

Steel E-Motive

Shaping the Future of Sustainable Transportation

ISSUE 4

Technical Microstudies Highlighting Design and Performance Innovations for Steel E-Motive

How MaaS Vehicles Like Steel E-Motive Are Shaping the Future of Sustainable Mobility

Introduction

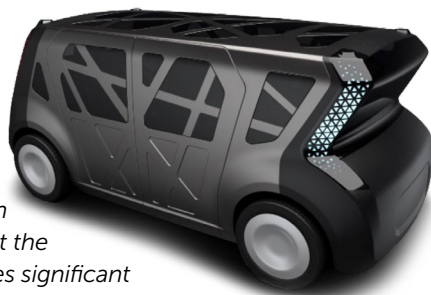
Urbanization and Net Zero Emissions targets are key contributors of the transportation shift to mobility on demand in densely populated urban environments. It's here that the mobility industry anticipates significant growth in ride sharing, with emphasis on the use of autonomous vehicle technologies and electrification to achieve that goal.

WorldAutoSteel's Steel E-Motive program demonstrates autonomous ride-sharing concepts that maximize occupancy and comfort through unique seating configurations and easy vehicle access, while offering a clear path to Net Zero.

The impact of transportation on Greenhouse Gas (GHG) emissions – and consequently on global warming – is well-established. Vehicle manufacturers, fleet operators and transport users all share the responsibility to minimise both individual and collective environmental footprints. Their efforts are essential to achieving global climate change targets.

Mobility as a Service (MaaS) transportation solutions, such as Steel E-Motive, offer critical solutions to reduce net GHG emissions in densely populated cities, supporting these goals.

A key tool in evaluating environmental performance is Life Cycle Assessment (LCA), which examines a product's full life span – from raw material extraction and manufacturing, through its operational use, to end-of-life disposal or recycling. LCA also accounts for the impact of energy consumed throughout each phase. This comprehensive methodology was embedded in the development of the Steel E-Motive concept, ensuring sustainability was prioritized throughout the design process. Steel-intensive MaaS transportation further optimizes emissions reduction, as steel is the only structural automotive material that delivers CO₂ reduction potential in **all** Life Cycle phases.



