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# The Role of Body-in-White Weight Reduction in the Attainment of the 2012-2025 US EPA/NHTSA Fuel Economy Mandate

Dr. Blake Zuidema
Automotive Product Applications – Global R&D
May 13, 2013

# The 2025 Challenge

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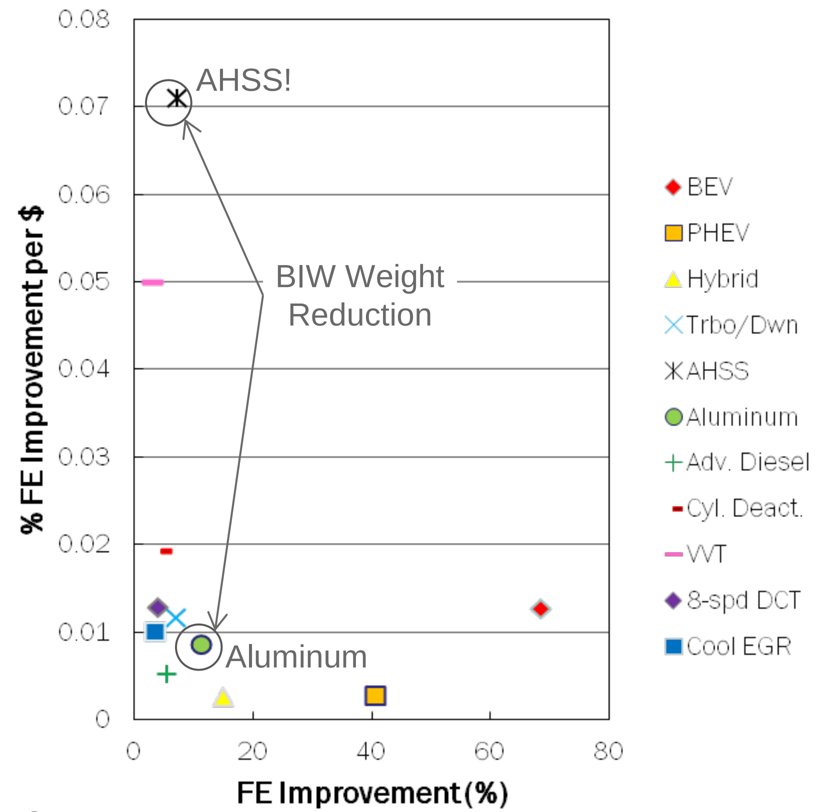
| Technology | % Impr. | Cost | %/$ |
|---|---|---|---|
| EV | 68.5 | $5,390 | 0.012 |
| PHEV | 40.7 | $14,517 | 0.003 |
| Hybrid | 14.9 | $5,810 | 0.003 |
| BIW WR – Aluminum | 11.4 | $1,320 | 0.012 |
| BIW WR – AHSS | 7.2 | $100 | 0.071 |
| Turbo/Downsize | 7.0 | $600 | 0.008 |
| Adv. Diesel | 5.5 | $1,040 | 0.005 |
| Cyl. Deact. | 4.7 | $244 | 0.019 |
| Var. Valve Timing | 3.0 | $60 | 0.050 |
| 8-Spd DC Trans. | 3.9 | $304 | 0.013 |
| Cool EGR | 3.6 | $360 | 0.010 |




Source: NHTSA Volpe Transportation Research Center CAFÉ Compliance and Effects Modeling System

***BIW weight reduction is at or near the top of list for both magnitude and cost effectiveness of fuel economy improvement***

# The Key Questions for Steel

- How much weight reduction can Steel provide?
- How much weight reduction is needed to get to 54.5 MPG?
  - *Can we get to 54.5 MPG with Steel?*
- Which material gets us to 54.5 MPG at the lowest cost?
- Which material gets us to 54.5 MPG with the lowest carbon footprint?

# How much weight reduction can Steel provide?

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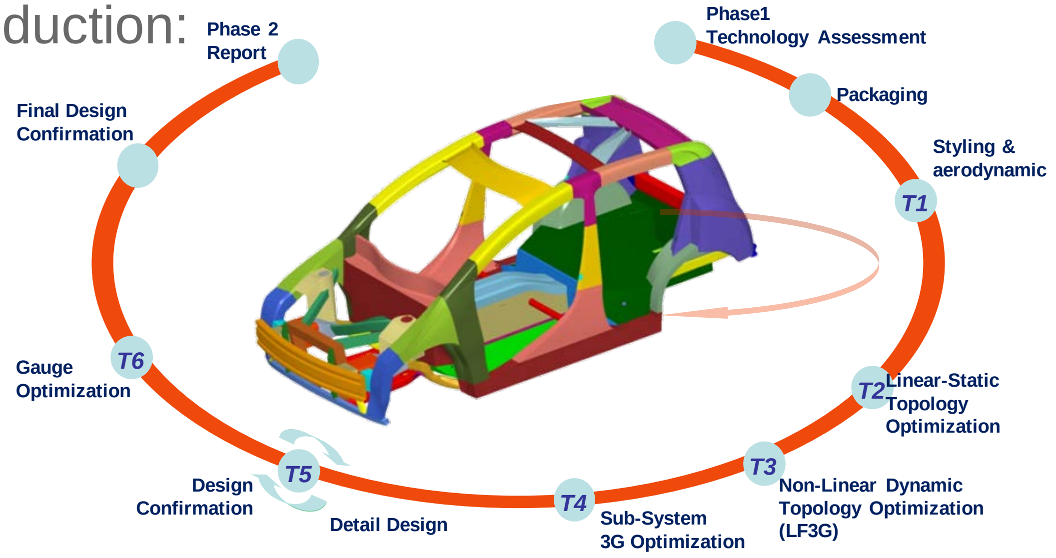
The importance of geometry optimization in achieving maximum weight reduction:




*Source:* WorldAutoSteel

- 2-G = Grade and Gauge optimization, typical of a carry over-constrained design
- 3-G = Geometry, Grade, and Gauge optimization, typical of a "clean sheet" design

FSV achieved a **29% BIW weight reduction** (2009 baseline, 39% from the 1996 Taurus PNGV baseline) using 3-G geometry, grade, and gauge optimization with today's advanced steel grades

# How much weight reduction can Steel provide?

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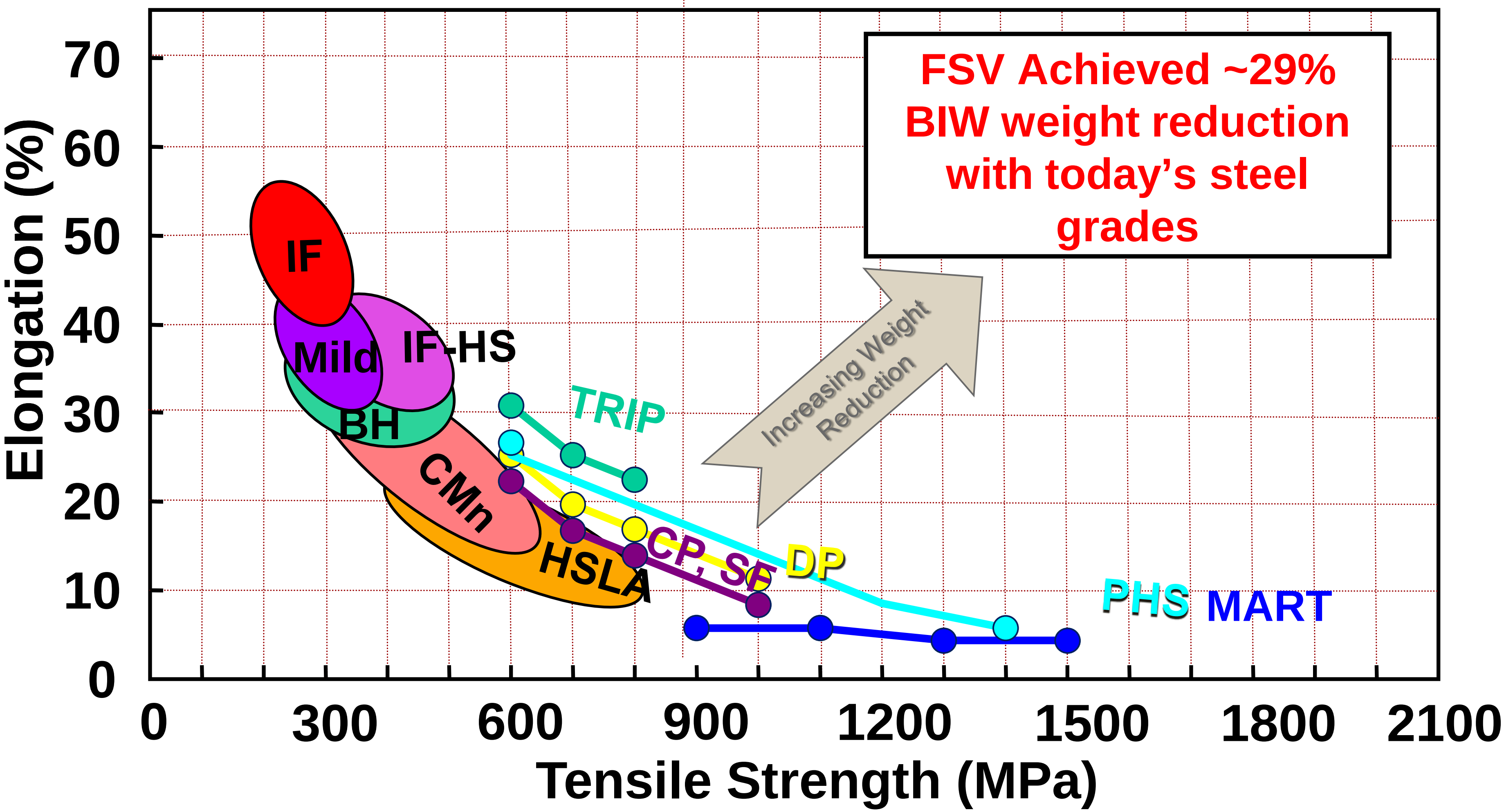
## Today's and FSV's Steel Grades



