MOVEMENT

transport energy environment

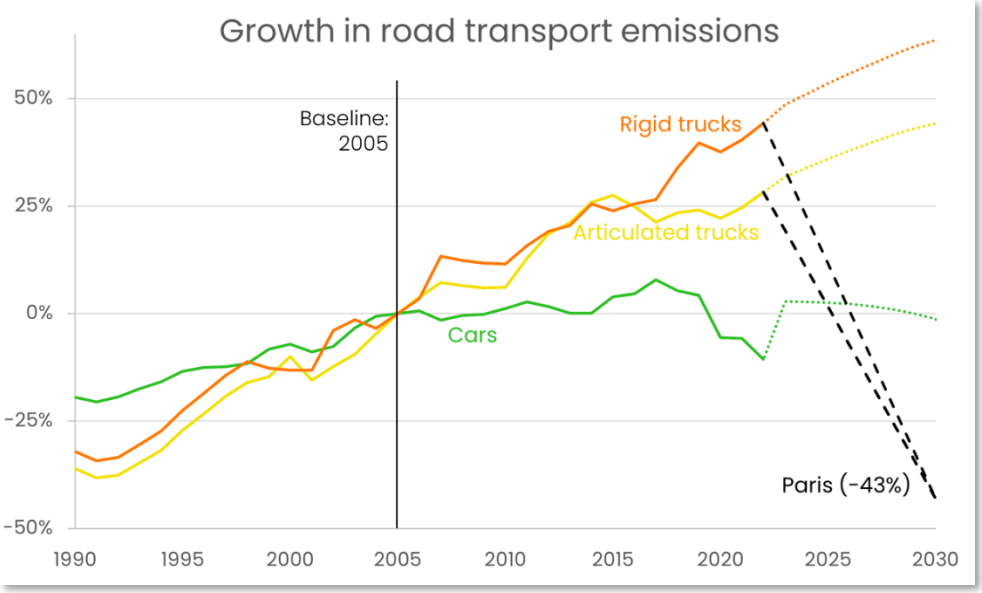
The Road to Zero

Decarbonising Australian Trucking

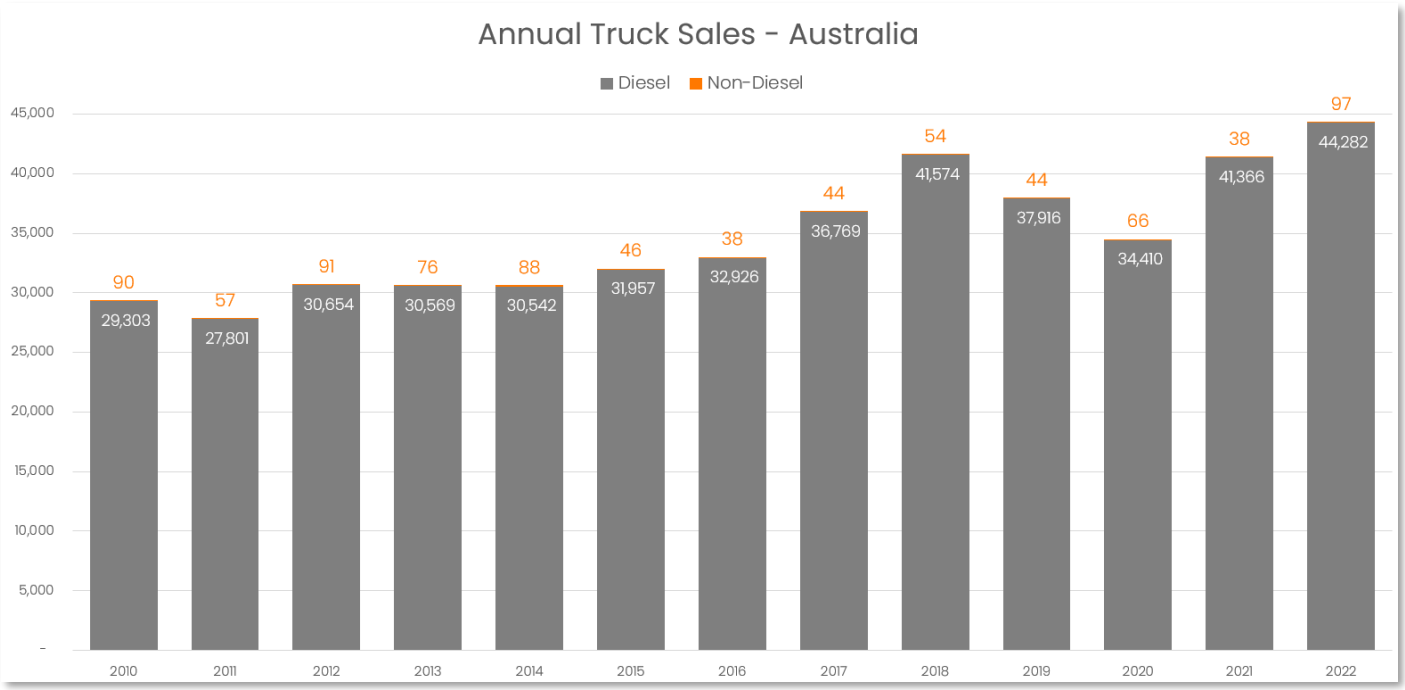
September 2023

TRUCKS ARE NOT ON TRACK

Transport is set to become Australia's highest-emitting sector by 2030. Whilst light vehicles are making progress on emissions reduction, the truck sector is not on track to meet Australia's economy-wide Paris targets. Growth since the reference year of 2005 shows emission projections for trucks clearly heading in the wrong direction:



Diesel dominates Australian trucking, with lower emission drivetrains barely perceptible as a fraction of annual truck sales (see graphic below). Trucks in Australia live a long life: many bought today will likely still be on the road in 2048. So, even if no further diesel trucks were sold in Australia, trucking emissions would still not even halve by 2030.



