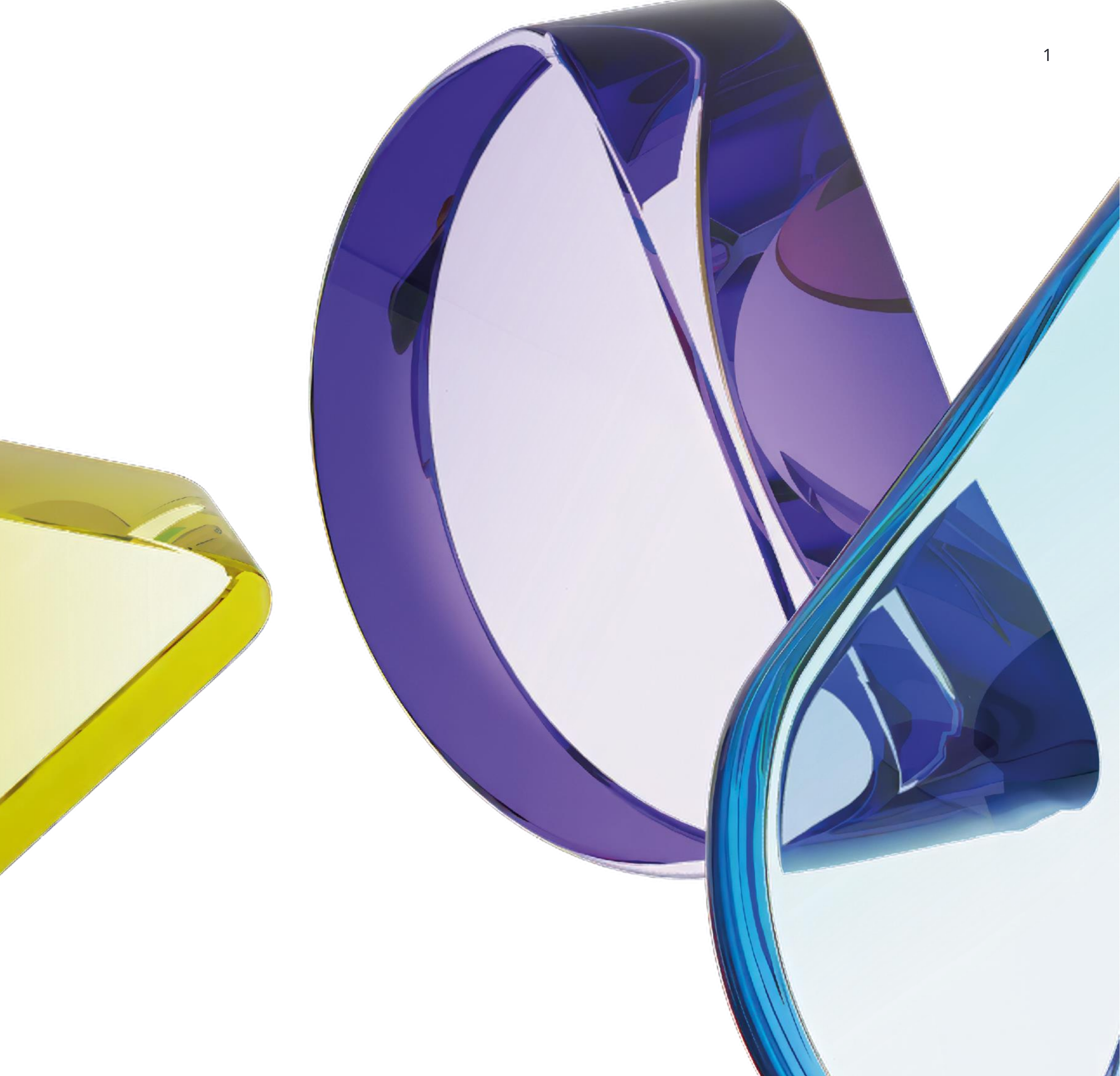

Connectivity and interoperability of zero-emission tractors and trailers

Review of current practice and stakeholder engagement

Your partner in progress

About BSI

BSI is a global thought leader in the development of standards of best practices for business and industry. Formed in 1901, BSI was the world's first National Standards Body (NSB) and a founding member of the International Organization for Standardization (ISO). Over a century later, BSI is focused on business improvement across the globe, collaborating with experts in all sectors of the economy to develop codes, guidance and specifications that will accelerate innovation, increase productivity, and support growth. Renowned as the originator of many of the world's best-known business standards, BSI's activity spans multiple sectors including aerospace, automotive, built environment, food, healthcare, and ICT.

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About the ZEHID Programme

We are supporting the Zero emission HGV and infrastructure demonstrator (ZEHID) programme, in partnership with the Connected Placed Catapult, funded by the Department for Transport and delivered by Innovate UK. The programme provides funding for the delivery of large-scale demonstrations of hundreds of 40-44 tonne hydrogen fuel cell and battery electric powered HGVs, and their associated charging/ refuelling infrastructure. Vehicles will operate in real-world commercial operations, with data being collected and disseminated between 2025-2030 while the demonstrations take place.

