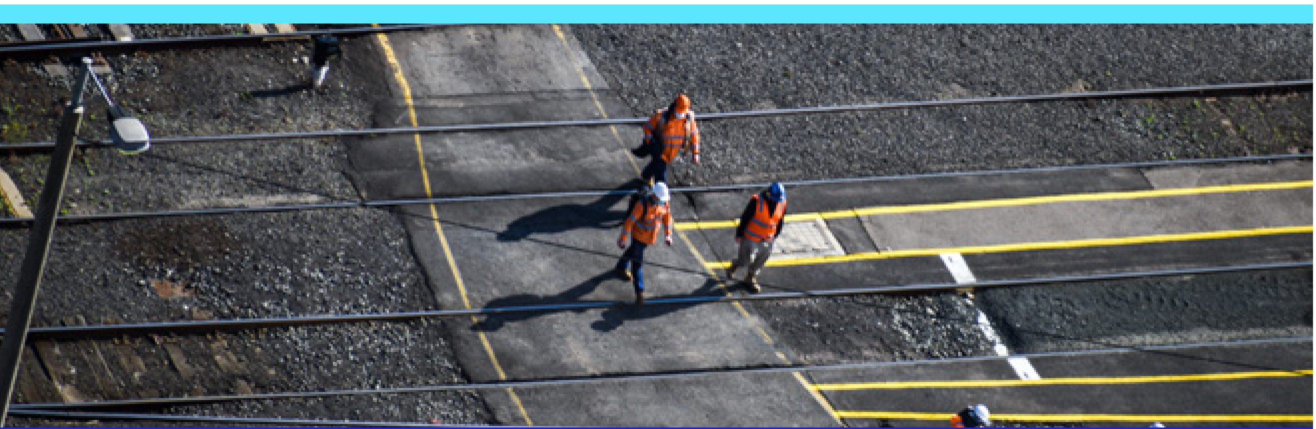
The Track to Decarbonised Rolling Stock

Integrating zero-emission technologies into Australian rolling stock standards



Jacobs

RISSB
RAIL INDUSTRY SAFETY AND STANDARDS BOARD

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Contents

Abbreviations

bar	100 kilopascals
BEL	Battery Electric Locomotive
BET	Battery Electric Tender
BESS	Battery Energy Storage System
CO_2	Carbon Dioxide
DEMU	Diesel Electric Multiple Unit
DMU	Diesel Multiple Unit
EMU	Electric Multiple Unit
Hz AC	Hertz Alternating Current
Kg/m^3	Kilogram per Cubic Metre
Km/h	Kilometres per Hour
kV	Kilovolt
kV AC	Kilovolt Alternating Current
kW/ kWh	Kilowatt/ Kilowatt Hours
LFP	Lithium Iron Phosphate
LRV	Light Rail Vehicle
LTO	Lithium Titanate
MPa	Megapascal
MWh	Megawatt hours
NH_3	Ammonia
NLR	Newcastle Light Rail
NMC	Lithium nickel manganese cobalt
PLR	Parramatta Light Rail
ppm	Parts per million
V DC	Volt direct current
Wh/kg	Watt-hours per kilogram
Wh/L	Watt-hours/ litre
ZE	Zero-emissions

Foreword

Setting emission reduction targets is one thing; meeting them while continuing to provide core services is another.

The road to zero emissions will be different for every rail operator, but a consistent approach to standards and procedures is critical. A consistent set of national rolling stock standards can provide operators with surety and confidence to invest in new zero-emission technologies while maintaining safe operating procedures, and help accelerate the industry's transition to a low carbon future.

At Jacobs, we challenging today to reinvent tomorrow by solving the world's most ritical problems. By supporting rail operators to embrace emerging technologies and solutions, we can help make the industry smarter, more connected and more sustainable.

We're proud to partner with RISSB in critically reviewing and developing Australia's national railway standards in line with existing and emerging zero-emission technologies, and I would like to acknowledge the effort of our combined team in developing this paper.

Daniel Richter

Jacobs Regional Solutions Director, Rail & Transit

The rail industry is increasingly recognising the importance of sustainability to the bottom line, making it a progressively pertinent aspect of business and product development.

Whilst there have been many improvements introduced into the Australian rail industry through the development and adoption of RISSB's standards and other products, continued innovation is critical to improving the sustainability of rolling stock technologies across the Australian rail industry.

At RISSB, we want to ensure that our standards and products continue to be relevant for industry and represent best practice. This white paper is a step towards that goal, identifying any gaps within our rolling stock related standards, with the aim of incorporating the most recent zero-emission technologies.

In commending this paper to industry, I would like to acknowledge the work done by Jacobs and Ulrike Schroeder to develop this important piece of work.

RISSB recognises it has a role and is committed to help steer the wider rail industry towards a more sustainable future.

Damien White

RISSB Chief Executive Officer

Executive summary

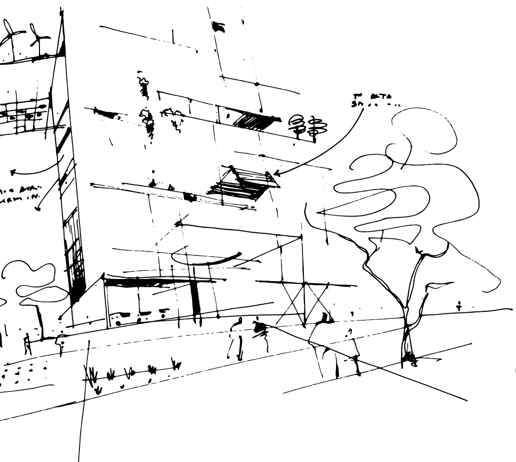
Globally, industries are moving to decarbonise their operations and reduce their emissions footprint.

Low- and zero-emission (ZE) technologies are evolving rapidly, and standards must keep pace to address new design and safety challenges.

The Rail Industry Safety and Standard Board (RISSB) plays a significant role in developing and maintaining standards including for net zero technology for the rail industry in Australia and New Zealand that will help drive reduction in rail related emissions. Further, RISSB Standards play a critical role in ensuring that any new technology is both interoperable and harmonised with the wider Australian Railway Industry so that efficiencies in both manufacturing and operation can be realised. Adoption and implementation of these Standards are critical to the rail industry achieving net zero targets in the future.

RISSB is currently re-writing its standards for railway rolling stock to include guidelines for charging infrastructure for ZE rolling stock, reflecting the industry's move towards more sustainable energy sources.

In this paper, Jacobs reviews 65 of RISSB's current rail and rolling stock standards, identifying the current gaps relating to ZE technologies.



We identify 30 standards that require updating, and of those, we identify eight that need updating as a matter of priority.

AS 7529.1	Rolling Stock - Fire Safety - Locomotive
AS 7529.2	Rolling Stock - Fire Safety - Freight
AS 7529.3	Rolling Stock - Fire Safety - Passenger
AS 7529.4	Rolling Stock - Fire Safety - Track Machines
AS 7520.2	Rolling Stock - Body Structural Requirements Part 2 - Freight Rolling Stock
AS 7520.3	Rolling Stock - Body Structural Requirements Part 3 - Passenger Rolling Stock
GUIDELINE	Rail Emergency Management Planning
AS 7527	Rolling Stock Event Recorders

For these eight standards, we identify relevant international standards and guidelines to provide preliminary guidance on potential alternative standards to consider during the RISSB standards update process. The nominated substitutes can also provide reference points and guidance for standards updates to ensure they align with international industry standards and global work carried out in this domain.

The review highlights the need for updates to current rolling stock related standards to accommodate new energy sources like lithium batteries, hydrogen and ammonia, and improve safety measures related to ZE technologies. In doing so, this paper provides a roadmap for successfully integrating ZE rolling stock technologies across the Australian rail industry.

1

Introduction

The need for alternative traction power and green energy supply for railway operations has gathered significant momentum over the past five years, driven by global government commitment to reduction targets, legislation, grants, and policies.

Some industries are benefiting from large global markets and product distribution, and high levels of investment in research and development and making good progress. Rail is currently lagging however, primarily due to fragmented and locally bespoke standards, operations, policies, function and lower levels of investment in research and development.

In Australia, the transport sector is responsible for 21% of the total carbon (CO_2) emissions, with rail transport contributing around 4%.[1] While our passenger and freight rolling stock fleet is relatively small, rail must decarbonise alongside other industries to meet national emissions reduction targets.

This transition is particularly urgent for Australia's freight fleet, around 65% of which is captured under the Australian Government's Safeguard Mechanism Policy. This policy is a key part of the Government's plan to ensure high carbon emitters take action to help meet national emissions reduction targets of 43% below 2005 levels by 2030 and net zero by 2050.[2] Under the policy, failing to keep up with the pace of reductions required to meet these targets will result in financial penalties for operators.

Overhead electrification powered by renewable energy sources offers a well-established path towards net zero for the rail industry.[3] Batteries, hydrogen and other emerging technologies offer alternative pathways, potentially at a lower cost, however. Several zero-emission (ZE) battery-powered or hydrogen-powered trains have already entered service in Europe, replacing Diesel Multiple Units (DMUs).[4] In the United States, manufacturers are trialling battery-powered mainline locomotives. Australia is set to receive some of the first of these to serve in the Pilbara region. As the technology develops further, the use of ZE units is expected to spread.

1.1

What's covered in this paper

This paper addresses multiple topics with respect to incorporating ZE technologies in RISSB's standards.

The guidance is equally relevant for passenger and freight rolling stock. Similarly, the guidance is equally relevant to the Australia and New Zealand markets, however the discussion is firmly grounded in the Australian context. In doing so, the paper plays a crucial role in steering the rail industry towards a sustainable future powered by ZE technologies.

Paper objectives

Identifying the gaps

The paper identifies gaps in the current rail and rolling stock standards that may hinder the adoption of ZE technologies. It provides a thorough review of the standards and pinpoints areas where they fall short in terms of accommodating ZE technologies.

Prioritising updates

Based on the gap analysis, the paper identifies and prioritises the standards that require updating to accommodate ZE technologies, to guide the industry's efforts towards decarbonisation and help allocate resources effectively.

Providing early guidance on alternative standards

The paper provides early guidance on alternative standards and substitutes that could be used while the existing standards are being updated.

Integrating global best practices

The paper highlights global best practices and standards related to ZE technologies into the Australian Rail industry, identifying those that can be adopted or adapted for the Australian context.

1.2

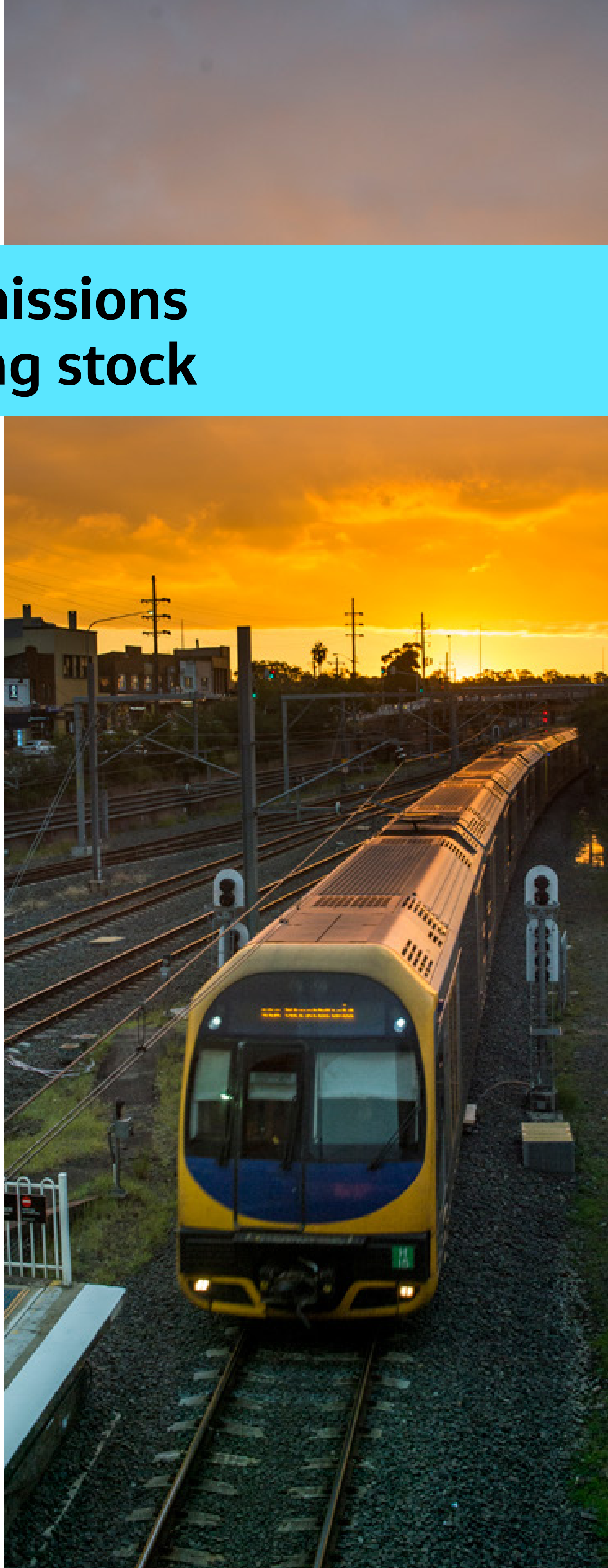
Assumptions

Boundary conditions and terms of reference were developed to focus the direction and approach to the review and outcomes.

- The review focused on rolling stock related standards. Other RISSB products could form a further review project.
- The review considered all rolling stock including passenger, freight and track machines.
- Each standard was reviewed in relation to ZE technology gaps relative to the content and topic of the standard. Standards were not reviewed for areas that are traditionally updated in a normal development group process.
- The review examined the nominated standards, not the overall standards structure, processes or custodianship. Gaps that the review team felt would be best filled by a new product are discussed in the conclusion and recommendation sections.
- The effectivity, suitability and applicability of each ZE technology relative to the others was not explored deeply, outside of a brief introduction and technical discussion for the context of this paper.
- The review did not go into the specifics of technical implementation of each ZE technology within rolling stock, nor any supporting infrastructure. Only the implications to the associated standard were considered.
- Nominated alternative standards were provided where global usage and evidence was accessed from to the reviewers. A full and complete side-by-side analysis was not undertaken. Users should undertake these reviews relative to the application it is being considered for.
- The Australian and New Zealand climate and environmental conditions were only considered where explicitly related to that standard, and not in relation to implications for each ZE technology application or suitability.
- Biofuels were only very broadly considered. The step change for adoption, while important in the context of railway decarbonisation, does not create a significant change in the RISSB risk register (unlike ammonia, hydrogen and lithium-ion batteries).

2

Overview of zero-emissions technology for rolling stock



Numerous ZE technologies already exist or are anticipated in future.

This section provides an overview of the different technologies, including their relative advantages and disadvantages, current use and potential for future application in Australia, and key hazards that must be considered in design standard updates.

2.1

Electrification

Electrification — transferring power from the distribution network to the rolling stock, traditionally via an overhead wire and pantograph system — is a key component in rail's transition towards zero emissions. It is also an effective way to avoid carrying a source of power on the rolling stock itself. However, it is generally expensive to install over long routes and in remote areas.

It costs around AU $1 million per kilometre for electrification, including assets, connection and installation. Substations are not included in this figure and would significantly increase this cost. Current projects in the United Kingdom are reporting AU $3.8 million (GBP 2 million) total cost per kilometre.*

Incorporating renewable energy into the electrification process can further enhance the move towards decarbonisation.

**Cost per km based on selected Jacobs engineering projects.*

The list below provides a summary of key advantages and disadvantages of electrification compared to other ZE technologies.

