Australian Academy of Technological Sciences & Engineering
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REPORT

Fortescue

Decarbonising diesel industries

Transition technologies and policy pathways for diesel reduction in Australian mining, freight and agriculture, fisheries and forestry

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Executive summary

Diesel fuel remains the dominant energy source powering Australia's mining, land freight, agriculture, fisheries and forestry sectors. It supports critical machinery, transport vehicles and infrastructure essential to the nation's economy and exports. However, this reliance on diesel comes with significant environmental, health, economic and strategic risks.

Diesel combustion contributes approximately 17% of Australia's total carbon emissions, posing a major obstacle to meeting the country's climate targets of a 43% reduction by 2030 and net zero emissions by 2050. Australia imports nearly 29 billion litres of diesel annually, reflecting a heavy dependence on international fuel markets and diminishing domestic refining capacity. This reliance presents national security vulnerabilities due to geopolitical risks and potential supply chain disruptions.

Despite these clear challenges, current policy settings inadvertently support diesel use by subsidising fossil fuel consumption. This delays critical investment and adoption of cleaner technologies.

Decarbonisation of diesel-dependent sectors requires a diversified technology approach.

Biofuels

Electrification

Hydrogen

There is no one-size-fits-all solution. A diversified technology map to achieve decarbonisation includes several pivotal approaches.

These key alternatives include:

BIOFUELS can be used as drop-in replacements in existing diesel engines without major modifications. This compatibility enables rapid emissions reductions, especially in remote areas and freight operations where infrastructure constraints limit electrification or hydrogen adoption.

ELECTRIFICATION can be used to replace diesel engines with electric vehicles and power stationary equipment with renewable energy sources. While urban freight and certain mining equipment are amenable to electrification, longer-distance freight and some heavy machinery face challenges related to battery range and charging infrastructure.

GREEN HYDROGEN produced from renewable electrolysis holds promise for heavy-duty applications in mining, freight and agriculture. Hydrogen fuel cells deliver zero tailpipe emissions and longer operating ranges than batteries, making them attractive for long-distance transport and off-grid mining operations.

ATSE 50 YEARS

Multiple barriers

The transition from diesel faces multiple barriers:

- Infrastructure gaps for electric charging and hydrogen refuelling stations, particularly in remote and regional areas.
- Higher upfront costs and uncertain total costs of ownership for new technologies.
- Operational challenges for electrification and hydrogen in heavy-duty, long-haul and off-grid contexts.
- Market distortions caused by fossil fuel subsidies and weak regulatory frameworks that reduce incentives for industry to invest in cleaner alternatives.
- Reliance on carbon offsets under current policy mechanisms, which can delay direct emissions reductions.

Potential solutions

Potential solutions to these barriers include:

- Phasing out subsidies and regulatory provisions that artificially lower diesel costs, thereby aligning market signals with emissions reduction goals.
- Strengthening the Safeguard Mechanism[1] by tightening baselines and limiting offset use to ensure direct emission reductions.
- Supporting industry investment through incentives, grants and financing for alternative fuel infrastructure and technology deployment.
- Promoting coordinated cross-sector strategies recognising that mining, freight and agriculture, fisheries and forestry sectors have different operational needs and technology readiness.
- Investing in R&D to advance hydrogen production, storage, and fuel cell technologies, while supporting pilot projects and early commercialisation.

Diesel decarbonisation offers Australia a unique opportunity to put to work its technical and innovation capabilities. Given the country's geography and sectoral expertise, Australia is well-positioned to take up a leading role in global R&D and early-stage deployment of low-emission solutions for heavy industry and land freight. Australia can meet its climate commitments whilst strengthening energy security, improving public health, and creating new economic value through green exports and technologies.

1. The Safeguard Mechanism is the Australian Government's policy for reducing emissions at Australia's largest industrial facilities. The mechanism is discussed in greater detail on page 23.

Recommendations

RECOMMENDATION 1

Conduct a national technical and economic assessment of decarbonisation pathways and evaluate how prepared key sub-sectors are for the transition.

Undertake a comprehensive independent economic assessment that evaluates a broad range of decarbonisation options beyond electrification. This assessment could:

- Identify least-cost transition pathways tailored to mining, freight and agriculture, fisheries and forestry, including non-road diesel uses.
- Support the development of a nationally coordinated transition plan to provide policy certainty, align investments, and harmonise efforts across states, industries, and technologies.

RECOMMENDATION 2

Review the financial incentives supporting diesel use.

Commission an independent review of existing financial incentives and support frameworks that currently underpin diesel use in Australian industry. The review could examine:

- The Fuel Tax Credits Scheme: Evaluate options for phasing out or reforming the FTCS with mechanisms that promote low-emission alternatives such electrification, biofuels and hydrogen.
- Changes to Australian market-based emissions reduction mechanisms: Explore the introduction of carbon pricing or adjustment of the Safeguard Mechanism to better reflect the environmental impact of diesel.
- Targeted financial support: Design financial supports to accelerate uptake of clean fuel technologies across hard-to-abate sectors.

RECOMMENDATION 3

Develop a coordinated Australian future diesel strategy, that includes a quantitative assessment of demand and supply across alternative energy scenarios.

Build on existing frameworks such as the Future Gas Strategy by creating a dedicated Future Diesel Strategy aligned with Australia's net-zero goals. This could:

- Clarify roles and responsibilities of Commonwealth and state agencies to ensure consistent policy settings.
- Establish accountability mechanisms for industry, including transparent reporting on technology adoption and emissions reduction progress where public funding is involved.

RECOMMENDATION 4

Invest in comprehensive infrastructure to support the clean energy transition.

In partnership with the state and territories, uplift Commonwealth investment (or facilitation of investment) in a wide range of infrastructure critical for decarbonisation across freight, mining and agriculture, including:

- Expanding electric rail networks to reduce freight emissions.
- Firmed renewable energy generation and shared transmission infrastructure, to lower electricity costs and enable large-scale electrification.
- Development of domestic biofuel production facilities, supply chains and distribution networks to provide viable alternatives where electrification is limited.

RECOMMENDATION 5

Provide targeted support across the technology maturity spectrum.

Recommendations to Commonwealth government

- Support early-stage research and development (TRL 2–5). Additional funding directed through existing mechanisms, such as ARENA, CRCs and university-industry partnerships, to address foundational technical barriers in next-generation technology.
- Enable commercial deployment of high-TRL technologies (TRL 6–8). Public co-investment may help de-risk and accelerate first-of-a-kind projects and create stronger market confidence. Support could include:
  - Grants and risk-sharing for pilot and large-scale demonstrations
  - Targeted procurement commitments to help establish demand
  - Infrastructure funding aligned with deployment needs.

Recommendations to industry

- Engage in research and commercialisation partnerships. Co-investment in early-stage R&D to support more commercially viable innovation.
- Lead deployment and integration of viable technologies. Where capital and capability allow, industry could take a leading role in scaling zero-emissions solutions. This may include investment in supply chains, workforce development and supporting infrastructure.

ATSE 50 YEARS

Introduction and scope

Reducing diesel use is a key component of Australia's broader climate strategy. As part of its commitment to achieving net zero emissions by 2050, the Australian Government has set an interim target to reduce national greenhouse gas emissions by 43% below 2005 levels by 2030.

Combined, the mining, freight and agriculture, fisheries and forestry sectors account for a substantial proportion (37%) of Australia's total emissions profile (DCCEEW, 2024). Decarbonising diesel use across these industries is essential to national climate targets and to maintain Australia's competitiveness in low-carbon global supply chains.

This report aims to demonstrate how Australia can adopt sustainable and economically viable technologies, enabling the transition away from diesel fuels and towards low-emissions technologies across mining, land freight and agriculture, fisheries and forestry. It focuses specifically on alternatives for diesel-powered equipment, vehicles and infrastructure, including electrification, hydrogen and biofuels. The report assesses the available technological alternatives, barriers to implementation and policy solutions to overcome these barriers.

The scope of this report is intentionally narrow, to allow a focus on the reduction of diesel use in the selected sectors. This focus reflects diesel's role as a core input to a wide range of heavy industry sectors, with its own existing infrastructure and commercial arrangements that differ from diesel and petrol use in sectors such as construction and passenger transport. It does not address diesel alternatives in public transport. The report also does not address air freight, as air transport primarily relies on jet fuel rather than diesel and therefore falls outside the report scope. In line with initial stakeholder feedback, synthetic fuels were also excluded from the scope due to concerns about their high cost and limited near-term commercial viability. This report examines the practicality and economic feasibility of diesel alternatives by drawing on desktop research, case studies, insights from a targeted industry survey and one-on-one consultations with experts. Details on methodology are provided in Appendix 2.

By identifying sector-specific barriers and opportunities, this report supports decision-makers, policymakers and industry leaders to explore a range of potential pathways to reduce diesel fuel dependence and support the transition to cleaner heavy industry in Australia.

The case for action

Current use of diesel in Australian mining, freight and agriculture, fisheries and forestry

At present, diesel is the dominant fuel source across Australia's mining, freight and agriculture, fisheries and forestry sectors. It powers a broad range of both stationary and non-stationary machinery (see Table 1). In agriculture, diesel accounts for approximately 84% of on-farm energy consumption, powering essential machinery such as tractors and harvesters, as well as irrigation pumps and generators (Australian Farm Institute, 2025; NSW Department of Primary Industries, 2021; NSW Government, 2025).

The mining sector also relies heavily on diesel. In the 2021-22 financial year, around 8.2 billion litres of diesel were consumed to power equipment such as haul trucks, excavators, locomotives and remote generators (Pollard & Buckley, 2023). This represents approximately 51% of the sector's total energy needs, with natural gas accounting for 19% and grid electricity supplying the remaining 27% (Assimi et al., 2023).

In the freight sector, the reliance on diesel is even more pronounced. During the 2019-2020 financial year, diesel accounted for 99.8% of all fuel consumed by rigid and articulated trucking (ABS, 2020). Rail freight accounts for approximately 95% of Australian direct rail emissions (Australasian Railway Association, 2024), with over 90% of heavy haul freight emissions caused by diesel consumption (University of Queensland, 2022). Diesel rail emissions were estimated at 2.5 million tonnes of CO_2 equivalent in 2021, adding to the sector's carbon footprint (Australasian Railway Association, 2024). Marine shipping also remains heavily dependent on diesel, with most vessels powered by heavy fuel oil or marine diesel oil (DCCEEW, 2025b).

Although international shipping falls outside national emissions reporting, Australia cannot import its critical supplies (including diesel) or export its goods without ships. Shipping accounts for 3-4% of global emissions, driven largely by heavy marine diesel or bunker fuels (Brear et al., 2025) (DCCEEW, 2025c).

Agriculture	Mining	Freight
Tractors Transport vehicles Harvesters Long and short haul trucks Pumps Generators Excavators Refrigerated transport	Underground and opencut mining equipment Excavators Generators Long and short haul trucks Transport vehicles Pumps Blasting and drilling rigs Rail transport	Long haul trucking Transport vehicles Refrigerated transport Diesel-powered trains Marine shipping

TABLE 1 — Main uses of diesel in the agriculture, mining and freight sectors as identified by survey respondents

2. Fuel used by marine vessels is also often referred to as bunker fuel.

Why is diesel use an issue?

The widespread use of diesel in Australian industry presents significant environmental, economic and public health risks. Diesel combustion contributes substantially to national emissions, comprising approximately 17% of Australia's total carbon emissions annually. Reducing diesel use presents as a critical opportunity for reaching Australia's emissions targets (Terrill, 2023).

For Australia to meet its commitment of 43% emissions reduction by 2030 and achieve net zero by 2050, decarbonisation of diesel-dependent sectors, especially road freight and industrial diesel, is essential and must begin immediately.

