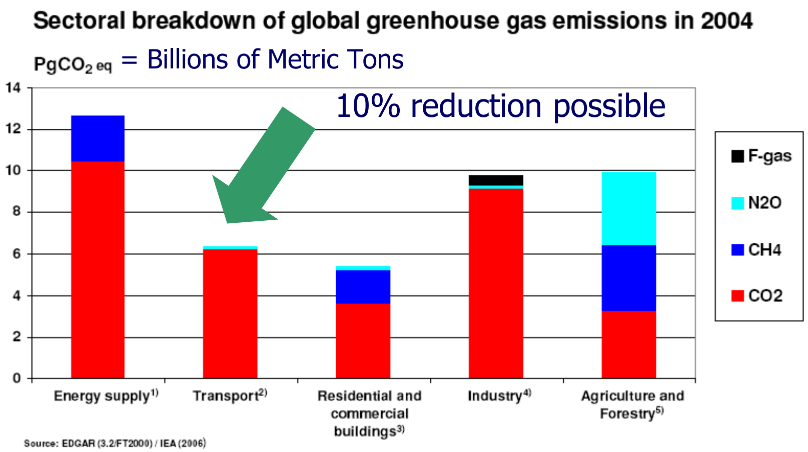


Huge CO_2 and fuel reduction potential

Highly complimentary with advanced drivetrains

Improves safety

Cost effective



5-7% Fuel Savings For 10% Weight Reduction

Ricardo Inc. Study Objectives:

- Quantify impact of vehicle weight reduction (5%, 10%, 20%)
  - Fuel economy
  - Performance
- Quantify impact of weight reduction with engine downsizing
  - Maintain vehicle performance level
- Evaluate weight reduction with different engine types
  - Gasoline
  - Diesel

Source: RICARDO

Vehicle Selection

- From five vehicle classes
  - Representative range of vehicle weights and engines
  - Passenger and light-duty truck
- Vehicle class / comparator vehicle

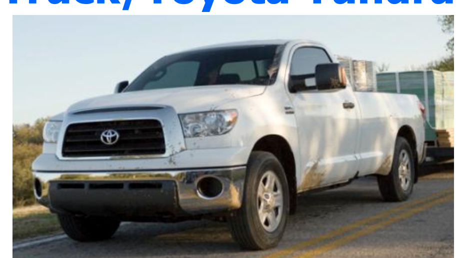
Small Car/Mini Cooper

Mid-Size Car/Ford Fusion

Small SUV/Saturn Vue

Large SUV/Ford Explorer

Truck/Toyota Tundra



Simulation Model

- Physics-based for each configuration
  - Vehicle
  - Engine
  - Driving schedule
- Simulates accelerator and/or braking to achieve driving schedule
- Runs on a millisecond-by-millisecond basis
- Simulates speed and fuel usage
- Industry standard drive cycles (EPA & ECE)

Vehicle Performance Matching

- Matched Wide Open Throttle (WOT) performance
- All fuel economy simulations were performed at ETW
- Accounted for additional cargo weight
- Engines were downsized to give equivalent performance

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Model Validation

- Simulation results compared to published data for comparator vehicle
  - No attempt to "calibrate" models

VEHICLE	Simulation Roadload Force Maximum Variation vs. Comparator	Simulated Fuel Economy vs. Comparator (% diff)		
		EPA City	EPA Highway	Combined
Small Car	0.2%	2.5%	-0.6%	1.3%
Mid-Size Car	2.5%	0.2%	-1.4%	-0.4%
Small SUV	1.1%	1.8%	-4.4%	-0.4%
Large SUV	1.7%	5.9%	-1.1%	3.5%
Truck	-1.3%	2.2%	-1.9%	0.7%

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Equivalent Performance With Less Horsepower

			0 - 10 MPH (sec)	0 - 60 MPH (sec)	30 - 50 MPH (sec)	50 - 70 MPH (sec)
		Baseline	1.49	9.7	3.2	4.6
Weight Reduction	5%	Baseline Engine	1.45	9.4	3.1	4.4
	10%		1.41	9.0	2.9	4.2
	20%		1.34	8.4	2.7	3.8
	5%	Engine Downsized to Baseline Performance	1.51	9.7	3.2	4.6
	10%		1.51	9.7	3.2	4.5
	20%		1.54	9.6	3.1	4.5

Mid-Size Car 3.0L-4V Gas Engine with Variable Intake Cam Timing

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20% Weight Reduction Gives 14.3% MPG Improvement

DRIVE CYCLE			EPA								European	
						FUEL ECONOMY BENEFIT						FE BENEFIT
			City FTP75	Highway HWFET	Combined	City FTP75	Highway HWFET	Combined	City Label	Highway Label	ECE	
			(mpg)	(mpg)	(mpg)	%	%	%	(mpg)	(mpg)	(mpg)	%
		Baseline	22.9	36.9	27.6				18.3	26.4	17.6	
Weight Reduction	5%	Baseline Engine	23.3	37.3	28.0	1.4%	1.2%	1.3%	18.5	26.7	17.8	1.0%
	10%		23.6	37.8	28.4	2.9%	2.4%	2.7%	18.8	27.0	18.0	2.1%
	20%		24.3	38.7	29.2	5.8%	5.0%	5.6%	19.3	27.7	18.3	4.1%
	5%	Engine Downsized to Baseline Performance	23.8	37.9	28.6	3.6%	2.7%	3.3%	18.9	27.1	18.3	4.0%
	10%		24.6	38.9	29.5	7.4%	5.4%	6.7%	19.5	27.8	19.0	7.9%
	20%		26.6	41.0	31.6	15.9%	11.3%	14.3%	21.0	29.3	20.6	16.9%