Authors:

Ian Foster, Catlynn Transport Consultants
Ian Warr, Catlynn Transport Consultants
Matteo Novati, BSI

The authors are grateful to all the engaged participants for their contributions and insights.

Disclaimer

This technical note has been prepared for general information purposes relating to its subject matter only. It is not intended to be advice on any course of action.

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1 Introduction

This technical note summarizes the findings of a study commissioned by British Standards Institution (BSI) with the aim of assessing the emerging zero emission (ZE) tractor and semi-trailer market. This included reviewing existing standards and common practices in tractor/trailer connectivity and identifying areas that may benefit from harmonization and standardization.

Currently the communication/connectivity between tractor units and trailers generally consists of the following harmonized links, depending on application:

- compressed air connections for braking;
- 24-volt supply for exterior lighting; optional additional 24-volt feeds for tail lifts, or other auxiliary equipment;
- CAN lines transmitting information in regard to anti-lock braking systems, suspension controls, axle weights.

There is currently no harmonized approach for the connection of power take-offs or auxiliary batteries to the main battery of an electric trailer.

The study initially involved a series of conversations with tractor and trailer original equipment manufacturers (OEMs). The collated information was used to build a set of questions that was circulated to a wider sample of truck and trailer manufacturers. The objective of the survey was to understand current strategies and future plans for the design and development of vehicles and components. A sample of fleet operators and repair/conversion businesses were also engaged to gather views on how the transition to ZE vehicles will affect the tractor and trailer market.

The following chapters provide:

- Background on the existing tractor and trailer market and on current policy targets in relation to the net-zero transition in the road freight transport sector.
- A summary of the views, challenges and opportunities expressed by stakeholders.

2 Background

2.1 Policy targets

In November 2021, the previous government expressed the intention to end the sale of new non-zero emission heavy goods vehicles (HGVs) weighing under or equal to 26 tonnes by 2035, with all new HGVs sold to be fully zero-emission at the exhaust by 2040[1]. This target mirrors the UK's ambitious regulatory framework for the switch to electric cars and vans set out in the Zero Emission Vehicle (ZEV) Mandate issued in January 2024 (100% of new cars and vans manufactured to be zero emission by 2035). It is worth noting that the extension of deadlines by the previous government for internal combustion engine (ICE) cars and vans from 2030 to 2035 has not been reflected in any change to the targets for HGVs.

European Union (EU) targets for road freight are even more ambitious: 45% reduction in CO_2 emissions (new vehicles) by 2030; 65% by 2035; and 90% reduction by 2040.[2]

To support the achievement of these targets, intermediate guideline objectives have been set for the vehicle manufacturing sector, similar to the arrangements for transitioning to ZE car and van production. This is especially relevant for truck and trailer manufacturers, as it involves integrating innovative technologies with older equipment that will remain in the market for several years.

Following Brexit, UK legislation for emissions from heavy-duty vehicles was amended. These changes are detailed in the "Guidance for Manufacturers on the new Heavy Duty Vehicles Carbon Dioxide Emissions Performance Standard Amended (EU Exit) 2020"[3]. Changes include penalties for manufacturers not complying with the new requirements. Most EU regulations were adopted under UK legislation after Brexit, but new GB standards will replace the EU Whole Vehicle Type Approval process, transitioning to GB Type Approval standards.

2.2 The existing HGV tractor and trailer market and the transition ZE vehicles

Overall, sales of heavy-duty trucks have recovered from the drastic reductions seen during the Covid-19 pandemic. ZE truck sales are, as expected, still only a fraction of the total when compared with diesel-powered models.

The majority of large hauliers operate using a mix of leased and financed vehicles. These larger operators generally run vehicles for a period of around three to seven years, until warranties have expired, or mileage limits are reached, and then resell them[4]. The application of this model to ZE trucks may prove difficult, until an immediate aftermarket is formed.

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[1] Outcome and response to the consultation on when to phase out the sale of new, non-zero emission HGVs - GOV.UK (www.gov.uk)

[2] Regulation on strengthening CO2 emission standards for heavy-duty vehicles - pdf (europa.eu)

[3] The New Heavy-Duty Vehicles (Carbon Dioxide Emission Performance Standards) (Amendment) (EU Exit) Regulations 2020 (legislation.gov.uk)

[4] According to manufacturers and operators, vehicles working high mileage are usually leased for 3-year lease / maintenance packages; when tractor units are purchased rather than leased, the window before resale extends to 3-5 years for trucks. Rigid lorries tend to have a slightly longer first-owner life, normally 4-7 years depending on the type of operations.

Many hauliers use a ‘Contract and Lease’ model, with contract maintenance packages in place so they are operating at known costs. It is expected that the transition to ZE trucks will be affected, at least initially, by the higher cost of vehicles, development of workshops, training of staff, etc. All these factors will add extra cost into a relatively low-margin sector.