Key advantages and disadvantages of electrification

Advantages

- ✓ High power output with minimal energy loss
- ✓ Established and reliable technology
- ✓ Demonstrated reliability
- ✓ Availability of multiple suppliers

Disadvantages

- Significant installation costs
- Potential high voltage risks to the public
- Maintenance requirements in remote areas
- Impact of external factors such as bush fires, storms

2.1.1 Current use in Australia and globally

In Australia, two forms of electrification are currently in use.

25 kV AC overhead electrification is used in Queensland, Perth and Adelaide. In Queensland, electrification extends from Brisbane to Rockhampton and through the coal fields.

1500 V DC electrification is used in Sydney and Melbourne. Sydney's electrification extends outside the city to Newcastle in the north, Kiama in the south and Lithgow in the west. 750 V DC overhead is used on Light Rail lines in Sydney and Canberra, and 600 V DC on the tram networks in Melbourne and Adelaide.

Globally, 25 kV AC is the default for most new systems.[5] The higher voltage reduces resistive losses, allowing for smaller conductor sizes and greater distance between feeder stations (50-100 km compared to around 5-10 km for 1500 V DC). 750 V DC is used extensively in the U.K. and U.S.A. but not in Australia (outside of some Light Rail Networks), while much of Europe, including Germany and its neighbours, use 15 kV, 16.33 Hz AC overhead.[6]

2.1.2 Potential hazards

Potential hazards of electrification:

- **Damage from external factors**

  Overhead wires are vulnerable to damage from storms, bushfires or falling trees, leading to service disruptions and potential safety risks.

- **Electrocution or electric shock**

  This can occur if individuals come into contact with the high-voltage overhead wires. The risk is particularly high in areas with public access or during maintenance operations.

- **Fire**

  The electrical components and overhead wires can overheat or short circuit, leading to fires. This risk is exacerbated in areas with flammable materials or during extreme weather conditions.

- **Logistical challenges in remote areas**

  Installing and maintaining electrification infrastructure in remote areas can pose logistical challenges and safety risks for the workforce.

2.1.3 Potential for future use in Australia

If electrical distribution networks with the necessary capacity and generation ability are accessible, electrification can be a stable and, to some extent, future proofed method to power rail networks.

Passenger rolling stock often has access to this type of infrastructure and many of Australia's metropolitan areas have electrified networks. In areas with no or limited access, the industry is looking to alternative solutions to transition away from diesel and fossil fuels. This is why the larger step change in adoption and prototyping is being seen in the freight and bulk transportation railway modes.

It is unlikely that we will ever have 100% electrification across the national railway network, but 'islands' of electrification are a potential solution. These islands could be long-term yet temporary measure while capacity, cost and range of ZE technologies improve with time. Located at specific points in a national network, these islands would bridge gaps in the range of ZE technologies, reducing the need to stop and recharge or reconfigure the rolling stock, until such time when reliable long-distance services and transportation can occur.

Refurbished and recycled batteries or fuel cells can be used for Battery Energy Storage Systems (BESS), acting as wayside storage, charged by renewable energy sources and off-peak supply. Given current battery performance life is sitting at eight years, this practice also helps with circular economy considerations, e-waste and sustainable designs.

2.2

Batteries

Onboard battery systems are an efficient way to power rolling stock without the need for a continuous external power source and a crucial element in the shift towards zero emissions; however, the technology is not without its challenges.

Current batteries have limited range and need frequent recharging. This presents challenges on longer routes and in remote areas. Integrating renewable energy sources for charging these batteries can further improve the transition towards zero emissions. This approach also eliminates the need for expensive infrastructure such as overhead wires, making it a more viable option in remote areas and difficult terrains.

The rate of charging is typically limited. Most battery types are rated 1C, meaning they take one hour to fully charge and discharge. At this rate, charging a 7 MWh battery would take seven hours, although latest developments in fast charging in the automotive field are seeing rates of 2C (30 minutes) or higher.

Compared to diesel, batteries have a relatively low power density, requiring much more space and adding considerable mass to a rail vehicle. For example, a 7 MWh battery weighs about 50 tonnes but has energy giving only a tenth of the range provided by an 18,000 litre diesel fuel tank which weighs approximately 15 tonnes (depending on fuel density).

This list provides a summary of advantages and disadvantages of batteries compared to other ZE technologies.

Key advantages and disadvantages of batteries

Advantages

- ✓ Saves the capital cost of electrification
- ✓ No maintenance on overhead
- ✓ More efficient in converting energy to movement compared to hydrogen
- ✓ Battery technology developing rapidly
- ✓ Low maintenance
- ✓ Socially accepted as a source of energy
- ✓ Larger research and adoption across other industries, fueling development and improvements

Disadvantages

- Heavy in current form
- Occupies significant space on vehicles
- Charging is relatively slow in cheaper chemistries
- Batteries may last less than 10 years depending on number and severity of charging cycles due to capacity degradation
- Fire risk (lithium ion)
- Currently limited rail applications
- Challenges and risks related to storage and monitoring of batteries

Battery chemistry is also a factor when looking at the type of application being considered.

- **Lithium Titanate (LTO) batteries** can handle higher charge and discharge rates compared to Lithium Nickel Manganese Cobalt (NMC) batteries.

  LTO batteries use the same basic chemistry as NMC batteries, but the anode material is lithium titanate instead of graphite. This makes LTO batteries safer and gives them a longer lifespan.

  However, LTO batteries have a lower energy density compared to NMC batteries, which means they store less energy for a given volume. This can be a problem in applications where space and weight are important considerations.

  LTO batteries are also the most expensive of the three battery types.

- **Lithium Iron Phosphate (LFP)** batteries have a lower energy density than NMC batteries, but they are safer and have a longer lifespan.

  They are a good choice for applications where safety and longevity are more important than energy density.

- **NMC batteries** have the highest energy density of the three types, which makes them a popular choice for electric vehicles. They are now also being used in U.S. locomotives.

  However, NMC batteries have a shorter lifespan compared to LFP or LTO batteries.

Table 1 provides a general comparison between battery chemistries.

Supercapacitors have also been used in rail applications, such as the Newcastle Light Rail (NLR). These high-capacity capacitors allow very fast charging but have an energy density that is around a tenth of that for LTO batteries. In the NLR application, the light rail vehicle (LRV) raises its pantograph to a charge-bar at each tram stop. With relatively short distances between the stops, the ability to charge quickly is more important than storage capacity.

Table 1: Comparison of different battery types

	Lithium Titanate (LTO Li_2TiO_3)	Lithium Iron Phosphate (LFP $LiFePO_4$)	Lithium Nickel Manganese Cobalt ($LiNiMnCoO_2$)
Nominal Voltage	2.4 V	3.3 V	3.7 V
Energy Density	100 Wh/kg	180 Wh/kg	260 Wh/kg
Volumetric	177 Wh/L	400 Wh/L	700 Wh/L
Cycle life	10,000 cycles	5,000 cycles	1,200 cycles
Safety	Best	Good	Fair
Discharge rate	10C	1C	1-2C
Charge rate	5C	1C	1C
Indicative Cost (USD/kWh)	$100	$100	$100

2.2.1 Current use in Australia and globally

There are currently no battery applications in freight rail service in Australia; however, there are already some in passenger service.

Adelaide's 3000/3100 class Diesel Electric Multiple Units (DEMUs), which feature an ABB traction system, are being upgraded with a small battery pack (shown in Figure 1 below) that allows the diesel engine to be shut down while inside Adelaide Station. The battery provides power for the air conditioning and auxiliaries and allows the train to leave the station before restarting the engine.

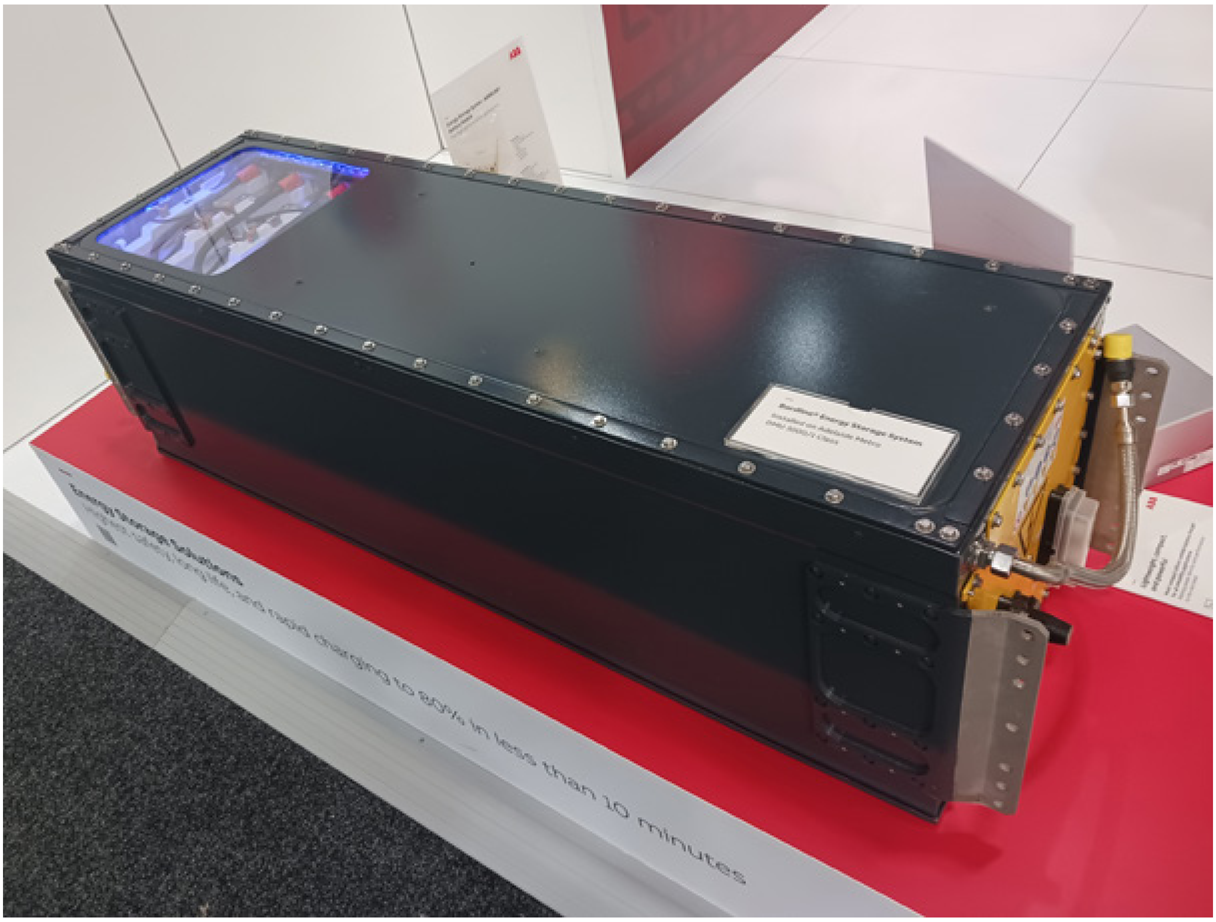
The NLR vehicles supplied by Construcciones y Auxiliar de Ferrocarriles (CAF) feature a range extender battery plus supercapacitor pack that allows operation without the need for overhead wires.

The pantograph is raised at designated stops to charge from a busbar. Similarly, the LRVs being supplied for Parramatta Light Rail (PLR), which is due to open in mid-2024, will operate from batteries with no overhead for about 2.3 km over the 10.8 km route.

Globally, Germany has extensive electrification, and 66% of non-electrified sections currently served by DMUs are less than 70 km in length, within the range of existing on-board battery technology.

Battery Electric Multiple Units (BEMUs) were introduced in Germany in early 2022 when the Alstom Talent BEMUs entered revenue service in Baden-Wurttemberg and Bavaria.[7] Other suppliers such as Siemens, CAF and Stadler have orders for similar trains, which are due to enter service in 2024/2025.

Figure 1: ABB Battery Module for 3000/3100 Class DMU



2.2.2 Potential hazards

Batteries, especially those of the lithium-ion variety, possess distinct characteristics and behaviours that pose unique challenges.

Potential hazards of batteries:

- **Thermal runaway and fire risk**

  Batteries, especially lithium-ion ones, can overheat and catch fire if not managed properly. Proper management and safety protocols when dealing with batteries are important.

- **Electrical hazards**

  The electrochemical reactions in batteries produce electrical power, which can pose risks such as electric shock or short-circuit. Safety measures are needed to prevent such incidents.

- **Crash and compression risks**

  Compared to a diesel fuel tank and engine system, batteries create an arguably greater incident as a result of an accident. Ruptured or damaged batteries may still pose a significant risk in removal (fire, gases, stored energy etc), where a diesel tank may be drained before removal.

- **Pressure build-up and explosion risk**

  Improper charging or damage can cause pressure to build up within the battery, leading to an explosion. This underscores the importance of proper charging and handling procedures.

- **Environmental hazards**

  Improper disposal of batteries can lead to harmful substances entering the environment. Proper disposal methods are needed to prevent environmental damage.

2.2.3 Future use in Australia

BEMUs charge while operating under the overhead. While some "islands of electrification" are required to achieve the required range on longer stretches, the cost of additional infrastructure is moderate.

BEMUs may have some limited application in Australia in extending Electric Multiple Units (EMUs) services into regions outside major cities but are unsuitable for longer intercity routes.

Australia will soon see battery electric locomotives (BELs) delivered to the Pilbara. Wabtec has orders from three of the iron ore miners - Roy Hill (one unit), BHP (two units) and Rio Tinto (project under review). Progress Rail has orders from BHP and FMG Fortescue for two each.[8] Further procurement projects are under feasibility stages and may significantly increase the numbers seen here.

Together, these locomotives represent the world's biggest application of BELs. They will initially be trialled in hybrid consists with the existing diesel electric locomotives. As the loaded direction from the mine is predominantly downhill, the batteries can use regenerative braking to return energy to the system and discharge only when needed on uphill gradients. In the longer term however, totally replacing diesel with batteries will require either static charging at the end points or some form of dynamic charging through partial electrification.

Outside of the Pilbara, locomotives developed for U.S. service are too large and too heavy to operate on Australian railways, but Progress Rail is converting a 4000 Class (narrow gauge) locomotive for Aurizon, replacing the existing diesel engine and generator with batteries. Aurizon has also announced a contract with Alta Technology to develop a battery electric tender (BET) which, in the first instance, will power a modified Diesel Locomotive but in the longer term be a range extender for a BEL.

2.3

Hydrogen

Hydrogen fuel cell technology is emerging as a promising solution for achieving zero emission rail transport.

Hydrogen can be stored in both compressed gas and liquid form. The density of compressed hydrogen is 22 kilograms per cubic metre (kg/m³). Hydrogen becomes liquid at 253 degrees Celcius and has a density of around 71 kg/m³ in density in this form. Liquid must be stored in a double-shelled vessel, with an evacuated space between the shells for insulation.

The storage volume required for compressed gas hydrogen makes it challenging to accommodate in a single locomotive along with the other necessary equipment. The extremely high storage pressures, typically 35 megapascals (MPa), necessitate the use of carbon-fibre reinforced, thick-walled pressure vessels. Often, the required volume necessitates the use of multiple, small diameter vessels.

One key advantage of hydrogen fuel cells over batteries is that equivalent energy can be transferred much more quickly, meaning the filling time is less than the charging time. Liquid hydrogen can be transferred to a tank similar to diesel fuel. The issue is more complex for compressed gas as an empty tank starts at low pressure, with the gas being re-compressed as it fills. Additionally, the transfer of liquid hydrogen requires very low temperatures and control systems to prevent boil-off which would increase pressure.

The energy required to compress is about 5-10% of the energy contained. The compression work causes heat, which limits the filling rate as the temperature must generally be kept below 80 degrees Celcius for composite vessels. Therefore, the filling rate in areas with high temperatures will be much slower than in lower temperature areas.

For this reason, in some applications, the compressed gas is pre-chilled to -40 degrees Celcius before filling.

The list below provides a summary of advantages and disadvantages of hydrogen fuel cells compared to other ZEs technologies.

