GREAT DESIGNS IN STEEL

DEVELOPMENT OF AN ADVANCED HIGH - STRENGTH STEEL BODY STRUCTURE FOR A NEW, FULLY AUTONOMOUS MOBILITY AS A SERVICE VEHICLE – STEEL E-MOTIVE

Dean Kanelos, Nucor

Juan Pablo Pedraza, Ternium, on behalf of WorldAutoSteel

2023

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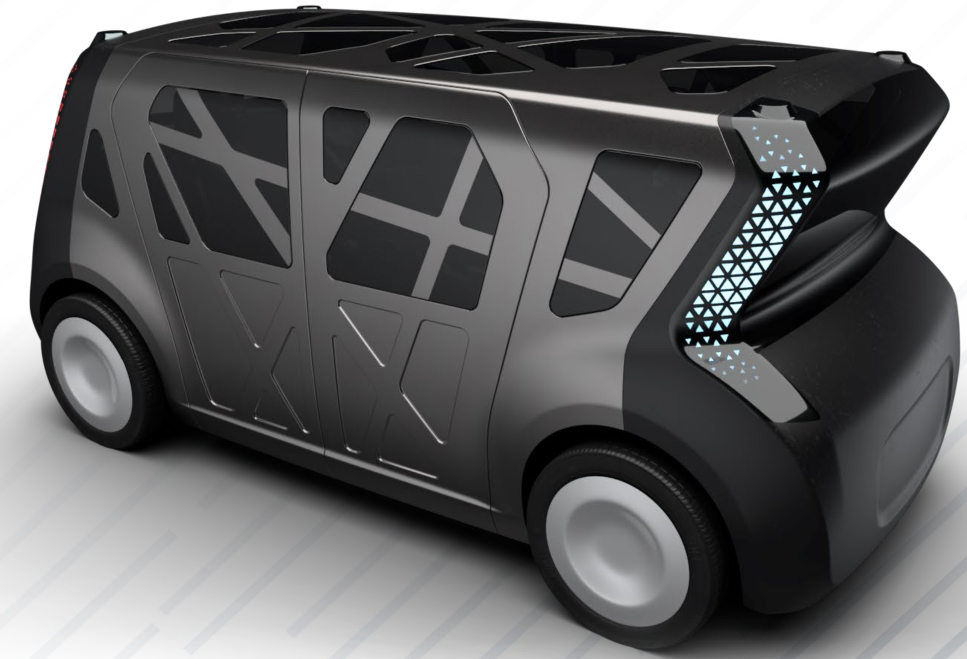
- Introduction to WorldAutoSteel and Steel E-Motive
- Mobility as a Service market influencers & roadmap
- Steel E-Motive: Vehicle and Body Concepts
- What you can see at the Exhibit Hall
- Question and Answer



STEEL E-MOTIVE — IN PARTNERSHIP WITH — WorldAutoSteel RICARDO

STEEL E-MOTIVE

IN PARTNERSHIP WITH

WorldAutoSteel

RICARDO

ANSTEEL

ArcelorMittal

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HYUNDAI STEEL

JFE

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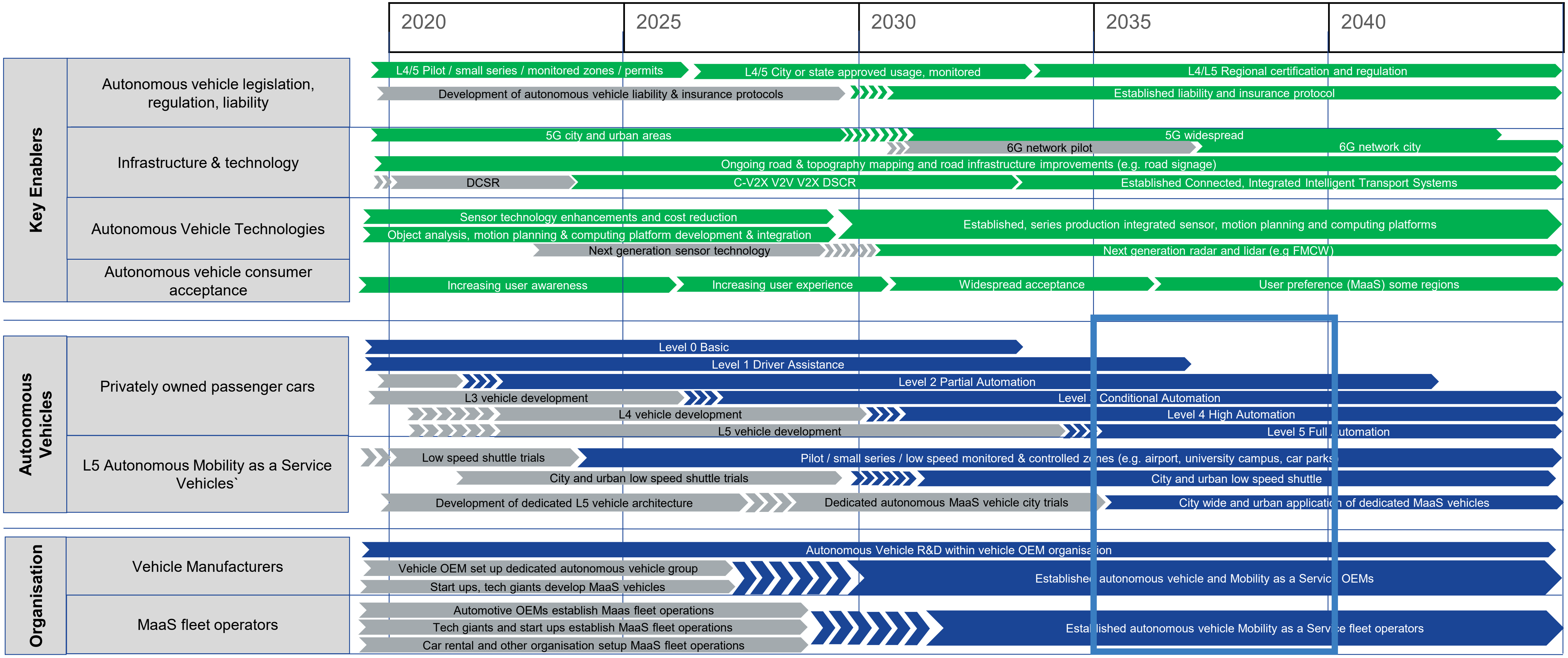
USS U. S. Steel

voestalpine ONE STEP AHEAD.

PESTEL ANALYSIS OF FUTURE MOBILITY CONFIRMS SIGNIFICANT CHALLENGES AND REQUIREMENT FOR MODAL SHIFT IN TRANSPORTATION

Political	Economic	Social	Technology	Environmental	Legal
- Global trade policies and tariffs	- Access to credit and credit costs	- Consumer behaviour changes (rent/lease vs outright ownership, on-demand, leisure time utilisation, convenience, lifestyle, flexible working)	- Digital and communications growth (connectivity, processing, radar, lidar, computation, artificial intelligence, big data, GPS & mapping)	- Global and local climate change agreements and policies	- Liability and insurance (WRT autonomous vehicles)
- Global energy security	- Impact of high inflation	- Ageing population	- Infrastructure improvements (road, rail, sea)	- Local air quality policies and directives	- Product warranty and recall
- Global stability (conflict)	- Economic growth	- Improved living standards and healthcare provision	- Vehicle propulsion system technologies (battery electric, hydrogen, charging)	- Towards complete life cycle evaluation, policies and regulation	- Data protection and data security
- Urbanisation, housing, health and living standards	- Cost of living (housing, food, clothing, leisure)	- Serving the underserved (impaired, disabled)	- Innovations in materials and manufacturing	- Land, river and sea pollution	- Labour laws and regulation
- Population growth	- Global and local transportation costs	- Cost of living and wage growth	- Green energy supply and innovations	- Recycling, reuse disposal policies	- Intellectual property management
- Taxation policies (e.g. environment related)	- Raw material costs (iron, steel, precious metal)	- Environmental awareness and responsibility		- Scarce resources availability and impacts	
- Reduced road traffic injuries and towards zero fatalities	- Cost of environmental impacts (floods, heatwave)			- Noise pollution	

ROADMAP ANALYSIS CONFIRMS THE REALITY OF ESTABLISHED AUTONOMOUS VEHICLE FLEETS IN OPERATION BY 2035



Source: Ricardo, CAR, ACEA, RolandBerger, McKinsey, Deloitte, ATKearney, SMMT, Earpa, EuCar

