# Insights from ICMM's Innovation for Cleaner, Safer Vehicles (ICSV) initiative

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## Accelerating the Adoption of Zero-Emission Haul Trucks in the Mining and Metals Industry: Creating the conditions to innovate at speed and scale

Climate change affects human wellbeing and environmental health in every country on every continent. Greenhouse gas (GHG) emissions must be reduced at pace and in absolute terms to meet the climate goals of the Paris Agreement.

Mining is at the heart of the global decarbonisation movement, providing the minerals and metals needed for renewable energy technologies, clean mobility, and green infrastructure. Without these materials, it will be difficult, if not impossible, to achieve net zero-emission targets by 2050, or wider UN Sustainable Development Goals (SDGs) by 2030.

But access to these materials alone is not enough. Minerals and metals are the foundation of almost all industries, so these goals will remain unattainable without the mining and metals industry's own decarbonisation journey.

Central to this challenge is surface haul trucks. There are around 28,000 large mine hauling diesel trucks in operation globally, collectively emitting 69 million tonnes of $CO_2$ every year.[1] And this is only set to increase based on more mines with lower ore grades that require trucks to go even deeper. Unabated, this number is projected to grow to over 77 million tonnes of $CO_2$ by 2030. This is roughly equivalent to the emissions of over 15 million passenger cars,[2] and can represent up to 25 per cent of the mining industry's direct (scope 1) source of emissions at mine sites.[3]

Transporting vast quantities of waste rock, ore and bulk materials across mine sites in haul trucks, often the size of a small house, has its own unique requirements from that of passenger vehicles and is therefore more complicated to decarbonise.

1. Source: Rocky Mountain Institute 2019. Added note: 54Mt for Scope 1, and an additional 15Mt $CO_2$ for Scope 3, based on 25 billion litres of diesel fuel
2. A typical passenger vehicle emits about 4.6 metric tons of carbon dioxide per year. This number can vary based on a vehicle's fuel, fuel economy, and the number of miles driven per year (EPA).
3. https://www.mckinsey.com/industries/metals-and-mining/our-insights/creating-the-zero-carbon-mine

## The journey towards zero-emission alternatives

Electric and hydrogen fuelled trucks offer alternatives to more traditional diesel-powered transportation used at surface mining operations. Progress in implementing these alternatives is evident across the globe, with noteworthy examples found at ICMM member pilot sites. These include at Boliden's Aitik and Kevitsa mines, Vale's Água Limpa and Sorowako mines, and Anglo American's Mogalakwena mine.

There is no universal or quick fix solution. Each site has its own unique set of challenges and potential solutions depending on several different factors such as, the commodity being mined, shape of the ore body, mine layout and available power supply. But there are common areas where collaboration can establish the conditions needed to scale solutions and innovate faster.

This is where ICMM's Innovation for Cleaner, Safer Vehicles (ICSV) initiative comes in. The collaboration, which was launched in 2018, brings ICMM mining companies together with original equipment manufacturers (OEMs) and the technology suppliers who design, supply, operate or maintain diesel-powered haul truck fleets deployed at mine sites.

One of the ambitions of the ICSV initiative is to enable zero carbon solutions for mobile equipment at global scale by 2030 with the aim of full adoption by the industry by 2040.

To do so, the initiative provides a non-competitive, collaborative space to accelerate adoption of zero-emission haul truck fleets and other mobile solutions:

— Identify the critical conditions to accelerate development.

— Encourage wider trialling and scaling to promote learning across the industry.

— Develop the strategies and tactics needed to minimise the operational impacts resulting from the transition of diesel-powered trucks to low/zero-emission fleets.

  - This includes tackling key challenges through option and design modelling with the goal of providing operational guidelines to members and the wider

mining and metals community. This analysis can also serve as a recommended approach for other industries to take inspiration from as they commence their own decarbonisation journeys.

- Aspects include impacts on truck fleet size and number, the influence of haul distances on next generation power-units (e.g., batteries, fuel cells, etc.) truck payload (tonnage of material transported) class considerations and how mine pit shapes and sizes influence the trucks' recharging/refuelling specifications.