Mid-Size Car 3.0L-4V Gas Engine with Variable Intake Cam Timing

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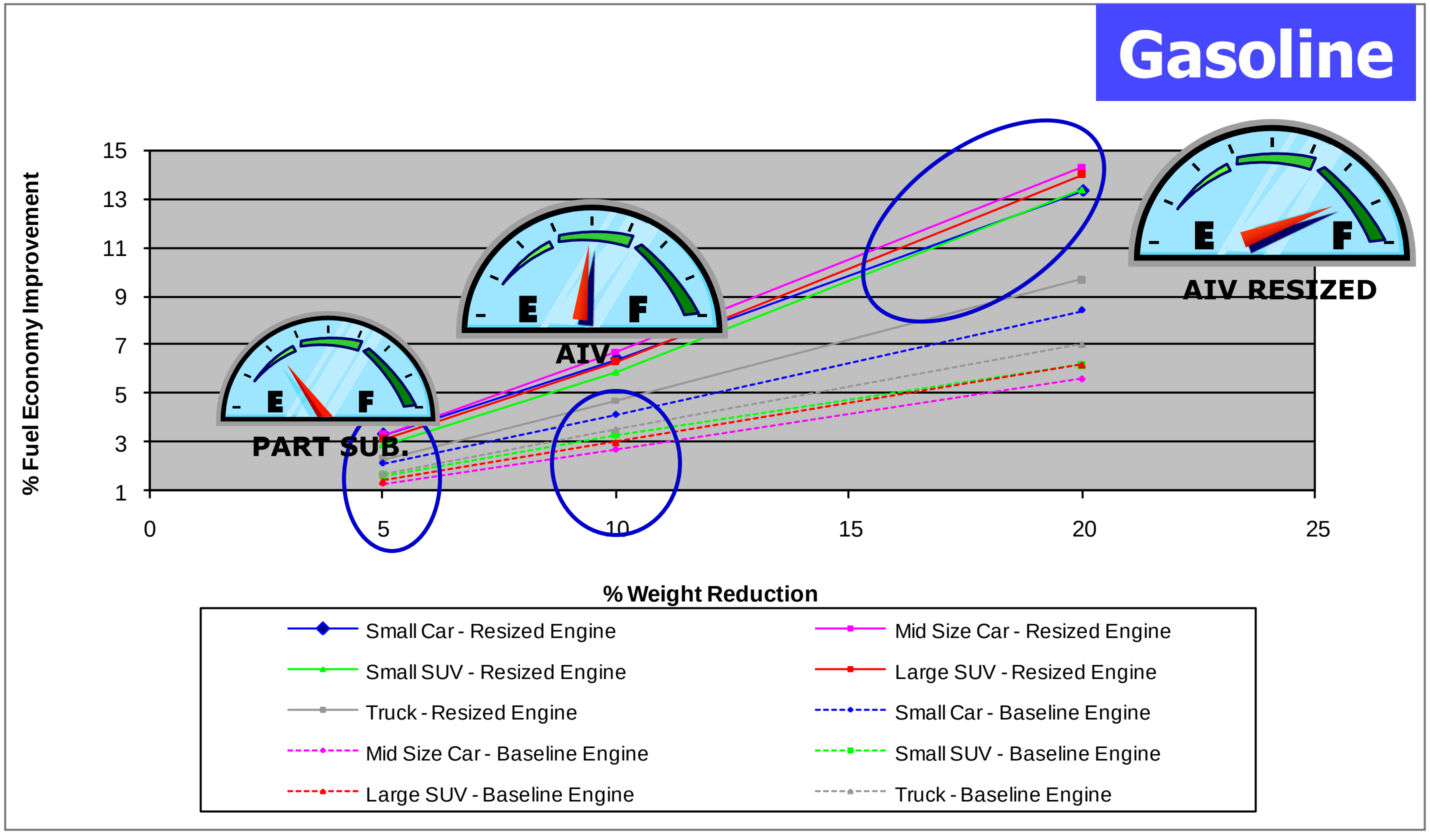
Fuel Economy Universally Improved



Weight Saving Potential With Aluminum

Baseline Vehicle
3500 lbs.

10% Weight Reduction
3150 lbs.

20% Weight Reduction
2800 lbs.