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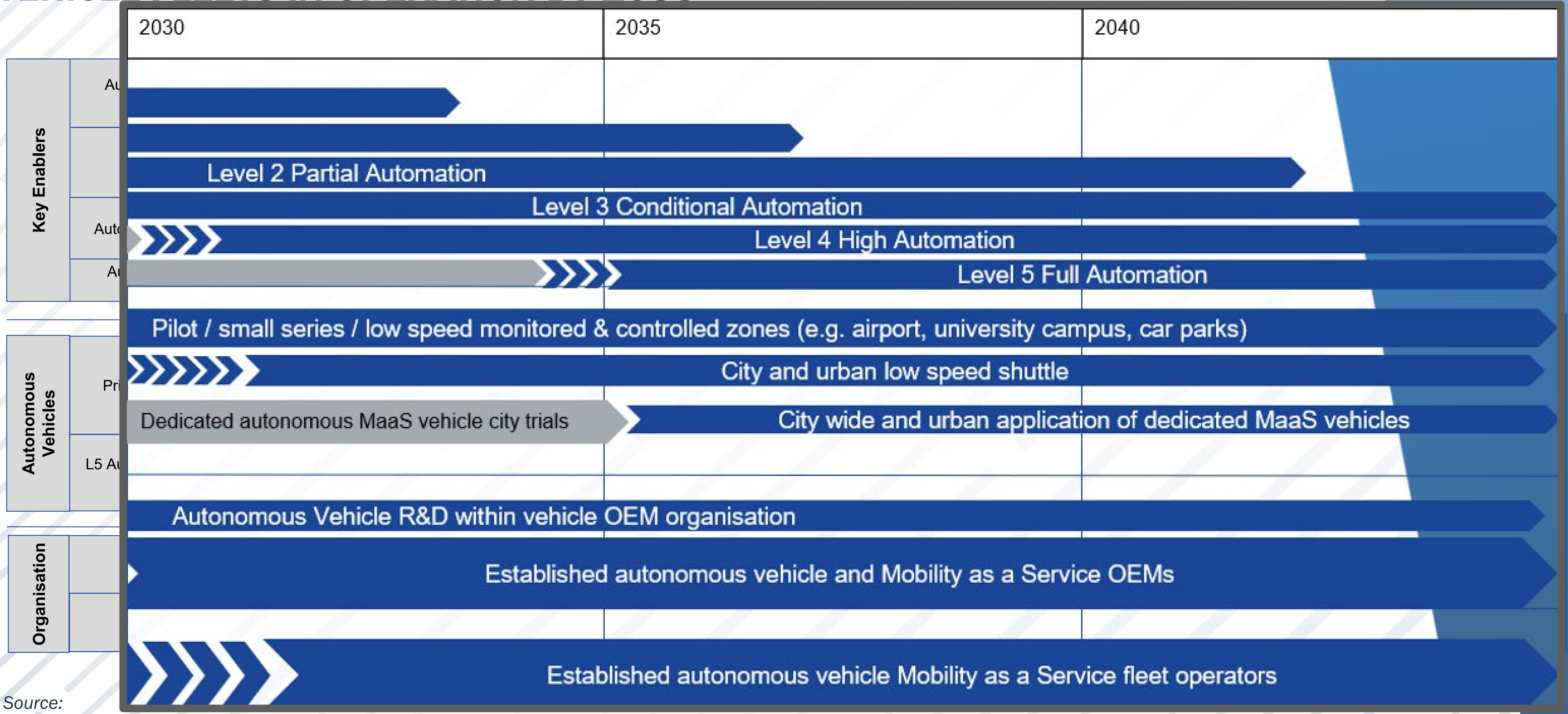

Source:

THE STEEL E-MOTIVE PROJECT IS A RESPONSE TO THE AUTOMOTIVE TRANSPORTATION SHIFT, DEVELOPING A NEW, FULLY AUTONOMOUS MAAS VEHICLE

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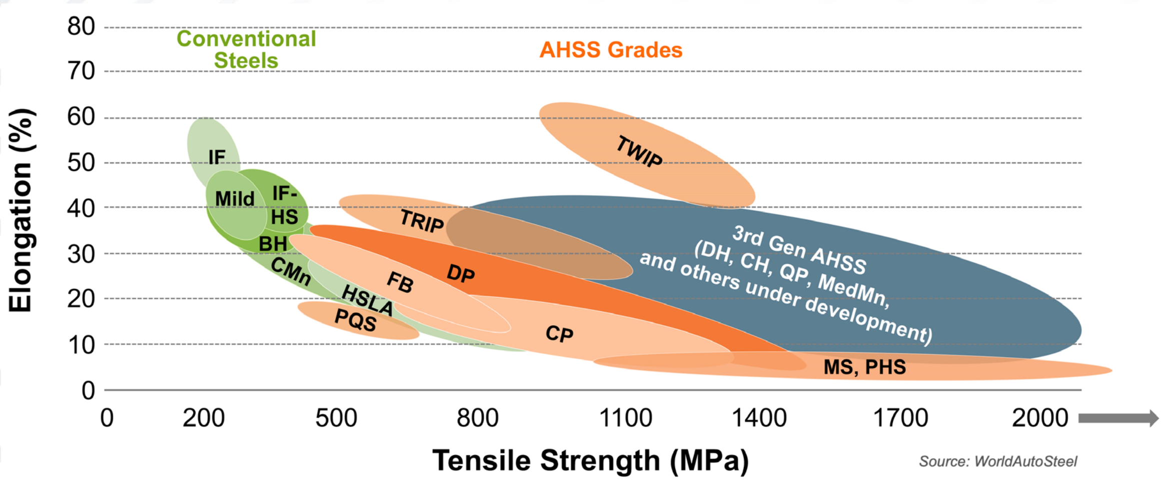
Steel E-Motive Objectives

Connecting the steel industry with OEM's and future mobility service providers

- To showcase the ***steel body structure*** modules of the autonomous battery electric vehicle
- To position steel as the ***leading material*** of choice for future vehicle architectures specifically demonstrating strength, durability, emissions and affordability
- To focus on ***future of mobility***
- *To focus on **environmental impact***

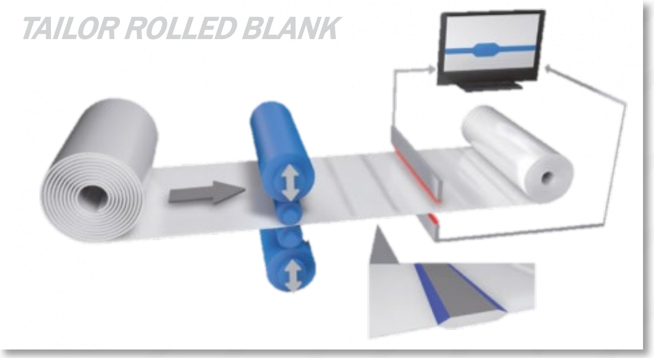
Development of a body structure for a clean sheet fully autonomous ride hailing vehicle

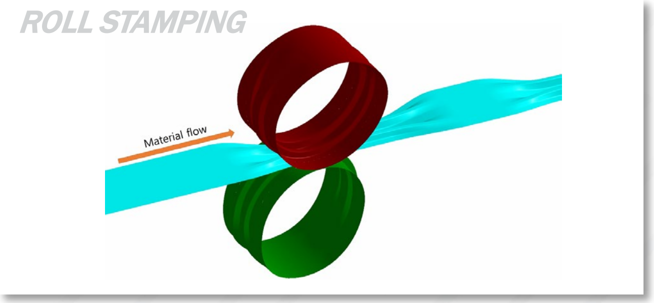
STEEL E-MOTIVE DRAWS UPON A COMPREHENSIVE PORTFOLIO OF STEEL GRADES AND FABRICATION PROCESSES

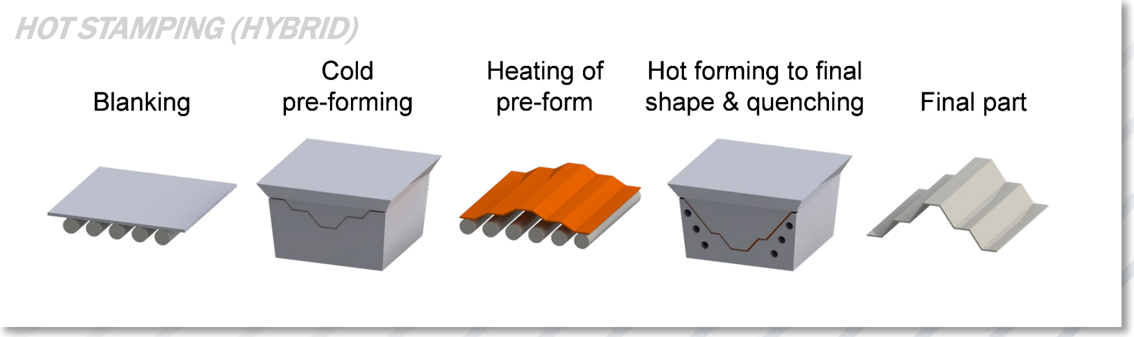


Example Steel Grades for Steel E-Motive

- Ultra-high strength: Martensitic and Press Hardened Steel
- 3rd Generation steel grades: DH, CH, RA, QP, MedMn
- High formability grades: BH, HSLA







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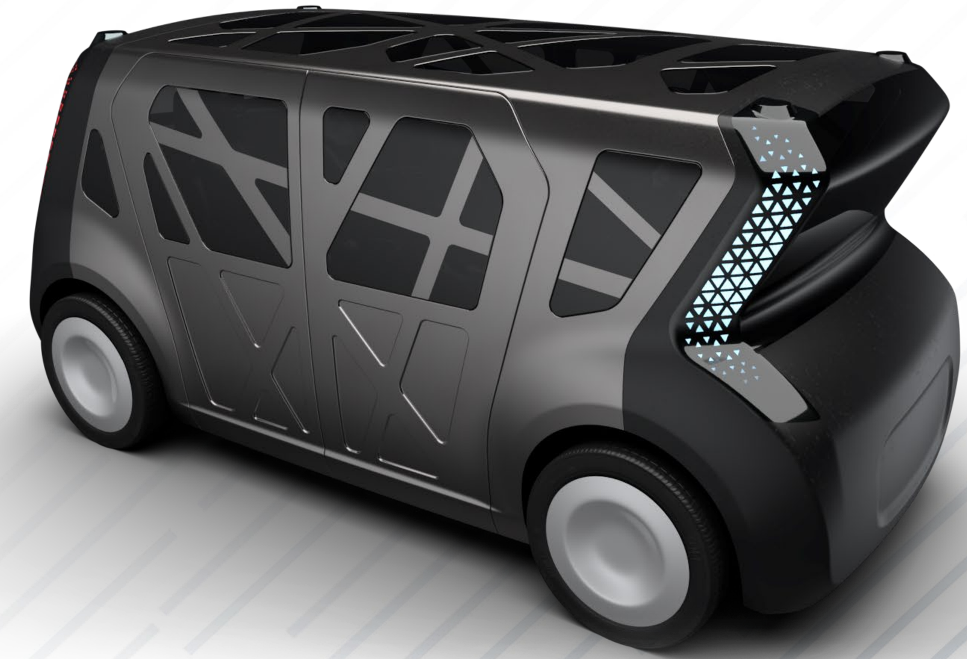
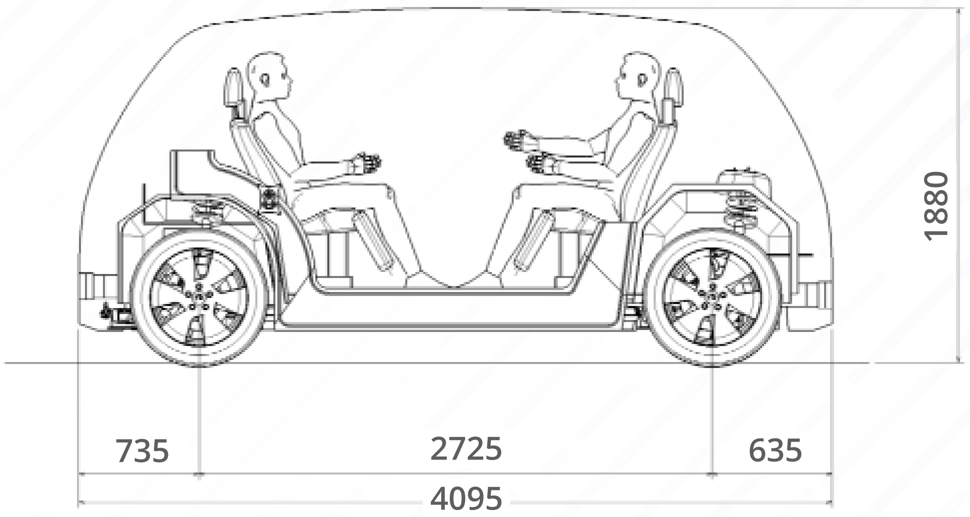
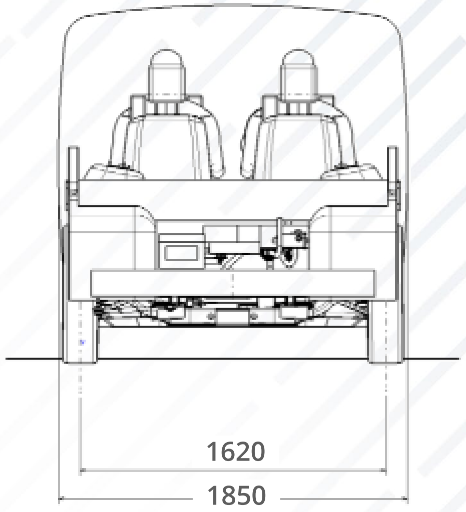