Health effects

Diesel engine exhaust (DEE) is a significant source of air pollution and presents well-established health risks. Diesel combustion emits high levels of nitrogen oxides (NO_x) and fine particulate matter ($PM_{2.5}$), both of which contribute to urban air pollution and have been linked to a range of adverse health outcomes (Terrill & Burfurd, 2022), as outlined in Table 2.

SHORT-TERM **Risks of diesel emissions exposure**	**LONG-TERM** **Risks of diesel emissions exposure**
Irritation of eyes, nose, throat and lungs Light-headedness Coughing & phlegm Nausea Asphyxiation (with high enough exposure)	Worsening of asthma Aggravation of allergies Increased risk of lung diseases such as emphysema, chronic bronchitis and pneumonia Increased risk of lung cancer Increased risk of heart disease Increased risk of bladder cancer

TABLE 2 — Common risks of short- and long-term exposure to diesel engine exhaust

Occupational exposure and workplace health and safety

In addition to broader public health concerns, diesel use presents specific risks in occupational settings particularly where exposure to DEE is frequent and prolonged. These risks are most acute in confined or poorly ventilated environments, such as underground mines or enclosed rail depots, where DEE concentrations can be significantly higher. Non-road diesel engines represent the largest unregulated air pollution source in Australia and emit more particulate matter than all on-road vehicles combined (Terrill & Burfurd, 2022; Boulter et al., 2022).

According to Division 7 of the *Model Work Health and Safety Regulations*, businesses must ensure that workers are not exposed to airborne substances above recognised exposure limits (Safe Work Australia, 2024).There is no currently legislated national exposure standard for diesel particulate matter through either state or federal WHS laws (NSW Resources Regulator, 2019). However, the Australian Institute of Occupational Hygienists recommends limiting DEE exposures to 0.1 mg/m^3 for workers (Australian Institute of Occupational Hygienists, 2017). This recommendation has been widely adopted as a best-practice guideline in the mining industry (NSW Resources Regulator, 2019).

Electrification, hydrogen and biofuels emit fewer pollutants and greenhouse gases than diesel. Given the regulatory obligations on employers and the well-documented health risks of diesel exhaust exposure, companies in diesel-intensive sectors have a strong incentive to reduce their reliance on diesel where practical. These alternative technologies offer a viable pathway forward.

Profitability

Australia imports the bulk of its diesel, the cost of which is built into the energy used to produce our mining and agricultural exports. By switching to locally made renewable fuel, this energy becomes a potential source of profit. Cleaner, renewable production methods can increase the value of Australia's products and help them stand out in global commodities markets.

National security

Australia's heavy reliance on imported diesel undermines both its fuel security and its capacity for energy independence. Over the past two decades, the number of operational crude oil refineries in Australia has declined from 12 to just two, significantly reducing the country's domestic refining capability (Sutton, 2025). This shift reflects long-term structural changes in global fuel markets, where the emergence of large-scale refineries in Asia has made imported refined fuels more cost-competitive than domestic production (Laidlaw, 2020).

In 2022-23, Australia imported approximately 29 billion litres of diesel, at a cost to the national economy of $33 billion (Pollard & Buckley, 2023). This high dependency creates a strategic national vulnerability. As an island nation, Australia's fuel supplies are delivered through a small number of maritime ports, making them susceptible to disruption from geopolitical instability, trade conflicts, natural disasters and global market volatility (Carter et al., 2022).

Why is urgent action required?

Australia's current policy settings continue to entrench diesel use across mining, freight and agriculture, fisheries and forestry despite clear environmental, health and economic risks. Key federal mechanisms significantly reduce the operating cost of high-emitting diesel equipment, effectively subsidising fossil fuel, and particularly diesel, consumption. This distorts market signals and delays commercial uptake of cleaner alternatives.

At the same time, the current approach to reducing industrial emissions — the Safeguard Mechanism[3] — allows large emitters to rely on carbon offsets rather than pursuing direct, on-site emissions reductions. This undermines the integrity and effectiveness of the Safeguard Mechanism as a tool for emissions reduction. Without stronger limits on offset use or a clear trajectory for tightening baselines, industries may continue to delay the capital investments and technology shifts needed to meaningfully reduce their emissions footprints. The upcoming 2026 review of the Safeguard Mechanism and broader policy frameworks provides an opportunity for structural reform to accelerate ambition and widen the scope of such policies. Aligning economic signals with decarbonisation goals will give industry the confidence to invest and reduce long-term emissions from diesel use.

3. The Safeguard Mechanism is the Australian Government's policy for reducing emissions at Australia's largest industrial facilities. The mechanism is discussed in greater detail on page 23-24.

Alternatives to diesel in mining, freight and agriculture, fisheries and forestry

As Australia's mining, freight and agriculture, fisheries and forestry sectors consider pathways toward decarbonisation, several alternative fuels and technologies have emerged as potential replacements for diesel: electrification, hydrogen and biofuels. Each of these alternatives has its own level of technical maturity, infrastructure requirements and suitability across different use cases. There is no linear or one-size-fits-all approach to decarbonising diesel in these sectors. A strategically diverse and well-coordinated set of technology approaches is therefore required. Case studies demonstrating the use of alternative technologies across mining, freight and agriculture, fisheries and forestry can be found in Appendix 4.

A survey of sector experts was conducted to rank the suitability of electrification, hydrogen, and biofuels as replacements for diesel across all use types (Figure 1; see Appendix 2). Respondents identified biofuels as the most suitable option, followed by electrification and then hydrogen.

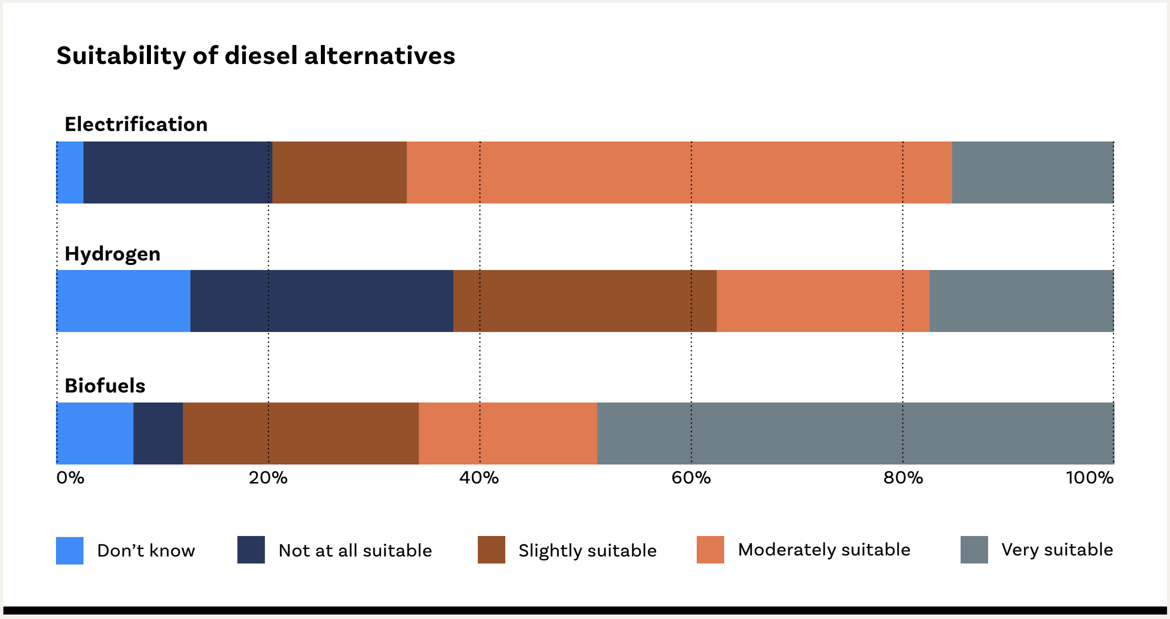

FIGURE 1 — Survey respondents' ranking of suitability of diesel alternatives

Technologies relevant to diesel replacement

BIOFUELS

Survey respondents ranked biofuels as the most suitable replacement for diesel, with 48% considering them very suitable and 17% rating them moderately suitable. Biofuels are derived from organic materials such as crops, agricultural residues, vegetable oils or animal fats, and offer a lower-emissions alternative to conventional diesel. Biofuels come in two forms, with different applications and limitations: conventional and advanced biofuels.

Conventional biofuels are typically produced from food crops, such as sugarcane, corn or wheat, which are processed into biodiesel or bioethanol (CEFC and ARENA, n.d.). Conventional biodiesel is often blended with diesel, however blends with over 5% biodiesel can cause compatibility issues with current engines and fuel systems (NSW Government, 2022).

Advanced biofuels include renewable diesel, green diesel and bio-gasoline. These are often referred to as drop-in fuels because they are compatible with existing petroleum infrastructure and engines without modification. Advanced biofuels are produced from non-food feedstocks such as woody biomass or waste materials like used cooking oils and animal tallow (CEFC and ARENA, n.d.) (Sustainable Future Australia, 2025c). This focus on waste and non-edible inputs directly addresses the 'food-vs-fuel' concern, which has been a major criticism of earlier biofuel generations. By using residues and by-products that would otherwise go to waste, advanced biofuels help decarbonise fuel use and reduce the need for waste disposal, without competing with food production or land needed for agriculture. A leading example is Hydrotreated Vegetable Oil (HVO), a renewable diesel that can fully replace fossil diesel. HVO is typically produced from waste streams such as used vegetable oils and animal fats, offering a high-performance, lower-emissions fuel without compromising food supply (Viva Energy Australia, 2025).

Biofuels in mining
In the mining sector, biofuels present a low-disruption option for reducing emissions, particularly where electrification or hydrogen solutions are not yet practical due to operational or infrastructure constraints. Biofuels can be used in existing diesel-powered equipment — such as haul trucks, excavators, generators and drilling rigs — without major modifications. This makes them an effective transitional fuel, especially in remote locations where grid access is limited and new fuelling infrastructure would be costly or logistically challenging (NS Energy, 2024) (Energy Technology Forum, 2025).

Several mining operations in Australia and internationally have piloted or adopted biodiesel blends or renewable diesel (HVO) to power off-grid generators and heavy mobile equipment. These fuels reduce lifecycle emissions, lower particulate matter, and can improve engine performance while maintaining operational continuity (Brann, 2025) (Sustainable Future Australia, 2025a).

Biofuels in agriculture, fisheries and forestry
In agriculture, biofuels can be used as drop-in fuels for existing diesel-powered machinery such as tractors, harvesters, trucks, irrigation pumps and stationary engines, without the need for major modifications. This ease of adoption gives biofuels an advantage over electrification and hydrogen in many regional or remote operations. In Queensland, sugar mills produce bioenergy from bagasse, a by-product of sugarcane processing. This is currently used for electricity generation, providing renewable power for industrial facilities and nearby communities while reducing agricultural waste (Sustainable Future Australia, 2025b).

Biofuels in freight
Due to the high energy density of liquid fuels, and ease of storage and refuelling, biofuels are especially well-suited for Australia's freight sector. Long travel distances, limited infrastructure for electrification, and the need for heavy-duty performance make biofuels a practical alternative. Advanced biofuels' compatibility with existing engines and refuelling systems means they can be adopted immediately, providing a viable near-term decarbonisation pathway while infrastructure for electric or hydrogen transport matures (CEFC and ARENA, n.d.) (Rae, 2024a).

ELECTRIFICATION

Survey respondents ranked electrification as the second most suitable alternative to diesel, with 14% ranking it as very suitable and 48% ranking it as moderately suitable.

Electrification of diesel-fuelled industry involves replacing diesel-powered systems with electric alternatives such as electric vehicles, battery energy storage systems (BESS) and microgrids that are powered by renewable sources such as solar or wind. These systems reduce fossil fuel reliance and enable cleaner on-site power generation in remote or off-grid locations. By enabling direct integration with renewable energy, electrification supports both national and global net-zero emission strategies.

