American Iron and Steel Institute

Steel Response to Challenges of a Modern Automotive (and Mobility) Industry

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Automotive Parts Suppliers Conference

October 11, 2022

Dearborn, MI

Outline

- AISI introduction
- Modern steel producing operations
- Steel grade development history
- Decarbonization and sustainability in the American steel industry
- Challenges with advanced steel materials
- Impact of vehicle electrification

AISI Introduction

Mission

The American Iron and Steel Institute's Mission is to influence public policy, educate and shape public opinion in support of a strong, sustainable American steel industry committed to manufacturing products that meet society's needs.

Vision

The vision of the Institute and its members is for a sustainable American steel industry strategically positioned for growth and innovation and as a leader in the global marketplace.

Producer Members

ArcelorMittal
Cleveland-Cliffs Inc.
DTE Energy Resources
Harsco Environmental
North American Stainless
Nucor Corporation
Outokumpu
SSAB Americas
Tenaris Bay City

Associate Members

Approximately 70 supplier and supporting companies

Steel Industry Collaboration

American Iron and Steel Institute

Automotive Applications Council

Focuses on innovation in automotive steel and advanced manufacturing, providing industry education and supporting technology transfer initiatives.

ArcelorMittal
CLIFFS
NUCOR

Auto/Steel Partnership

Pre-competitive Collaborative Research & Development; Leveraging joint contributions and intellectual capital providing more value and quicker results

Ternium
Gestamp
gm
MARTINREA
NUCOR
posco
STELLANTIS
TOYOTA

WorldAutoSteel

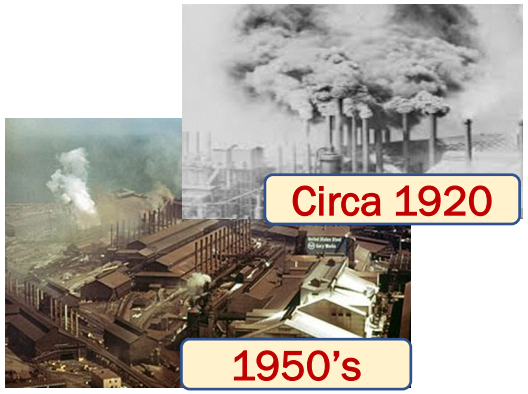
Leverages the global industry to meet society's needs for automotive and mobility related steel products in a sustainable and environmentally responsible way

www.steel.org
www.autosteel.org
www.a-sp.org

Modern Steel Producing Operations

Steelmaking Modernization in the U.S.

- Today's American steel industry is high tech and clean, resulting from significant modernization and new technology investments
- Globally developed improvements in the steelmaking process have been and continue to be implemented by American steelmakers
- There has been SIGNIFICANT investment in personnel training, new mill facilities and highly capable process equipment



Industry Consolidation and New and Announced Investments in Recent Years

CLEVELAND-CLIFFS INC.

Acquisition of AK Steel
Acquisition of ArcelorMittal USA
Toledo, OH HBI production facility
Silver Bay, MN upgrade
Acquisition of Ferrous Processing and Trading

ArcelorMittal

Calvert, AL EAF

NUCOR®

Sedalia, MO EAF
Frostproof, FL EAF
Gallatin, KY expansion
Brandenburg, KY EAF
Mason County, WV EAF
Kingman, AZ EAF
Lexington, NC Micro Mill
Acquisition of majority interest in CSI

CMC Commercial Metals

Acquisition of Gerdau assets
Mesa, AZ expansion
Eastern US Micro Mill

United States Steel

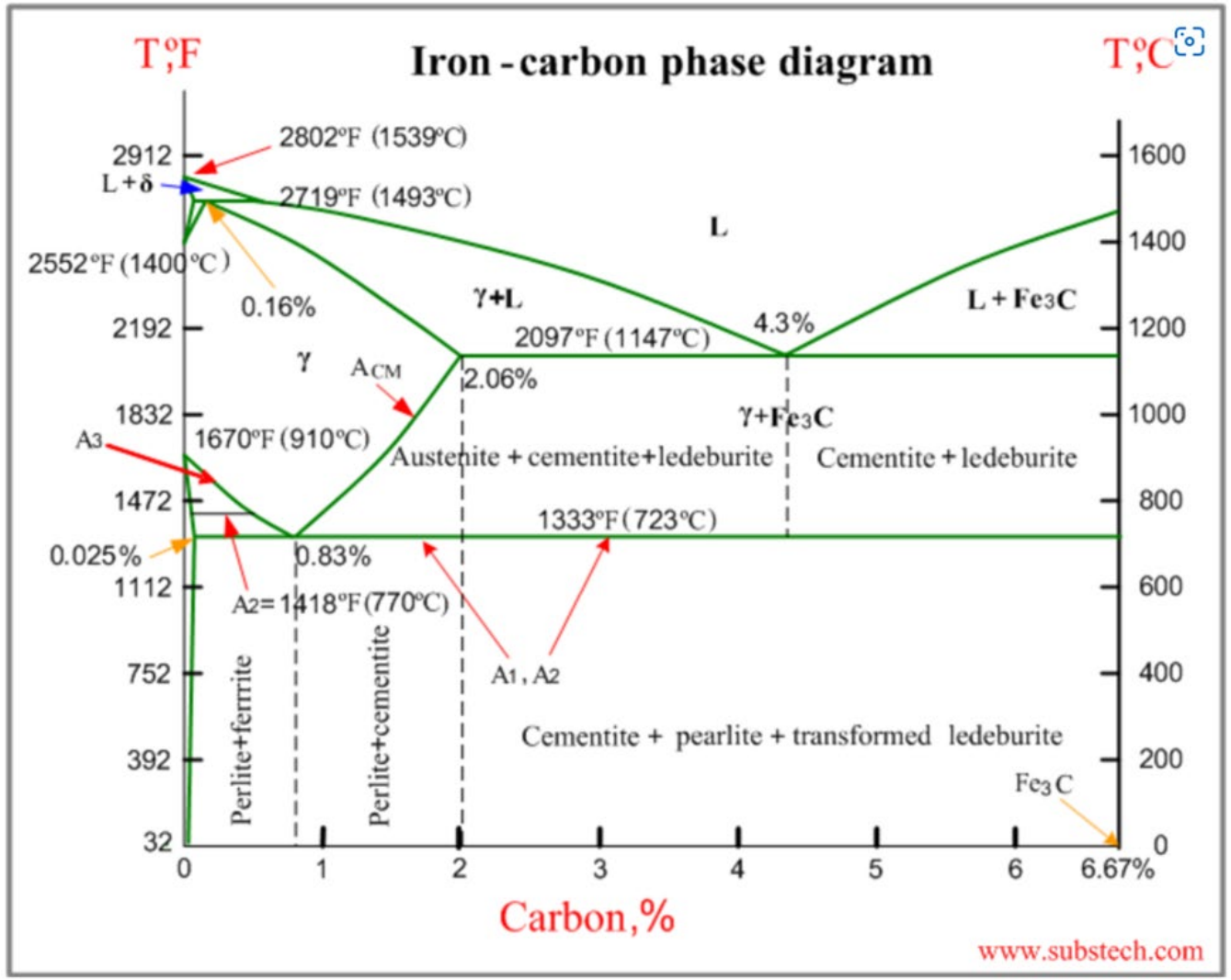
Big River Osceola, AR expansion
Osceola, AR EAF Plant

Steel Dynamics, Inc.

Columbus, MS upgrade

Total sheet mill investment nearing $10 Billion (USD) with added capabilities for electrical steels and 3rd Gen AHSS

Honorary Member of Our Team



Equilibrium Phase Diagram

- A range of equilibrium solid solution phases can be observed in this unique alloy system
- 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 innovation in steel grade design

Steel Grade Development History

The Existing Material Paradigm

TRUE or False?

Higher-strength materials have lower ductility

TRUE

Civilization is rife with examples of the impact of heating metals to reduce strength and improve ductility (improve malleability). The paradigm of higher-strength equating with lower ductility remains.

Steel Facts

- The steel industry over the past several decades has been actively engaged in implementing state-of-the-art processes and modernizing its infrastructure

- These upgrades focused on very precise control of the thermomechanical processes to produce ***NEW*** steel grades with ***BOTH*** high strength and high ductility

- The ***time*** to process steel in the ***temperature*** range of 1300°F - 1700°F (725°C to 900°C) and the ***speed*** with which the steel is cooled creates different phases and content ratio of phases

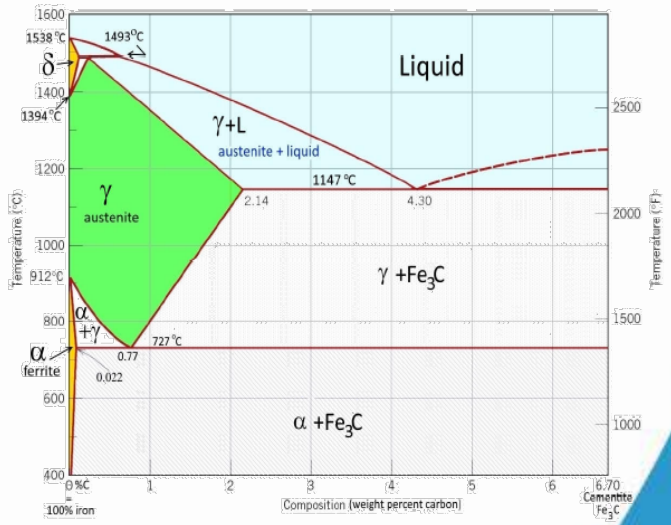
In short …
The steel industry continues to improve its product value!

Iron-Carbon Equilibrium Phase Diagram

Engineering Quality Solutions

Time/Temperature/Speed manipulation to achieve steel grades with variety of properties

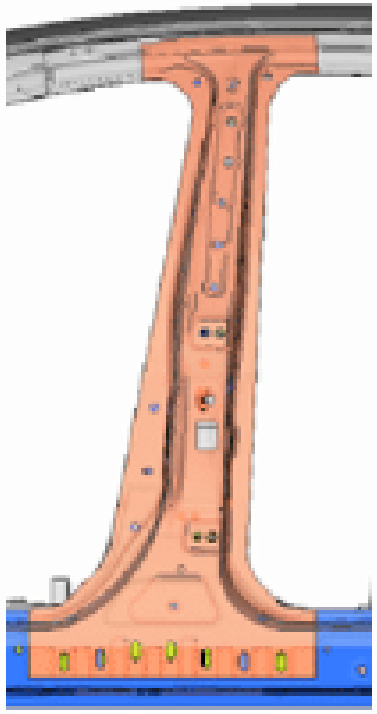
BH – Bake Hardenable
DP – Dual Phase
MP – Multi Phase
CP – Complex Phase
TRIP – High Austenite content MP
MS – Martensite
PHS – Press Hardened Steel

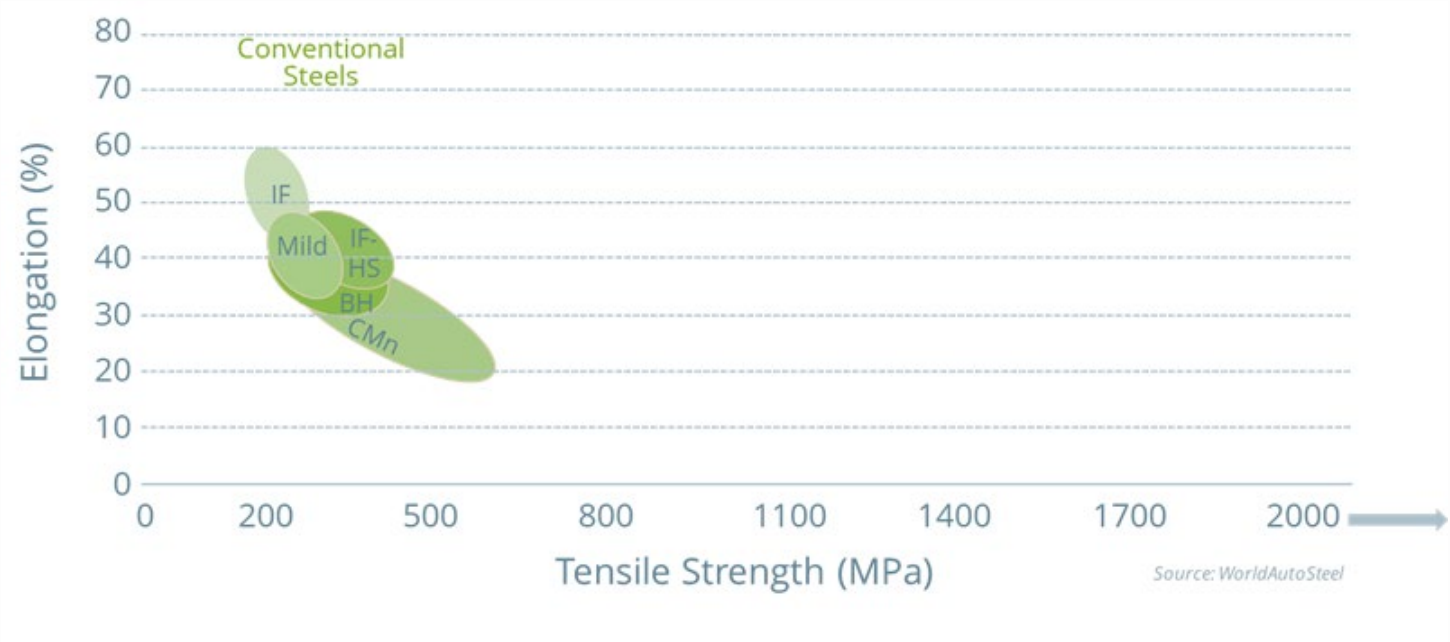


Source: Engineering Quality Solutions, Inc.