In the absence of a nationally agreed decarbonisation pathway for trucks, this Roadmap provides one. Balancing the operational and commercial demands of Australia's diverse truck fleet with best available abatement options, it recommends effective and achievable actions for fleets, freight buyers/customers, policymakers and OEMs.

ZERO EMISSION TECHNOLOGIES AND FUELS

Zero emission trucks (ZETs), alternative fuels, and new technologies are developing rapidly, bringing both potential and uncertainty. While different options are at different stages of maturity, none of them represent a silver bullet for net zero road freight. As at 2023, the following technologies are the most likely and feasible ZET options.

Plug-In Battery Electric Trucks (BETs) are selling in the light/medium-duty market with trials of heavier BETs also underway. BETs draw their energy exclusively from large on-board batteries powering the motor and any ancillary equipment. The more energy required, the larger (and heavier) the battery. BETs are recharged from an external energy source, making them only as sustainable as the grid they recharge from. Recharging times vary with vehicle range (i.e. the size of the battery) but BETs typically require at least an hour for a full recharge, or 30-40 min with megawatt charging.

+ *Zero tailpipe emissions; abundant fuel source; high energy efficiency; low fuel costs*
− *Requires fleet replacement; recharging downtime; high purchase costs; high grid upgrade costs; undeveloped recharging network; payload penalty from heavier drivetrain (+1-3t)*

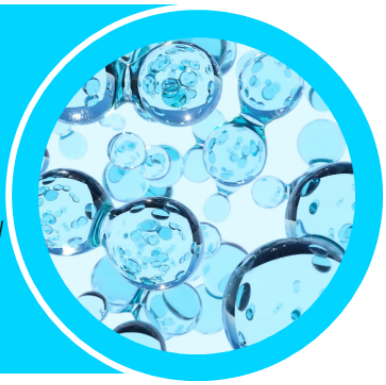
BETs can also be used through a **battery swapping** model that relies on a fully removable battery pack that can be exchanged for a fully-charged pack when exhausted. Battery swapping therefore relies on a Battery-as-a-Service business model as part of a broader ecosystem of charging infrastructure. In practice, this often means that vehicle owners do not own the vehicle's battery. The swapping system minimises recharging downtime, achieving similar 'refuelling' speeds to diesel.

+ *Zero tailpipe emissions; abundant fuel source; high energy efficiency; lower grid infrastructure requirements; minimal refuelling downtime*
− *Requires vehicle replacement/retrofit; undeveloped recharging network; payload penalty from heavier drivetrain; high purchase costs; ongoing battery hire costs*

The sustainability of biofuels hinges on the energy used to produce them and the biomass used as feedstock (palm oil, soya, corn, waste, animal fats, algae, used cooking oil).* The most promising biofuel is **renewable diesel (RD)** as it is refined to be chemically identical to fossil diesel. RD can 'drop in' to the existing fuel mix at blend rates up to 100%. This contrasts with **biodiesel**, where blends above 20% (B20) typically require engine modifications.

+ *'Drop in' potential (RD) including for existing fleets; scope for net zero over fuel lifecycle; no fleet replacement required*
− *Tailpipe & production emissions; feedstock unsustainability (land use, deforestation, food security); nil Australian production; strong feedstock demand competition from other sectors; high ongoing fuel costs ($3-4/L)*

Hydrogen fuel cell electric trucks (FCETs) are entering the Australian market, typically in small numbers for limited trials. FCETs draw most of their energy from stored hydrogen (either compressed gas or cryogenic liquid) that is converted into electricity via the on-board fuel cell. FCETs are impacted by the high cost of 'green hydrogen' and its inherent chemical properties (high energy density but very low volumetric density).



