American Iron and Steel Institute

Body Material Selection in the Changing Landscape of Automotive Requirements

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Major Events and Automotive Material Trends

Event	Automotive and Materials Response
Wood as initial automotive material	• Development of improved steel finishing methods • Automotive die and stamping technology • Development of effective welding/joining processes (RSW)
Mid 20th Century	• Era of styling and massive additional features • Wood phasing out, body on steel frame architecture • Chrome plated bumpers, large 4-door “family” sedans • Pick-up truck durability and functionality
1970’s Oil Pricing, CAFÉ requirements	• Vehicle downsizing • Introduction of SMC and aluminum body structures and closures • Advanced High-Strength Steels for ULSAB, Future Steel Vehicle • Engine and powertrain efficiencies
54.5 by 2025	• Disciplined, engineering approach to fuel economy • Increased focus on aluminum sheet applications • Die cast components of aluminum or magnesium alloys
Carbon intensity, GWP and sustainability	• Electrification details influence material decisions • Steel evolves to Gen 3 AHSS with high-strength and good formability

Automotive Materials Advancement, Proliferation and Acceptance

- Materials development and growth
  - Lucrative automotive market
  - Increased technology for component manufacturability
  - Collaborative approach to market
  - Production capacity and service capability enhancements

- Ancillary support development
  - Adhesives and adhesive technology
  - Novel joining methodologies
  - Laminated products and over-molding
  - Risks taken by leading automakers

Targets Impacting Automotive Material Selection

Categorical objectives of a vehicle program (short list)

- Business (Enterprise) targets:
  - Capital investment, manufacturing capability, business continuity, recyclability and sustainability
- Program (Vehicle) targets:
  - Architecture, mass, cargo and passenger objectives, pricing (affordability)
- Vehicle (Performance) targets:
  - Crashworthiness, ride, handling, noise, vibration & harshness (NVH), fuel efficiency, electrification

Material selections must support these criteria

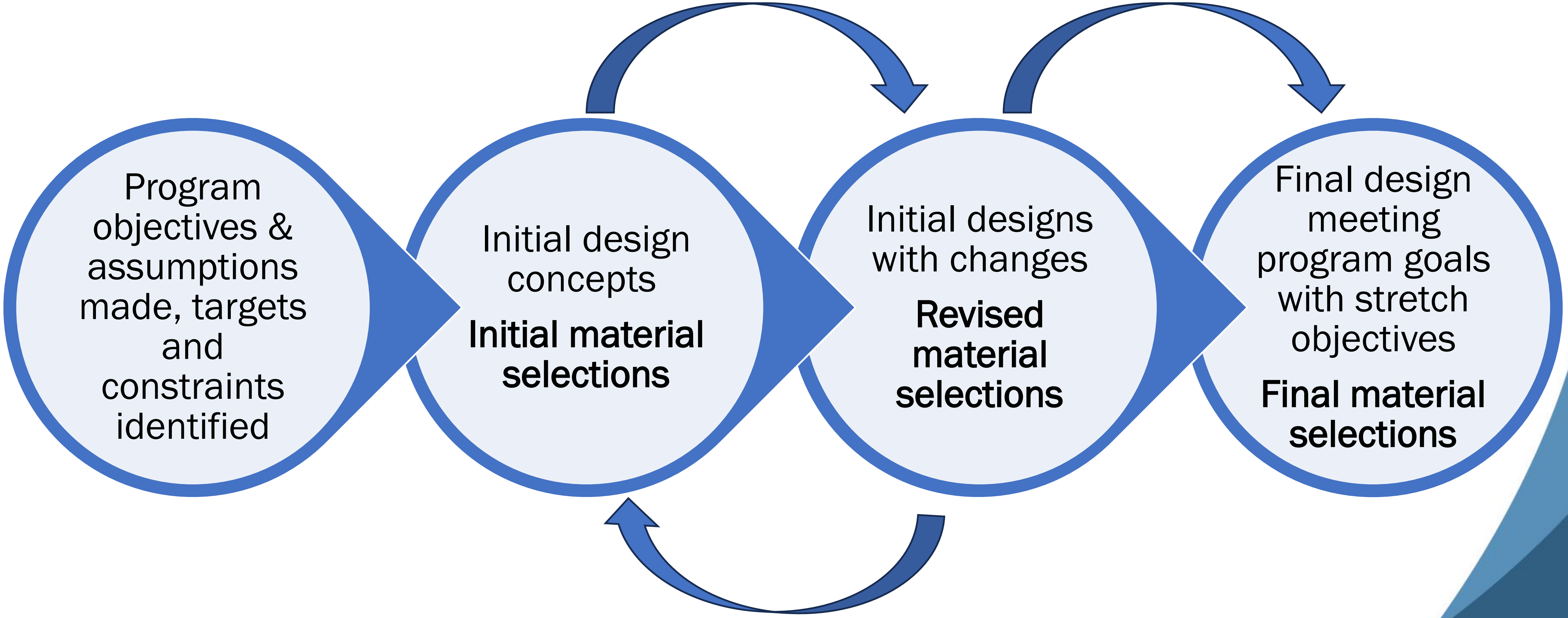
Vehicle Electrification Factors Impacting Automotive Materials and Designs