Key advantages and disadvantages of hydrogen

Advantages

- ✓ Saves the cost of electrification
- ✓ No maintenance on overhead
- ✓ Faster filling (depending on climate and temperatures)
- ✓ Can be made as green hydrogen to save on emissions
- ✓ Water is the consumption by-product

Disadvantages

- Fuel cells expensive
- Supplied hydrogen would require very cheap renewable electricity to make is economically viable
- Low energy efficiency over cycle (<30%)
- Very high pressure or cryogenic temperature
- Fire and explosion risk, challenging to handle
- Additional cost for production, storage, and maintenance infrastructure, including specialist skills required
- Additional weight for cooling units, bracketry, and tanks
- Relatively low asset life for electrolysers and fuel cells (~3yrs)
- Currently requires large areas to set up next to railway operations for distribution and supply.

2.3.1 Current use in Australia and globally

In Australia, Aurizon has long-term plans to develop trains that use liquid hydrogen, but there are not currently any hydrogen fuel cell trains in operation.

Globally, the first train powered by a hydrogen fuel cell, the Alstom Coradia iLint, commenced service in Lower Saxony, Germany, in 2018. By 2022, the fleet had grown to 14 trains, with an additional fleet replacing diesel units in Frankfurt.

The iLint is a two-car train with hydrogen compressed to 350 bar stored in reservoirs mounted on the roof. It can reach a top speed of 140 kilometres per hour (km/h) and has an operating range of approximately 800 km. However, it cannot maintain full power for extended periods. Each car's fuel cells, which provide a maximum of 200 kilowatts (kW), continuously charge a 220 kilowatt hour (kWh) battery. Full power can only be sustained for limited periods until the battery is depleted. This setup is ideal for regional service with reasonably frequent stops, allowing the battery to recharge. It is not suitable for extended, high-speed service.

To date, most development efforts from other European manufacturers, such as CAF, Siemens and Hitachi, have focused on trains with a similar configuration to the iLint to replace small diesel multiple units (DMUs).

In the U.S.A., long-distance passenger trains are typically hauled by diesel locomotives, except for the electrified sections in the northeast corridor. For instance, the Surfliner operates on a 565 km route from San Diego through Los Angeles to San Luis Obispo, reaching speeds of up to 130 km/h. California has enacted legislation to eliminate all diesel by 2035, and studies are underway to replace diesel on this service with hydrogen fuel cell-powered locomotives.

2.3.2 Potential hazards

The unique properties and behaviours of hydrogen present a distinct set of hazards.

Potential hazards of hydrogen:

- **Material selection and hydrogen embrittlement**

  Hydrogen has the potential to cause embrittlement in certain metals. This highlights the importance of selecting suitable materials that are resistant to degradation when dealing with hydrogen.

- **Ventilation and leak detection**

  Hydrogen's flammability and the difficulty in visually detecting leaks or flames necessitate advanced detection systems and effective ventilation to prevent the accumulation of hydrogen gas.

- **Cryogenic and high-pressure storage**

  Storage methods for liquid and gaseous hydrogen can pose risks, such as cold burns or explosions, if not managed properly. This underscores the importance of careful construction and maintenance of cryogenic and high-pressure tanks.

- **Shock and vibration resistance**

  Hydrogen fuel cell systems can be susceptible to the rigorous vibrations and shocks typical in the rail environment. This highlights the need for robustness and durability in these systems.

- **Pressure-relief devices**

  The function of pressure-relief devices in hydrogen systems can differ from those in other fuel types due to hydrogen's unique properties. This emphasises the need for careful design, testing, and functionality of these devices when dealing with hydrogen.

2.3.3 Future use in Australia

The rollout of hydrogen-powered rolling stock is being seen mostly in northern hemisphere countries.

In Australia, a confidential feasibility study was undertaken in 2021 to assess the introduction of hydrogen-powered trains for bulk freight. This work concluded that a Hydrogen Electric Tender was the preferred configuration to pursue given the lack of space on the locomotive to store the required amount of hydrogen fuel.

2.4

Ammonia

Ammonia (NH_3) is a carbon-free compound that can be used as a fuel for power generation. Ammonia has some potential advantages over other fuels. As with hydrogen, the equivalent energy can be transferred much more quickly, meaning the filling time is less than battery charging time. Compared to hydrogen, liquid ammonia has a higher volumetric density of hydrogen atoms than liquid hydrogen — 122 kg/m^3 versus 71 kg/m^3 — at a temperature of -33 degrees Celcius versus -253 degrees Celcius, making it easier to transport and store.[9]

There are still many technical issues and safety risks associated with the use of ammonia, however. When combusted in a gas turbine, the nitrogen in ammonia converts to nitric oxides (NOx) at a high rate. This results in NOx emissions in excess of 1000 parts per million (ppm), which is a significant challenge when using ammonia as a fuel. Research and development efforts are ongoing to address these challenges and make ammonia a viable fuel for the future.

The list on page 19 provides a summary of advantages and disadvantages of ammonia compared to other ZEs technologies.

Key advantages and disadvantages of ammonia

Advantages

- ✓ Higher volumetric density than liquid hydrogen LH2
- ✓ Low ignitability, low explosion risk
- ✓ Liquid at -33 degrees Celcius or 1000 kPa
- ✓ Can be cracked to give hydrogen

Disadvantages

- Toxic
- Combustion produces NOx
- Corrosive to many materials
- Irritant above 100ppm

2.4.1 Current use in Australia and globally

Several companies and organisations are exploring the use of ammonia as a fuel. For example, Fortescue Future Industries (FFI), a subsidiary of Fortescue Metal Group, is developing an ammonia-powered locomotive. The locomotive is based on an existing diesel engine modified to run on green ammonia made from hydrogen produced from renewable energies. A prototype of the engine is currently being tested.

2.4.2 Potential hazards

The characteristics and behaviours of ammonia require a unique set of safety measures.

Potential hazards of ammonia:

- **Ignitability and explosion risk**

  Ammonia has low ignitability, hence posing a low explosion risk in the event of a leak.

- **Solubility and toxicity**

  Ammonia is soluble in water and quite toxic. This highlights the need for effective safety measures to prevent and manage spills, and to ensure the safe disposal of ammonia-contaminated water.

- **Odour and detection**

  In low concentrations, ammonia has a strong odour and is easily detected at 5ppm. It can be tolerated up to 25ppm, which underscores the importance of effective ventilation.

- **Exposure risks**

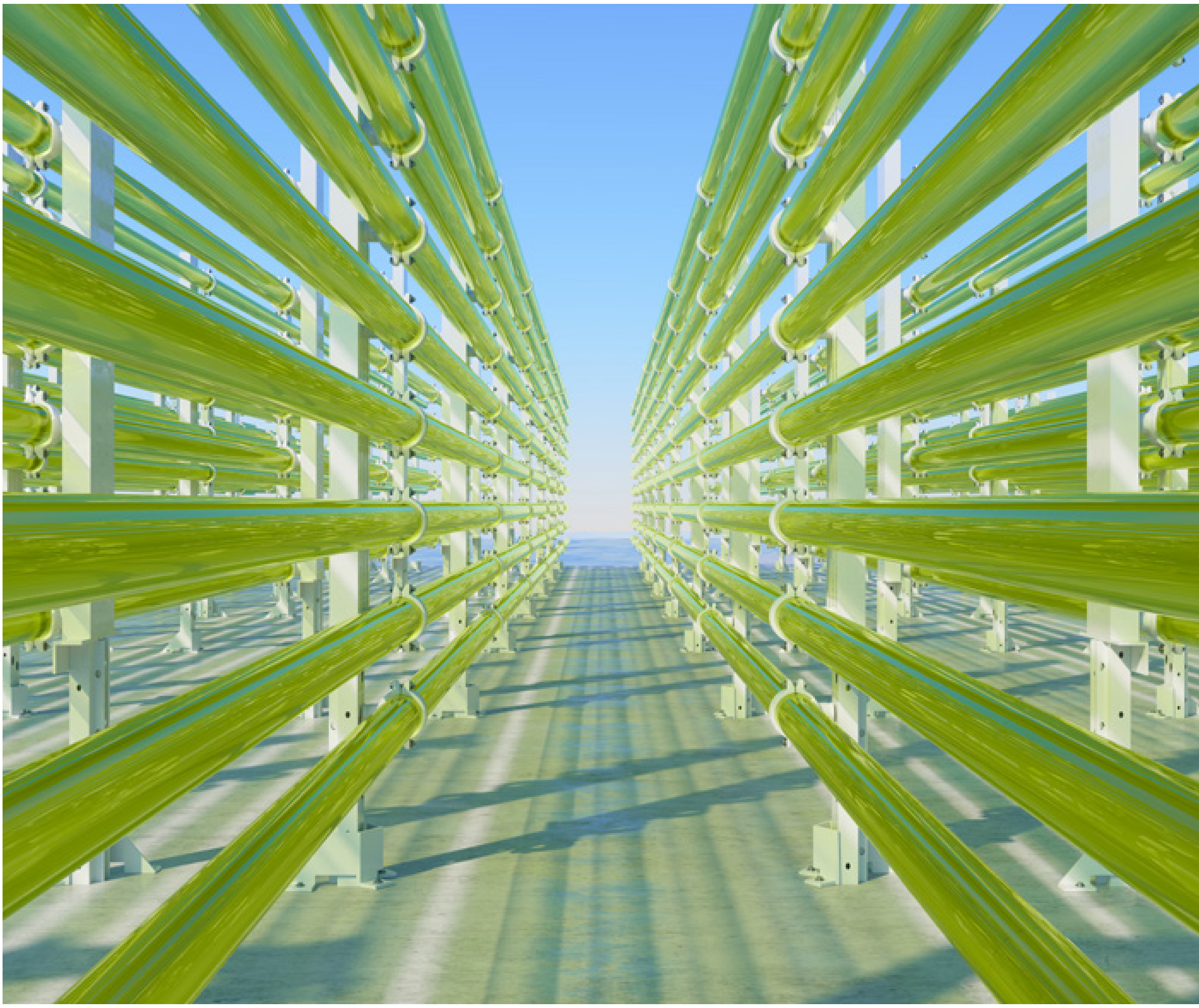
  Exposure to concentrations over 35ppm for over 15 minutes may be harmful, while concentrations above 2,500ppm may be fatal upon extended exposure. This underscores the importance of effective ventilation and PPE to limit exposure.

- **Corrosiveness**

  Ammonia is corrosive to the skin, emphasising the need for suitable protective clothing and equipment when handling ammonia.

2.4.3 Future use in Australia

The use of ammonia in rolling stock is still in the research and development stage. It will likely be some time before we see widespread adoption of this technology in Australia's rail transport sector.



2.5

Biofuels

Biofuels produced from organic sources like crops or waste organic material are also being considered as a potential solution for reducing greenhouse gas emissions in the railway sector. Biofuel can serve as an alternative to traditional fossil fuels in rolling stock, helping to reduce greenhouse gas emissions and dependence on fossil fuels.

The introduction of biofuels in rolling stock poses a number of challenges, such as technical compatibility, feedstock supply, fuel quality, cost competitiveness and regulatory compliance.

The engines and fuel systems of rolling stock are designed to operate on traditional fossil fuels. Biofuels have different properties, such as viscosity and energy content, which can affect engine performance and longevity. The quality of biofuels can vary depending on the feedstock used and the production process. Poor quality biofuels can lead to engine problems and reduced performance.

The industry must work with stakeholders to develop and implement standards for the safe and effective use of biofuels in rolling stock. This could include safety standards for the storage and handling of biofuels, emissions standards for biofuel-powered engines and quality standards for biofuel production.

3

Net zero transition challenges in Australia

In addition to those relating to the technology itself, the ZE rolling stock transition poses other related challenges in Australia.

3.1

Policy and regulatory environment

The Australian Code for the Transport of Dangerous Goods by Road and Rail (the Code) provides comprehensive guidelines for the safe transport of dangerous goods, including classification, packaging, consignment procedures, documentation and safety equipment requirement and emergency response procedures to prevent and reduce damage to people, property, and the environment. Compliance is mandatory.

In the context of ZE rolling stock, the Code is particularly relevant to the introduction of new power sources such as hydrogen, which is highly flammable or batteries, which can pose risks such as thermal runaway. Hydrogen and batteries are classified as dangerous goods and therefore must comply. However, the Code provides an exemption for dangerous goods in vehicle fuel tanks and in appliances and plant that form part of a vehicle and are necessary for its operation.

The Rail Industry Safety and Standards Board (RISSB) plays a crucial role in developing and maintaining standards for the passenger and freight rail industry in Australia and New Zealand. It is responsible for safety standards, improving efficiency, conducting research, and providing tools for safety management. RISSB also shares best practices and helps businesses shape their strategic vision. Its work is key to ensuring the safety and sustainability of the rail industry.

RISSB is currently re-writing its standards for railway rolling stock to include guidelines for charging infrastructure for ZE rolling stock, reflecting the industry's move towards more sustainable energy sources.

Further details on national rail policies and strategies can be found in Appendix A.1.

A number of decarbonisation initiatives and working groups have also been established in the Australasian Rail industry. Further details are in Appendix A.2.

3.2

Increasing load on the grid

Increasing electrification and introducing battery powered rolling stock pose significant challenges to Australia's power grid.

Electrification will lead to direct increased demand for electricity, increasing the load on the grid. Battery-powered rolling stock requires robust and widespread additional infrastructure, including charging stations at depots and potentially along routes, which will need to be connected to the grid, further increasing the load.

Most electricity retailers offer a GreenPower accredited product that allows customers to purchase between 10% and 100% of their electricity from renewable sources. This means that individuals and businesses have the option to power their operations with renewable energy. However, right now, just under 40% of Australia's grid power is derived from renewable sources. While there is potential for a significant portion of rail operations to be powered by renewable energy, the actual percentage would depend on the overall mix of energy sources in the grid.

Current rolling stock standards do not fully address the requirements and implications of such a significant shift in electricity demand.

The standards should provide guidance on how to manage the increased load on the grid. Furthermore, the standards should consider the specifications and safety requirements of charging infrastructure for battery-powered rolling stock. They should also address the interoperability of these new technologies with existing rail infrastructure and how to integrate these new technologies into the existing rail network in a safe manner. This could include standards for the design and operation of charging stations, guidelines for grid management to handle the increased load, and safety protocols for the use and maintenance of battery-powered rolling stock.

3.3

Hybrid consists

Hybrid consists, for example diesel locomotives running in a consist with BELs or hydrogen fuel cell powered locomotives, will be required while the industry transition to ZE rolling stock. This poses additional challenges for rolling stock management, operations and maintenance, including:

- **Interoperability and standardisation**

  Different types of rolling stock will need to operate seamlessly together. For example, alarms play a vital role in identifying issues in real-time. In a hybrid consist, alarms will need to be integrated across all types of rolling stock; an alarm triggered on a diesel locomotive should be identifiable on a battery electric locomotive and vice versa. This requires standardisation of operating procedures, messages and alarm systems.

- **Performance and efficiency**

  Traction and braking curves, which represent the acceleration and deceleration capabilities of a train, will vary between different types of rolling stock. In a hybrid consist, managing these differences to ensure smooth operation will also be a challenge. Advanced control systems are needed to optimise performance and efficiency.

- **Maintenance facilities and depots**

  Hybrid consists will require mixed depots that can cater to both conventional and ZE rolling stock. This means having the necessary equipment, trained personnel, and safety measures in place to handle, accommodate and service the different technologies efficiently.

A new set of rolling stock standards that encompass the management, operations and maintenance of hybrid consists will be required to ensure that hybrid consists are managed, operated and maintained effectively, maximising their potential benefits while minimising their challenges.

3.4

Energy transport and delivery for ZE technologies

The power supply for stationary battery charging for rolling stock closely mirrors that of a feeder for 1500 V DC electrification. The power requirement, depending on the number of locomotives being charged simultaneously, is typically around 10MW at approximately 1500 V DC. The charging requirements for BEMUs vary based on various factors such as their size and weight.