STEEL E-MOTIVE: TWO VEHICLE VARIANTS BASED ON A SINGLE, MODULAR PLATFORM

SEM1: Short Wheelbase Urban Version

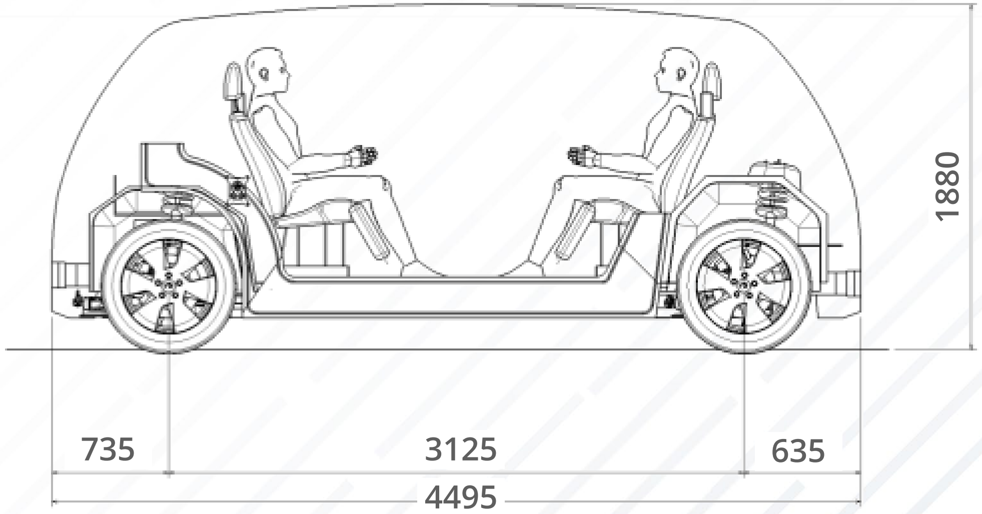
- Single speed front electric drive
- Compact design and vehicle footprint
- Comparable to European B/C segment size

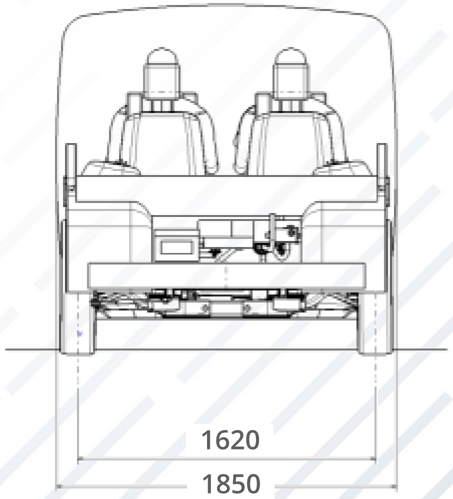




SEM2: Long Wheelbase Extra Urban Version

- Front and rear wheel electric drive
- Extended wheelbase. Up to 6 occupants
  Maximise SEM1 carry-over





STEEL E-MOTIVE ADDRESSES THE KEY EXPECTED USER AND FLEET OPERATOR REQUIREMENTS FOR AUTONOMOUS RIDE HAILING VEHICLE

Creating a desirable, comfortable and convenient journey experience

PASSENGER COMFORT & CONVENIENCE

Protection of occupants and road users in all eventualities

SAFETY

Ensuring competitive pricing for passengers and profitability for fleet operators

TOTAL COST OF OWNERSHIP

Addressing global sustainability challenges

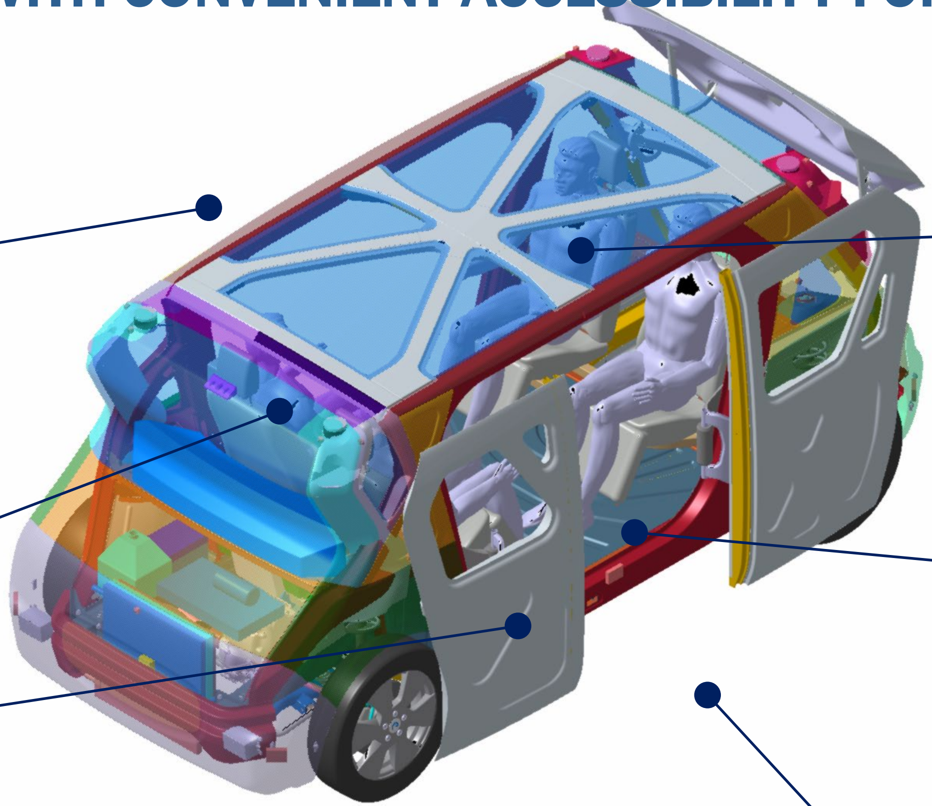
ENVIRONMENT & SUSTAINABILITY

STEEL E-MOTIVE BATTERY; MODULES MOUNTED TO CARRIER FRAME WHICH IS INTEGRATED TO BODY STRUCTURE. LIGHTWEIGHT, LOW COST SOLUTION ACHIEVING SAFETY, STIFFNESS AND DURABILITY REQUIREMENTS

- Battery modules and cooling plates mounted (inverted) to steel carrier frame (off-line)
- Carrier frame mounted to body structure (general assembly)
- BIW floor acts as battery top cover and provides sealing
- AHSS bottom cover plate provides impact protection
- Efficient package. 37% weight saving*. Improved NVH. No compromise to safety. Improved package, enables lower floor height and flat floor

* Compared to conventional sealed pack unit

PASSENGER COMFORT AND CONVENIENCE: DESPITE IT'S COMPACT SIZE, STEEL E-MOTIVE HAS A SPACIOUS INTERIOR WITH CONVENIENT ACCESSIBILITY FOR ALL USERS



One-box architecture providing an open, spacious interior and occupant positioning. B pillar in door enabling a more open cabin environment

Rear facing front occupants for enhanced journey experience

Unique scissor doors, enabling >1.0m aperture for enhanced occupant ingress/egress. The pillar mounted scissor hinge mechanism is lower cost & weight and easier to integrate than a sliding door, solution where the tracks and rails can impinge the rockers and cantrail

Semi-glazed panel roof, enhancing airiness spacious feeling

Flat floor and competitive step in height. Enabled by efficient steel sections and integrated battery frame design

Front and rear wheel steer. Tighter turning circle enables the vehicle to operate and access more enclosed locations