Address remaining challenges in truck design and charging infrastructure with existing and new ICSV participants.

One critical challenge beyond the initiative's scope is the need to increase the supply of green fuel. Governments, regional authorities, mineral extraction/exploration contract organisations and financiers need to collaborate to enhance capacity to adopt these zero-emission haul trucks at scale as well as ensure that the zero-emission solution at the mine does not simply move emissions to another location.

To illustrate, replacing the 30 billion litres of diesel used globally in 2023 by large haul mining trucks with low carbon equivalents[4] would require roughly 70% of Australia's current electricity demand.[5] Achieving this through solar farms would require an area nearly the size of London.[6] Alternatively, transforming these diesel trucks into green-hydrogen powered fuel-cell trucks would require enough water to fill around 28,000 Olympic-size swimming pools annually.[7]The quantity of water needed for green hydrogen production is a critical issue for regions where water is not abundantly available.[8]

This report outlines the ICSV initiative's unique innovation model and approach and sheds light on the lessons learned, and remaining challenges.

It drills down on three themes:

1. **Transition to zero-emission haul trucks**
2. **Infrastructure**
3. **Evolving company culture**

Most importantly, it highlights the window of opportunity to turn these big challenges into transformational opportunities through collaboration.

# ICSV's unique innovation model

## Overview of the initiative

ICMM brings together a third of the global mining and metals industry to enhance contribution of mining and metals to sustainable development. In this spirit, in October 2018 ICMM launched the ICSV initiative to accelerate action in three key areas: reducing greenhouse gas emissions, exposure to diesel exhaust particulates and fatalities from vehicle interactions.

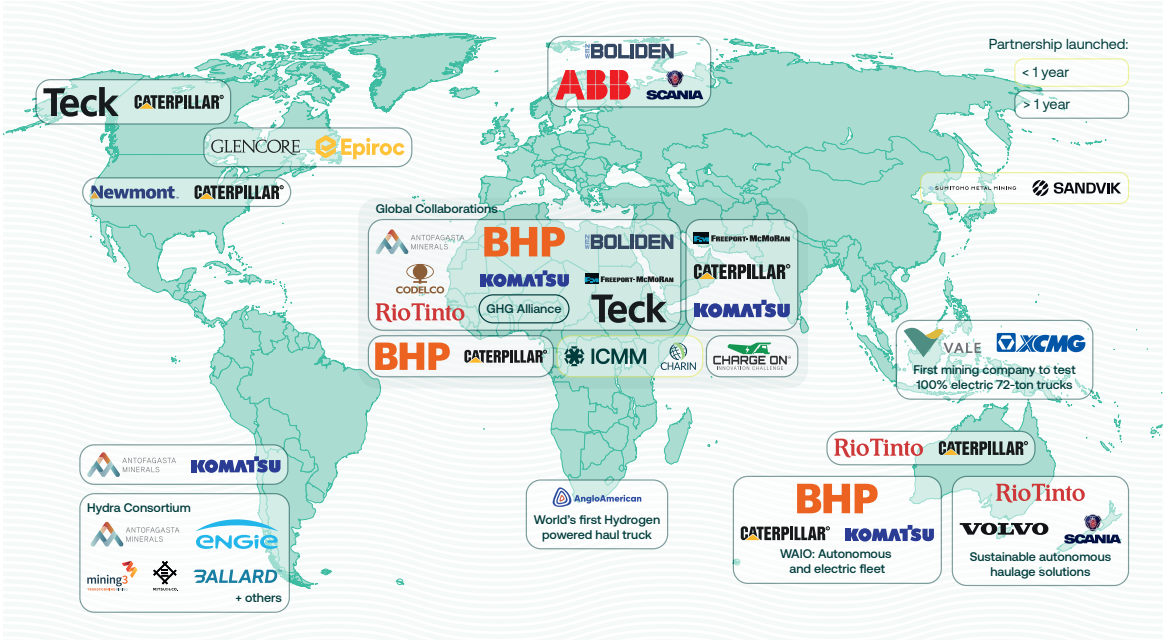
Leveraging the strength of partnerships to bring diverse viewpoints and capabilities together, the initiative is demonstrating how the power of collaboration can help to build trust that in turn concentrates intellectual and financial resources, bridges differences and builds the confidence needed to fast-track development and implementation of solutions.