- Impact of battery technology on automotive design
  - Volumetric and gravimetric energy density
  - Cost of battery technology and total range
  - Potential thermal event risks
  - Consumer acceptance (range and recharge-ability)
  - Future battery technology a step away
- Structural integration requirements with battery fuel
  - Increase in vehicle mass from batteries
  - Lower center of gravity
  - Crash energy load path management
  - Structural effectiveness of enclosures
  - Enclosure integration with body structures and features

Sustainability Concerns have Reached Critical Mass, Impacting Auto Materials and Designs

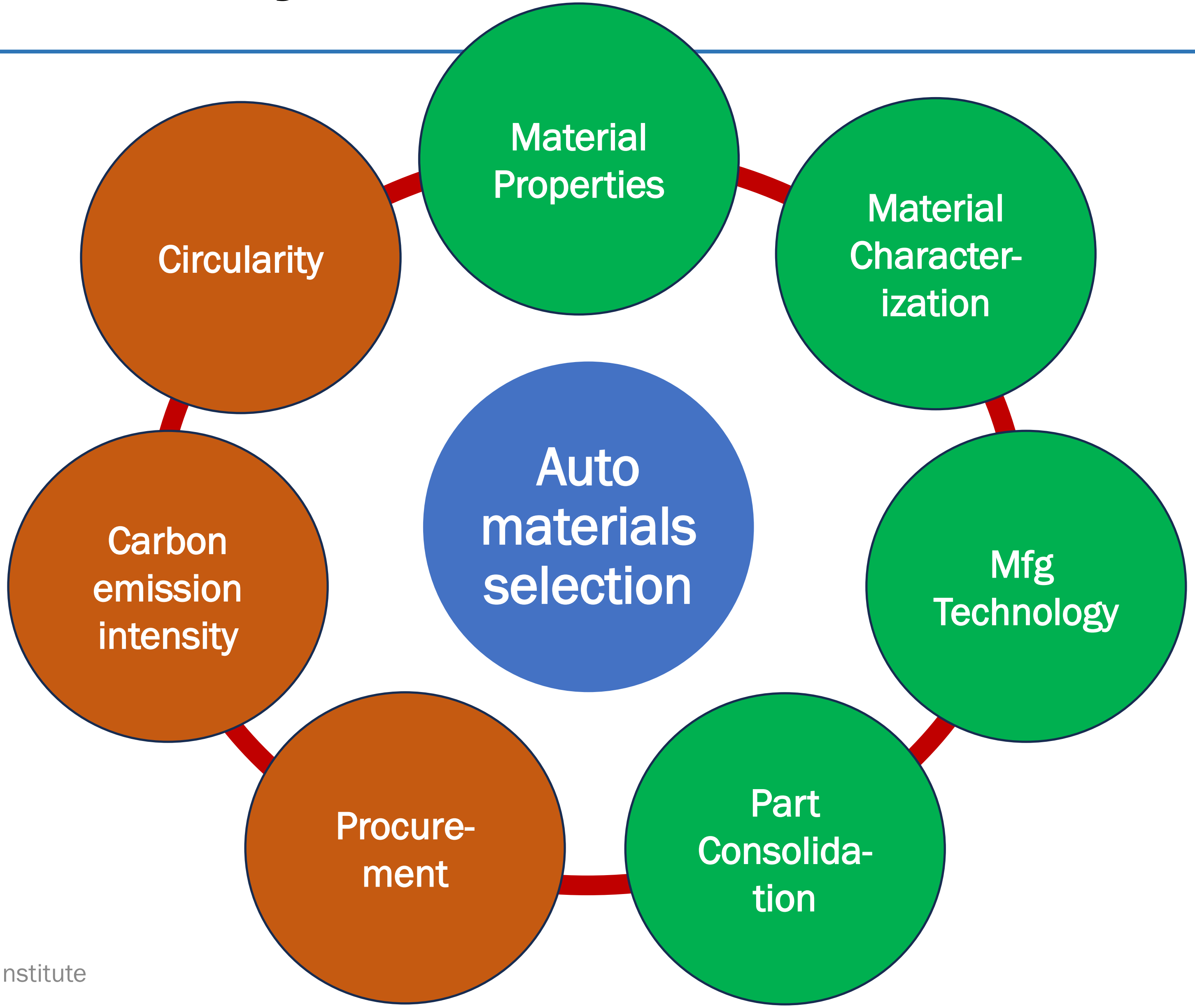
- Impact of all GHG emission factors and relationships
  - Use phase vs. production phase ratio
  - Source and carbon footprint of supplied energy
  - Critical minerals extraction and supply chain
  - Other vehicle materials contribution to GWP
  - Carbon intensity of (all) raw materials production
  - Full LCA considerations of the supply chain