The benefits of electrification extend beyond emissions reduction. Electric equipment reduces the reliance on imported diesel fuels which has a national security benefit. Furthermore, such equipment produces less heat, noise and vibration, enhancing safety and reducing maintenance requirements.

Mining electrification
Electrification is a highly efficient long-term strategy for reducing diesel dependence across Australian mining operations (Rio Tinto, 2025a). Two main avenues exist for mine operation electrification. Fixed mining equipment such as conveyor systems, crushers, ventilation fans and pumps can be connected to electricity grids, ideally powered by renewable sources supported by BESS. Small to medium haul trucks and loaders used in underground mining can also be electrified through onboard batteries and electric charging stations.

Freight electrification
Electrification in the freight sector includes the deployment of battery-electric trucks and charging infrastructure. This involves replacing internal combustion engines with electric drivetrains, while some applications use hybrid systems that combine electric power with diesel engines to reduce fuel consumption. Urban freight is generally more suited to electrification due to shorter travel distances, a wider range of vehicle options, and better access to charging infrastructure. In contrast, intra- and inter-state freight face greater challenges, including longer distances and limited infrastructure.

Agriculture, fisheries and forestry electrification
Electrification in agriculture includes the development of large electric tractors by major equipment manufacturers. In addition to machinery, stationary energy generation and storage applications such as solar photovoltaics, battery storage, microgrids and small-scale wind turbines offer viable options to reduce diesel use and energy costs. Pilot projects are also exploring the electrification of infrastructure such as irrigation pumps and heating systems, providing additional potential pathways for reducing emissions from agricultural operations (NSW Government, 2025).

HYDROGEN

Survey respondents ranked hydrogen as the least suitable alternative to diesel, with 24% stating it is not at all suitable. This perception is largely driven by the high current cost of hydrogen relative to diesel, as well as the availability of other low-emission alternatives

There are multiple methods for producing hydrogen, each with varying emissions profiles. This report focuses solely on green hydrogen, which is produced through electrolysis powered by renewable electricity. Other hydrogen production methods are not considered low-emission alternatives (Climate Council, 2023). Green hydrogen is generated by splitting water molecules using electricity from renewable sources such as solar and wind. It has a significantly lower emissions footprint—releasing less than 1 kg of CO_2 per kilogram of hydrogen produced (MIT Climate Portal, 2024). However, green hydrogen remains a small part of the global market, accounting for an estimated 4% of total hydrogen production (Hossain Bhuiyan & Siddique, 2025).

Due to its high energy density, hydrogen presents opportunities for large-scale heavy industry applications. Hydrogen fuel cells are more energy-efficient than diesel engines and emit only water as a by-product. Hydrogen's gravimetric energy density is 143 MJ/kg, compared to 46 MJ/kg for diesel, meaning it can deliver over three times more energy per kilogram (Hossain Bhuiyan & Siddique, 2025).

Hydrogen in agriculture, fisheries and forestry
Hydrogen's high energy density may enable practical energy storage and use in remote agricultural locations where regular fuel deliveries are limited. Hydrogen fuel cells powered by green hydrogen can replace diesel engines in equipment such as tractors and trucks, offering a zero-emissions alternative. These systems also benefit from lower maintenance requirements and longer operational lifespans, owing to fewer moving parts compared to internal combustion engines (Hossain Bhuiyan & Siddique, 2025) (Stargate Hydrogen, 2024).

Hydrogen in freight
Hydrogen has been proposed as an alternative fuel source to replace diesel for several modes of freight transport, including rail, shipping and haul trucks. Hydrogen has many of the advantages of diesel – refuelling is relatively quick and simple; it doesn't rely on continual electrical grid availability (like many grid-connected trains) and onboard fuel storage can be increased to facilitate long-distance travel. Together, this makes hydrogen a potentially attractive alternative to diesel for long-distance freight transport on land and sea (Scania, 2020) (CSIRO, 2023).

Hydrogen in mining
In mining, hydrogen fuels offer several opportunities for zero-emissions operation, primarily through fleet decarbonisation and energy storage, and hydrogen-fuelled trucks supporting fast refuelling, heavier payloads and longer ranges compared to battery-electric vehicles.

Hydrogen also enables better integration of renewable energy in mining. Onsite electrolysis systems can convert excess renewable electricity into hydrogen for later use — helping to smooth out supply variability and enhance energy reliability in off-grid locations.

Green ammonia, produced from green hydrogen, is also under investigation as a zero-emissions fuel storage medium for mining applications. As a hydrogen carrier, green ammonia offers lower storage and transportation costs compared to compressed or liquefied hydrogen, making it particularly practical for remote mine sites (Southway, 2024).

The following table summarises the primary barriers to transitioning away from diesel across five key categories, providing a clear overview of the challenges faced by industry and policymakers.

Category	Key barriers
Cost	High upfront capital costs for electric and hydrogen vehicles and equipment Green hydrogen and biofuels are currently more expensive than diesel Lack of transparent techno-economic data for investment decisions High financial risk due to first-of-a-kind deployments
Infrastructure	Limited charging and refuelling infrastructure for EVs and hydrogen Insufficient grid capacity in regional and remote areas Absence of hydrogen distribution networks Limited biofuel refining and production facilities
Policy & regulation	Fuel Tax Credit Scheme subsidises diesel discouraging uptake of alternative fuels Weak incentives for adopting zero-emission technologies Lack of consistent, strong emissions pricing signals Fragmented and uncertain policy landscape across jurisdictions Outdated axle mass regulations limiting zero-emission vehicle adoption Absence of national hydrogen regulatory framework
Technology	Lower energy density of alternatives reduces operational efficiency Battery weight and degradation challenges for electric vehicles Technical limitations for electrification of certain mining processes Limited global OEM production capacity prioritising larger markets
Behavioural & market	Industry risk aversion and reluctance to adopt new technologies Small operators with limited capital and infrastructure access Market size too small to attract early access to emerging technologies Preference for established suppliers over smaller biofuel producers

TABLE 3 — Summary of key barriers to replace diesel

Economic, policy and technological barriers

While diesel replacement technologies are advancing, widespread adoption is being slowed by technological, policy, regulatory and economic barriers. Addressing these barriers is critical to achieving Australia's decarbonisation goals in mining, agriculture and freight. Figure 3 outlines the significance of a range of barriers as ranked by survey respondents.

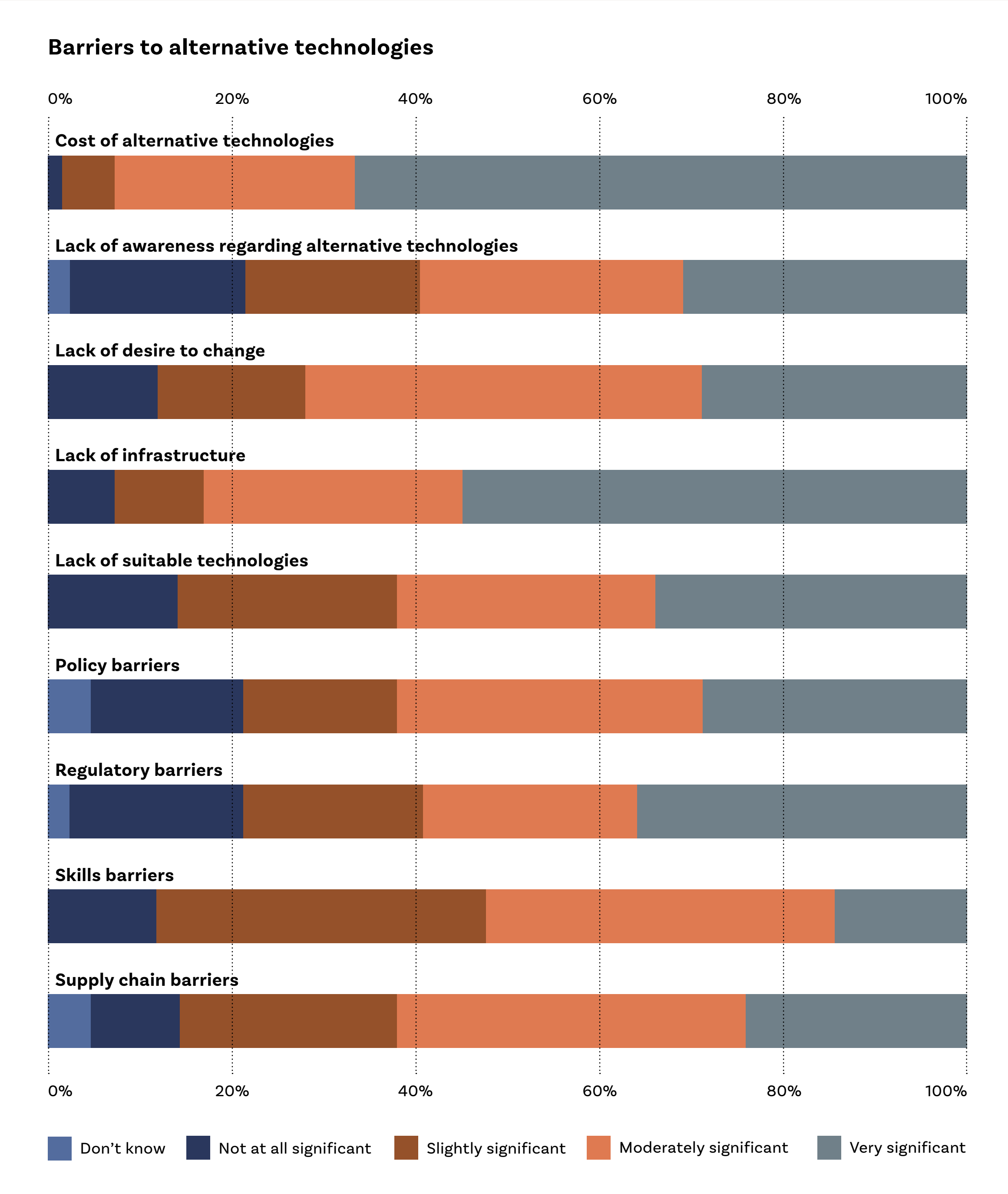

FIGURE 2 — Significance of each barrier for reducing reliance on diesel as rated by survey respondents

COST BARRIERS

Cost is the most significant barrier to diesel replacement, with 67% of survey respondents rating it very significant and 26% as moderately significant. Key concerns include high upfront capital costs, high costs to replace or retrofit diesel equipment, and the ongoing price gap between diesel and low-emissions alternatives.

Respondents noted that the upfront costs place a heavy financial burden on businesses, especially small and medium size operators. High capital costs of first-of-a-kind deployments deter most companies from taking on the investment risk. A lack of transparent, Australia-specific cost and performance data across electrification, hydrogen and biofuel options further complicates investment decisions. Better public access to information such as capital cost data, total cost of ownership and infrastructure requirements is critical to reduce uncertainty and accelerate uptake.

Electrification cost barrier
Electric heavy vehicles and machinery offer lower operating and maintenance costs over their lifespan. For example, electric trucks can operate at a cost of between $14–$42 over a 300 km range, compared to $116 for a diesel equivalent (Electric Vehicle Council and Australian Trucking Association, 2022). However, these savings come with a significantly higher upfront investment. In the mining sector, electric equipment can cost up to four times more than diesel alternatives. Stakeholders also noted that battery degradation from frequent charging and discharging can reduce the operational lifespan of heavy electric vehicles to around one-quarter (25%) of their diesel counterparts. This accelerates replacement timelines and further complicates cost and return-on-investment calculations.

Beyond the cost of electric vehicles and machinery themselves, one of the most significant barriers to electrification is the enormous capital investment required to build the supporting renewable energy infrastructure — particularly in remote and off-grid areas like mine sites and farms (Jafarizadeh et al., 2024). Replacing the amount of diesel used annually in the mining sector would require building out vast amounts of new generation capacity to match current energy needs. Delivering reliable, 24/7 power to these remote locations also requires extensive battery storage systems, high-voltage transmission lines, inverters and site-level microgrid infrastructure. The cost of such a build-out is significant (Zadeh, 2025).