Compressed hydrogen is usually transported via road trailers in steel "torpedos" pressurised to 18MPa. With a capacity of roughly 350kg, they carry about 4% of the energy in a volume of diesel. The Linde facility, responsible for refuelling the fleet of 14 iLint in Bremervoerde, stores about 1,800kg of compressed hydrogen on-site in 64 vessels pressurised to 50MPa. To meet the fleet's daily consumption, up to 8 trailers per day are required.

Liquid hydrogen is not currently used in rail applications; however, a single trailer equipped with a cryogenic vessel can carry around 4.5 tonnes. This significantly improves the logistical efficiency of liquid hydrogen compared to compressed hydrogen gas. However, liquefying hydrogen needs a complex, capital-intensive facility, suggesting that there would likely be a limited number of sources, resulting in supply chain risk and lower adoption rates with operators.

Ammonia is generally liquefied at a temperature of -33 degrees Celcius for transportation. The same road trailers or rail tank wagons used to transport liquid propane gas can be used to transport ammonia. Because of the lower energy density of ammonia, each tank carries about 40% of the energy in an equivalent volume of diesel.

Ammonia can be used directly as a fuel in diesel engines, although it does require a pilot fuel such as diesel for ignition. CSIRO has developed a process using catalysts to "crack" ammonia to separate the nitrogen and hydrogen.

Ammonia delivered to site could be cracked to give hydrogen which can then be compressed for storage on the rail vehicle. CSIRO has also demonstrated this process for filling fuel cell-powered cars. It could conceivably be used on the rail vehicle, with liquid ammonia transferred and stored on the train, and then cracked to provide hydrogen for fuel cells.

Figure 2: Example of an Ammonia Transportation Container

4

Review of current RISSB standards

The rail industry is at a point where considering ZE technologies is not an option, but an important step towards sustainable development.

However, the current standards do not fully accommodate or consider these technologies, creating potential barriers to their adoption. Addressing the hazards of ZE technologies through standards will foster a regulatory environment that promotes both safety and the efficiency of future rolling stock and is essential to the successful implementation of ZE technologies in the rolling stock industry.

In consultation with RISSB, Jacobs identified 65 standards and conducted a thorough review of each, exploring areas where they currently fall short in terms of accommodating ZE technologies and proposing necessary updates. We also identified alternative international standards and guidelines that can inform updates to address some of the identified gaps and be used in the interim update period.

A list of the 65 standards reviewed can be found in Appendix A.3.1.

4.1

Assessment methodology

The RISSB standards were assessed against four core criteria, as shown in Figure 3.

Figure 3: Assessment criteria.

Age of standard

As per RISSB Product Development Procedures ADMIN 4.7 Product and Maintenance, each RISSB product has a review period of seven years. In rating the Standards for this paper, the oldest standards were assigned the highest rating (5) and the newest standards were assigned the lowest rating (1).

Urgency in relation to industry need and importance

The urgency of updates focusses on how quickly the proposed changes should be implemented, with standards requiring urgent action assigned the highest rating (5) and standards requiring non-urgent action assigned the lowest rating (1).

Volume of content update required

The volume of updates focusses on the amount of changes required for each standard, with standards requiring a rewrite in the light of ZE technology assigned the highest rating (5) and standards requiring only minor changes or updates assigned the lowest rating (1).

Criticality of the system or aspect affected

The criticality of the system was evaluated in terms of impacts on safety-relevant systems, with the highest rating (5) assigned to safety critical systems and the lowest rating (1) assigned.

Standards were graded from one to five based on the potential impact and size of review required, and a weighting was applied to the rankings of urgency and criticality, as shown in Table 2 below. The scores for urgency and criticality were given a higher weighing due to their direct correlation with the operational outcomes for rolling stock and fundamental role in ensuring the safety of the rolling stock respectively.

Finally, the numbers assigned to each category were used to determine a priority ranking of each standard. This prioritisation process plays a crucial role in informing the updates that need to be made, identifying those that require immediate attention and those that can be updated at a later stage.

A detailed outline of our assessment methodology can be found in Appendix A.3.

Table 2: Grading framework

Rating	Age of standard	Urgency (Industry need and importance)	Volume of content update required	Criticality of the system or aspect affected
5	9+ years	Major	Overhaul	Major
4	8 years	High	High	High
3	4 - 6 years	Medium	Moderate	Medium
2	2 - 3 years	Low	Low	Low
1	1 year	Minimal	Minimal	Minor
Weighting	1	2	1	2

5

Key findings

Out of the 65 products reviewed, we identified 30 standards that need updating to accommodate the introduction of ZE rolling stock. Out of those 30 standards, eight require updating as a matter of high priority.

These are listed in Table 3 below. Proposed changes for the eight standards identified as a high priority are outlined in the discussion below. Findings relating to the remaining 22 standards reviewed can be found in Appendix A.4.

Table 3: Eight standards identified as high priority

Standard	Ranking score	Priority
AS 7529.1 - Rolling Stock - Fire Safety - Locomotive	29	1
AS 7529.2 - Rolling Stock - Fire Safety - Freight	29	2
AS 7529.3 - Rolling Stock - Fire Safety - Passenger	29	3
AS 7529.4 - Rolling Stock - Fire Safety - Track Machines	29	4
AS 7520.2 - Rolling Stock - Body Structural Requirements Part 2 - Freight Rolling Stock	26	5
AS 7520.3 - Rolling Stock - Body Structural Requirements Part 3 - Passenger Rolling Stock	26	6
Guideline - Rail Emergency Management Planning	25	7
AS 7527 - Rolling Stock Event Recorders	20	8

5.1

AS 7529.1 - 4

Rolling Stock - Fire Safety – Locomotive, Freight, Passenger and Track Machines

The AS 7529 standard suite, which includes Part 1 - 4, outlines the fire safety requirements for rolling stock in Australia, covering locomotives, freight rolling stock, passenger rolling stock and track machines specifically, including aspects of design, construction, and maintenance. It emphasises the significance of mitigating fire risks, maintaining the fire performance of materials and adhering to fire safety standards during any modifications or refurbishments.

5.1.1 Assessment ranking and justification

Each standard included in this suite was assigned an overall score of 29 out of 30 (refer to Table 4).

The standard suite is 10 years old and is due for an update. The current version does not cater for the emergence and existence of lithium batteries, hydrogen or ammonia as onboard energy sources and therefore needs an update urgently. Integrating ZE technologies requires a significant revision of these standards.

5.1.2 Recommended changes

The updated standards should outline the fire safety approaches specific to ZE technologies, including prevention, detection and suppression measures. This should include a discussion on methods to prevent and monitor hydrogen leaks and electrolyte or gas leaks from batteries.

A section on compliance testing considerations for batteries and hydrogen should also be included. This section can refer to existing standards for testing batteries (for example, IEC 62928) and hydrogen (for example, EN 63341-2). Specific requirements for testing related to fire protection, including leakage testing and fire barrier efficacy, should also be outlined.

A specification of requirements for Pressure Relief Valves (PRVs) and Temperature-Pressure Relief Devices (TPRDs) in hydrogen fuel systems should be included in an updated version of the standard. Safe fuelling/defueling procedures and compliance testing considerations need to be defined, referring to relevant standards such as EN 63341-2.

The required changes are outlined in Table 5.

Table 4: Assessment Ranking and justification for AS 7529.1 - 4

	Age	Urgency	Volume	Criticality
Initial rating	5	5	4	5
Weighted rating	5	10	4	10
Overall score				**29**

Table 5: Proposed changes for AS 7529.1 - 4

Section	Title	Comment
Changes to AS 7529.1-4		
Section 1.8	Referenced Documents	The standards referenced in this section should be updated to include any new standards relating to ZE technology.
Section 4.2	Deemed to safety provisions	This section requires significant revision for hydrogen, as references to leaks of flammable fluids and drainage points are not applicable for hydrogen. This could also apply to some types of batteries. This also needs to consider the placement of hydrogen fuel cells to allow hydrogen gas to escape easily instead of accumulating. This section requires adjustments to account for new ignition sources and risks associated with ZE technology.
Section 5.1	Material Fire Performance	All performance values should be reviewed for suitability with hydrogen or batteries to ensure they are compatible with ZE technology and do not increase the fire risk.
Section 7	Portable Fire Extinguishers and fire blankets	The location and size of extinguishers should be in proportion to the size of fires. In scenarios involving battery thermal runaway or a hydrogen fire, the use of a portable extinguisher might pose lethal risks to the user. While it remains sensible to have extinguishers on hand for smaller fires originating from other sources, it should be explicitly stated that escape and preservation of life is the highest priority. The introduction of ZE technology will require an update of existing referenced standards or introduction of new standards regarding hydrogen fires and battery fires.
Section 11 (Part 1, 4) **Section 12 (Part 3)** **Section 7 (Part 2)**	Maintenance, Modifications and Refurbishment	The introduction of ZE technology may require adjustments to existing maintenance procedures to account for the unique characteristics and potential hazard. Proper protocols should be developed to address the storage, handling and servicing of ZE technology equipment safely. If hydrogen or ammonia storage is incorporated into this suite of standards, more detailed requirements for inspection checks will be required, this could be referenced to BS EN 45545-7.
Additional changes to AS 7529.1		
Section 9	Fixed Fire Protection Systems	While this is a sound requirement for power cars with engines, it is unlikely that any system would be capable of dealing with the energy in a battery. Guidance on the minimum level of protection to be provided is suggested.

Additional changes to AS 7529.2		
Section 4.2.4	Audible or visual alarm	The presence of an audible or visual alarm in the driver's cab should be mandatory for battery thermal runaway or a hydrogen fire.
Section 7.2.1.4	High pressure lines	High pressure lines for hydrogen would need special inspection procedures.
Additional changes to AS 7529.3		
Section 8	Crew/passenger ventilation system control	When considering ZE fluids such as hydrogen or batteries, ventilation system control becomes a subject which needs more consideration. It is essential to ensure that the ventilation systems are designed to be safe and effective with these alternative power sources. This may involve addressing unique characteristics of ZE fluids, like hydrogen's flammability, proper ventilation requirements and ensuring the safety of occupants in case of any system failures or emergencies.
Section 9	Fixed fire protection systems	Specialised detection systems capable of identifying fire hazards linked to batteries, hydrogen or ZE fluids need to be included in the standard. This update may involve deploying advanced sensors for early detection and differentiation of various fire types, facilitating prompt response actions. Fixed fire protection systems must also demonstrate compatibility with ZE fluids and competence in containing and suppressing fires involving batteries or hydrogen. It is crucial to validate these systems through testing under realistic conditions to ensure their effectiveness in managing fire incidents specific to these scenarios.
Section 11	Rolling stock evacuation measures	The existing protocols for rolling stock must be reevaluated and potentially revised to cater to the unique challenges posed by ZE technology. This reassessment should consider factors such as evacuation routes, emergency communication systems, and procedures for handling incidents involving these alternative power sources
Additional changes to AS 7529.4		
Section 6.2.2.1	Driver's Cab	This section uses a value of 15 minutes for fire resisting partitions, but it is not clear if this time considers the escalation of a lithium battery or hydrogen system fire. A review should be undertaken to confirm.
Section 6.3	Compartments containing combustion engines and high-powered equipment	It is not clear whether this section includes lithium batteries under definition of high-power equipment. Clarification of inclusion of lithium batteries is required. The review should consider including a new section related to ZE technology including batteries, and liquid or gaseous systems such as ammonia or hydrogen.

Additional changes to AS 7529.4 (continued)		
Section 9	Fixed fire protection systems	Specialised detection systems capable of identifying fire hazards linked to batteries, hydrogen or ZE fluids need to be included in the standard. This update may involve deploying advanced sensors for early detection and differentiating various fire types, facilitating prompt response actions. Fixed fire protection systems must also demonstrate compatibility with ZE fluids and competence in containing and suppressing fires involving batteries or hydrogen. It is crucial to validate these systems through testing under realistic conditions to ensure their effectiveness in managing fire incidents specific to these scenarios.
Section 10.2.3	Running Capability in the event of a fire	This section refers to self-rescue devices that provide smoke protection but does not cover the aspect of toxicity for any fumes, emissions or vapours as a result of fires involving lithium, hydrogen or ammonia.

5.1.3 Alternative international standards and guidelines

A number of international alternative standards and substitutes could be used in the interim while the existing standards are being updated, as outlined in Table 6 below.

Table 6: International alternative standards for AS 7529.1 - 4

Australian Standard	International Standard / Guideline	Comment
AS 7529.1 - Rolling Stock - Fire Safety - Locomotive **AS 7529.2 - Rolling Stock - Fire Safety - Freight** **AS 7529.3 - Rolling Stock - Fire Safety - Passenger** **AS 7529.4 - Rolling Stock - Fire Safety - Track Machines**	NFPA 2 Hydrogen Technologies Code	This code provides fundamental safeguards for the generation, installation, storage, piping, use and handling of hydrogen in compressed gas form or cryogenic liquid form. It addresses the primary and most common applications of hydrogen, including storage, transfer and use in stationary, portable and vehicular applications. It is a critical element of the framework for deploying hydrogen technologies in the U.S.
	ANSI/AIAA G-095A Guide to Safety of Hydrogen and Hydrogen Systems	This guide presents information that designers, builders and users of hydrogen systems can use to ensure safe hydrogen systems or resolve hydrogen hazards. It provides guidance on general safety systems and controls, usage, personnel training, hazard management, design, facilities, detection, storage, transportation and emergency procedures.
	BS EN 45545-7	This part of EN 45545-7 specifies requirements for flammable liquids and liquefied petroleum gas installations, e.g., for traction, auxiliary power units, heating or cooking, to cover the objectives defined in EN 45545-1123. It is particularly relevant when considering hydrogen fuel cells, which involve the use of flammable gases. The standard provides guidelines for the safe installation, maintenance and operation of these systems, which would be crucial in the context of ZE rail vehicles.

5.2

AS 7520.2

Australian Railway Rolling Stock - Body Structural Requirements Part 2 - Freight Rolling Stock

AS 7520.2 is an Australian Railway Standard that specifies the body structural requirements for freight rolling stock, including design verification, construction and maintenance. It focuses on ensuring the safety and structural integrity of freight vehicles under normal and extreme operating conditions.

5.2.1 Assessment ranking and justification

The standard was assigned the ranking of 26 out of 30 (refer to Table 7.)

This standard is in the old format and is under review, requiring a general update. The sections addressing collision performance, shock loading and changes to tank cars to include ZE technology need revision if ZE storage systems are fitted, unless these are addressed with in a separate standard.

Table 7: Assessment Ranking and justification for AS 7520.2

	Age	Urgency	Volume	Criticality
Initial rating	5	5	3	4
Weighted rating	5	10	3	8
Overall score				**26**

5.2.2 Recommended changes

Table 8: Proposed changes for AS 7520.2

Section	Title	Comment
Section 9.1	Collision Performance	Substantial changes will be needed for vehicles equipped with batteries, hydrogen or ammonia. Special consideration must be paid to scenarios involving rollovers or a vehicle lying on its side.
Section 15.2	Shock Loading	For structures housing battery cells or packs, both deflections and stress should be considered. Deflections must not cause short circuit, or any contact between batteries which might damage cells in a way which subsequently result in thermal runaway. High pressure pipework for hydrogen must be designed to prevent fractures or leaks.
Section 18	Tank Cars	The requirements for vehicles carrying either liquid or compressed hydrogen are very different and more stringent. These should likely be excluded from this standard and addressed in a dedicated standard instead.

5.3

AS 7520.3

Australian Railway Rolling Stock - Body Structural Requirements Part 3 - Passenger Rolling Stock

AS 7520.3 sets the body structural requirements for passenger rolling stock, including design verification, construction and maintenance. It aims to ensure safe performance under normal operating conditions and minimise risks training crew and the public in the event of collisions or derailments.