STEEL E-MOTIVE, SEM1 BODY IN WHITE STEEL GRADE UTILISATION

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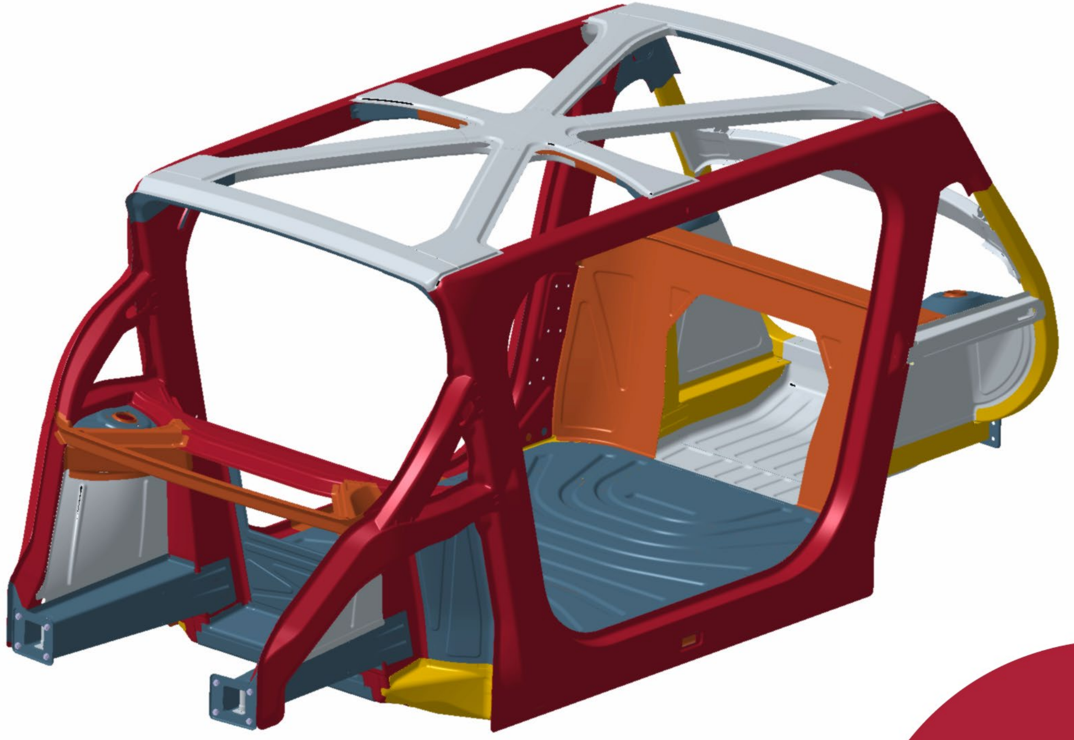
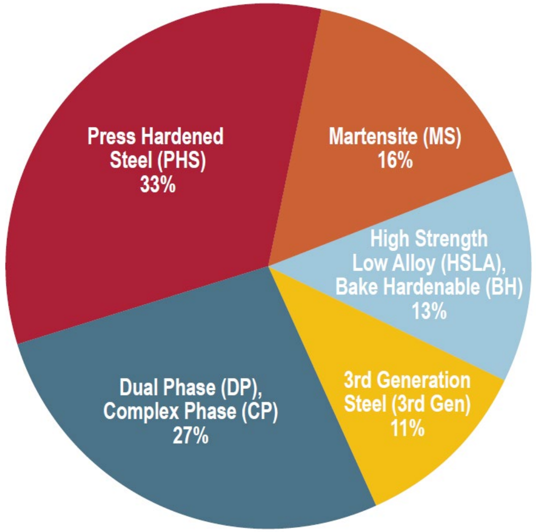
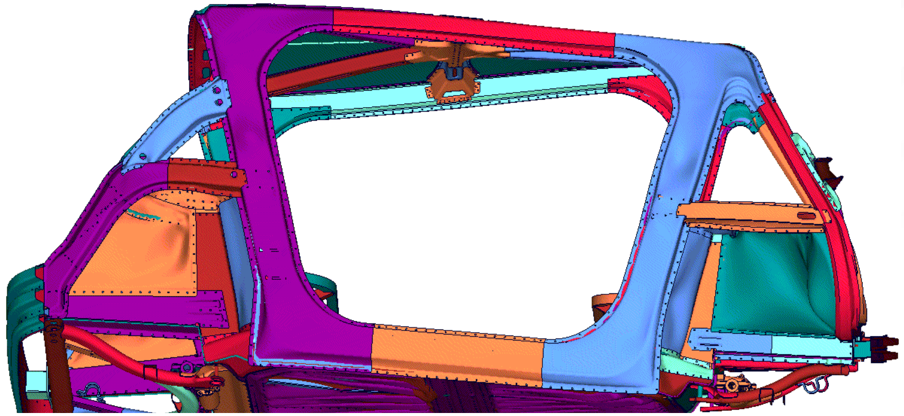
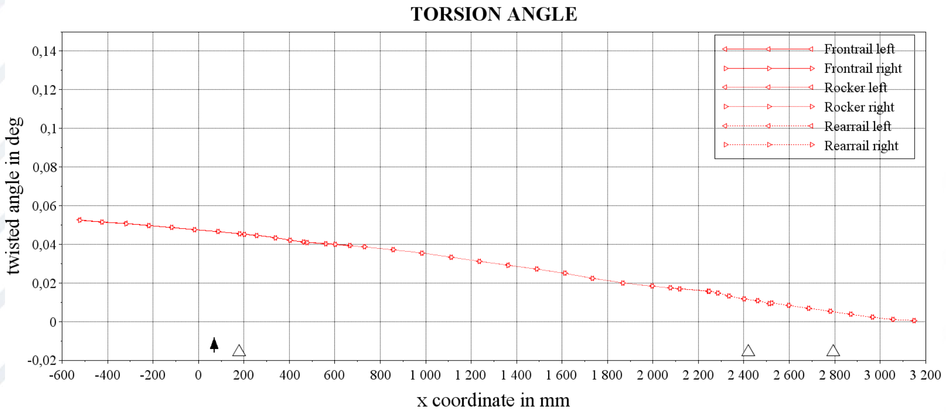




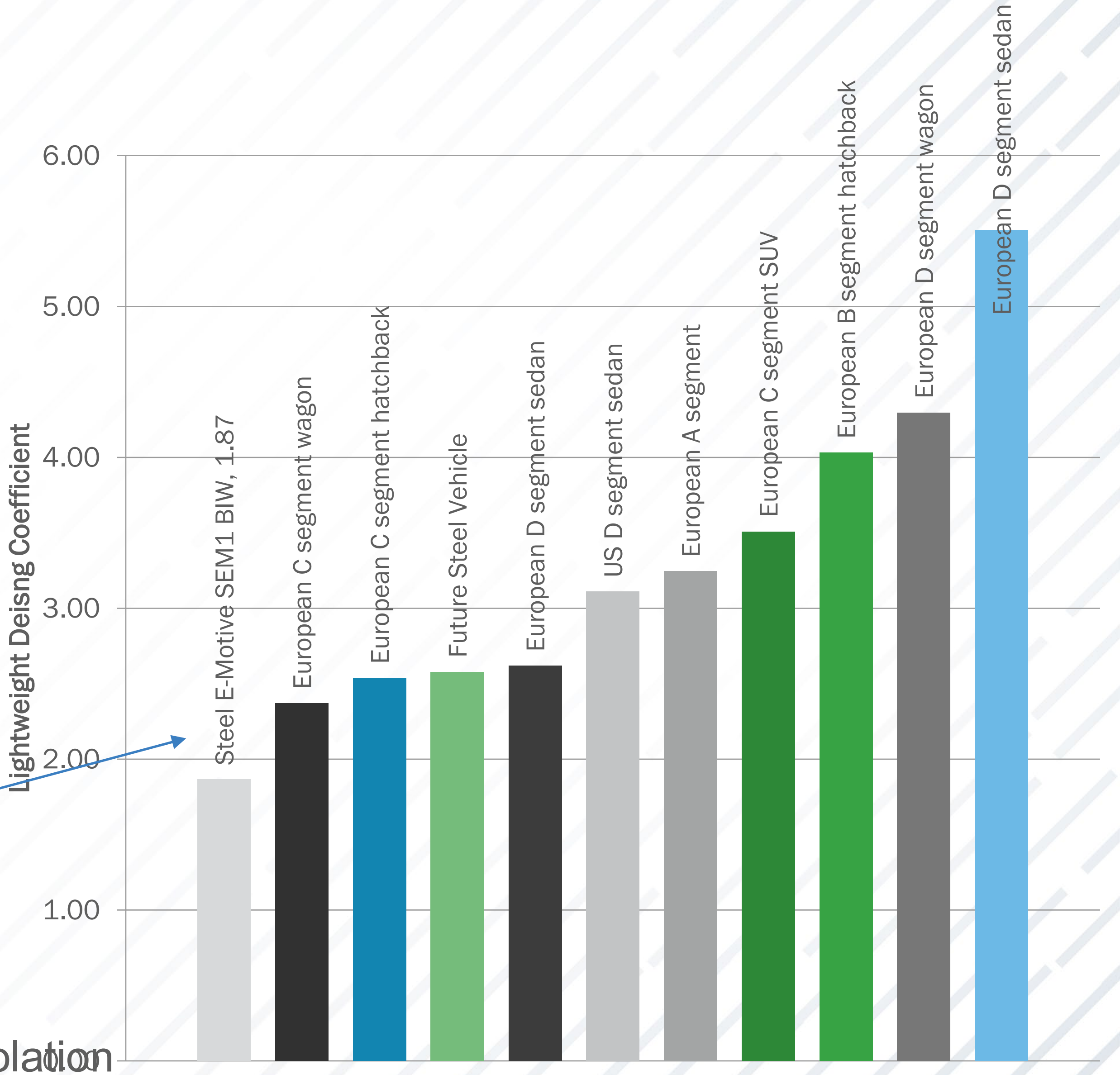
- The right steel grade in the right place
- High application of UHSS grades (>1500MPa), primarily for occupant and battery crash protection
- Mixture of stamped, roll formed, roll stamped, TWB, press hardened steel and hydroformed parts
- Spotweld, laser weld and structural adhesive
- Competitive BIW mass 282kg