The initiative has been fundamental in creating an environment that encourages knowledge sharing which has led to faster innovation and a willingness to challenge established thinking as well as accelerated the development and availability of zero-emission haul truck solutions.

This work started with conversations aimed at fostering operational and technological innovations, leading to the development of Maturity Frameworks designed to assess the current and future desired status of operations. The journey continued with the establishment of a knowledge hub. These first steps evolved into concentrated effort to study and glean insights from pioneering sites, accelerating the widespread adoption of innovations.

4. Wood Mackenzie Emissions Benchmarking Tool, which includes scope 1 and 2 emissions from site to gate (refinery or smelter) for the following commodities: steel, iron ore, coal (thermal and met, includes methane), zinc, lead, copper, nickel, lithium, aluminium, gold.
5. https://www.energy.gov.au/publications/australian-energy-statistics-table-o-electricity-generation-fuel-type-2021-22-and-2022
6. Approximately 15,800 solar farms (79 GW @ 25% capacity factor assuming 5MW covering ~25 acres each), which will need ~1600 sq. km land.
7. Approximately 70,000ML water annually to produce Green hydrogen.
8. While some water used in the production of green hydrogen will be released back into the atmosphere when the fuel is used (water vapor in tailpipe emissions), water abstraction remains a critical constraint for areas of water scarcity.

Figure 1. Examples of ICSV participants and partnerships growing momentum for accelerated uptake




Ongoing collaborations[9] are actively identifying solutions to specific bottlenecks, unlocking barriers to large-scale implementation, and supporting the development of solutions for global market uptake.

In essence, the success of the ICSV initiative lies in its ability to reduce uncertainty and accelerate action by creating a non-competitive space for OEMs and mining and metals companies to collectively explore innovative solutions.

This outcome has been made possible through the direct leadership of CEOs, the establishment of a corporate-level Steering Committee and technical expertise of working group members. The critical mass of approximately 650 member sites globally has played a pivotal role in instilling investment confidence amongst partner organisations and faster technical progress.

## Approach and partnerships for reducing GHG emissions

Efforts to accelerate solutions critical for reducing the GHG emissions of surface mining haul trucks have been particularly successful. Thanks to the proactive engagement of ICMM members, there has been a 'pull' effect, prompting investors and governments to expedite research and development funds for zero-emission solutions. Members have already established collaborations to pilot breakthrough solutions at sites with the right conditions for implementation.

We are now anticipating that zero-emission haul trucks will be available at scale on sites before 2030 rather than by 2040, which had previously been considered an ambitious target. The key constraint is operational readiness and the presence of the right conditions at site level to enable the transition.