5.3.1 Assessment ranking and justification

The standard was assigned the ranking of 26 out of 30 (refer to Table 9.)

A comprehensive update is imperative to accommodate the integration of ZE technologies. This update should specifically incorporate provisions addressing the safeguarding of batteries and hydrogen storage tanks. The focus should be on crashworthiness performance, towing fixtures, body mounted equipment and fuel tanks to incorporate ZE technology in the standard.

Table 9: Assessment Ranking and justification for AS 7520.3

	Age	Urgency	Volume	Criticality
Initial rating	5	5	3	4
Weighted rating	5	10	3	8
Overall score				**26**

5.3.2 Recommended changes

Table 10: Proposed changes for AS 7520.3

Section	Title	Comment
Section 9.1	Crashworthiness Performance	The standard should set stringent requirements that ensure the structural integrity and safety of passenger rolling stock during collisions, considering the unique characteristics and potential hazards associated with ZE components. The crashworthiness criteria should be designed to reduce impact forces and enhance passenger safety, while also considering potential environmental implications of ZE technologies in the context of collision scenarios. Unless they are excluded from this standard and dealt with in another standard, substantially changes are needed for vehicles carrying batteries, and especially vehicles carrying hydrogen. Special consideration must be given to the case of rollover or a vehicle lying on its side.
Section 14	Towing Fixtures	This standard covers mandatory requirements to safely secure, uncouple and couple rolling stock. The separation activities are almost purely mechanical in nature and involve managing the pneumatic brake system. However, additional requirements will be needed if there are electrical connections to a battery tender or hydrogen tank tender.

Section	Title	Comment
Section 15	Body mounted equipment	A dedicated standard should be introduced for body-mounted equipment in the context of ZE technologies, which could encompass fuels such as hydrogen or ammonia, batteries or a combination of all. This standard provides detailed guidelines for comprehensive shock and vibration testing procedures. These procedures should be specifically updated to assess the impact on body-mounted equipment associated with various ZE technologies.
Section 16	Fuel Tanks	This section needs to be updated to include vehicles carrying hydrogen tanks as their requirements are very different and much more onerous compared to conventional fuel tanks. Requirements for hydrogen tanks should encompass the following criteria for both fuel tanks and batteries: ▪ **Location:** Specify the optimal positioning of fuel tanks and batteries, considering factors such as safety, accessibility and adherence to applicable regulations. ▪ **Strength requirements:** Establish rigorous design and performance standards to ensure the structural integrity and strength of both fuel tanks and batteries, outlining criteria that must be met under various load conditions. ▪ **Componentry:** Define the required components, including gauges, pipework, isolating mechanisms, vents, breathers, clean-out ports and monitors, for both fuel systems and battery installations. Ensure that all componentry meets specified standards for safety and functionality. ▪ **Spill control:** Outline measures and design considerations to prevent spills of fuel or hazardous substances from both fuel tanks and batteries during all foreseeable in-service and accident scenarios. ▪ **Fuelling:** Establish standards for fuelling systems associated with both fuel tanks and batteries, incorporating mechanisms such as dry-break compatibility and compatibility with existing fuelling systems. Address safety considerations to prevent accidental ignition. ▪ **Safety cut-off devices:** Define requirements for safety cut-off devices in both fuel systems and battery installations. Specify the design and installation of devices that, when activated, prevent the flow of fuel or electrical energy from the tank or battery to the vehicle's prime mover or system.

5.3.3 Alternative international standards and guidelines

Table 11: Proposed changes for AS 7520.3

Australian Standard	International Standard / Guideline	Comment
AS 7520.3 - Australian Railway Rolling Stock - Body Structural Requirements Part 3 - Passenger Rolling Stock	AAR M-1004	This standard developed by the Association of American Railroads (AAR) contains general requirements, functional requirements (e.g., piping, tender-to-locomotive interfaces, etc.), track worthiness, and crashworthiness requirements for fuel tenders. It provides a grade crossing impact case scenario between the LNG tender and an 80,000-pound truck at 40 mph.

5.4

Guideline

Rail Emergency Management Planning

The Rail Emergency Management Planning Guideline covers the roles of leading organisations when coordinating the response to rail emergencies. It seeks to clarify the legislative rail emergency management requirements of the Rail National Safety Law to improve rail emergency management capability and organisational resilience.

5.4.1 Assessment ranking and justification

The guideline was assigned the ranking of 25 out of 30 (refer to Table 12.)

The guideline is well structured and would only require minor updates to the sections about "Rail emergencies and notifiable occurrences" and "Typical lead roles for rail emergency responders to consider responding to" when the rolling stock is fitted with batteries or hydrogen that could pose a fire risk.

Table 12: Assessment Ranking and justification for Guideline - Rail Emergency Management Planning

	Age	Urgency	Volume	Criticality
Initial rating	3	4	2	5
Weighted rating	5	8	2	10
Overall score				**25**

5.4.2 Recommended changes

The guideline is well structured and would only require minor updates to the sections about "Rail emergencies and notifiable occurrences" and "Typical lead roles for rail emergency responders to consider responding to" when the rolling stock is fitted with batteries or hydrogen that could pose a fire risk.

Table 13: Proposed changes for Rail Emergency Management Planning

Section	Title	Comment
Table 1, row 9	Rail Emergencies and notifiable occurrences	Current wording is "spills and potential fires (e.g chemicals, oil, contaminated products, dangerous goods)". This could be updated to include batteries (lithium, others) and hydrogen so there is an increased awareness on the typical batteries used in rolling stock traction, but it is broadly covered by "chemicals".
Table 4, rows 6 and 9	Typical lead roles for rail emergencies	Current wording is "explosion/fire" and "spills and potential fires (e.g chemicals, oil, contaminated products, dangerous goods)". This could be updated to include batteries (lithium, others) and hydrogen to ensure these different types of fires are identified and treated appropriately. The treatment of those fires can be covered in separate firefighting documentation.

5.5

Rolling Stock Event Recorders

AS 7527

AS 7527 outlines requirements for event recorders on rolling stock, detailing requirements for data recording, compliance, and maintenance. It emphasises the importance of capturing essential data for forensic investigations of rail incidents and ensuring the event recorders' integrity and survivability.

5.5.1 Assessment ranking and justification

The standard was assigned a ranking of 20 out of 30 (refer to Table 14.)

The integration of ZE technology requires that the event recording system is compatible with the new equipment and its specific operational characteristics.

While no major technical constraints were identified for the deployment of battery or hydrogen traction options, there would be a significant change in current operations and infrastructure requirements. This aspect is not included in this review but highlighted for awareness.

Table 14: Assessment Ranking and justification for AS 7527 - Rolling Stock Event Recorders

	Age	Urgency	Volume	Criticality
Initial rating	5	3	3	3
Weighted rating	5	6	3	6
Overall score				**20**

5.5.2 Recommended changes

Event Recorders may need to record additional signals introduced by the new battery or hydrogen system, and improve energy efficiency. Maintainers, operators and investigators may need to understand performance values from the zero emission systems, such as battery temperature, fire detection, suppression, storage pressures etc. The concept would be to review and include parameters that would provide insightful to understand system health.

The integration of ZE technology into AS 7527 involves ensuring that the event recording systems are fully compatible with the unique operational and safety characteristics of rolling stock equipped with ZE technology. This includes accommodating additional data types, adjusting to different power supply characteristics, and considering new hazard profiles.

6

Conclusion

The review and assessment of rolling stock standards in the Australian industry reveals gaps related to ZE technologies which creates potential barriers to their adoption.

The gap analysis conducted provides insights into the areas where the current standards fall short. This information is used to prioritise the standards that require updates to accommodate ZE technologies, helping guide the industry's efforts towards decarbonisation and allocate resources effectively.

Early guidance on alternative standards and substitutes that can be used in the interim while the existing standards are updated will improve industry awareness and enable informed discussions within the industry. The research and benchmarking on global standards related to ZE rolling stock highlights several best practices and standards that could be adopted or adapted for the Australian context. Integrating these global best practices into the Australian rolling stock industry will enhance its competitiveness and sustainability and ensure its alignment with global trends and advancements in ZE technologies.

The gaps suggest that the current standard development process may not be keeping pace with technological advancements. As ZE technologies evolve, anticipating future changes and incorporating them into standards in a timely manner is key.

Given the rapid advancements and the quantity of changes required to accommodate the introduction of ZE technology in Australian Rolling stock standards, it is important for RISSB to expedite the standard update process to accommodate these changes.

RISSB plays a critical role in ensuring the safe and effective integration of ZE technologies into the rail industry. By engaging closely with industry stakeholders, RISSB helps to bridge the current gaps in standards and pave the way for a more sustainable future for the rail industry. Industry stakeholders can provide valuable insights into the practical challenges faced on the ground to shape more effective and relevant standards. A proactive approach is part of RISSB's commitment to keeping pace with technological advancements in the rail industry and ensuring the standards developed are both effective and relevant. Looking at practices in other countries such as the U.K. and U.S.A., RISSB can bridge the current gaps by nominating alternative standards to help the industry while updating its current standards regarding ZE technology.

6.1

Rolling Stock Event Recorders

While RISSB develops and maintains standards for the passenger and freight rail industry in Australia and New Zealand, these standards are not mandatory. Respective rolling rail authorities are responsible for developing their own standards which may or may not be based on the RISSB national standard. This means rolling stock standards in Australia vary across jurisdictions.

This poses challenges when it comes to implementing new ZE technologies across the country.

Currently, Rail Infrastructure Managers (RIMs) in each rail jurisdiction must review its standards in light of these new ZE technologies, considering both the specific needs and constraints of the jurisdiction, as well as the broader goal of creating a unified, sustainable rail system across the country.

It would be more efficient and effective for all jurisdictions to follow the RISSB standards, eliminating the need for each jurisdiction to separately consult with industry and revise their standards.

RISSB is well positioned to undertake the necessary consultation with industry stakeholders, including train manufacturers, energy providers and safety regulators. By adopting RISSB standards that include ZE technology, the management of the introduction of new rolling stock in Australia will be improved.

7

Appendices

A.1

National rail policies and strategies

A.1.1 Rail Safety National Law review

The Rail Safety National Law (RSNL) regulates rail operations in Australia and applies in all states and territories. It aims to ensure a consistent and coordinated approach to rail safety regulation by the Office of National Rail Safety Regulator (ONRSR).[10] However, the RSNL requires each accredited party to ensure a suitable Safety Management System is in place. Due to historical differences and the complexity and integrated nature of existing rail safety systems, many parties have disparate safety frameworks and sets of standards, which can affect the efficiency and harmonisation in the rail industry. An independent review of the RSNL led by the National Transport Commission (NTC) is in progress and will report to the transport ministers in mid-2024.[11]

The NTC is an independent statutory body that was established under the National Transport Commission Act 2003. Its primary role is to develop regulatory and operational reform for road, rail and intermodal transport. The NTC works collaboratively with the Commonwealth, State and Territory transport agencies and regulators, as well as industry and community stakeholders.

A.1.2 National Rail Action Plan

The National Rail Action Plan (NRAP) aims to improve the performance and safety of Australia's rail system by harmonising standards and systems across different networks and modes.[12] In 2019, Infrastructure and Transport Ministers endorsed the NRAP, which is led by the NTC. The NRAP addresses challenges arising from historical rail development, including limited interoperability, high costs and lack of innovation. The NRAP promotes collaboration between government and industry to streamline infrastructure, rolling stock, control and communication standards and systems for improved efficiency and safety and address critical skills and labour requirements in the rail sector.

A.1.3 National Rail Manufacturing Plan

The National Rail Manufacturing Plan aims to improve the efficiency, safety and competitiveness of Australia's rail industry.[13]

This comprehensive plan unfolds across three distinct phases:

- **Foundation for Growth (Phase 1):**

  During this initial stage (spanning from Q3 2023 to Q4 2024) key activities include implementing the National Rail Procurement and Manufacturing Strategy, conducting a nationwide analysis of rail procurements, and identifying immediate collaborative opportunities that go beyond state and territorial boundaries.

- **Global Supply Chain Opportunities (Phase 2):**

  From Q1 to Q4 2024, Phase 2 centres on exploring pathways for Australian manufacturing within the global rail supply chain. This involves assessing domestic rail manufacturing capabilities, selecting growth areas for both local and export markets, and rigorously testing these opportunities. Additionally, mapping the national rail innovation ecosystem and prioritising research and innovation align with this phase's objectives.

- **Domestic Capability Development (Phase 3):**

  Starting in Q3 2024 and extending into subsequent years, Phase 3 focuses on nurturing domestic capabilities in priority growth areas. The plan emphasises targeted growth plans, capitalising on freight and heavy haul manufacturing, fostering research and innovation, and cultivating a skilled workforce. Notably, this phase aims to propel Australia's rail industry toward global excellence.

The plan involves collaboration between government, industry, unions, and research institutions to develop a nationally coordinated approach to procurement, investment, innovation, and skills development.

The plan has already delivered some outcomes, such as setting up the Office of National Rail Industry Coordination, appointing a National Rail Manufacturing Advocate and a Rail Industry Innovation Council.

A.1.4 National Rail Procurement and Manufacturing Strategy

In November 2023, the National Rail Procurement and Manufacturing Strategy was shared as an integral component of the broader National Rail Manufacturing Plan.[14] This strategic initiative aims to improve the way rolling stock is procured and manufactured in Australia.

The strategy aims to simplify the buying process, make standards more consistent across different states and territories, increase innovation, and improve the skills and abilities of the people who work in the rail manufacturing sector.

The strategy encompasses six main parts:

- Developing a national approach to buying rolling stock
- Making the standards for manufacturing rolling stock more consistent
- Adopting a national approach to supporting local businesses
- Maximising the opportunities for manufacturing freight and heavy haul vehicles
- Improving the research and innovation outcomes in the rail sector
- Establishing the foundation for good jobs and rewarding careers in rail manufacturing.

A.1.5 National Freight and Supply Chain Strategy

The National Freight and Supply Chain Strategy (NFSCS) is a framework to improve the performance of freight systems across all modes and networks in Australia.[15] It has a 20-year vision and goals, and five-year action plans to achieve them. The NFSCS sets a vision for Australia's freight systems and domestic and international supply chains.

The goals outlined in the NFSCS are:

- **Improved efficiency and international competitiveness**

  The strategy aims to enhance the efficiency of freight operations, making them more streamlined and competitive on the global stage.

- **Safe, secure, and sustainable operations**

  Ensuring the safety and security of freight movements while also promoting sustainability is a critical objective. This includes minimising environmental impact and ensuring long-term viability.

- **A fit-for-purpose regulatory environment**

  The NFSCS seeks to create regulations that align with the evolving needs of the freight industry. A regulatory framework that supports efficient and safe operations is essential.

- **Innovative solutions to meet freight demand**

  Anticipating future demands, the strategy encourages innovative approaches to address freight challenges. This includes leveraging technology, data, and new models of operation.

- **A skilled and adaptable workforce**

  Recognising the importance of human capital, the NFSCS aims to develop a skilled and adaptable workforce capable of meeting the evolving demands of the freight sector.

- **An informed understanding and acceptance of freight operations**

  Public awareness and acceptance of freight operations are crucial. The strategy seeks to foster understanding and appreciation of the role that freight plays in Australia's economy and daily life.