Automotive Design Process (high level)



Automotive Body Material Selection Criteria

Program and corporate level objectives

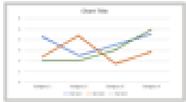


Design and manufacturing engineering Concerns

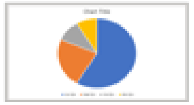
Automotive Body Materials Considerations

Steel

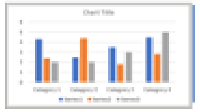
Material Properties
(strength and ductility relationship)



Material Characterization
(adequacy for models to support simulations)

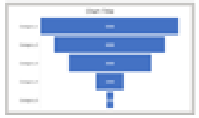


Manufacturing Technology
(available part manufacturing options)

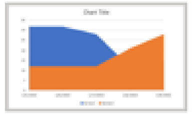


Part Consolidation
(opportunity to reduce automotive assembly costs)

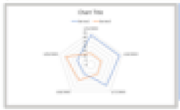
Procurement
(availability,harmonization,cost)



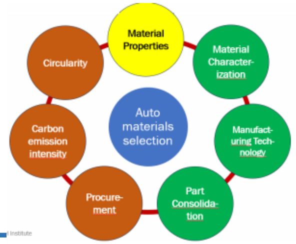
Carbon Emission Intensity
(as embodied carbon, emitted CO_2/GHG, GWP)

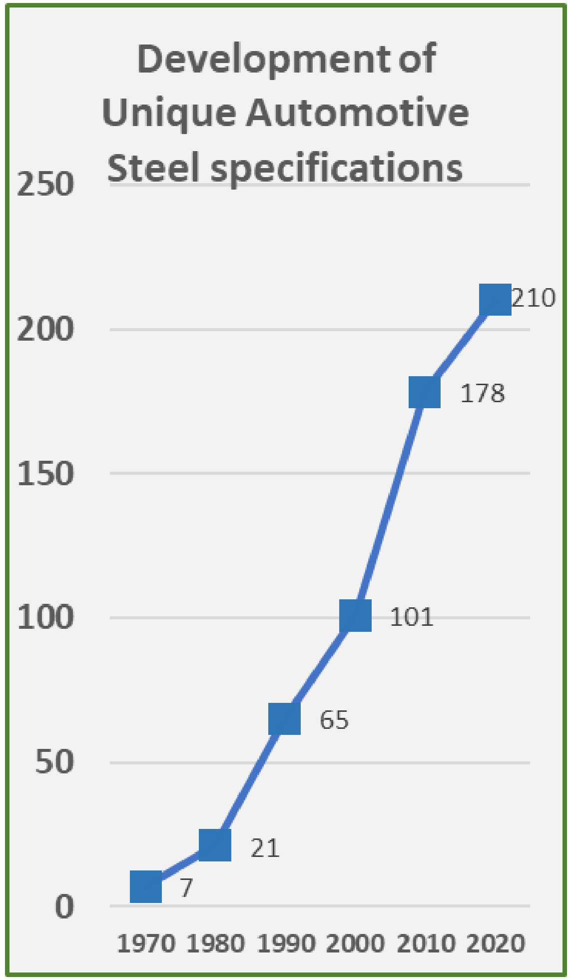


Circularity
(rates, ease of capture and actual recycling)



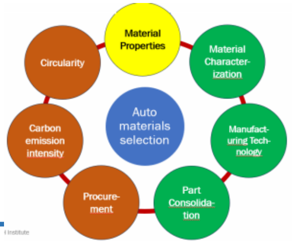
Material Property Options Using Steel Example