Similar to the tractor market, the trailer market operates with a mix of leased and financed vehicles. Trailers have a much longer service life: the trailer park in the UK is thought to number around the 300,000 active units, and many of these are over 15 years old, lacking the safety features which are now applied generically to newer models. For example, older trailers do not have electronic stability control and advanced emergency braking systems, that are now common features on modern trailers, and some do not even have anti-lock braking systems.

It is acknowledged that there is a large pool of trailers that are normally parked up and only brought into service in times of high demand (e.g., pre-Christmas period). Information on vehicle testing may not be entirely accurate as to the number of actual trailers available for service.

The long operational life of trailers (sometime in excess of 20 years) can be a barrier to the rapid replacement of the existing trailer park, potentially slowing down the replacement of tractors in situations where interoperability issues do not allow interchangeability in using ICE tractors and ZE tractors with the existing trailer park.

The transition towards ZE vehicles will most likely start from the larger/multinational operators, who have the capacity to regularly upgrade their fleet and have ambitious decarbonization targets supported by investments. Smaller businesses will undergo a slower transition, not having the financial resources to run radical upgrade programmes on their fleets. The obsolescence of components and systems, as the technology moves forward, is a further big residual risk for early adopters.

The end of sale dates for new non-zero emission HGVs, announced by the previous government, may therefore induce this segment of the market to hold on to older vehicles for a significantly longer period than they would have previously, causing an effect on the second-hand vehicle market - as witnessed already in the private or light goods vehicles[5] (PLG) markets, where targets for the reduction in ICE vehicles production and associated penalties for non-compliance have limited the choices for fleet owners.

In the LGV market, reluctance to purchase ZE vehicles (driven by lack of confidence in range and reliability) means that buyers are either holding on to their existing vehicles or trying to source from the second-hand market. Therefore, the price of second-hand ICE vehicles is increasing substantially, due to the supply of vehicles for resale being throttled back.

It is more difficult to forecast trends in the future second-hand market of ZE heavy-duty vehicles. The cost of battery and components replacement, with many components and systems being deemed obsolete as the technology moves forward, may affect prices. Similar problems have been seen with hybrid and electric PLG vehicles.

[5] Private cars and goods vehicles weighing up to 3,500kg

2.3 Standards and regulatory landscape

In advance of conducting the engagement exercise, a review of relevant technical and industry standards, research papers and other publications was undertaken. A list of the most relevant references is provided in the Appendix.

The review highlighted that, whilst there is widespread co-operation across the globe in many aspects of vehicle connectivity and interoperability, there is still some divergence (for example in the application of certain technologies or security protocols). As the roll out of battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs) increases, the cooperation and coordination between countries will need to ramp up to realise the benefits of a widespread harmonized approach.

The UK is a signatory to the United Nations Regulation for the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles that came into force on 20th June 1959. This agreement sets out the basic requirements adopted at that time in vehicle design, including for calculating axle weights, vehicle lengths, turning circles, braking efficiencies, and many other elements to ensure consistent standards for vehicle design and construction across all the members signed up to the group.

This has allowed the development of a highly regulated system of standards, working parties' reviews, update, and the introduction of new internationally recognized arrangements for technological advancement and now the reduction in emissions from transport.

There is also current legislation in place, introduced during the time the UK was a member of the European Union that is gradually been adopted and updated as UK legislation, with new legal frameworks being developed as part of the GB type approval and Construction and Use Regulations.

As vehicle manufacturers selling into the UK will also be selling into the EU as a much bigger market, any significant divergence of EU and GB type approval could provide serious difficulties and result in European vehicles unable to enter the GB market and vice versa. As such, significant discrepancies are not expected.

3 Stakeholder engagement on current vehicle design strategies

We undertook a further round of focused engaged in to investigate the challenges and opportunities highlighted during the preliminary discovery phase[6],. Contact was made with all the major truck and trailer manufacturers selling in the UK to arrange interviews aimed at identifying what current strategies are being adopted in relation to vehicle design and technical solutions, and what future trends they predict in the market.

The series of interviews were followed up with a survey that was circulated to a wider sample of manufacturers spanning all areas touched on during the interviews, with the aim of confirming the findings of 1-to-1 discussions and identifying the most common solutions and strategies. Further interviews were conducted with a small sample of other industry groups (fleet operators and workshop operators) to test the concerns highlighted by manufacturers.

The engagement confirmed some of the areas previously highlighted in the ZEHID Prioritization Report[7] but delve into more detail on the technical solutions currently adopted, and future pathways for both vehicle and trailer development. It also highlighted possible divergence in the approach used across the sector to deal with some of the key technical challenges. The following sections provide further details on each of the focus areas that emerged during discussion.

3.1 Vehicle technology and evolution of the driveline

Based on the engagement undertaken, it has become apparent that truck manufacturers are adopting different strategies in the designs of electric powered tractor units.

Some of them are evolving previously existing models, using standard driveline technology with an electric primary power source. These evolving models use an electric drive motor, transmitting power through an automated shift manual gearbox, standard prop shaft and rear axle. This strategy enables manufacturers to continue using most of the components from ICE models, already present in their existing supply chain, and consequently providing scale and commercial efficiencies. Moreover, these models give a driving experience similar to ICE vehicles.