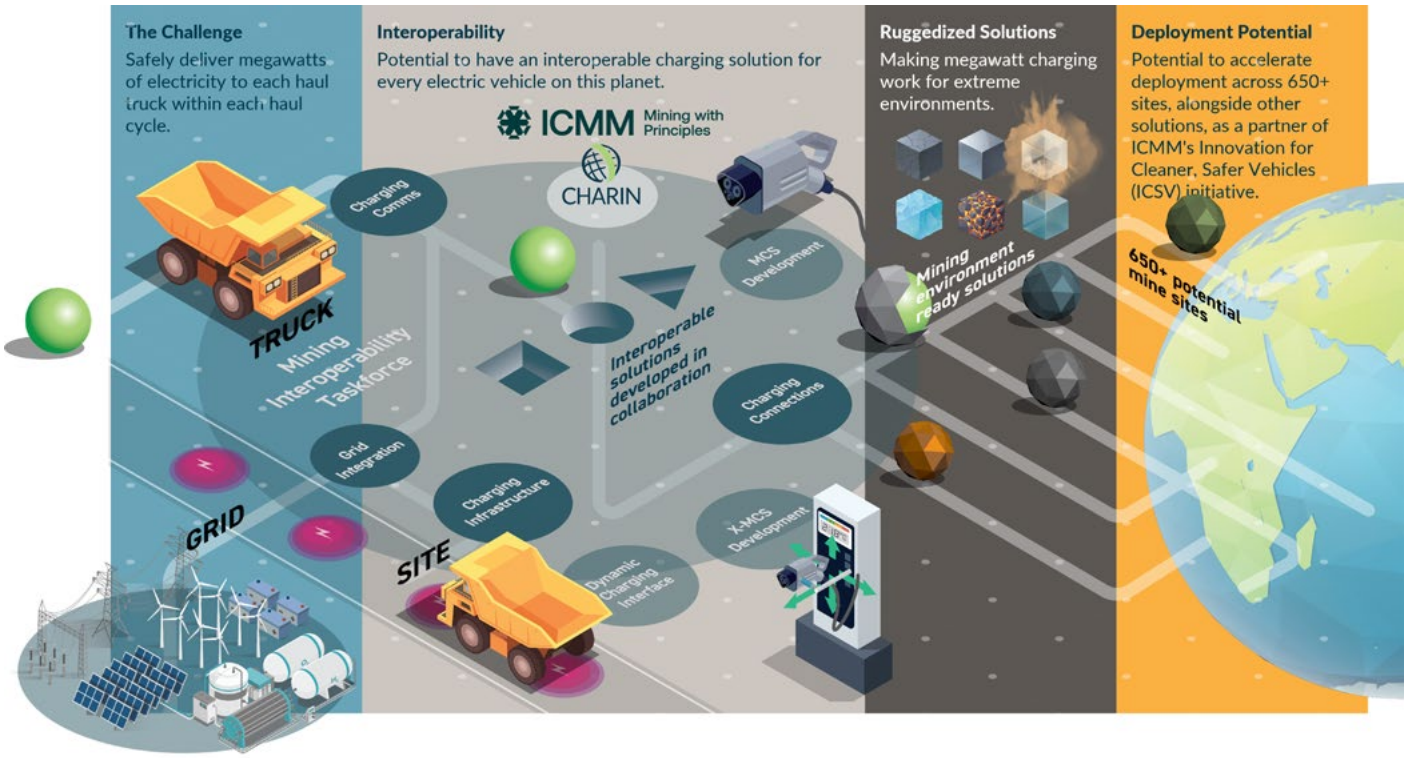
This advancement is being driven by an increasingly competitive dynamic across OEMs but also various partnerships around the world that are tackling critical bottlenecks hindering adoption of solutions. Among these is a collaboration between ICMM's ICSV initiative and CharIN e.V.[10] which is focused on overcoming the global challenge of charging interoperability (the state where any electric haul truck can be charged at any charging station).

The crux of the matter lies in the necessity for haul trucks from different suppliers to seamlessly utilise the same charging stations. This requires defining uniform requirements and standards to allow for the charging interoperability of different infrastructure components.

This approach – of identifying common global challenges faced by most mine sites testing zero-emission haul trucks and then building partnerships to jointly tackle them – is a key responsibility of the ICSV initiative. The partnership with CharIN evolved from the 'Charge On Innovation Challenge': a platform for solution providers and technology innovators from across different sectors to work with the mining industry, with nearly half of ICMM members among its participants, to devise novel battery-electric truck charging solutions that address charging interoperability.[11]

9. https://www.icmm.com/en-gb/case-studies/2022/innovation/accelerating-implementation-of-zero-emission-vehicles
10. https://www.icmm.com/en-gb/news/2023/charin-mining-taskforce-with-icmm
11. https://chargeoninnovation.com/winning-technology-innovators-announced/

Figure 2. CharIN Mining Taskforce to define requirements, pilot, and test the technical capabilities of the interoperable ruggedised charging solutions in mining environments.[12]




Another initiative is the GHG Komatsu Alliance, a collaboration that counts ICMM company members Antofagasta Minerals, Boliden, BHP, Codelco, Freeport-McMoRan, Rio Tinto and Teck Resources as founding participants. Through this framework, partner companies actively collaborate on product planning, development, testing and deployment of the next generation of zero-emission mining equipment and infrastructure. The alliance's initial target is advancing Komatsu's power agnostic haul truck concept that can run on a variety of power sources.