	Aluminum	Steel	Delta (lbs)
Hood	17	31	14
Deck	13.2	24	10.8
Fenders	4.8	9.6	4.8
Fr Doors	40.4	62.2	21.8
Rr Doors	38.4	59.1	20.7
Sum			**72.1**
Cradle	46.2	77	**30.8**
Bumper	13.2	19.8	**6.6**
Wheels	167.2	180.4	**13.2**
Suspension	88	103.4	**15.4**

Possible Fuel Economy Savings Up To 14.3%

- Fuel economy improvement of 5-7% is expected with 10% reduction in weight
- Excellent correlation between simulation and actual vehicle
- Similar results for gasoline and diesel engine vehicles
- What about hybrids and advanced powertrains?

Source: RICARDO

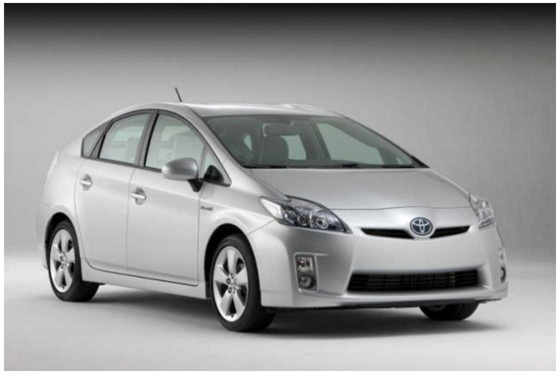
Weight And Alternative Powertrain Equation

Future offers lighter, cleaner vehicles for all consumers.

Chevy Tahoe (Hybrid Electric)

Chevy Volt
(Plug-In Hybrid)

Honda FCX Clarity
(Fuel Cell)



Toyota Prius
(Hybrid)

More Cost Effective To Reduce Mass

	Steel Baseline	Aluminum Baseline	Steel Hybrid	Aluminum Hybrid	Steel Diesel	Aluminum Diesel
Cost $ (BIW+Panels+PowerTrain)	5532	5642	8016	7787	6629	6737
Combined Mileage MPG	25.2	27.7	34.8	38.2	33.5	36.8
Mileage Improvement Over Steel Baseline MPG (%)		2.5 (9.9%)	9.6 (38.1%)	13 (51.6%)	8.3 (32.9%)	11.6 (46.0%)
Delta Cost per 1MPG improvement $/MPG		44	259	173	132	104

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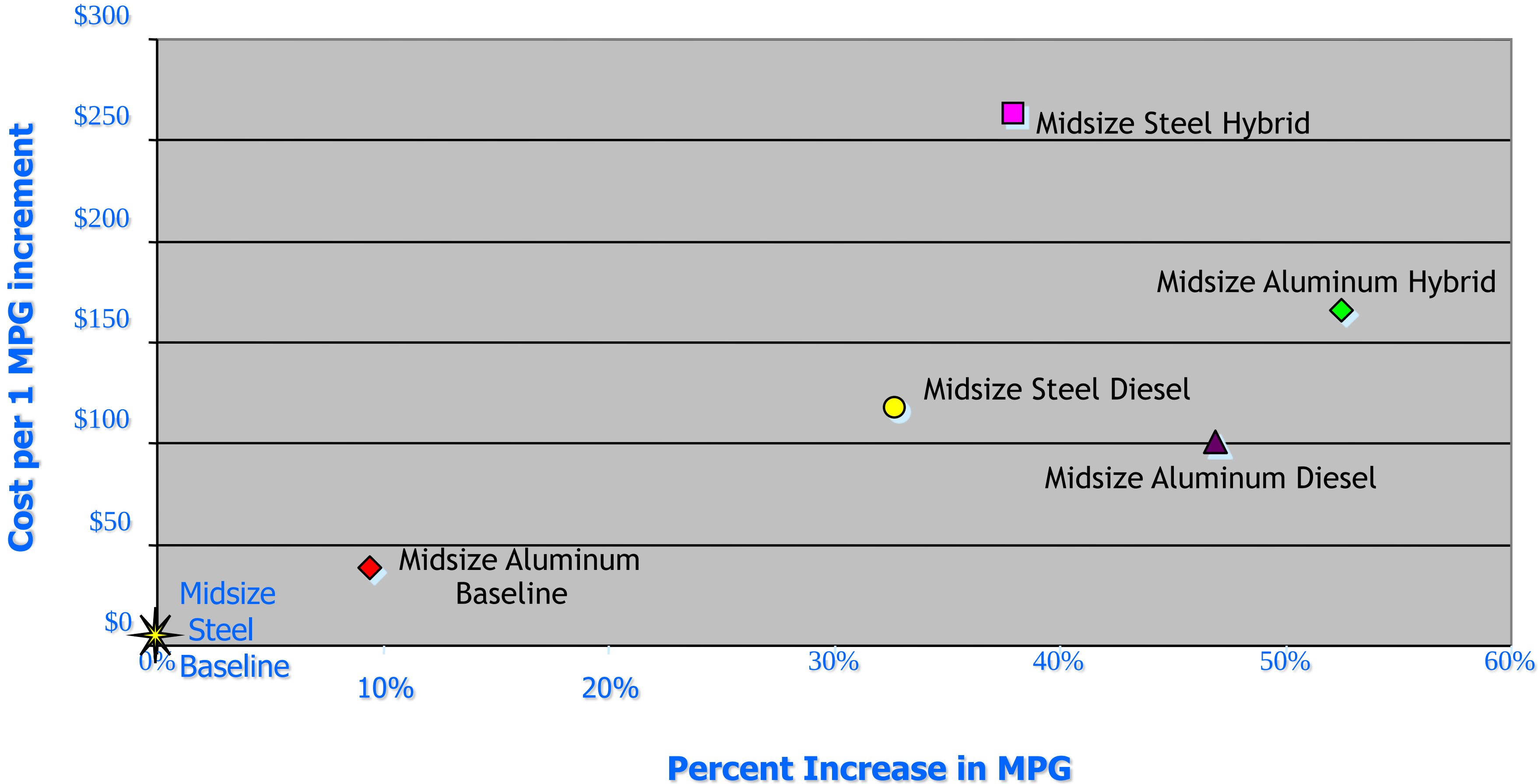
Maximizing Powertrains In Cost-Effective Manner