This strategy has allowed OEMs to have a presence in the ZE trucks market while newer systems are developed and drivelines are refined, with the goal of maximizing both mechanical and electrical efficiency. Others are focusing directly on introducing an electric powered driveline into a standard drive axle. This solution reduces power losses incurred by standard drive trains and provides a greater level of control over the torque being delivered to the final drive. When combined with a two-speed axle or an intermediate two-speed gearbox, the power usage can be reduced significantly when compared to a standard driveline.

The disadvantage of using an electric powered driveline is the additional weight and space associated with housing the ESS (energy storage system – i.e., battery pack) which is located on the outside of the chassis. Removing the large gearbox and prop shaft enables the ESS to be mounted within the chassis. If vehicle weights allowed, this space efficiency gives potential to locate additional

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[6] BSI, Zero Emission HGVs and Infrastructure Standards Prioritization Report, https://pages.bsigroup.com/zero-emission-hgvs-and-infrastructure-standards-programme-report?

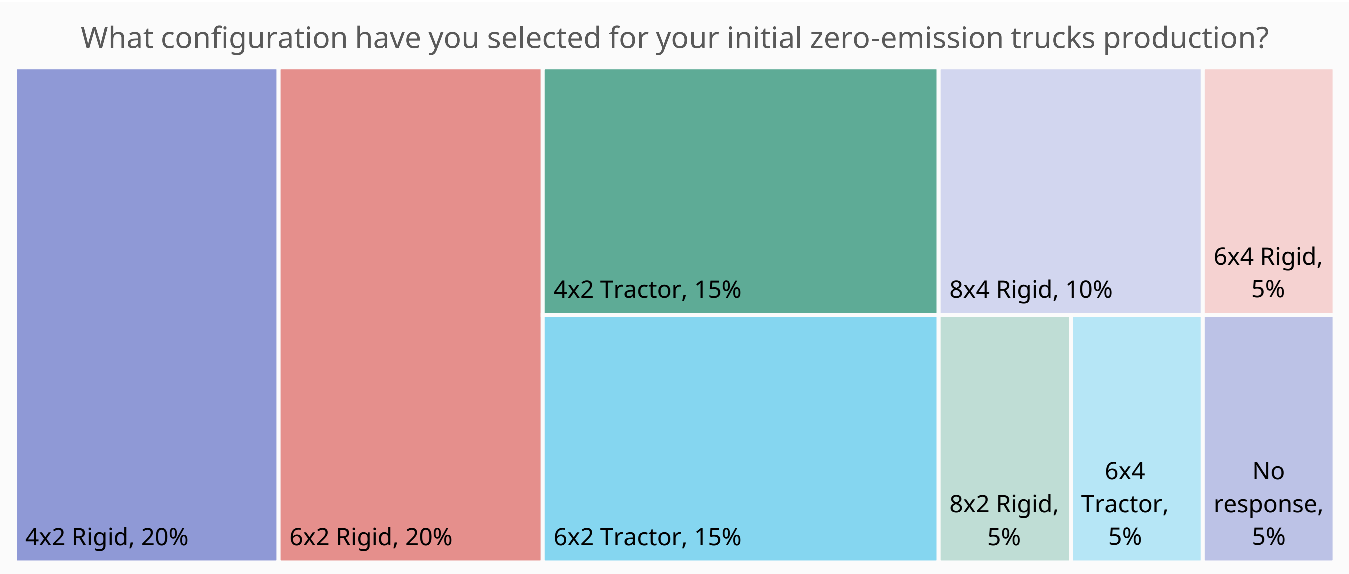
power storage on the outside of the chassis, increasing the vehicle's range. 20% of respondents are currently looking at removing the gearbox and locating the main battery within the chassis.

The development of e-axles (integrating motor, gearing and power electronics into a compact, modular package that sits between the vehicle's driven wheels) will provide a further step forward in efficiency, and could be deployed on both tractors and trailers, increasing drive efficiency, and capturing greater regenerative brake power into one or more ESS packs.

The development of e-axles has faced several challenges, but as software improves, the advantages of this solution over the current driveline technologies are increasing: a key benefit lies in ability of deploying a single unit covering drive capability without a differential, regenerative power linked to the ESS, and hence a more compact packaging for prime mover manufacturers. Another benefit is that the use of e-axles on semi-trailers would reduce brake wear and provide regenerative braking options for on-trailer ancillary batteries or for the tractor unit.

Axle capacities and any impact on current vehicle train weights will need to be considered, in the context of the broader weight issues that are mentioned within this document.

Figure 1: Configurations currently adopted by ZE tractor manufacturers



3.2 Charging systems and batteries

All tractor manufacturers interviewed are adopting a combined charging system 2 (CCS2) standard for their ZE truck charging system. Approximately half of them are already adopting or considering megawatt charging in their vehicle design. The majority (60%) use lithium nickel manganese cobalt oxide (Li-ion NMC) batteries, whilst the remainder (40%) adopts lithium nickel cobalt aluminium oxides (NCA) batteries.