Hydrogen cost barrier
Green hydrogen currently costs around $5-6 per kg (PWC, 2025), making it significantly more expensive than diesel for industrial users. According to the latest petroleum statistics from DCCEEW, the average wholesale price of diesel is under $0.90 per litre. At a density of approximately 0.84 kg per litre, this equates to around $1–1.10 per kg (DCCEEW, 2025a).To be cost competitive with diesel in these sectors, green hydrogen would need to fall below $2 per kg, or benefit from comparable subsidies to close the price gap (Black, 2024).

Another barrier to competitiveness is the high capital cost of electrolysers required to produce green hydrogen. Scaling up this infrastructure is critical to reducing production costs, but uncertain demand continues to hinder investment. Without clearer market signals or government intervention to de-risk early projects, private capital remains hesitant (Lee & Saygin, 2023).

Biofuels cost barrier
High production and feedstock costs remain a major barrier to the widespread adoption of biofuels in Australia. Depending on the feedstock and processing method, biofuels can cost between 1.5 and 3 times more than petroleum-based fuels (AgriFutures, 2022a). These costs are highly sensitive to both global oil price fluctuations and feedstock availability. When oil prices fall, biofuels become less economically attractive. For instance, in 2016, sustained low oil prices led to the three-year closure of the Barnawartha biodiesel plant, which in turn disrupted national supply and pushed up domestic prices (AgriFutures, 2022a). While some survey respondents noted that biofuel imports could help offset limited local production, this is not currently a cost-effective solution. Global supply of renewable diesel is still constrained, keeping import prices high and limiting availability for Australian markets.

INFRASTRUCTURE BARRIERS

Survey respondents ranked infrastructure as the second most significant obstacle to transitioning from diesel, with 54% rating it as a very significant barrier and 26% as moderately significant. Australia's vast geography, low population density and long-distance freight corridors require a tightly coordinated rollout of vehicles, fuel supply and refuelling and recharging infrastructure. Without coordinated planning and investment, these technologies will not be able to scale.

Infrastructure barriers to electrification
A lack of widespread charging infrastructure provides a disincentive for companies seeking to adopt electric trucks (Duong, 2025). Establishing high-power charging stations is often constrained by limited grid capacity, particularly in rural and regional areas (ARENA, 2024). Experts consulted for this report noted that grid capacity is especially limited in regional and remote parts of Western Australia, South Australia and the Northern Territory, areas where the rail network is also not electrified. As a result, significant infrastructure investment or major improvements in battery technology would be required before diesel locomotives can be replaced with electric alternatives for long-distance freight tasks.

More broadly, electrifying Australian industry will require a grid capable of withstanding the increased electricity demand that would result from mass adoption of electric vehicles. Meeting future demand will require coordinated investment across electricity generation, transmission, distribution and charging infrastructure (Hill, 2025).

Infrastructure barriers to hydrogen
Producing green hydrogen requires the large-scale installation of electrolysers, which are currently supply-constrained (Lee & Saygin, 2023). In addition, the absence of a dedicated distribution network, including large-scale transport and storage infrastructure, is an obstacle. Building this infrastructure would require substantial upfront capital investment, ongoing operational costs and complex coordination. As a result, green hydrogen use is likely to remain limited to areas near its point of production in the near term (Monaghan, 2024).

Infrastructure and supply barriers to biofuels
Of the three diesel alternatives explored in this report, biofuels present the fewest machinery and fuel delivery infrastructure barriers, as they can often be used in existing engines with minimal modification. However, this relative advantage is balanced by significant challenges in scaling production and refining capacity to industrial levels. Australia currently lacks large-scale biorefineries capable of processing diverse feedstock (ARENA, 2015).

Even if refining capacity were expanded, feedstock availability and supply chain logistics present major barriers. Australia's potential for biofuel production is constrained by the seasonal nature, low density, and geographically dispersed location of most biomass sources. Transporting feedstocks more than 100 kilometres is often uneconomical, making large-scale aggregation and processing viable only in limited, high-yield agricultural zones.

While biofuels may play a role in location-specific applications—particularly where integrated waste streams or existing oilseed crops such as canola or cotton are already present—these opportunities are limited in scope. Enabling broader deployment would require stronger price signals, as well as targeted regional policy support.

Importantly, unlike some international markets, food vs. fuel competition is less of a concern in Australia due to high levels of food security; approximately 70% of agricultural output is exported (Parliament of Australia, 2023). However, the scale of land-use change required to make biofuels a major diesel substitute must not be underestimated. Any future biofuel strategy would need to be grounded in a clear understanding of land availability, crop yields, and the technical realities of scaling logistics and infrastructure (Rae, 2024b).

TECHNOLOGY BARRIERS

Energy density limitations of alternative fuels
Energy density limitations of diesel alternatives pose a significant barrier to adoption in high-demand sectors such as agriculture, mining, and freight. These industries require machinery that can operate at high power outputs over long duty cycles, making performance constraints a key issue (AgriFutures, 2022a).

Adoption of biofuels is constrained by the energy limitations of feedstocks. While diesel has a gravimetric energy density of approximately 46 MJ/kg, biodiesel derived from oil crops has a lower energy density of around 38 MJ/kg, and conventional biofuels produced from sugar or starch-based crops are even lower, at approximately 25 MJ/kg (Ozsoz et al., 2020). These differences reduce energy efficiency and can result in shorter operational ranges or more frequent refuelling, which presents logistical challenges for heavy industry.

Hydrogen presents a different set of constraints. While its gravimetric energy density is high, its volumetric density is significantly lower than diesel, at just 5.6–10.1 MJ/L (liquid and compressed forms) compared to diesel's 34.6 MJ/L. This creates challenges for mobile and remote applications where space for fuel storage is limited.

In addition, hydrogen fuel cell systems are thermodynamically less efficient than battery-electric alternatives (Whitehead et al., 2018). Starting with 100 kWh of electricity, a battery-electric system can deliver approximately 80 kWh of kinetic energy after charging losses and motor conversion. By contrast, converting the same 100 kWh to hydrogen via electrolysis, compression, storage, and fuel cell conversion typically results in only 25–30 kWh reaching the wheels (Australian EVs, 2022). This lower overall efficiency reduces hydrogen's competitiveness for mobile applications unless specific conditions, such as range requirements or refuelling speed, offset the disadvantage.

Weight of battery systems in electric vehicles
Batteries increase the overall mass of a vehicle, which may reduce the allowable payload under vehicle mass limits. This presents a challenge in long-haul freight and mining, where payload capacity is directly linked to revenue. Reduced payload can impact productivity and operating margins. The issue is further complicated by inconsistencies in how the Heavy Vehicle National Law is applied across jurisdictions, requiring separate approvals or exemptions for electric trucks operating interstate. Battery-electric haul trucks often exceed traditional weight thresholds, forcing operators to reduce the volume of material carried to remain within legal or operational limits, further undermining efficiency (NHVR, 2023).

Storage and transportation of hydrogen
Storing and transporting hydrogen presents significant technical and economic challenges that constrain its viability as a diesel alternative. Due to hydrogen's low volumetric energy density under ambient conditions, it need to be either compressed to high pressures (typically 350–700 bar depending on purpose) or liquefied at cryogenic temperatures (–253°C) for storage and transport, both of which are energy-intensive and costly processes (IEA, 2019). These safety and regulatory issues complicate mobile and remote applications. Additionally, hydrogen embrittlement can degrade metal pipelines and storage tanks over time, necessitating specialised materials and infrastructure (Bruce S et al., 2021).

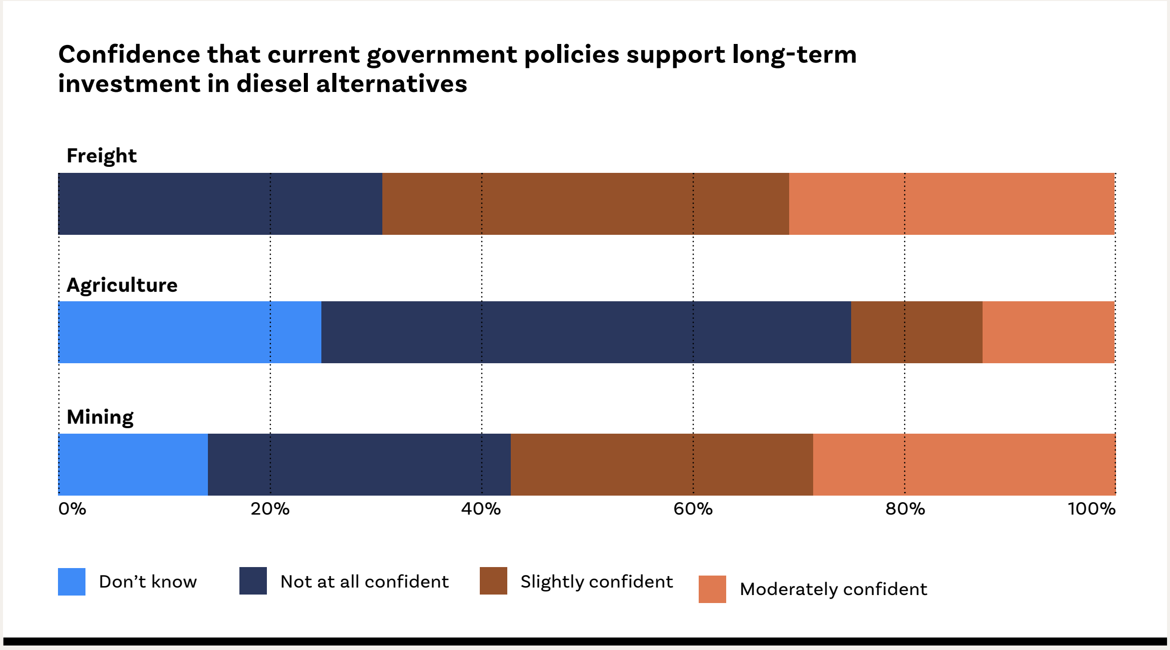

FIGURE 3 — Confidence of survey respondents in current government policy supporting long-term investment in diesel alternatives

Survey respondents expressed little confidence that current government policies support the long-term investment in alternatives to diesel. 36% stated that they were not at all confident, while 29% stated that they were only slightly confident. Experts raised several policy concerns, outlined below.

The Fuel Tax Credit Scheme

The Fuel Tax Credit Scheme (FTCS) remains a major disincentive to diesel substitution in Australian industry. The scheme allows the mining, freight and agriculture, forestry and fisheries sectors to receive full or partial refunds on the fuel excise paid for the diesel used in heavy vehicles and non-road equipment (The Grattan Institute, 2023). In the 2025–26 financial year, the credit is set at 19.2 cents per litre for diesel used in heavy vehicles on public roads, and 51.6 cents per litre for all other eligible uses. These rates are indexed twice annually in line with the Consumer Price Index (ATO, 2025).

While the current FTCS was established in 2006, its origins go back several decades. In 1957, when the federal government extended a fuel excise to on-road diesel to help fund road construction and maintenance, it also introduced an exemption certification scheme for off-road users. This was in recognition that those not using public roads shouldn't pay a tax designed to support road infrastructure. However, in 1959, the government ended the practice of linking fuel excise revenue directly to road funding. From that point on, fuel taxes became a general source of government revenue. Later reforms, including the Diesel Fuel Rebate Scheme in 1982 and the creation of the FTCS under the Fuel Tax Act 2006, retained the credit structure, even though the original justification tied to road use had been removed (Pollard & Buckley, 2025).