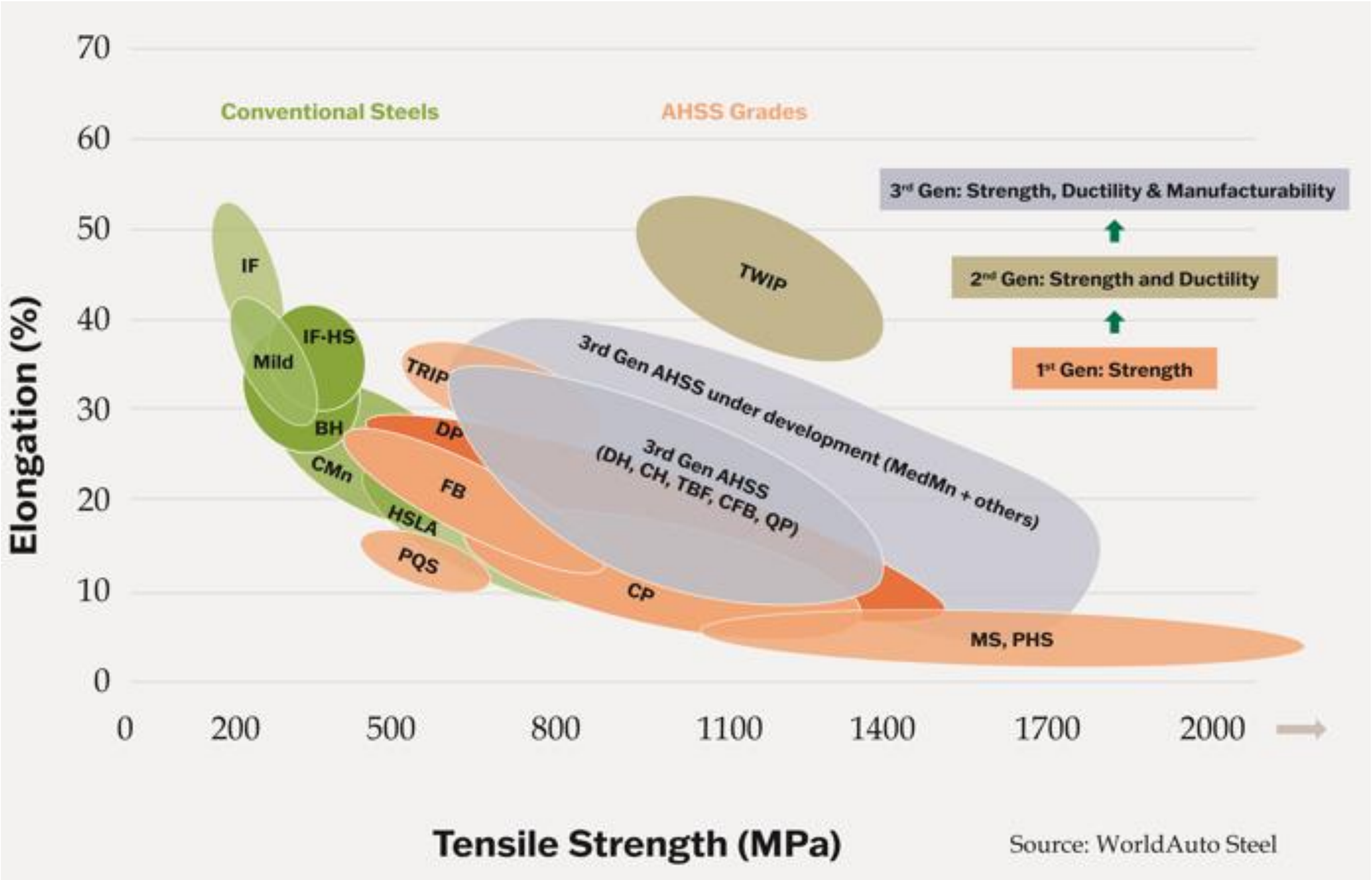




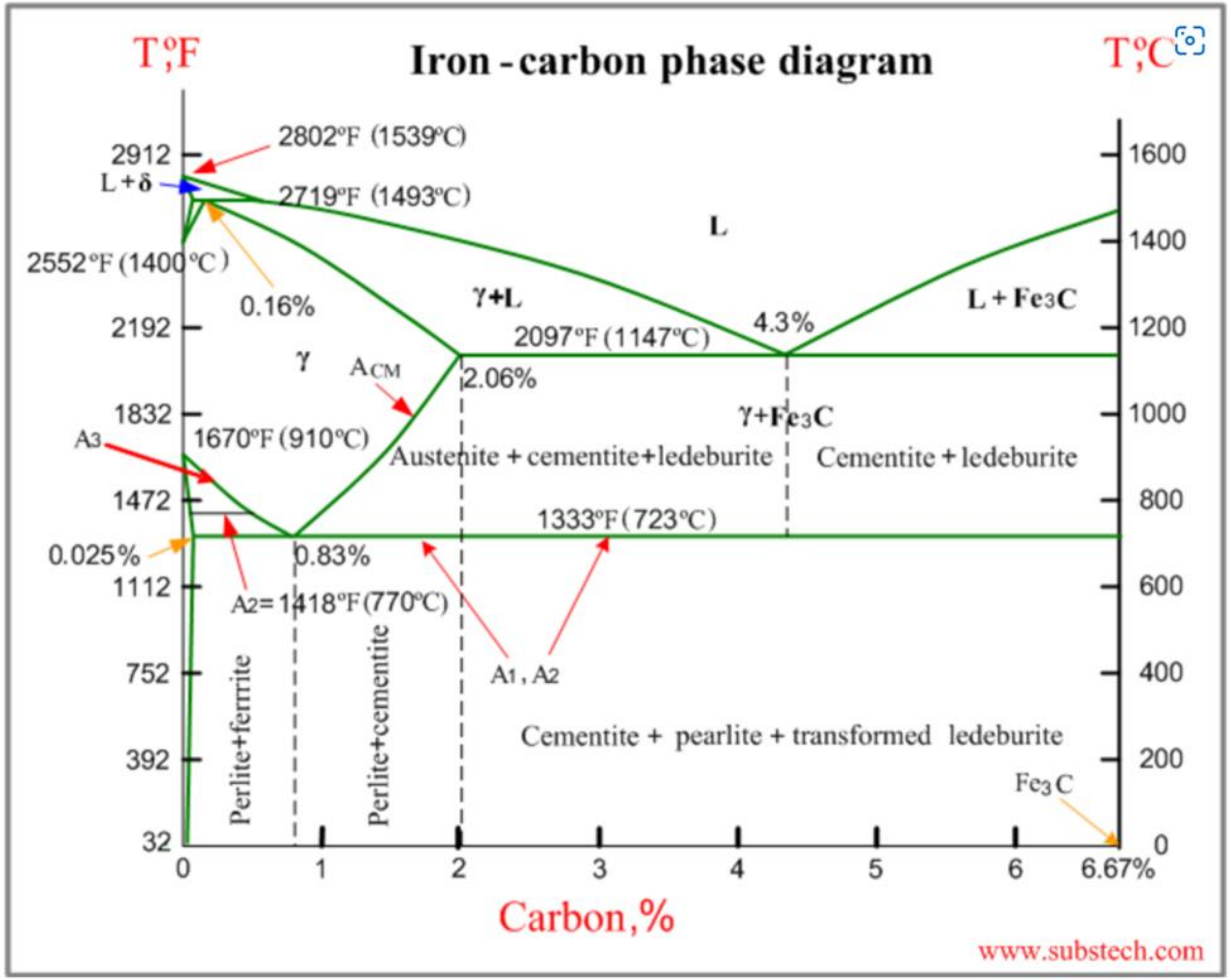
- Pre 1970: Basic Fe-C- Mn metallurgy, good options for the times
- 1980's: HSLA steels expanded range of steel property windows
- 1990's: Dual phase steels offer new windows of strength/ductility
- 2000's: Hot stamped martensite steel for complex high-strength parts
- 2010's: Complex phase steels with multi-phase microstructure
- Current: Gen 3 AHSS challenging paradigms with combined high-strength and improved ductility

