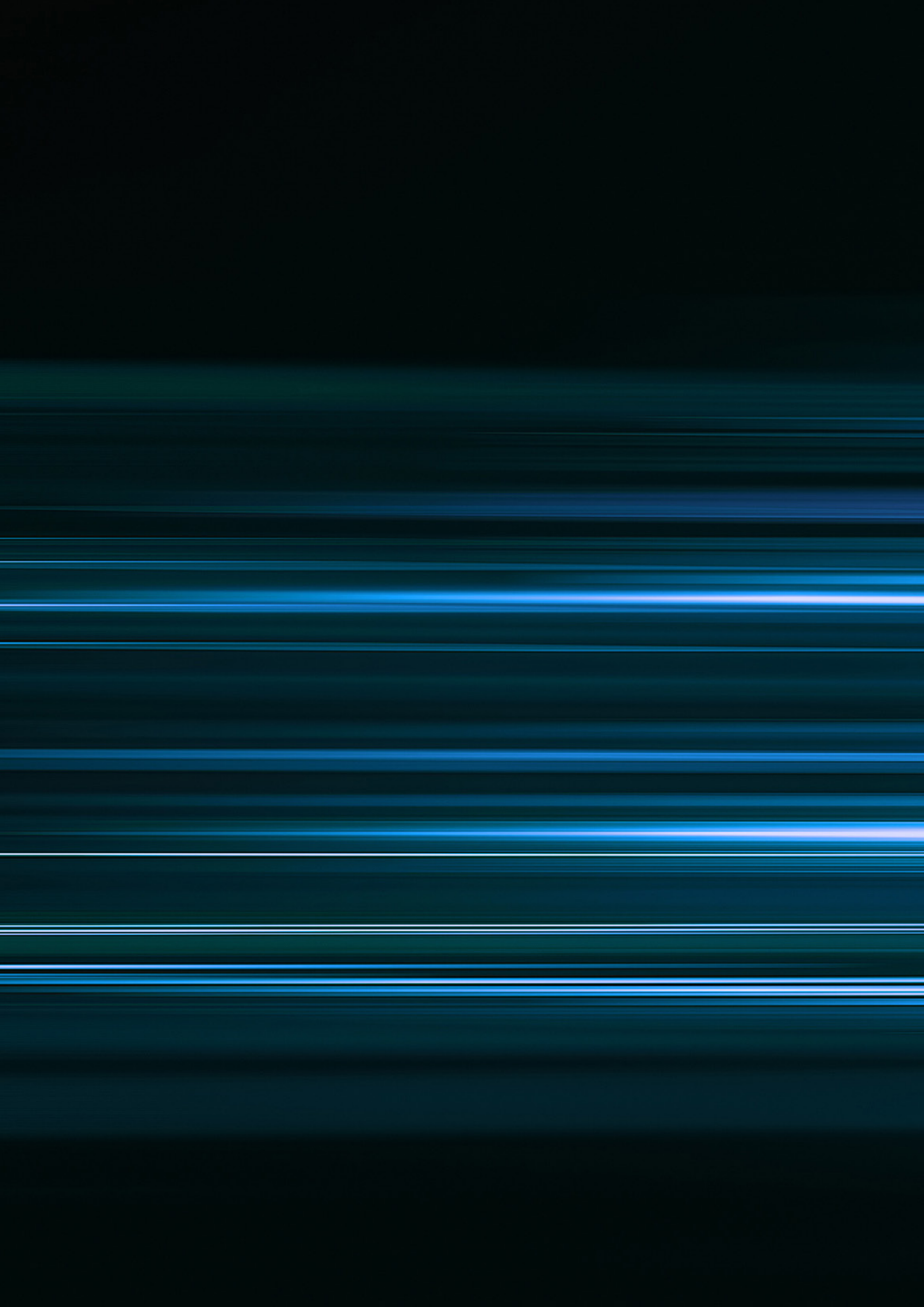
Emissions and economic modelling of road freight in NSW

Research summary

14 December 2023



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Research summary

This research modelled the reductions in emissions and economic benefits resulting from targeted policy interventions for decarbonising road freight in NSW. The research focused on key tasks that included:

- A comprehensive literature review that surveyed and interpreted relevant studies to identify the current state of knowledge, opportunities, challenges, and barriers that could influence uptake of low and zero emissions trucks (LZET) in NSW. The review also considered international best practice case studies and identified important insights that were used to inform the research directions.
- Identification and feasibility assessment of targeted policy interventions. Several policy options for the uptake of LZETs were analysed to determine their feasibility in the context of NSW based on a series of qualitative metrics. This helped to develop a good understanding of the expected policy impacts on freight demand and LZET adoption rates over time, which in turn informed the development of modelling scenarios in this study.
- Choice Experiment and modelling of uptake. A Choice Experiment and associated survey was undertaken to collect evidence from fleet operators on the responsiveness of technology uptake to the purchase price and ongoing cost, willingness to pay extra for LZETs, potential impacts of certain non-financial policy interventions, and impacts on decisions of access to charging and refuelling infrastructure. Scenarios on key parameters such as future costs of fuels and vehicles were also established, and the results were then used to determine the demand for LZETs. Models of LZET uptake rates were then developed up to 2061 based on 20 scenarios that included single and various combinations of multiple policy interventions.
- Estimation of emissions and health impacts under policy interventions. An emissions modelling framework was then used that considered VKT by truck type (rigid and articulated), emissions factors for diesel trucks, and LZET uptake rates from the modelling of uptake (drawing on the Choice Experiment results). The output of the emissions model included CO_2-e, NO_x, $PM_{2.5}$ emissions (exhaust and non-exhaust) and monetised health costs for each of the 20 scenarios evaluated in this research.
- Economic assessment of policy interventions. An economic assessment framework which followed cost effectiveness analysis principles was used in this research. The analysis was based on comparing the monetised emissions and air quality impacts associated with the policy interventions, and the likely public sector costs of implementing these interventions.
- Stakeholder consultations. A survey-based stakeholder consultation was conducted in this research to gain insights from freight operators on their perceptions, expectations, and knowledge of LZET technologies. This helped to develop a good understanding of the barriers and challenges faced by the industry and the support they need to improve uptake of LZET fleets.

Key findings

LZET technology acceptance appears high in NSW, providing the basis for incentivising decarbonisation of freight

The Choice Experiment and econometrics approach helped to understand how freight operators make trade-offs between key parameters when purchasing trucks, and this provided information on how they would respond to policies, and how they assign value and preferences to LZETs. The Choice Experiment estimated respondents' relative valuation of a set of financial and non-financial options in relation to truck operators choosing between diesel and LZET technologies. The results showed a high acceptance of LZETs and preference for these (amongst most participants) when suitable alternatives are available. Specifically, in the largest group of participants (around 65%) there was a statistically significant positive willingness to pay extra for LZETs. Only about a third of respondents were not willing to pay extra for LZETs, but rather this group had a reverse preference in that they had a statistically significant willingness to pay to avoid LZETs (for example by paying penalties or a higher purchase price). The methodology used the equations parameterised by the Choice Experiment, which allowed for calculating the probability of operators choosing one type of vehicle over another in future scenarios. This provided the basis for modelling LZET adoption rates for the period 2023–2061, across a suite of availability scenarios, stipulating which types of trucks that are available for purchase. This was based on ensemble modelling, considering a multitude of scenarios for the possible availability of different vehicle types, aggregated to a single adoption rate for each vehicle type, using Bayes formula. This was used to test and evaluate the impacts on freight decarbonisation resulting from different scenarios that explored a variation of financial and regulatory/policy settings.

This research modelled 20 scenarios (referred to as iMOVE 1 to iMOVE 20) that include a base scenario (iMOVE 1) reflecting the baseline 'Current 2022 Policy', in addition to 19 policy intervention scenarios (**Table ES.1**). The scenarios are based on assumptions related to OPEX and CAPEX financial subsidies, non-financial incentives and considerations such as improved LZET availability, road access to reserved lanes and low emissions zones, discounted loans and phase out year 2035 beyond which ICE trucks would not be available.

Key findings

Table ES.1: Policy intervention scenarios

OPEX subsidy	$5 rebate on per 100km operating costs -approximately 16.6% rebate
CAPEX subsidy	Percentage of the differential in purchase price between LZET and an ICE equivalent (40% and80%)
Availability	(1) Available (0) Not available A qualitative indicator capturing whether a business can purchase a LZET that matches their needs
Road access	Policy package consisting of road/network access to reserved lanes, low emissions zones, and relaxation of right-time curfews for LZETs
Discounted loan	This a low or zero interest loan offered by the state for the procurement of new LZETs (4% or 6%)
Phase out	Year beyond which Internal Combustion Engine trucks would no longer be available on the Australian market

Scenario	iMOVE 1	iMOVE 2	iMOVE 3	iMOVE 4	iMOVE 5	iMOVE 6	iMOVE 7	iMOVE 8	iMOVE 9	iMOVE 10
OPEX subsidy	0	0	0	0	0	0	0	0	$5	$5
CAPEX subsidy	0	0	0	0	0	0	40%	80%	0	0
Availability	0	0	0	0	0	1	0	0	0	1
Road access	0	0	0	0	1	0	0	0	0	1
Discounted loan	0	0	4%	6%	0	0	0	0	0	6%
Phase out	0	2035	0	0	0	0	0	0	0	2035

Scenario	iMOVE 11	iMOVE 12	iMOVE 13	iMOVE 14	iMOVE 15	iMOVE 16	iMOVE 17	iMOVE 18	iMOVE 19	iMOVE 20
OPEX subsidy	$5	0	0	0	0	5	5	5	0	5
CAPEX subsidy	40%	0	0	40%	80%	0	40%	80%	40%	40%
Availability	1	1	1	1	1	1	1	1	1	1
Road access	1	0	1	0	0	0	0	0	0	0
Discounted loan	0	0	0	0	0	0	0	0	0	0
Phase out	2035	2035	2035	2035	2035	2035	2035	2035	0	0

Key findings

Financial incentives matter, but regulatory changes have the greatest short to medium term effect

The modelling results showed improved adoption rates for all proposed policy intervention scenarios compared to the baseline scenario (**Table ES.2**).