Beyond batteries, hydrogen as a replacement of diesel is also an area of interest among some ICMM company members. Latest studies[13] highlight the potential of green hydrogen as the 'energy of the future'.

## Transition to zero-emission haul trucks

The shift from diesel to full zero-emission haul trucks will not be made in a single leap. As trucks are replaced, each mine site operation will need to address several questions:

— What are my near-term emissions reduction targets and how do trucks fit in at the time of replacement?

— What are the key conditions my operation needs in place to move to zero-emission truck systems?

— What truck systems can my operation support over time?

Currently, mining companies have several options commercially available to lower, but not completely eliminate emissions. Each solution comes with its own pros and cons considering costs, fuel availability, mine plan and ore body suitability. OEMs selling surface mine trucks offer the following 'off the shelf' solutions:

— Diesel/electric hybrid haul trucks in all haul truck classes
  - The addition of electrified overhead trolley systems to offset additional diesel consumption, especially on haul ramps.

— Haul trucks using alternative fuel types ranging from 100% equivalent drop-in fuels to conversion kits

12. https://www.charin.global/news/charin-launches-new-mining-taskforce-in-partnership/
13. https://www.angloamerican.com/our-stories/innovation-and-technology/green-hydrogen-latest-studies-highlight-potential-of-energy-of-the-future

- Natural gas or dual fuel (diesel and natural gas)
- Biofuel diesel
- Renewable diesel

— Retrofitting trucks with proliferating low carbon powertrain solutions.

Operations evaluating these near-term solutions will need to start thinking about what kind of future low-emission, or zero-emission, haul trucks – or a mix of both – could best fit into their particular operations. Considering trucks average 60,000 to 70,000 operating hours, lasting 10 to 12 years or fewer, depending on how much units are operated or how well they are maintained, the next generation zero-emission haul trucks are just over the horizon.

For solutions like trolley-assist technology, which reduces local diesel emissions through use of overhead electricity supply lines, there are infrastructure and logistical challenges relating to the location of trolley-lines/poles and substations. So, in these cases, an interim approach may be needed.

Consideration needs to be given to whether there are likely to be changes in haul-routes in the near future. Changes in haul road configuration are harder to adapt to when using trolley-assist technology as lines are laid to a predefined configuration that will take time, planning and investment to change.

“Planning is bringing the future to the present so that you can do something about it now,” (Alan Lakein). This quote rings true as miners should use the present window of time to plan, prove and scale future site specific zero-emission haul trucks solutions. Considerations include:

— Completing mine electrification assessments to develop site roadmaps, including simulations.

— Investigating technologies and understanding selection and design aspects including haul truck power plants, charging systems, battery systems, cooling requirements

— Researching potential environmental limitations when operating zero-emission systems including cold to hot temperature extremes

— Designing on-site energy infrastructure and working with grid or other third-party providers to ensure adequate power is available in case there is a need to electrify other equipment, such as prime earthmovers (moving away from diesel hydraulic shovels and front-end loaders), dozers, graders, scrapers, and water trucks.

— Assessing zero-emission haul truck fleet integration into current fleets and into wider mine operations now and into the future

— Considering how the vast amounts of data that will be generated will be used or integrated into existing systems.

— Understanding:
  - Human resource requirements from management to maintenance and operations as well as challenging traditional shift lengths

  - How carbon schemes could play a role for economic evaluations
  - Options for short versus long life mines
- Assessing capital and operating costs though discussions with OEMs and other service providers
- Planning solutions around existing mature mine sites
- Considering how to futureproof greenfield mines while retrofitting existing mines.
- Evaluating safety considerations and necessary policy development
- Working with OEMs and other providers to understand future supply chain bottlenecks.
- Understanding shipping and storage requirements (e.g., batteries, spare parts, combustible fuels etc.)
- Understanding support strategies from OEMs for transition to zero-emission haul truck fleets to:
  - Technical support, e.g. specialised tooling
  - Storage and handling requirements for batteries and fuel-cells in dusty, rugged, humid, and harsh environmental conditions at mines
  - 'Outside of the box' business models including 'batteries as a service' (similar to vehicle leasing)
  - Commissioning and performance assessment

To achieve the ambition of the ICSV initiative, the mining and metals industry needs to assess the trade-offs between infrastructure and operational impacts. Ultimately, decisions over capital (CapEx) vs. operational (OpEx) expenditure will be informed by productivity assessments (machine utilisation), total cost of operation (TCO) and cost-per-tonne (CPT) as well as risk appetite at each mine site.