Since 2006–07, the FTCS has cost taxpayers an estimated $122.7 billion, with the mining sector alone receiving $57.5 billion, followed by agriculture and forestry at $15.2 billion (Pollard & Buckley, 2025). Over this period, the scheme will have subsidised over 815 $MtCO_2$-e[5] of direct emissions from diesel and petrol combustion, primarily in coal and iron ore mining. Recognised by the IEA and IMF as a fossil fuel subsidy, the FTCS is now one of the top 20 expenses in the federal budget, costing almost $11 billion per year and forecast to exceed $13 billion annually by the end of the decade (Pollard & Buckley, 2025).

5. Megatonnes of Carbon Dioxide Equivalent

Without reform, the scheme is projected to cost the Federal government a further $61.5 billion between now and 2030, bringing the total outlay to an estimated $184.3 billion over 24 years. The mining sector will receive almost $84 billion of this, 3.6x the assistance provided to agriculture, and 2.4x the assistance provided to transport (Pollard & Buckley, 2025).

By subsidising diesel use, the FTCS distorts market signals and encourages high-emitting sectors to continue using fossil fuels. It works opposite to the aim establishing a more accurate social cost for carbon dioxide emissions. This not only undermines national emissions reduction goals but also removes the financial incentives necessary to drive industry investment in cleaner, alternative fuels and low-carbon technologies.

Weakness in the Research and Development Tax Incentive
The R&D Tax Incentive (RDTI) is the largest form of research and development support in Australia, costing the Federal budget $4.23 billion in FY2023–24 (Swanson Reed, 2025). The scheme is intended to stimulate investment in innovation across the economy, by offsetting the cost of industry-led research and development (R&D).

However, a 2016 independent review found that the RDTI fails to deliver on its core objectives. It has limited impact on encouraging additional R&D that would not otherwise occur, and it produces few broader spillover benefits. Much of the subsidised activity is likely to have proceeded without public support. Key reforms proposed by the review, including an R&D intensity threshold, a collaboration premium for projects with public research institutions, and improved administrative transparency, have been only partially implemented (Ferris et al., 2016). As a result, the RDTI is less effective at encouraging R&D, reducing industry investment in technologies to transition away from diesel.

Inadequate incentives to introduce new technologies
While the Fuel Tax Credit Scheme represents a significant subsidy for diesel fuels, experts have noted that alternative low-emission fuels such as hydrogen, electrification and biodiesel do not receive equivalent fiscal support. This inequality disincentivises the adoption of cleaner alternatives and further entrenches diesel as the default fuel in high-emitting sectors, meaning an even greater disparity exists between the private and social cost and the price of optimal fuels than would otherwise be the case.

By contrast, nations such as Canada have adopted policies to address the high upfront cost of zero-emission heavy vehicles. The Incentives for Medium- and Heavy-duty Zero-Emission Vehicles (iMHZEV) Program provides businesses that purchase or lease eligible medium- and heavy-duty zero-emissions vehicles (those over 3,855 kg in weight) with incentives of up to CAD $200,000[6] per vehicle, capped at 10 vehicles or CAD $1 million[7] per year per company. In parallel, the Green Freight Program offers cost-sharing support for retrofitting existing diesel vehicles, covering up to 50% of costs for eligible technologies (Government of Canada, 2024) (Government of Canada, 2025).

The uptake of zero-emission heavy vehicles in Australia is further constrained by limited global Original Equipment Manufacturer (OEM) production capacity, with international OEMs focusing their limited stock on large Northern Hemisphere markets where strong policy mandates and financial incentives already exist. Australia, lacking equivalent support schemes, is unable to compete effectively for early supply.

Inadequate emissions cost signals
Experts also noted the absence of a strong policy mechanism that reflects the true (i.e. social) cost of emissions-intensive operations. Without a consistent emissions pricing framework, businesses have limited financial incentive to reduce their carbon footprint or invest in low-emissions alternatives to diesel technologies.

Australia's major carbon cost signal policy is the Safeguard Mechanism, which applies only to industrial facilities emitting over 100,000 tonnes of CO_2- equivalent per year. In the 2023-2024 financial year, this covered approximately 219 facilities across the mining, manufacturing, transport, oil, gas and waste sectors. Collectively these were responsible for around 30% of Australia's greenhouse gas emissions (DCCEEW, 2025f), leaving 70% of emissions without a clear price signal.

Recent reforms to the Safeguard Mechanism introduced a 4.9% annual decline rate in emissions baselines, which is intended to drive gradual reductions in industrial emissions over time (DCCEEW, 2025f). However, the mechanism excludes emissions from the agricultural sector and leaves significant gaps in some other diesel-intensive activities, particularly off-road use and transport-related fuel consumption (Clean Energy Regulator, 2025). These sectors not only escape the scope of the Safeguard Mechanism but are also supported by the Fuel Tax Credit Scheme, resulting in price signals that support continued diesel consumption. This undermines the transition to cleaner fuels and distorts investment decisions in high-emitting industries.

6. AUD$223,594 in August 2025
7. AUD$1,117,970 in August 2025

Further weakening its effectiveness, the Safeguard Mechanism relies heavily on the use of offsets through carbon credits, rather than requiring direct on-site emissions reductions. Carbon credits have been criticised for their lack of quality and permanence. There is some evidence that carbon credits are not equivalent to a direct reduction in carbon emissions (Zickfield et al., 2023), while activities that produce Australian Carbon Credit Units are only required to last 25 or 100 years (Wilson et al., 2023). Projections suggest that due to heavy reliance on offsets, the Safeguard Mechanism may result in only a 2% direct reduction in emissions by 2030, despite reducing baseline thresholds. This is significantly less than the emissions reduction trajectory needed to meet Australia's 43% reduction target by 2030 (Hare, 2025).

Policy uncertainty
A further issue raised by stakeholders is the lack of alignment between Commonwealth, state, and territory governments on emissions reduction and transport decarbonisation policy. While the Commonwealth sets national emissions targets and manages the Safeguard Mechanism and the Fuel Tax Credit Scheme, the state and territory governments are implementing their own decarbonisation strategies.

This fragmented approach leads to policy discontinuity and uncertainty for industry, particularly for nationally operating freight, mining and logistics companies that must navigate a patchwork of regulations, funding programs and emissions reporting requirements. Experts noted that the absence of coordinated, long-term national frameworks has created investment risk and delayed the replacement of diesel in heavy transport and industrial applications.

REGULATORY BARRIERS

Regulatory barriers to construction
Regulatory barriers remain a significant constraint on the timely deployment of large-scale renewable energy projects in Australia. These projects are primarily driven by private sector investment; however, progress is heavily influenced by the complexity and variability of planning and government approval frameworks across jurisdictions.

Inconsistencies between state-based regulations, overlapping environmental and land-use assessments, and prolonged approval timelines create uncertainty that can deter investors and delay construction. For example, average approval times for major renewable energy projects vary widely, with some wind projects in New South Wales taking up to 3,488 days — more than nine years — to receive full development consent, compared to significantly shorter timeframes in states like Queensland. Pumped hydro and transmission projects can also face multi-year approval processes, despite their critical role in supporting grid stability (Nexa Advisory, 2023). These delays add to project costs, strain delivery timelines, and risk undermining national decarbonisation targets.

Wheel and axle mass limits
Experts cited outdated axle mass limits as a barrier to zero-emission vehicle adoption. Battery-electric and hydrogen fuel cell vehicles require large onboard energy systems. This increases overall vehicle weight, particularly over the front (steer) axle (Climateworks, 2023).

Current Australian regulations restrict steer axle loads to 6.5 tonnes, a limit that many zero-emissions models exceed. This makes many internationally available trucks ineligible for Australian roads. This not only discourages global OEMs from introducing their most advanced models into the Australian market but also adds risk and compliance complexity for early adopters (Heavy Vehicle Industry Australia, 2023).

Hydrogen regulatory barriers
Australia lacks a unified national regulatory framework for hydrogen production, storage, distribution and end-use. This gap makes hydrogen project planning and execution challenging for businesses. A key concern amongst respondents is the absence of consistent safety and technical standards across jurisdictions (Standards Australia, 2024). While hydrogen is classified as a gas, its properties differ significantly from conventional natural gas and requires unique standards and safety protocols for high-pressure storage, refuelling infrastructure, and fuel cell applications.

Additionally, each Australian state and territory has its own gas technical regulator, resulting in a patchwork of regulations for hydrogen infrastructure projects (DCCEEW, 2025g) (DCCEEW, 2025e). Without cohesive national standards, businesses must navigate multiple approval processes when operating across state lines. This inconsistency increases development timelines, costs and legal risk, particularly for larger-scale projects.

LACK OF DESIRE TO CHANGE

Many experts noted that reluctance to change remains a significant barrier to diesel replacement. Risk aversion is high across mining, transport and logistics, where operations are often complex and profit margins slim. Even minor disruptions from new technologies can threaten productivity, discouraging uptake.

This hesitation is especially pronounced in the mining sector, where the high upfront costs of developing a new mine make companies wary of additional risks associated with new technologies, such as alternative haulage trucks. Additionally, many smaller mining companies do not own their haul trucks but instead rely on renting these from larger companies. In these cases, decision-making power rests with the vehicle owners, adding another layer of complexity.

OTHER BARRIERS

Lack of fuel diversity in policy focus
Several stakeholders expressed concern that government policy and funding frameworks remain overly focused on electrification, with insufficient attention paid to renewable fuels. The limited attention to these fuels in policy conversations was described by one expert as "myopic," noting that a successful energy transition requires a holistic view that considers the full range of fuel pathways and sector-specific solutions.

Limited national influence on international maritime emissions
International shipping accounts for an estimated 3-4% of global greenhouse gas emissions. However, the sector is largely governed by global frameworks, established by the International Maritime Organization (IMO). As a result, Australia has limited influence over emissions standards in this space. This lack of control limits Australia's ability to drive decarbonisation in its shipping sector (Brear et al., 2025).

However, the IMO has approved a draft Net-Zero Framework aimed at achieving net-zero greenhouse gas emissions in the shipping industry by or around 2050. This framework was approved in April 2025, with formal adoption scheduled for October 2025. Once adopted, the enforcement of standards will commence in 2027 for ships over 5,000 gross tonnage (IMO, 2025).

The IMO Net-Zero Framework is the first global initiative to combine mandatory emissions limits and greenhouse gas pricing across the entire shipping sector. It includes a new fuel standard for ships and introduces a global carbon pricing mechanism for emissions exceeding specified thresholds (IMO, 2025). Once adopted, this framework could create an economic opportunity for Australia to produce and bunker zero-emission fuels along major shipping routes to Asia.

Solutions

Category	Focus	Potential solutions
Fuel tax credit scheme reform	Remove market distortions favouring diesel	Phase out the FTCS, especially in high-emission sectors Introduce cap + Transition Tax Incentive to reinvest credits into clean tech infrastructure
Carbon pricing & safeguard mechanism	Strengthen economic signals to reduce emissions	Broaden carbon pricing coverage Reform Safeguard Mechanism to reflect true emissions costs
Financial incentives & grants	Reduce upfront cost barriers to clean tech	Targeted tax incentives, grants, and accelerated depreciation
Regulatory frameworks	Remove outdated rules blocking zero-emission vehicles	Revise axle weight limits for electric/hydrogen vehicles Harmonise state/territory vehicle regulations
Grid & infrastructure investment	Enable electrification and clean energy supply	Invest in grid upgrades, especially in remote regions
Biofuel industry development	Establish domestic biofuel refining capacity	Attract investment in biorefineries Develop supply chains and workforce Support feedstock production
Early-stage technology R&D (TRL 2–5)	Advance fundamental innovation in batteries, hydrogen, biofuels	Increase public R&D funding Facilitate university-industry collaboration
High-TRL technology deployment (TRL 6–8)	Scale up commercially viable low-emission technologies	Co-invest in pilot projects and demonstrations Government procurement and fleet commitments
Institutional coordination	Align roles and responsibilities across agencies	Clarify roles of DCCEEW, ARENA, CEFC, Infrastructure Australia, AEMO, research bodies Foster cooperation for tech development and infrastructure

TABLE 4 — Summary of key solutions to enable transition from diesel

Solutions to economic, policy and technological barriers

Transitioning away from diesel presents a complex, multi-dimensional challenge. While the barriers are significant, potential solutions are available. Importantly, the options discussed here are not exhaustive but instead represent just some of the potential solutions that were highlighted by stakeholders during consultation. The transition is dynamic, and ongoing innovation will continue to open new pathways that have yet to be fully explored.