In terms of a single policy measure, the greatest CO_2-e emissions reduction impacts were associated with two regulatory options. The iMOVE 6 scenario (i.e., truck availability, which assumes a faster than expected availability of trucks for purchase across various freight market segments) had the single largest impact (11.22% reduction on baseline). Currently, freight operators don't have the opportunity to purchase all types of LZETs that they would need for decarbonisation. When such vehicles will be fully available on the Australian market is uncertain, due to a range of factors, including the willingness of manufacturers to bring vehicles into Australia, the uncertainty of technological progress, as well as regulatory barriers, including width and weight requirements in Australia. The iMOVE 6 scenario simply assumes earlier availability of LZETs compared with the current expectation, meaning that the regulatory levers to achieve this outcome are also uncertain, indicating an important knowledge gap. IMOVE 2 (phase-out 2035) similarly resulted in greater rates of decarbonisation (5.37% reduction in CO_2-e on baseline). Financial incentives (subsidies on purchase costs, interest payment support or fuel rebates) also matter, but their effectiveness is likely downwards biased given the limited choice and availability of LZETs in Australia today.

Comprehensive LZET packages that include both regulatory as well as financial incentives had the largest combined impact on adoption rates. The iMOVE 10 (OPEX subsidy, availability, road network access, discounts and phase out by 2035), iMOVE 11 (OPEX subsidy, CAPEX subsidy, availability, road network access and phase out by 2035), and iMOVE 18 (OPEX subsidy, CAPEX subsidy, availability and phase out by 2035) policy scenarios provided the largest combined benefits and CO_2-e emissions reductions impacts compared to other scenarios (15.88%, 15.82% and 15.77% reductions on baseline, respectively). These high impact policy scenarios include a combination of OPEX subsidies ($5 rebate per 100 km operating costs), CAPEX subsidies (40% or 80% of the difference in purchase price between a diesel and zero emissions truck), availability of zero emissions trucks that are readily accessible for purchase in the NSW market, provision of road access to special traffic lanes and zero emissions zones, a zero interest loan offered by the state to freight operators to help them with procurement of zero emissions trucks, and finally policy settings for the phase-out of all diesel trucks by 2035.

Key findings

Table ES.2: Results of policy intervention scenarios

Scenario	iMOVE 1 (Baseline)	iMOVE 2	iMOVE 6	iMOVE 10	iMOVE 11	iMOVE 18
OPEX subsidy	0	0	0	5	5	5
CAPEX subsidy	0	0	0	0	0.4	0.8
Availability	0	0	1	1	1	1
Road access	0	0	0	1	1	0
Discounted loan	0	0	0	0.06	0	0
Phase out	0	2035	0	2035	2035	2035

Results

Emissions	iMOVE 1 (Baseline)	iMOVE 2	iMOVE 6	iMOVE 10	iMOVE 11	iMOVE 18
CO_2-e (Mt)	177.95	168.39	157.98	149.69	149.80	149.88
NO_x (Kt)	271.98	266.79	254.69	248.94	248.96	248.88
$PM_{2.5}$ exhaust (Kt)	4.62	4.54	4.34	4.24	4.24	4.24
$PM_{2.5}$ non-exhaust (Kt)	19.9	19.90	19.90	19.9	19.90	19.90
$PM_{2.5}$ total (Kt)	24.52	24.44	24.24	24.14	24.15	24.14

Reductions on iMOVE 1	iMOVE 2	iMOVE 6	iMOVE 10	iMOVE 11	iMOVE 18
CO_2-e reductions (Mt)	9.56	19.97	28.26	28.15	28.07
NO_x reductions (Kt)	5.19	17.29	23.04	23.01	23.1
$PM_{2.5}$ exhaust reductions (Kt)	0.09	0.28	0.38	0.38	0.38
$PM_{2.5}$ non-exhaust reductions (Kt)	0.00	0.00	0.00	0.00	0.00
$PM_{2.5}$ total reductions (Kt)	0.09	0.28	0.38	0.38	0.38

Percent Reductions on iMOVE 1	iMOVE 2	iMOVE 6	iMOVE 10	iMOVE 11	iMOVE 18
CO_2-e reductions (%)	5.37%	11.22%	15.88%	15.82%	15.77%
NO_x reductions (%)	1.91%	6.36%	8.47%	8.46%	8.49%
$PM_{2.5}$ exhaust reductions (%)	1.89%	6.11%	8.20%	8.18%	8.20%
$PM_{2.5}$ non-exhaust reductions (%)	0.00%	0.00%	0.00%	0.00%	0.00%
$PM_{2.5}$ total reductions (%)	0.36%	1.15%	1.55%	1.54%	1.55%