# How much weight reduction can steel provide?

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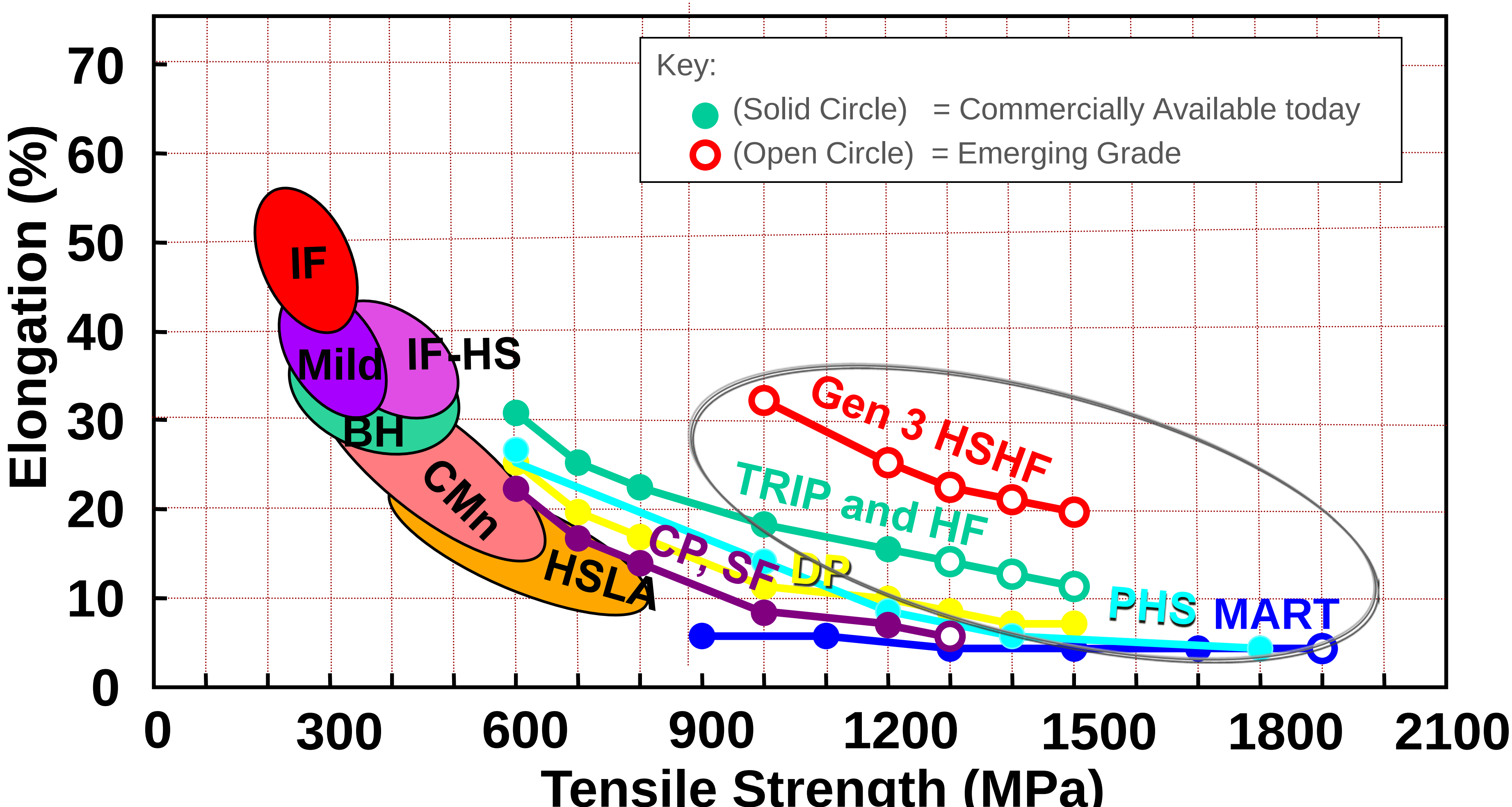
## Work beginning on third generation AHSS



# Lotus ICCT Venza Phase 1 Study

- 2-G Approach
- 2009 Toyota Venza baseline

| | Baseline | Low Dev | % WR |
|---|---|---|---|
| Body | 382.50 kg | 324.78 kg | |
| Closures | 143.02 kg | 107.61 kg | |
| Bumpers | 17.95 kg | 15.95 kg | |
| Total | 543.47 kg | 448.34 kg | 17.5% |

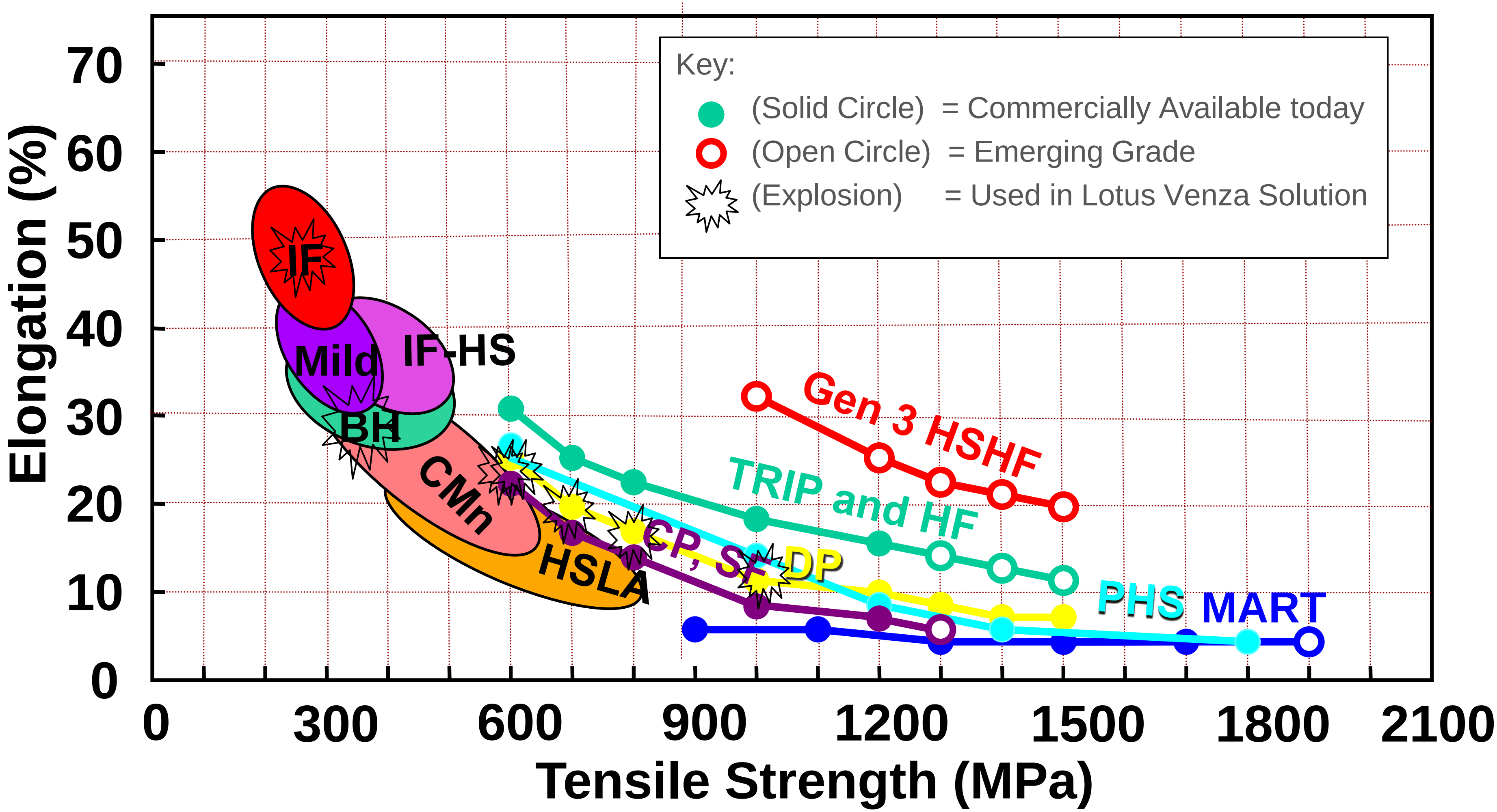
- 18% BIW weight reduction
- 21% vehicle weight reduction
- 20% BIW cost increase
- 3% net vehicle cost DECREASE

Steel Grade Composition

| Grade | Baseline | Low Dev |
|---|---|---|
| Mild | 80% | 7% |
| IF MS | 12% | 4% |
| DP490 | | 13% |
| DP500 | | 11% |
| DP590 | 8% | 31% |
| DP780 | | 33% |
| DP980 | | 1% |

# Steel Grades in Lotus/ICCT Venza

**All steel grades are commercially available today**



# FEV Venza Phase 2 Study

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- 2-G Approach
- *2010* Toyota Venza baseline

| | Baseline | Phase 2 | % WR |
|---|---|---|---|
| Body | 386.2 kg | 332.7 kg | |
| Closures | 135.3 kg | 118.3 kg | |
| Bumpers | 7.5 kg | 7.1 kg | |
| Total | 528.9 kg | 458.1 kg | 13% |

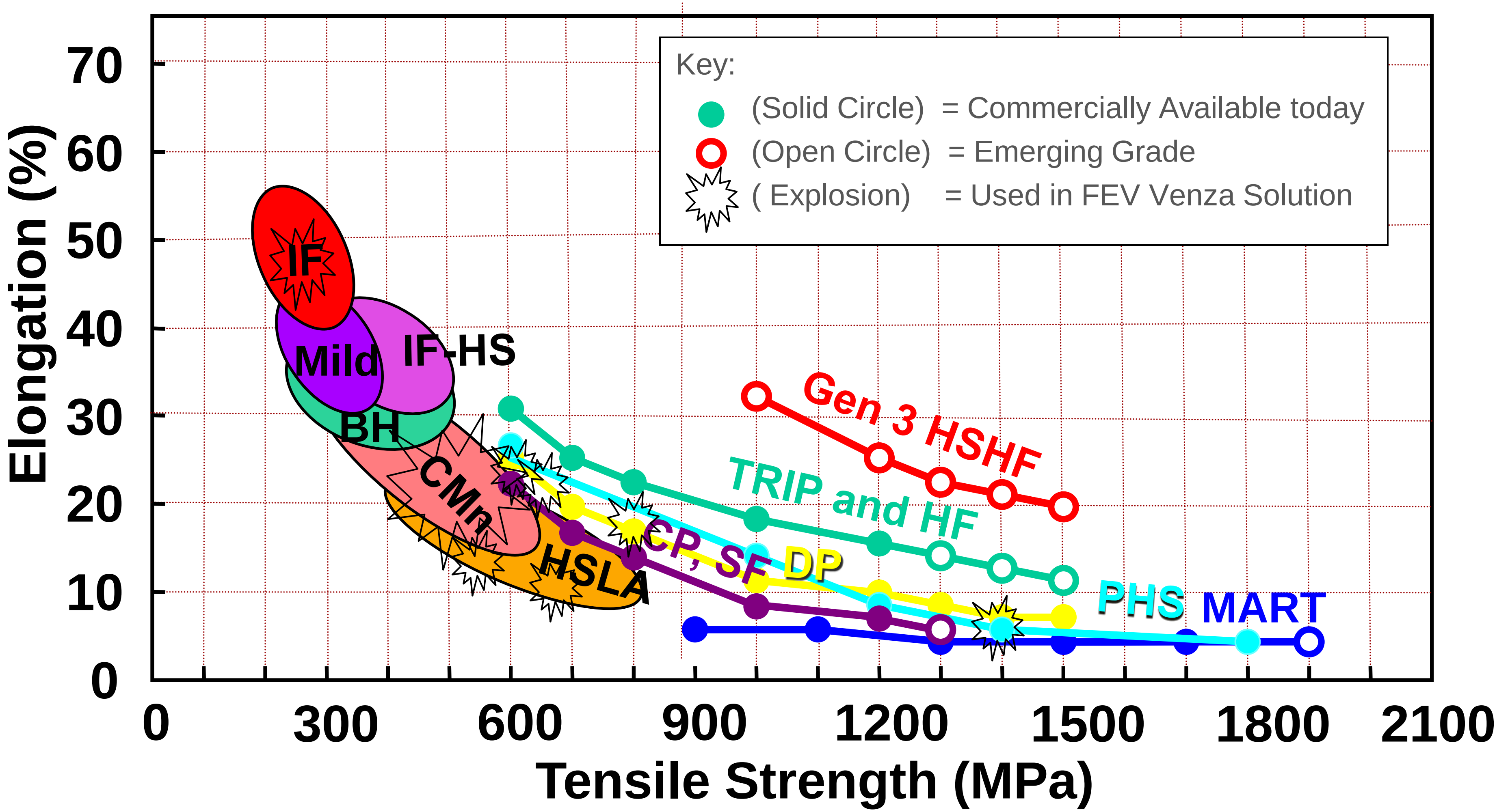
- 13% BIW weight reduction
- 18% vehicle weight reduction
- $3.33/kg weight saved in BIW