The NFSCS covers four critical areas:

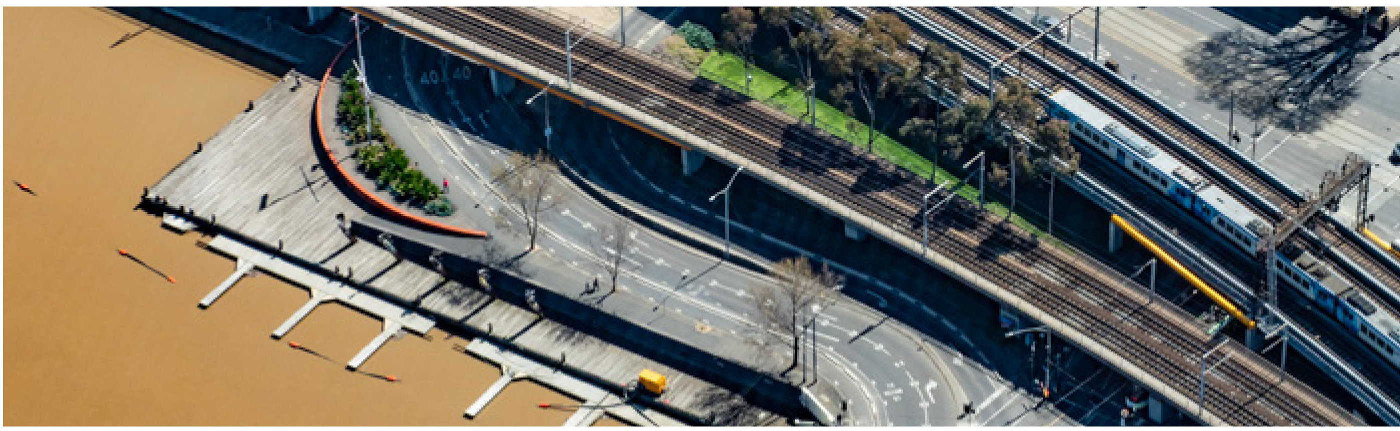
- Smarter and targeted investment
- Improved supply chain efficiency
- Better planning, coordination and regulation
- Better freight data and information.

The Strategy is reviewed every five years, the first review will be undertaken in 2024. Each review will involve consultation with industry and government stakeholders to ensure the strategy remains relevant and effective.

The review will also consider the outcomes of other related reviews and priorities, such as the rail infrastructure and systems review, the rail access undertaking review, and the national freight and supply chain strategy review.

A.1.6 RISSB Harmonisation plan

The RISSB Harmonisation Plan aims to harmonise the standards and rules for rail infrastructure and operations across Australia, to improve safety, efficiency, interoperability and innovation. It involves developing a National Rolling Stock Register,[16] a National Rail Safety Data Strategy and a National Rail Safety Incident Investigation Framework. [17] It also includes reviewing and updating the Australian Network Rules and Procedures and the Australian Standard for Interoperability. The plan is led by RISSB in collaboration with government and industry stakeholders. [18]



A.2

Decarbonisation initiatives and working groups in the Australasian railway industry

Following on from the momentum discussed above, this section aims to provide deeper context of specific and targeted teams, activities and stakeholder engagements, aligning for a common purpose.

A.2.1 ARA Decarbonisation in Rail Critical Path Working Group

This group is part of the Australasian Railway Association (ARA). It focuses on the transition to diesel alternatives in the rail industry.[19] This group plays a pivotal role in shaping the future of the rail industry in the context of environmental sustainability. It is specifically focused on developing a "critical path" for the transition from diesel to alternative energy sources. This involves conducting research, planning industry workshops, and discussing other initiatives to support the adoption of zero or low emissions rolling stock.

The group met in February 2024 to discuss the commencement of new research to develop a critical path for this transition. They confirmed plans for an industry workshop to inform the research and discussed other initiatives underway in the rail industry to support the adoption of zero- or low-emissions rolling stock.

A.2.2 ARA Rail Decarbonisation Working Group

This group is part of the ARA. It supports information sharing, advocacy, and discussion to enable the decarbonisation of rolling stock across Australia and New Zealand, identify potential barriers to change and support a national approach to the transition.

This group has a broader focus on the overall decarbonisation of rolling stock across Australia and New Zealand.

It serves as a platform for information sharing, advocacy, and discussion, identifies potential barriers to change, and supports a national approach to the transition to more sustainable practices in the rail industry. By fostering collaboration and dialogue, this group helps to accelerate the rail industry's shift towards more sustainable practices.[20]

A.2.3 ARA Freight Decarbonisation Working Group

This group is part of the ARA. It facilitates information sharing among rail freight operators on their progress towards decarbonisation and identifying opportunities to progress collaborative activity to accelerate the transition. By focusing on the freight sector, this group addresses a significant portion of the rail industry and contributes to the overall goal of decarbonisation.[21]

A.2.4 RISSB releasing new targeted standards

(Charging infrastructure for ZE rolling stock)

RISSB is currently re-writing the Australian standards for railway rolling stock. These standards will include guidelines for charging infrastructure for ZE Rolling Stock, reflecting the industry's move towards more sustainable energy sources. The development of these standards is a crucial step in ensuring the safe and effective implementation of ZE technology in the rail industry.

A RISSB Standard Development Group is currently authoring AS7655 Wayside Electrical Charging Interface for Low Emissions Rolling Stock. The standard will provide guidelines and standardise the methods for charging rolling stock with on-board battery storage.

This includes charging via cables such as currently used in the automotive and road transport industry, reverse pantographs, and overhead catenary.

A.2.5 Feasibility Studies for South Australia and Western Australia

South Australia's Department for Infrastructure and Transport (DIT) is currently conducting a study to determine the most appropriate traction power technologies for routes on the Adelaide Metro rail network.[22] The feasibility and technology study will support future investment decisions as the Department strives to ensure rail operations support the Government of South Australia's objective of net zero emissions by 2050.

Western Australia's Public Transport Authority (PTA) commissioned a feasibility study on practicalities of using hydrogen to power the Perth to Kalgoorlie Prospector service.[23] This was one of the early opportunities to come to market and signalled ambition for operators to explore options and learn more about the complexities of railway decarbonisation.

A.1.6 Dedicated rail decarbonisation conferences

There are several conferences dedicated to rail decarbonisation, which provide exposure to new trends and thinking from a variety of perspectives as part of the ongoing conversation around how to decarbonise Australia's rail industry. The conferences focus on the following key aspects:

- **Industry collaboration**

  Bringing together operators, manufacturers, technology and innovation experts, energy industry innovators and investors to discuss operational and technical aspects of decarbonisation.

- **Case studies and practical applications**

  Sharing case studies and explore practical applications and learnings on the journey to net zero.

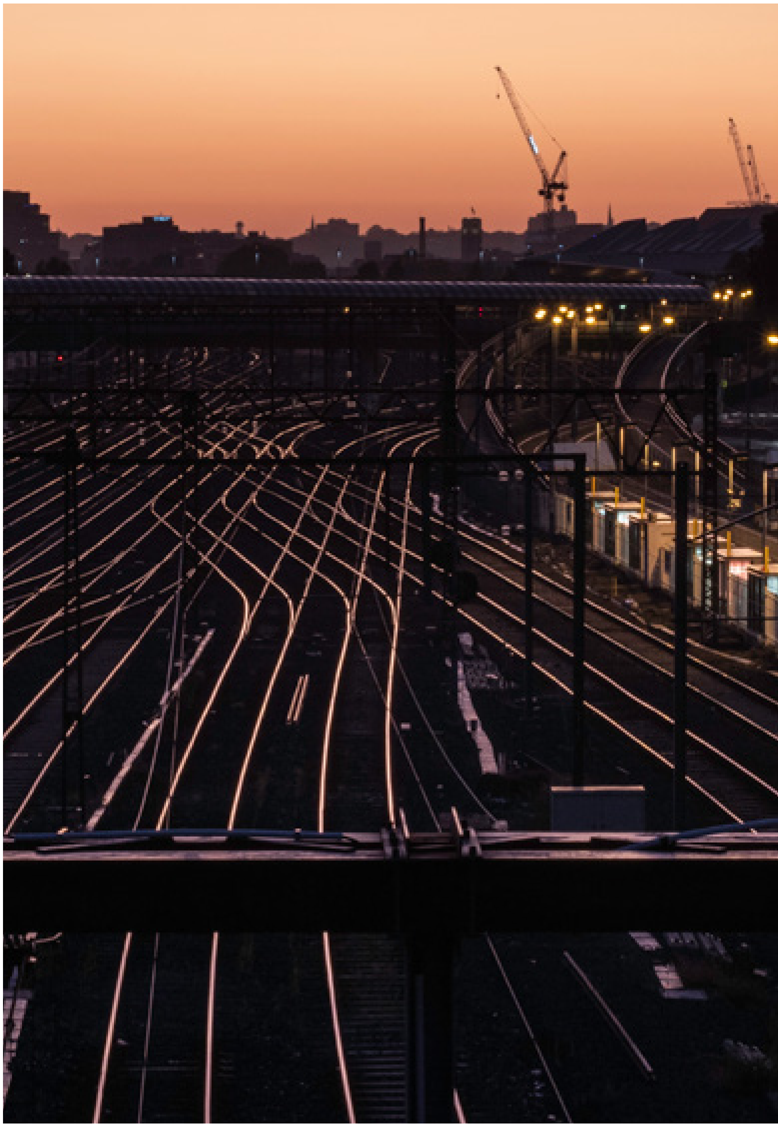
- **Innovative solutions**

  Showcasing the latest innovations and business opportunities, connecting technology, knowledge, and people for an interactive exchange of ideas and solutions.

- **Sustainability goals**

  Addressing rail industry's initiatives to decarbonise operations, assets and supply chains, contributing to economies, the environment and passenger benefits.

These conferences are pivotal in driving the sustainable future of the rail industry.

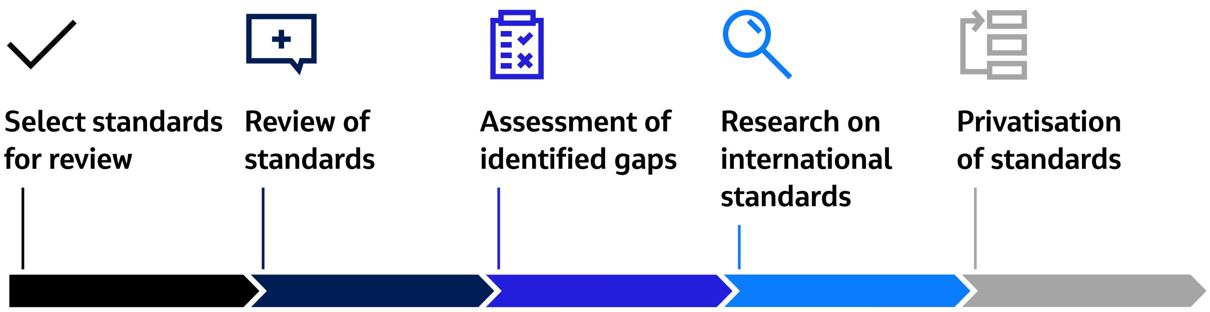


A.3 Review methodology

This section outlines our systematic and comprehensive approach to achieve the objectives of this White Paper. It details the criteria for the selection of affected standards, the methodology for reviewing and assessing these standards, and the process for researching relevant international standards. The following subsections provide detailed descriptions of each step throughout the process.

The review and assessment of standard was an extensive process, involving a dedicated team of eight engineers with a breadth of knowledge and experience across the Australian Rolling Stock industry. The team was moderated by senior engineers with over 20 and 35 years of Rolling Stock experience to ensure that the review was based on extensive industry knowledge and practical experience.

Figure 5: Standards Review Process



A.3.1 Step 1: Identifying the affected standards

Identifying the affected standards was a critical first step in this process. The team reviewed 65 RISSB standards to determine their relevance to ZE technologies. The products reviewed are:

AS 7529.1	Australian Railway Rolling Stock - Fire Safety - Locomotive
AS 7529.2	Australian Railway Rolling Stock - Fire Safety - Freight
AS 7529.3	Australian Railway Rolling Stock - Fire Safety - Passenger
AS 7529.4	Australian Railway Rolling Stock - Fire Safety - Track Machines
AS 7520.2	Australian Railway Rolling Stock - Body Structural Requirements Part 2 - Freight Rolling Stock
AS 7520.4	Australian Railway Rolling Stock - Body Structural Requirements Part 4 - Infrastructure Maintenance
AS 7520.3	Australian Railway Rolling Stock - Body Structural Requirements Part 3 - Passenger Rolling Stock
Guideline	Rail Emergency Management Planning
AS 7527	Rolling Stock Event Recorders
AS 7523.1	Railway Rolling Stock Emergency Equipment Part 1 - Locomotive Rolling Stock
AS 7523.3	Railway Rolling Stock Emergency Equipment Part 3 - Passenger Rolling Stock
AS 7523.4	Railway Rolling Stock Emergency Equipment Part 4 - Infrastructure Rolling Stock
AS 7502	Road Rail Vehicles
AS 7530	Electrical Systems
Code of practice	Light rail network safeworking
AS 7513.1	Rolling Stock Interior Environment Part 1 - Locomotive
AS 7474	Rail industry – System safety
AS 7509	Rolling Stock - Dynamic Behaviour
AS 7510.1	Braking Systems Part 1 - Locomotive Rolling Stock
AS 7510.3	Braking Systems Part 3 - Multiple Unit Passenger Rolling Stock
AS 7510.6	Braking Systems Part 6 - Train
AS 7513.3	Rolling Stock Interior Environment Part 3 - Passenger Rolling Stock
AS 7513.4	Rolling Stock Interior Environment Part 4 - Infrastructure Maintenance Rolling Stock
AS 7722	EMC Management
AS 7511	Onboard train protection systems
AS 7520.1	Australian railway rolling stock - Body structural requirements - Part 1 - Locomotive
AS 7522	Access and egress
Guideline	Condition Monitoring of Rolling Stock
AS 7486	Railway energy storage: Rolling stock onboard electrical energy storage
AS 7482	Railway rolling stock-Heating ventilation and air conditioning (HVAC)

AS 7528	Interior Communications
AS 7521	Interior Crashworthiness
AS 7470	Human Factors Integration in Engineering Design - General Requirements
AS 7533	Driving cabs
AS 7501: 2019	Rolling stock compliance certification
AS 7770	Rail Cyber Security
Code of Practice	Distributed Power Freight Trains
Code of Practice	ECP Braking
Code of Practice	Rail Cyber Security for Rolling Stock & Train Control Systems
Code of Practice	Rail Safety Investigation
Guideline	Derailment Investigation and Analysis
Guideline	Integration of Human Factors in Engineering Design
Guideline	Reliability, Availability, Maintainability (RAM)
Guideline	Rolling Stock Safety Assessment
AS 7450	Rail systems interoperability
AS 7471	Australian rail - Personal protective equipment (PPE) - Minimum requirements
AS 7472	Railway Operations - Management of Change
AS 7473	Complex system integration in railways
AS 7504	Brake Blocks
AS 7505	Signalling Detection Interface
AS 7507	Rolling Stock Outlines
AS 7508	Track Forces and Stresses
AS 7510.2	Braking Systems Part 2 - Hauled Rolling Stock
AS 7510.4	Braking Systems Part 4 - Infrastructure Maintenance Rolling Stock
AS 7514 (Amdt 1)	Wheels
AS 7515	Axles
AS 7516	Axle Bearings
AS 7517	Wheelsets
AS 7519	Bogie structural requirements
AS 7524	Coupler and Draw Gear
AS 7531	Lighting and Visibility
AS 7532	Railway Rolling Stock - Audible Warning Devices
AS 7451	Train integrity
AS 7503	Rail vehicle identification and markings
AS 7518	Rolling Stock Suspension

This step identified 30 current standards that will be impacted by the adoption of ZE technologies, as shown in Table 10. 35 standards will be unaffected.

A.3.2 Step 2A: Scoring each standard

All standards that were assessed as being impacted be ZE technology and requiring updates due to the introduction of ZE technologies were subsequently scored across the following factors:

1. **Age of standard**

   As per RISSB Product Development Procedures ADMIN 4.7 Product and Maintenance each RISSB product has a review period of seven years. In the rating for this white Paper, the oldest standards were assigned the highest rating (5) and the newest standards were assigned the lowest rating (1).