Some respondents provided additional information on the level of ESS protection and testing they are considering, and declared how they are complying with ECE R100[8] regulation and other international standards: side impact and rollover testing; vibration/thermal shock, short circuit,

[8] https://unece.org/transport/documents/2022/03/standards/regulation-no-100-rev3

overcharge/over-discharge. Regenerative braking systems are provided with a cut off mechanism at a fixed percentage to avoid overcharging.

3.3 Design restrictions

As mentioned above, current weight and length limits are unanimously considered key barriers to the uptake of battery electric HGVs. The recently approved increase in maximum gross train weight[9] is a step towards achieving parity with traditional ICE vehicles but is not sufficient. Some stakeholders highlighted how an alignment with the ACEA paper[10] on a novel approach combining axle weight and length could inform a revision of existing regulation.

The Society of Motor Manufacturers and Traders (SMMT) is working with the International Association of the Body and Trailer Industry (CLCCR) and feeding into the work of United Nations Economic Commission for Europe (UNECE) working groups, to review existing international standards and design restrictions. The industry envisages that such review will have to affect design principles including weight limitations, turning circles, combined length limits, axle weights limits, trailer king pin design, and other long accepted design requirements. Global Technical Regulations will also need to be amended as part of this review process.

Based on industry feedback, it is estimated that a minimum 2,000 kg increase in Gross Vehicle Weight (GVW) to 46,000 kg (although other figures suggest a current average payload loss of up to 20%, which would be offset by an increase to up to 48,000 kg) and an increase of at least a metre in combined vehicle length is required to maintain current payload efficiency.

The potential changes to vehicle lengths and axle weights being considered to maintain payloads, may have further implications for the design of tractors and trailers. The legislators could, for example, introduce additional rear steer requirements for both tractors and trailers, to minimize increases in turning circles that could render some existing roads and turning areas unsuitable.

The increase in axle weight may also drive further innovation in tyre compounds to mitigate tyre pollution from wear, as well as road surface design and materials.

Table 1: Current Gross Vehicle Weight (GVW) for articulated vehicles (UK)

Current GVW in kg for articulated vehicles (UK)	Number of axles	The Road Vehicles (Construction and Use) Regulations 1986	The Road Vehicles (Authorised Weight) Regulations 2023	
			ICE	ZE
	3	25,000 (26,000 with RFS[11])	26,000	28,000
	4	32,500 (35000 with RFS)	36,000 (38,000 with RFS)	38,000 (40,000 with RFS)
	5	38,000(44000 with RFS)	40,000	42,000
	6	44,000	44,000	44,000

[9] The Road Vehicles (Authorised Weight) (Amendment) Regulations 2023 (legislation.gov.uk)
[10] https://www.acea.auto/files/ACEA-position-paper-Weights-and-dimensions.pdf
[11] Road Friendly Suspensions

3.4 Considerations on the impact of hydrogen fuel cell technology

The engagement with manufacturers has included considerations on hydrogen fuel cell vehicles and their impact on connectivity and interoperability. It is worth mentioning that the product development of FCEVs is at a less mature stage than BEVs, and OEMs are still working on their industrial strategies. The first demonstrations of hydrogen fuel cell HGVs are currently expected in 2026.

As emerged during interviews, the design of hydrogen fuel cell vehicles requires tanks to be positioned away from areas at high risk of potential impact, to minimize hazards related to leakages and bursts. Therefore, the tanks are most likely to be placed behind the cab, limiting the use of close-coupled semi-trailers. As such, the impossibility to operate with older close-coupled semi-trailers can induce fleet operators to exclude FCEVs from their transition strategies, particularly if they require the flexibility to operate them with an existing trailer park.

4 The challenge of connectivity and interoperability of ZE tractors and trailers

The topics of connectivity and interoperability between e-tractors and trailers were highlighted in the original prioritization report among the most concerning areas, particularly for OEMs and road hauliers.

The table below summarizes the key considerations that emerged in discussions with industry stakeholders during the 2023 prioritization exercise.

Table 2: Opportunities and challenges of battery electric tractors and trailers

Opportunities	Challenges
• Possibility to extend the range provided by the main battery of electric tractors using ancillary batteries on the trailer • Opportunity for the e-trailer to act as 'battery swap' system in particular scenarios • Ancillary battery to serve double function of power take-off power source and range extender • Harmonization need for high-power transfer connection between ancillary batteries and tractor	• Impact of power take-offs on range and performance of the tractor's main battery • Interoperability and additional connections required between tractor and trailer increasing complexity of interface • Loss of payload related to the weight of the additional battery • High cost and battery lifespan

4.1 Ancillary power on trailers

As previously mentioned, the evolution of the trailer provides an opportunity to store power, provide additional drive if e-axles are used, and increase charge in the tractor unit by power transfer from trailer to tractor. This could be a relatively simple solution for extending the range of the tractor trailer combination. Range extension could play an important part in the ZE transition for long-haul freight, particularly in the first stages of deployment.[12]

This new round of engagement has shown that many of those original concerns are still in place. Most tractor manufacturers are not yet seeing the value of exploring the opportunity of ancillary batteries on the trailer for specific applications. They are currently focusing on segments with an operational range requirement below 130 miles (210km).