Life Cycle Assessment Approach

Figure 1. Comprehensive Life Cycle Assessment

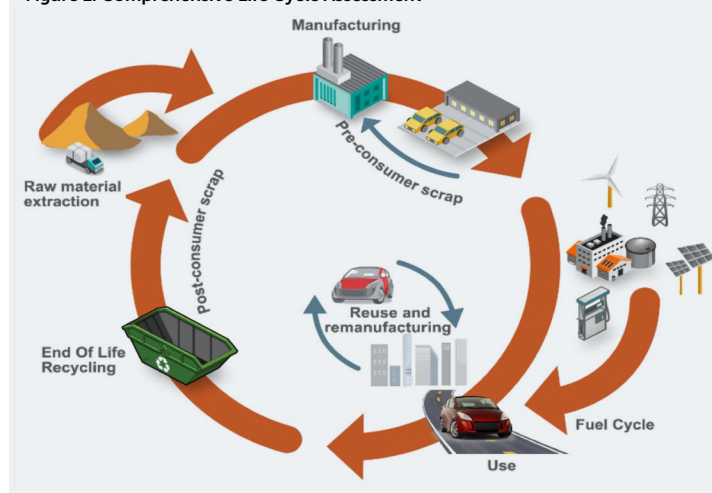
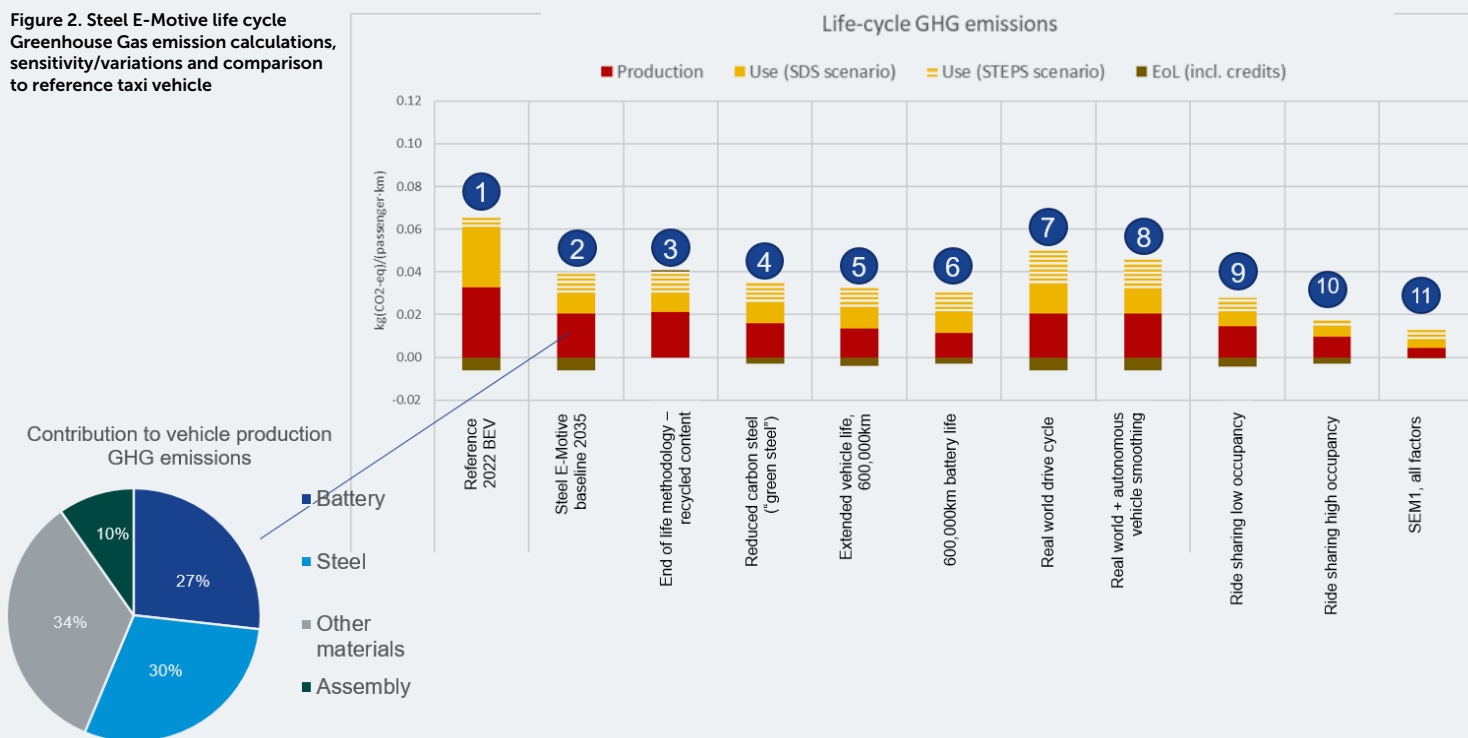


Figure 1 shows the main LCA considerations for a passenger vehicle such as Steel E-Motive. The key contributions to a vehicle's life cycle emissions consist of the manufacture, use and end-of-life stages. The manufacture of a BEV vehicle can produce 50% or more of a vehicle's total life cycle emissions. Significant quantities of energy and resources are required to extract and process the raw materials and convert them into manufactured parts. The parts are then transported to the vehicle final assembly location, where further resources build the vehicles and then transport them to their final destinations.

For a BEV, the energy supply is provided from a domestic electricity supply, which charges the battery and is then converted to propulsion forces via the electric traction motor(s). BEVs have zero tailpipe emissions, but for life cycle calculations and methodology, the GHG emissions are derived from the carbon emissions of the source electricity generation. A BEV using a grid electricity supply from renewable sources, such as wind or solar power, will have lower use-phase GHG emissions than a vehicle obtaining its electricity source from gas- or coal-powered stations. The electricity source(s) must therefore be considered in vehicle life cycle assessments.

Figure 2. Steel E-Motive life cycle Greenhouse Gas emission calculations, sensitivity/variations and comparison to reference taxi vehicle



The end-of-life LCA calculation considers both the disposal of the vehicle and the potential to recycle or reuse its parts at time of disposal. Different LCA calculation methodologies account for recovery of the vehicle life cycle carbon emissions based on the amount of material expected to be recycled and reused in the creation of new vehicles.