Global Formability Diagram for Steel





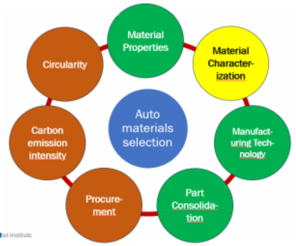
Innovation and Evolution of New Steel Grades



Equilibrium Phase Diagram

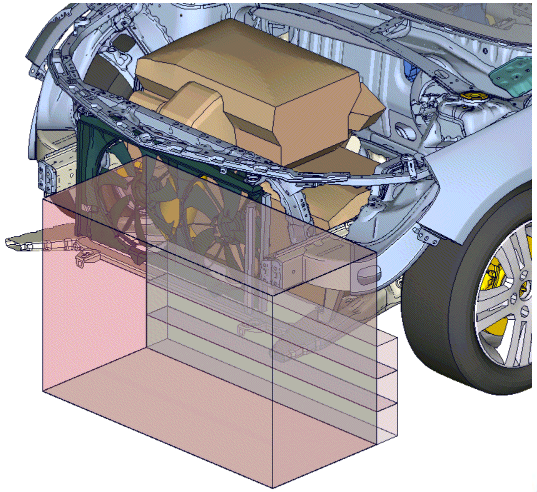
- A range of equilibrium solid solution phases can be observed in this unique alloy system
- Controlled **Non-equilibrium processing** (fast heating and/or rapid cooling) can precisely modify and combine these phases to create new steel grades
- That's what drives tailored innovation in steel grade design

Modeling Provided with New Steel Grades

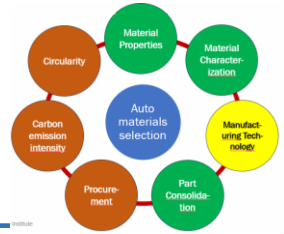


- Standardized testing and validation of material properties
- Stamping simulation that calculates imparted strain
- Apply constitutive models that estimate the post strain props
- Apply to models that predict the response to high strain rate deformation
- Utilize models that predict fracture mechanisms for sections
- Achieve reliable and verifiable part stamping and crash modeling

Euro NCAP ODB

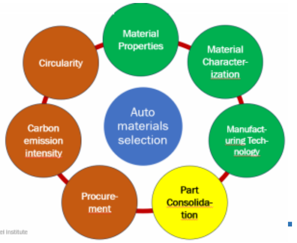


Advancements in Manufacturing Technology using Steel



- AISI recently convened an analysis which detailed close to 70 advancements in manufacturing technology
- Geared towards reducing complexity of automotive part production and simplifying assembly
  - Roll forming in 3 dimensions (Major commercial implementation)
  - Welded blanks, welded coils, blanking flexibility
  - Tubular hydro-forming
  - Hot gas forming
  - Variable quenching in hot stamping
  - Integration of localized heating/cooling in stamping technology