As such, implications of integrating ancillary batteries are not currently high priority for truck manufacturers, even though the possibility of ancillary power source located on the trailer is recognized as an opportunity. Several referenced the impact on weight and payload as key barrier. Whilst the technology for trailers with ancillary batteries is ready for scale up, current legislation needs to be amended before they can begin large scale production.

Similarly, trailer manufacturers expressed a wide range of views on the potential for power storage and drive from trailers. Most referenced the need to change the description of a trailer under the UN

[12] Ranges above 200 miles, currently advertised by some OEMs, are yet to be reached in typical operational conditions.

standard (designated as having no drive potential)[13]. Some trailer manufacturers quoted previous or ongoing trials on regenerative braking proving ineffective and unreliable.

There are varied views on how charging operations should take place when an ancillary battery is present on the trailer. Some manufacturers highlighted the need for double outlet connections, while others suggested the ancillary battery should be charged jointly with the main tractor battery, via a connection between the two.

4.2 Power take-offs

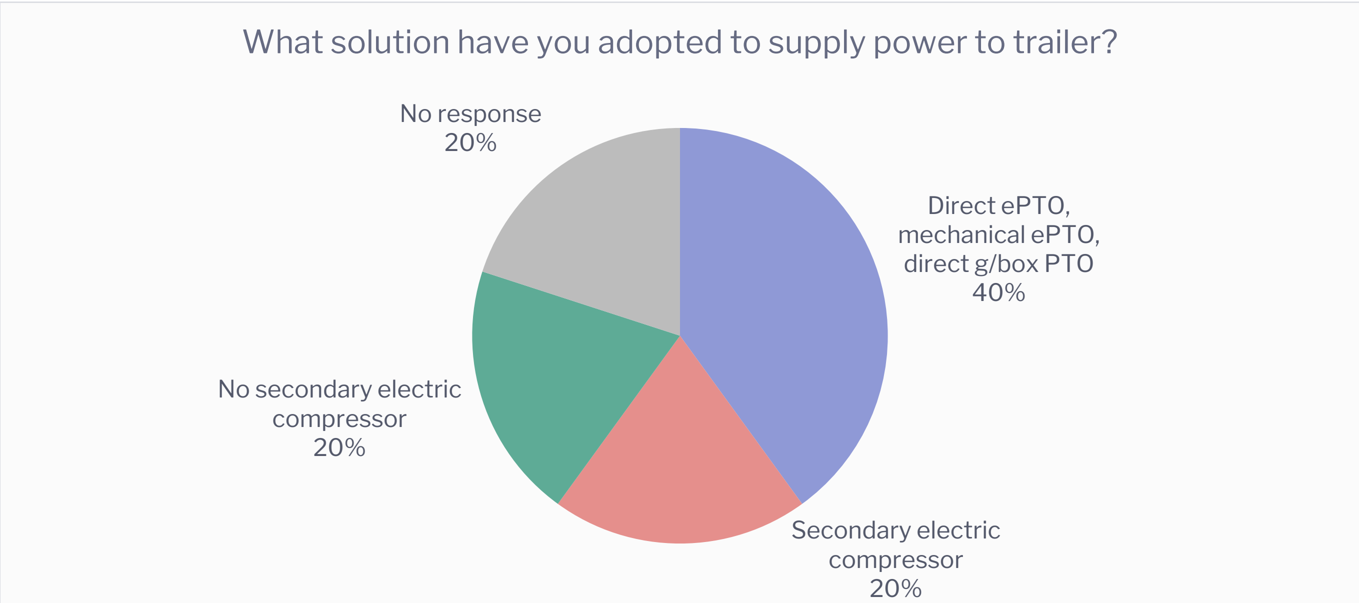
Interviews revealed that tractor manufacturers are addressing the requirement for power take-offs (PTOs) in both traditional drive line and electric drive lines; trailer manufacturers are also working on solutions to introduce power storage on trailers and alternative options to make the trailer self powering.

A traditional electromechanical or pneumatic mechanical PTO uses drive from the gearbox to provide hydraulic or electrical power to a trailer. This would traditionally be used for tankers, bulk tippers and tail lifts. Options are available for purely electric driven PTOs that can be mounted anywhere on the tractor unit chassis.

Similarly, trailers that might have had a petrol or diesel driven PTO/ pump system can now be powered directly by an electric version.

Increasingly stringent limits on noise and emissions have encouraged manufacturers of refrigerated trailers to adopt electric chiller units[14]. These are quiet and efficient but need an electric supply which is delivered via the tractor unit power supplies in ICE trucks.

