FutureSteelVehicle

Phase I Report

Nature's Way to Mobility

History (1)

- Steel industry's series of initiatives
  - Increase the fuel economy
  - Reduce Green House Gas emissions
  - Improve safety, performance
  - Maintain affordability

- 1998, Ultra-Light Steel Auto Body (ULSAB)
- 2000, Ultra-Light Steel Auto Closures (ULSAC)
- 2000, Ultra-Light Steel Auto Suspension (ULSAS)
- 2001, ULSAB-AVC (Advanced Vehicle Concepts)

History (2)

ULSAB
UltraLight Steel Auto Body

ULSAC
UltraLight Steel Auto Closures

ULSAS
UltraLight Steel Auto Suspensions

ULSAB-AVC
Advanced Vehicle Concepts

TIMELINE

History of Steel Industry Innovation

1998 — UltraLight Steel Auto Body

- Mass savings of 25% over the benchmark at no cost penalty
- First demonstration in the world of extensive (80%) High-Strength Steel (HSS) use

2000 — UltraLight Steel Auto Closures

- Up to 46% lighter than the average benchmark
- First demonstration of ultra-thin (0.6 mm) Dual Phase Class A surface materials

2002 — UltraLight Steel Auto Suspensions

- Mass savings up to 34% at no additional cost
- Matched aluminium design mass, while achieving 30% cost benefit

2003 — ULSAB (Advanced Vehicle Concepts)

- Fuel Efficient (3.2 to 4.5 L/100 km; 52 to 73 MPG) at no cost penalty
- Low GHG Emissions
- Demonstration of HSS and Advanced High-Strength Steel (AHSS)

2011 — FutureSteelVehicle

- 177 kg body structure mass
- 97% use of HSS and AHSS
- Nearly 50% GigaPascal Steels
- Low Total Life Cycle Emissions
- Mass savings at no cost penalty
- Near-term production applicable

2020-22 — Steel E-Motive

STEEL E-MOTIVE

IN PARTNERSHIP WITH

WorldAutoSteel

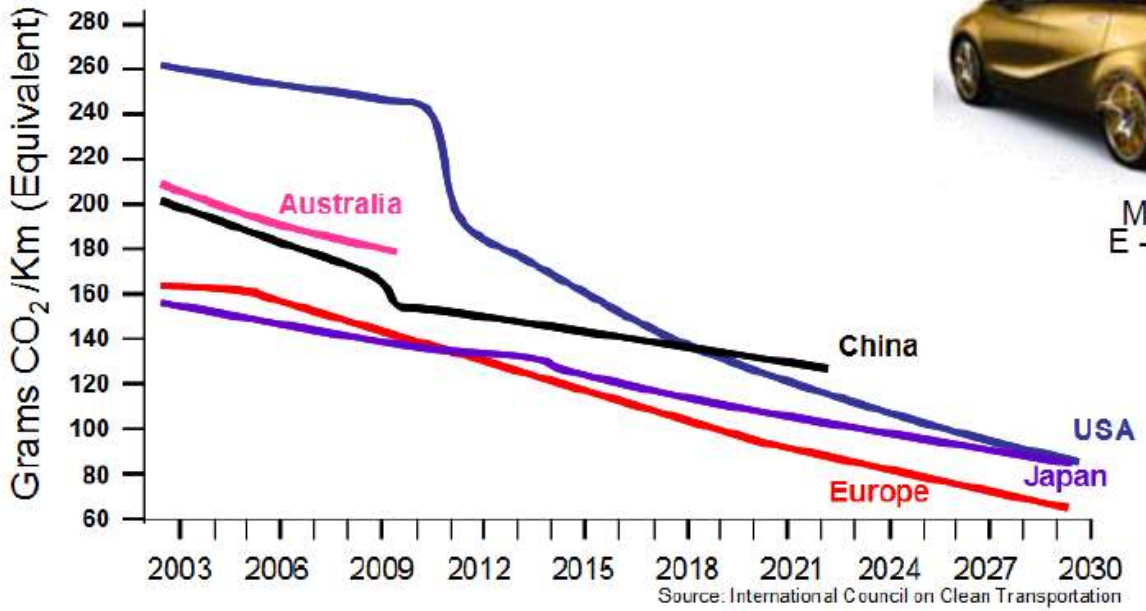
RICARDO

Steel E-Motive, a new steel industry collaboration, will demonstrate the benefits of steel for global mobility as a service (MaaS) challenges, characterized by fully connected and autonomous electric vehicles.