Historical Progression of Automotive Structural Applications

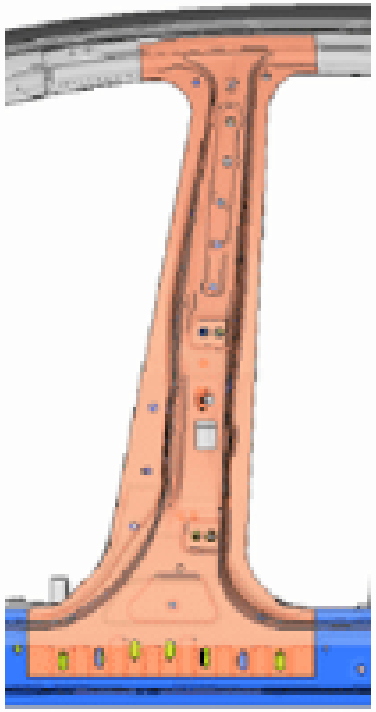
- Baseline low carbon “structural” steel grade
  - Carbon limited for weldability
  - Conventionally rolled, not heat treated or thermo-mechanically processed
  - Typically utilized heavy thicknesses for added strength
  - Used with reinforcement “patches” for door locks and strikers/hinge plates

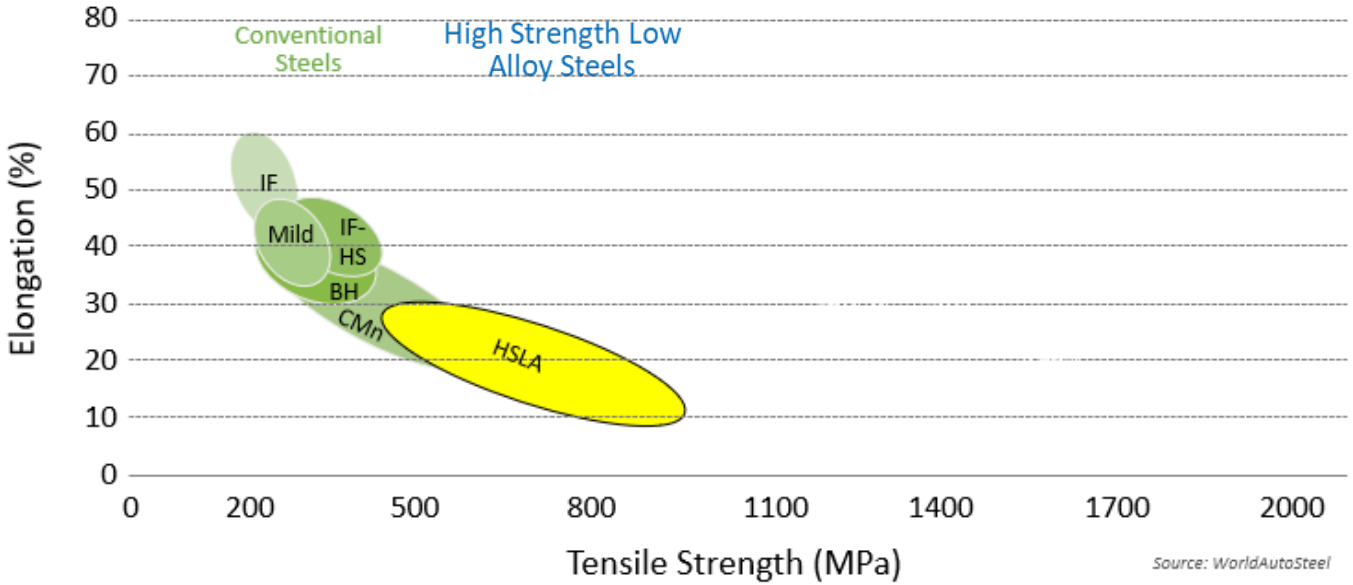




Historical Progression of Automotive Structural Applications

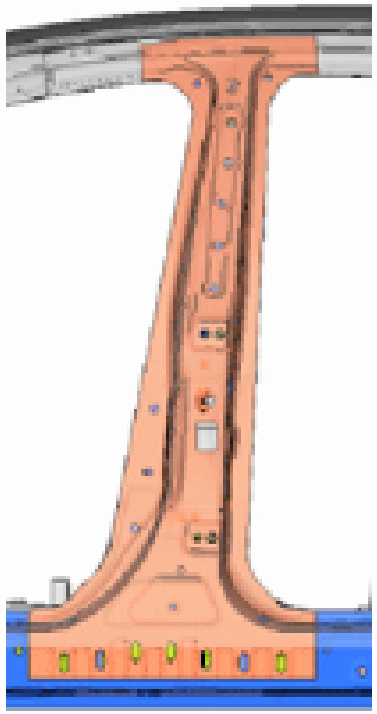
- Application of High-Strength Steel grades (HSS)
  - A low carbon alloy with some substitutional alloying elements (manganese, silicon)
  - Small additions of micro-alloys (Nb, V, Ti) added to aid in precipitation hardening
  - Strength levels increased allowing some downgauging for formability and weight reduction
  - Called High-Strength Low Alloy (HSLA) as an indicator of differentiation from structural carbon steel

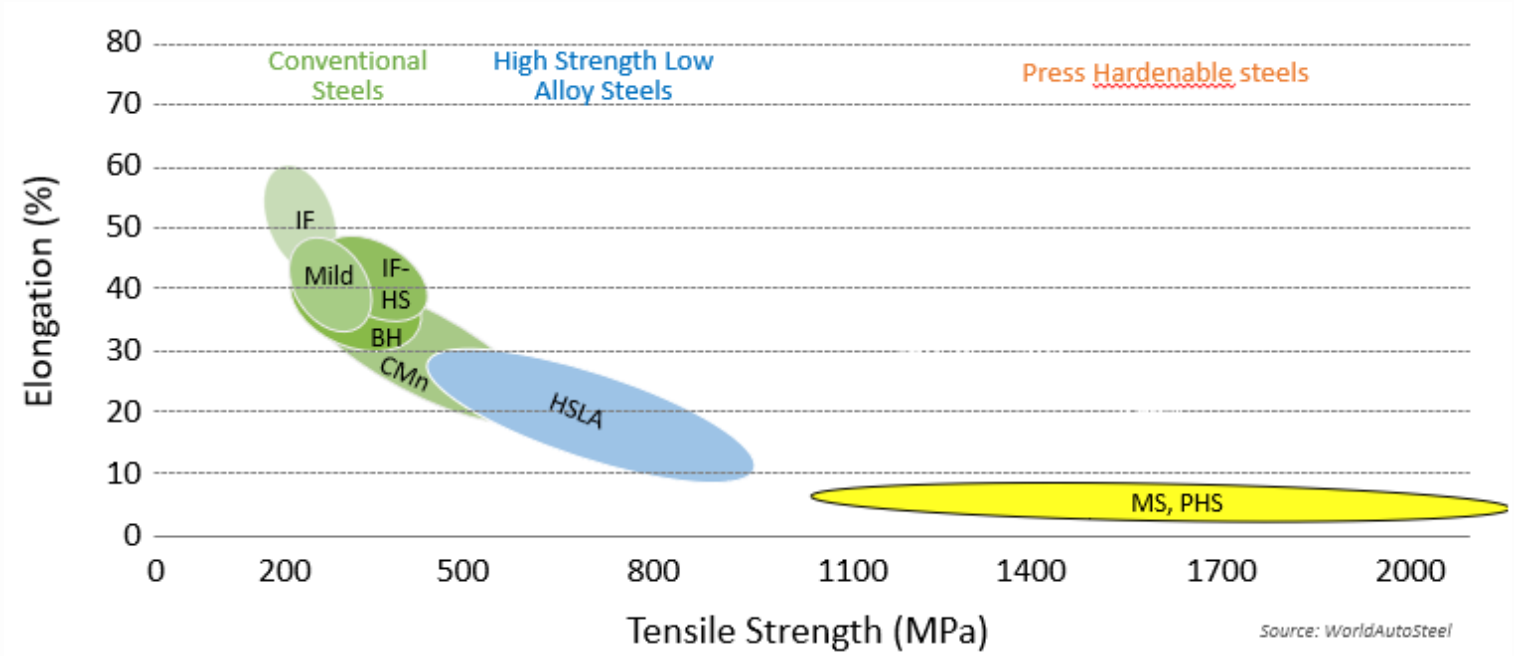




Historical Progression of Automotive Structural Applications

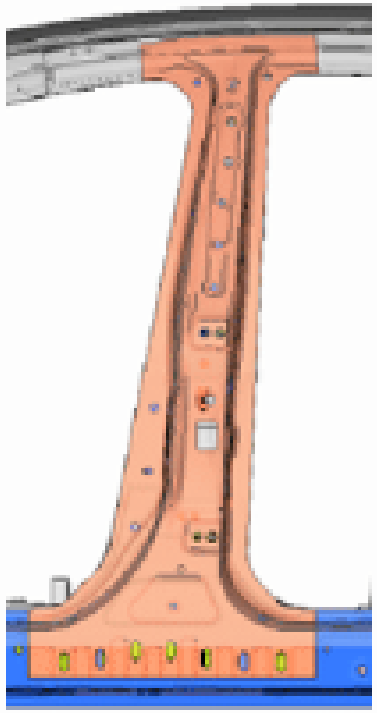
- **Hot Stamped Press Hardened Steels**
  - Boron additions to 1522 steels are stamped above 1500F (850 C) and then quenched in die
  - Forming in the austenite region of the Fe-C phase diagram became a relevant steel processing method developed to support complex parts at high strength levels
  - Hot Stamping (Press Hardening) required post stamping processing (descaling, trimming) but became an effective path to create complex parts at very high strength levels