PASSENGER COMFORT: VERY GOOD BODY STIFFNESS & NVH PERFORMANCE





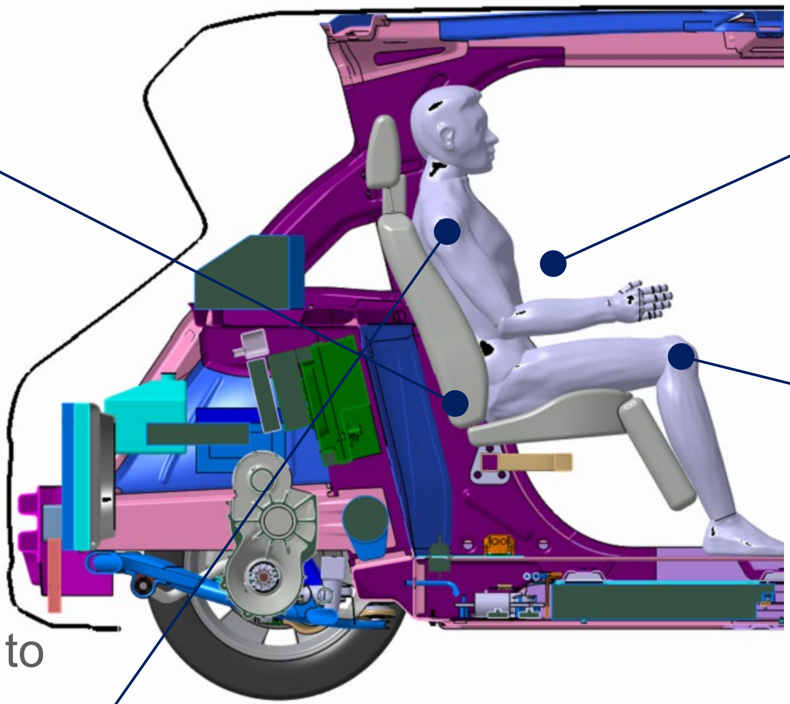
- Static torsional stiffness:
  - Body in white **34,236 Nm/deg**
  - Body (incl. battery frame & cover) **63,285 Nm/deg**
- NVH trimmed BIW modal frequencies > **35Hz**
- Attachment point dynamic stiffness enabling good NVH isolation



STEEL E-MOTIVE — IN PARTNERSHIP WITH — WorldAutoSteel — RICARDO

SAFETY – DIFFERENT APPROACH AND CONSIDERATIONS ARE REQUIRED FOR THE PROTECTION OF REAR FACING FRONT OCCUPANTS. (EFFECTIVELY THE FRONT OCCUPANT EXPERIENCES A HIGH SPEED REAR IMPACT)

Occupant deceleration loads are primarily through the seat frame and mounting structure. Energy management and design of the seat structure and headrest is more critical



Seat belt loads on front occupant are generally lower than forward facing. No frontal airbag

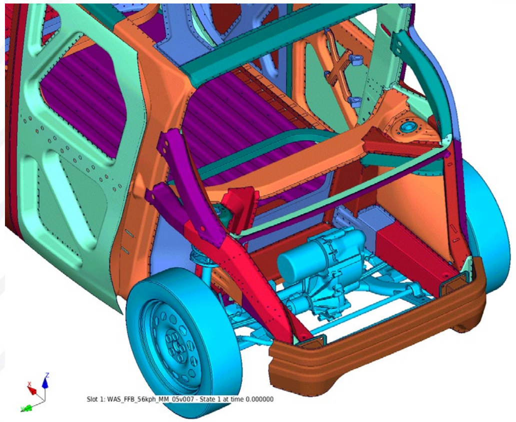
Front occupant legs, feet, arms less risk of injury from intrusion (no dash, steering wheel)

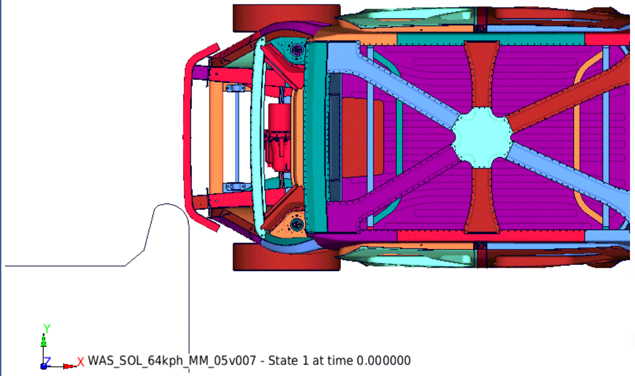
Occupant head and torso is closer to the front crash zone. Higher risk of intrusion injury. Intrusion targets have been adjusted to account for this. UHSS protection zone around front occupant

For ride hailing MaaS vehicle, we need to account for greater degree of changing occupant size. We may require smart sensors and actuators to ensure occupants are appropriately seated and restrained

SAFETY: IMPRESSIVE FRONT CRASH PERFORMANCE DESPITE COMPACT VEHICLE SIZE AND OCCUPANT POSITION. ENABLED BY TUNING OF ADVANCED HIGH STRENGTH STEEL PROPERTIES

USNCAP 56kph FFB

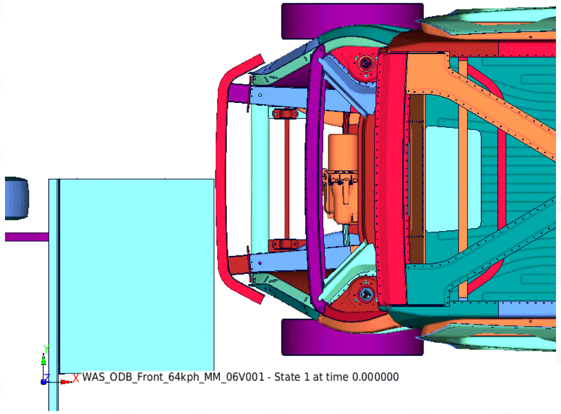


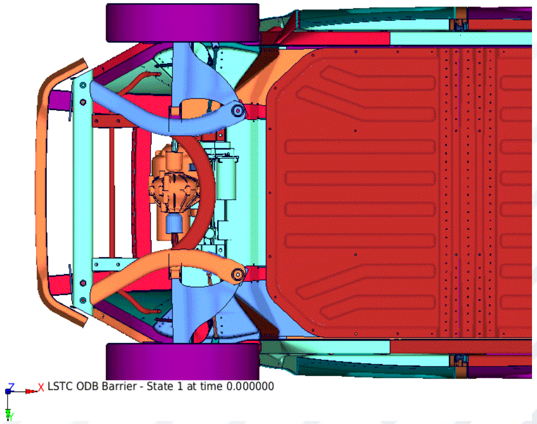


IIHS 64kph SORB

- Development focussed on 4 front crash test load cases – requiring both crush and strength characteristics from body structure
- Challenge in achieving crush-strength balance with short front overhang and occupant position
- IIHS “good” rating achieved
- “glance off” achieved in IIHS SORB test

EuroNCAP 50km/h MPDB





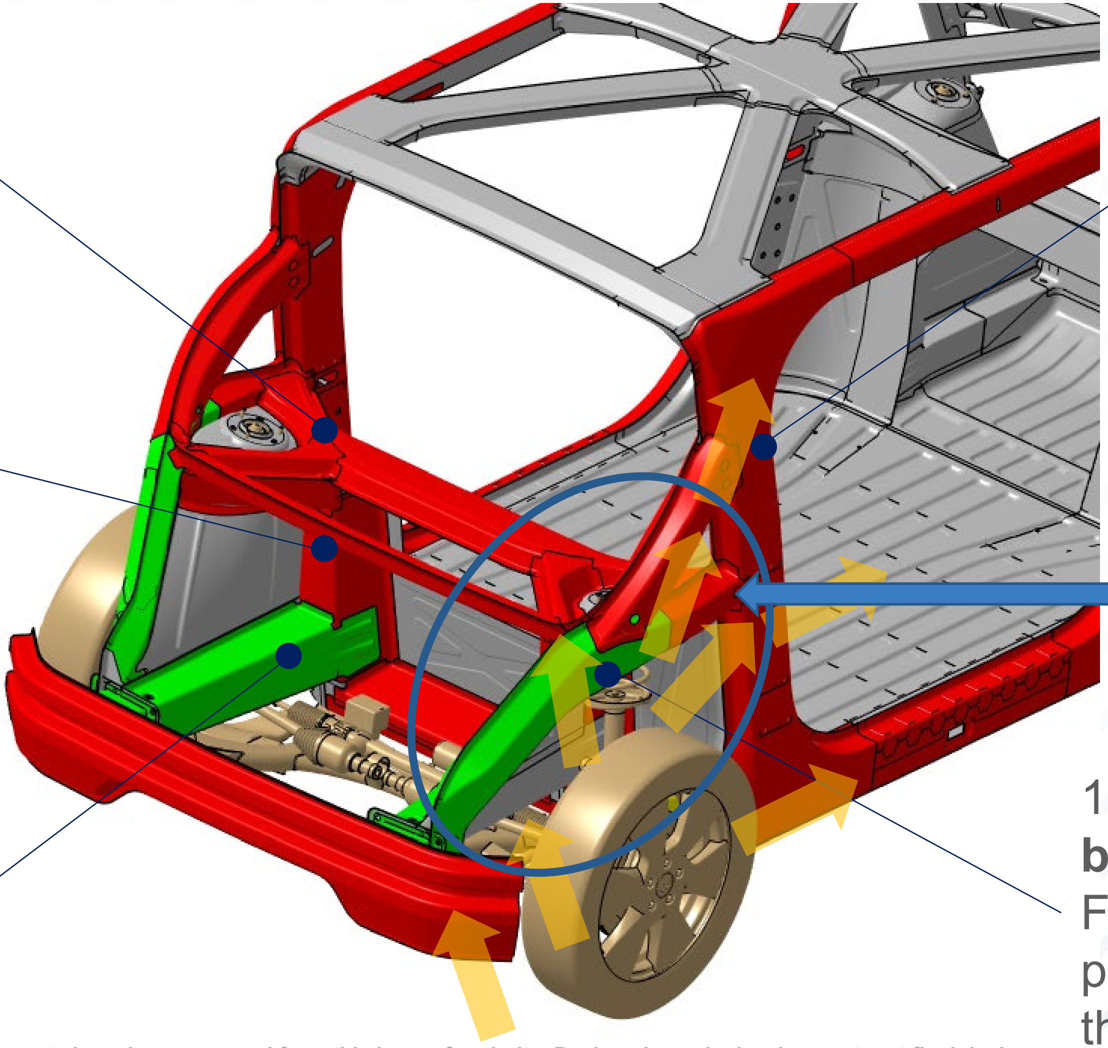
IIHS 64kph ODB

SAFETY – FRONT CRASH STRUCTURE ENGINEERED TO BALANCE THE REQUIREMENTS OF USNCAP FFB, IIHS ODB, IIHS SORB AND EURONCAP MPDB LOADCASES