Across ICMM member companies, we can already see some of the steps being taken to manage and mitigate these considerations. For example, over half a dozen member sites across Chile, operated by Codelco, Anglo American, Antofagasta Minerals and BHP, are showing that it is possible to sustainably roll out zero-emission solutions at scale. Chile is a leading jurisdiction as the country has significant capacity for renewable power.

They are teaming up to introduce zero-emission solutions supported by advances in renewable electricity generation at site level or in combination with national green hydrogen plans. These infrastructure developments are allowing for trolley, battery-electric and hydrogen fuel-cell vehicles to be introduced in the region.

# Infrastructure

## Providing the conditions to power zero-emission haul trucks – at the mine level

Under today's lens, diesel truck infrastructure requirements are simple when compared against the shift and build up required for zero-emission haul trucks. Diesel fuel is readily transported to mine sites and can be stored safely in containers for distribution – simply drive up, fill the tank and you're ready for a shift or two. Employee training is minimal. This is not the case for zero-emission haul trucks.

An entirely new infrastructure is required to accommodate the next generation of mine haul trucks. The fuel is either electricity and/or high-pressure hydrogen. The once simple act of refuelling now involves high voltage charging (for battery trucks) or pumping high-pressure hydrogen (for fuel-cell trucks) into pressurised and thermally insulated fuel tanks.

Another critical consideration is where and what miners are responsible for beyond the truck. Can OEMs supply the truck, charging/refuelling infrastructure, and substations/hydrogen storage facility as part of the fleet packages or do miners just buy a truck and are on their own to plan and work with other infrastructure suppliers? Defining boundaries for scope, cost and responsibility needs to be considered.

## Powering zero-emission haul trucks – at the power grid level

The industry is also working in parallel to decarbonise its energy supply, a critical enabler for any zero-emission solution to be successful. This brings its own infrastructure challenges that need to be addressed to meet the needs of miners, including pragmatic generation and transmission planning at the mine and regional level, assurance of adequate green power

supply, access to capital to develop electricity infrastructure, and proper regulatory frameworks and timelines.

Planning for energy supply and the wider grid is complicated by the generation interplay between intermittent renewable, energy storage and baseload fossil fuel supply. Growing green energy supply, to service not only mines but other industries, demands strong strategic regional planning as well as a deep understanding of asset load (energy consumption) requirements.

There are many power solutions available to miners navigating a low carbon world. Depending on risk appetite, miners can for example, own and operate ”off-grid” or remote power plants to meet their needs, invest with other third parties to supply power under contractual arrangements or develop a regional microgrid.

Understanding future financial and operational boundaries for power supply is also important. Does the miner’s obligation begin at the mine site substation or is it much wider and in extreme case also includes power generation?

The most popular approach by miners currently is to sign renewable power purchase arrangements (PPAs) with existing or new power producers for electricity supply without the capital commitment. Whatever approach is taken, careful consideration for current and future energy requirements is necessary. This should include not only the required generation of electricity or production of green energy alternatives but also all the electric grid reinforcement and expansion needs as well as energy supply chain requirements.


## Interoperability and charging

Development of zero-emission haul trucks is progressing at a rapid pace, buoyed by efforts from OEMs, consortiums, and miners. Critical to this development is a focus on interoperability across machine and charging systems. Widespread adoption is predicated on power systems being suitable to all equipment, irrespective of its OEM.

Charging/fuelling are fundamental scope considerations for successful zero-emission haul trucks’ rollouts. As part of a wider site mine electrification plan, miners need to undergo an analysis of charging needs and constraints.