Steel E-Motive Life Cycle Calculations

Steel E-Motive's LCA calculations were performed using a tool created by University of California Santa Barbara (UCSB) and WorldAutoSteel. The tool contains datasets, parameters and calculation formulas that enable rapid assessment of vehicle life cycle GHG emissions and total energy consumption. Adjustments were made to the final calculation and evaluation methods to account for the ride sharing MaaS operation of Steel E-Motive. Vehicle GHG emissions and energy calculations are typically reported in tonnes CO₂ equivalent and kilojoules. Steel E-Motive's LCA calculations applied a kgCO₂ per passenger-km and megajoules per passenger-km metric. The per-passenger adjustment accounted for the MaaS operation and multi-passenger occupancy expected to reduce the overall number of vehicle journeys and the per-km adjustment for the consideration and potential to extend the life of the vehicle, having the effect of reducing the overall number of vehicles manufactured over a given period.

Autonomous vehicles such as Steel E-Motive communicate directly with other vehicles and road infrastructure, such as traffic control signals. This connectivity yields more modest acceleration and deceleration to maintain flow within traffic, and the tempered operation results in up to 20% further reduction in emissions – known as *drive-cycle smoothing* – a benefit captured in Steel E-Motive and reflected in the study results.

Engineers used a present-day, C-segment BEV operating as a taxi as a comparative benchmark vehicle for the Steel E-Motive LCA calculations. Distinct sensitivity studies were performed to evaluate different vehicle attributes and operational scenarios. **Figure 2** shows LCA calculations and study results for both the reference taxi vehicle and Steel E-Motive baseline, as well as nine sensitivity scenarios.

The Steel E-Motive comprehensive LCA study referenced two alternative data sets for Use Phase grid supply. The International Energy Agency (IEA) World Energy Outlook provided predictions for electricity grid supply carbon intensity for a "Sustainable Development Scenario" (SDS), where global climate targets would be achieved, and for a "Stated Policies Scenario" (STEPS), a more conservative scenario, assuming not all government targets would be achieved. SDS and STEPS were extracted and included for multiple geographic regions. The results shown in **Figure 2** reflect a European vehicle. **Table 1** provides additional detail for these scenarios, including CO₂ reduction achievements; greener grids and steel production; extended vehicle and battery lives; and various driving cycle simulations.

Scenario 11 in **Table 1** combines all possible benefiting factors into the Steel E-Motive LCA calculations, resulting in a predicted 86% reduction in life cycle GHG emissions compared to the reference C-segment BEV taxi. This significant reduction can be attributed to many factors, including vehicle design and the implementation of autonomous mobility; decarbonisation of the electricity supply grid; road infrastructure improvements and a shift in end-user personal transportation habits.

Roadmap for MaaS Net-Zero Emissions

Figure 3 shows the potential for a staged implementation of MaaS vehicles in densely populated urban areas and the subsequent emissions reductions that could be achieved.

Step 1 shows potential for short-term implementation. The BEV taxi is assumed as the basis for MaaS transportation, as the regulatory and widespread infrastructure for fully autonomous vehicles is not expected to be available within the short-term timeframe. Modest weight reduction of the vehicle is expected to be achieved, as well as a low application of reduced carbon steel in the body structure and chassis. Ongoing efforts to reduce

carbon emissions associated with propulsion battery manufacture are anticipated and vehicle occupancy rates increased to three passengers due to reflect social shifts and cost-benefit journey incentives. These measures are expected to result in a potential short-term 60% like-for-like reduction in vehicle GHG emissions compared to the baseline BEV taxi.