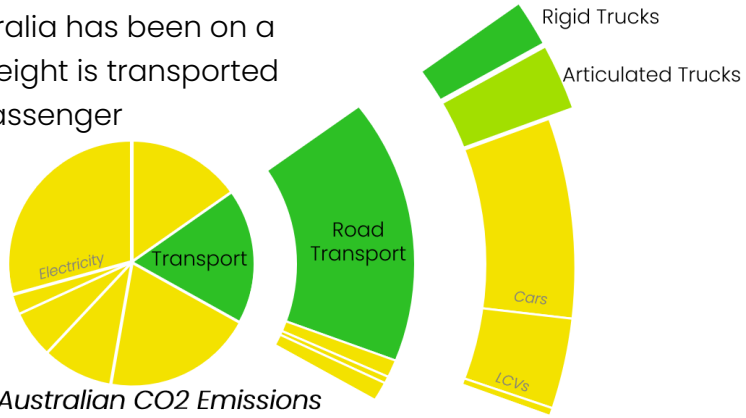
+ *Zero tailpipe emissions (except water); more energy per kg than diesel; minimal refuelling downtime*
− *Requires fleet replacement; low production volume of green H2; undeveloped refuelling infrastructure; payload penalty from H2 tank volume; high purchase costs; high ongoing fuel costs ($6-18/kg)*

* Other alternative combustion fuels include renewable natural gas, hydrogen combustion and e-fuels, all of which face significant technical and commercial barriers. Renewable natural gas is also derived from renewable biomass but requires a simultaneous shift to gas injection engine technology, which has not succeeded in Australia to date. Hydrogen combustion is still a nascent technology and will remain constrained by the availability (and cost) of green hydrogen. E-fuels are a 'drop in' substitute for diesel but rely on non-fossil CO_2 and green hydrogen, neither of which is commercially available yet. For these reasons, these options are not considered viable near-term pathways.

TRUCKS TODAY

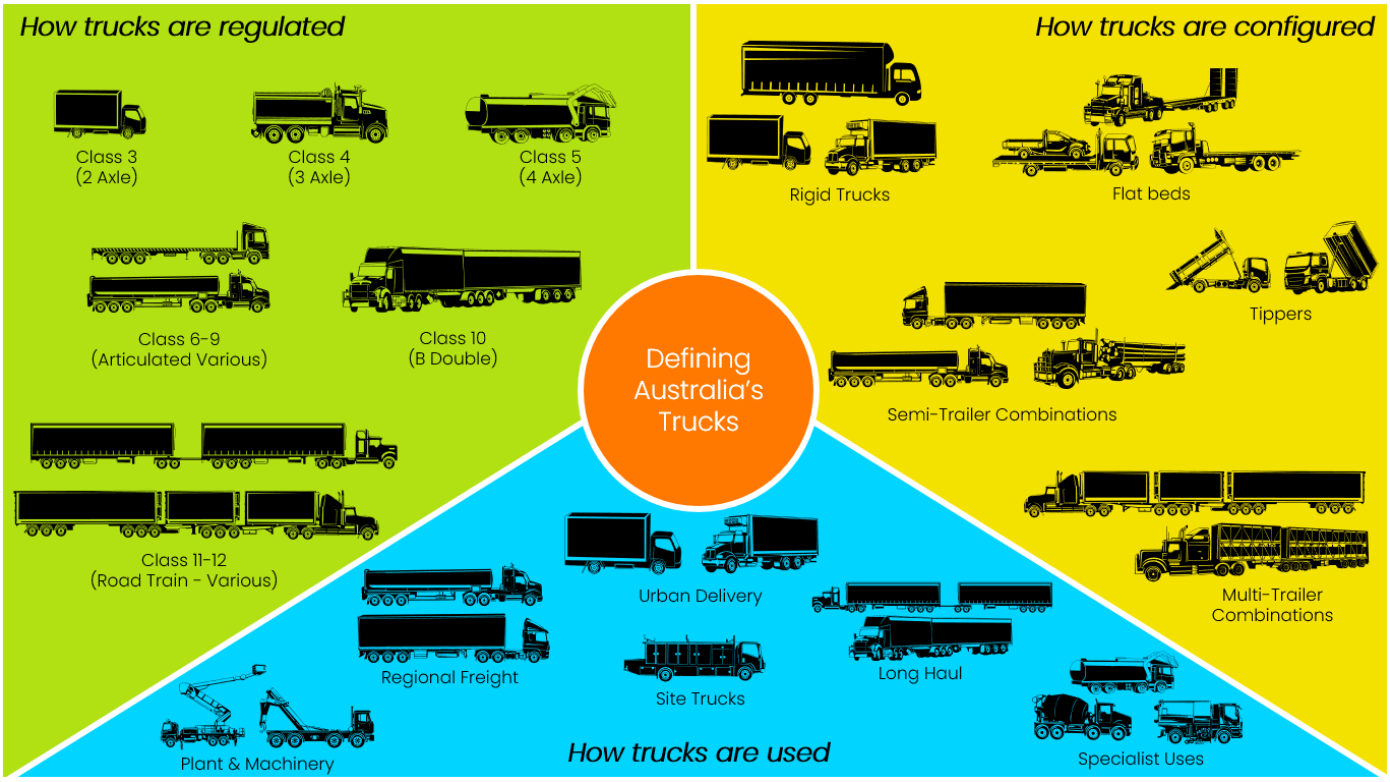
Almost everything bought or sold in Australia has been on a truck. Around 80% of national non-bulk freight is transported by road, making trucks second only to passenger vehicles as the largest contributor to transport emissions.

While rigid trucks outnumber articulated trucks almost 5 to 1, higher utilisation of articulated trucks accounts for the majority of Australia's truck emissions.



Australian CO2 Emissions
2021-22

Australia has a diverse truck fleet that is not uniformly classified. Some distinguish heavy vehicles by their size and body type, while regulators often define them by their potential pavement damage (e.g. Austroads' classes).