www.steelemotive.world

Background

More Aggressive Automotive Fuel Economy and CO_2 Emissions Regulations



Honda Clarity FCX

Mercedes
E -Cell Plus

Mercedes F-Cell

Early Introductions of Dedicated Platforms for Advanced Powertrain Vehicles

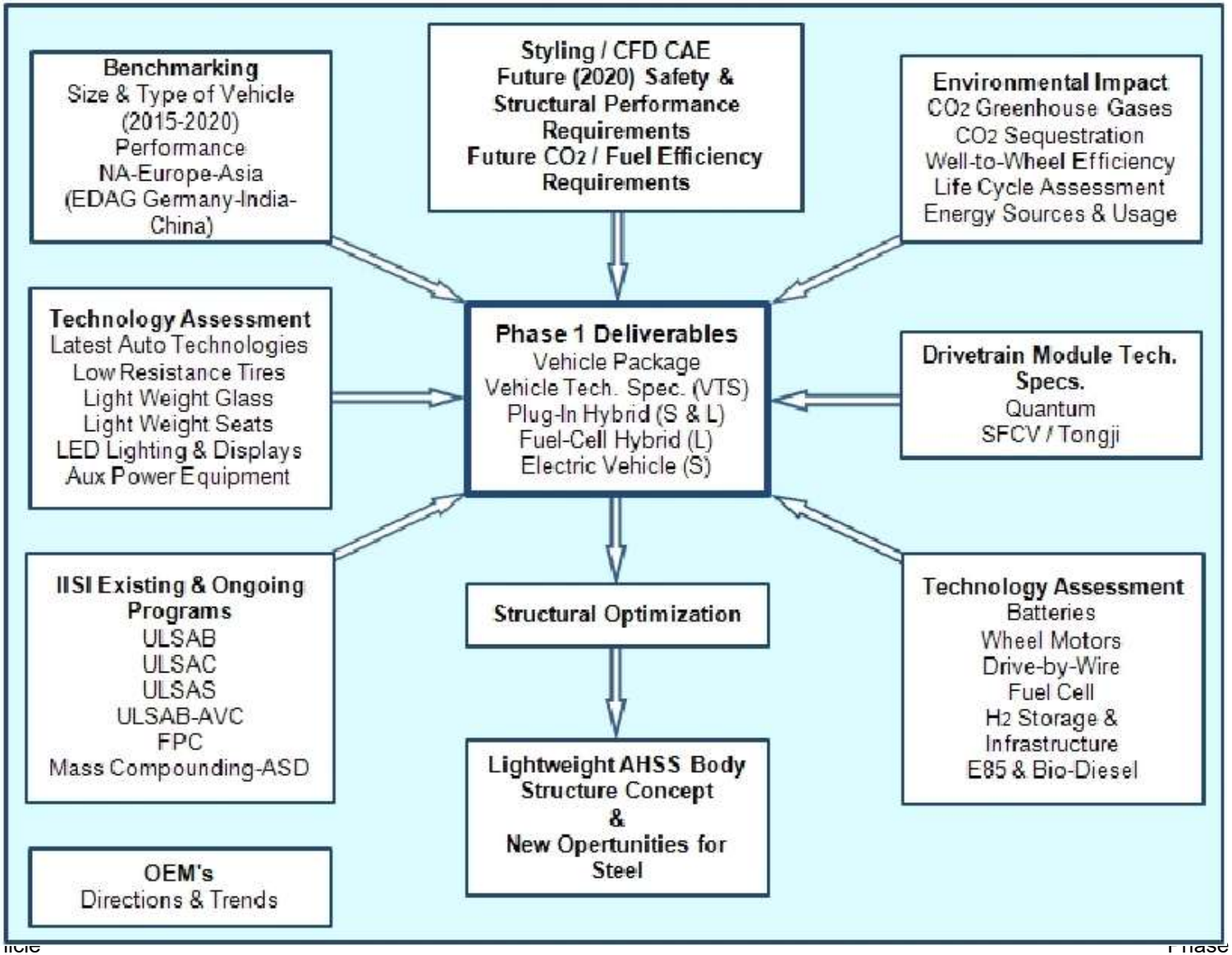
Future Steel Vehicle (FSV)