Steel Grade Composition

| Grade | Base | Phase 2 |
|---|---|---|
| Mild | 80% | 12% |
| IF MS | 12% | 12% |
| HSLA 350 | | 6% |
| HSLA 550 | | 8% |
| DP500 | | 10% |
| DP590 | 8% | 34% |
| DP780 | | 6% |
| PHS 1370 | | 8% |
| Al | | 4% |

# Steel Grades in FEV/ICCT Venza

**All steel grades are commercially available today**



# EDAG NHTSA Accord Study

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- 3-G Approach
- 2011 Honda Accord baseline

| | Baseline | Optimized | % WR |
|---|---|---|---|
| Body | 328 kg | 255 kg | |
| Total | 328 kg | 255 kg | 22% |

- 22% BIW weight reduction
- 22% vehicle weight reduction
- $2.02/kg weight saved in BIW

Steel Grade Composition

| Grade | Base | Opt. |
|---|---|---|
| Mild | 52 | 3% |
| BH 210 | 2 | 4% |
| BH 280 | | 5% |
| HSLA 350 | 4 | 6% |
| DP 500 | | 6% |
| DP 590 | 42 | 7% |
| DP 780 | | 10% |
| DP 980 | | 12% |
| MART 1200 | | 12% |
| CP 1200 | | 15% |
| PHS 1370 | | 19% |

# Steel Grades in EDAG/NHTSA Accord

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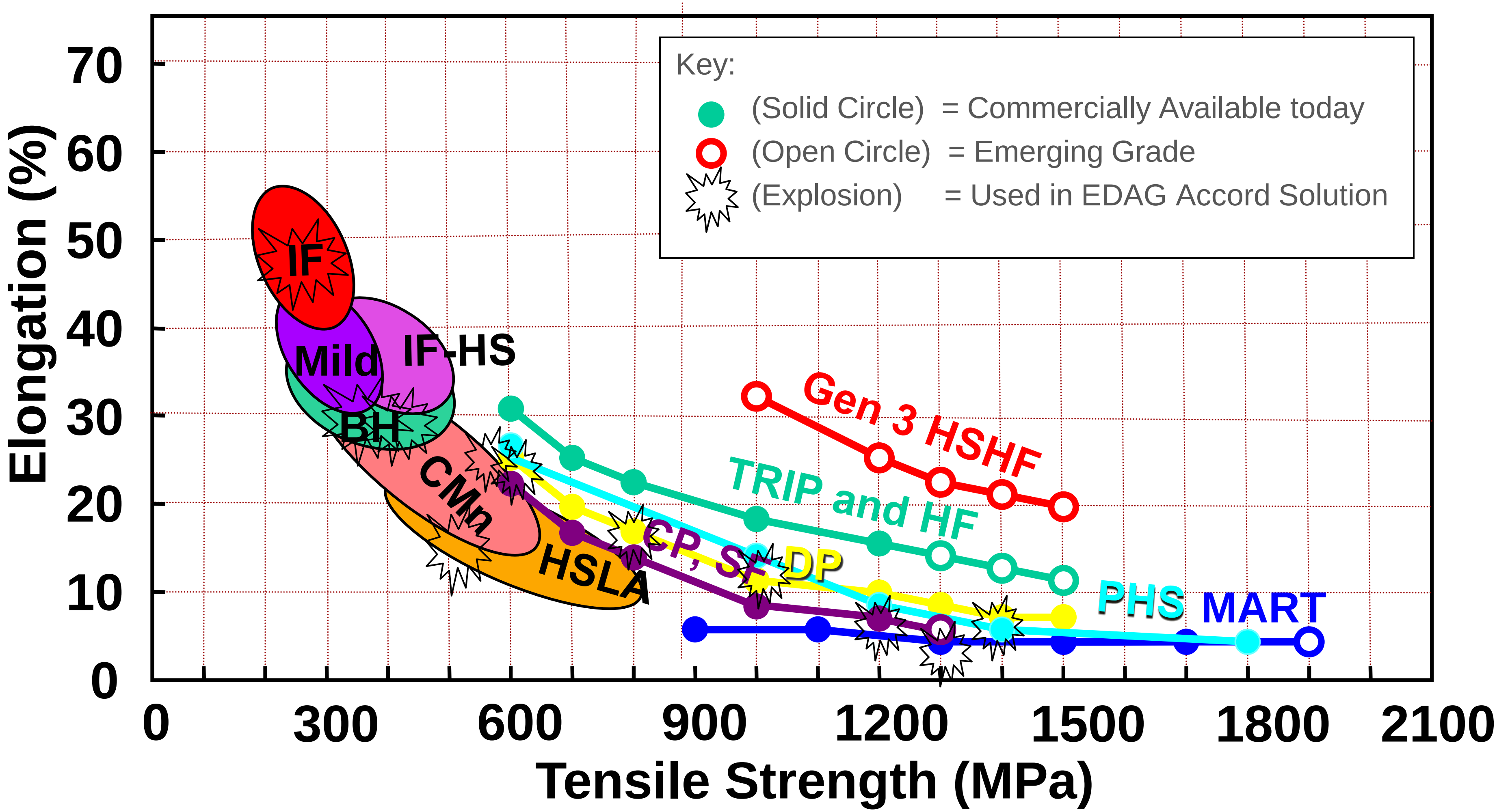
## All steel grades commercially available today



# How much weight reduction can Steel provide?

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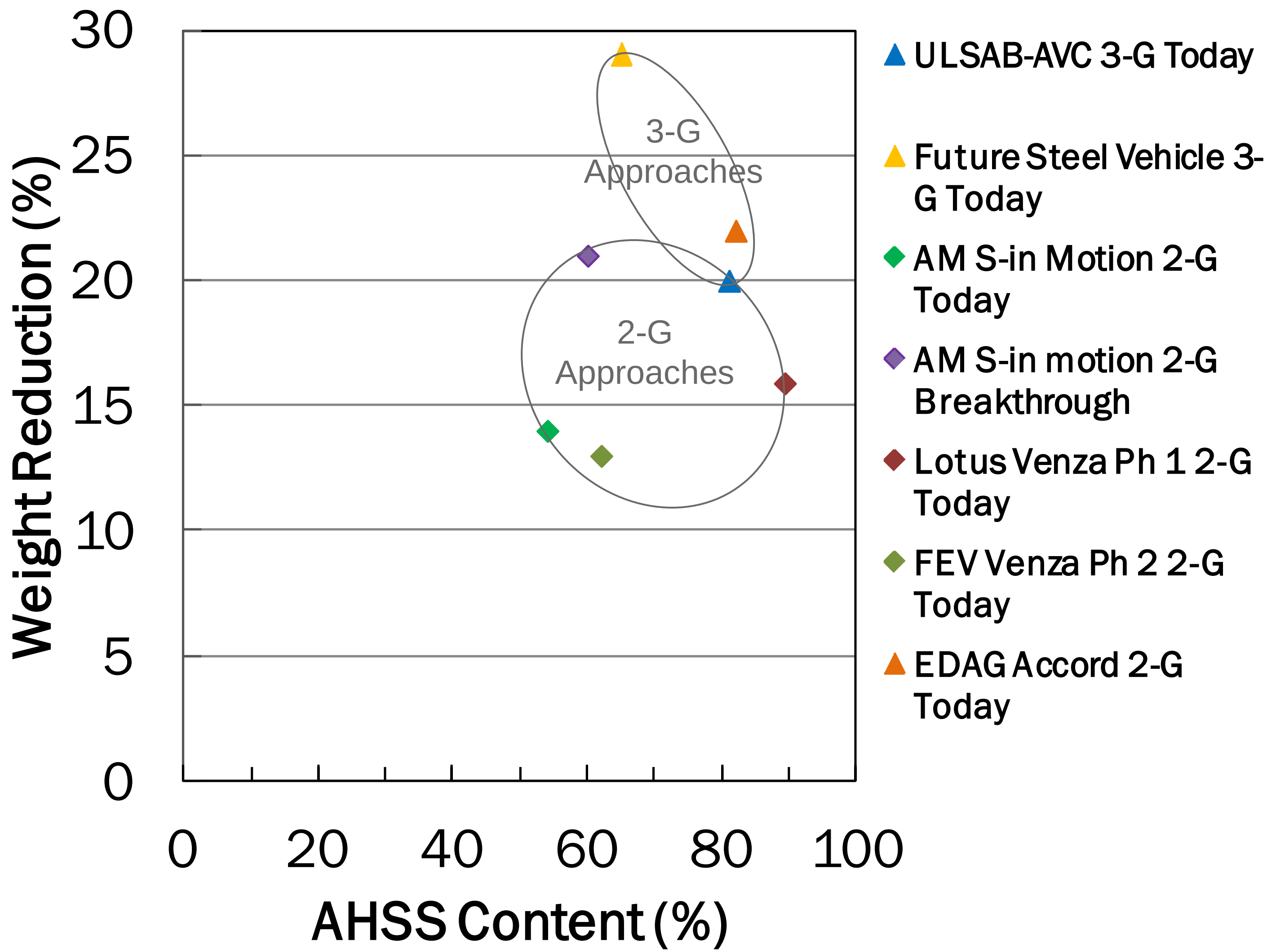