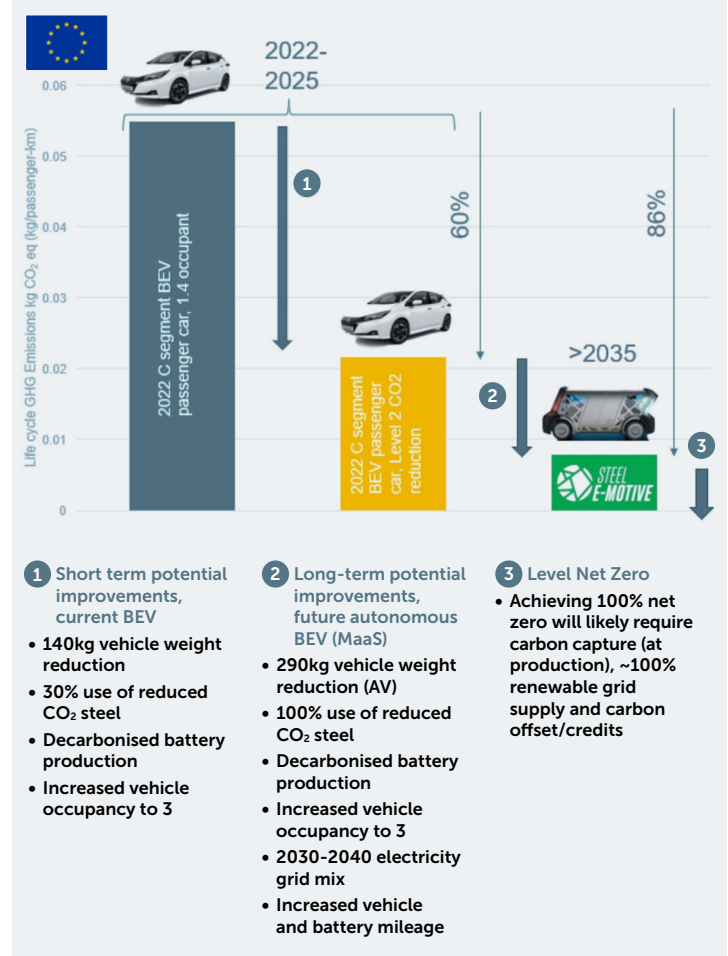
Step 2 demonstrates the longer-term emissions reduction potential, with the full implementation of purpose-designed fully autonomous MaaS vehicles such as Steel E-Motive. More significant vehicle weight reductions are expected to be achieved (and are demonstrated in the Steel E-Motive concept design) and the life of the vehicle and battery extended to 600,000 km. The European electricity grid supply is expected to continue the shift to very high levels of renewable energy in the 2030 to 2040 timeframe – the impact of this is included in Step 2.

Considering the long-term, wide-scale deployment of MaaS vehicles such as Steel E-Motive, an overall reduction in vehicle life cycle GHG emissions of 86% is predicted (for vehicles operating in Europe). To achieve “net zero” (or 100% reduction in GHG

Table 1. Steel E-Motive LCA sensitivity and scenario studies

Model/Result Number	Description	Key Result
1	Reference BEV, 2022	Used as datum/reference for SEM
2	Baseline Steel E-Motive. 25% vehicle weight reduction versus (1), 2030-2040 electricity grid mix	57% life cycle GHG reduction compared to (1)
3	Steel E-Motive. As (2) with End of Life methodology changed from avoided burden method to recycled content	Recycled content EOL methodology results in a 13% increase in life cycle GHG
4	Steel E-Motive. As (2) with all AHSS in the vehicle substituted with decarbonised steel production	22% reduction in vehicle production GHG emissions. 3% decrease in GHG over vehicle life cycle. Note, the effect is diluted due to the GHG contribution in the use phase
5	Steel E-Motive. As (2), with vehicle lifetime kilometers increased from 300,000 km (2) to 600,000 km (5)	20% reduction in vehicle life cycle GHG
6	Steel E-Motive. As (5), with battery lifetime increased from 300,000 km to 600,000 km	A further 7% reduction in life cycle GHG emissions compared to (5)
7	Steel E-Motive. As (2) with real-world driving cycle. (all other models assume a standard WLTP drive cycle)	Real world drive cycle results in overall 21% increase in life cycle GHG emissions
8	Steel E-Motive. As (7) with effect of autonomous vehicle drive cycle smoothing	7% reduction in life cycle GHG emissions compared to (7)
9	Steel E-Motive. As (2) with vehicle occupancy passenger increased from 1.4 to 2.0	30% reduction in life cycle GHG emissions compared to (2)
10	Steel E-Motive. As (2) with vehicle occupancy passenger increased from 1.4 to 3.0	53% reduction in life cycle GHG emissions compared to (2)
11	Steel E-Motive. As (2), with combined effects of (4), (5), (6), (10)	86% reduction in life cycle GHG emissions compared to reference 2022 BEV vehicle (1)

Figure 3. Roadmap for MaaS vehicle deployment and potential GHG emissions reductions



emissions) requires efforts beyond the design of MaaS vehicles. The electricity supply grid will require a transition to 100% renewable sources, and technologies, such as carbon capture, will be required at the material and vehicle production sites. Additionally, carbon credit approaches could be applied to offset any remaining fossil fuel carbon emissions.

Steel E-Motive Deployment Study

A hypothetical deployment study demonstrates the potential impact that a staged rollout of MaaS vehicles, such as Steel E-Motive, could achieve for densely populated cities, such as London and New York. **Figure 4** shows the potential impact of a MaaS rollout in London and neighbouring boroughs. Scenarios for “baseline” (=no MaaS), “SEM baseline” (=MaaS, manual operation, 1.4 vehicle occupancy), “SEM pragmatic” (=MaaS autonomous, 1.4 average passenger occupancy, standard vehicle lifetime) and “SEM optimistic” (=MaaS autonomous,

3 passenger occupancy, higher vehicle lifetime) are calculated. A progressive, staged rollout is modelled, starting in 2030 with 4% of passenger journey miles using MaaS, increasing to 43% by 2040.