- Launched at the 2007 United Nations Climate Change Conference in Bali
- Multi-million Euro, three-year programme to deliver safe, light weight Advanced High-Strength Steel (AHSS) body structures
  - address radically different requirements for advanced powertrains
  - reduce Greenhouse Gas (GHG) emissions over the entire life cycle
- Application of lightweight multi-grade advanced high strength all steel body structures in vehicle designs using advanced powertrain technologies
- Holistic approach to the concept development of innovative vehicle layout and optimized vehicle body structure, using the latest advanced steels and manufacturing technologies
- Computer aided optimization techniques, to achieve an optimal mass efficient design

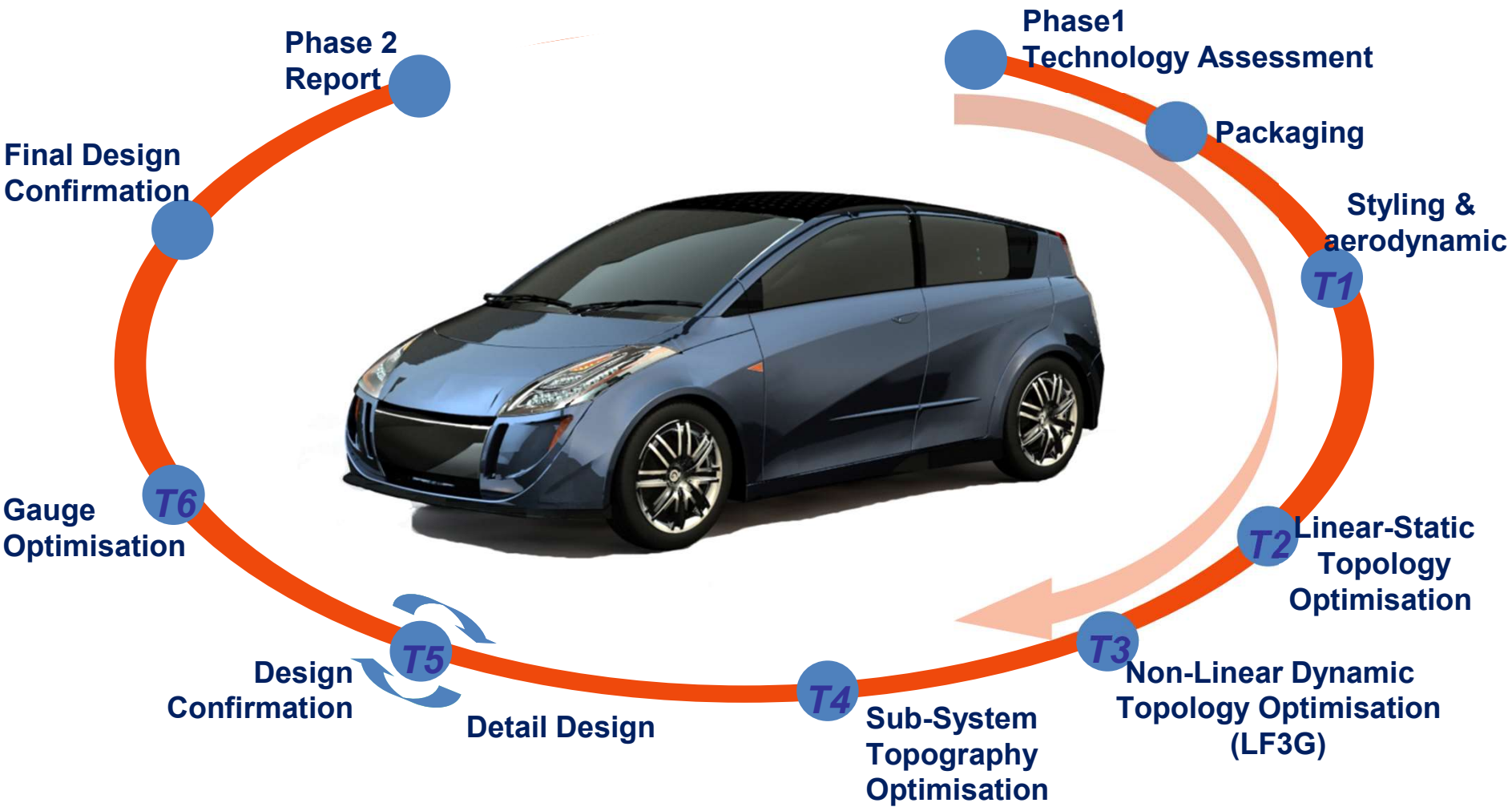
Project Objectives

- Meet year 2015-2020 performance criteria while achieving a 35% mass reduction target in addition to a detailed project cost analysis and life cycle impact assessment
  - Phase 1: Engineering Study (2008 - July, 2009)
    - Comprehensive assessment and identification of advanced powertrains and future automotive technology applicable to high-volume vehicle production in the 2015-2020 timeframe
  - Phase 2: Concept Designs (August, 2009 - 2010)
    - Designing optimised AHSS body structures for four proposed vehicles
  - Phase 3: Demonstration and Implementation (2011 - 2012)

Phase 1: Engineering Study



Phase 2: Overview



Contents

- Market Analysis
- Future Steel Vehicle Propulsion Systems
- Future Steel Vehicle - Technology Implementation
- Vehicle Package Development
- Sensitivity Analysis
- Environmental Impact
- Advanced Powertrain Technologies
- Steel Technologies
- Other Advanced Technologies
- FSV Structure Design Methodology

Market Analysis

- Global market analysis
- OEM directional trends
- Alternative propulsion vehicles benchmarks
- Future safety requirements
- Future fuel economy requirements
- Future ozone emission standards
- Vehicle classification