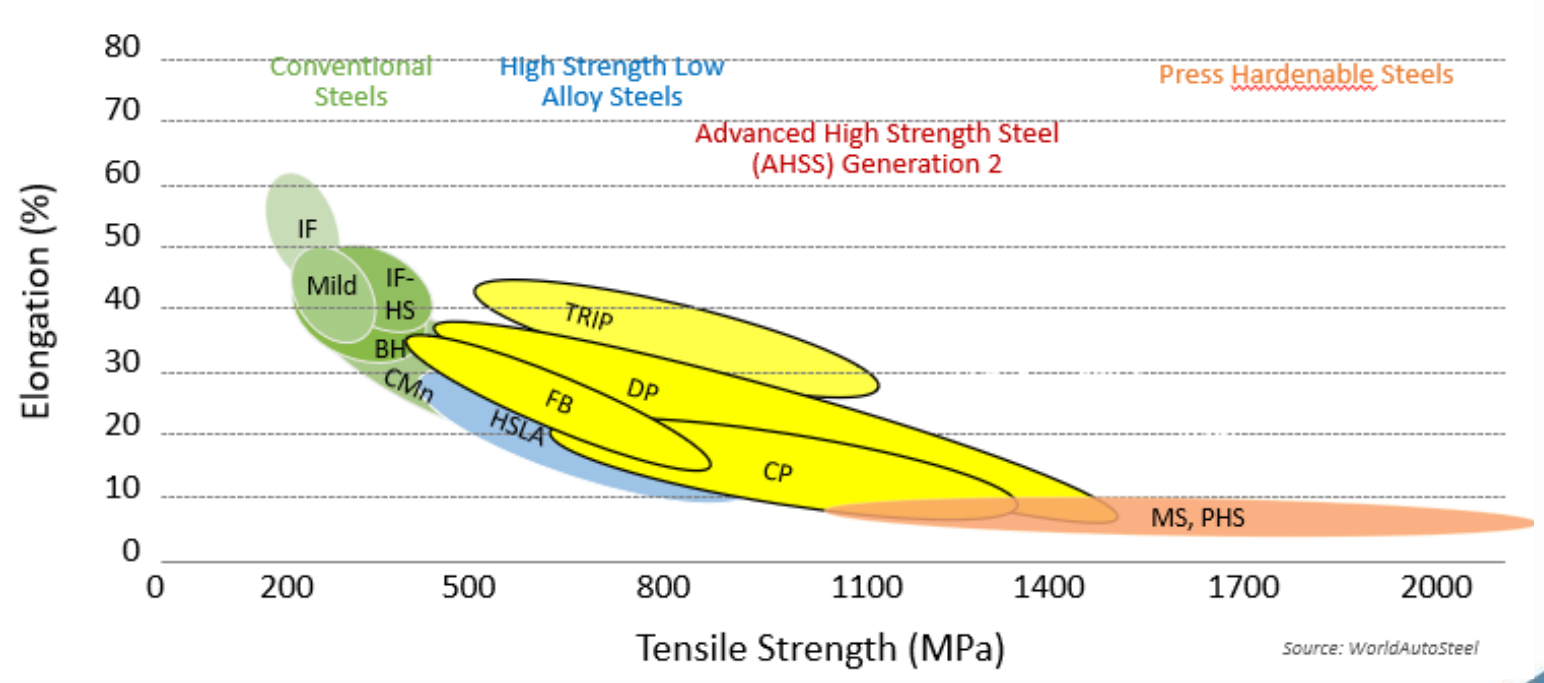




Historical Progression of Automotive Structural Applications

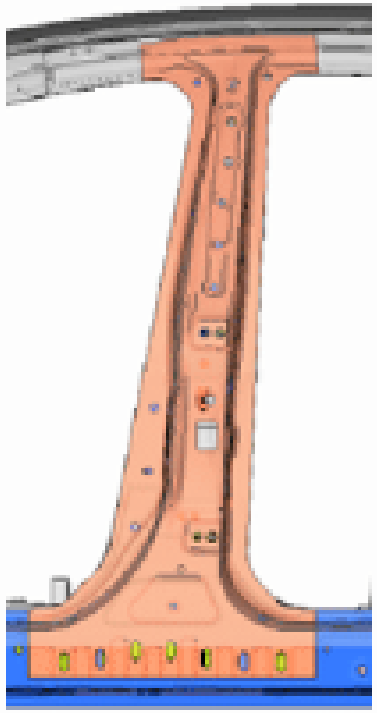
- Application of 2nd Gen AHSS and UHSS
  - Improved steelmaking process design and facilities allow for these grades of steel
  - These are precisely alloyed with substitutional elements to increase baseline strength (Manganese, Silicon) and stabilize required Fe-C phases
  - These are continuously annealed and precisely cooled (quenched) at controlled rates to create multiple phase in the final microstructure adding strength and preserving ductility
  - The terms Dual Phase (DP) and Complex Phase (CP) are used to define the microstructure

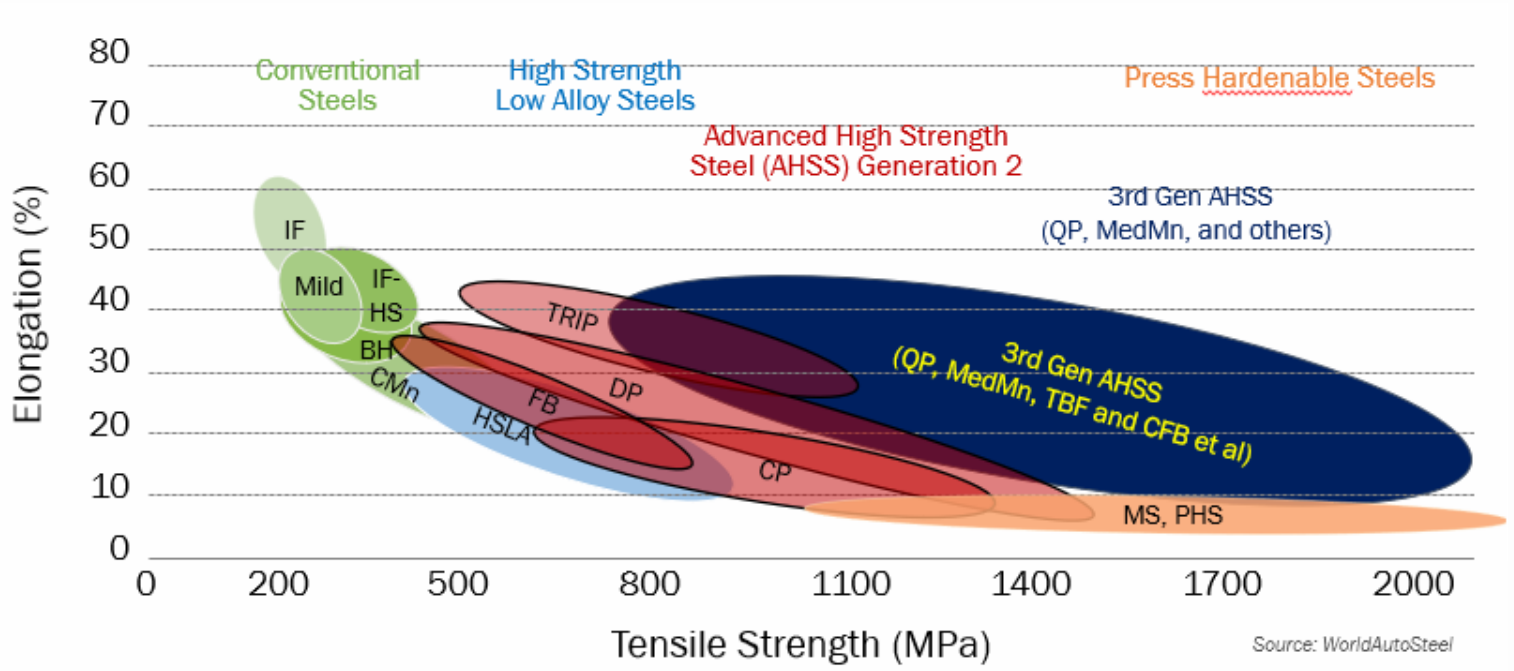




Historical Progression of Automotive Structural Applications

- Introduction of 3rd Gen Steel
  - Recently, modern steel grades, referred to as Generation 3 steels, utilize processing techniques that improve the typical strength/ductility relationship, can be cold or hot formed and are downgauged due to increased material strength
  - They possess high strength and have sufficient ductility to be cold formed in stamping operations
  - These are the product of significant R&D on the part of the steel industry and facility upgrades to be capable of the required thermal heat treatment and rapid cooling process control





Automotive Steel Processing Line (AHSS, UHSS and 3rd Gen)

Improved technologies and equipment for gas jet cooling to precise temperature windows

AHSS, UHSS

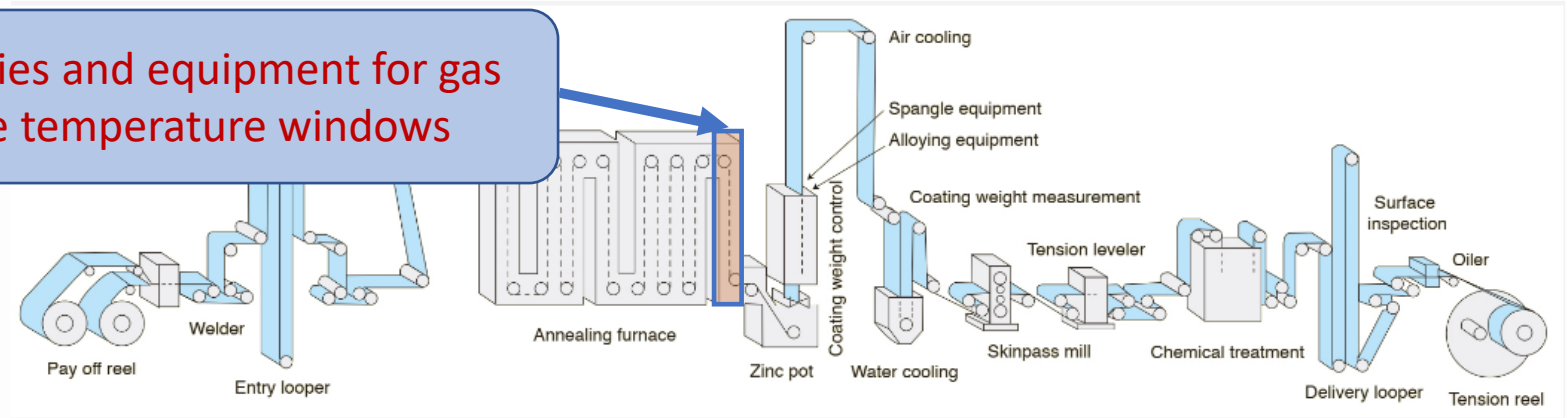


Figure 1: Schematic of a typical hot dipped galvanizing line with galvanneal capability.

AHSS, UHSS and 3rd Gen

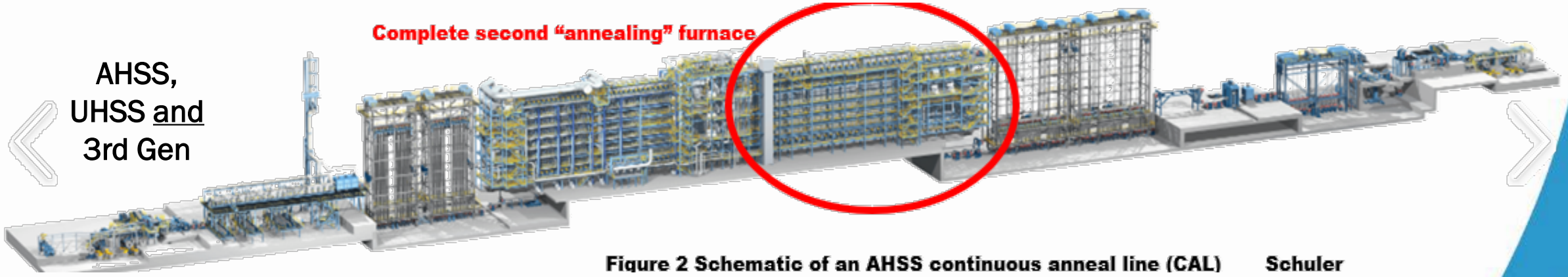


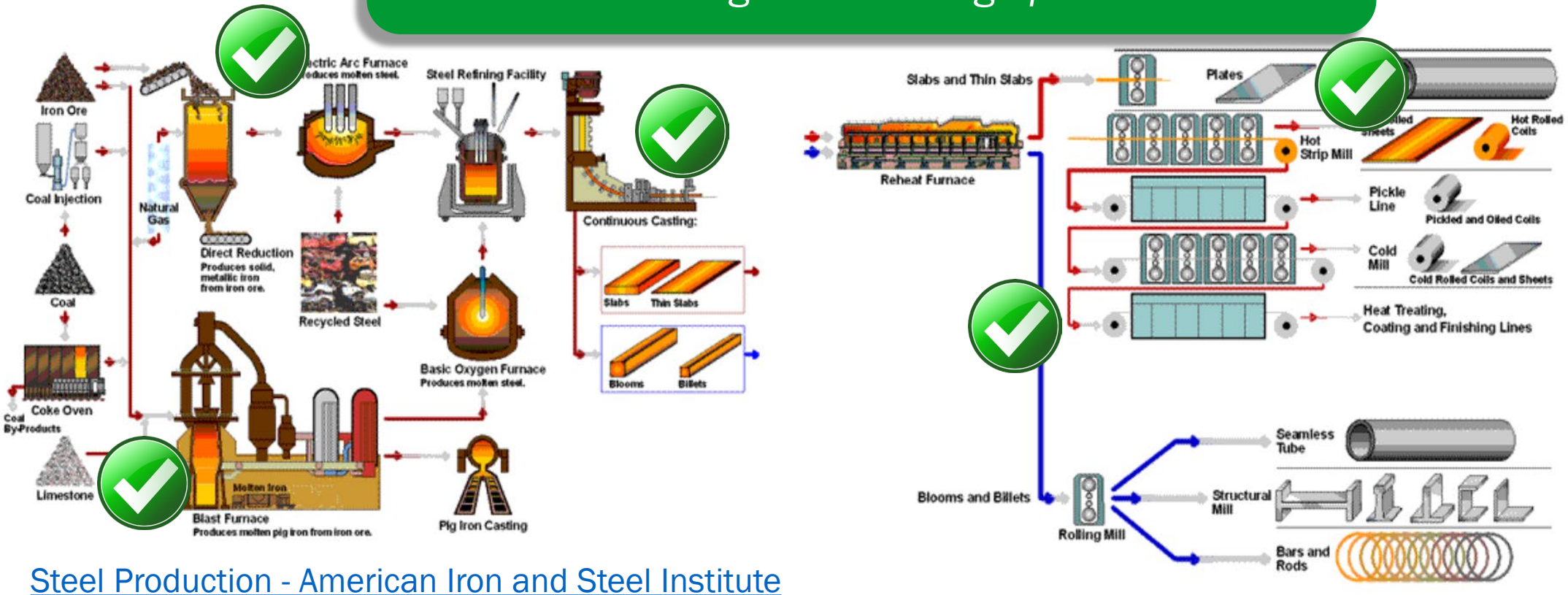
Figure 2 Schematic of an AHSS continuous anneal line (CAL) Schuler

3rd Gen CAL lines are very large, complex, and highly advanced in process control and automation. These lines are in production now.