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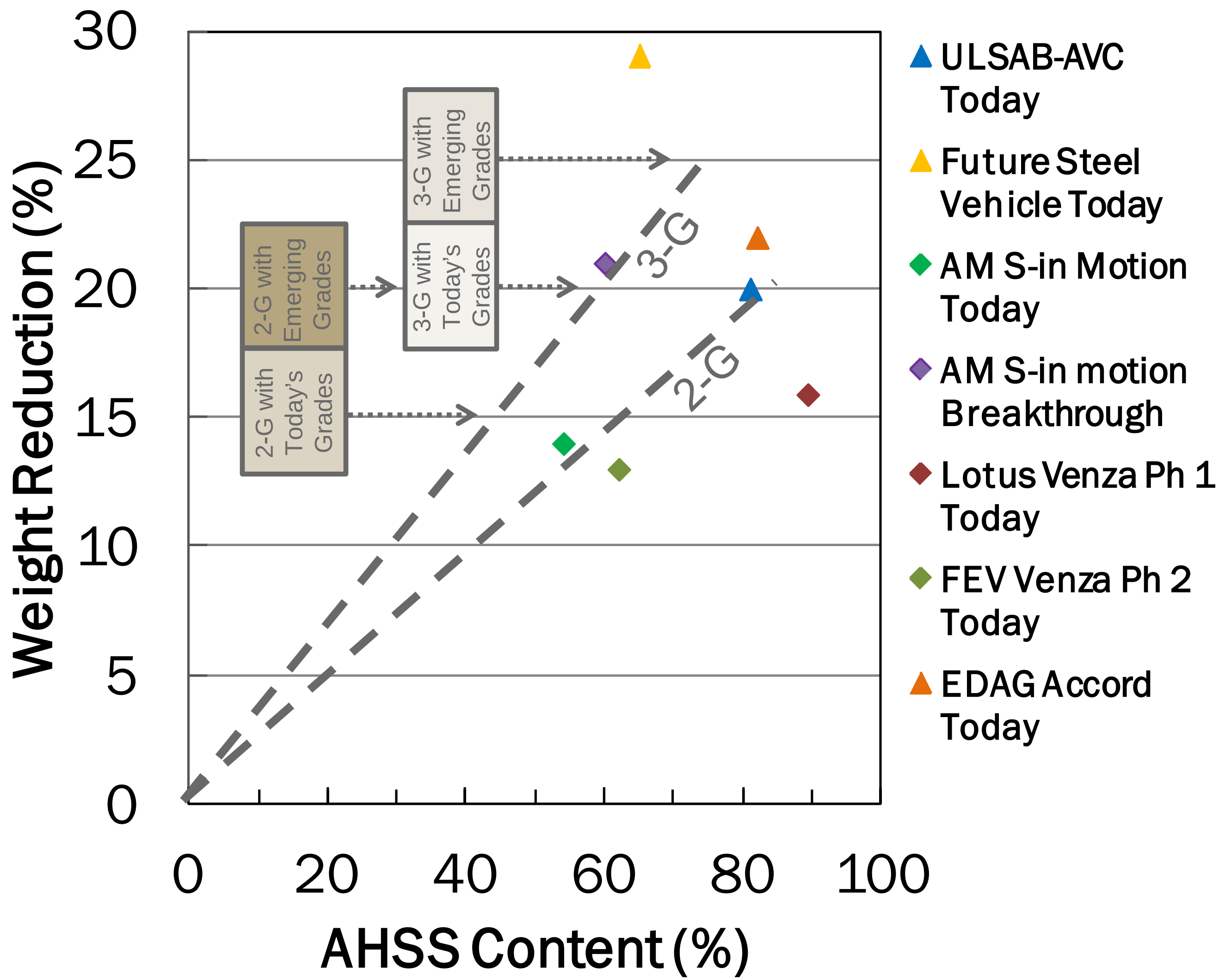

# How much weight reduction is needed to get to 54.5 MPG?

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Publically-available models for assessing fuel economy improvement potential

| Source | Model |
|---|---|
| US EPA | Data Visualization Tool |
| US EPA | Alpha Model |
| US EPA | Omega Model |
| US NHTSA Volpe Transportation Research Center | Cafe Compliance and Effects Modeling System ("Volpe Model") |

← Used for this study

# Building a Credible Model
# Primary BIW Weight Reduction

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- Perimeter = BIW structure, closures, bumpers, frame/engine cradle
  - Including box in pickups

- BIW weight reduction potentials from industry claims

- Primary BIW weight reduction potentials relative to a 2009 baseline:
  - Conv. = 0% (No BIW weight reduction)
  - AHSS = 15% (2G –with today's grades)
  - AHSS = 20% (2G –with emerging grades, 3G – with today's grades)
  - AHSS = 25% (3G – with emerging grades)
  - Aluminum = 40% (Achievable with 2025 technologies)
  - CFRP = 50% (Achievable with 2025 technologies)

# Other Key Input Assumptions

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- Secondary Mass Savings – 35% of Primary
- Weight Elasticity of FE - 7% for each 10% CW reduction
- BIW Weight – 30-33% of CW
- Non-BIW WR – Zero and 7.2% CW reduction (per EDAG)
- Over-Cost – per industry claims
- Alt. Power Train Penetrations – per literature forecasts
- Power Train Improvement Potentials –
  - Reduced by up to 20% from EPA assumption to determine increased role of WR if power trains do not deliver the improvements expected

# How much weight reduction is needed to get to 54.5 MPG?

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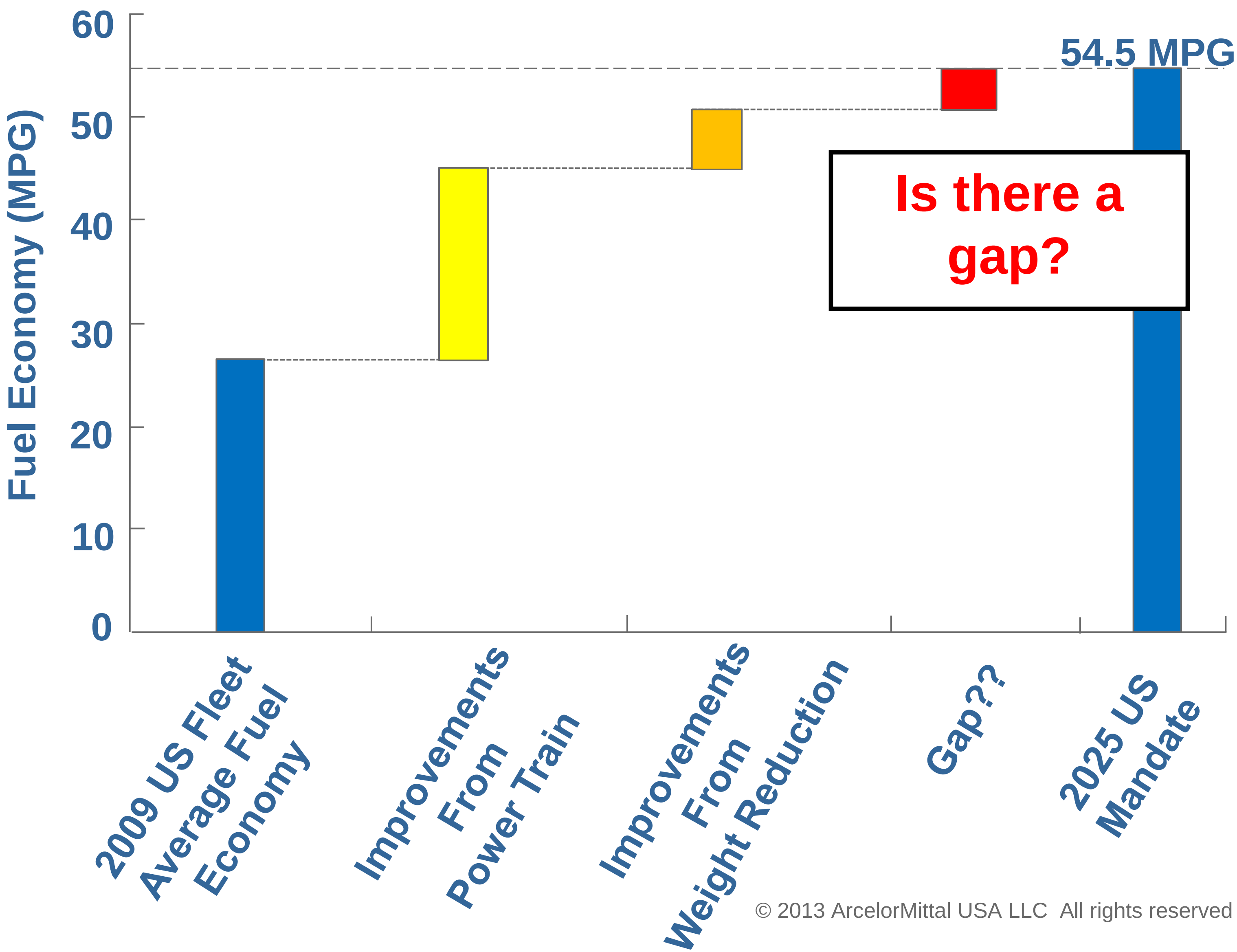
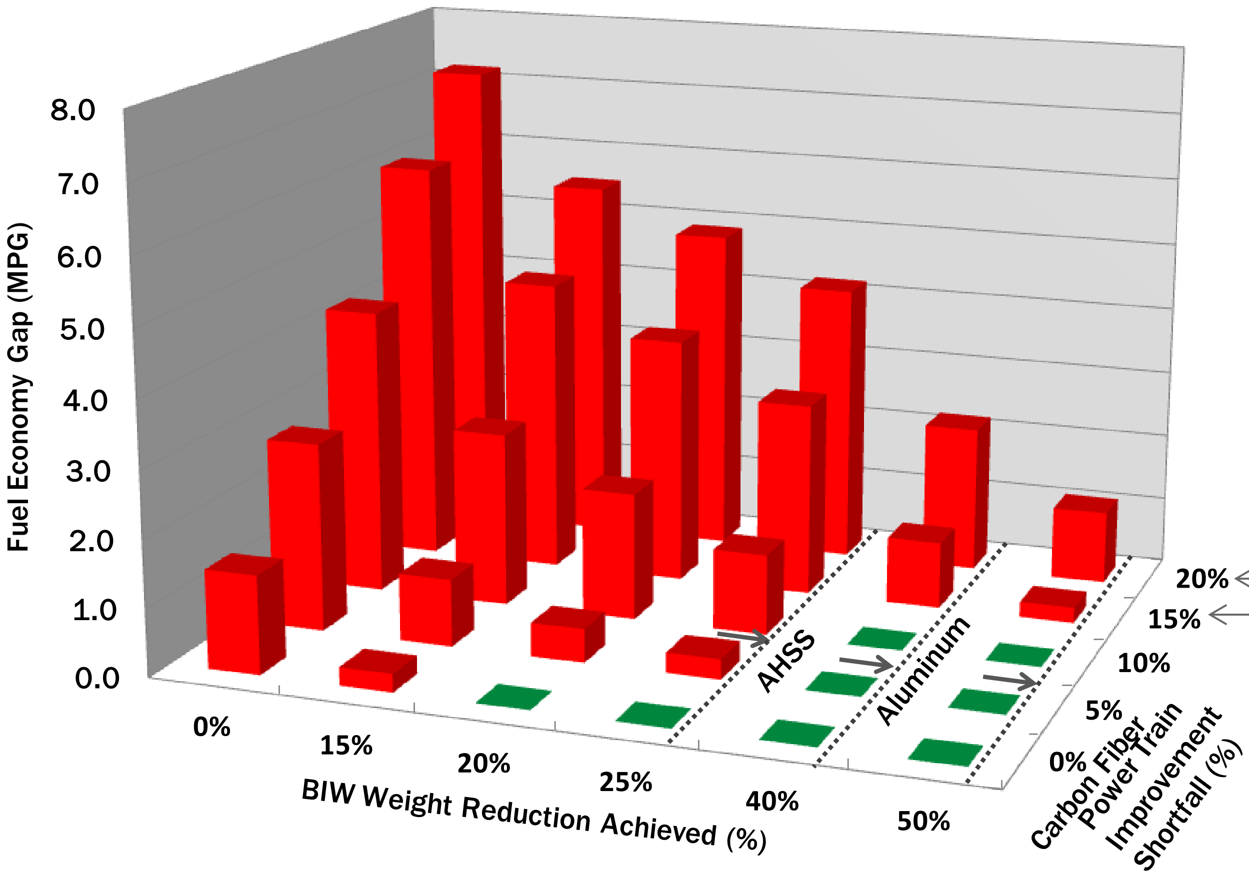