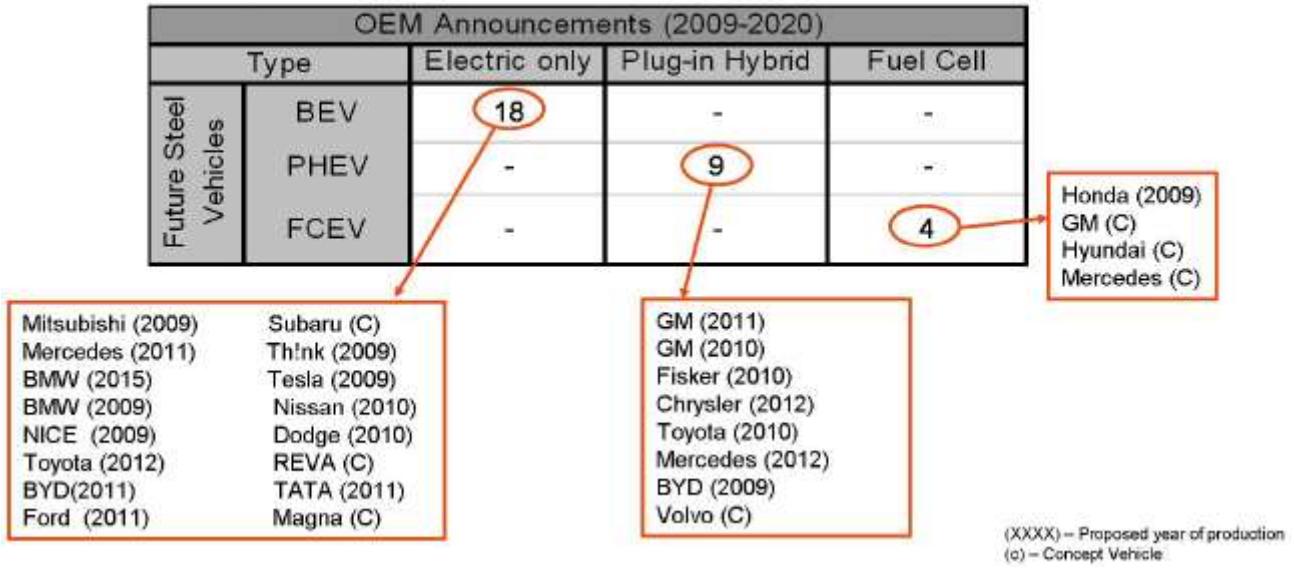
Global Market Analysis

- Small cars represented 25% of new car sales globally in 2005, but this ratio is expected to rise to 31% in 2010
- 80% of this demand is expected to come from the developing economies of India and China
- India and China are expected to lead the growth trend with 11% and 34% of the global output of low-cost cars by 2014
- By 2012, consumers around the world are expected to buy a record 29 million small cars annually, up 65% from a decade earlier
- Small cars account for more than 70% of the Indian car market
- Mini cars account for 35% of total volumes in Japan. The demand for mini vehicles in the Japanese market is expected to grow, eventually pushing sales past 2 million units per year
- A large number of Japanese consumers are moving from luxury cars to mini-cars due to environmental standards and increasing gas prices

OEM Directional Trends

- Conventional internal combustion engine (ICE) based vehicles that are smaller, and utilize more efficient gasoline/diesel engines
- Higher-efficiency hybrids (HEV) predominantly using fossil based petroleum fuels
- Plug-in hybrids (PHEV) with limited range of miles driven in electric mode. This option offers a significant reduction in fossil based petroleum usage, especially when the daily miles driven are close to the vehicle's electric range. The additional miles being driven above the vehicle's electric range, using petroleum or bio-fuels
- Battery Electric Vehicles (BEV) with a driving range of approximately 200 km
- Fuel Cell Electric Vehicles (FCEV) using hydrogen gas as a fuel source

OEM Announcements



- Exterior dimensions
- Luggage volumes
- Seating capacities
- Performance
  - Vehicle range (km)

- 0-100 km/h performance
- Top speed performance
- Drivetrain specifications