Key findings

Modelled policies generate significant decarbonisation and air quality improvements, but more is required to drive emissions towards zero

In terms of emissions reductions over the period 2023–2061, the iMOVE 10, iMOVE 11 and iMOVE 18 scenarios were found to reduce CO_2-e emissions from around 178 million tonnes (Mt) in the baseline scenario to around 150 Mt (around 16% reduction). These scenarios were also found to provide an improvement in NO_x reductions by around 8.5%, $PM_{2.5}$ exhaust reductions by around 8.2% and $PM_{2.5}$ total emissions reduction of around 1.55%, compared to the baseline scenario. Analysis of the emissions produced in the year 2050, however, showed that the CO_2-e emissions produced by the iMOVE scenarios ranged between a maximum of 3.473 million tonnes in 2050 (iMOVE 7) to a minimum of 2.550 million tonnes in 2050 (iMOVE 10). These findings suggest that more interventions are needed, beyond truck electrification, to meet net zero targets in the road freight sector. These could include efforts to increase the shift of road to rail freight and wide adoption of high-performance vehicles.

Key findings

Emissions reductions resulting from a shift of road to rail freight

In addition to decarbonising the vehicle fleet and shifting from diesel trucks to LZETs, this research also evaluated the emissions reductions that would result from shifting road freight to rail (**Table ES.3**). Although not considered a direct intervention policy, several scenarios were modelled, including a potential shift of 20%, 30% and 40% between 2023–2061. The CO_2-e emissions reductions from these three scenarios were substantial, amounting to 17.1 Mt, 25.70 Mt and 34.20 Mt for the 20%, 30% and 40% shift scenarios, respectively. These reductions are comparable in magnitude or exceed what can be achieved through the iMOVE scenarios relating to a shift towards LZETs. Importantly, the total reductions can reach 45.36 Mt, 53.96 Mt and 62.46 Mt when combining the iMOVE 10 with the 20%, 30% and 40% rail shift scenarios, respectively.

An important consideration for future research is that although the iMOVE 10 scenario combined with shifting road freight to rail represent significant reductions from the baseline scenario, they still fall short of meeting 2050 net zero emissions targets. This still leaves a large gap in emissions that cannot be met through these interventions and policy settings. To address this, these measures would need to be considered holistically as part of a comprehensive transport decarbonisation strategy that includes demand management, optimisation of freight distribution networks, establishment of freight consolidation centres, and similar freight and transport improvement and innovation projects.

Table ES.3: Emissions reductions from a shift of road to rail freight

	iMOVE 10	20% Shift to rail	30% Shift to rail	40% Shift to rail
CO_2-e reductions	28.26 Mt	17.10 Mt	25.70 Mt	34.20 Mt
Combined iMOVE 10 and rail shift reductions		45.36 Mt	53.96 Mt	62.46 Mt
Combined iMOVE 10 and rail shift (% reductions on baseline)		25%	30%	35%

Key findings

Emissions reductions resulting from a shift to high performance vehicles

A key challenge in rapid decarbonisation of freight is the absence of current technological availability, particularly in larger truck classes (articulated trucks). Modern High Productivity Vehicles (HPV), particularly Performance Base Standards (PBS) vehicles, provide emissions reductions potential, and represent an intermediate transition opportunity with emissions reduction potential until LZET technology becomes available.

HPVs are novel heavy road freight transport solutions that can carry a greater payload than general access vehicles, which is achieved through optimised vehicle designs and configurations for specific freight tasks. Their key advantage is that by travelling fewer kilometres and using generally newer vehicles, they require smaller amounts of fossil fuels to complete the same freight tasks compared to their conventional counterpart trucks. Their emissions reductions benefits have been documented in several studies.

A study by the Industrial Logistics Institute (ILI, 2017) examined several scenarios for deployment of HPVs in Australia. The findings showed that under a moderate growth scenario, HPVs will save 8,860 million kilometres by 2034. This will result in reducing fuel consumption by around 3.2 billion litres, saving at least 8.7 million tonnes of CO2 in addition to operational savings of at least $17.2 billion in all sectors of the economy. The study also found that just for the year 2016, PBS vehicles were estimated to have reduced fuel consumption by 94 million litres.

A subsequent study by the National Heavy Vehicle Regulator (NHVR, 2019) showed that since the introduction of PBS, and as of March 2019, the PBS fleet had provided annual reductions of 200 million litres of fuel and 486,000 tonnes of carbon dioxide emissions. These savings would continue to increase as the PBS fleet size grows.

A study by the International Transport Forum (ITF, 2019) also showed that HPVs require less energy per unit of transported cargo and thus offer reduced emissions and less impact on the climate.

Similarly, a 2020 study undertaken jointly by the National Heavy Vehicle Regulator (NHVR) and the Australian Road Transport Suppliers Association Institute (ARTSA-I) showed that the improved productivity of PBS combinations was estimated to have reduced the heavy vehicle road transport task by over 2 billion kilometres since they were introduced (NHVR, 2020).