Economic and policy solutions

Phasing out or reforming of the Fuel Tax Credit Scheme

Phasing out or reforming the Fuel Tax Credit Scheme would remove the market distortions that favour diesel and discourage investment in low-emissions alternatives. Experts consulted consistently identified the FTCS as one of the most significant economic barriers to the transition from diesel.

Option 1: Phasing out the FTCS
Eliminating the FTCS would eventually end public subsidies for fossil fuel consumption and generate approximately $11 billion in annual savings for the federal budget, rising to over $13 billion in annual savings over the current forward estimates. It would also send a strong price signal, encouraging industry to shift towards renewable energy and low-emissions alternative (Terrill et al., 2023). However, as diesel use declines in response to this signal, the resulting budget savings would likely diminish over time.

With approximately 300,000 businesses currently registered to claim fuel tax credits, many of which are small and medium-sized enterprises, sudden repeal would likely encounter significant resistance (ATO, 2024) and may cause financial distress to some businesses unable to adjust rapidly. Industries operating in regional and remote areas, including agriculture and small-scale operators who depend heavily on diesel and face limited access to alternatives, would be particularly impacted.

Option 2: Phasing out the FTCS in certain sectors
A phased reduction of the FTCS would offer a more targeted alternative to an immediate full removal. This approach would focus reform on industries with the greatest capacity to transition, protecting smaller businesses and vulnerable sectors in the short term.

One reform option, proposed by the Grattan Institute, suggests the removal of the FTCS eligibility entirely for on-road vehicles over 4.5 tonnes and to approximately halve the credit for off-road diesel users. This reform would save the federal budget around $4 billion annually, while sending a clear market signal that a transition to low-emissions alternatives is expected (Terrill et al., 2023).

Option 3: Cap on the FTCS for large emitters and the introduction of a Transition Tax Incentive
The FTCS currently provides uncapped diesel subsidies to high-emitting sectors, with the mining industry receiving the largest share. A proposal from Climate Energy Finance recommends the introduction of a $50 million annual cap on FTCS payments per consolidated corporate entity. Under this model, any FTCS payments above the cap would be converted into a Transition Tax Incentive (TTI). Companies would retain the value of these credits only if they reinvest the funds into defined decarbonisation activities. These include electrification infrastructure, charging networks, renewable energy, firming capacity, and procurement of zero-emissions heavy equipment such as battery-electric mobile mining equipment. From CEF's analysis, the introduction of the TTI could have mobilised almost $2.2 billion per year into decarbonisation in FY24 under a federal government revenue-neutral approach. By 2029-30, this could total more than $13.6 billion.

This reform would target the largest emitters. In FY24, only 15 mining entities would have exceeded the $50 million threshold including Fortescue, Rio Tinto, BHP, Glencore, Hancock Prospecting, Peabody, Yancoal, Whitehaven and Anglo American. The proposal would have no impact on any firm in the agriculture and road freight sectors, ensuring no small-to-medium enterprises or smaller are captured. This proposal would result in no impact to food supply chains or transport costs.

By linking public fuel tax relief to clean technology investment, the cap-and-reinvest model would transform the FTCS from a fossil fuel subsidy into a mechanism for accelerating industrial decarbonisation. It would unlock major infrastructure investment in regional areas, accelerate the deployment of electrification technologies, and support a more competitive, lower-emissions industrial base without imposing costs on farmers or road freight operators (Pollard & Buckley, 2025).

Option	Description	Estimated budget impact	Affected sectors
Phasing out the FTCS	Full elimination of the FTCS scheme for all sectors	$11B savings	All sectors
Partial phase out of the FTCS	Removal of the FTCS eligibility entirely for on-road vehicles over 4.5 tonnes and to approximately halve the credit for off-road diesel users.	$4B savings	On-road & off-road
Cap for large emitters	Introduction of a $50 million annual cap per consolidated corporate group, converting excess credits into conditional TTIs that must be reinvested in decarbonisation infrastructure and technology.	~$2.2B/year mobilised into clean capex (revenue-neutral) ~$750M/year still received by top 15 firms under cap	Large companies only

TABLE 5 — Summary of Fuel Tax Credit Scheme reform options

Strengthening the Safeguard Mechanism and introducing carbon pricing

Reform of the Safeguard Mechanism

Some experts consulted proposed that distortions caused by diesel subsidies could be addressed through future changes to the Safeguard Mechanism. However, the value of diesel subsidies far exceeds the emissions cost imposed by the mechanism. Offsetting the incentive created by the Fuel Tax Credit Scheme would require the price of Australian Carbon Credit Units (ACCUs) or Safeguard Mechanism Credits (SMCs) to reach $190 per tonne. This is far above the recent average ACCU price of $30 to $40 (Pollard & Buckley, 2025). Such an extreme change is not only politically difficult but economically disruptive, especially because it would impact all sources of emissions, not just diesel.

In addition, the next formal review of the Safeguard Mechanism is not scheduled until 2026, with any resulting policy changes unlikely to take effect for several years. However, the Productivity Commission's 2025 interim report *Investing in Cheaper, Cleaner Energy and the Net Zero Transformation* recommended that the federal Government use this review to broaden the scheme as much as possible. Specifically, the Commission suggested lowering the emissions threshold from 100,000 tonnes to 25,000 tonnes of CO_2-equivalent per year. This change would significantly expand the number of covered facilities. The report also recommends phasing out trade-exposed baseline-adjusted status for facilities covered by a future border carbon adjustment mechanism (Productivity Commission, 2025).

Compared to raising the ACCU price, broadening the Safeguard Mechanism represents a more targeted and politically viable approach to addressing diesel-related emissions. Expanding the mechanism's coverage would increase emissions accountability across a greater number of facilities, including many reliant on diesel, without triggering the economic disruption that would likely accompany an extreme increase in carbon prices.

Carbon pricing mechanisms
A consistent and credible carbon price is used internationally as an effective policy tool to drive emissions reductions across the economy. However, Australia currently lacks a comprehensive emissions pricing framework. The Safeguard Mechanism applies to just 30% of national emissions, leaving 70% outside the scope of any direct price signal. Additionally, it does not cover sectors such as agriculture, transport and smaller industrial operations.

Carbon pricing is widely used internationally. As of 2024, more than 80 jurisdictions have implemented either emissions trading schemes (ETS) or carbon taxes. These mechanisms typically apply economy-wide or to all major sectors, including transport and agriculture, creating consistent cost signals across the economy (World Bank Group, 2025).

Australia's system in contrast remains fragmented, with significant gaps in coverage and weak emissions cost signals. Introducing a broader and more consistent carbon price would address these shortcomings. A well-designed pricing framework has the potential to send a clear, economy-wide signal discouraging carbon-intensive practices and rewarding early investment in clean alternatives.

Introduction of incentives

To support industries facing higher upfront costs and operational challenges associated with the shift away from diesel, governments could introduce a combination of tax incentives, direct grants and accelerated depreciation allowances. These measures would help reduce the burden on small and medium-sized enterprises and ensure more equitable access to cleaner technologies.

Public support would need to prioritise reducing capital barriers and de-risking early investment in zero-emissions alternatives. Introducing subsidies toward renewable energy sources would create stronger price signals to accelerate change (Terrill et al., 2023). Financial and technical assistance for farmers integrating biofuel crops, particularly on marginal land, could improve regional energy resilience and fuel security (ARENA, 2021).

At the state level, early-stage grant funding, public–private partnerships and streamlined regulatory approvals are critical for enabling timely deployment of clean infrastructure. State governments also play a pivotal role in commercialising emerging technologies by supporting pilot and demonstration projects. These early interventions help build the market confidence and industry capability needed to make low-emissions fuels viable.

Institutional coordination and delivery

Delivering a coordinated transition away from diesel will require clear roles and responsibilities across government and industry. Institutions such as the DCCEEW, ARENA, CEFC and Infrastructure Australia need to work in tandem to fund, regulate and deliver critical infrastructure and technologies.

ARENA and CEFC are well positioned to support technology demonstration and early deployment, while the National Reconstruction Fund can strengthen domestic supply chains. Infrastructure Australia and AEMO could lead the planning and delivery of shared transmission and recharging infrastructure. At the same time, supporting research agencies, Cooperative Research Centres (CRCs), and university–industry partnerships would help accelerate the development of emerging technologies.

Together, these reforms form an integrated strategy to phase out diesel across Australia's hardest-to-abate sectors. By combining regulatory reform, fiscal incentives, infrastructure investment and sustained technological development, Australia could accelerate industrial decarbonisation while boosting innovation and regional economic resilience.

Technology and infrastructure solutions

Strengthening grid capacity

Meeting demand for high-capacity charging infrastructure and firmed renewable power from electrification will require coordinated investment. Regional and remote areas would need to be prioritised for upgrades to enable high-power charging and all-electric industrial operations. A major part of this transition involves building a firmed renewable energy grid, that integrates utility-scale wind and solar with storage and dispatchable backup to ensure reliability (ARENA, 2024).

Shared transmission infrastructure will also be critical. Collaborative investment in common-use transmission corridors could significantly lower the cost of clean electricity. Lower electricity prices in these areas would also unlock broader benefits: attracting clean industry, supporting energy exports and enhancing regional economic resilience (AECOM, 2025).

Supporting early-stage technology research and development

Early-stage R&D is essential to addressing the technical challenges that currently prevent zero-emissions technologies from replacing diesel in heavy-duty and remote applications. Without sustained investment to reach commercial viability, these future electrification, hydrogen and biofuel technologies will remain in laboratory or prototype stages.

As a global leader in mining, freight and agriculture, fisheries and forestry, Australia is well positioned to shape the next generation of low-emissions technologies in hard-to-abate sectors. Our industrial strengths mean that breakthroughs made here are not only relevant to domestic decarbonisation but could also be exported to global markets as demand for clean solutions in heavy industries accelerates.

In electrification, current lithium-ion battery chemistries are often unsuitable for use in high-heat, high-load or off-grid environments such as mine sites and remote farms. Research into next-generation storage, such as solid-state or lithium–sulphur batteries, aims to deliver lighter, safer and more durable options (Monash University, 2024) (Deakin University, 2021). Their successful development could overcome current limitations around axle weight in trucking and offer payload reductions in electric heavy vehicles, unlocking new markets for Australian innovation.

The widespread implementation of hydrogen technologies continues to face significant technical challenges. The storage, transport and delivery of hydrogen remain costly and energy intensive. Research into potential solutions, such as onboard hydrogen cracking and chemical storage methods, could lead to safer and more efficient systems (Nguyen et al., 2025) (Moudio et al., 2026). However, these technologies are still at a low Technology Readiness Level (TRL 2–5[8]) and require further development.

Early-stage innovation in advanced biofuels offer a solution for sectors where full electrification or hydrogen is not practical. Fuels derived from agricultural waste, or carbon capture could be used as drop-in replacements for diesel. However, these fuels face challenges in feedstock availability, conversion efficiency, and production cost. Continued research into agronomic practices, such as trials of new biofuel crops and novel rotation strategies, is needed to improve feedstock reliability and yield (AgriFutures, 2022b)(Whittaker, 2025). National expertise in this area could play a critical role in advancing globally scalable solutions.

To progress these technologies, targeted public investment is essential, particularly in pre-commercial R&D. However, government funding alone is not enough. Stronger collaboration between universities, industry, research centres and government-backed innovation hubs is also needed to ensure that research is relevant, scalable, and directed toward the highest-impact opportunities. Without early investment, these technologies are unlikely to reach market readiness within the next decade, and Australia may miss a significant opportunity to lead global innovation.