Steel Processing is Modern Beyond Perception of People

Advanced process controls that support the production of "new" AHSS steels exist throughout the steelmaking and finishing operations.

Steel Flowlines



[Steel Production - American Iron and Steel Institute]

Existing Paradigm is Challenged by Modern Steel Mills

TRUE or False?

Higher-strength materials have lower ductility

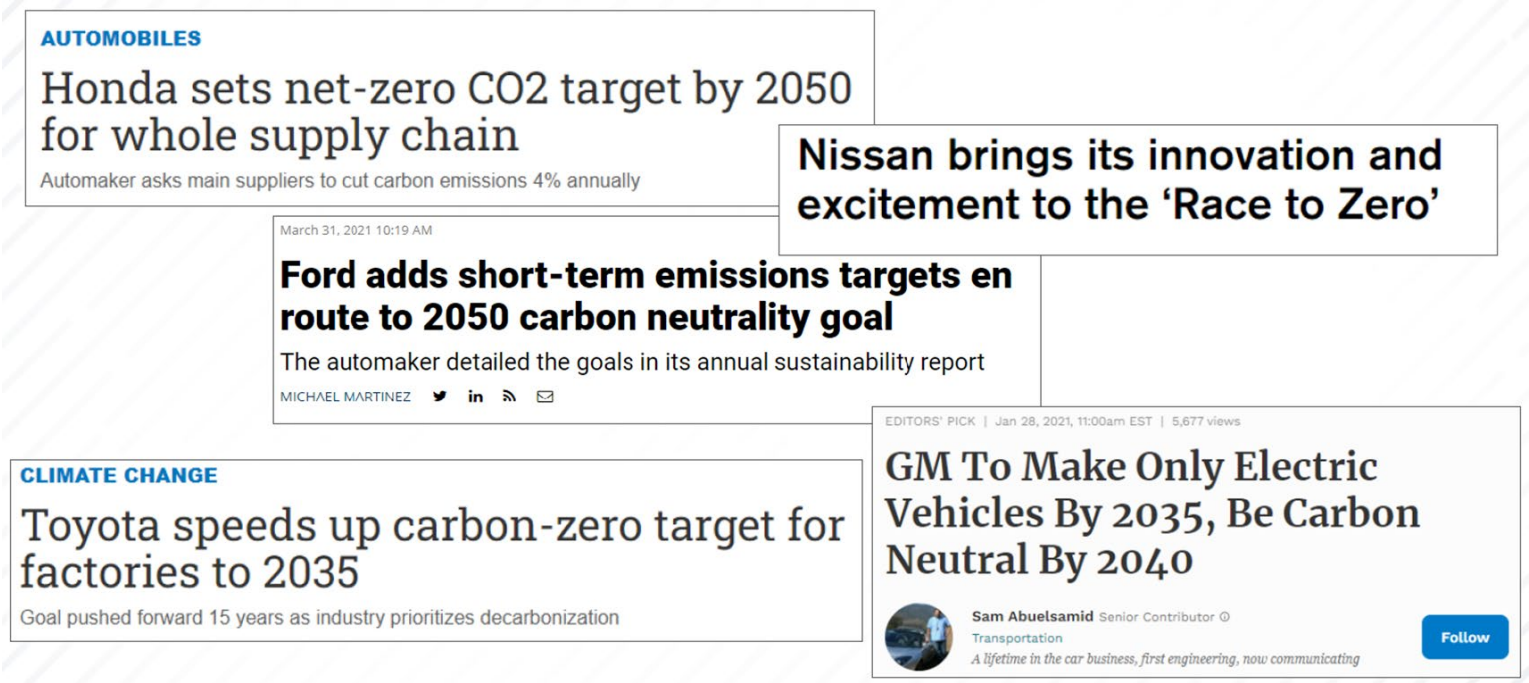
FALSE

Modern thermo-mechanical steel processing with precise automation and control can produce high-strength material with vastly improved ductility to allow for the cost and mass efficient use of Advanced High-Strength Steel in automotive Body in White designs

Decarbonization and Sustainability in the American Steel Industry

Sustainability, CO_2 Emissions, GHG

- The automotive industry is a leading player in the drive to lower environmental footprint by reducing CO_2 emissions
- This will have an impact on major parts and materials suppliers to the industry



U.S. GHG Emissions and the Role of Steel

- The global steel industry contributes 8% of total global GHG emissions
- In the U.S., the steel industry emits only 1-2% of total U.S. GHG emissions

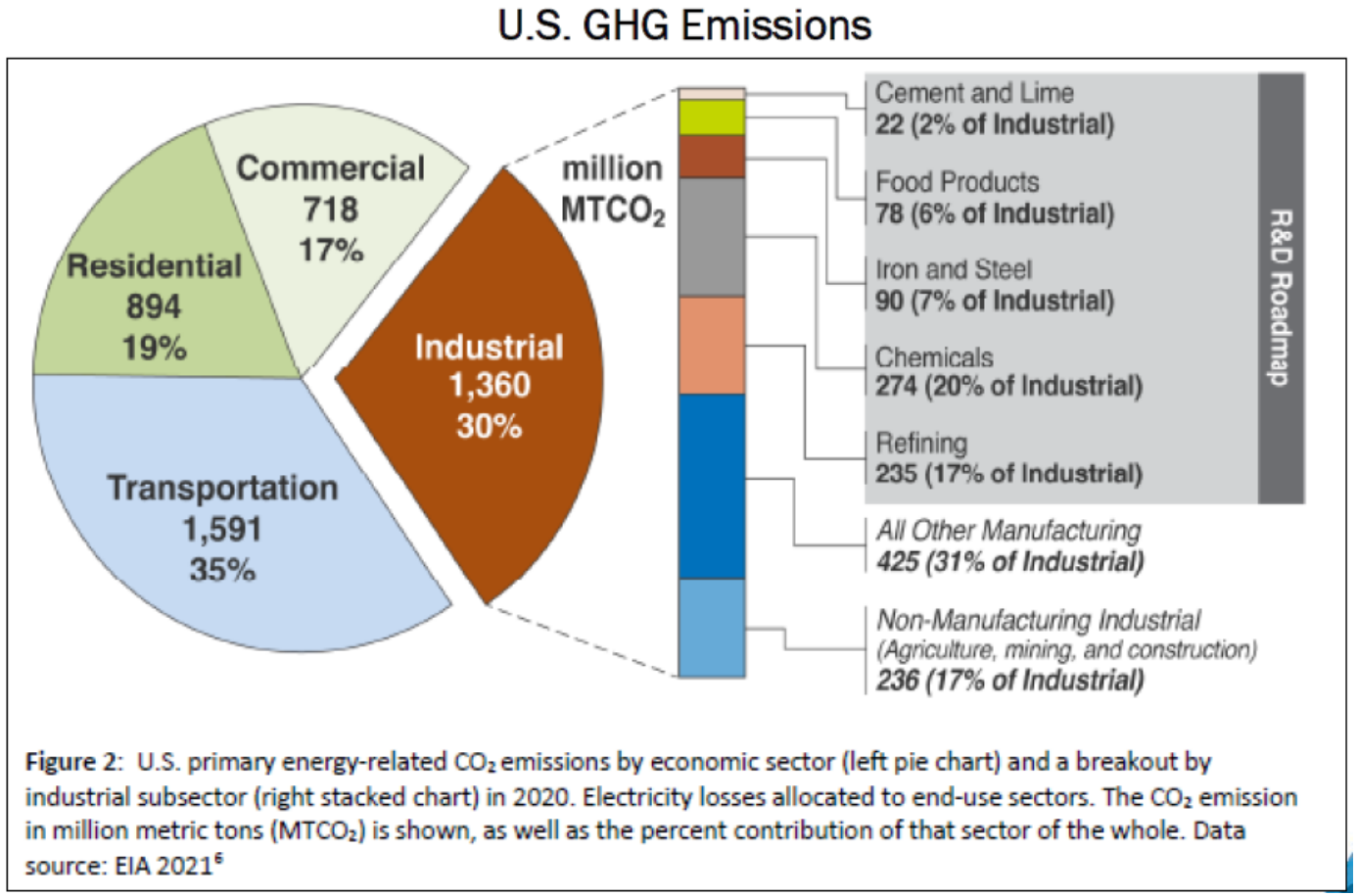
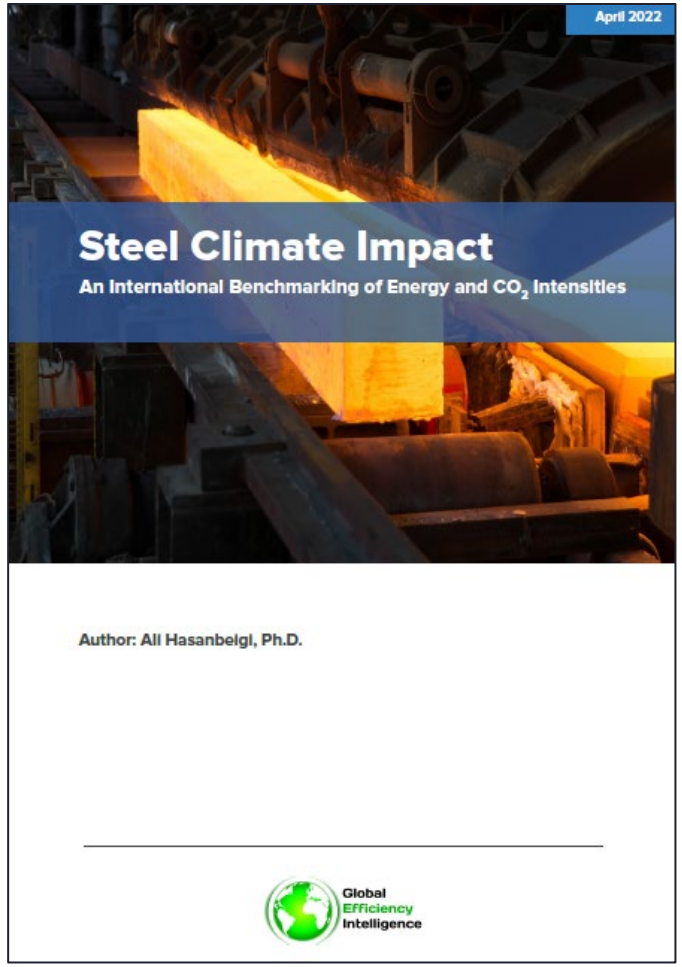
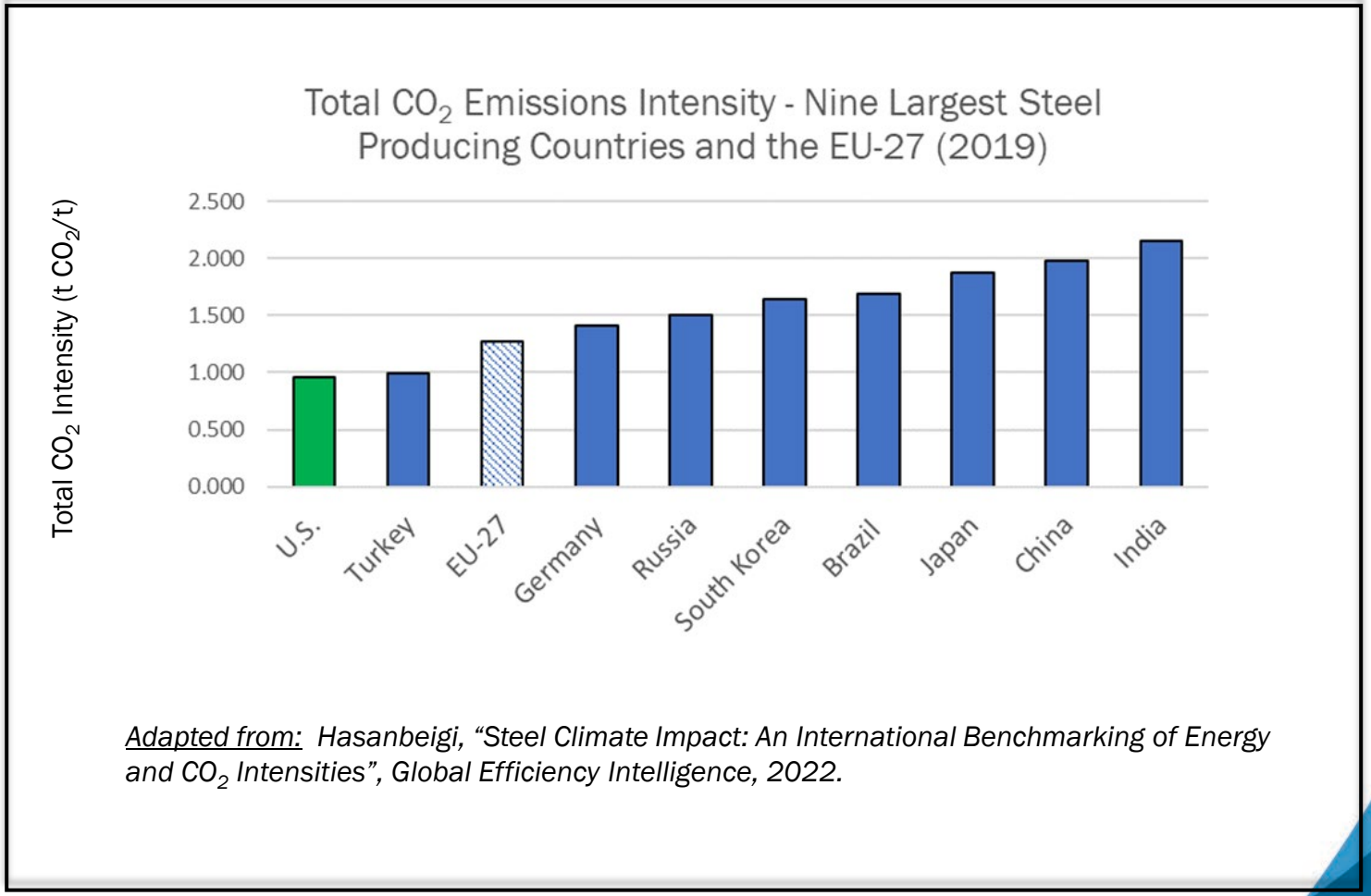