Potential emissions reductions resulting from replacing existing medium articulated trucks with high productivity large articulated trucks

Four scenarios were modelled representing the potential replacement of 10%, 20%, 30% and 40% of existing ART-M trucks (that are more than 10 years old) with HPV ART-L trucks. In this simplified analysis, it was assumed that two ART-M trucks would be replaced by an ART-L HPV each year. The results (**Table ES.4**) show these shifts will reduce emissions by around 4.9 Mt, 8.4 Mt, 12.3 Mt and 15.6 Mt for the 10%, 20%, 30% and 40% scenarios, respectively, compared to the baseline iMOVE 1 scenario.

In future work, it is recommended that these truck types are included in the modelling as a separate category to diesel trucks. While freight optimisation and reduction in VKT are sources of GHG emissions reductions, the magnitude of any reductions remain more uncertain given limited data on their GHG emissions profile. Future studies should also look to undertake field studies and operational performance to establish their emissions profiles.

Table ES.4: Emissions reductions from a shift of ART-M trucks to HPV ART-L

	iMOVE 1	10% Shift to HPV	20% Shift to HPV	30% Shift to HPV	40% Shift to HPV
Articulated trucks - cumulative total CO_2-e emissions (Mt) (2023–2061)	108.5	103.6	100.1	96.2	92.83
Articulated trucks – cumulative CO_2-e reductions (Mt) (2023–2061)		4.9	8.4	12.3	15.6
Percent reduction on iMOVE 1 (%)		4%	8%	11%	14%

Key findings

Financial incentives should be carefully designed to enhance the economic impact of public expenditure

The societal and public sector costs and benefits associated with the policy options varied substantially. The benefits are primarily determined by the degree of decarbonisation and air quality improvements (reduction in externalities) as well as reduction in real resource use associated with fuel consumption by truck operators. To compare the economic impact of policy options against the baseline decarbonisation assumption, most cost categories can be set aside. However, faster rates of decarbonisation will likely be associated with additional road wear (LZEV vehicle technology is typically heavier than diesel trucks) and additional infrastructure requirements, at least until battery technology improves and LZETs become lighter over time.

As with the impact on emissions themselves, the net social benefit of regulatory options such as iMOVE 2 (phase-out 2035) and iMOVE 6 (availability) exceeded other single policy options. These two options also generated the greatest net societal benefit per dollar of public expenditure (**Table ES.5**). A key reason for this finding is that they are primarily regulatory in nature, with little additional costs beyond road wear and tear (public cost) or infrastructure (either public or private). These two policy options are modelled to generate $203m and $1bn in net social benefit (2023–2061), respectively. Comprehensive policy packages combining several initiatives, including subsidies, do generate higher social benefits, but also come at greater social costs.

Table ES.5: Societal benefits analysis

Scenario	iMOVE 2	iMOVE 6	iMOVE 8	iMOVE 10	iMOVE 11
Societal analysis	**Phase-out 2023**	**Availability**	**Capex 80%**	**Comprehensive**	**Comprehensive**
NPV Total Benefits (million, $)	$1,108m	$2,731m	$101m	$4,090m	$3,720m
NPV Total Costs (million, $)	$905m	$1,697m	$126m	$2,779m	$2,589m
NPV Net Benefits (million, $)	$203m	$1,034m	-$26m	$1,311m	$1,131m
Ratio analysis					
Societal B/C	1.22	1.61	0.80	1.47	1.44

Key findings

This study also found that financial incentives are comparatively less effective in reducing emissions, i.e., promoting decarbonisation. Consequently, they generate lower net social benefits and add considerably to public sector expenditure. For example, iMOVE 8 (80% subsidy on price differential between ICE and LZEV alternatives) illustrates the comparatively higher cost. These results must be seen in relation to the currently very limited availability of LZET options in Australia in 2023. Insights from behavioural finance show that reduction in upfront costs can be important to reduce barriers to large capital expenditure outlays. However, financial incentives are also expensive because even at a time of relatively high baseline demand for LZETs, they can be poorly targeted. The reason for this is that, a priori, it is difficult to establish which LZET purchases are the result of any specific financial incentive, and which would have taken place anyway. As a result, each purchase potentially requires/obtains a subsidy payment. Thus, while iMOVE 8 has a total cost of $126 million (low efficacy), the cost under iMOVE 10 and iMOVE 11 is inflated due to poorer targeting.

Importantly, financial incentives can nevertheless generate important signalling effects that work on buyers (in terms of commitment to uptake) and producers (in terms of assessing Australia's market potential and viability).

A key determinant of decarbonisation in the modelling and economic assessment is the rate with which existing vehicles are retired (the vehicle retirement rate was fixed in the modelling). We recommend that future research should consider how financial incentives could be targeted by subsidising the removal of older trucks and more polluting trucks. Financial rates could also be differentiated by age and emissions to ensure that the removal of lower-polluting trucks is not subsidised to the same extent as higher-polluting trucks.