This analysis requires focus on both functional and non-functional requirements for charging and refuelling, such as:

- Range of charge/fuelling rates required.
- Automated vs manual charging/fuelling connections while integrating/speaking with power systems.
- Locations and portability of charging/fuelling stations plus substation and cabling demands
- Operating mixed OEM fleets including autonomous units
- Integrating short and long term mine planning with charging needs, haul truck speeds, and grid load balancing
- Frontloading additional charging/refuelling infrastructure capital
- Reduced productivity due to recharging/refuelling frequency/more trucks required
- Redesigning maintenance and shift schedules based on the range/autonomy of new fleets, recharging/refuelling/swapping operations, systems and equipment supplier/dealer support, inventory management, and change management while transitioning to newer technologies and fleets.
- For green hydrogen (produced through renewable energy from electrolysis), water security and quality requirements need to be recognised and thoroughly investigated to not impact local communities or other land users.
  - As water becomes scarcer in some mining regions, with demand for fresh water expected to surpass supply by 40 per cent by 2030[14], the necessary enabling environment for these haul trucks needs careful and contextually sensitive consideration.
- Battery storage, service centres and end of life planning/recycling

14. https://www.weforum.org/agenda/2023/03/global-freshwater-demand-will-exceed-supply-40-by-2030-experts-warn/

For regions with a significant number of mines and operators, consideration of shared spares and repair facilities handling zero-emission haul trucks' energy storage and power management requirements for charging battery powered trucks can be addressed through several plausible solutions:

— Static or stationary charging of batteries while the haul truck is parked at the end of the shift or stopped during filling. This optimises idling time by allowing charging whenever possible, rather than having all trucks charge together at any one time.

— Dynamic or in-motion charging when the haul truck is moving or in operation.

— Swapping empty batteries with fully charged back-up batteries to save time lost when idling and allow for off-peak charging of those batteries not in use. The size of mine haul batteries, especially for larger payload trucks where batteries will tip the scale at over 10 tonnes, may limit this option to underground equipment.

— On-site hydrogen production with adequate storage and transportation

— Hydrogen pipelines for on-demand requirements and storage

## Safety, policy and regulatory requirements

The environment of operating diesel trucks safely within established regulatory rules is assumed by today's mine operators. With new zero-emission haul trucks come new rules for everything from charging batteries to maintenances procedures at the mine site and with occupational health and safety regulators.

The ICSV initiative recognises this challenge and is working to develop green energy and refuelling infrastructure maturity analyses as a key step towards ensuring the roll out of zero-emission haul trucks at speed and scale.

Development and adoption of prudent economic and carbon policies will be a critical ally in promoting the decarbonisation of metals and mining, acting as both a

carrot and a stick to mobilise public and private capital and promote lower carbon options like zero-emission haul trucks.

To keep work safe in the new world of zero-emission haul trucks, governments need to come to the table with operators and OEMs to keep pace with the necessary changes in occupational health regulations. Working with electricity and hydrogen brings its own safety concerns and challenges that need to keep place with technology adoption. Operating autonomous zero-emission haul trucks requires a heightened safety overview.

Operators need to establish training and development programs to address technical and safety requirements in-line with new regulations.

## Evolving company culture

ICMM members, as well as OEMs that have joined the ICSV initiative, have a few things in common: a willingness to take the lead and find solutions to difficult challenges; a commitment to collaboration and innovation in and outside of their business; and an ambition to push their business further in the most innovative and most responsible way.

Company culture is a core driver of innovation and change, from the boardroom down to the mine site. For change to happen at scale, leadership at all levels of an organisation is key. It allows for the investment of time and resources to drive change, and, in this case, the successful transition of diesel fleets to zero-emission solutions.

Over the past several years of broad engagement, operational trials, knowledge shares, and assessment, the members of the ICSV initiative have observed the cultural traits that companies need to adopt zero-emission solutions at a faster pace. These include:

— **Leadership is critical**
Visible CEO and Board leadership is a key driver of pace and ambition to achieve zero-emission solutions at scale. Bound by approaching emissions reduction targets, this strong foundation fosters agile decision making, empowers senior leaders and teams, and supports the ability to innovate. To have full zero-emission solutions in place at all trailblazing ICSV sites by 2040, including all of the required renewable infrastructure, requires a significant volume of investment ($1.7 trillion in the next 15 years[15]). Without visible, dedicated, and impactful CEO support, these types of decisions risk taking longer and/or result in insufficient capital allocated to these projects.