8. For more information on Technology Readiness Levels please see Appendix 4

Early-Stage Technologies (TRL 2–5)	High-TRL Technologies (TRL 6–8)
Focus	
Fundamental R&D and lab-scale innovation	Deployment, commercial readiness, scaling
Examples of technologies	
Solid-state and lithium–sulphur batteries Onboard hydrogen cracking and storage systems Advanced biofuels from novel feedstocks Agronomic trials for novel biofuel feedstocks	Battery-electric mining trucks and loaders Hydrogen fuel cell long-haul trucks Renewable diesel
Support needed	
Public R&D grants and programs University–industry collaboration Open-access testbeds and pilot labs Long-term research prioritisation	Co-investment in large-scale pilots First-of-a-kind funding, risk-sharing, deployment grants Public procurement and fleet commitments Policy certainty and infrastructure planning
Key role of industry	
Informing research priorities Partnering in proof-of-concept development Piloting agronomic innovation	Leading demonstrations and commercial pilots Investing in supply chains and infrastructure Partnering with government to scale deployment

Table 6 — Targeted support for technologies at different stages of maturity

Bridging the deployment gap for high TRL (TRL 6-8) technologies

A growing number of low-emissions technologies are now technically viable and have been successfully demonstrated in pilot projects. These include battery-electric mining vehicles, hybrid-electric agricultural equipment, hydrogen fuel cell freight trucks and drop-in renewable diesel. However, despite their technical readiness, these technologies face persistent economic and operational barriers that prevent them from scaling.

In mining, battery-electric haul trucks and loaders have been trialled with promising results, yet high capital costs, infrastructure requirements and integration challenges continue to limit broader uptake. Similarly in agriculture, biofuels and electric machinery already exist, but face constraints in performance, power density, and affordability for heavy-duty use.

These obstacles are typical of first-of-a-kind deployments where technologies remain stuck in the pilot phase due to high upfront risk and limited market confidence. Without intervention, many of these technologies may not progress beyond demonstration.

An Australian deployment strategy would bridge this gap. This could include public co-investment in large-scale pilots, government procurement to create stable demand, and targeted infrastructure investment in charging and refuelling corridors. Stronger regulatory signals, such as performance standards or fleet mandates would also give industry the certainty needed to invest.

More pilot and demonstration projects can also play a critical role in shifting industry perceptions, particularly among stakeholders who are currently hesitant to move away from diesel. Seeing technologies in real-world use can build confidence, demonstrate viability, and help overcome institutional resistance to change. Without these measures, many high-TRL technologies that can support a transition from diesel may remain out of reach commercially, despite their technical readiness.

By driving early deployment, Australia could help bring down costs through scale, grow domestic supply chains, and position its industries as first movers in markets that will increasingly value low-emissions performance.

Conclusion

The decarbonisation and transition away from diesel fuels in Australia's freight, mining and agricultural, fisheries and forestry sectors is a complex challenge. There is no one-size-fits-all solution. Success will require an innovative strategic mix of alternative fuels, policies, investments, and industry engagement to meet the needs of different technologies and sectors.

At the core of this transition is the need to shift economic incentives: reducing the cost of green alternatives while revealing the true cost of diesel and other high-emission fuels. This approach would create market signals strong enough to encourage adoption of clean technologies. Achieving this requires the gradual removal of diesel subsidies and targeted support to clean alternatives throughout the technology development cycle, from early-stage innovation to commercial deployment, and must also be timed to coincide with the capital replacement cycles within industry.

Many of the barriers outlined in the report are interconnected. For example, the lack of infrastructure (technological) is both a result of and a contributor to limited market demand (economic), which in turn is shaped by unclear or insufficient regulatory signals (policy). To overcome these barriers and reduce diesel reliance in Australian industry, a nationally coordinated approach is required. This approach would integrate policies across jurisdictions, align infrastructure development with technology readiness, and provide clear, consistent regulatory frameworks that support investment confidence and industry accountability.

A comprehensive national strategy would assist in orchestrating this transition effectively. This strategy could combine reforms to financial incentives, such as phased changes to the Fuel Tax Credit Scheme and enhanced carbon pricing, with substantial investment in infrastructure. At the same time, supporting research, development and deployment across the full spectrum of technology readiness levels is crucial to overcoming technical hurdles and enabling scalable deployment of clean alternatives.

Strengthening institutional coordination to ensure clear roles, responsibilities and accountability across Commonwealth and state governments, industry and research bodies would assist the transition. Only through coordinated governance can Australia overcome fragmented policy environments and market uncertainties that currently impede progress.

Decarbonising Australia's most emissions-intensive sectors is an urgent yet achievable goal. By reducing the cost of green alternatives, investing in clean new technologies, and increasing the cost of diesel in a targeted and balanced way, Australia can accelerate its industrial decarbonisation. This will support the nation to fulfill its climate commitments, while growing its economic resilience and innovation leadership in the global clean energy transition.

Appendices

Appendix 1

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Appendix 2

METHODOLOGY

This study employed a mixed-methods approach, combining desktop research with expert consultation and stakeholder engagement to develop a comprehensive understanding of the opportunities and challenges in transitioning away from diesel use in Australia's mining, freight and agriculture, fisheries and forestry sectors.

Desktop research
Extensive desktop research formed the foundation of the analysis. This included a review of:

- Academic literature relevant to low-emissions technologies, transition pathways and sectoral decarbonisation
- Industry reports from mining, agriculture, freight and energy organisations
- Government publications and data from relevant departments and agencies
- Media and news articles to capture recent developments, announcements and public discourse.

The desktop research helped identify the current state of technology readiness, key challenges and barriers, and the role of enabling infrastructure and policy settings.

Expert consultation and interviews
To supplement the literature and data review, targeted consultations were conducted with six sector experts across mining, freight, biofuels and energy. These consultations were used to:

- Test and refine the scope and structure of the study
- Provide insights into sector-specific dynamics and practical considerations for diesel reduction
- Validate findings from the desktop research phase.

Consultations were conducted via email and structured interviews in July 2025.

Expert Survey
A broader survey of stakeholders and experts was conducted using SurveyMonkey to gather additional perspectives and quantify sector sentiment. The survey was open from 15 July to 3 August 2025 and was distributed through the following channels:

- To Fellows who are members of ATSE's Energy, Agriculture, Infrastructure, Industry and Innovation, and Minerals Forums
- Shared with all ATSE Fellows via the ATSE monthly newsletter
- ATSE's LinkedIn account to engage a broader professional audience
- A BioEnergy Australia–Low Carbon Fuels Alliance of Australia and New Zealand meeting, where the survey link was shared with attendees.
- 84 additional identified experts

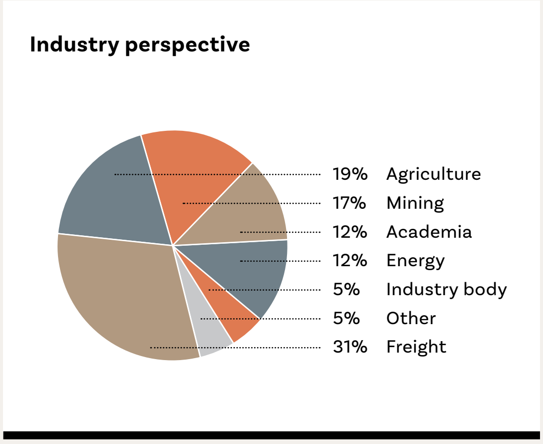

FIGURE 4 — Industry perspective of survey respondents

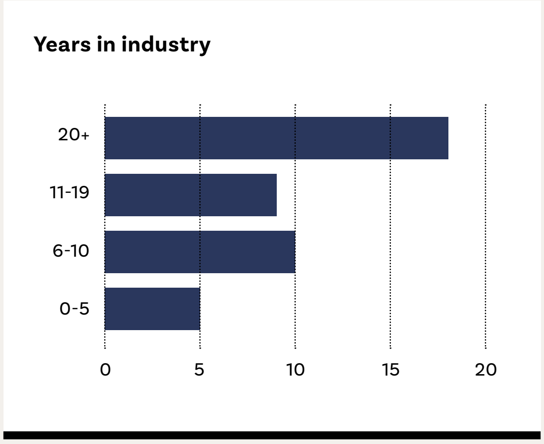

FIGURE 5 — Years in industry of survey respondents

42 people responded to the survey, and their responses helped validate key findings, highlight areas of consensus or uncertainty, and ensure the analysis was informed by a diverse set of expert perspectives.

69% of survey respondents responded as an individual, and 31% responded on behalf of an organisation.

Peer review and quality assurance
The final draft of the report was subject to expert peer review prior to publication. This process helped strengthen the analysis, test assumptions, and ensure the accuracy and relevance of the recommendations.

Appendix 3

SECTOR MAPPING

Ongoing government planning		
Project	**Lead agency**	**Description**
Net Zero Sectoral Plan	Department of Climate Change, Energy, the Environment and Water	As part of planning to reach Net Zero by 2050, the Australian government is preparing a series of sectoral plans (including for the agriculture and land, transport and infrastructure, industry, and minerals sectors) to support emissions reductions in each sector (DCCEEW, 2025d).
Strategic Examination of Research and Development (SERD)	Department on Industry, Science and Resources	The SERD is an ongoing wide-ranging review of Australia's research and development ecosystem, examining policy and investment settings to strengthen the sector (DISR, 2025).
Economic Reform Roundtable	Treasury	Supported by 5 Productivity Commission inquiries, the economic reform roundtable intends to develop new policy positions to increase Australia's Productivity, including in emissions reductions (The Treasury, 2025).
Research facilities		
Facility name	**Funders / host institution**	**Description**
Future Fuels CRC	Deakin University, RMIT University, the University of Adelaide, the University of Melbourne, the University of Queensland, University of Wollongong, South Australian Government, Tasmanian Government, NSW Government, Western Australian Government and others	Aims to enable Australia's energy sector to adapt to net zero fuels by providing new knowledge. The CRC conducts research ion new fuel technologies, markets, social acceptance, safety and supply security (Future Fuels CRC, 2025).
Heavy Industry Low-Carbon Transition CRC	Australian National University, CSIRO, Curtin University, Swinburne University of Technology, the University of Adelaide, Fortescue, Hancock Iron Ore, South32, Liberty, Hydro, Grange Resources and others.	Aims to develop new low-carbon technologies and methods to overcome barriers and support the transition of the steel, iron, alumina and cement industries to decarbonise. The CRC conducts research on green industrial processes, cross cutting technologies and addressing barriers to low carbon products (HILT CRC, 2025).
Net Zero Emissions in Agriculture CRC	Australian National University, University of Adelaide, University of Melbourne, University of Western Australian, University of New England, University of Southern Queensland, University of Tasmania, University of Queensland, Agriculture Victoria, Bega Group, Coles, Cotton Research and Development Corporation and others.	Aims to improve the competitiveness, productivity and sustainability of Australian agriculture. The CRC researchers low emissions plant solutions, methane free livestock, whole-farms system and net zero circular economy solutions (ZNEAg CRC, 2025).