Part Consolidation Opportunity



- Laser technology for cutting and welding dissimilar blanks and coils
- Multi-blank laser weld pre-processing
- Rolling process control managing cyclical gauge increases
- Roll stamping replaces long thin stamped assemblies
- Hot stamping with controlled differential cooling rates

Consolidation ratios as high as 6:1

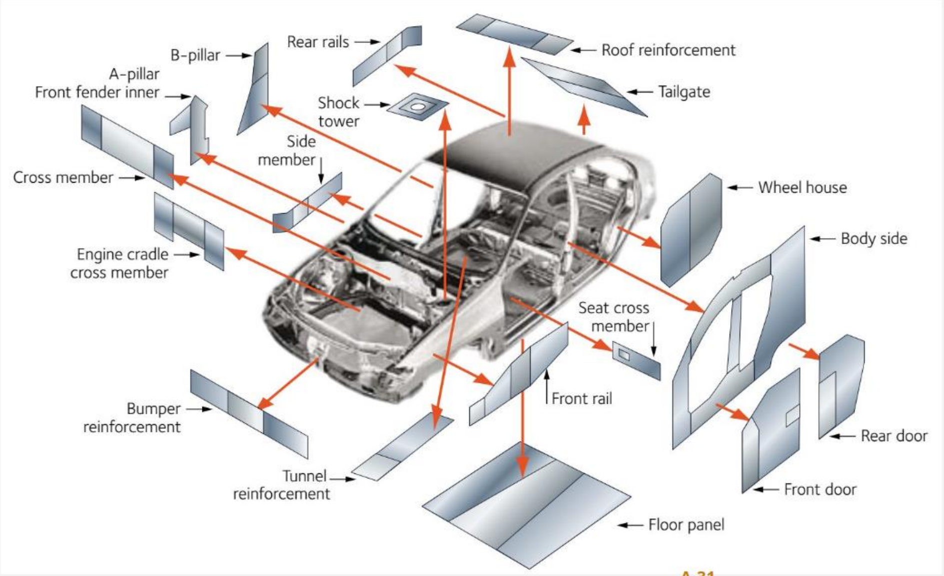
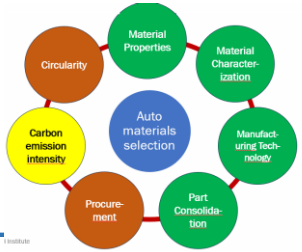
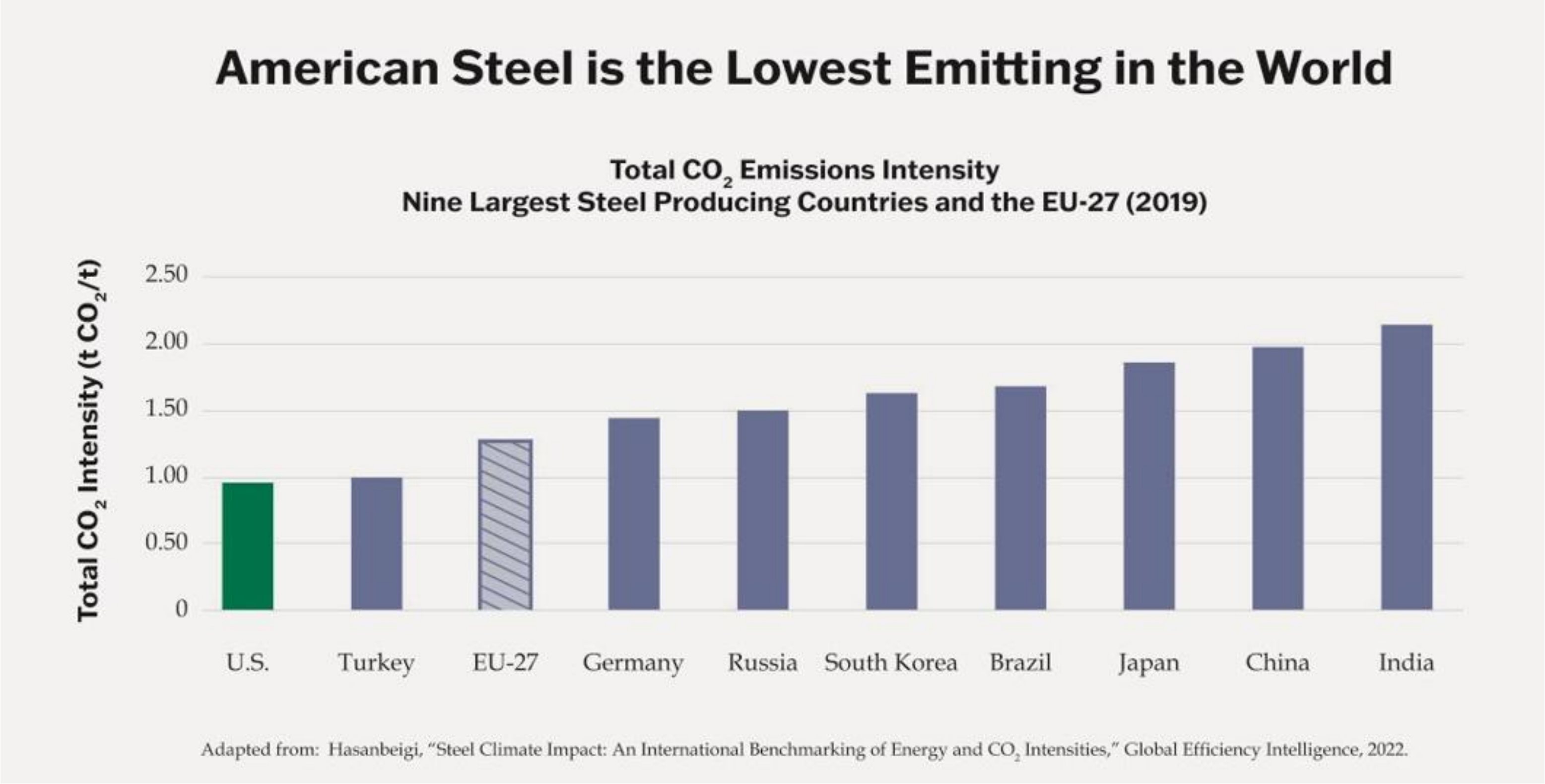