- Material of choice for body-structure, closures and sub-frames

Battery Electric Vehicles

Vehicle	Manufacturer	FSV	Mitsubishi	Mercedes	BMW	Toyota
	Name	BEV	I Miev	E cell	Mini-e	EV
	Production year	2020	2009	2011	2009	2012
	Picture					
Exterior Dimensions	Length (mm)	3700	3395	4220	3714	3048
	Width (mm)	1680	1475	1890	1683	1676
	Height (mm)	1518	1600	1590	1407	1498
	Wheel base (mm)	2524	2550	unknown	2467	1998
	Curb Weight (kg)	1234	1080	unknown	1465	unknown
	Seating capacity	4+	4+	5	2	3+1
	Luggage volume (L)	250	246	500	60	unknown
Performance	All Electric Range(km)	250	160	190	250	80
	0-100kmph (secs)	10-12	9	10.8	8.4	unknown
	Top Speed (kmph)	150	155	150	152	112
Drive Train / Battery	Battery Technology	Li-ion	Li-ion	Li-ion	Li-ion	Li-ion
	Battery Capacity (Kwh)	35	16	35	35	11
	Battery Weight (kg)	345	200	unknown	260	unknown
Drive Train / Motor	Electric motor PP (kw)	67	47	100	150	45
Material Usages	Body Structure	Steel	Steel	Aluminum	Steel	Steel
	Closures	Steel	Steel	Aluminum	Steel	Steel
	Sub Frames	Steel	Steel	Aluminum	Steel	Steel
Estimated Cost	purchase cost (USD)		28000		60000	
	lease cost (USD/month)		NA		850	

Benchmark Vehicle Selection

- 2009 Mitsubishi i-MiEV: FSV-1
- 2011 Chevrolet Volt: FSV-2 PHEV
- 2009 Honda Clarity FCX: FSV-2 FCEV
- Mercedes Blue-Zero concepts: E Cell, F Cell, E Cell+


2020 FSV1 BEV

2010 Mitsubishi IMiev


Mercedes E cell (prototype)


2020 FSV2 PHEV$_{40}$


2011 Chevrolet Volt


Mercedes E cell Plus (prototype)


2020 FSV2 FCEV


2009 Honda Clarity FCX


Mercedes F cell (prototype)

Benchmark Study

- Exterior Dimensions
- Material Usage
- Powertrain Packaging
- Electric Drive Components: battery module, traction motor, inverter and DC/DC converter
- Packaging: underhood, rear
- Suspension: front, rear
- Tires and Wheels
- Interior: passenger compartment, instrument cluster, shifter
- Safety: underbody structure