Key Takeaway:
Aluminum Is Fuel-Efficient Solution

- Use of aluminum boosts fuel economy
  - 5 % to 7% fuel saving can be realized for every 10% weight reduction

- Provides even greater benefits – including cost savings – when used as a complement to advanced powertrains
  - Quicker payback period for consumer

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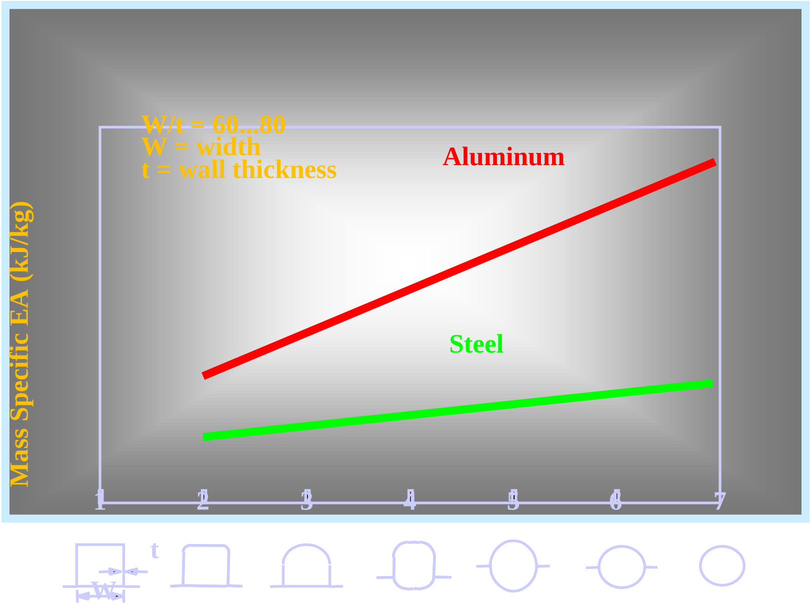
Reduce Weight, Not Size

- Direct benefits:
  - Absorbs more energy, pound for pound, than steel
  - Predictable deformation
  - Not strain-rate sensitive
  - Extruded structures – design flexibility

Better crash compatibility – reduce weight, not size



Building Safer Vehicles With Aluminum

- Secondary benefits:
  - Handling (accident avoidance) advantages
  - Braking distance reduction
- We believe aluminum can build a safer car than steel

Jaguar XJ

Audi A8

Studying Affect Of Weight On Safety

- Objective of the DRI (Dynamic Research Inc.) Study:
  - - Interplay of vehicle weight vs. size in occupant protection
- Methodology:
  - - Real-world crash data from 3500 collisions
  - - Car to SUV, SUV to SUV, and SUV to fixed obstacle
  - - NCAP pulse and NASS/CDS descriptors
  - - ELU (Injury Index) as proxy for occupant safety

- Scenarios:
  - - 20% weight reduction – no length reduction
  - - 4 inch length increase – no weight increase