Figure 1: Applications suited for welded tailored blanks. A-31

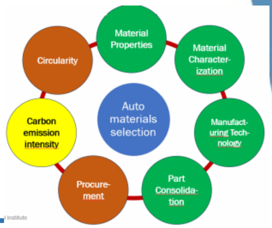
Sustainability (Carbon emission intensity)

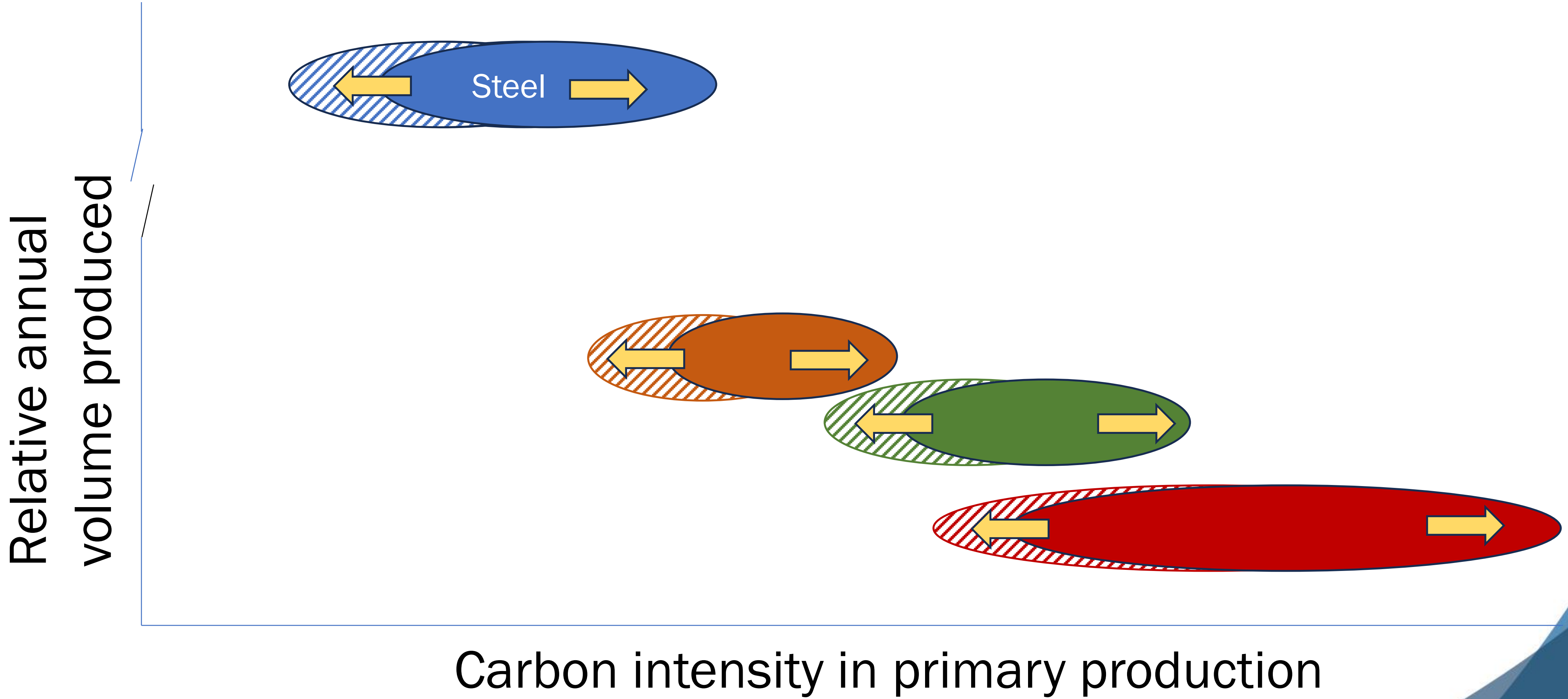


- American made steel is the lowest carbon emission intensity of the nine largest steel producing countries