Figure 2: U.S. primary energy-related CO_2 emissions by economic sector (left pie chart) and a breakout by industrial subsector (right stacked chart) in 2020. Electricity losses allocated to end-use sectors. The CO_2 emission in million metric tons ($MTCO_2$) is shown, as well as the percent contribution of that sector of the whole. Data source: EIA 2021[6]

DOE RFI on Industrial Decarbonization Priorities, DOE-FOA 0002687, 1/27/2022

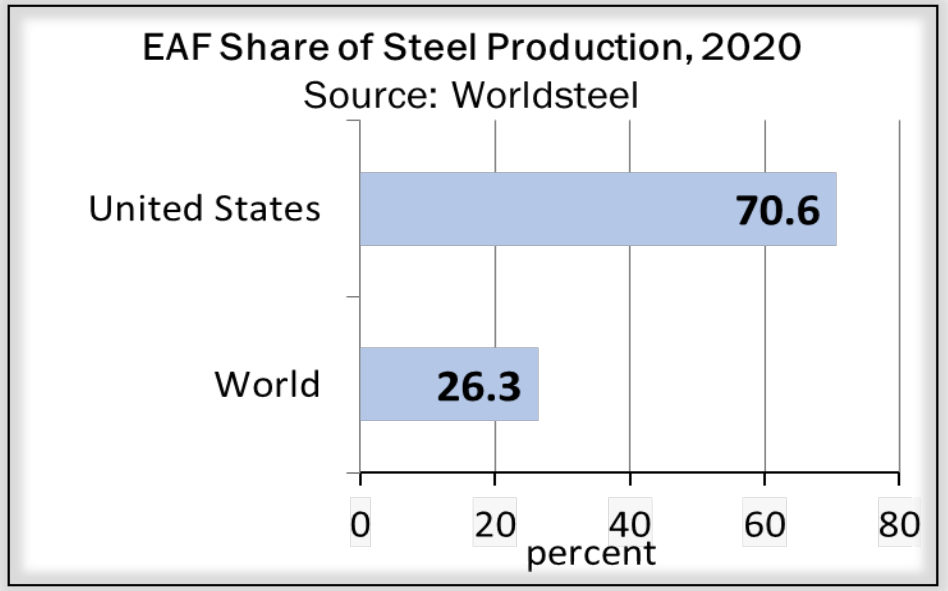
American Steel is the Lowest Emitting in the World

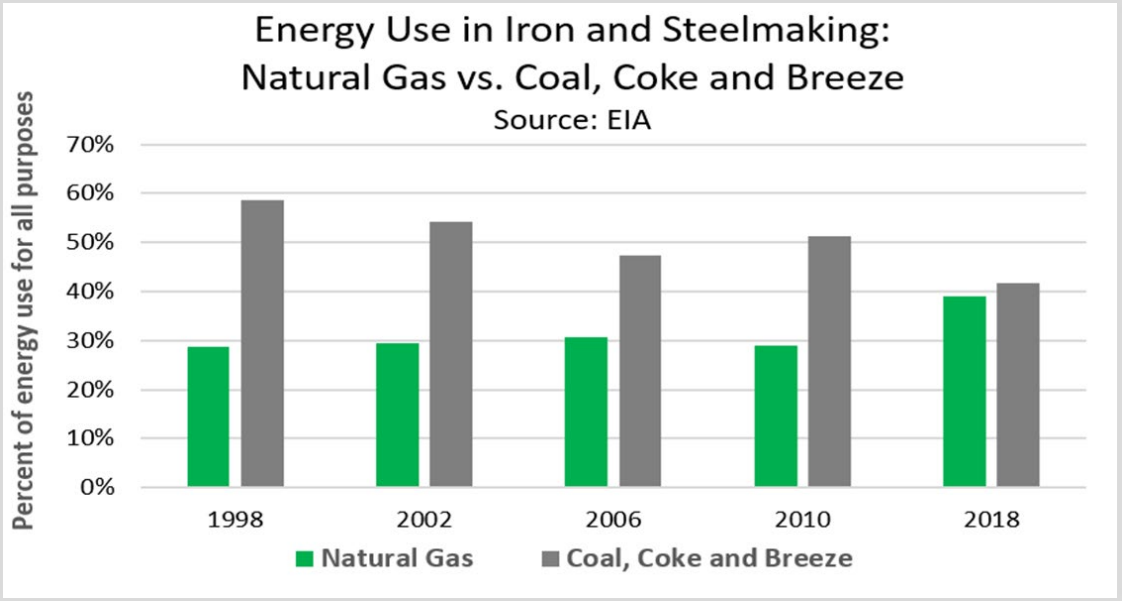




Adapted from: Hasanbeigi, "Steel Climate Impact: An International Benchmarking of Energy and CO_2 Intensities", Global Efficiency Intelligence, 2022.

The Sustainability of American-Made Steel

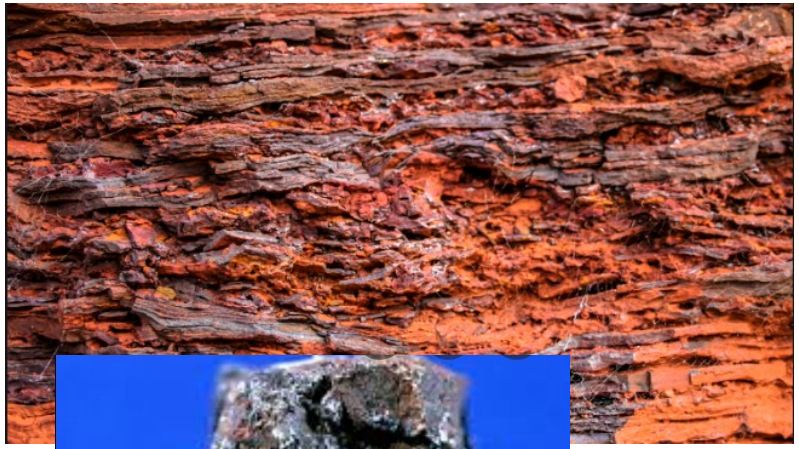




SUSTAINABILITY INITIATIVES IN US STEELMAKING

- More EAF-based steelmaking, including supplemented scrap alternatives
- Beneficiated and pelletized Iron ore, versus lower quality sintered ores in China and elsewhere
- Higher percentage of natural gas vs coal

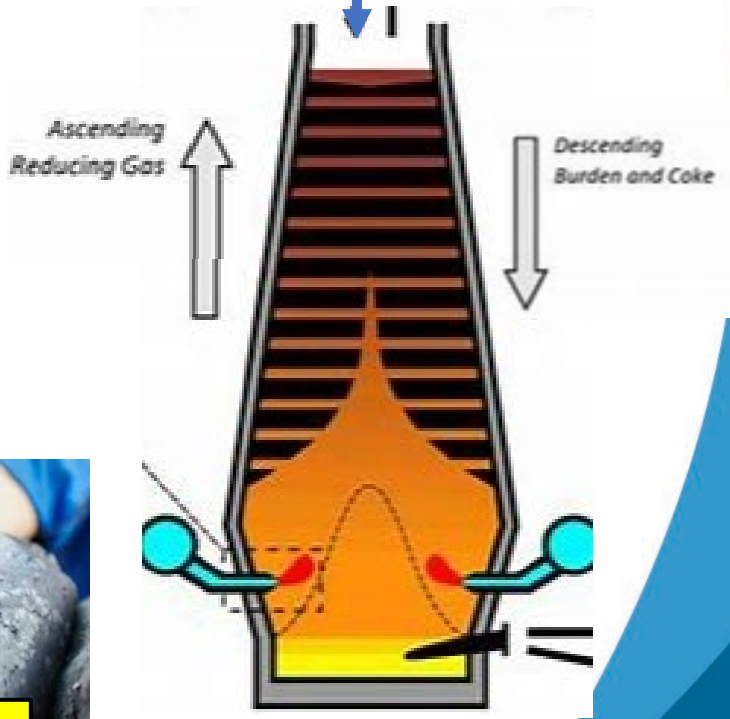
Pictorial essay: Iron Ore to Charge Materials



"beneficiated" Iron ore pellets

DRI

HBI



Efforts to Further Enhance Sustainability

Work is underway on projects to further enhance the sustainability of American steelmaking:

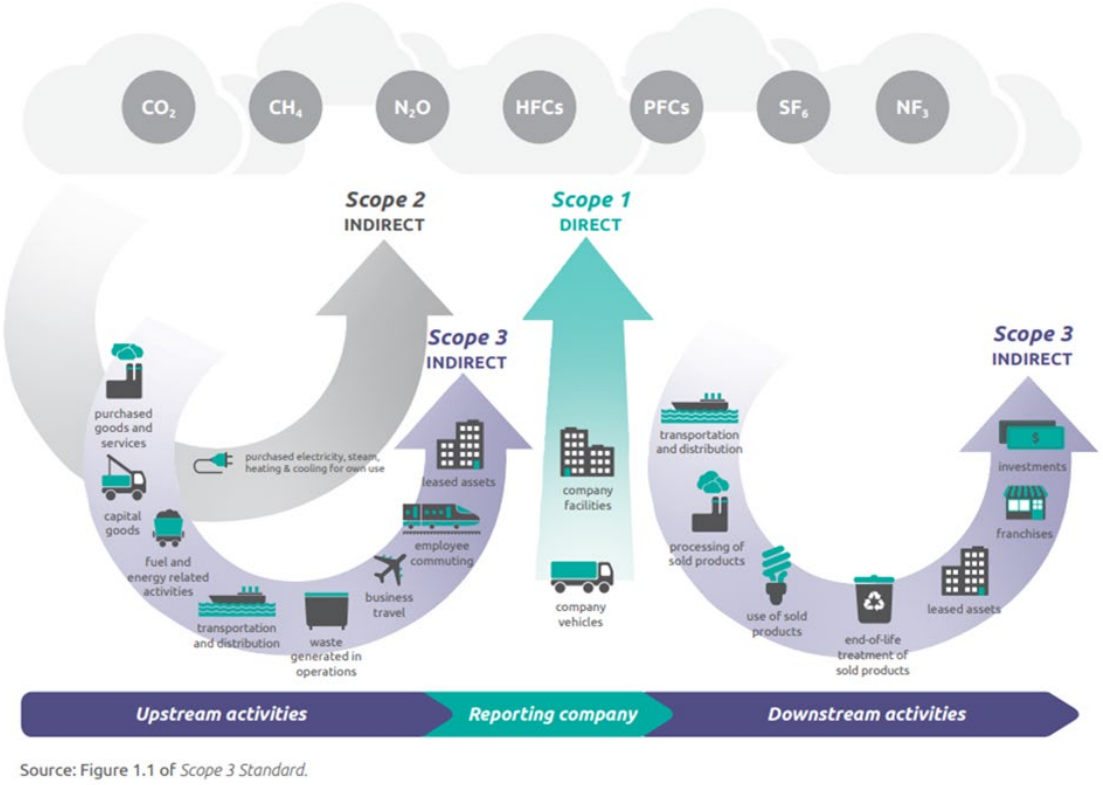
- Advancements in the use of natural gas- based Direct Reduced Iron (DRI) and Hot Briquetted Iron (HBI)
- Increasing use of renewable energy in steel industry facilities
- Carbon capture and storage/use of emitted CO_2
- Potential use of renewable energy-based hydrogen as a reducing agent in DRI/HBI production, and in the Blast Furnace

Direct Reduced Iron Pellets

Hot Briquetted Iron (direct reduced)

GHG Calculation Terminology – Scope 1, 2 and 3

Figure [I] Overview of GHG Protocol scopes and emissions across the value chain



Source: Figure 1.1 of *Scope 3 Standard.*

Scope3_Calculation_Guidance_0.pdf (ghgprotocol.org)

Scope 1 [illegible] that an organizat[illegible] for example from burning fuel in owned vehicles.

SCOPE 1
Fuel and company car gas

Scope 2 are emissions that a company causes indirectly from the [illegible]n production. For exam[illegible]neration of the electricity that powers manufacturing equipment falls into this category.

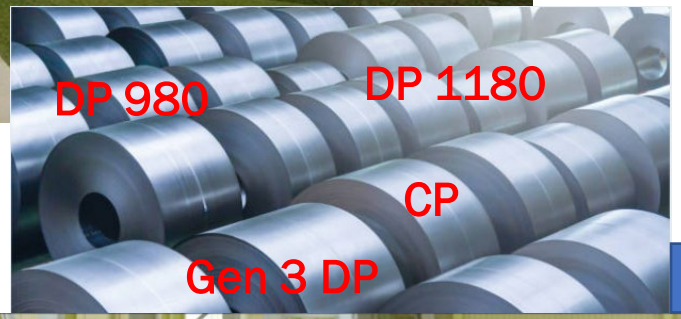
SCOPE 2
Purchased power/steam

Scope 3 are emissions not produced by the company itself, and not the result of activities from assets owned or contro[illegible]sions that it's indirectly [illegible]s value chain. An examp[illegible]and dispose of products from suppliers. Scope 3 emissions include all sources not within the scope 1 and 2 boundaries.

SCOPE 3
GHG from all else bought and or used and or done.

Challenges with Advanced Steel Materials

Supplier Capability Tantamount to Success



Processors
Slitting,
Blanking

Training/Experience

Forming Ops
Roll
Forming,
Tiered
stamping

Certified Processor Training/Education

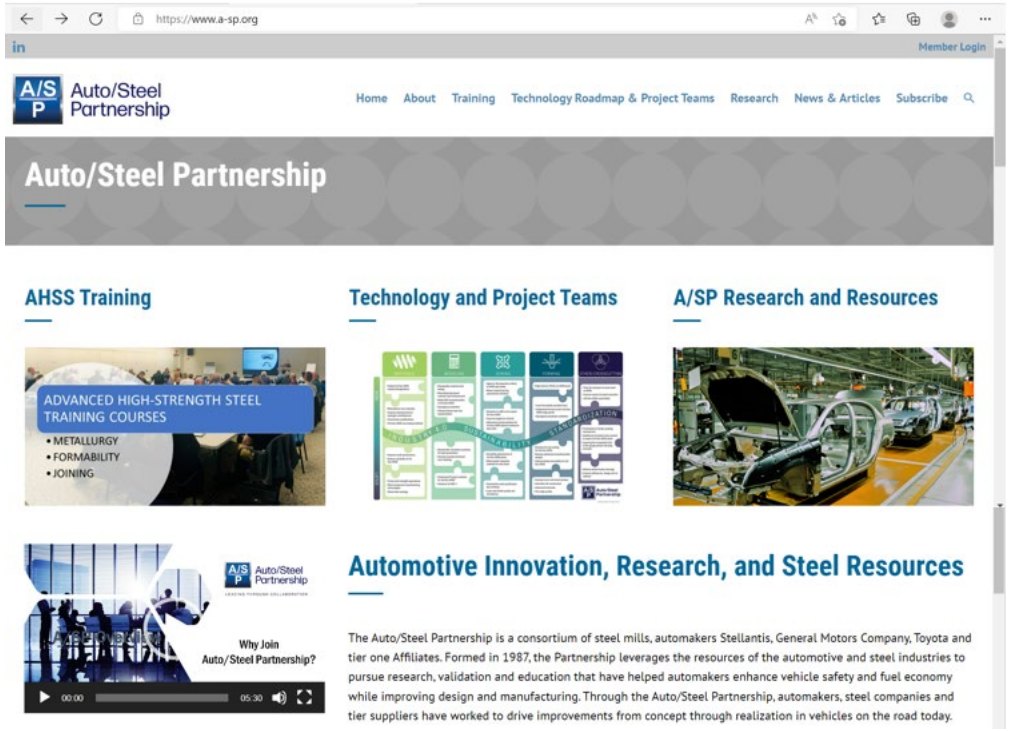
- Currently an envisioned initiative for the AISI Automotive Applications Committee
- Objective is to improve awareness and prevent problems associated with transforming coiled AHSS products into automotive parts
  - Collect information on problems/resolutions with processing AHSS
    - Survey real-world processors, stampers, roll formers, tubers
  - Automotive assembly lessons (joining, springback)
    - Assemble a fact-based exposition for causes and countermeasures
  - Create an endorsable training program, launch the training.
    - Develop a network of “Certified processors” to enhance marketability and reduce impact of incomplete awareness

Certified Processor Training/Education Concepts

- Review available tool materials for cutting inserts and/or slitting knives
- Blank and trim steel insert maintenance intervals
- Slitting gap and clearance recommendations to develop best internal practice
- Slit or trim edge conditions with steel multiphase materials, countermeasures
- Press tonnage and energy requirements and calculations for blanking or stamping
- Stamping lubricants for AHSS materials
- Die surface coatings to counter friction wear (current work, contact distribution)
- Die stiffness importance, structure requirements, locations of parallels (when used)
- Springback and countermeasures
- Blank and part design tactics to avoid excessive edge strain
- Radius to thickness ratio recommendations to prevent cracking
- Laser blanking opportunities

Current Technical Support for Challenges of AHSS

Auto/Steel Partnership



www.a-sp.org, www.steel.org

A/SP Technology Roadmap:

The A/SP agenda is based upon a technology roadmap which informs research project prioritization and resource allocation. More than 30 projects are currently underway across 8 project teams:

- AHSS Stamping
- Stamping Tooling Optimization
- Constitutive & Fracture Modeling
- Joining
- Steel Testing & Harmonization
- Repairability
- Gas Metal Arc Welding of AHSS
- AHSS Corrosion Protection

A/SP Focal Projects:

Three focal projects lead the A/SP research agenda.

- **LME of 3rd Gen AHSS – Industrial Welding Solutions**
- **3rd Gen AHSS Press Tonnage Predictions**
- **Spring Back Prediction, Control and Validation**

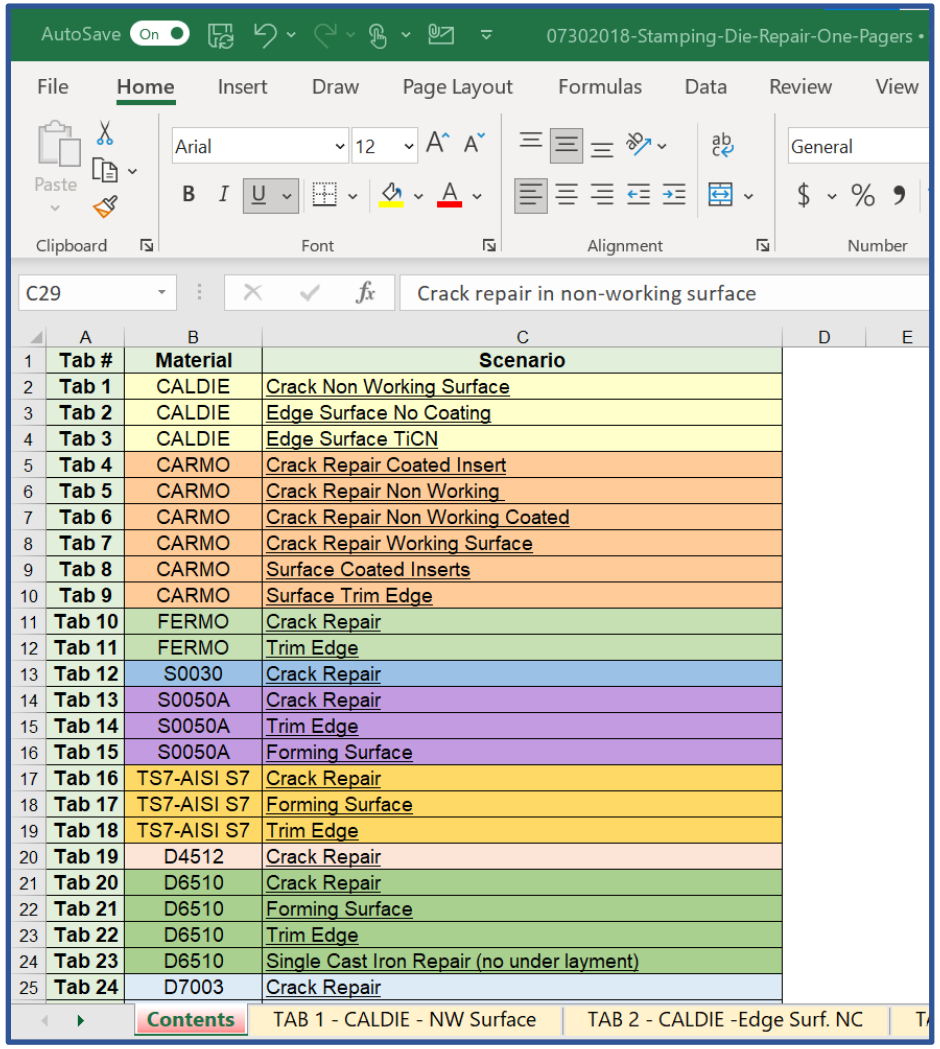
DIE SHOP SUPPORT
- Laser Hardening
- Die Wear
- Friction
- Die Materials

WELDING TECHNOLOGY
- Stackups
- Opt schedules
- LME
- HAZ modeling

DIE DESIGN DEVELOPMENT
- Die bead options
- CM to Local Props limits
- Springback prediction