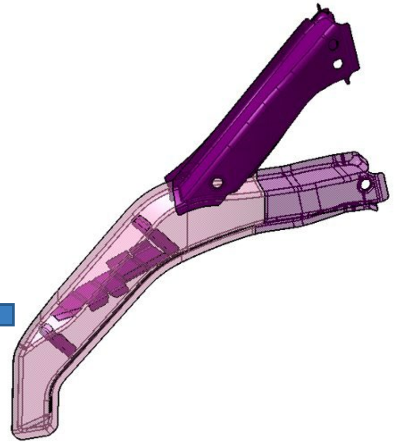
1900MPa PHS **Front strut brace** protects occupants and supports SORB load barrier reaction

1900MPa PHS **vertical dash brace and #1 bar** reacts crush loads and minimises intrusion to battery and cockpit

Longitudinal crush rail: TWB Dual Phase 780/980MPa, tuned for FFB crush performance. Plan view angle optimised for Small Overlap Barrier engagement



UHSS PHS + MS occupant protection zone

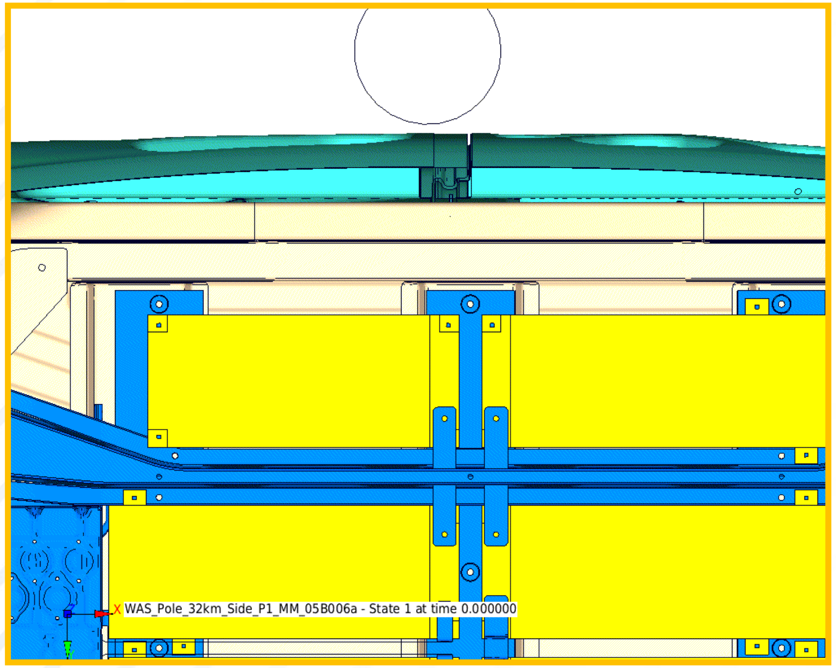


1500MPa PHS **"SORB beam"**, engineered to crush in Frontal Rigid Barrier and provide lateral load reaction in the Small Overlap Barrier

Note: components have been removed from this image for clarity. Design shown is development, not final design

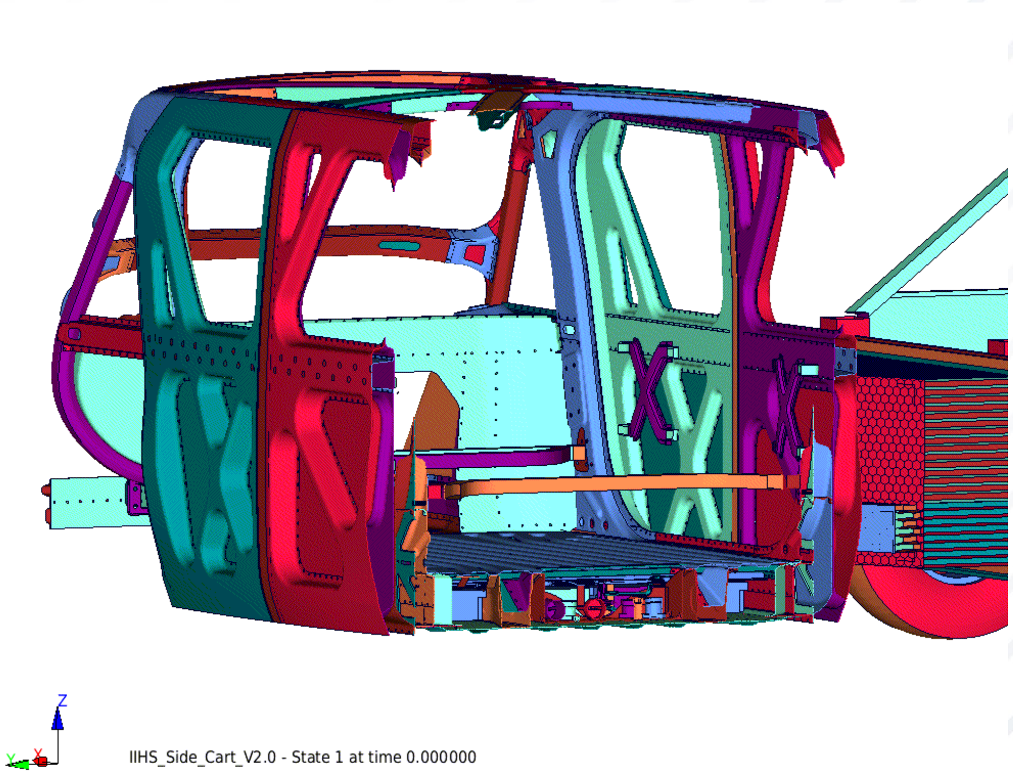
SAFETY – SIDE CRASH. VERY GOOD BATTERY AND OCCUPANT PROTECTION. IIHS "GOOD" RATING ACHIEVED (BARRIER 2)

USNCAP 32kph side pole (battery protection)



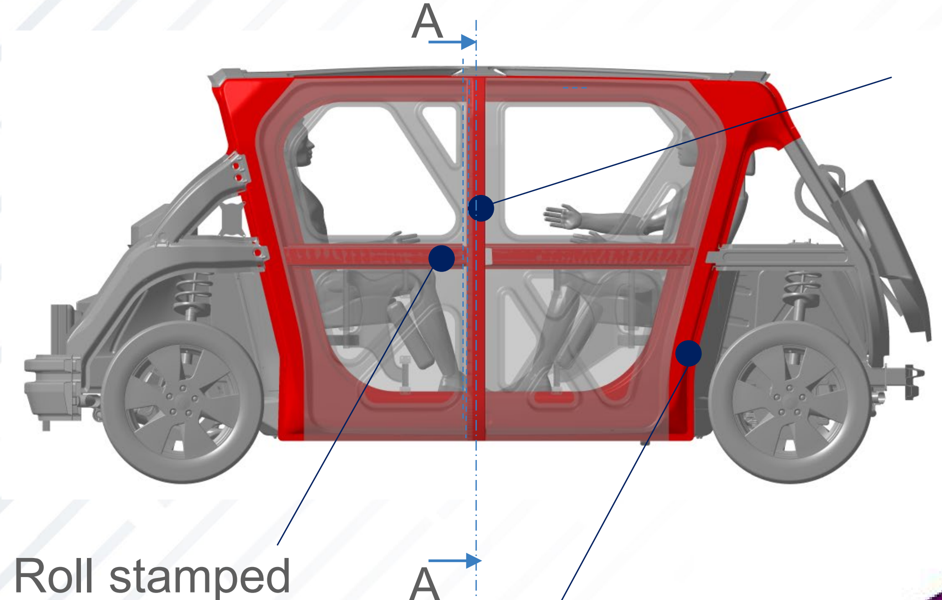
- In addition to the occupant protection test, additional side pole loadcases to ensure battery protection
- >30mm intrusion clearance to battery maintained

IIHS 60kph side barrier II (occupant protection)



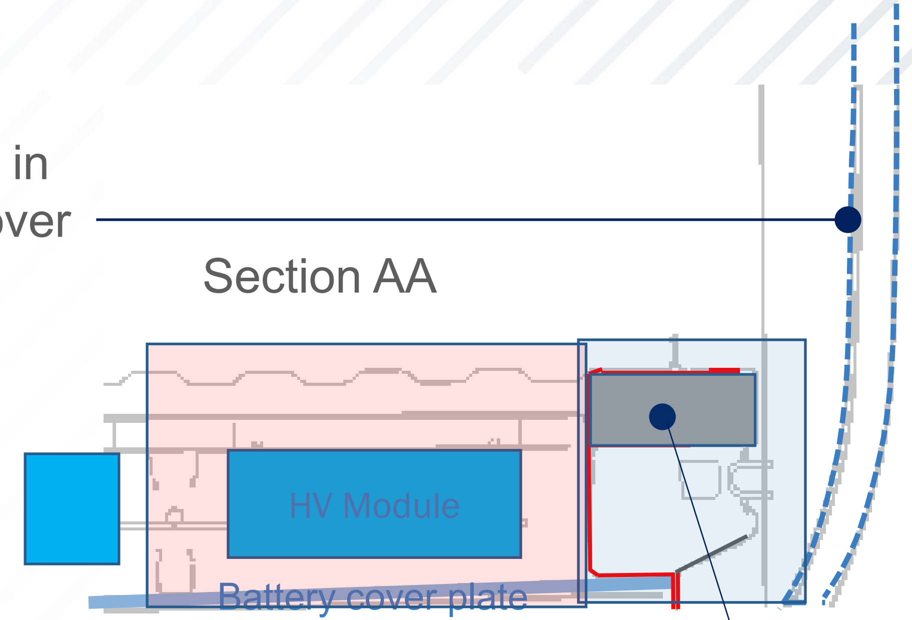
- IIHS "good" rating (based on predicted intrusions)