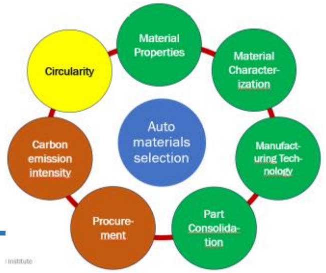


Relative Carbon Emission Intensity in Primary Production of Steel to Competing Materials

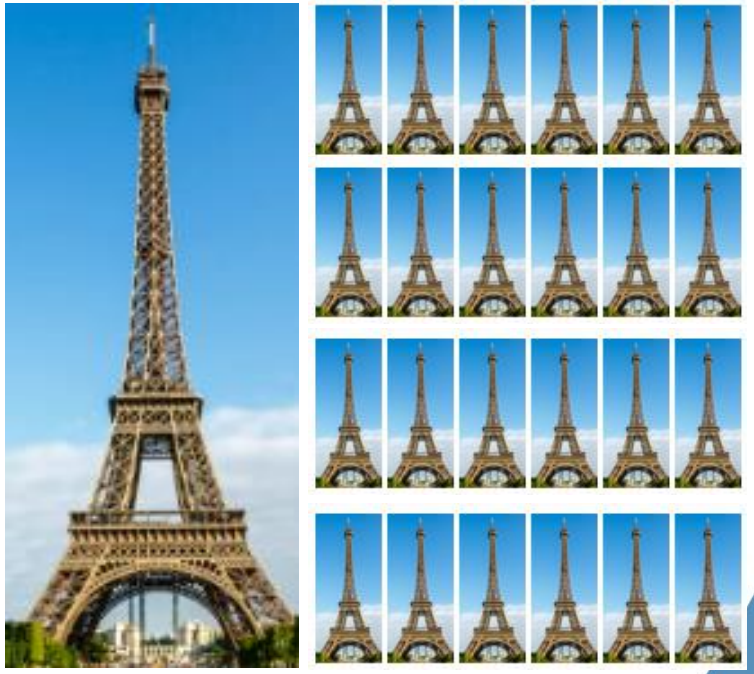




Recyclability / Circular Lifecycle



- Steel is 100 percent recyclable, and is repeatedly recycled into the same material of the same quality
- Typically, 60 to 80 million tons of non-closed loop steel scrap is recycled every year into new steel products in North America
- Each of two main steelmaking processes utilize scrap, from 30% to 100% of each new furnace charge
- United States processes enough ferrous scrap daily, by weight, to build 25 Eiffel Towers every day of the year



Steel Meets Automotive Body Material Selection Criteria

Comprehensive range of modern ***steel grades***

C-Mn Interstitial Free | HSLA | Martensitic | Dual Phase | Complex Phase | 3rd GEN

Characterization *for advanced modeling*

Resistance Spot Welding | Non-Linear Strain Simulation | Fracture Mechanics | DIC Monitoring of Strain | Computational Material Design | Forming Simulation

Steel pre-processing for ***part consolidation***

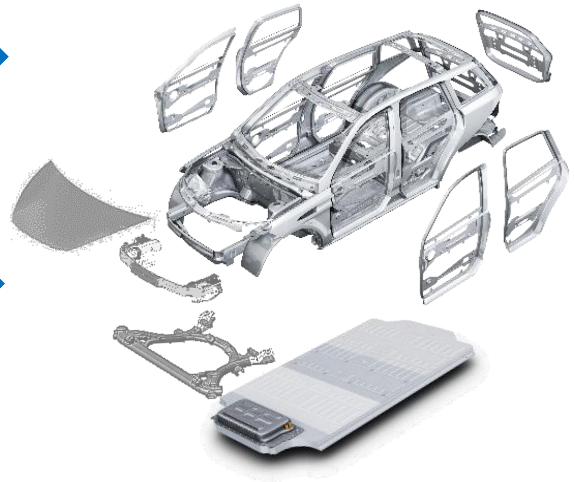
Laser Welded Blanks | Multi Piece Laser Welded Blanks | Tailor Rolled Coil | Laser Blanking | Laser Welded Coil | Specialty Coatings

Advanced ***manufacturing*** *technologies*

Forging & Stamping | Roll Forming Hydroforming | (PHS) Hot Stamping | PHS Variable Quench Welded Blanks | 3D Roll Forming, Roll Stamping | Hot Metal Gas Forming

Best ***sustainability*** *and decarbonization potential*

Natural Gas reductants | Direct Reduction processes | Hydrogen injection | Carbon Capture and Sequestration | Closed Loop recycling | Sourcing Green Energy Tech



"Right Weighted" Mass Efficient automotive structures

Thank You / For More Information

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