TABLE 7(a) — Summary table of relevant work in the sector

Recent reports		
Report title	**Author or publisher**	**Description**
Refined Ambitions: Exploring Australia's low carbon liquid fuel potential	Clean Energy Finance Corporation	Identifies the economic opportunities from developing a strong low-carbon fuels industry (CEFC, 2025).
The critical path to decarbonise Australia's rail rollingstock	Australasian Railway Association	Outlines options for decarbonising rollingstock in Australia (Australasian Railway Association, 2024).
Hydrogen: Hype, hope, or hard work?	The Grattan Institute	Examines the use of hydrogen in meeting Australia's emissions reduction target (Wood et al., 2023).
The diesel transition: Petroleum diesel alternatives for the Australian agriculture, fisheries and forestry sector	AgriFutures	Outlines how Australia's agriculture, fisheries and forestry sector can reduce reliance on diesel fuels(AgriFutures, 2022a) .
The Grattan truck plan: Practical policies for cleaner freight	The Grattan Institute	Provides recommendations for reducing the emissions from, and impact of, trucks and road freight (Terrill & Burfurd, 2022).
Fuelling budget repair: How to reform fuel taxes for business	The Grattan Institute	Examines the impact of fuel tax credits on the federal budget and on net-zero targets (The Grattan Institute, 2023).
Over a barrel: Addressing Australia's liquid fuel security	The Australia Institute	Examines demand-side solutions to increase Australia's energy independence (Carter et al., 2022).
Technology solutions for decarbonation: Mining in a low emissions economy	Clean Energy Finance Corporation and the Minerals Research Institute of Western Australia	Examines the role of the mining and resources sector in meeting Australia's net zero targets (CEFC and MRIWA, 2022).
Biofuels and Transport: An Australian opportunity	Clean Energy Finance Corporation and the Australian Renewable Energy Agency	Examines the challenges and opportunities of biofuels to support emissions reduction in the transport sector (CEFC and ARENA, n.d.).
Electric Trucks: Keeping shelves stocked in a net zero world	Electric Vehicle Council and the Australian Trucking Association	Provides recommendations to addressing barriers to widespread adoption of electric trucks (Electric Vehicle Council and Australian Trucking Association, 2022).
Delivering freight decarbonisation: Strategies for reducing Australia's transport emissions	Climateworks	Examines how to implement emissions reduction solutions for short-haul freight and develop and scale new solutions for long-haul freight (Climateworks, 2023).
Electrifying Road Freight: Pathways to Transition	AECOM for the Australian Renewable Energy Agency	Examines the electrification of urban, intrastate and interstate freight (AECOM, 2025).
Fuel Tax Credit Scheme and Heavy Haulage Electric Vehicle Manufacturing in Australia	Climate Energy Finance	Examines the Fuel Tax Credit Scheme and its budgetary and climate implications (Pollard & Buckley, 2023).
Transition Tax Incentive: Reforming Fuel Tax Credits into a Decarbonisation Tailwind	Climate Energy Finance	Examines the Fuel Tax Credit Scheme and proposes a cap- and-reinvest reform to the scheme to drive decarbonisation in Australia's mining sector (link).

TABLE 7(b) — Summary table of relevant work in the sector

Appendix 4

CASE STUDIES OF ALTERNATIVE TECHNOLOGIES

Electrification

Agriculture, forestry and fisheries	John Deere recently unveiled three prototype electric tractors with aims to deliver a fleet of vehicles that combine electric motors with autonomous vehicle, battery and charger technology (Glacier FarmMedia LP, 2025). A Dutch electric tractor manufacturer EOX Tractors also has plans to sell its machinery in Australia by mid-2026 (Biss, 2025). Smaller-scale electric vehicles have widescale availability and adoption, including electric drones that support surveying and crop spraying. Over 300,000 electric drones are used in agriculture worldwide, treating more than 500 million hectares of farmland (DJI Agriculture, 2024).
Mining	Bellevue Gold's hybrid power combines solar, wind and battery storage to supply up to 80% of electricity needs at their project site in WA (Bellevue Gold, 2024). BHP and Rio Tinto are trialling battery-electric haul trucks with Caterpillar and Komatsu, evaluating both static and dynamic charging methods (Rio Tinto, 2024). In partnership with Liebherr, Fortescue is deploying zero emission machines including electric excavators and cutting-edge battery haul trucks. The haul trucks will be fitted with a power system developed by Fortescue Zero, marking a significant step toward decarbonising mining.
Freight	A prototype of Australia's first battery-powered heavy-haul freight locomotive that can haul up to 400 km is due to begin testing in late 2025 (Aurizon, 2023). The world's first electric container ship was launched in 2021 by fertiliser company Yara and is able to carry 100 containers on an approximately 13 km journey from its processing plant to the port of Brevik (Murray, 2023). Chinese company COSCO Shipping has launched its own battery-powered electric container ship capable of carrying 700 containers, that regularly sails 965 km (Randall, 2024). While these are positive developments for the electrification of cargo shipping, they are currently only making a small contribution. More development is needed before electric cargo ships are well placed for widespread adoption.

TABLE 8(a) — Summary of case studies of alternative technologies in mining; freight; and agriculture, forestry and fisheries

Hydrogen

Mining	In 2022, Anglo American presented a prototype of a hydrogen-powered mine haul truck (link) and in 2024, Fortescue released a prototype of a hydrogen-powered mine truck that travelled from Perth to Pilbara for site-based testing (Fortescue, 2024). New Holland's first hydrogen powered tractor debuted in 2009 (Blue Fuel Solutions, 2025), with Fendt (Fendt, 2023) and Massey Ferguson (Fuel Cell Works, 2025) launching hydrogen-powered tractors in 2023 and 2026 respectively. Glencore's Raglan mine in Canada has been running on a hydrogen-powered microgrid since 2015 (CSIRO, 2020). In Australia, Horizon Power is currently running a demonstration project to produce power to a microgrid using green hydrogen in Denham that produces and consumes green hydrogen on site (CSIRO, 2025). Liebherr is exploring powering generators and off-board mobile power units using green ammonia, produced from green hydrogen (Southway, 2024).
Freight	Volvo has announced commercially available hydrogen freight trucks, with trials scheduled for 2026 and commercial models expected by decade's end (Volvo, 2024). The governments of Germany and the United Kingdom have invested in proposals to build new hydrogen trains and converting existing trains to hydrogen fuel sources, respectively (ARENA, 2019), but trials have proven problematic in Germany (Collins, 2024) and Austria (Martin, 2024) and suggest battery electric has won this technology race over hydrogen. Hydrogen is currently used internationally for smaller vessels and passenger ferries (Shipping Australia, 2021). In June 2025, the world's first hydrogen-powered bulk carriers were ordered, by Norwegian shipping company Møre Sjø with an agreement to purchase hydrogen at prices comparable to marine oil gas (Collins, 2025). Additional trials of hydrogen-powered freight shipping will be needed before widespread adoption is possible.

TABLE 8(b) — Summary of case studies of alternative technologies in mining; freight; and agriculture, forestry and fisheries

Biofuels

Agriculture, forestry and fisheries	New Holland has developed an entirely methane-powered tractor, the T6 Methane Power tractor, which claims to run at 30% of the cost of diesel and results in an 80% reduction in overall emissions (AgriFutures, 2022a). In December 2024, the Department of Primary Industries & Regional Development finished trialling HVO in commercial fishery trawlers in NSW. The trial had promising results, setting the first step for HVO use at scale in Australian fisheries (Refuelling Solutions, 2025). Using HVO as a 'drop-in' fuel in fisheries is better for the water quality of sensitive marine environments and improves air quality.
Mining	In 2025, Rio Tinto reported the successful trial of renewable diesel in their Pilbara operations with renewable diesel producer Neste (Rio Tinto, 2025b). In this trial, 10 million litres of used cooking oil was integrated with diesel to create a fuel mix of about 20% renewable diesel before being distributed across the company's mining vehicles and equipment. The trial provided insights into how renewable diesel use could be scaled up and integrated into Rio Tinto's supply chain (Rio Tinto, 2025b). BP and BHP have also trialled the use of blended diesel with HVO in iron ore operations in Western Australia, in an attempt to reduce carbon emissions (BP Australia, 2025).
Freight	In 2022, ANL and the Woolworths group announced a successful containerised shipping marine freight trip powered by biofuel. For this trial, the container ship was powered by 500 metric tonnes of biofuel made up of BP Marine's Very Low Sulphur Fuel Oil blended with biodiesel. The freight ship completed a 42-day rotation from Brisbane, South-East Asia and key Australian ports (ANL, 2022). This voyage was also successfully completed with the support of the Queensland government's 'Bio Futures 10-Year Roadmap and Action Plan'. Cleanaway Waste Management in partnership with Bioenergy Australia, launched a renewable diesel trial in 2024, operating two heavy collection vehicles on HVO (Cleanaway, 2024b). The use of this renewable diesel reduced reportable scope 3 emissions by 91% while providing the same performance (Cleanaway, 2024a).

TABLE 8(c) — Summary of case studies of alternative technologies in mining; freight; and agriculture, forestry and fisheries

Appendix 5

TECHNOLOGY READINESS LEVELS

Any commercially viable and successful technology will have transitioned through the full range of Technology Readiness Levels. TRLs are a critical tool for researchers to incorporate into the development of any new technology. Almost all developed economies use some version of TRLs, which can range from simple to complex. The Australian Department of Defence have developed a high-level illustrating of TRL descriptors as outlined below.

Technology readiness level definition	
TRL level	**Description**
TRL 1	Basic research: Initial scientific research has been conducted. Principles are qualitative postulated and observed. Focus is on new discovery rather than applications.
TRL 2	Applied research: Initial practical applications are identified. Potential of material or process to solve a problem, satisfy a need, or find application is confirmed.
TRL 3	Critical function or proof of concept established: Applied research advances and early-stage development begins. Studies and laboratory measurements validate analytical predictions of separate elements of the technology.
TRL 4	Lab testing / validation of alpha prototype component / process: Design, development, and lab testing of components/process. Results provide evidence that performance targets may be attainable based on projected or modelled systems.
TRL 5	Laboratory testing of integrated / semi-integrated system: System component and /or process validation is achieved in a relevant environment.
TRL 6	Prototype system verified: System / process prototype demonstration in an operational environment (beta prototype system level).
TRL 7	Integrated pilot system Demonstrated: System / process prototype demonstration in an operational environment (integrated pilot system level).
TRL 8	System incorporated in commercial design: Actual system / process completed and qualified through test and demonstration (pre-commercial demonstration).
TRL 9	System proven and ready for full commercial deployment: Actual system proven through successful operations in operating environment, and ready for full commercial deployment.

TABLE 9 — Technology readiness level definitions

For Australian domestic research to deliver a profitable industrial scale critical mineral recovery process sector, it must transition from basic research through to TRL9. This requires the following:

- Research should begin with the explicit objective of developing superior environmental, economic, and net zero outcomes. Objective descriptors of how the research aims to achieve these outcomes should also be developed, and progress should be measured and refreshed as research is undertaken.
- Environmental, economic and carbon outcomes with commercially available alternate processing approaches be maintained through the research cycle.
- Research groups need to articulate how the transition to a TRL9 outcome will be managed.

Transition periods between TRL levels are pivot points in the development of critical mineral processing technology. These periods typically involve collaboration, coordination and commercial exchanges with other parties required to launch a successful technology.

Appendix 6

ABBREVIATIONS

Abbreviation	Standard form
ACCU	Australian Carbon Credit Units
AEMO	Australian Energy Market Operator
ARENA	Australian Renewable Energy Agency
BESS	Battery Energy Storage System
CEFC	Clean Energy Finance Corporation
CNG	Compressed natural gas
CO_2-	Carbon dioxide
CRC	Cooperative Research Centre
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DEE	Diesel engine exhaust
ETS	Emissions Trading Scheme
EU	European Union
EV	Electric vehicle
FTCS	Fuel Tax Credit Scheme
HVO	Hydrotreated vegetable oil
IEA	International Energy Agency
iMHZEV	Incentives for Medium- and Heavy-duty Zero-Emission Vehicles
IMF	International Monetary Fund
IMO	International Maritime Organisation
LCLF	Low carbon liquid fuel
NO_x	Nitrogen Oxides (a group of gases including NO and NO_2)
NT	Northern Territory
OEM	Original Equipment Manufacturer
PEM	Proton Exchange Membrane
R&D	Research and Development
RDTI	Research and Development Tax Incentive
SA	South Australia
SMC	Safeguard Mechanism Credits
TRL	Technology Readiness Level
TTI	Transition Tax Incentives
US	United States
WA	Western Australia

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