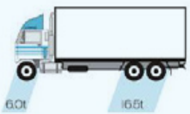
Key findings

Disaggregation of emissions impacts by freight vehicle subclass can help identify priority intervention of fleet segments

The emissions impact for each truck subclass (e.g., rigid small, rigid medium, articulated large etc) was evaluated in this research as a function of how polluting each subclass typically is, and how many kilometres trucks in each subclass typically travel (**Table ES.6**). This analysis, however, is limited in that it does not consider payload and total tonne-kilometres of travel per truck subclass (i.e., that larger trucks can move more cargo per trip). A strategy to address the lack of technological availability, particularly for large articulated trucks, is the greater utilisation of HPVs. While their emissions profile remains uncertain, their associated VKT reductions provide the potential for some GHG emissions savings. HPVs offer potential payload efficiencies compared to their traditional counterparts, which means that they can move goods more productively (in terms of tonne-kilometres). The use of more HPVs to move freight across the network would reduce emissions per tonne-kilometres because fewer vehicles would be required to perform the same task.

Key findings

Table ES.6: Emissions and social cost according to truck subclass

Vehicle type		Number of trucks	Avg VKT per truck	CO_2-e (tonnes) per average truck	Total CO_2-e (tonnes)	Social cost per average truck
Rigid truck (small)		71,330	23,561	8.6	613,438	$1,127
Rigid truck (small-medium)		19,160	21,113	8.3	159,028	$1,080
Rigid truck (medium)		29,220	20,957	12.6	368,172	$1,649
Rigid truck (medium-large)		17,167	21,899	14.0	240,338	$1,833
Rigid truck (large)		23,816	23,591	22.1	526,334	$2,892
Articulated truck (small)		4,697	73,561	105.8	496,943	$13,825
Articulated truck (medium)		28,243	60,899	79.9	2,256,616	$10,435
Articulated truck (large)		10,868	66,670	110.2	1,197,654	$14,395

Key findings

Independent pilot studies, field testing and knowledge sharing could support operators with informed decision making

The stakeholder consultation survey provided insights into the perceptions, expectations, and levels of knowledge of fleet operators about LZETs. Analysis of survey responses showed low and varying level of zero emission truck knowledge, and a high level of uncertainty about LZET technical features (e.g., range, payload, and reliability). These factors, if not addressed, could impact decision making and delay the fleet operators' adoption of LZETs. Independent pilot studies and testing of different LZET technologies in the context of Australian urban and regional settings would help to provide guidance on most appropriate use cases for each technology solution. Furthermore, vehicle performance evaluation is important to reduce new product introduction for heavy vehicle manufacturers, particularly to build trust among users about the technology and its benefits.

Recommendations for future research

Updating and refining the modelling of uptake

As the Choice Experiment and Modelling results were used to predict LZET adoption rates and fleet proportions, there are many assumptions being used, including about sales of vehicles per truck class, the number of kilometres travelled by each truck each year, depending on the type and age of the truck, as well as the survival function of different truck types, i.e., after how many years that a truck is being retired and scrapped. Currently, this is largely modelled based on aggregate assumptions, and an alternative approach would be to describe each truck individually in a computational sense (this is referred to as an Agent-Based Model) – thereby enabling more detailed policy analysis. There is therefore an opportunity to develop this capability which would allow easier integration between different models used by the various planning departments. Specifically, we suggest that this activity would explore the following issues:

- Review and update of survival functions for each of the eight truck types.
- Review and update of the VKT by age functions for each of the eight truck types.
- Review and update of the new truck purchase rates for each of the eight truck types.
- Review and update of the emissions factors for each of the eight truck types.
- Further development of an individual-truck based Agent-Based Model that could predict the future adoption of LZETs as well as fleet proportions of LZETs.

Deep dive into industry beliefs, understanding, and attitudes

The Choice Experiment and Modelling undertaken in this study have provided some important insights but also highlighted current knowledge gaps about how freight operators think about LZETs. A surprising insight is that there are distinctly different perceptions of BETs and FCETs, with many study participants showing a preference for FCETs. The reasons behind this discrepancy are still unclear, and the follow-up survey showed that most freight operators use a diverse mix but also relatively unreliable sources of information, when doing their exploration on which types of truck to purchase. In our research, we also identified that there are two main groups of decision-makers, with the first smaller but not insignificant group having a strong preference for the status quo (i.e., Diesel trucks), and the second relatively larger group being quite open to transitioning towards LZETs. The underlying reasons for this polarisation of views are still unclear. To deal with these issues (i.e., the unexpected preference for FCETs, and the polarisation of the freight industry on this topic) we suggest an investigation based on in-depth interviews with about 20-30 freight operators, to clarify the underlying causes. This would also provide an opportunity to further explore the issue of perceived risk, and how this risk could be reduced through various types of government support. This research would aim to answer the following questions:

- What is driving the polarisation of views and preferences on the topic of LZETs?
- What is driving the relative preference for FCETs over BETs?
- What is the opportunity for reducing misinformation in the industry on this topic and thereby influencing freight operators through education and information campaigns?
- What type of additional resources, training, or support could help induce more operators to purchase LZETs?