2. **Urgency in relation to industry need and importance**

   The urgency for updates focusses on how quickly the proposed changes should be implemented, with standards requiring urgent action assigned the highest rating (5) and standards only requiring minor updates assigned the lowest rating (1).

3. **Volume of content update required**

   The volume required describes the amount of changes required for each standard, with the lowest rating (1) representing minor changes or updates to referenced documents and the highest rating (5) representing standards that require a rewrite in the light of ZE technology.

4. **Criticality of the system or aspect affected**

   The criticality of the system was evaluated in terms of impacts on safety-relevant systems, with the highest rating (5) assigned to safety critical systems and the lowest rating (1) assigned.

Table 10 provides a description of how the scores were allocated. The individual criteria scores for each standard are in Table 15.

Table 15: Scoring and weighting of criteria

Criteria	Age	Urgency	Volume	Criticality
Weighting / **Score**	**1**	**2**	**1**	**2**
5	9+ years	Major	Overhaul	Major
4	8 years	High	High	High
3	4 – 6 years	Medium	Moderate	Medium
2	2 – 3 years	Low	Low	Low
1	1 year	Minor	Minimal	Minor

A.3.3 Step 3: Weighting criteria

After the scores were assigned to each standard, a weighting was applied to the rankings of **urgency** and **criticality.**

The ranking for **urgency** was given a higher weighing due to its direct correlation with the operational outcomes for rolling stock. Urgency, in this context, refers to the immediate need for attention or action on a particular standard. A higher urgency ranking implies that the standard in question has a significant impact on the operational efficiency and service delivery for rolling stock, and therefore, requires prompt update to incorporate ZE technologies as the urgency of updates may directly impact the speed and success of the transition to ZE technology.

The ranking for system **criticality** was given a higher weighting due to its fundamental role in ensuring the safety of the rolling stock. System criticality refers to the degree to which a system's operation and functionality are deemed crucial or essential for the safe operation of the rolling stock. A higher criticality ranking indicates that the standard plays a vital role in maintaining the safety and integrity of the rolling stock. This becomes even more important when introducing ZE technologies, which must not compromise the safety of the system.

The process of weighting the scores for urgency and criticality highlights their significance in the assessment of rolling stock standards. It ensures that these key aspects are given sufficient consideration, therefore enabling a more comprehensive and accurate evaluation of the standards. This facilitates the implementation of necessary updates and improvements to the rolling stock standards in a timely and efficient manner.

A.3.4 Step 4: Calculating the final priority ranking

Upon completing the process of assigning scores to the various criteria, including the weighted criteria, a basic formula was used to determine the overall priority ranking of each standard.

$$\text{Priority Ranking} = \text{Age} + (\text{Urgency} \times 2) + \text{Volume} + (\text{Criticality} \times 2)$$

Once the formula was applied, each standard received a ranking score. These scores ranged from a minimum of 6, which represents the lowest possible ranking, to a maximum of 30, which represents the highest possible ranking.

The ranking of the standards was then carried out based on these scores. This resulted in a prioritised list of standards, with the standard having the highest score at the top and the one with the lowest score at the bottom.

This prioritisation process plays a crucial role in informing the updates that need to be made to the standards. It helps in identifying the standards that require immediate attention and those that can be updated at a later stage, thereby ensuring an efficient and effective update process. The final order of product updates will be determined by RISSB as part of their work program and may not reflect the sequence shown here. Product users are encouraged to discuss specific needs and requirements with RISSB, as per the normal product update process.

Table 11 outlines the individual criteria scores, including the weighted criteria scores, and total overall scope for each standard.

Table 11: Scoring and priority rankings

		Age	Urgency	Weighted Urgency	Volume	Criticality	Weighted criticality	Priority Ranking
AS 7529.1	Australian Railway Rolling Stock - Fire Safety - Locomotive	5	5	10	4	5	10	29
AS 7529.2	Australian Railway Rolling Stock - Fire Safety - Freight	5	5	10	4	5	10	29
AS 7529.3	Australian Railway Rolling Stock - Fire Safety - Passenger	5	5	10	4	5	10	29
AS 7529.4	Australian Railway Rolling Stock - Fire Safety - Track Machines	5	5	10	4	5	10	29
AS 7520.2	Australian Railway Rolling Stock - Body Structural Requirements Part 2 - Freight Rolling Stock	5	5	10	3	4	8	26
AS 7520.3	Australian Railway Rolling Stock - Body Structural Requirements Part 3 - Passenger Rolling Stock	5	5	10	3	4	8	26
Guideline	Rail Emergency Management Planning	3	4	8	2	5	10	23
AS 7527	Rolling Stock Event Recorders	5	3	6	3	3	6	20
AS 7523.1	Railway Rolling Stock Emergency Equipment Part 1 - Locomotive Rolling Stock	5	3	6	2	3	6	19
AS 7523.3	Railway Rolling Stock Emergency Equipment Part 3 - Passenger Rolling Stock	5	3	6	2	3	6	19
AS 7523.4	Railway Rolling Stock Emergency Equipment Part 4 - Infrastructure Rolling Stock	5	3	6	2	3	6	19
AS 7502	Road Rail Vehicles	4	2	4	4	3	6	18
AS 7530	Electrical Systems	3	3	6	3	3	6	18
Code of practice	Light rail network safeworking	2	2	4	3	4	8	17
AS 7513.1	Rolling Stock Interior Environment Part 1 - Locomotive	5	2	4	2	2	4	15
AS 7513.3	Rolling Stock Interior Environment Part 3 - Passenger Rolling Stock	5	2	4	2	2	4	15
AS 7513.4	Rolling Stock Interior Environment Part 4 - Infrastructure Maintenance Rolling Stock	5	2	4	2	2	4	15
AS 7722	EMC Management	4	3	6	1	2	4	15
AS 7511	Onboard train protection systems	3	2	4	3	2	4	14
AS 7520.1	Australian railway rolling stock - Body structural requirements - Part 1 - Locomotive	2	2	4	2	3	6	14
AS 7522	Access and egress	2	2	4	2	3	6	14
Guideline	Condition Monitoring of Rolling Stock	2	2	4	4	2	4	14
AS 7486	Railway energy storage: Rolling stock onboard electrical energy storage	2	2	4	1	3	6	13
AS 7482	Railway rolling stock-Heating ventilation and air conditioning (HVAC)	2	2	4	2	2	4	12
AS 7521	Interior Crashworthiness	3	2	4	1	2	4	12
AS 7470	Human Factors Integration in Engineering Design - General Requirements	4	1	2	1	1	2	9
AS 7501: 2019	Rolling stock compliance certification	3	1	2	1	1	2	8
AS 7451	Train integrity	1	1	2	1	1	2	6
AS 7503	Rail vehicle identification and markings	1	1	2	1	1	2	6
AS 7518	Rolling Stock Suspension	1	1	2	1	1	2	6

A.3.5 Nominating relevant international standards

In addition to reviewing the RISSB products, research was conducted to identify relevant international standards and good practice that could be used to bridge the identified gaps in the RISSB standards.

The aim was to identify good practice, innovative approaches and effective strategies that had been adopted internationally, in an effort to create value for operators and asset owners while the RISSB products are updated in time.

These findings have the potential to inform the development of RISSB standards and facilitate the incorporation of global best practices into the Australian Rail industry.

A.4 Additional review findings

Review findings for the first eight standards are outlined in the main body of this document. Findings for the remaining 22 standards are outlined below.

A.4.1

Railway Rolling Stock Emergency Equipment Part 1 - Locomotive Rolling Stock

AS 7523.1

Railway Rolling Stock Emergency Equipment Part 3 - Passenger Rolling Stock

AS 7523.3

Railway Rolling Stock Emergency Equipment Part 4 - Infrastructure Rolling Stock

AS 7523.4

The standard suite for AS 7523, which includes Part 1, Part 3 and Part 4, maintains a consistent structure across each standard. The necessary updates for each standard are largely similar, with the primary distinction being the type of equipment each part applies to. Specifically, Part 1 relates to Locomotive Rolling Stock, Part 3 to Passenger Rolling Stock, and Part 4 to Infrastructure Rolling Stock.

Special requirements may arise for emergency equipment associated with either batteries or hydrogen, necessitating further development. However, it might be acceptable to maintain the current standard as it already refers to other existing standards. Should new standards or procedures be developed, they should be incorporated as references in this document.

- **Section 1.7 Referenced documents:**

  This section may require updates to reference additional standards that address ZE technology.

- **Section 5 Fire:**

  It currently only refers to AS 7529, this may need to reference additional standards.

- **Sections 10 Tools and 11 Spares and Repair Items:**

  Both sections may require updates to encompass specific tools, spare and repair items relevant to ZE technologies. It is worth noting that both these sections contain a list of "typical potential tools" and "typical potential spare parts and equipment" respectively. Therefore, it could be argued that the current lists are not exhaustive and may need to be modified based on operating conditions.

A.4.2

Road Rail Vehicles

AS 7502

AS 7502 outlines the safety, design, construction and maintenance standards for road rail vehicles. It details various classifications, compliance requirements and operational guidelines to ensure the safe integration of these vehicles into the rail network.

The standard was released in 2016 and therefore is due for an update. Europe is currently looking at battery powered road rail vehicles (2024) and may soon develop newer standards as a result. Many of the yellow machine or track machine suppliers are based in Europe and the potential for Australian Rail Infrastructure Maintainers (RIM) to procure new ZE vehicles could accelerate the requirement for a suitable standard here. The standard does not contain any references to onboard energy storage or registration processes required for batteries, liquid, or gaseous energy storage solutions.

Dynamic or regenerative braking is not considered for testing or braking rates.

Thermal runaway protection, detection or prevention is not considered as a current risk or hazard. The emergency equipment mandated for the vehicle does not consider hazards associated with onboard energy storage systems.

A.4.3

Electrical Systems

AS 7530

AS 7530 outlines the minimum performance requirements and good practice guidelines for the design, construction and maintenance of electrical systems on rolling stock, excluding locomotives, freight vehicles and infrastructure maintenance vehicles. It is intended to ensure safety of people against hazards and damages, which may arise because of electrical equipment on rolling stock. It covers protection against electric shock, thermal eroding, effective earthing and insulation and some installation and testing procedures.

Modifying the requirements for certain electrical equipment introduced by the inclusion of ZE technology and extending the list of hazards should be considered.

The details provided below may impact individual sections:

- **Section 1.4:**

  The following standards are examples for new standards that should be incorporated in:

  - ***IEC 62864-1:2016*** Railway applications - Rolling stock - Power supply with onboard energy storage system - Part 1: Series hybrid system.
  - ***IEC 62928:2017:*** Railway applications - Rolling stock - Onboard lithium-ion traction batteries.

- **Section 6.1 Circuit and Earthing:**

  Charging circuit and earthing and bonding requirements need to be incorporated.

- **Section 6.7 High Voltage Switchgear:**

  The potential impact on battery current (especially during fast charging, if applicable) and the inclusion of the battery circuit and charging circuit should be considered.

- **Section 6.8 Circuit protection:**

  Details regarding supercapacitors, batteries, and charging circuit protection need to be incorporated.

- **Section 6.9 Capacitors:**

  Details regarding supercapacitors should be incorporated.

- **Section 7.19 Enclosure designs:**

  This section needs to be updated with details and special requirements for batteries and supercapacitors to mitigate potential hazards.

- **Section 8: Testing:**

  Testing for ZE technologies and their operations should be added, or their relevant standards should be referenced in this section.

- **Section 9: Appendix A:**

  New hazards related to ZE technologies should be added, and some hazards should be amended to include ZE technology.

A.4.3.1 Alternative international standards and guidelines

Australian Standard	International Standard / Guideline	Comment
AS 7530 - Electrical Systems **AS 7722 - EMC Management**	IEC 62864-1:2016 Railway applications - Rolling stock - Power supply with onboard energy storage system - Part 1: Series hybrid system	This standard applies to series hybrid systems (electrically connected) with onboard energy storage. It specifies the design, operation parameters, safety recommendations, data exchange, routine and type tests, as well as marking and designation for onboard lithium-ion traction batteries for railway applications.
	IEC 62928:2017: Railway applications - Rolling stock - Onboard lithium-ion traction batteries	This standard specifies the design, operation parameters, safety recommendations, data exchange, routine and type tests, as well as marking and designation for onboard lithium-ion traction batteries for railway applications. It is used for the energy storage system (ESS) for the traction power of railway vehicles.

A.4.4

Light rail network safeworking

Code of Practice

This Code of Practice (CoP) outlines safeworking principles, operational procedures and safety measures for light rail networks, including separating vehicles, managing rail safety workers, and interface with hazardous equipment. It was released in 2022.

The CoP considers onboard energy storage systems (OESS) already, but does not consider gaseous or liquid storage and distribution systems (e.g. Hydrogen). Hydrogen light rail vehicles are being trialled globally and in anticipation of such a system entering ANZ, this CoP should be updated with minor changes to cater for the new technology.

This CoP does include the LRV driver requesting de-energisation of the electrical traction system or onboard power supply, but does not include isolation or shut-off of any gaseous or liquid storage or distribution tanks (e.g. Hydrogen). Managing hydrogen or other storage mediums requires different techniques and requirements to electrical energy systems. This may only require a small update to the section wording to include hydrogen or gaseous systems.

A.4.5

Rolling Stock Interior Environment Part 1 – Locomotive

AS 7513.1

AS 7513.1 details the requirements for the interior environment of locomotives, including aspects such as noise, vibration, temperature and air quality, to ensure both safety and comfort.

The Standard provides both mandatory and recommended practices for new, modified and existing rolling stock, with a strong emphasis on hazard control and alignment with international standards.

In general, ZE technologies have minimal impact on this standard with the only exception being in Section 5.8: In addition to exhaust gases, fresh air intakes should be positioned to avoid ingesting flammable or toxic gases, as might the case for leaking hydrogen or ammonia, or from a battery thermal runaway.

A.4.6

Rolling Stock Interior Environment Part 3 - Passenger Rolling Stock

AS 7513.3

AS 7513.3 outlines the specifications and performance requirements for the interior environment of passenger rolling stock, focusing on factors such as noise, vibration, ride comfort, air quality and temperature to ensure safety and comfort. It includes both mandatory and recommended practices for new, modified and existing rolling stock, aiming to prevent injury and control fatigue among crew and passengers by aligning with existing Australian and international standards.

- **In Section 1.9 definition**

  It is suggested that the definition of battery electric/hydrogen powered multiple units be included.

- **Sections 2.2 Stationary Noise and 2.3 Running Noise**

  There is a need for clarification on whether electric multiple units include battery electric multiple units.

- **Section 5 Fresh Air**

  It is advised that in addition to exhaust gases, fresh air intakes should be positioned to avoid ingesting flammable or toxic gases, which might be the case for leaking hydrogen or ammonia, or from a battery thermal runaway.

A.4.7

Rolling Stock Interior Environment Part 4 - Infrastructure Maintenance Rolling Stock

AS 7513.4

AS 7513.4 describes the requirements for the interior environmental specification and performance of infrastructure maintenance rolling stock. The standard focuses requirements for noise, vibration, acceleration, temperature and humidity, radiation and magnetic fields, to prevent injury and reduce fatigue for crew.

The standard was published in July 2014 and is well overdue for an update. Additionally, the standard is in the old format standard layout.

The standard applies to design, construction and maintenance of infrastructure maintenance vehicles. It currently does not discuss items such as emergency equipment (associated fire extinguishers), alarms, alerts etc.

A minor consideration should be given in addition to exhaust gases, fresh air intakes should be positioned to avoid ingesting flammable or toxic gases, as might be the case for leaking or venting hydrogen or ammonia, or from a battery thermal runaway event.

A.4.8

EMC Management

AS 7722

AS 7722 defines the requirements for managing electromagnetic emissions and susceptibility of devices used in the railway so that all systems used in the railway are electromagnetically compatible. These requirements define the minimum effort required to manage the risk associated with electromagnetic compatibility (EMC) and to ensure compliance with legal and regulatory, safety and reliability requirements; situations may require more detailed assessment.