Figure 2: Solutions adopted to supply power to trailer



[13] Consolidated Resolution on the Construction of Vehicles (R.E.3): https://unece.org/fileadmin/DAM/trans/main/wp29/wp29resolutions/ECE-TRANS-WP.29-78r5e.pdf

[14] EU Regulation 540/2014 introduced decreasing noise limit value levels for all vehicle categories, which have been gradually applicable as of 2016, 2022 and 2026.

As supplying energy from the e-tractor's ESS is problematic due to impact on range, EV trailer manufacturers are therefore looking at mounting battery packs on refrigerated trailers to provide the power to the fridge unit. Forward looking manufacturers are also investigating utilizing regenerated power from the trailer braking system to charge up the ESS on the trailer, not utilizing any output from the tractor unit.

New technologies are emerging, relying for example on passive cooling systems, and may negate in the future the need for active refrigeration from a power source.

4.3 Connectivity

All e-tractor manufacturers have indicated that they are allowing for the supply of 24V electricity to the trailer for lighting, and compressed air for the trailer braking system. There will soon be a requirement for electronic breaking connectivity, controlled by the tractor and semitrailer CAN Line signals. Compressed air could then be delivered to the braking system directly from the trailer.

Trailer manufacturers highlighted significant potential for improvement in the performance and efficiency of on-trailer systems, reducing power requirements.

For high-voltage power transfers between ancillary batteries and drive, it is a common opinion that the most practicable solution for the transmission of power between tractors and trailers should either use a new dedicated coupling, or a redesign of the 5th wheel coupling.

However, whilst most manufacturers see high-voltage power transfer as a likely future evolution, this is not an immediate area of interest for those interviewed. There are concerns that such ad-hoc solutions may only work with an EV tractor and EV trailer, but not with other combinations of traditional tractors and trailers.

Whilst a strategy to overcome interoperability issues may be a cable plug system for 600v supply, manufacturers consider that this solution would add complexity to the already intricated system of compressed air supply ducts and electric supply cables that normally link tractors to trailers.

4.4 Interoperability

The interoperability of tractors and trailers is a particular concern raised by fleet operators and workshop operators. In the majority of applications, the road freight industry currently relies on a drop-off/pick-up process, where tractors and trailers can be easily interchanged.

The gradual introduction of e-tractors and e-trailers will generate new combinations of tractor/trailer interactions that could prove problematic, especially during the initial stages of adoption. Stakeholders expressed uncertainty on how the various vehicle types would communicate with each other correctly and allow mixed fleet usage.

In addition to the complexity of operating with multiple interfaces between different tractor types and trailer types, further concerns relate to the different impact that weight restrictions can have on the payload for different combinations of tractors and trailers (see section 3.3). Trunking of goods generally relies on a vehicle delivering and unloading a trailer to a destination, before picking up a return load or a different load to be delivered in a second destination. Discussions with large freight operators indicated that factoring a variety of maximum payload on outward and return journeys, would impact flexibility of operations, and significantly affect the scheduling, and would lead to increased costs to suppliers or the public.

5 Summary

Our research, based on conversations with tractor and trailer manufacturers, fleet operators and workshop operators, led to the following key findings.

Vehicle design

Manufacturers are following different pathways in the evolution of the driveline to enable the transition to ZE trucks:

- Some manufacturers are developing direct drive EV systems, where the motor delivers power from an e-axle; some are using an electric drive motor fixed directly to a conventional axle; some are fitting an electric motor combined with a conventional gearbox-to-axle arrangement.
- All tractor manufacturers interviewed are adopting CCS2 standards. Approximately half of them are already adopting or considering megawatt charging.
- Axle weight limitations and consequent impact on batteries and payload are seen as the key barrier to the achievement of comparable performance to diesel ICE vehicles. Substantial changes in design legislation are called upon, to unleash the potential for trailer systems (e.g., design requirements on axle weights, trailer king pin design and weight limitations, turning circles).

Connectivity and Interoperability

Whilst most manufacturers see high-voltage power transfer from an ancillary battery to the tractor as a likely future evolution, implications of integrating ancillary batteries are not currently high priority for truck manufacturers:

- It is considered a relatively simple solution for extending the range, particularly in the first stages of deployment, as current vehicles cannot easily reach 200 miles.
- Several referenced the impact on weight and payload as key barrier. Whilst the technology for trailers with ancillary batteries is ready for scale up, current legislation needs to be amended before they can begin large scale production.

Moreover, there are concerns (particularly from fleet operators) that the connectivity solutions currently explored may only work with an EV tractor and EV trailer, but not with other combinations of traditional tractors and trailers.

- The most practicable solutions consider that power should be transmitted either by a specific coupling between the tractor/ trailer, or by a redesign of the 5th wheel coupling.
- Fears were expressed that systems on each vehicle type (ZE and conventional tractors and trailers) would not communicate with each other correctly and allow mixed fleet usage.
- The concerns raised by fleet operators relate to the high additional costs due to inefficiencies in load planning on outward/return journeys that could be caused by incompatibility between conventional and zero-emission tractors and trailers.