— **Willingness to collaborate**
There is an understanding that competition is appropriate only when a robust demand for zero-emission solutions exists and that as an industry, we must collaborate to accelerate the creation of that market. Without demand, there are no zero-emission solutions at scale, and without solutions at scale, the scaling near-term emission reduction and longer-term net zero targets established by our ICMM members are difficult to achieve.

— **Drive to move quickly**
Speed and scale are essential to compound progress. This means being open and supportive of the research and trialling efforts of others so that lessons can be learnt and shared in ways that support the implementation of solutions faster.

— **Risk appetite**
Companies need an appetite to take risks when the right conditions exist. This means recognising that not all sites are equal. There are some sites that have the right conditions to accelerate adoption of zero-emission solutions and others where planning and trialling is a more realistic option. For those sites that are immediately suitable, the commitment of senior leadership needs to translate to budget commitments and strong support equal to the implementation needs of the proposed zero-emission solutions, and a willingness to set key performance indicators that reflect the company's ambitions and emissions targets. And for those mine sites that are not yet ready, the conditions for future introduction need to be understood and fostered.

— **Focus on learning, not 'failure'**
Recognise that at this stage, there are no 'failures', only learnings. Implementation is complex and organic, so maintaining focus with a willingness to try new technologies and approaches, while learning from both successes and failures, is critical. Mapping all challenges that are vital to unlock zero-emission solutions at scale is undoubtedly important, but deciding which ones are the most critical for progress at a mine site is arguably even more so. This requires a culture of collaboration, pragmatism, and endurance to ensure that critical challenges are addressed in a timely manner to create opportunities down the line.

15. https://www.woodmac.com/news/opinion/faster-decarbonisation-and-mining-a-crisis-of-confidence-or-capital/

## The path forward

We are at the beginning of an S-curve trend – an initial time of slow growth/adoption followed by a rapid uptake of technology with an eventual plateauing as the technology and market mature. At this time, bridging technologies play a crucial role in the short to medium term. The need to transition from diesel to zero-emission fleets is unquestionable, but it is a very challenging undertaking. As we have underscored, it also requires a new way of framing the problems and a new way of solving them.

As haul trucks come due for replacement over the next decade, we anticipate a gradual, step-by-step transition towards zero-emission solutions, with commercially available diesel/electric hybrids, low emission power train retrofitting and alternative fuels offering realistic options for short and mid-term transitional phases or for those companies unable to afford a new fleet of haul trucks, at least in the short term.

As has happened with solar and wind technologies for power generation and more recently with EVs and electrolyser technology, we expect zero-emission solutions to become increasingly competitive into the future, but it will be an evolution over time.

Transition options will however ensure stepwise, measured, and demonstrable emissions reductions can be achieved before more innovative net zero-emission options are fully tested and integrated in the most sustainable way possible. These early investments in transition alternatives will give confidence to keep investing and move faster over time.

The ICSV initiative is focussing effort on developing bridging strategies to identify existing operational challenges and the mitigation strategies required to reduce emissions in the short, and medium-term.

## Conclusion

To decarbonise a global fleet of 28,000 trucks will require an incredible effort across many players. While this is a massive challenge, it is also one that opens the door to a number of transformational opportunities. The ICSV initiative provides the leadership and mechanisms to take advantage of this opportunity together with OEMs, solution and service providers, governments, researchers, and financial institutions.

The initiative's work remains far from complete, with new strategies developing as our knowledge of the challenges and opportunities evolve. We urge all large and mid-sized —haul truck OEMs, technology manufacturers, integrators and researchers working on the solutions which will help drive the transition to zero-emission solutions to reach out to the ICSV initiative and ICMM member companies directly.

Join us in sharing expertise in a non-competitive and innovative space to ensure that zero-emission solutions become a reality on mine sites across the globe.

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**About ICMM**
ICMM stands for mining with principles. We bring together a third of the global metals and mining industry, along with key partners to drive leadership, action and innovation for sustainable development, ultimately delivering a positive contribution to society. Through collaboration, ICMM member companies set the standard for responsibly produced minerals and metals in a safe, just and sustainable world.

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