Future Safety Requirements

- US
  - Mandatory regulations: FMVSS
  - Consumer metrics tests: NCAP, IIHS

Regulation	Timeline	Mass	Cost	Fuel Used
Roof Crush/Rollover (FMVSS 216)	2016	~ 2 kg	$54	N/A
Roof Crush/Rollover (IIHS)	2016	~ 2 kg	N/A	N/A
Electronic Stability Control (ESC)	2011	~ 1 kg	$92.00	9.8 l (2.6 ga)
Pole Impact	2012	~ 6-8 kg	$208.00	N/A
Frontal Impact	TBD	N/A	N/A	N/A
Bumper Impact	2008	1 kg	N/A	N/A
Ped-Pro	2011	1-2 kg	N/A	N/A

Future Fuel Economy Requirements: US

- Environmental Protection Agency (EPA) operating under the Department of Transportation (DOT)
  - U.S. Department of Energy (DOE) to publish the annual Fuel Economy Guide
  - U.S. Department of Transportation (DOT) to administer the Corporate Average Fuel Economy (CAFE) program
  - Internal Revenue Service (IRS) to collect gas guzzler taxes

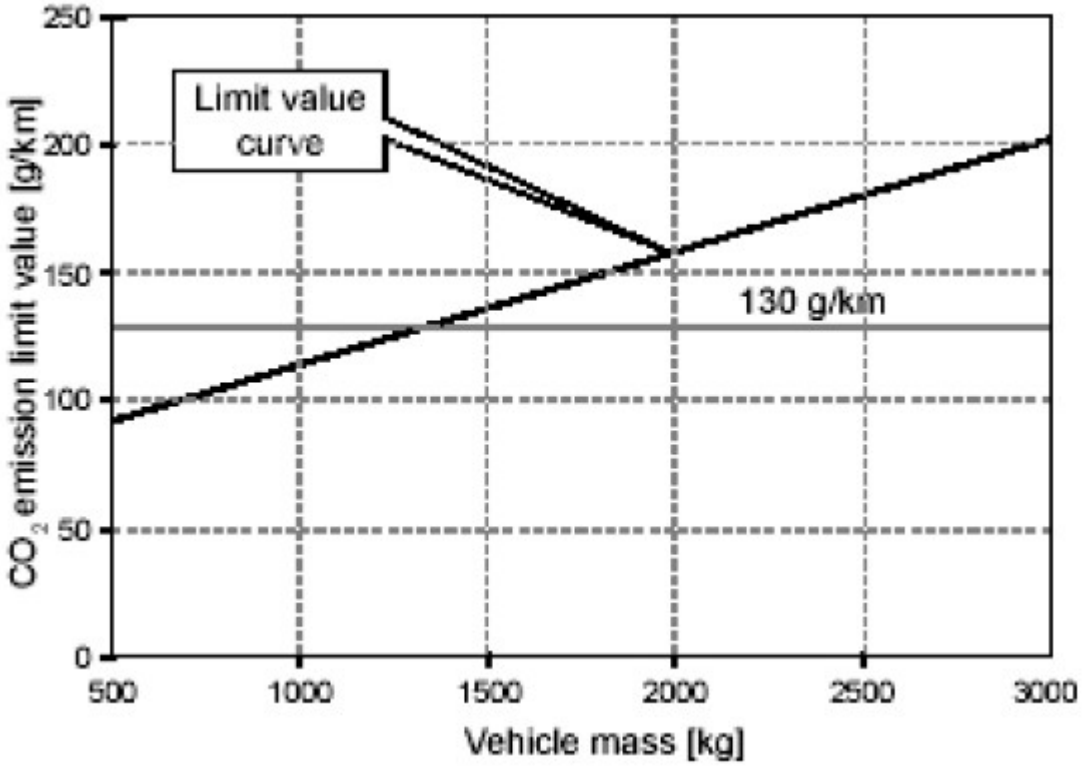
CO_2 Emissions		Fuel Economy			
		Gasoline		Diesel	
year	$[\frac{g(CO_2)}{km}]$	[mpg]	[km/l]	[mpg]	[km/l]
2008	200	27.46	11.67	31.51	13.39
2008	160	34.33	14.59	39.39	16.74
2015	153	35.70	15.17	41.19	17.51
2012	130	42.25	17.96	48.48	20.60
2012	120	45.77	19.45	52.52	22.32
2020	95	57.82	24.57	66.34	28.20