Batteries on trailers (for PTO or support to main battery):

- Trailer manufacturers are already working on electric solutions for power take-offs such as refrigeration units, as petrol/ diesel models will be gradually phased out.
- Forward looking manufacturers are investigating utilizing regenerated power - however the current reliability of these systems is unclear due to inconclusive trial results.
- The opportunity of ancillary batteries on the trailer to extend the range of the tractor is recognized by all trailer manufacturers, however connectivity issues, interoperability and weight limitations are seen as particularly challenging barriers, limiting the development of such solutions.

6 Areas for future harmonization

Based on the findings of the engagement activities, it is recommended that the following areas will benefit from harmonization:

- Connection between ZE tractor and trailer (initial recognition, pass through of charging and communications). Considerations on interoperability between ZE tractors and trailers and their traditional equivalents.
- Standards for coupling and uncoupling combinations (e.g., including protocols for safety shut down of high voltage where required).
- Update the existing construction standards and use standards for both tractors and trailers to reflect increased axle weight, fifth wheel/ king pin loadings, and any other update to design parameters.

Appendix - Information sources and reference documents

All relevant regulations, industry standards and bets practice documents are listed in alphabetical order.

Relevant regulations

European Parliament and Council, 2024. Regulation (EU) 2024 *amending Regulation (EU) 2019/1242 as regards strengthening the CO2 emission performance standards for new heavy-duty vehicles and integrating reporting obligations, amending Regulation (EU) 2018/858 and repealing Regulation (EU) 2018/956*

UK Government legislation, The Road Vehicles (Authorised Weight) (Amendment) Regulations 2023.

UK Government legislation, 1988. Road Traffic Act and amendments

United Nations Economic Commission for Europe (UNECE), 1958. *Agreement concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts which can be fitted and/or be used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these Prescriptions.*

United Nations Economic Commission for Europe (UNECE), 1998. *UN Global Technical Regulations (GTR).*

United Nations Economic Commission for Europe (UNECE), 1998. *Classification and Definition of Vehicles*

United Nations Economic Commission for Europe (UNECE), 2014. Electric Vehicle Regulatory Reference Guide.

United Nations Economic Commission for Europe (UNECE), 2015. *UN Regulation No. 100: Uniform Provisions Concerning the Approval of Vehicles with regard to Specific Requirements for the Electric Powertrain.*

United Nations Economic Commission for Europe (UNECE), 2020. *UN Regulation No. 13: Electromechanical Brakes*

United Nations Economic Commission for Europe (UNECE), 2023. *Consolidated Resolution on the Construction of Vehicles (R.E.3)*

Relevant industry standards

BS EN 1986 (Part 1) - Electrically propelled road vehicles. Measurement of energy performances - Pure electric vehicles

BS EN 61851 (Part 23-3) - Electric vehicle conductive charging system - Part 23-3. DC electric vehicle supply equipment for Megawatt charging systems

BS EN IEC 62196 (series) Plugs, socket-outlets, vehicle connectors and vehicle inlets. Conductive charging of electric vehicles

BS EN ISO 15118 (series) - Vehicle to grid interface, communication interface

BS EN ISO 21177 – TC - Intelligent transport systems. ITS station security services for secure session establishment and authentication between trusted devices

EN 17186 - Identification of vehicles and infrastructures compatibility. Graphical expression for consumer information on EV power supply

EN 50620/prA2 – Electric cables - Charging cables for electric vehicles

ETSI TS 101556 (Parts 1-3) - Intelligent Transport Systems (ITS) - Infrastructure to Vehicle Communications

IEC 61851 (Part 23) - Electric vehicle conductive charging system - Part 23: DC electric vehicle supply equipment

IEC 62752 - In-Cable Control and Protection Device for mode 2 charging of electric road vehicles (IC-CPD)

IEC 62893 (Part 4) - Charging cables for electric vehicles of rated voltages up to and including 0,6/1 kV

ISO 1726 (series) - Mechanical coupling between tractor and trailer

ISO 7638 (series) - Electrical connection for towing and towed vehicles

ISO 12098 - Road vehicles — Connectors for the electrical connection of towing and towed vehicles — 15-pole connector for vehicles with 24 V nominal supply voltage

ISO 17409 - Electrically propelled road vehicles — Conductive power transfer — Safety requirements

ISO 19885 (Part 1) - Gaseous hydrogen — Fuelling protocols for hydrogen-fuelled vehicles - Part 1: Design and development process for fuelling protocols

ISO 24534 (series) - Intelligent transport systems — Automatic vehicle and equipment identification - Electronic Registration Identification (ERI) for vehicles

ISO 24534 (Part 5) - Intelligent transport systems — Automatic vehicle and equipment identification - Electronic Registration Identification (ERI) for vehicles - Part 5: Secure communications using symmetrical techniques

ISO/CD TS 5616 - Intelligent transport systems - Secure interfaces governance - Minimum requirements and governance procedures

SAE J 3271 - Megawatt charging systems for electric vehicles

Best practice documents and policy guidance

British Standards Institution (BSI), 2023. *ZERFD Prioritisation Report*

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