# 2025 Fuel Economy Gap Results Without Non-BIW Weight Reduction



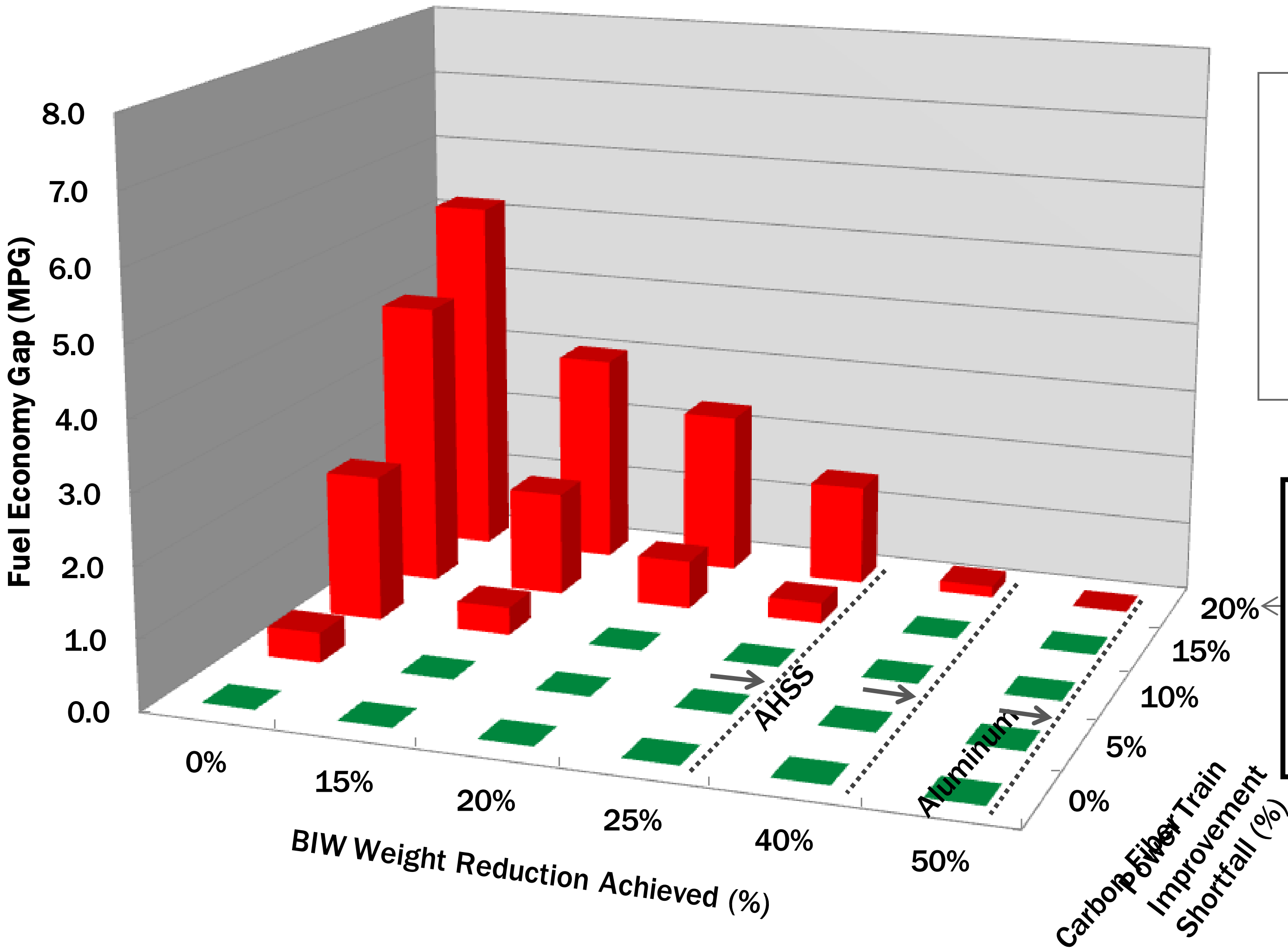

**Based on EPA projections of US 2025 vehicle sales**

**Weight reduction only from BIW light weighting in all cases**

**Unrealistic scenarios – NO material gets fleet to 54.5 MPG**

**Fuel economy standard would need to be relaxed**

# 2025 Fuel Economy Gap Results With Non-BIW Weight Reduction




Based on EPA projections of US 2025 vehicle sales

7% non-BIW vehicle weight reduction assumed in all cases

**Unrealistic scenario – NO material gets fleet to 54.5 MPG**

**Fuel economy standard would need to be relaxed**

# Which material gets us to 54.5 MPG at lowest cost?

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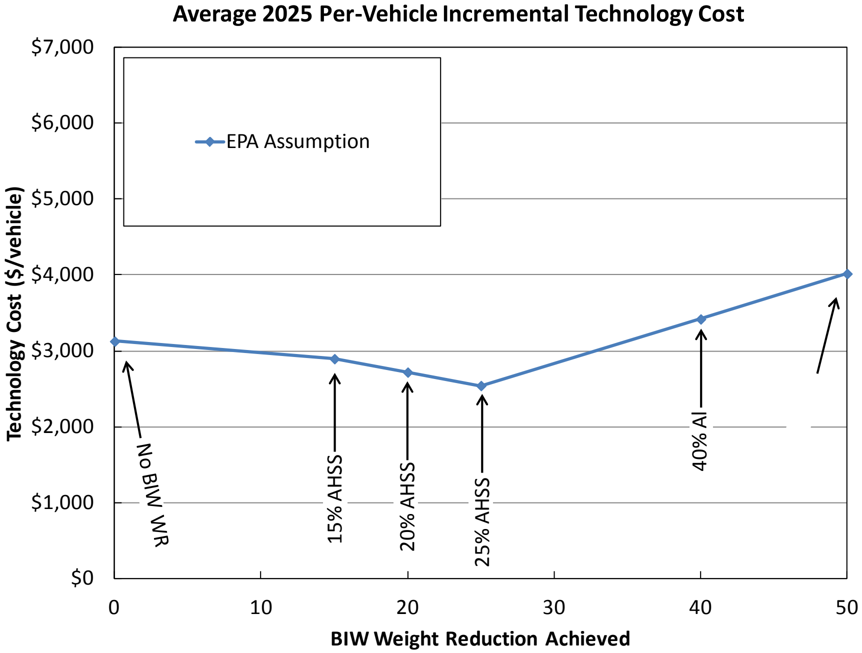
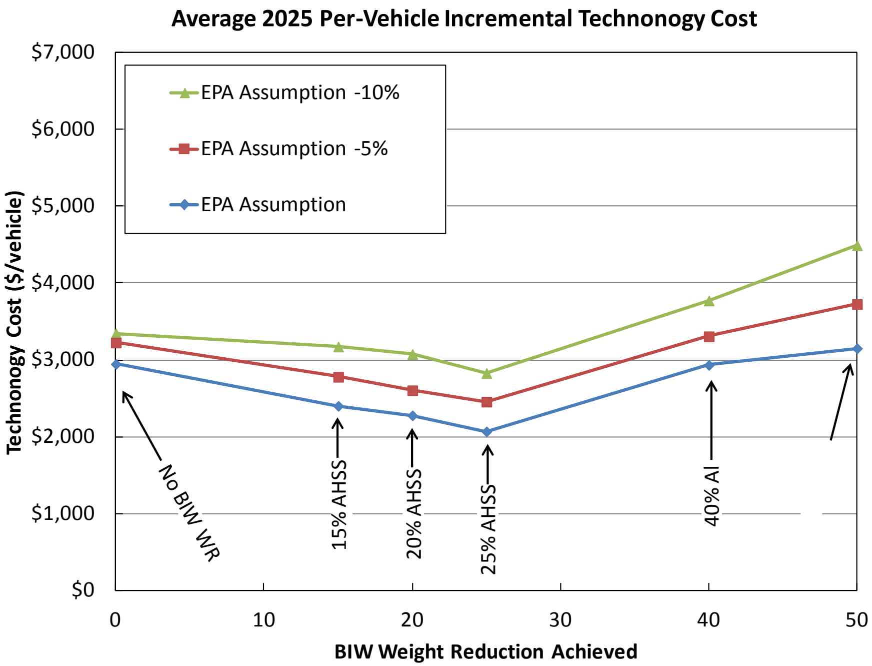
## All weight reduction from BIW




## With non-BIW weight reduction




**Under scenarios where Steel gets the 2025 fleet to 54.5 MPG, it does so at a lower cost than if Aluminum or Carbon Fiber were used**

# Which material gets us to 54.5 MPG at the lowest carbon footprint?

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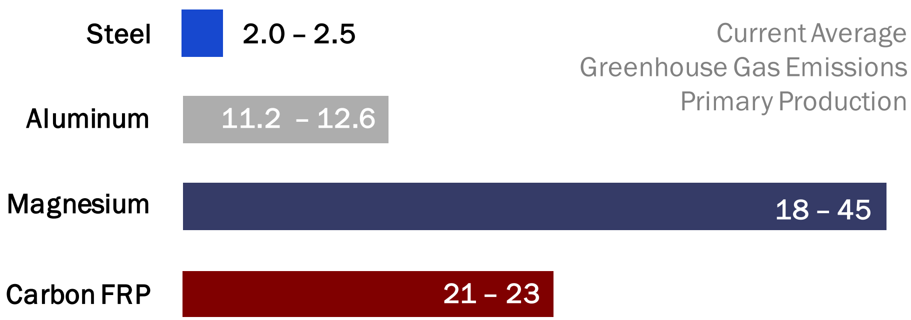
**Greenhouse Gas from Production** (in kg $CO_2$e/kg of material)

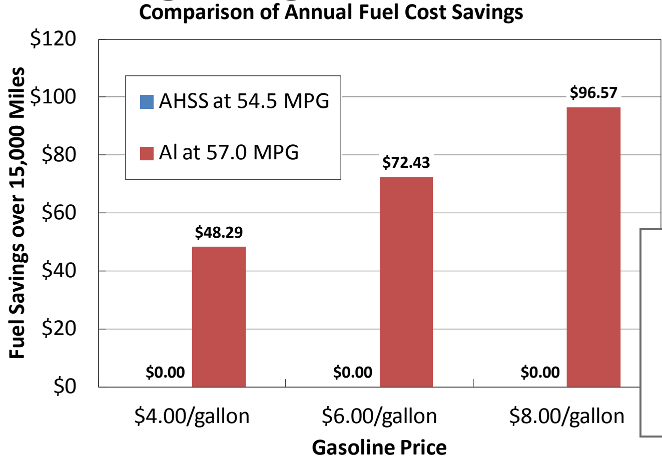



Footnotes:

- All steel and aluminum grades included in ranges.
- Difference between AHSS and conventional steels less than 5%.
- Aluminum data - global for ingots; European only for process from ingot to final products .