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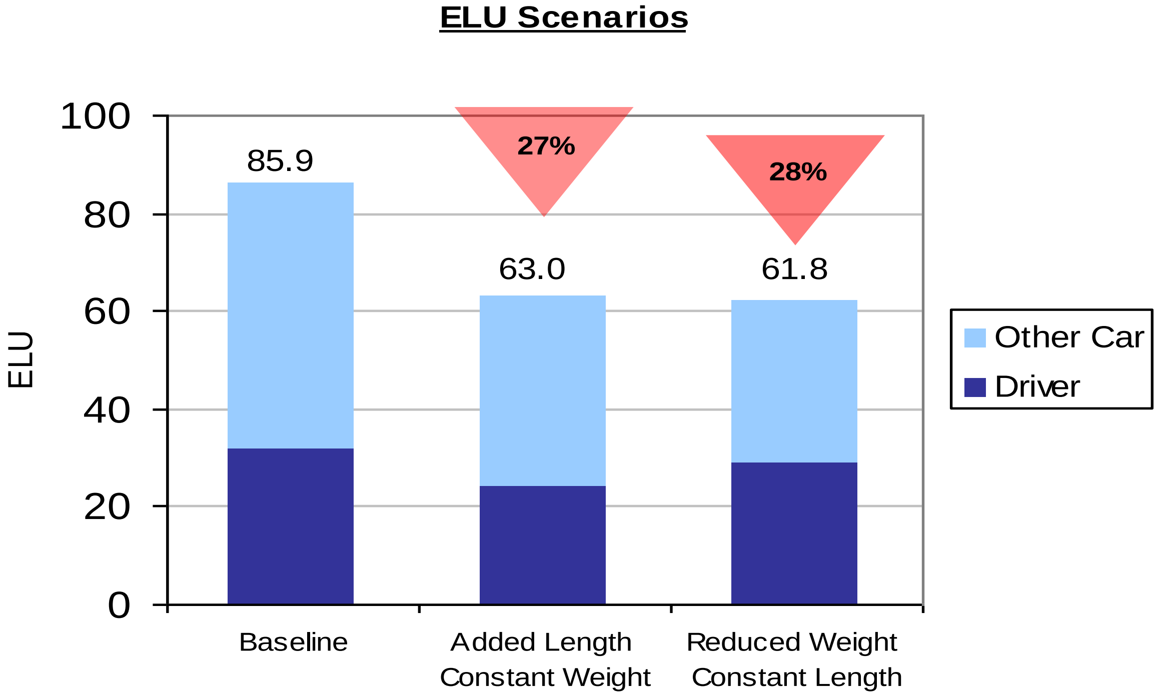
Improving Occupant Safety

- Adding crush space without adding weight improves ELU 27%
- Reducing weight further improves fleet safety



SUV to Car Crashes

Improving Occupant Safety

	Crash Type	Number of Cases	Total ELU's Baseline Case SUV	Total ELU's Reduced Weight Case SUV	Total ELU's Increased Length Case SUV	Net Benefit (%) Reduced Weight Case SUV	Net Benefit (%) Increased Length Case SUV
SUV Driver	Rollover	175	2.23	2.48	0.53	-11.2	76.2
SUV Driver	Hit Object	420	2.54	1.74	0.81	31.5	68.1
SUV Driver	Hit PC	1750	1.21	2.47	1.19	-104.1	1.7
SUV Driver	Hit LTV	1155	25.97	22.03	21.61	15.2	16.8
	Subtotal	3500	31.95	28.72	24.14	10.1	24.4
OV Driver	In PC	1750	28.00	9.70	16.79	65.4	40.0
OV Driver	In LTV	1155	25.99	23.40	22.09	10.0	15.0
	Subtotal	2905	53.99	33.10	38.88	38.7	28.0
	Overall Total	3500 SUV + 2905 OV	85.94	61.82	63.02	28.1	26.7

20% Reduced Weight SUV and Conventional Cars

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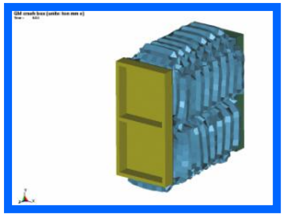
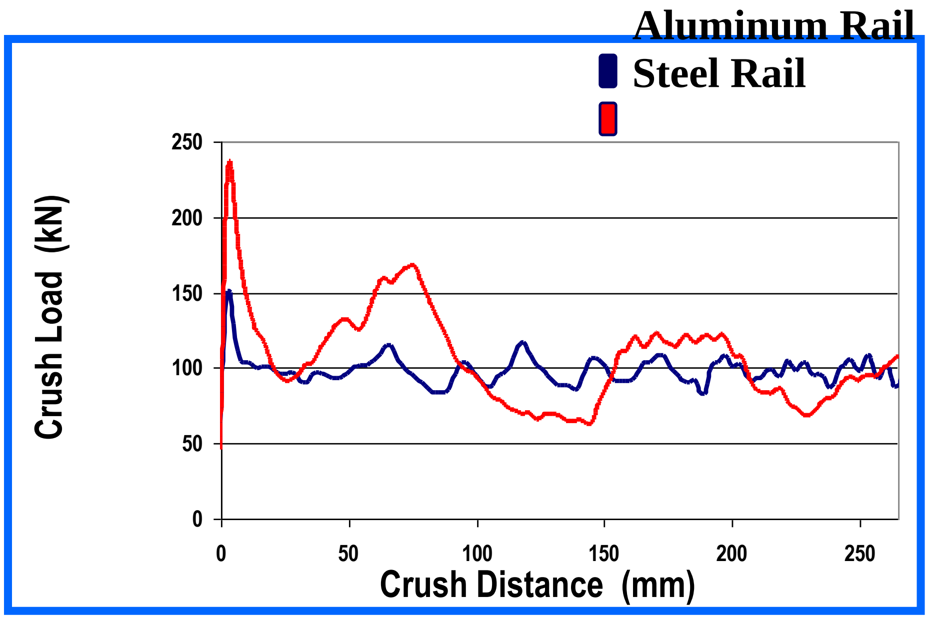
Aluminum Safety In Action

Crush Rail:

- 56% mass savings vs. mild steel – (38% vs. HSS)
- Lower peak loads
- Consistent crush performance at all speeds