SAFETY – SIDE CRASH STRUCTURE



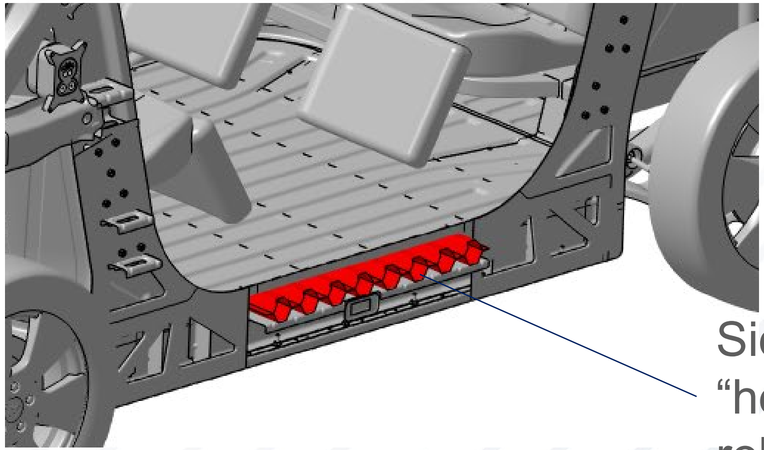
TRIP690 hydroform tubes in side door B pillars (wrap over rocker and cantrail)

Section AA



Roll stamped martensitic door waistrail beams

One piece TWB, Press Hardened Steel door ring outer. A and C pillars in line with occupants providing good side impact protection



Side impact crush “hex” beam. 2 piece roll formed DP590

TOTAL COST OF OWNERSHIP: VEHICLE AND BODY DESIGNED FOR CONVENTIONAL FABRICATION AND ASSEMBLY PROCESSES

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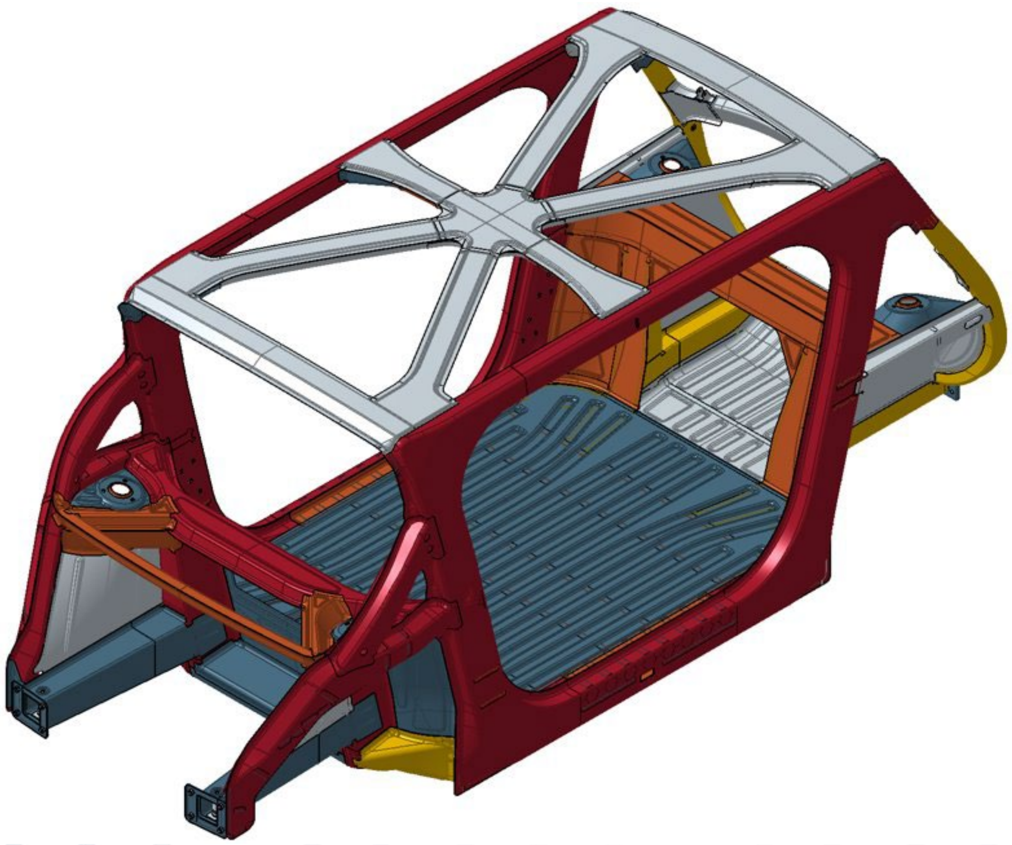
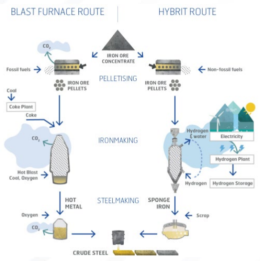


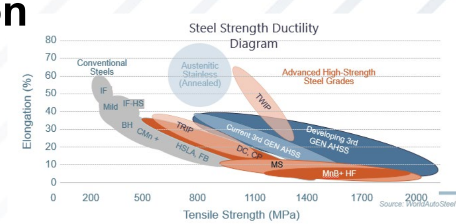
- Steel body design optimised to maximise material utilisation, minimise scrap rate
- Full formability analysis for critical/challenging panels
- Suitable for >250,000 units/year
- Conventional press, fabrication and joining tools
- Compatible with existing global automotive manufacture facilities

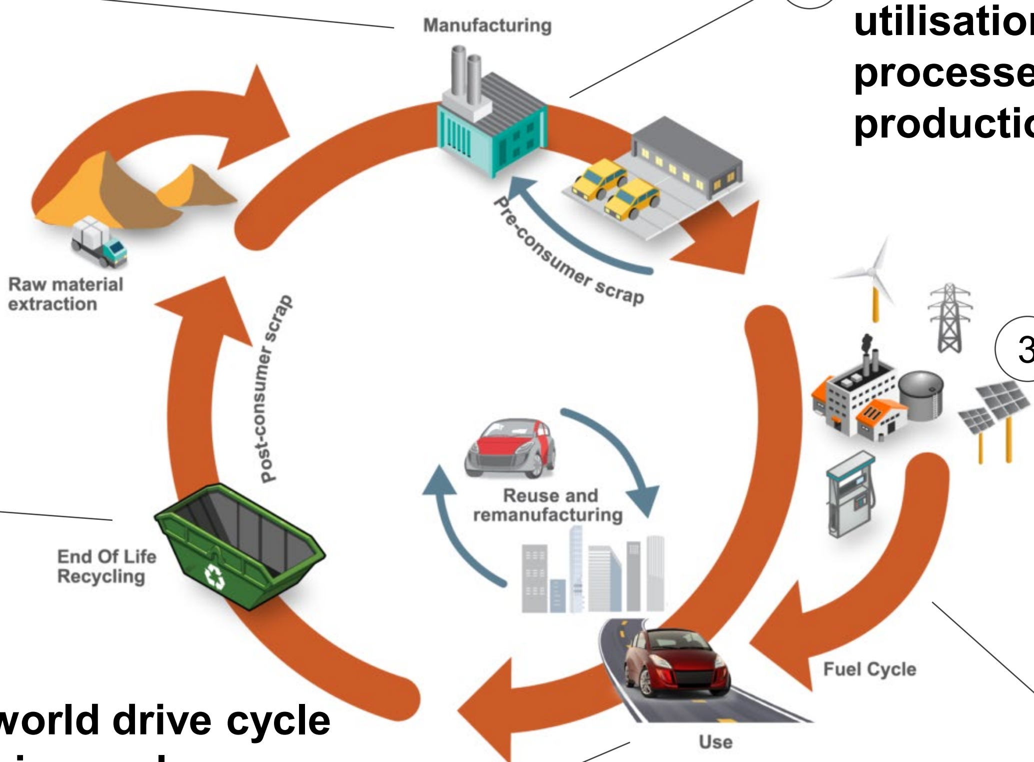
ENVIRONMENT & SUSTAINABILITY: COMPREHENSIVE LIFE CYCLE ASSESSMENT AND OPTIMISATION, DEMONSTRATING POTENTIAL FOR 92% REDUCTION IN GHG (2020 VS 2035 SCENARIO)

1 **Decarbonise steel production (e.g. hydrogen Electric Arc Furnace)**

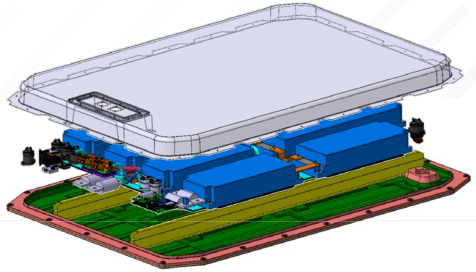


2 **Optimise vehicle design, material utilisation and fabrication processes to minimise production emissions**

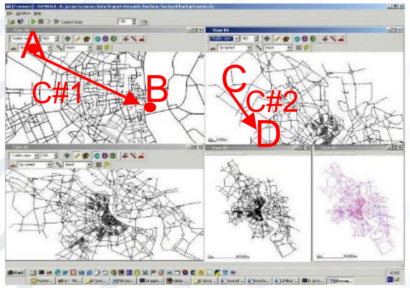




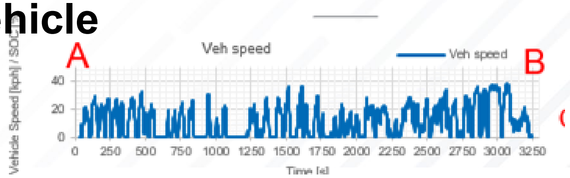
3 **HV battery production emission study and > 2030 forecast**