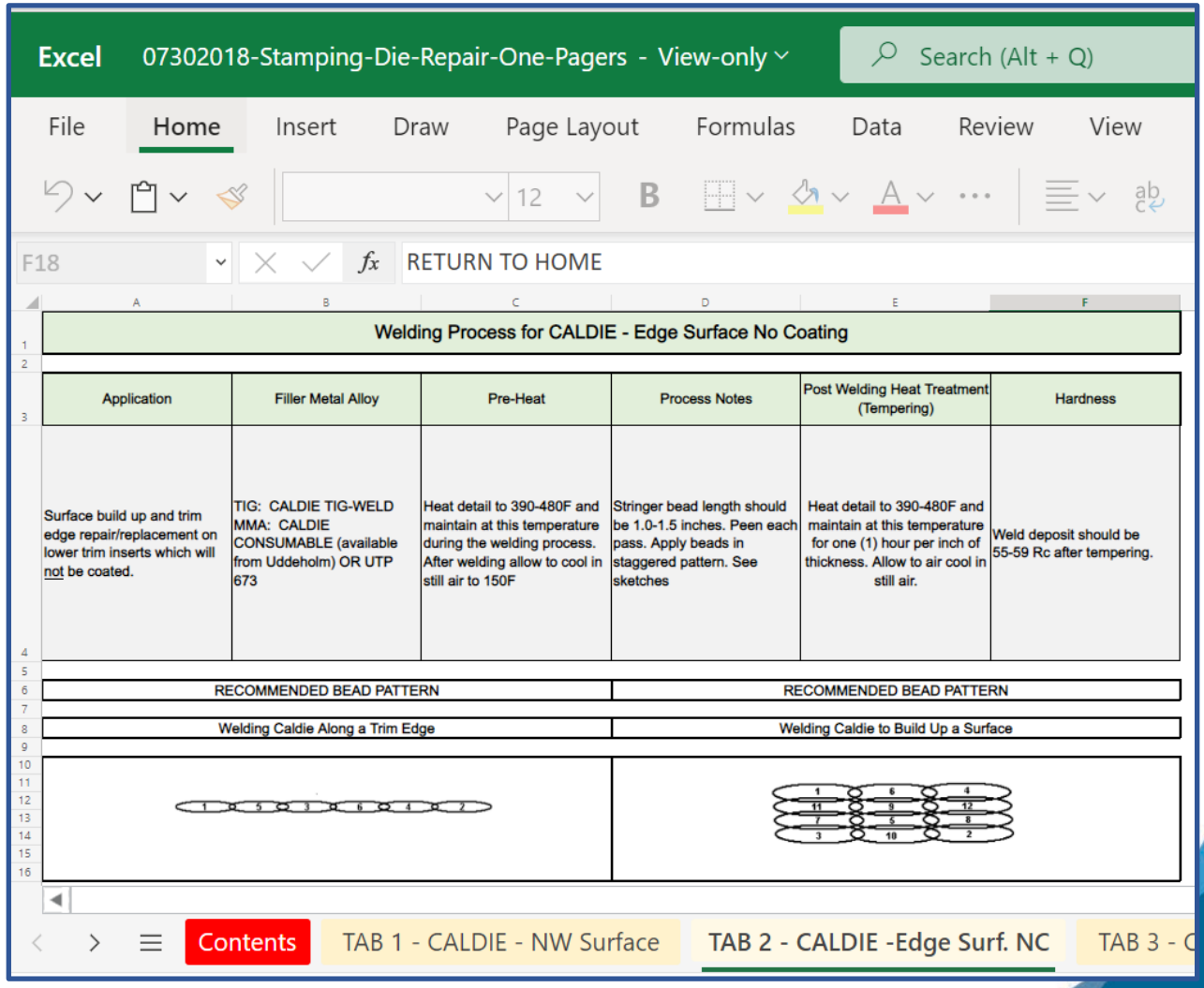
SUPPORT TO STAMPERS
- Laser welded blanks
- AHSS spring-back CMs
- Local and global properties

Auto/Steel Partnership Web Page: Die Repair



Tab #	Material	Scenario
Tab 1	CALDIE	Crack Non Working Surface
Tab 2	CALDIE	Edge Surface No Coating
Tab 3	CALDIE	Edge Surface TiCN
Tab 4	CARMO	Crack Repair Coated Insert
Tab 5	CARMO	Crack Repair Non Working
Tab 6	CARMO	Crack Repair Non Working Coated
Tab 7	CARMO	Crack Repair Working Surface
Tab 8	CARMO	Surface Coated Inserts
Tab 9	CARMO	Surface Trim Edge
Tab 10	FERMO	Crack Repair
Tab 11	FERMO	Trim Edge
Tab 12	S0030	Crack Repair
Tab 13	S0050A	Crack Repair
Tab 14	S0050A	Trim Edge
Tab 15	S0050A	Forming Surface
Tab 16	TS7-AISI S7	Crack Repair
Tab 17	TS7-AISI S7	Forming Surface
Tab 18	TS7-AISI S7	Trim Edge
Tab 19	D4512	Crack Repair
Tab 20	D6510	Crack Repair
Tab 21	D6510	Forming Surface
Tab 22	D6510	Trim Edge
Tab 23	D6510	Single Cast Iron Repair (no under layment)
Tab 24	D7003	Crack Repair

Contents | TAB 1 - CALDIE - NW Surface | TAB 2 - CALDIE -Edge Surf. NC



Welding Process for CALDIE - Edge Surface No Coating

Application	Filler Metal Alloy	Pre-Heat	Process Notes	Post Welding Heat Treatment (Tempering)	Hardness
Surface build up and trim edge repair/replacement on lower trim inserts which will not be coated.	TIG: CALDIE TIG-WELD MMA: CALDIE CONSUMABLE (available from Uddeholm) OR UTP 673	Heat detail to 390-480F and maintain at this temperature during the welding process. After welding allow to cool in still air to 150F	Stringer bead length should be 1.0-1.5 inches. Peen each pass. Apply beads in staggered pattern. See sketches	Heat detail to 390-480F and maintain at this temperature for one (1) hour per inch of thickness. Allow to air cool in still air.	Weld deposit should be 55-59 Rc after tempering.

RECOMMENDED BEAD PATTERN	RECOMMENDED BEAD PATTERN
Welding Caldie Along a Trim Edge	Welding Caldie to Build Up a Surface

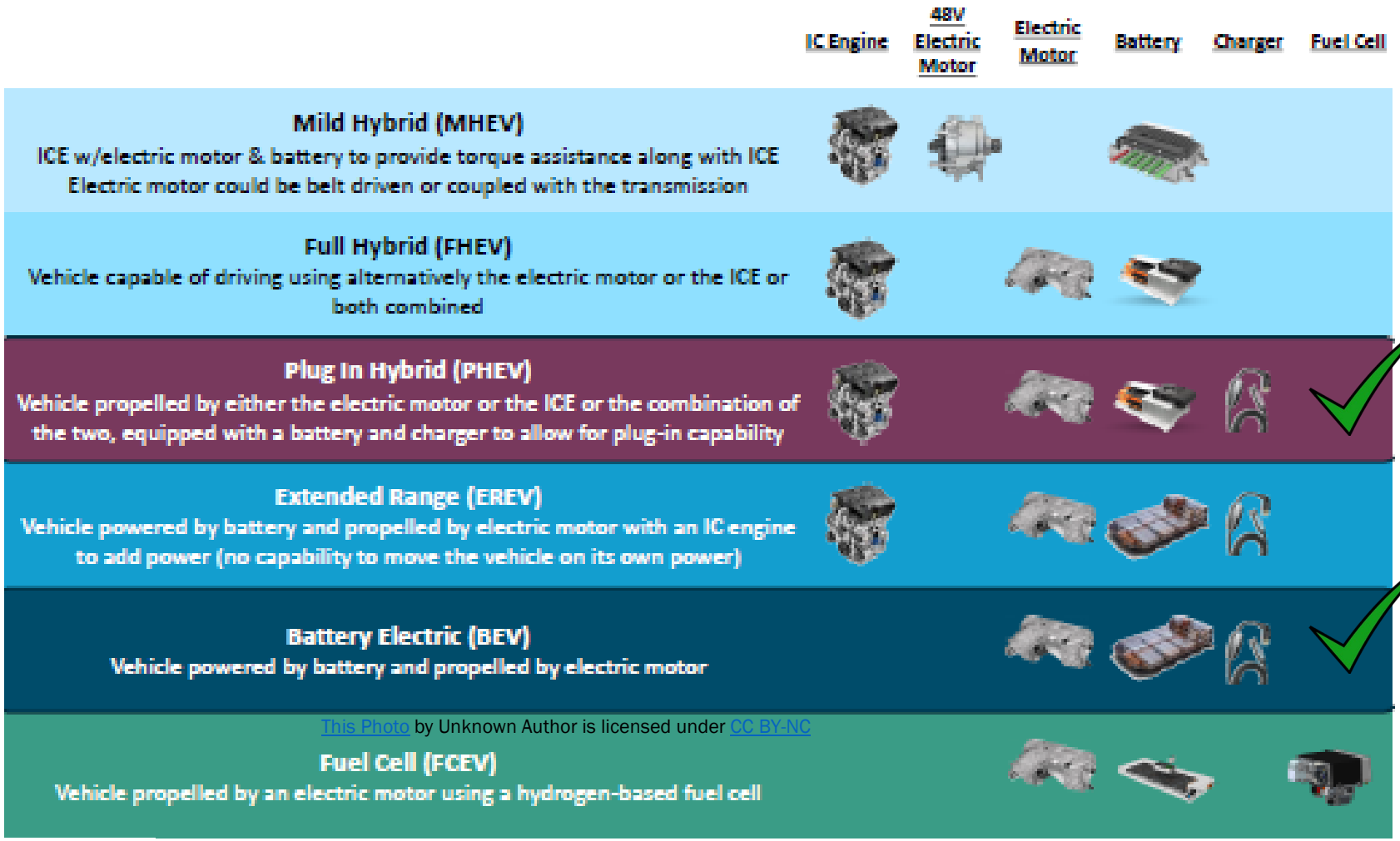
Contents | TAB 1 - CALDIE - NW Surface | TAB 2 - CALDIE -Edge Surf. NC | TAB 3 - C

Impact of Vehicle Electrification

Vehicle Electrification Impacts

- Is a revolutionary change happening before our eyes
  - Changes to the automotive supply base will occur
  - Battery technology has potential to change material
  - The internal combustion engine (ICE) won't go away immediately
- Up to 30% of all new U.S. car sales may be EV by 2030
  - Real constraints, now only being discussed, must be addressed
  - Critical minerals, electric supply capacity, battery energy density, range, charging stations and plugs, operating temperature range of batteries
- Automotive OEM's may become assemblers of pcs/parts
  - GM has begun calling themselves an automotive technology company

Many Types of “EV”s



BEV most popular, but PHEV may be most practical

Sources: Ducker

EVs Are Coming – Short Term

BEV sales are outperforming total Light Vehicles

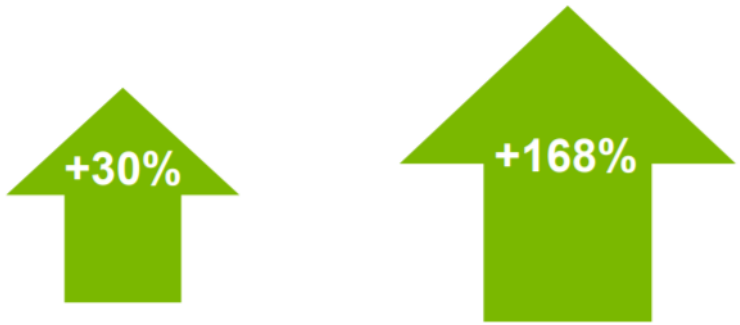
Global LV Sales

Global LV sales % change H1 2021 from H1 2020

Global BEV sales % change H1 2021 from H1 2020

YTD SAAR 84.5mn

US LV Sales



US LV sales % change H1 2021 from H1 2020

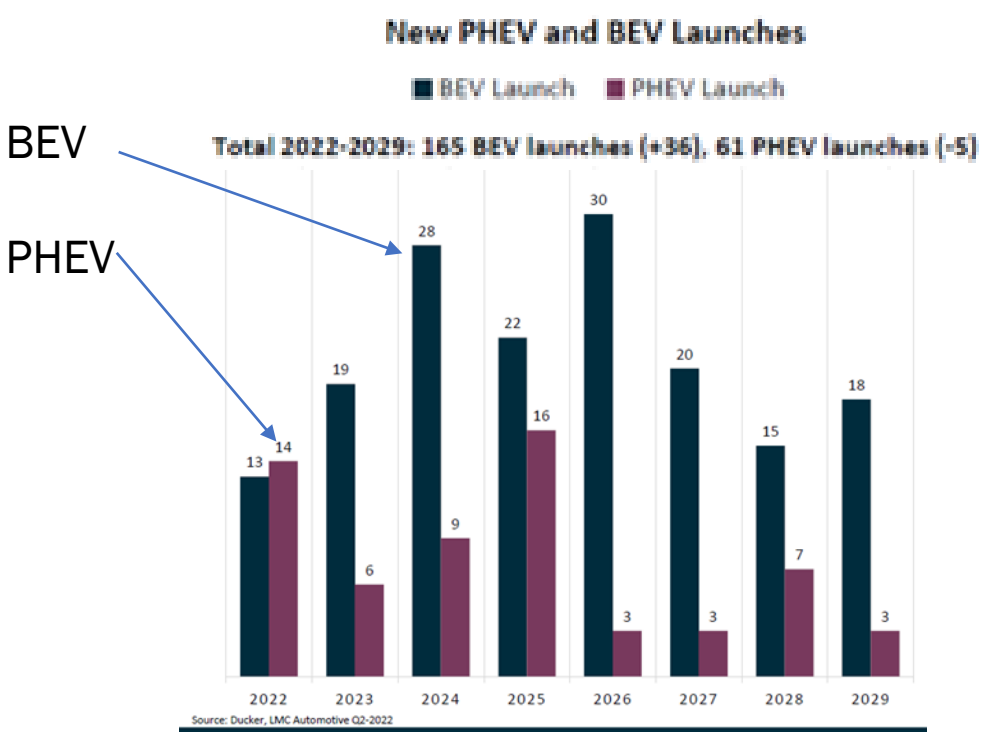
US BEV sales % change H1 2021 from H1 2020