But what really matters for the net zero transition is how much energy a heavy vehicle uses and when. For that, it is critical to combine the size of the truck with what *work* it does. Variously called 'applications', 'missions' or 'market segments', the **duty cycle** describes how a truck is used. This has a direct bearing on how readily different trucks can transition to ZET drivetrains and which technologies match best.

In Australia, the work that trucks perform can be broadly segmented into 7 duty cycles, each with distinct energy and operational requirements. The first three are most significant as they account for over 90% of total energy demand from Australian trucking.

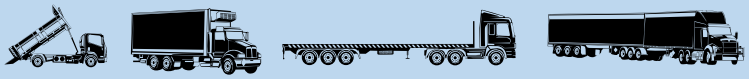
URBAN DELIVERY

Trucks used mainly for retail distribution in urban and built -up areas. Characterised by stop/start driving, frequent braking, low speeds in high traffic areas

km/day (avg)	Energy Use (diesel)	Double Shifts	Powered Equipment	Applications
100-200	14-45 L/100km	Rarely	Low (excl. refrigeration)	B2B, residential delivery, postal, fast moving consumer goods

REGIONAL FREIGHT

Medium-distance freight with infrequent stops, often between distribution centres. Characterised by high-speed driving, single shift cycles on regional/intercity routes



km/day (avg)	Energy Use (diesel)	Double Shifts	Powered Equipment	Applications
350-500	25-60 L/100km	Rarely	Low (excl. refrigeration)	Hub-to-Hub; bulk freight; FMCG; fuel/liquids

LONG HAUL

Mainly long -distance freight and logistics typically on interstate/ regional highways. Characterised by high-speed driving, multi-shift cycles & high on -board energy demand

km/day (avg)	Energy Use (diesel)	Double Shifts	Powered Equipment	Applications
500+	>45 L/100km	Often	Low (variable)	Commodities; agriculture; mining; heavy haul

Beyond these broad use cases, 4 additional niche applications can be defined:

PLANT & EQUIPMENT

km/day (avg)	Energy Use (diesel)	Double Shifts	Powered Equipment	Applications
<100	20-100 L/100km	Rarely	High	Electricity utilities; fire safety; forestry

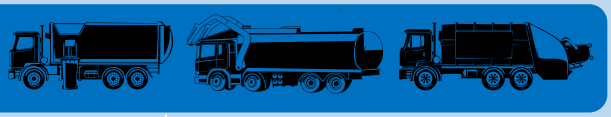
SITE TRUCKS

km/day (avg)	Energy Use (diesel)	Double Shifts	Powered Equipment	Applications
<100	14-25 L/100km	Rarely	Low-Medium	Suburban/commercial construction; trades

CONCRETE

km/day (avg)	Energy Use (diesel)	Double Shifts	Powered Equipment	Applications
50-150	60-80 L/100km	Rarely	Very High	Construction; major infrastructure

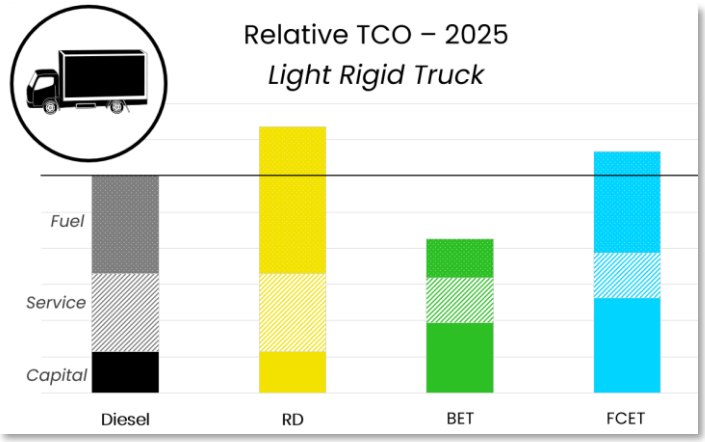
WASTE

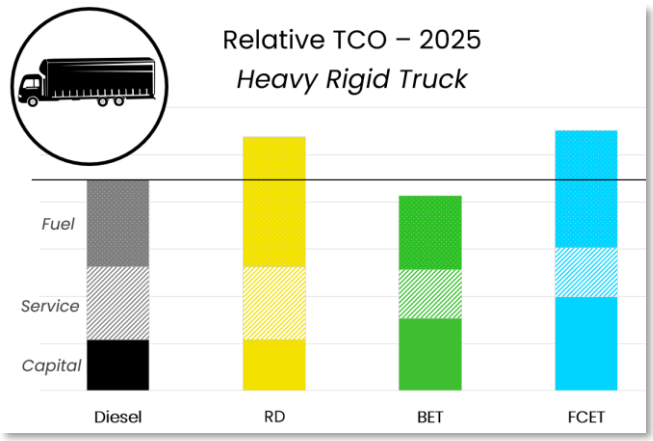


km/day (avg)	Energy Use (diesel)	Double Shifts	Powered Equipment	Applications
80-100	<150 L/100km	Sometimes	Very High	Garbage collection; municipal services