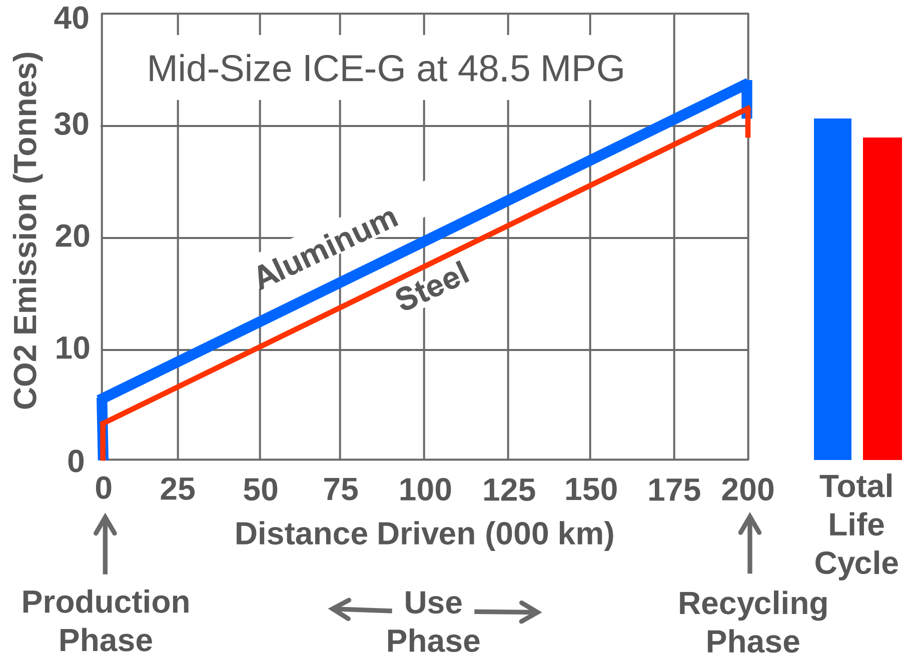
***Source:*** *WorldAutoSteel*

## Fuel Savings if Lighter Aluminum Solution Used




**Consumers are unlikely to pay for fuel savings beyond 54.5 MPG**

**With no use phase CO2 emissions advantage, aluminum and carbon fiber vehicles will present a larger lifetime carbon footprint than AHSS vehicles**




**Source: UCSB GHG Comparison Model V3.0**
**Note: Identical recycling rates assumed for both Steel and Aluminum**

# Key Conclusions

- NHTSA's Volpe Model shows that today's commercial and emerging advanced steel grades provide sufficient weight reduction to, when combined with anticipated improvements in power train technologies, get the 2025 US light vehicle fleet to 54.5 MPG
- Steel gets the 2025 fleet to 54.5 MPG at a lower cost than if aluminum or carbon fiber were used
- Steel gets the 2025 fleet to 54.5 MPG at a lower total life cycle carbon footprint than if aluminum or carbon fiber were used

# Thank You

- For more information on this study, contact:

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ArcelorMittal Global Research and Development

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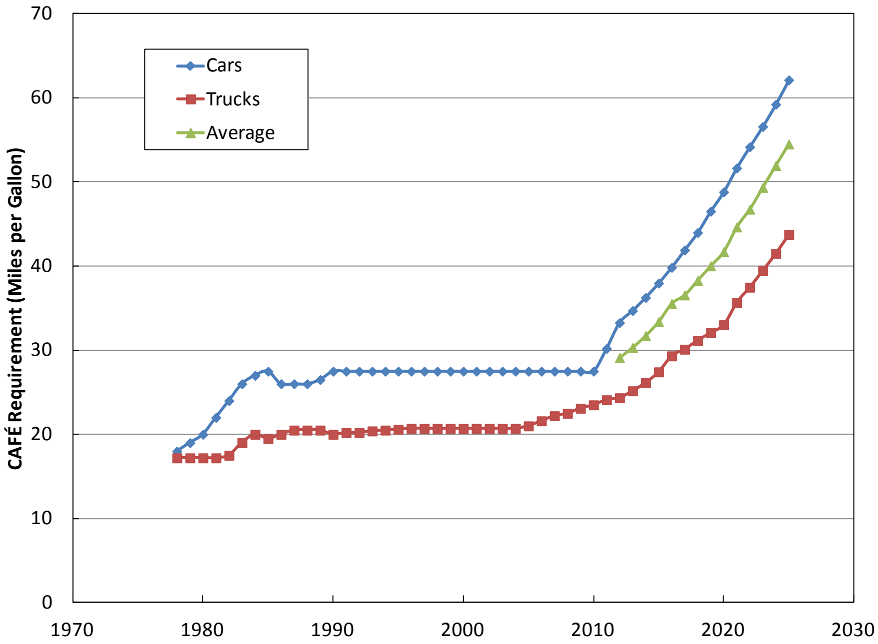
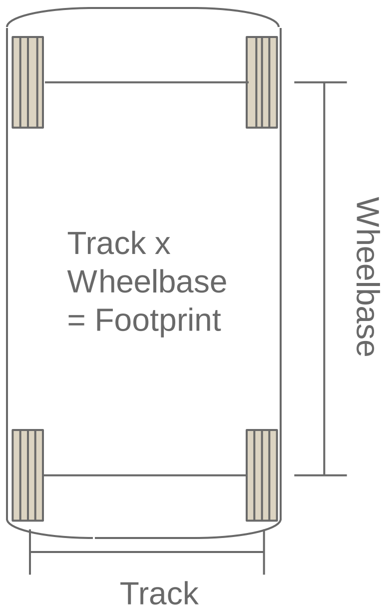
# Backup Slides

# The 2025 Challenge

The 2012-2025 US NHTSA Fuel Economy Rules:




- 2012-2025 standards are based on each vehicle's footprint
- 54.5 is the sales volume averaged-fuel economy of the EPA/NHTSA's projected 2025 fleet

# How much weight reduction can Steel provide?

AHSS weight reduction potentials used in this study:

| Scenario | AHSS Weight Reduction |
|---|---|
| 2-G with today's grades | 15% |
| 2-G with emerging grades<br>3-G with today's grades | 20% |
| 3-G with emerging grades | 25% |

# The Volpe Model

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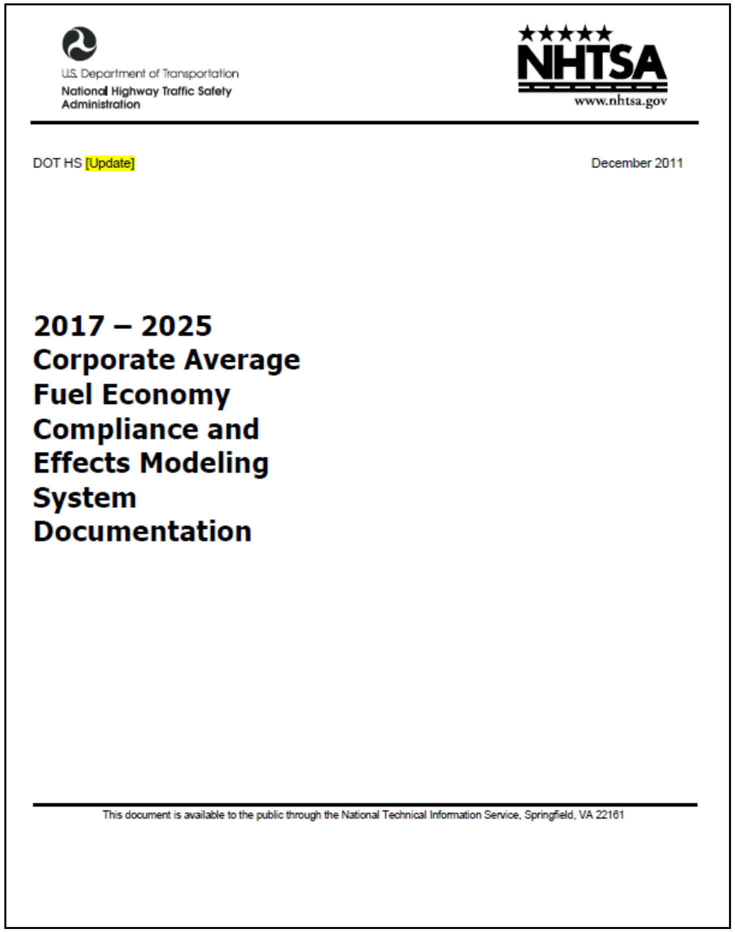

U.S. Department of Transportation
National Highway Traffic Safety Administration

NHTSA
www.nhtsa.gov

DOT HS [Update]

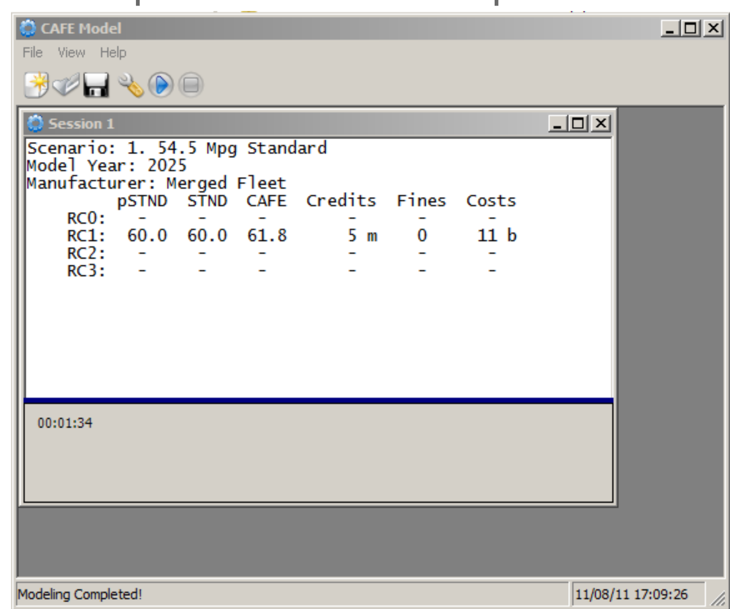
December 2011

**2017 – 2025**
**Corporate Average**
**Fuel Economy**
**Compliance and**
**Effects Modeling**
**System**
**Documentation**

This document is available to the public through the National Technical Information Service, Springfield, VA 22161