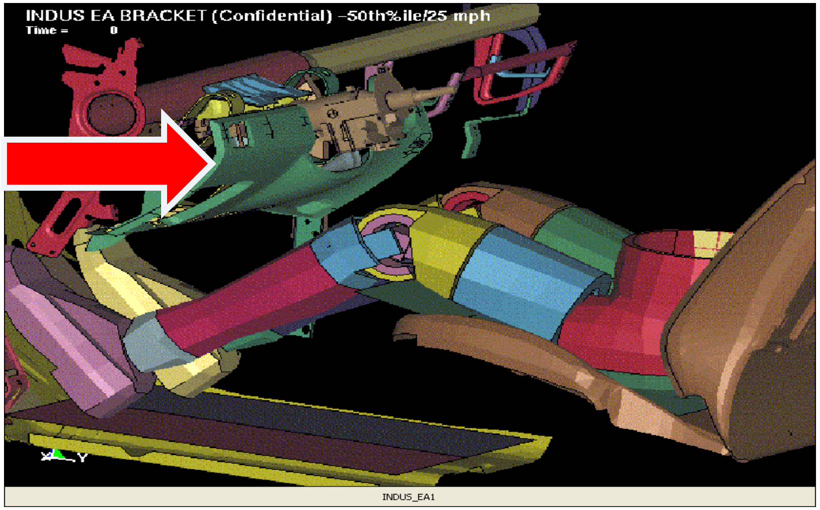


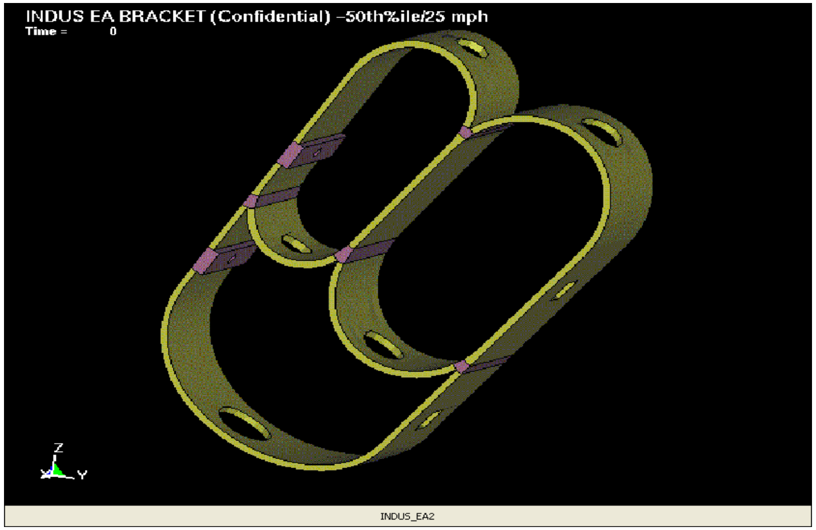
Aluminum Safety In Action

Knee Bolster:

Aluminum can play a key role in energy management in vehicle interiors

- Example:
  - Extruded knee bolster consolidates three parts into one
  - 48% weight reduction vs. steel
  - 50^{th} percentile male unbelted sled test passed for a N. American OEM





Key Takeaways: Weight Reduction Proves Beneficial To Safety

- Size – not weight – is best determinant of vehicle safety
- Aluminum can safely take weight out
- Aluminum performs as well, if not better than steel in crash
- Aluminum offers design flexibility and innovative solutions for energy management