MATCHING TECHNOLOGY TO TASK

The demands of each duty cycle play to the strengths and weaknesses of each ZET drivetrain. Using conservative cost estimates,[1] some zero emission technologies may already be approaching parity with diesel on a Total Cost of Ownership basis (TCO). For example, annualised costs for light/medium-duty BETs are projected to be lower than diesel in urban delivery applications within 3 years:

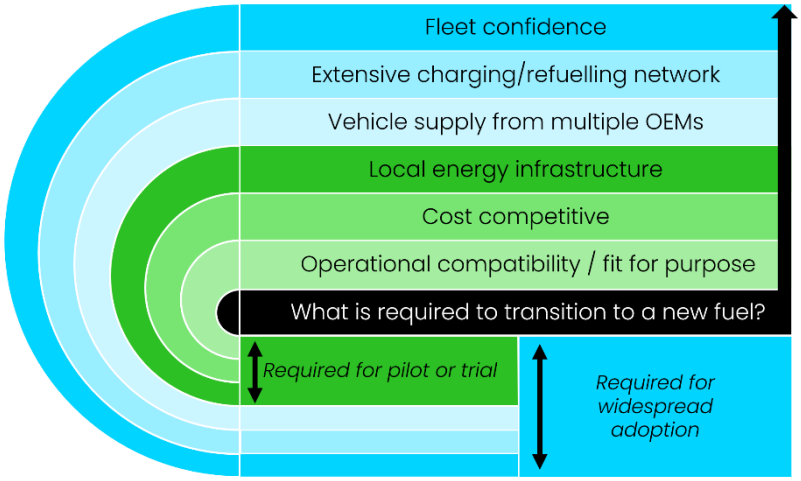




In practice, it is the *relative* performance of each technology against operational needs that will determine viability. Apart from cost competitiveness, this also depends on the availability of refuelling infrastructure and, crucially, whether new models can actually do the work required by Australian fleets.

There are also key differences between what 'early adopters' need to begin ZET trials and what is required for industry-wide uptake (see below graphic).

Previous experiments with alternative fuels (e.g. CNG, LNG) ultimately failed due to insufficient model choice, a slow rollout of refuelling infrastructure, and/or lack of confidence from fleet managers in the business case or the technology itself.



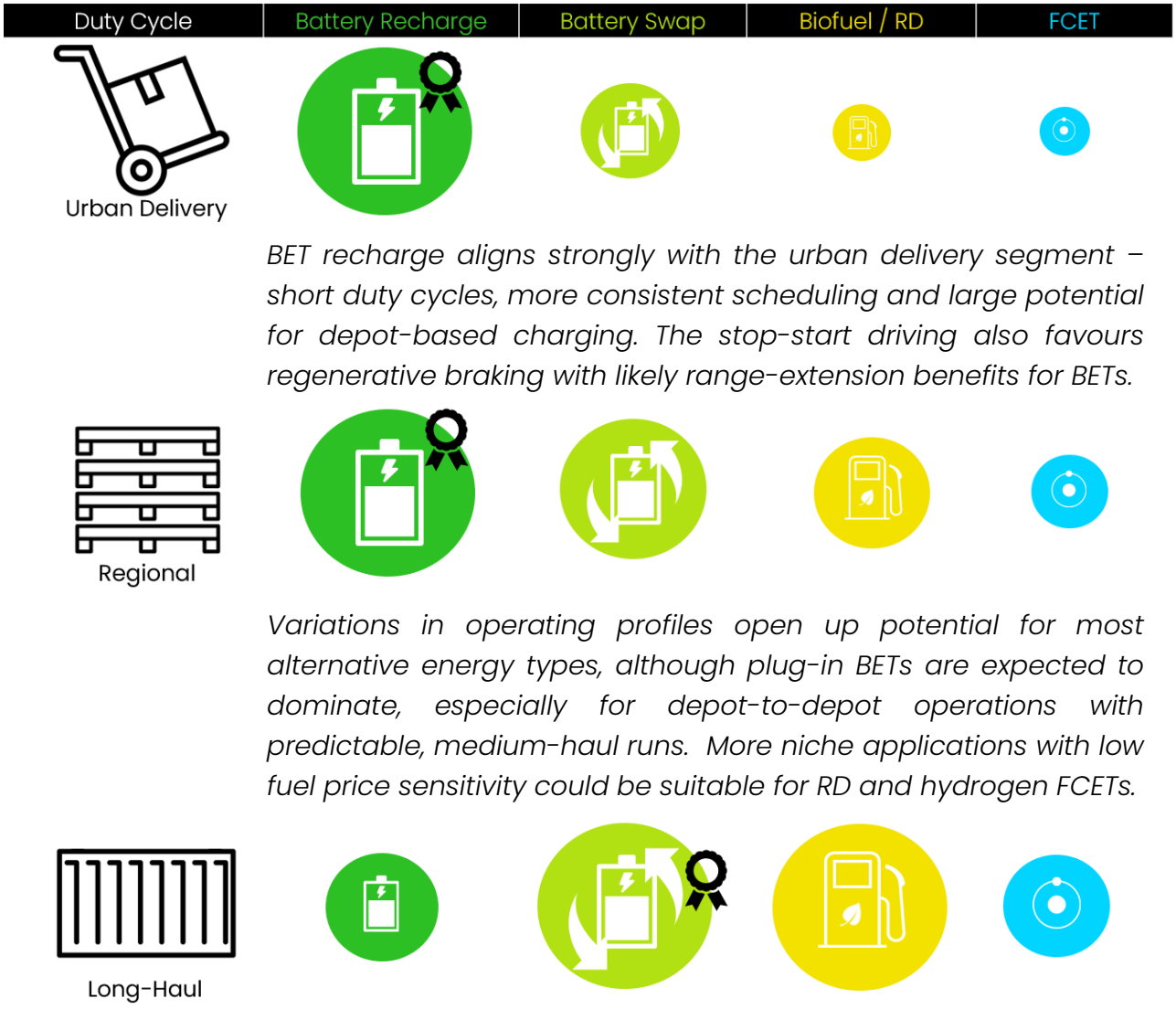
Addressing these factors in the ZET transition will be at least as important as advances in cost and technology.