The modelling demonstrates that this level of MaaS deployment has the potential to reduce cumulative CO₂ (equivalent) vehicle emissions in London and its boroughs by 7.4 million tonnes.

A similar methodology was applied for New York City for the time period 2030 to 2050, as shown in **Figure 5**.

The study shows the potential to achieve a cumulative GHG emission reduction of up to 95 million tonnes CO₂ equivalent by the deployment of MaaS transportation, such as Steel E-Motive.

Together, these studies demonstrate the real potential for fully autonomous MaaS vehicles to make significant contributions to local authority net zero transportation goals.

Figure 4. Life cycle impact modelling study of MaaS deployment in London and boroughs, 2030 to 2040

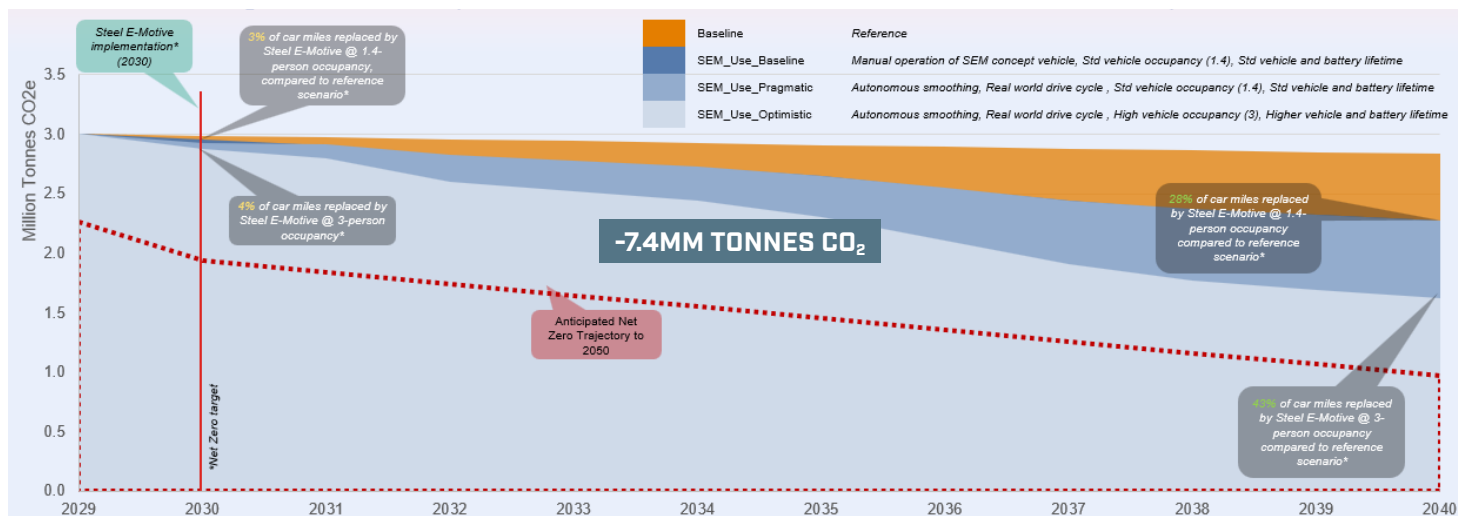
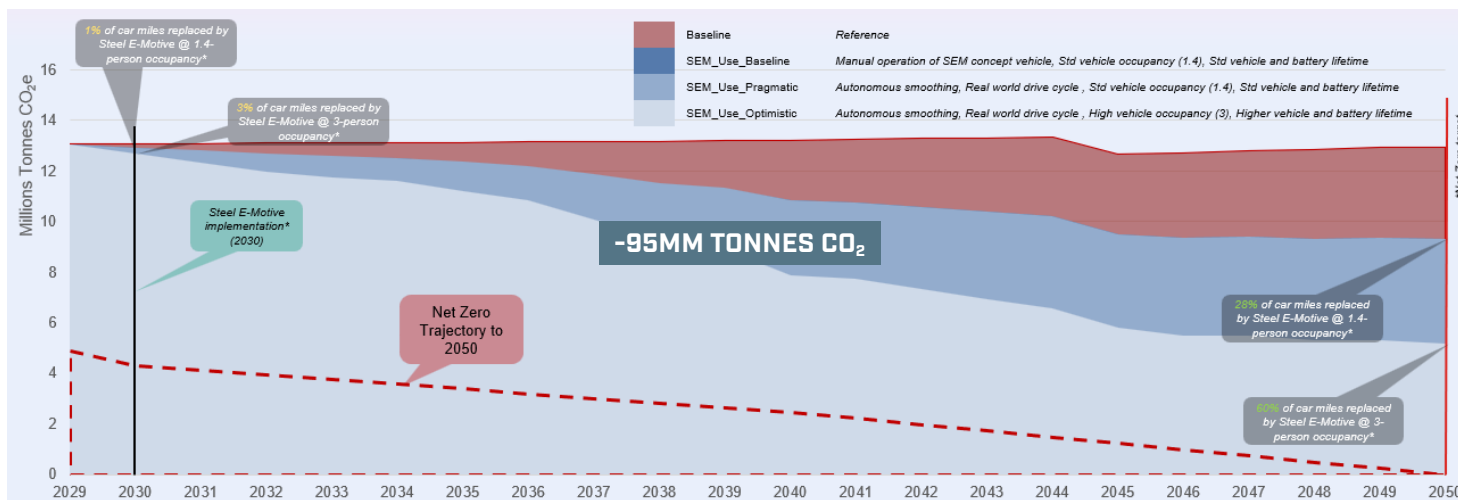