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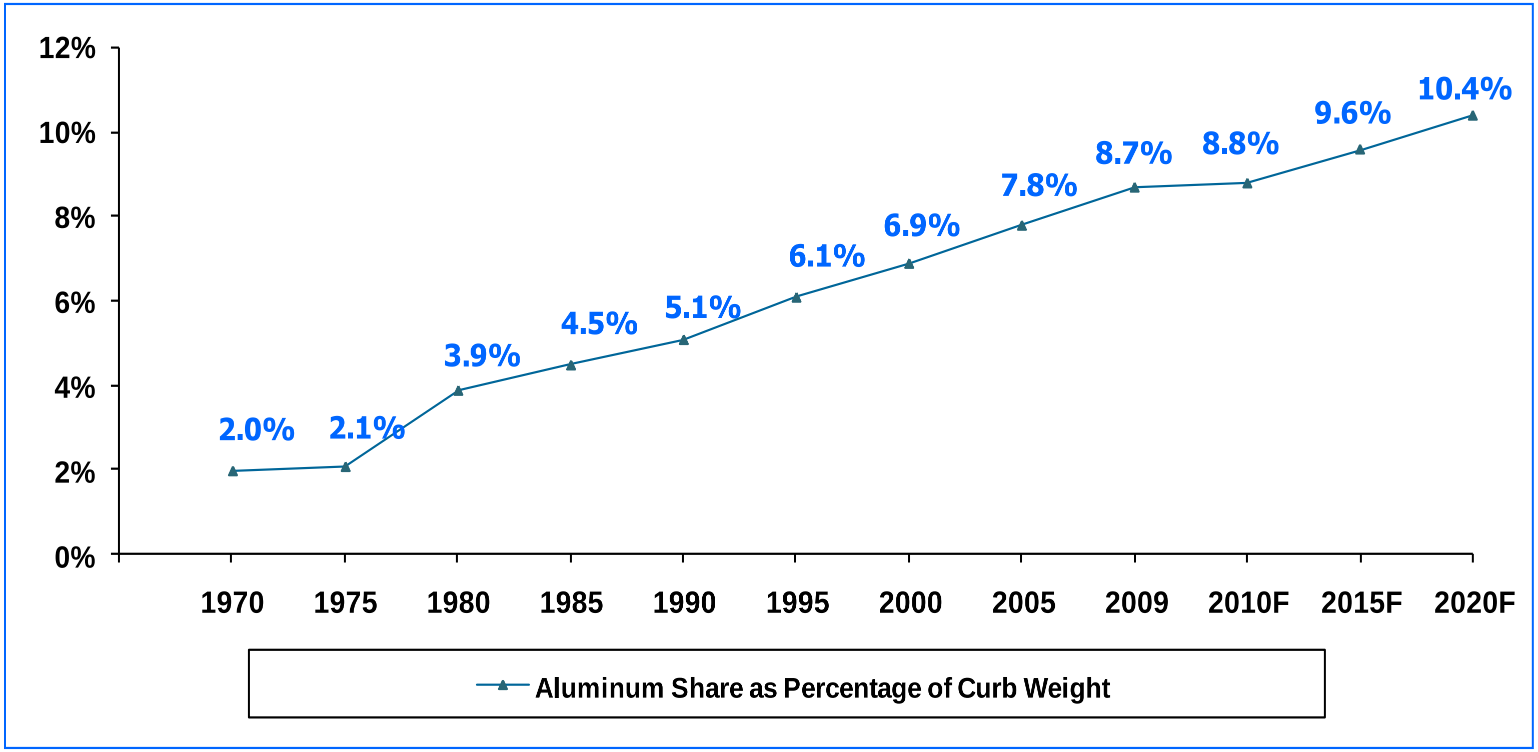
Auto Aluminum Use Climbs

North American Light Vehicle Aluminum Content



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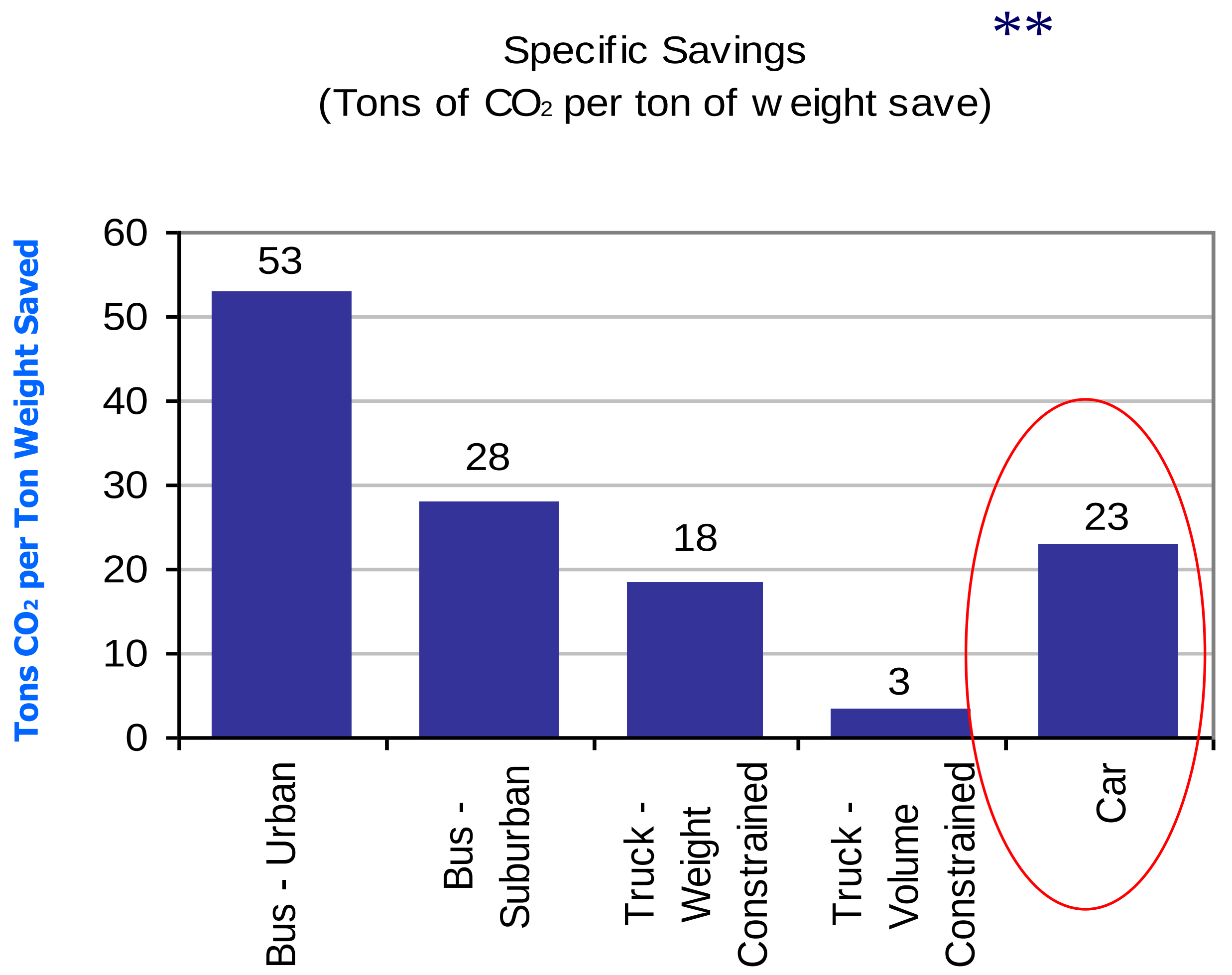
DUCKER WORLDWIDE