[1] MOV3MENT works closely with OEMs, major fleets and peak industry bodies to regularly update commercial forecasts including ZET model availability, pricing, depreciation, fuel prices, charging/refueling infrastructure, biomass feedstocks and grid electricity supply. For further information on MOV3MENT's proprietary TCO modelling, contact one of our team.

The three largest applications were assessed against the four leading zero-emission technology options, based on:

- the suitability to the duty cycle's operational requirements
- the forecast availability of truck models in the Australian market
- the relative Total Cost of Ownership (vehicle price, fuel, infrastructure, servicing)

All technologies will likely experience some degree of uptake (shown below by circle size), reflecting fleets' differing business needs and leadership ambitions. Nevertheless, the distinct demands of each duty cycle naturally lend themselves to particular technologies, with some clear winners already apparent.



BET recharge aligns strongly with the urban delivery segment – short duty cycles, more consistent scheduling and large potential for depot-based charging. The stop-start driving also favours regenerative braking with likely range-extension benefits for BETs.

Variations in operating profiles open up potential for most alternative energy types, although plug-in BETs are expected to dominate, especially for depot-to-depot operations with predictable, medium-haul runs. More niche applications with low fuel price sensitivity could be suitable for RD and hydrogen FCETs.

Enroute refuelling is a primary consideration for long-haul operations, favouring battery exchange and RD. The mass/volume constraints of large on-board batteries/hydrogen equipment present payload and range difficulties given the large distances involved. Future battery technology and liquid H2 storage may overcome these issues.

For lower volume segments, various ancillary equipment and high power-take-off (PTO) usage contribute to challenging energy demand profiles, with no clear 'winner':

Given its diversity, net zero pathways for plant and equipment vary considerably. BET options will be less feasible in mass-constrained applications while FCETs are hampered by TCO and poor model supply. Biofuels still produce tailpipe pollutants so may face future health or workplace opposition in the face of zero-emission options.

Most ZET technologies may be technically suitable for site trucks, but utilisation (km) in this application is typically low; so higher cost alternatives (FCETs, RD) will be less viable.

The high non-motive energy demand and mass sensitivity of concrete agitators limit technical feasibility for BETs and FCETs; the "drop-in" capability of biofuels may prove decisive.

Both BET and FCET compactors are already being trialled; viability will depend on individual loading demands, regenerative braking potential, and local route conditions.

Despite the uncertainty and niche operational demands of these less common duty cycles, the largest abatement potential remains in applications where zero emission options are already apparent. Decarbonising urban delivery and regional freight alone could conceivably remove Scope 1 emissions from almost 50% of Australia's trucks.

EMISSIONS ABATEMENT OPTIONS

The investment choices fleets make in the next decade will determine the sustainability of Australia's freight system. Despite the importance of fleet replacement and emerging technologies, some of the most cost-effective abatement options can be achieved now.

There are **four** main abatement options that must be pursued simultaneously, many of which offer co-benefits to broader business operations.

1. Fleet Replacement/Repower: Switching to ZETs is the only long-term pathway to reaching zero emissions but upfront costs will be higher for the foreseeable future. Switching out a diesel truck with a ZET at the end of its term, or mid-life as engines are overhauled, will be the most feasible strategy, particularly if fleets target their oldest trucks first. This could include:

- Switching from diesel to diesel-electric hybrid trucks
- Switching from diesel to new battery electric trucks (plug-in or battery swap)
- Switching from diesel to new hydrogen fuel cell trucks
- Retrofitting diesel trucks to one of these technologies.

2. Renewable Fuel Switch: Replacing diesel in fleet operations offers the next most effective decarbonisation measure with up to 100% emission savings, albeit at a high per kilometre cost. Renewable diesel (RD) will be the least disruptive for fleet operations but can cost up to 3 times diesel. B20 (20% biodiesel blend) may be more cost-effective in the short-term.

- Fuel switching to 100% renewable diesel (RD)
- Fuel switching to diesel-RD blends (e.g. 50% RD)
- Fuel switching to B20 (20% biodiesel).