6 **Maximise Re-use, Re-manufacture, Recycling. End of life methodology**



5 **Real world drive cycle and drive cycle smoothing with autonomous vehicle control**



4 **Decarbonise electricity grid supply for xEV. Global variations & >2030 forecast (production and vehicle use)**

Image source: SSAB, ArcelorMittal

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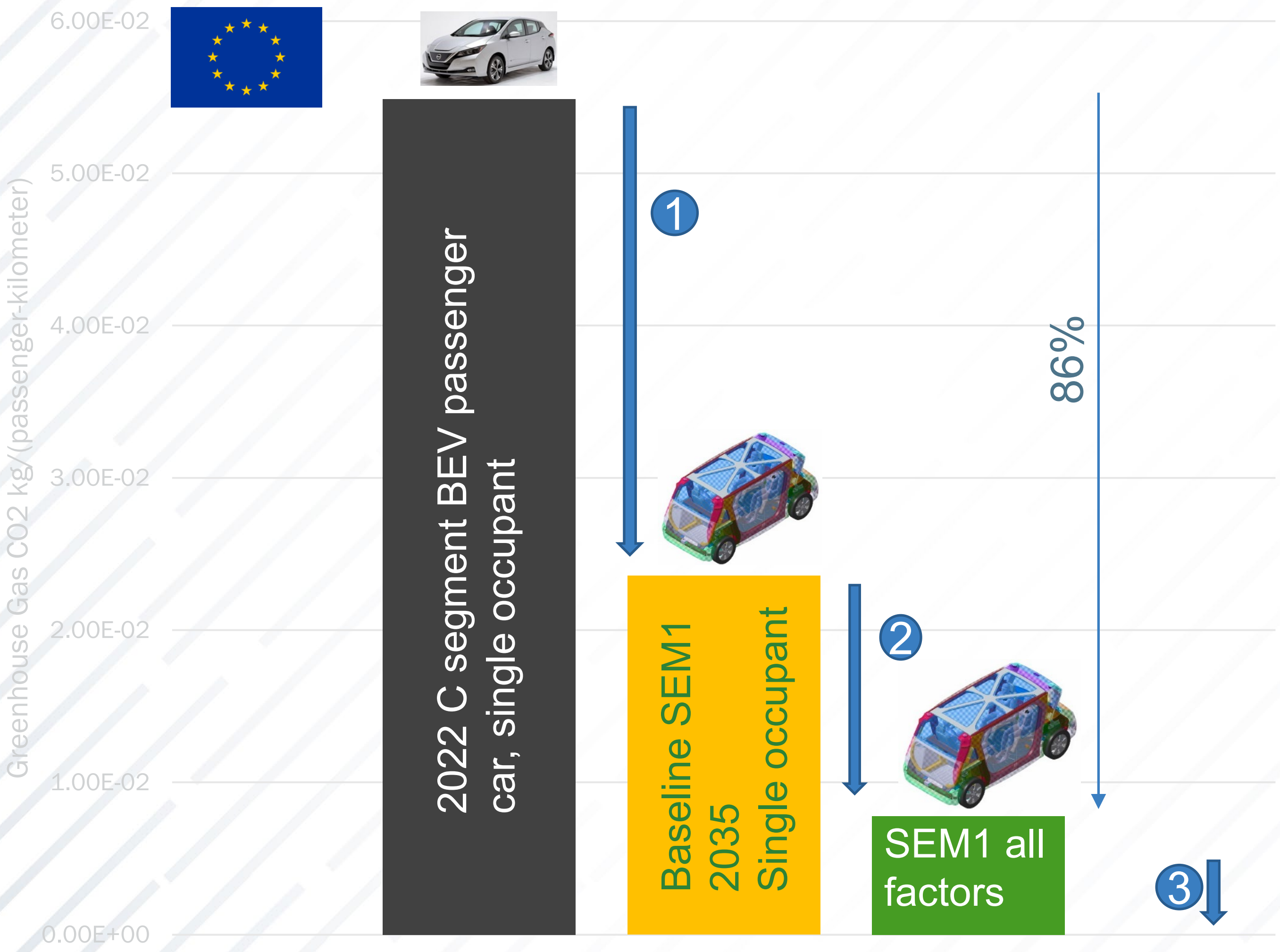
SEM1 VEHICLE LIFE CYCLE ANALYSIS. APPROACH AND SENSITIVITY STUDIES



1 ↓
- AV vehicle weight reduction
- HV battery technology improvement
- Electricity grid (green) improvements 2022 to 2035

2 ↓
- Decarbonized steel production
- Apply MaaS operation factors: 3 occupants, autonomous vehicle drive cycle smoothing, extended vehicle & battery life

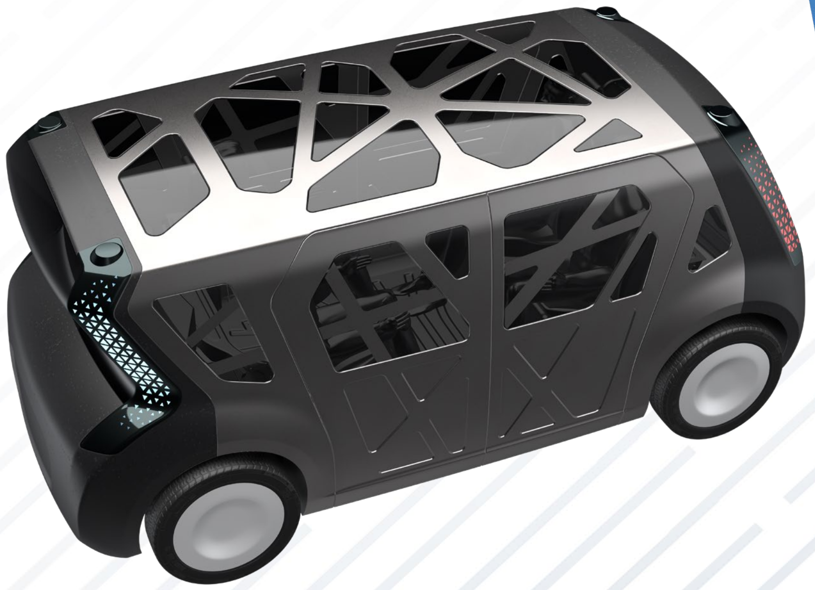
3 ↓
- Achieving 100% net zero will likely require carbon capture (at production), ~100% renewable grid supply and carbon offset/credits

STEEL E-MOTIVE – SUMMARY

- The Steel E-Motive project has engineered an innovative vehicle and body structure concept, taking into consideration the freedoms and differences offered by full autonomy

- Through application of the complete steel grade portfolio, the Steel E-Motive concept demonstrates:
  - Safety – very good level of protection of occupants and battery
  - High levels of occupant comfort and good accessibility
  - Cost effective design, suitable for global high volume production
  - Significant reduction in life cycle greenhouse gas emissions

- Follow us on our journey at www.steelemotive.world



STEEL E-MOTIVE TECH TRANSFER

- Full engineering report released to automotive engineers *at no charge, available for download later this year.* Subscribe at *steelemotive.world* to be notified!
- Available through our Steel Member Companies:
  - CAD Models
  - Crash Models
  - Review of the Cost and LCA models
  - Virtual Reality tours
  - Discussion on the steel applications demonstrated

@ THE NUCOR BOOTH

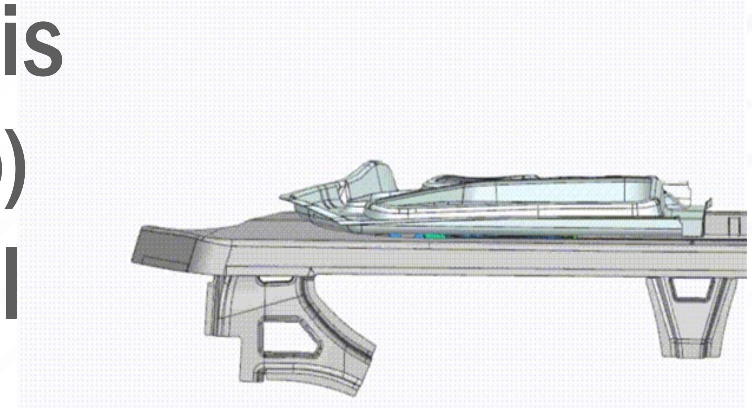
- 3-D Printed Body Structure Prototype
- 1/3 Scale

STEEL E-MOTIVE
IN PARTNERSHIP WITH
WorldAutoSteel
RICARDO

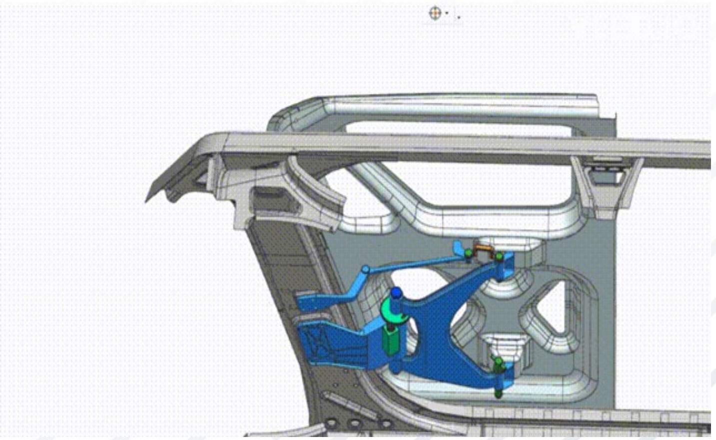
SENIOR CAPSTONE PROJECTS

1. Steel E-Motive Scissor Door Analysis
   Michigan Tech (Auto/Steel Partnership)
2. Adaptation of SEM2 to Commercial Delivery of Goods
   Michigan Tech (WorldAutoSteel)
3. Joining of 5T AHSS Stack-up
   Ohio State University (WorldAutoSteel)

3D Printed Working Model



Door operation: Top view.



Door operation: Inside angle view.

FOR MORE INFORMATION

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GREAT DESIGNS IN

STEEL