This standard could potentially be impacted by the inclusion of ZE technology, but no significant modifications are necessary as it refers to IEC 60571 / EN50155 and IEC 62336-3-2 as overarching standards. These referenced standards need to incorporate the impact of ZE technologies and related tests, which in turn directly influence EMC testing of rolling stock.

The EMC plans and tests, which are to be managed by the responsible parties as referred to by this standard, also play a role, so no major changes are required in this standard. These documents need to account for any new ZE technology and its impact on the rolling stock and infrastructure.

Potential impact on sections:

- **Section 1.6 Referenced documents:**

  The following standards should be incorporated:

  - ***IEC 62928: 2017*** Railway applications - Rolling stock - Onboard lithium-ion traction
  - ***IEC 62864-1:2016*** Railway applications Rolling stock - Power supply with onboard energy storage system - Part 1: Series hybrid system
  - Include EMC compliance with HV mobile charging structures (such as mobile charger). Refer to AS 7655 (under development)

- **Appendix A: EMC threat matrix:**

  New hazards and threats associated with ZE technologies should be incorporated.

A.4.8.1 Alternative international standards and guidelines

Australian Standard	International Standard / Guideline	Comment
AS 7530 - Electrical Systems **AS 7722 - EMC Management**	IEC 62864-1:2016 Railway applications - Rolling stock - Power supply with onboard energy storage system - Part 1: Series hybrid system	This standard applies to series hybrid systems (electrically connected) with onboard energy storage. It specifies the design, operation parameters, safety recommendations, data exchange, routine and type tests, as well as marking and designation for onboard lithium-ion traction batteries for railway applications.
	IEC 62928:2017: Railway applications - Rolling stock - Onboard lithium-ion traction batteries	This standard specifies the design, operation parameters, safety recommendations, data exchange, routine and type tests, as well as marking and designation for onboard lithium-ion traction batteries for railway applications. It is used for the energy storage system (ESS) for the traction power of railway vehicles.

A.4.9

Onboard train protection systems

AS 7511

AS 7511 sets the standards for onboard train protection systems (OTPS), including their application, design and maintenance. The Standard highlights the importance of interoperability, safety management and the integration of OTPS with other rolling stock systems, all aimed at improving rail safety and performance.

Only minimal impact to AS 7511 in the case of integrating Battery or Hydrogen Systems, or traction replacement has been identified.

While no major technical constraints were found in this standard, there may be a significant change in current operations and infrastructure requirements. This is not included in this review but highlighted for awareness only.

In conclusion, the standard may not need to change as long as the design of ZE technologies does not interfere with the current operation of OTPS. The integration design of ZE technologies and OTPSs should be fully compatible electrically, mechanically and during all modes of operation in its lifecycle in the railway environment.

A.4.10

Australian railway rolling stock - Body structural requirements - Part 1 – Locomotive

AS 7520.1

AS 7520.1 outlines the structural requirements for Australian locomotive bodies, detailing the standards for design, construction and maintenance.

It emphasises the importance of structural integrity, safety in extreme conditions and compliance with various industry standards to ensure the safe performance of locomotives.

In general, ZE systems do not affect structural requirements, except for the following:

- **Section 4 Maintenance:**

  A warning should be provided that in case of on-board storage, this should be isolated, and an assessment should be conducted to determine whether it is necessary to remove the energy storage system (ESS) before handing it over to the structural repair crew. If not removed, a certificate of "Safe to Work" should be provided to the repair crew, noting any special limitations on access or where work can be conducted.

- **Section 4.2.3 Jacking and Lifting:**

  Any twisting of the underframe while lifting should not impose loads or deflections on the ESS support structure which might cause structural or electrical failure.

- **Section 9.2 Rollover performance – locomotive rolling stock:**

  The ESS should be added to the principal components (engine, alternator, compressor) which should be retained in the event of derailments, collisions, and rollovers.

In addition to the brackets and other components for exterior mounting, an extra category for internal mounting of the ESS should be added. While these may still be retained within the body after a structural failure, moving items which could cause shorting, arc-flashes or even fire.

A.4.11

Access and egress

AS 7522

AS 7522 establishes the criteria for access and egress in a variety of rolling stock including locomotives and vehicles for freight, passengers and infrastructure maintenance. It highlights the significance of ensuring safety, efficiency and accessibility, with a particular focus on accommodating passengers and workers with disabilities.

While there is no impact on the standard, one important consideration has been identified – the assurance of a safe evacuation path during emergencies. For example, in the event of battery thermal runaway or the release of toxic gases like ammonia, it is imperative that the evacuation route avoids hazardous areas.

A.4.12

Condition Monitoring of Rolling Stock

Guideline

This guideline elaborates on the methods, measures and technologies employed to oversee and manage railway operations. It also explores the progression of condition monitoring, data management and the significance of wayside monitoring systems in the Australian rail industry.

ZE technology introduces new risks to the railway as an emerging system. This guideline may require a comprehensive update to ensure these risks are mitigated through condition monitoring.

A dedicated section should be incorporated, focusing specifically on the systems used for monitoring battery systems (state of health, charging cycles, thermal management) and hydrogen systems (fuel cell performance, hydrogen purity, pressure integrity).

Given the unique risks associated with ZE technology, an 'Emergency Response and Safety' section could be beneficial. For hydrogen systems, in particular, a section on emergency response and safety monitoring is recommended. This should encompass elements like hydrogen leak detection, emergency shut-off systems, and safety protocols for managing high-voltage battery systems.

Below are explanations per section of the standard:

- **Section 1 Introduction:**

  While there is no impact, the introduction could emphasise the need for decarbonisation or provide an environmental overview, as ZE technology is still in the infancy stage.

- **Section 2 Rolling Stock CM (Wayside):**

  This section should include condition monitoring for battery health, state of charge, and integrity for Battery ZE technology. For Hydrogen ZE technology, it's crucial to monitor the condition of hydrogen tanks, fuel cells, and associated piping and equipment with a focus on detecting hydrogen leaks and ensuring the integrity of high-pressure components. The existing CM data systems section should be enhanced to include software tools and data analytics techniques specifically designed for interpreting data from ZE technology. This could involve predictive analytics for battery life expectancy, fuel cell efficiency and other critical parameters.

- **Section 3 Vehicle Identification:**

  This section refers to AS 7503 which already included specific identification for alternative energy source vehicles (Section 9.4), so no further updates are required in this section.

- **Section 4 Train Inspection:**

  Inspection procedures should include specific checks relevant to ZE technology, such as inspecting battery casings for damage or swelling and inspecting fuel cell stacks and hydrogen storage systems for Hydrogen ZE technology.

- **Section 5 Couplers, Draw Gear, and Undercarriage:**

  Modifications might be necessary to accommodate for the additional weight or distribution differences in ZE technology, particularly with heavy battery packs.

- **Sections 6 and 7 Bearing and Wheels:**

  The additional weight of ZE technology could lead to different wear patterns on bearings and wheels, suggesting the need for adjusted monitoring practices.

- **Section 8 Brakes:**

  Considering the regenerative braking systems common in electric and hydrogen fuel cell trains, this section should address the unique aspects of monitoring these systems.

- **Sections 9 and 10 Bogies, Bogie Geometry and Tracking:**

  The altered weight distribution in Rolling Stock with ZE technology might affect bogie performance and alignment, necessitating revised monitoring and maintenance approaches.

- **Section 11 Load Evaluation at Line Speed:**

  The loading patterns and dynamics of Rolling Stock with ZE technology, especially those with heavy battery packs, will differ, suggesting the need for adjusted evaluation methods.

- **Section 12 Pantographs:**

  For Battery ZE technology that use overhead lines, the condition monitoring of pantographs remains relevant. For Hydrogen ZE technology, this section might be less applicable unless they also utilise overhead electric power in some capacity.

- **Section 13 Environmental:**

  Considerations for monitoring environmental impacts specific to ZE technology, like battery temperature extremes or hydrogen fuel storage safety should be included.

- **Section 14 Wayside Site Considerations:**

  Adjustments to wayside monitoring equipment and site setup might be required to accommodate the specific needs of monitoring ZE technology.

- **Section 15 Case Studies:**

  Incorporating case studies related to ZE technology could provide real-world examples of challenges and solutions in monitoring these systems.

A.4.13

Railway energy storage: Rolling stock onboard electrical energy storage

AS 7486

AS 7486 provides guidelines for Australian rolling stock operators (RSOs) to specify and effectively use onboard batteries and electric double-layer capacitors primarily for traction purposes (propulsion and braking). The standard ensures safe, reliable and efficient use of ESS throughout their operational life in the Australian rail context. This standard is already in existence and specifically about battery storage. However, the following points are suggested as possible improvements.

- **Section 2.2 Description of the ESS within rolling stock:**

  The block diagram Figure 3 shows the battery as a component of the BMS. However, considering the battery's significance, it could be beneficial to represent it as a separate component.

- **Section 3.3 Operational requirements for energy and power performance:**

  The final paragraph says that the ESS should be removed from service if it fails to meet the minimum performance thresholds. It might be more practical to consider potential remedial measures which could enhance the performance above the specified minimum and therefore avoiding the need to replace the whole battery.

- **Section 3.10 Maintenance**

  - ***(b):*** Along with ease of access, the design should also aim to minimise risks associated with maintenance activities. For example, dropping a tool during maintenance which could cause a flash. Therefore, all terminals should be protected.

  - ***(a):*** Note that there is a second 3.10(a) after the first list. The requirement to discharge the whole battery before maintenance could be overly onerous, especially considering the large energy capacity of locomotive batteries. For instance, a large locomotive battery may be 14.5 MWh, which is a lot of energy to discharge.

Instead, as large batteries are made up of several stacks, which in turn are made of smaller assemblies, it should be possible to isolate and discharge only a portion of the battery. Furthermore, given that Li-ion batteries should not be fully discharged and assuming the manufacturer has designed a safe handling process at the module level, discharging may not be necessary at all.

- **Section 4.2 (a) Collision and Crashworthiness**

  While passenger cars may be designed with crumple zones, locomotives and freight wagons typically are not. Therefore, it could be beneficial to include an additional requirement that batteries should not be placed within, e.g., 2m, from the end of the vehicle.

- **Section 4.4 Thermal runaway, fire and explosion**

  - ***4.4.1(a):*** It might be prudent to include an explicit requirement that the battery should be of a type which is not prone to thermal runaway.
  - ***4.4.2(c):*** Given the likelihood that battery locomotives will be operate in mixed consists with diesel-electric locomotives, it is inevitable that diesel fuel will be present. This factor should be considered in the safety considerations.

A.4.14

Railway rolling stock-Heating ventilation and air conditioning (HVAC)

AS 7482

AS 7482 provides heating, ventilation, and air conditioning (HVAC) design principles, comfort parameters and test requirements for new and modified locomotive, freight, passenger and infrastructure maintenance rolling stock.

It aims to ensure passenger comfort, system efficiency, and compliance with safety and environmental regulations in the Australian rail industry.

There is minimal potential impact on this standard as ZE technologies or equipment will not impact design or operation of HVAC on rolling stock. The only impact that needs to be considered is the design requirements for fresh air intake when hydrogen or ammonia are used as fuels. The design should ensure that fresh air inlets avoid drawing in toxic or flammable gases, such as leaking hydrogen or ammonia, gases released by battery thermal runaway, or exhaust gases. The fresh air intake should be equipped with sensors to detect any leakage from the fuel tank and should automatically shut off the fresh air intake fans and louvre in response.

A.4.15

Interior Crashworthiness

AS 7521

AS 7521 outlines the minimum requirements for the interior crashworthiness of rolling stock to minimise injury risk during accidents. It covers various aspects such as collision energy management, glazing, seating and occupant constraints, ensuring safety in the design and modification of passenger and crew areas.

This standard primarily applies to areas occupied by crew members or passengers. It may be assumed that any energy storage equipment would be installed outside these areas.

In Section 4.7 reference is made to storage of corrosive materials. In instances of ammonia stored on a vehicle, this would typically be located outside the cab. However, it could be beneficial to consider the implementation of leak detection systems to prevent the entry of vapour into the cab and to serve as a warning when exiting the cab.

A.4.16

Human Factors Integration in Engineering Design - General Requirements

AS 7470

AS 7470 supports the integration of human factors into the engineering design process within the rail industry. It focuses on harmonising standards, improving safety and enhancing efficiency through collaboration between stakeholders. The standard is expected to remain unaffected as it is formulated in a universal manner that incorporates all ZE technologies. It is advisable to conduct a review of the RISSB Hazard Guidelines to incorporate potential hazards associated with ZE technology.

A.4.17

Rolling stock compliance certification

AS 7501

AS 7501 provides a standardised method for certifying rolling stock compliance with issued Australian Standard brand standards and referenced standards. It covers new, modified and existing rolling stock, facilitating network registration and ensuring safety and efficiency in rail operations.

Minor changes are needed to include ZE equipment in the provided lists and registers. However, it is noted that there is generally no reference to ZE technology through the Independent Competent Person (ICP) process.

- **Section 8.4 Verification checklist:**

  The list of systems and subjects might need to be updated. This would depend on whether batteries are covered in electrical equipment, or if gaseous or liquid hydrogen falls under a new item referring to OESS. An additional item related to gaseous or liquid storage or distribution systems for fuel, hydrogen, or alternative sources should also be considered.

- **Appendix B Example Data Register:**

  Several updates are suggested due to their potential impact. The Rolling Stock type in B1.1 should be updated to include ZE technology like Hybrid, BEL, BET, tri-mode rolling stock etc. In B1.5, 'primary energy source' could be added to identify battery, capacitors, fuel, electrical, hydrogen systems. In B1.6, 'Battery Nameplate Capacity', 'Battery Usable Capacity' and 'Battery Chemistry' could be added to the electrical characteristics section and should be reviewed for capacitors as well. In B1.13, 'Hydrogen Capacity (gaseous or liquid)' could be added if ammonia is involved. Lastly, in B1.21, new items related to Safety Systems such as fire suppression, fire detection, e-stop, shut-off values etc. should be considered.

A.4.18

Train integrity

AS 7451

AS 7451 is a standard for train integrity in the rail industry. It outlines requirements for preventing uncontrolled train movements, train inspection and carding requirements for vehicles needing repair, aiming to ensure safe and reliable operations. The standard is anticipated to stay relevant as its written in a general manner that includes ZE technologies. It is recommended to undertake a revision of the RISSB Hazard Guidelines to include potential risks linked with ZE technology.

A.4.19

Train identification and integrity

AS 7503

AS 7503 describes the requirements for the identification and markings on new and modified rolling stock, including locomotives, freight vehicles, passenger vehicles, light rail vehicles and infrastructure maintenance vehicles. The Standard covers the information to be displayed on the vehicle body, data panels, bogies, manufacturers plates, wheelsets and AEI tags, as well as the format, size, contrast and maintenance of the markings.

Appendix A, Table A2, might require updating to include specific characters for hydrogen tank cars and battery electric tenders as these differentiate from common tank vehicles.

Additionally, the Hazard Register should be reviewed and updated to incorporate hazards associated with ZE technology.

A.4.20

Rolling Stock Suspension

AS 7518

AS 7518 is the Australian Standard that outlines the requirements, recommendations and guidance for rolling stock suspension, including the design, installation, maintenance and requalification of springs, dampers and other suspension components to ensure safety and performance. It applies to various types of rolling stock, with specific provisions for compliance, and includes commentary for clarification, aiming to reduce the risk of hazards associated with suspension component failures.

In the context of ZE systems, one possible impact has been identified. Although highly unlikely, it is important to assess the potential consequences if resilient suspension components are near a potential source of fire while the vehicle is in motion. This consideration becomes particularly relevant when a vehicle is being converted to ZE system.

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