CO2 emissions from a gallon of **gasoline** = 2,421 g x 0.99 x (44/12) = 8,788 g = 8.8 kg/gallon = 19.4 lbs/gallon
CO2 emissions from a gallon of **diesel** = 2,778 g x 0.99 x (44/12) = 10,084 g = 10.1 kg/gallon = 22.2 lbs/gallon

Data source: US EPA

Future Fuel Economy Requirements: EU

- Average CO_2 emissions of new passenger cars
  - 130 g/km by 2012, 95 g/km by 2020



Future Ozone Emission Standards

g/mi	Durab.	Bin 8	Bin 7	Bin 6	Bin 5	Bin 4	Bin 3	Bin 2
NMOG	50 k	0.100	0.075	0.075	0.075			
	120 k	0.125	0.090	0.090	0.090	0.070	0.055	0.010
CO	50 k	3.400	3.400	3.400	3.400			
	120 k	4.200	4.200	4.200	4.200	2.100	2.100	2.100
NOx	50 k	0.140	0.110	0.080	0.050			
	120 k	0.200	0.150	0.100	0.070	0.040	0.030	0.020
PM	120 k	0.020	0.020	0.010	0.010	0.010	0.010	0.010
HCHO	50 k	0.015	0.015	0.015	0.015			
	120 k	0.018	0.018	0.018	0.018	0.011	0.011	0.004

Table 3.42: *US EPA - emission limits*

g/mi	Durab.	LEV_2	$ULEV_2$	$SULEV_2$	ZEV_2
NMOG	50 k	0.075	0.040	-	0
	120 k	0.090	0.055	0.010	0
CO	50 k	3.400	1.700	-	0
	120 k	4.200	2.100	1.000	0
NOx	50 k	0.050	0.050	-	0
	120 k	0.070	0.070	0.020	0
PM	50 k	-	-	-	0
	120 k	0.010	0.010	0.010	0
HCHO	50 k	0.015	0.008	-	0
	120 k	0.018	0.011	0.004	0

Table 3.43: *CARB emission limits*

Low Emission Vehicle (LEV)

Ultra Low Emission Vehicle (ULEV)

Super Ultra Low Emission Vehicle (SULEV)

Zero Emission Vehicle (ZEV)

Tier	Date	CO	HC	NOx	HC+NOx	PM
EM1	1989	2.72 (3.16)	-	-	0.97 (1.13)	-
Euro 2	1993	2.20	-	-	0.50	-
Euro 3	1997	2.30	0.2	0.15	-	-
Euro 4	2003	1.00	0.1	0.08	-	-
Euro 5 (Future)	2009	1.00	0.1	0.06	-	0.0055
Euro 6 (Future)	2014	1.00	0.1	0.06	-	0.0055

Table 3.45: *European emission standards for gasoline*

Vehicle Classification

American	British	Segment	Euro NCAP	Vehicle Example
MicroCar	Microcar	N/A	N/A	Smart For Two
N/A	City Car	A	Super Mini	Renault Twingo
Sub-compact	Super Mini	B		Hyundai Accent
Compact	Small family	C	Small family	Ford Focus
Mid-size	Large Family	D	Large family	VW Passat
Entry level Luxury	Compact Executive			Audi A4
Full-size	Executive	E	Executive	Chrysler 300
Mid-size Luxury				BMW 5-Series
Fill-size Luxury	Luxury	F	N/A	Mercedes S-Class
N/A	Leisure Activity	B	Small MPV	Peugeot Partner
N/A	Mini MPV			Opel Meriva
Compact Mini Van	Compact MPV	C		Mazda 5
Mini Van	Large MPV	D	MPV	Toyota Previa
Mini SUV	Mini 4x4	B	Small Off-Roader	Suzuki SX4
Compact SUV	Compact 4x4	C/D		Honda CR-V
Mid-size Crossover SUV	Large 4x4	E	Large Off-Roader	BMW X5
Mid-size SUV	Off-Roader			Jeep Cherokee
Full-size SUV		N/A		Cadillac Escalade
SUV=Sports Utility Vehicle, **MPV**=Multi Purpose Vehicle, **N/A**=No comparable classification				