Figure 5. Life cycle impact modelling study of MaaS (i.e. Steel E-Motive) deployment in New York 2030 to 2050



Steel's Role In Decarbonising Passenger Transportation

Steel is considered the most efficiently converted material in the world and is unique among automotive structural materials in that it contributes emissions reduction potential in all vehicle life cycle phases. Importantly, advanced high strength steels continue to grow in their application density in the face of increasingly stringent emissions reduction policies and crash performance. Production from Electric Arc Furnace (EAF) and Hydrogen Direct Iron (DRI) grows and yields one of the lowest GHG emission factors compared to other automotive materials. Vehicles containing steel parts and systems which are manufactured using these processes also benefit from lower GHG emissions.

Automotive stamping is generally the most common part fabrication method but is characterized by about 50% engineered scrap, meaning twice as much material is produced compared to the material that makes the part and is found in the vehicle. Where possible, Steel E-Motive intentionally utilized

advanced steel fabrication processes for significantly greater material utilization efficiency and lower net scrap. This means less material is produced for the same parts, lowering energy and emissions. Parts manufactured from advanced high strength steels also require less thickness for comparable strength and stiffness performance, achieving competitive weight performance with low-density materials and resulting in lower energy consumption and GHG emissions during the use phase.

The high strength and fatigue properties of steel can increase the durability and total life of a vehicle, resulting in fewer vehicles manufactured. This can reduce overall GHG emissions due to lower vehicle production volumes, whilst maintaining equivalent journey transportation miles.

Finally, steel is a highly recyclable material. Prompt steel scrap from the vehicle manufacture process can be easily recycled and reused for primary manufacture. At the end of a vehicle's life, steel can be easily extracted from the complete vehicle and recycled.



Summary and Conclusions

The life cycle emissions study for Steel E-Motive evaluated the contribution and sensitivities from material production, vehicle manufacture, vehicle use and end-of-life stages.

Key findings include:

- Full deployment of fully autonomous, battery electric MaaS vehicles, such as Steel E-Motive, have the potential to reduce like-for-like GHG emissions up to 86%, compared to a present-day C-segment BEV operating as a passenger taxi.
- Optimal emissions reduction can be achieved by a combination of decarbonisation efforts, including:
 - large-scale implementation of low carbon steel production methods, such as DRI and EAF
 - carbon emissions reduction from the manufacture of the battery
 - improvements to the vehicle design and operation, such as lightweighting, connected autonomous systems, and extended vehicle and battery lifetimes
 - decarbonising the electricity supply grid by increased renewable energy sources such as wind and solar power

Further deployment studies demonstrated how end users can embrace multi/shared vehicle occupancy and driverless operations in congested cities as a favoured mode of transportation.

- An LCA implementation study using London and New York as examples validated significant contributions to regional transport carbon reduction initiatives.



For additional details on the Steel E-Motive project, including specific design and simulation results, visit steelemotive.world/resources