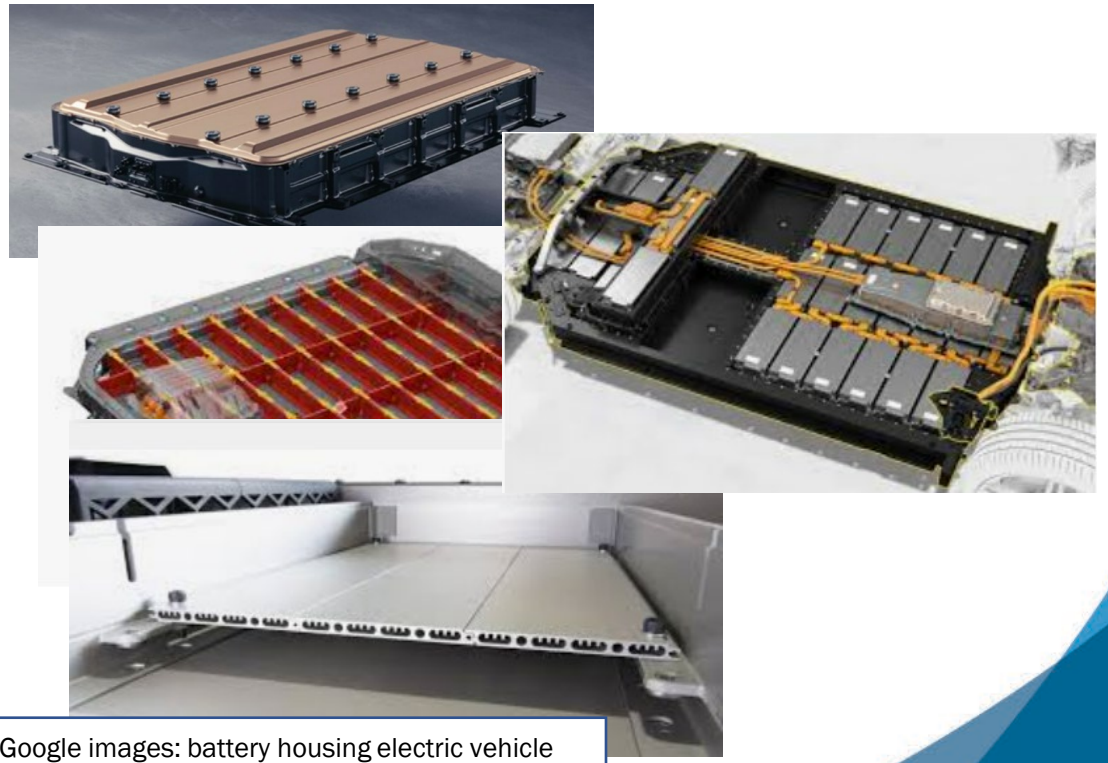
YTD SAAR 16.9mn

Source: LMC Automotive

Materials and Steel Related Battery Pack Manufacturing

- More than 200 new EV's (BEV and PHEV) will launch thru 2029
- Battery housing designs and material choices seem to be as numerous as the number of new vehicles announced

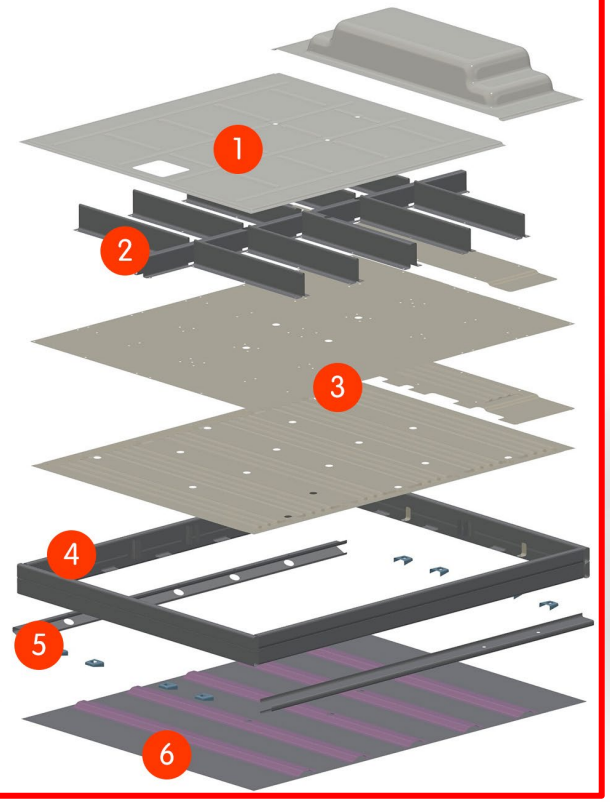


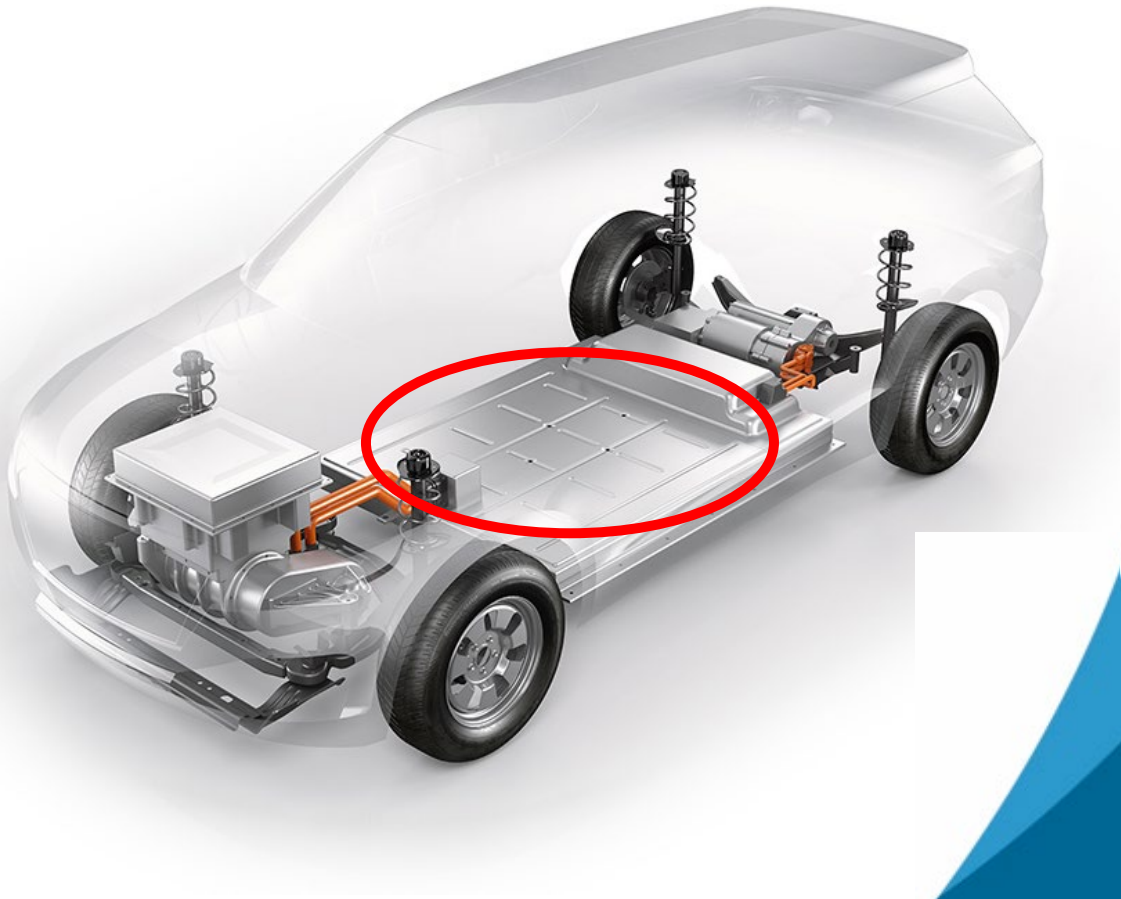


Google images: battery housing electric vehicle

Architectural Impact - Battery Enclosure/Protection

1. **Top cover**
   CR6
2. **Cross-members**
   MartINsite® 1500
3. **Cladded cooling system**
   Steel panels
4. **Frame**
   MartINsite® 1500
5. **Brackets & Rails to BIW**
   CP800HR, MartINsite® 1500
6. **Lower shield & Reinforcement**
   DP1180, MartINsite® 1500

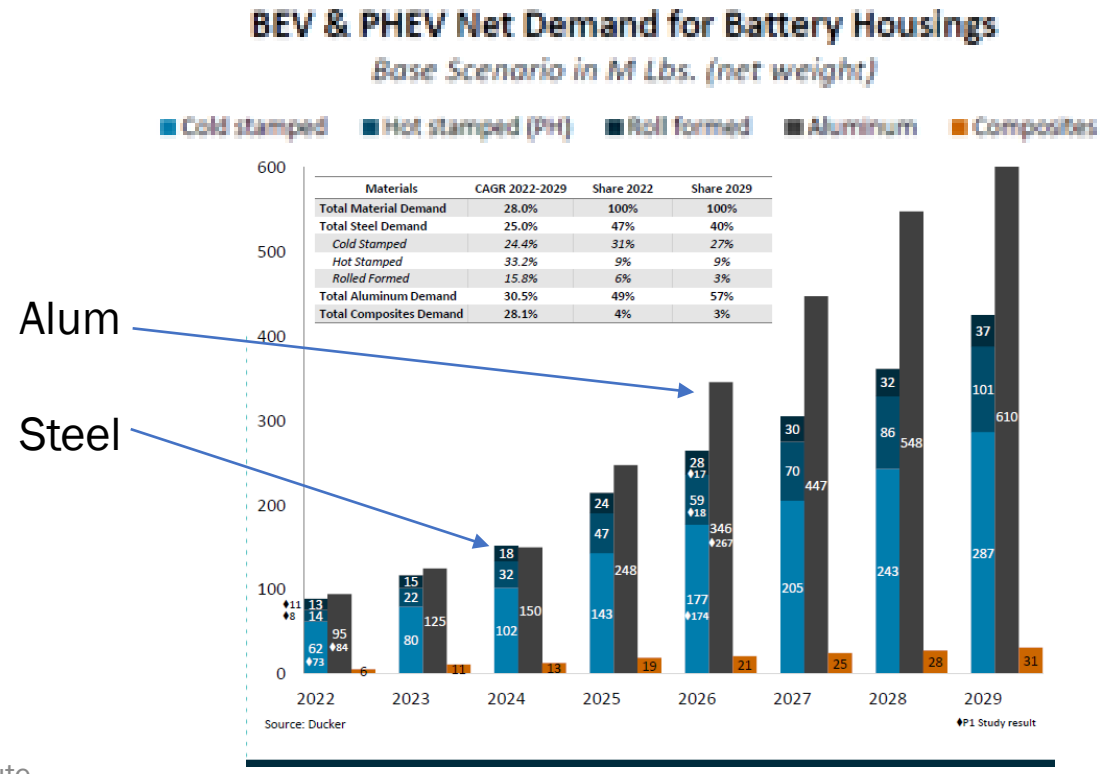




Source: automotive.arcelormittal.com

Materials Forecast for Battery Pack Manufacturing

- Material selection for parts will get more complicated
- Range, battery volume, vehicle size, structure and COST are factors
- Advanced steel materials anticipated for battery housing variations



Thank You / For More Information

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