Recommendations for future research

Ongoing monitoring of willingness to pay for LZETs

The Choice Experiment and Modelling undertaken in this study has been informative in the sense of taking the pulse of industry sentiments, and their willingness to pay for LZETs. We have shown that, at the very least, industry willingness is no major impediment to large-scale adoption of LZETs. Whilst some of the industry still prefer the status quo, most decision-makers are willing to make the switch, if there are appropriate truck options on sale that will help them effectively carry out their truck tasks. With financial performance being what primarily drives decision-making, we have also shown that financial incentives are likely to have an impact on adoption rates. We do note, however, that this is a point-in-time estimate of willingness to pay, and that this is a dynamic situation that is likely to change as more and more freight operators choose to use LZETs. As LZETs are normalised in the industry, and infrastructure becomes more adapted to this new technology, preferences are likely to follow, unless major obstacles appear. This has implications for choice of appropriate policy settings, and whether there is a net benefit of government's investment in subsidies. Therefore, we suggest that there is an ongoing monitoring of willingness to pay for LZETs that also better accounts for key performance parameters like range and access to infrastructure. This research activity would explore the questions:

- How does the willingness to pay for LZETs change over time?
- How can we better account for the range of the truck and access to charging infrastructure when measuring willingness to pay?

Industry willingness to invest in charging infrastructure

It is clear, both from the Choice Experiment but also especially from the follow-up survey, that access to charging infrastructure is a key consideration when freight operators decide to invest in LZETs. There are many types of actors that may invest in such charging infrastructure, including freight operators themselves, petrol station operators, warehouse operators, or even new actors entering the market through novel business models. Whilst it is recognised that this is a key part of the transition towards large-scale adoption of LZETs, further knowledge is required to understand the potential role of government in supporting such investment decisions. Therefore, we propose a study to explore the willingness and economic drivers that would lead various industry actors to invest in charging infrastructure. Specifically, we suggest that this research would explore the following questions:

- Is there a legitimate way that TfNSW can intervene to increase the rate of rollout?
- What is the business model behind such roll-out of infrastructure?

Performance based standards and high productivity trucks

There may be immediate benefits of PBS/HPV as options for limiting emissions mainly in the large classes (ARTS) until LZETs catch up in cost and viability. In future work, it is recommended that these truck types are included in the modelling as separate categories to diesel trucks as they are more likely to be greener and more efficient. Future studies should also look to undertake field studies and operational performance to establish their emissions profiles.

Recommendations for future research

Update emissions factors to reflect EURO VI/VII standards

The Australian Government has adopted Australian Design Rule 80/04 mandating Euro VI for all new approved heavy vehicle models supplied from 1 November 2024. The EURO VII standards are proposed internationally for 2027 but are probably not expected to be applied in Australia before 2030–2032. Future work should consider inclusion of these standards into emissions estimation models taking into consideration the timeframe expected for their introduction.

Update emissions models to include cargo and payload data

Current emissions estimation models only consider the total VKT by each type and subclass of trucks. Given that large trucks carry heavier loads, consideration of VKT alone is not sufficient and needs to be complemented with information on payload and tonne-km of travel for each truck subclass.

Multi-region comparative analysis

Building upon this research, a compelling direction for future exploration is a multi-region comparative analysis spanning several Australian states. By investigating the regional nuances in emissions and the economic repercussions of decarbonisation efforts, a better understanding of the varied challenges and opportunities faced across the nation can be gained. Beyond offering a holistic national overview, this comprehensive research can identify synergies between states, allowing for more targeted interventions. Diving deeper, such an analysis could elucidate the varying readiness and barriers each state faces, fostering opportunities for collaboration. This could pave the way for tailored, state-specific policy interventions, and more importantly, unified action. With such a combined effort, Australia would be better poised to take decisive and harmonised steps toward its broader emission reduction ambitions.

Modal shift analysis

Investigating the potential emissions reductions and economic benefits of shifting freight from road to rail or other alternative modes. Factors such as infrastructure investment, operational efficiency, and environmental impacts could be explored in depth.

- Evaluate factors such as fuel efficiency, payload capacity, transit times, reliability, and flexibility across different transport modes.
- Evaluate potential emission reductions and environmental benefits of moving freight to rail.
- Assess the feasibility of different freight tasks for mode shift, identifying which could transition quickly and which might face challenges, providing insights for policy makers on where immediate and efficient mode shifts can be realised.
- Examine potential economic gains, considering reduced road maintenance and congestion costs.
- Gather views of freight operators, logistics companies, and end-users on feasibility.
- Identify policy measures that could encourage a shift from road to rail.
- Explore technological innovations to make rail freight more efficient and attractive.

Recommendations for future research

Integration with renewable energy

Studying the synergies between freight decarbonisation efforts and the expansion of renewable energy and renewable energy zones (REZ) could be highly relevant. Exploring ways to align energy generation and consumption patterns for optimal sustainability would be insightful.