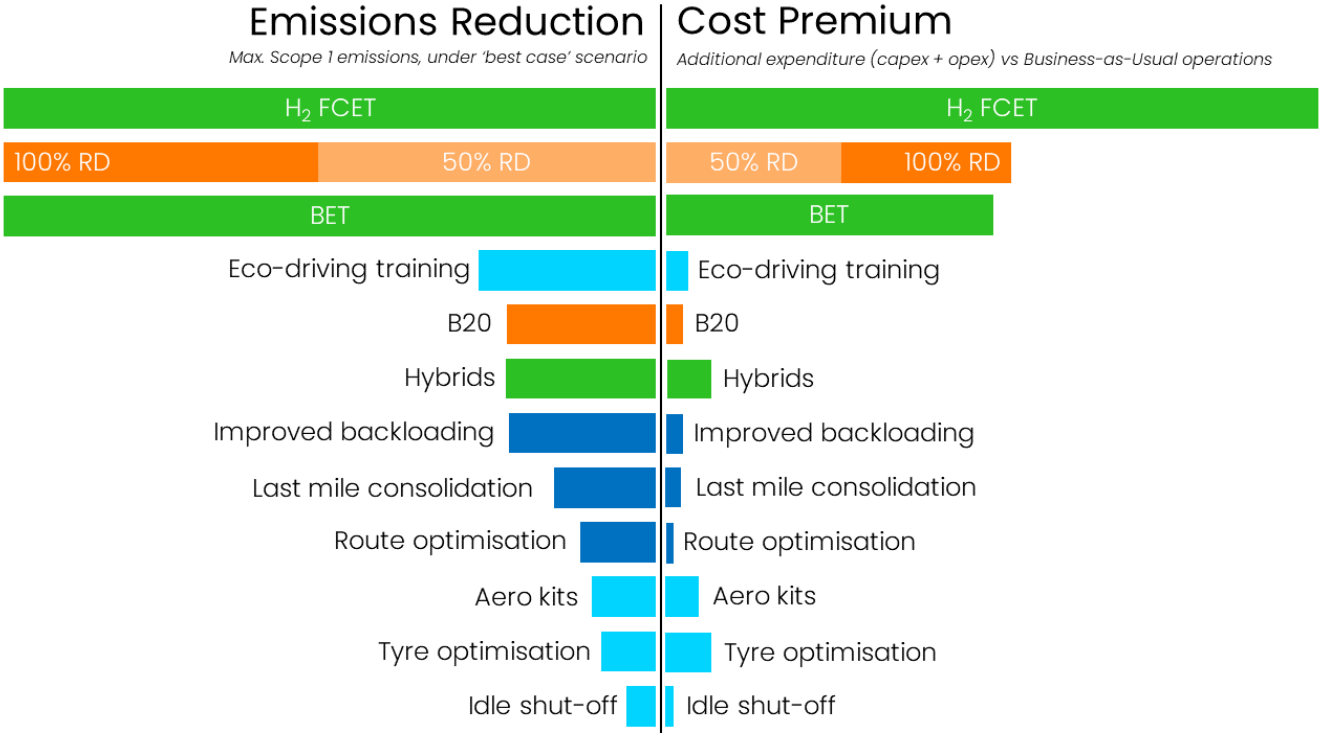
3. Vehicle Efficiency: Reducing fuel consumption through vehicle efficiency also offers scope to minimise energy inputs and emissions outputs. Improving energy efficiency also benefits ZETs in the form of longer driving range. Options include:

- Training/monitoring eco-driving techniques: acceleration, braking, anticipation
- Installing aero kits to minimise aerodynamic drag
- Tyre optimisation (e.g. low rolling resistance tyres, improved pressurisation)
- Anti-idling measures (e.g. engine shut-off systems).