Source: http://www.nhtsa.gov/Laws+&+Regulations/CAFE+-+Fuel+Economy/CAFE+Compliance+and+Effects+Modeling+System:+The+Volpe+Model

- NHTSA Volpe Transportation Research Center - 2017-2025 CAFE Compliance and Effects Modeling System ("Volpe Model")
  - Used by EPA/NHTSA to set 2012-2016 and 2017-2025 $CO_2$/Fuel Economy standards
  - Assesses the cost and improvement potential of numerous fuel economy technologies, including weight reduction
  - ArcelorMittal has consulted with NHTSA officials to verify proper set-up, operation, and interpretation of the Volpe Model



# Building a Credible Model
# Secondary Weight Reduction

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- Secondary weight reduction potentials from fka/Univ. of Michigan study:
  - 35% of primary weight reduction

| | Mass influence coefficients based on simple (one-step) secondary reduction | |
|---|---|---|
| **Subsystem** | **fka Analytical Method** | **U of M Regression Method** |
| Body Structure | 0.0961 | 0.1267 |
| Bumpers | n/a | 0.0347 |
| Suspension | 0.0495 | 0.0548 |
| Brakes | 0.0367 | 0.0238 |
| Powertrain | 0.1063 | 0.1169 |
| Fuel System | 0.0101 | 0.0257 |
| Steering | 0.0070 | 0.0086 |
| Tires/Wheels | 0.0358 | 0.0497 |

# Building a Credible Model
# Weight Elasticity of Fuel Economy

- Rate at which fuel economy goes up as vehicle weight goes down

- Without power train re-sizing:
  - 2-4% MPG improvement for each 10% reduction in total vehicle weight

- With power train re-sizing:
  - 6-8% MPG improvement for each 10% reduction in total vehicle weight

- Elasticity chosen for this study:
  - Assumes sufficient weight reduction to justify power train re-sizing
  - 7% MPG improvement for each 10% reduction in total vehicle weight

# Building a Credible Model
# BIW Contribution to Vehicle Weight

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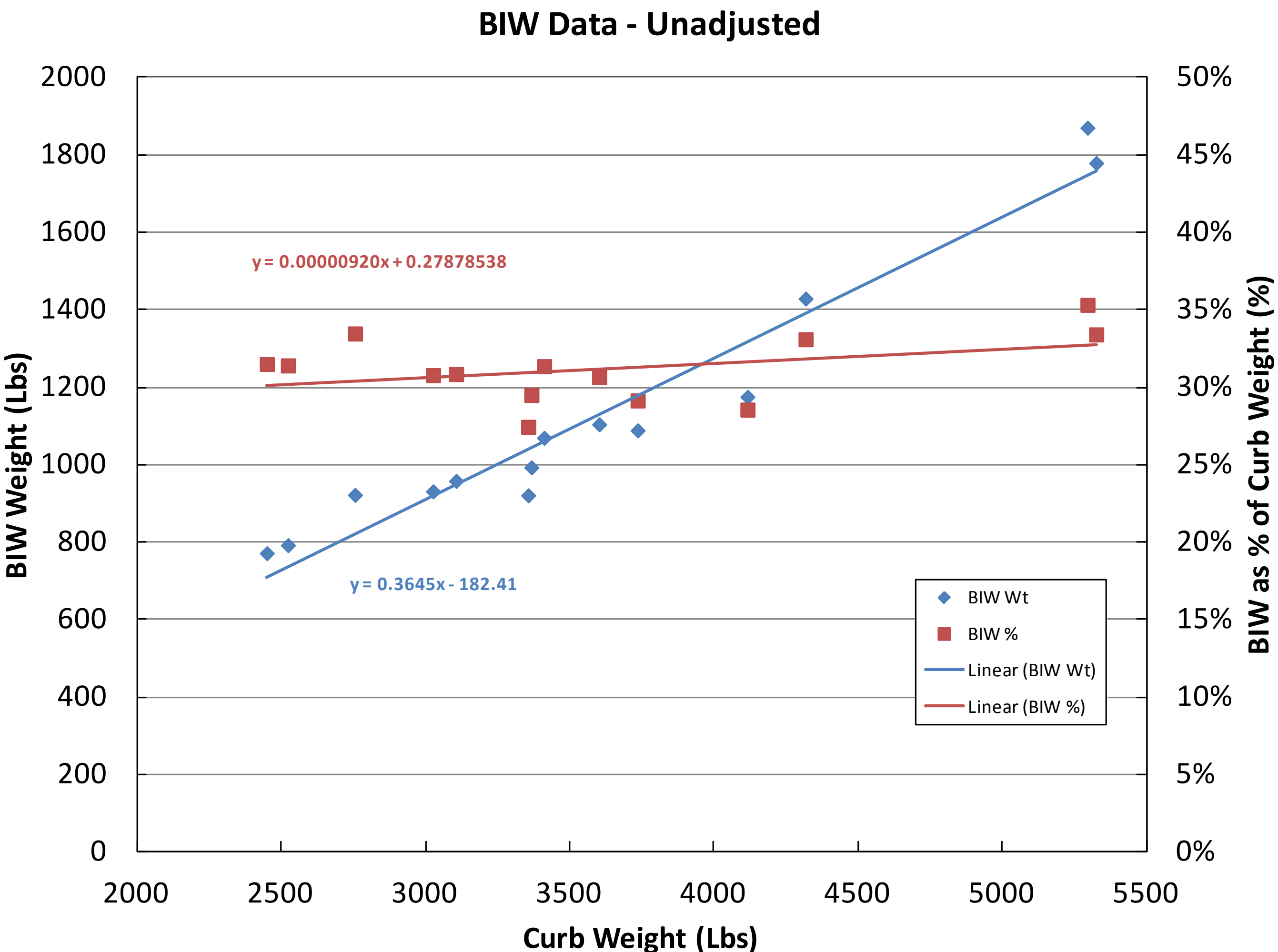
- Sheet metal weights from A2MAC1 database for representative vehicle segments



# Building a Credible Model
# Light Weighting Material Over-Cost

- Using industry claims for over-cost:
  - AHSS = $0.30/pound of weight saved
  - Aluminum = $2.71/pound of weight saved
  - CFRP = $4.87/pound of weight saved

# Building a Credible Model
# Alternative Power Train Penetration

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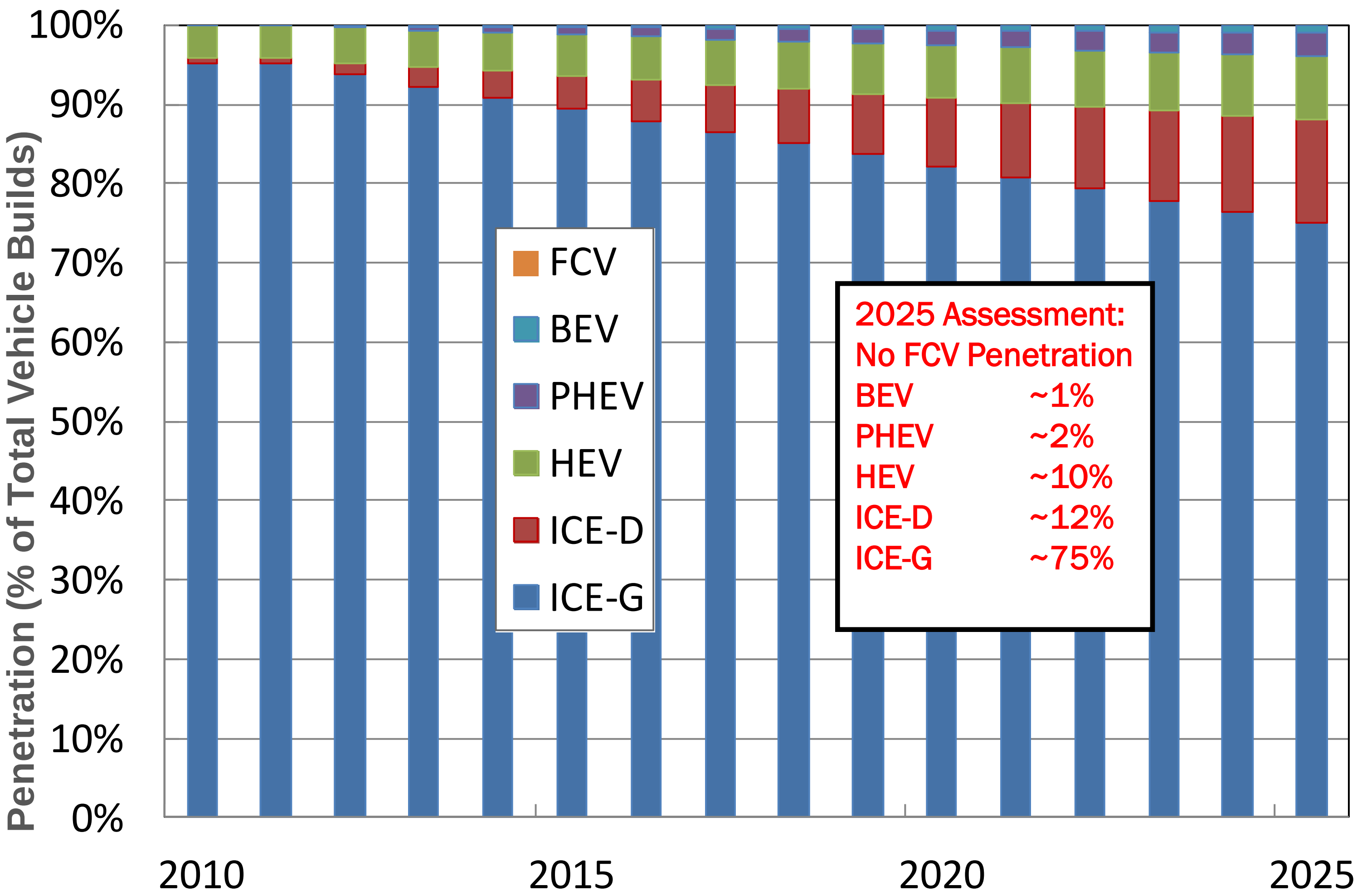

# Building a Credible Model
# Power Train Application

- Power trains allowed for application:

| Class | BEV | PHEV | HEV | Diesel |
|---|---|---|---|---|
| Subcompact PC | Yes | Yes | Yes | Yes |
| Subcompact Perf PC | Yes | Yes | Yes | Yes |
| Compact PC | Yes | Yes | Yes | Yes |
| Compact Perf PC | Yes | Yes | Yes | Yes |
| Midsize PC | No | Yes | Yes | Yes |
| Midsize Perf PC | No | Yes | Yes | Yes |
| Small LT | Yes | Yes | Yes | Yes |
| Large PC | No | No | Yes | Yes |
| Large Perf PC | No | No | Yes | Yes |
| Minivan LT | No | No | Yes | Yes |
| Midsize LT | No | No | Yes | Yes |
| Large LT | No | No | Yes | Yes |

# Building a Credible Model
# Other, Non-BIW Light Weighting Sources

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**EDAG 2012 report to NHTSA**