All Modes of Transport Benefit

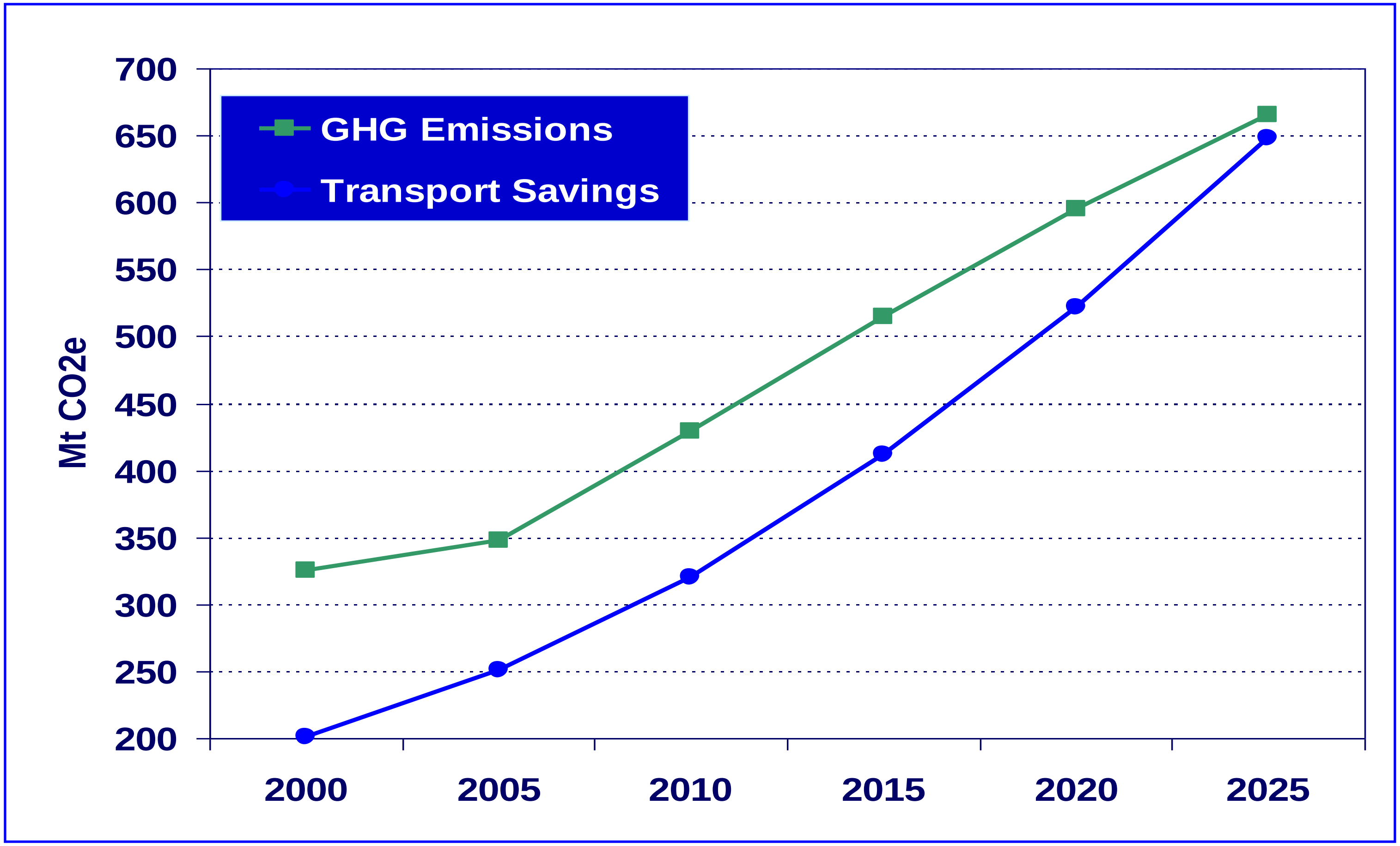


Potential Weight Savings: 3000-3500 lbs | 3500-4500 lbs | 300-500 lbs

IFEU Heidelberg study 2003 for EAA

** vs. steel

Aluminum Potential To Be GHG-Neutral



Potential emissions savings from transport growing faster than emissions from aluminum production

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