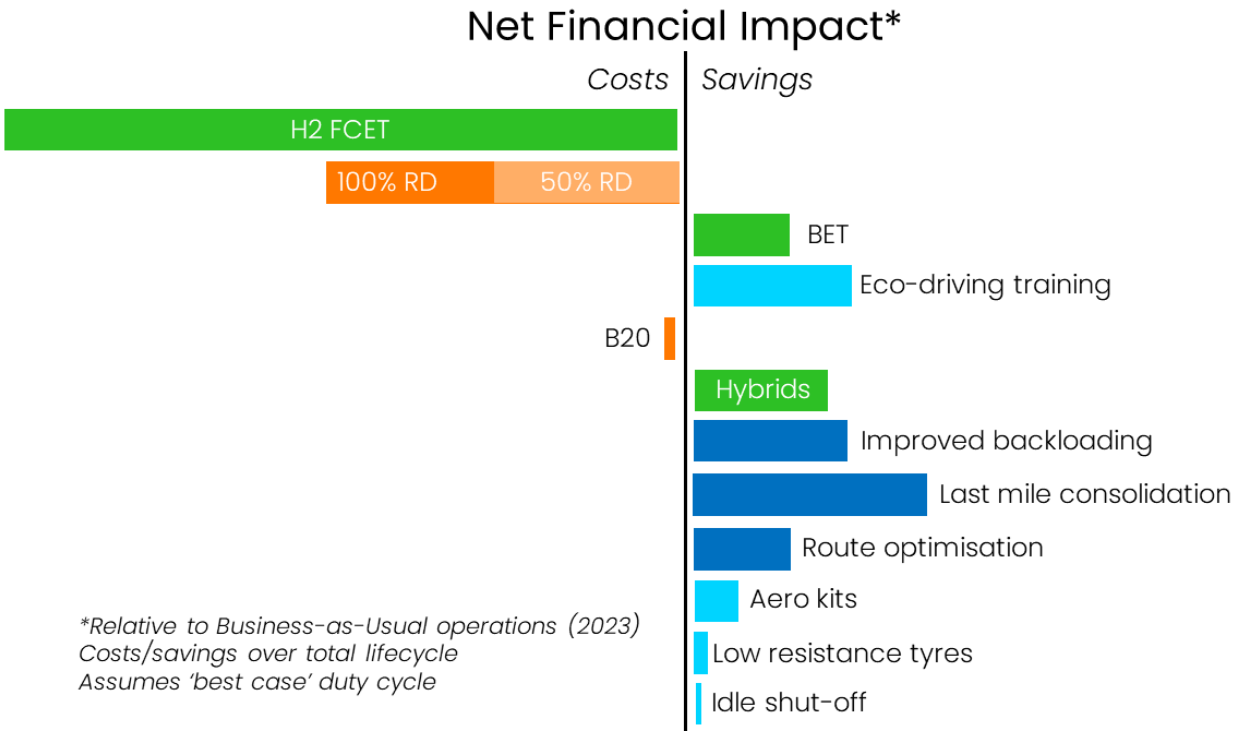
4. Supply Chain Optimisation: Improving operational efficiency through redesign of supply networks offers a no-regrets pathway to minimising emissions. Abatement potential depends on the degree of efficiency realised, but options include:

- More efficient route planning (i.e. above and beyond BaU)
- Last mile consolidation (i.e. reducing trips and kilometres travelled)
- Improved backloading (i.e. utilising spare capacity to reduce trips required).

Each abatement pathway brings its own emissions reduction potential and costs:



While upfront costs will remain front of mind for fleets, assessing abatement actions over their full lifetime reveals major differences in the net return on investment:



There is more to decarbonising Australia's truck sector than buying shiny new tech. Reaching net zero will mean taking simultaneous action on alternative fuels, vehicle improvements, and supply chain optimisation.

ACTIONS

The scale of the decarbonisation transition will require all stakeholders to collaborate across multiple initiatives simultaneously. The table below lists actions (in no particular order) for some of the key actors in the freight supply chain.

FLEETS	GOVERNMENT
1. Data baselining to develop detailed picture of energy used in *current* fleet task 2. Identify 'quick win' efficiency measures to right-size existing operations (e.g. fuel efficiency, supply chain optimisation) 3. Define the duty cycles / applications whose energy profiles can be transitioned to ZETs *first* 4. Calculate transition costs and build business case triggers for vehicle replacement schedules 5. Bring your people with you; corporate learning to build internal momentum for change	1. Reform regulatory barriers to ZET supply (e.g. unharmonised standards, axle limits, access restrictions) 2. Mandate minimum requirement for renewable fuel (e.g. RD) in the diesel supply chain 3. Targeted funding, incentives and concessions to increase model supply to the Australian market 4. Zero Emission Zones in state capital cities, phased in over the coming decade 5. Co-fund a collaborative industry-government Green Freight Program to increase energy related knowledge, skills & data
OEMS	**FREIGHT BUYERS**
1. Transparent communications about which ZETs best suit which applications and their associated energy profiles and costs 2. Generate real-world Australian case studies through trials/ demonstrations with fleet customers 3. Share knowledge across full value chain and upskill dealer network 4. Take steps to secure ZET supply for the *Australian* market (from head office) 5. Simplify the transition through an integrated ZET product offering across energy/refuelling/planning	1. Map supply chain; calculate/ report Scope 3 emissions 2. Update vehicle procurement policies (incorporating ZET targets, preferential contract terms, etc.) 3. Provide charging or refuelling at origin/destination sites to support fleet providers 4. Co-invest with key fleet partners to lower the barriers to ZET operations 5. Collaborate across industry on a Green Freight Program to aggregate ZET freight demand and share operational learnings

ABOUT MOV3MENT

Motor vehicles enable the modern economy but also impose burdens on society. MOV3MENT's mission is to make vehicles part of the solution not the problem. We take complex energy and cost questions and simplify them into actionable fleet strategies, policies, and programs.

MOV3MENT specialises in the three Es of cleaner vehicles and fuels: Energy, Environment and Economics. Our knowledge and advice are built on practical, cost-effective improvements that benefit vehicle operators and the community, with a particular focus on truck and bus operators, suppliers, and policymakers.

We leverage this knowledge to help governments develop programs and policies that overcome barriers to improvement, demonstrate real-world benefits, and increase awareness and knowledge. This includes innovation projects that use information to transform the market – like our world-first Smart Truck Rating.

We're fiercely proud of the things that set us apart: our independence, our principled approach, and our evidence-based advice.

To accelerate your net zero transition, get in touch or find out more on our website www.mov3ment.com.au.

MOV3MENT
transport energy environment

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