Baseline Vehicle – 2011 Honda Accord (2008 launch), 1480 kg curb weight

| System | Base Weight (kg) | Weight Reduction (kg) | % | Net Cost Increase ($) |
|---|---|---|---|---|
| Front Suspension | 81.33 | 39.90 | 49% | -$11.00 |
| Rear Suspension | 53.20 | 13.27 | 25% | $43.87 |
| Wheels | 93.86 | 14.24 | 15% | $8.80 |
| Instrument Panel | 31.90 | 9.45 | 30% | $15.43 |
| Seats | 66.77 | 20.03 | 30% | $96.84 |
| Interior Trim | 26.26 | 3.03 | 12% | $0.00 |
| A/C Ducting | 10.30 | 2.60 | 25% | $0.00 |
| Wiring | 21.70 | 4.30 | 20% | $0.00 |
| Total | | 106.82 | | $153.94 |

Together, these technologies have the potential to further reduce the full vehicle curb weight by an additional 7.2%, and gain an additional 5.04% improvement in fuel economy, at a cost of $0.65/lb weight saved

Source: Mass Reduction for Light-Duty Vehicles for Model Years 2017–2025, Report No. DOT HS 811 666, Prepared by Electricore, Inc, EDAG, Inc. and George Washington University for NHTSA under DOT Contract DTNH22-11-C-00193, August, 2012

# Building a Credible Model
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Baseline Vehicle – 2011 Honda Accord (2008 launch), 1480 kg curb weight

| System | Base Weight (kg) | Weight Reduction (kg) | % | Net Cost Increase ($) |
|---|---|---|---|---|
| Front Suspen | [illegible] | [illegible] | [illegible] | -$11.00 |
| Rear Suspen | [illegible] | [illegible] | [illegible] | $43.87 |
| Wheels | [illegible] | [illegible] | [illegible] | $8.80 |
| Instrument P | [illegible] | [illegible] | [illegible] | $15.43 |
| Seats | [illegible] | [illegible] | [illegible] | $96.84 |
| Interior Trim | [illegible] | [illegible] | [illegible] | $0.00 |
| A/C Ducting | [illegible] | [illegible] | [illegible] | $0.00 |
| Wiring | 21.70 | 4.30 | 20% | $0.00 |
| Total | | 106.82 | | $153.94 |

**Some of these weight reductions may be offset by weight gains to address safety or consumer preferences**

Together, these technologies have the potential to further reduce the full vehicle curb weight by an additional 7.2%, and gain an additional 5.04% improvement in fuel economy, at a cost of $0.65/lb weight saved

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# Building a Credible Model
# Power Train Improvement Potentials

- EPA has made certain assumptions regarding the magnitude to which various power train technologies will improve fuel economy and of what these improvements will cost the OEM's

- The OEM's will argue that the EPA has over-estimated their improvement potential and under-estimated their cost

**The Volpe Model power train improvement coefficients were reduced by 0 to 20% in 5% increments to assess the impact of lower improvements on weight reduction requirements**

# Building a Credible Model
# Summary of Major Input Variables

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| Parameter | Range Studied |
|---|---|
| BIW Weight Reduction | - 0% (No BIW WR)<br>- 15%, 20%, 25% (AHSS)<br>- 40% (Al)<br>- 50% (CFRP)<br>along with corresponding non-BIW secondary weight savings |
| Non-BIW Weight Reduction | - 0% (All WR from BIW)<br>- 7.2% vehicle weight reduction |
| EPA Non-WR Fuel Economy Technology Improvement Coefficient Reduction | - 0% (No Reduction)<br>- 5%<br>- 10%<br>- 15%<br>- 20% |

# Can we get to 54.5 MPG with Steel?

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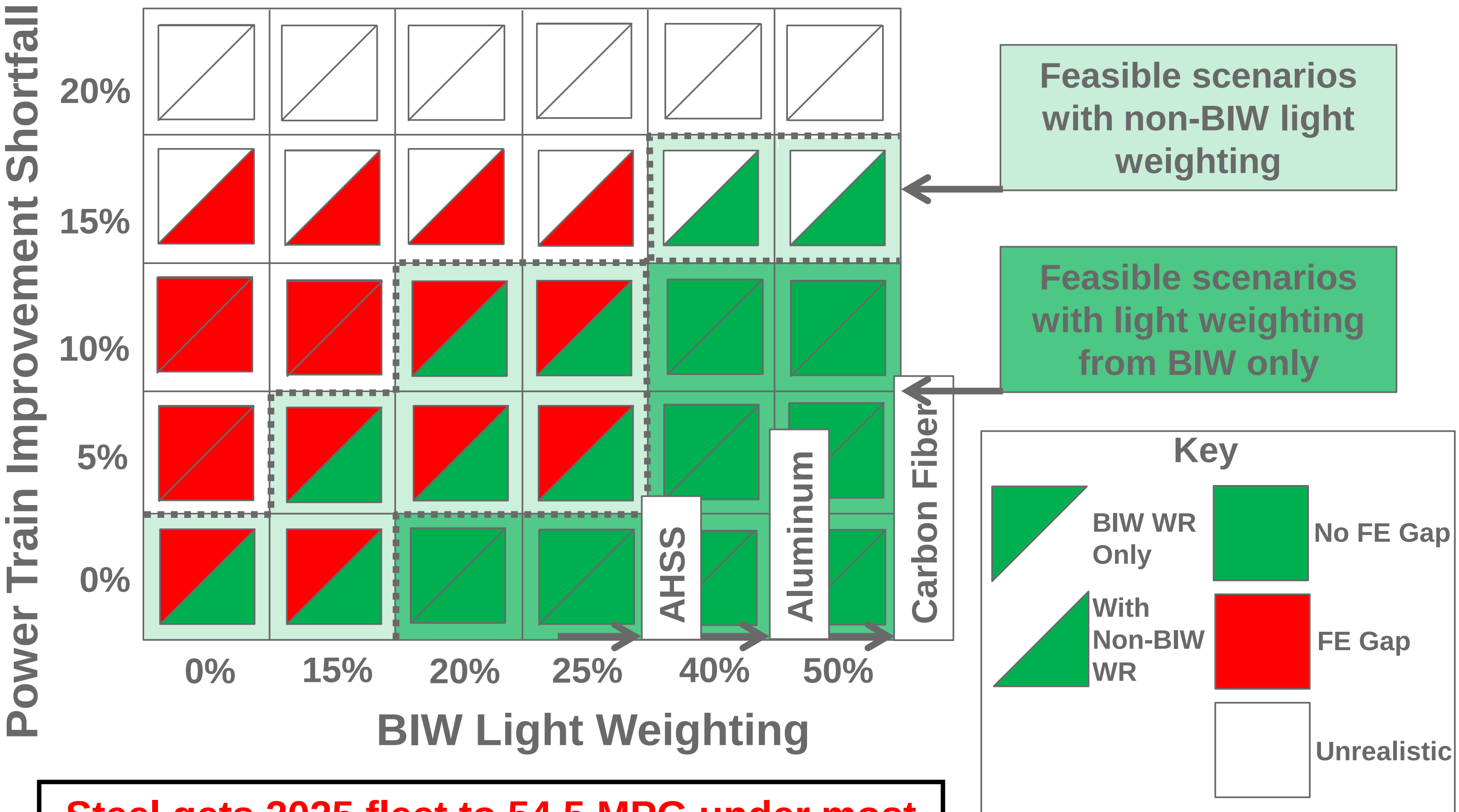
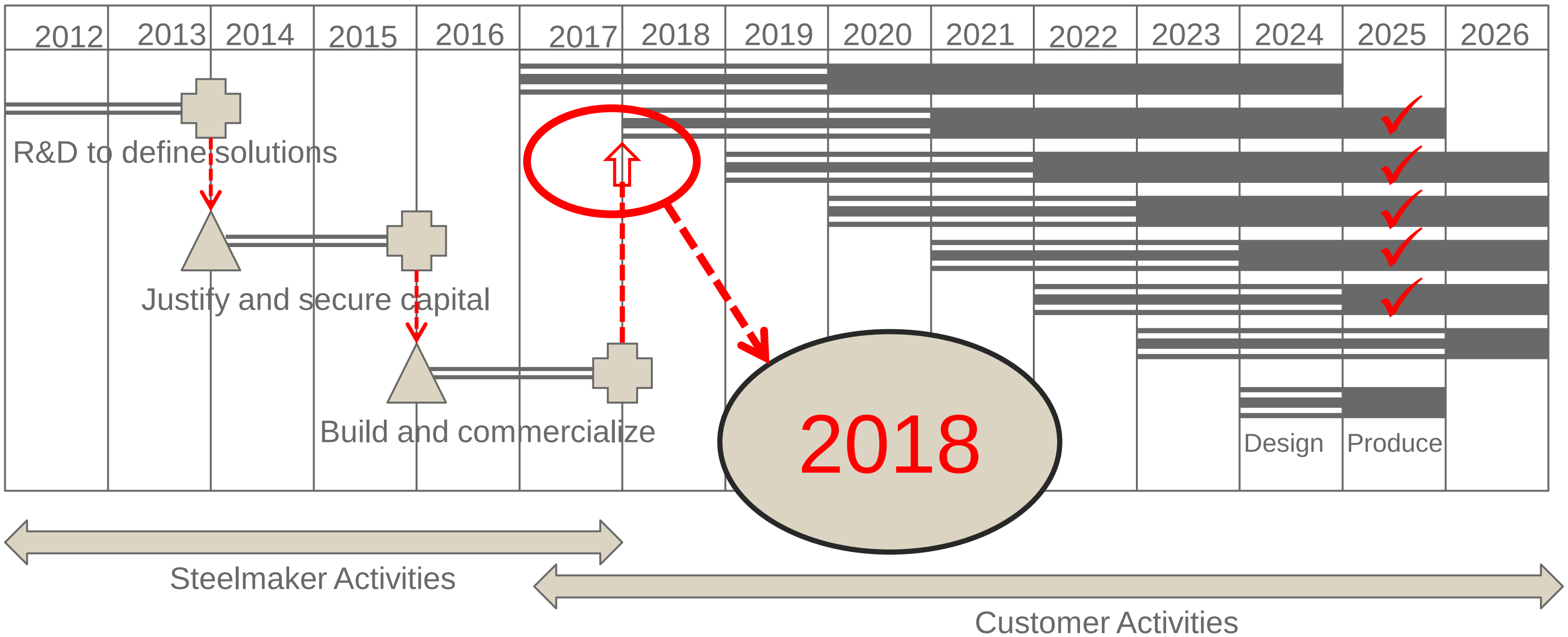



**Steel gets 2025 fleet to 54.5 MPG under most of the "realistic" scenarios considered**

# A Note on Timing




- Cars launched in 2021 will still be produced in 2025 and will need 2025 weight reduction technology
- Cars launched in 2021 will start being designed in 2018
- For 2025 new AHSS to get designed into cars in 2018, they must be commercial

***Given normal investment justification and construction lead times, R&D to define proper solutions to 2025 gaps must be complete by 2014, so that products can be commercialized by 2018***