- Analysis of locations and capacities of REZs in proximity to major freight routes and hubs.
- Opportunities for freight depots as renewable energy hubs.
- Evaluating the potential for battery electric or hydrogen-powered freight vehicles to act as energy storage.
- Identifying potential policy incentives to promote synergy between freight decarbonisation and renewable energy expansion.
- Exploring the potential role of smart grids and energy management systems in balancing renewable energy demand and supply for freight.

Lifecycle analysis

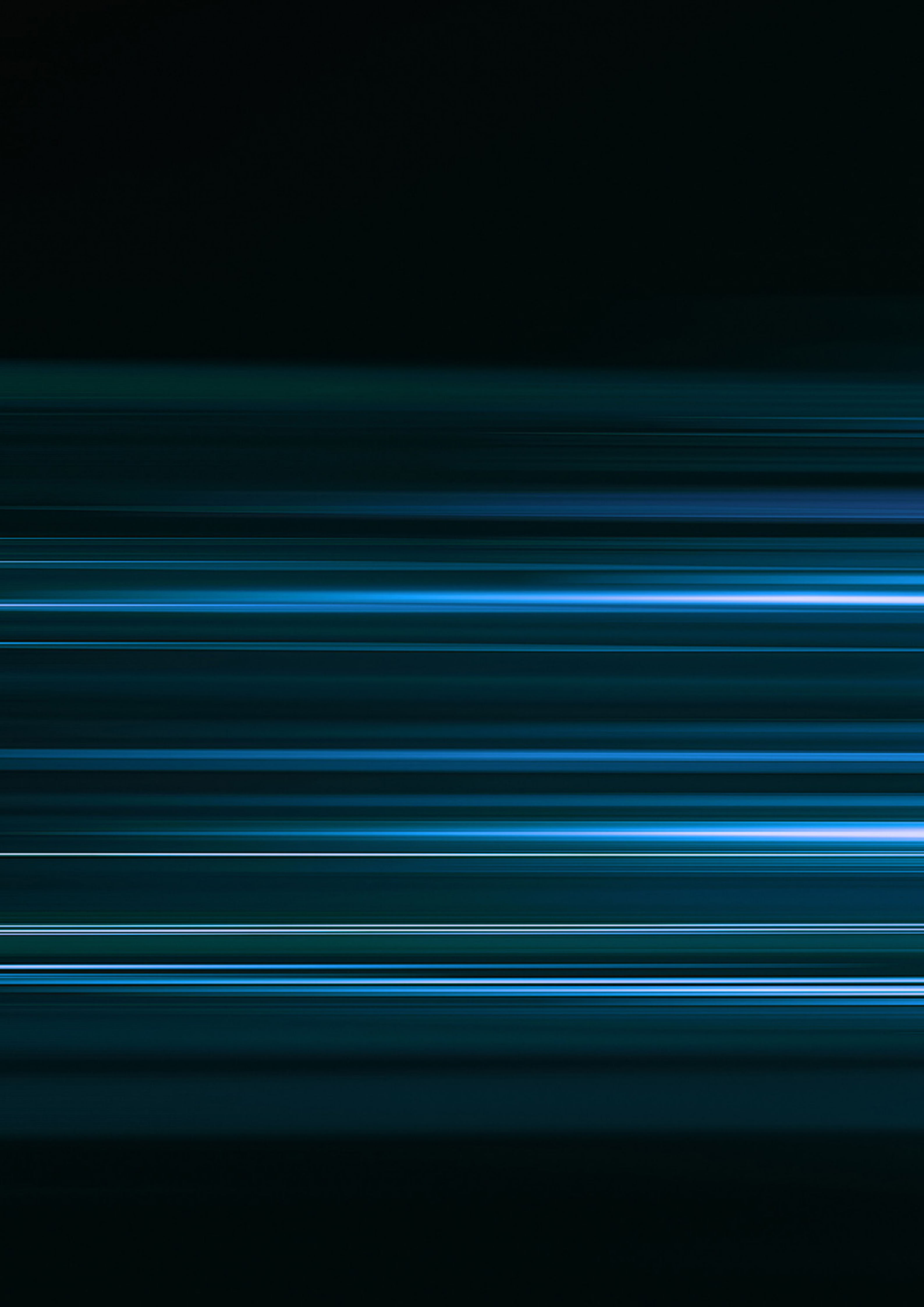
A comprehensive lifecycle assessment of various freight modes and technologies, considering not only direct emissions but also broader environmental and social impacts.

- Comparing the full environmental footprint of different freight modes, from production to disposal.
- Understanding the end-of-life impacts and potential for recycling or repurposing of freight infrastructure and vehicles.

Long-term infrastructure planning

Analysing the long-term infrastructure requirements and investments needed to support a decarbonised freight sector – considerations such as charging stations, alternative fuel infrastructure, and smart transportation systems could be explored in detail.

- Assess the placement, density, and capacity needs for charging stations to support electric freight vehicles.
- Determine the demand and optimal distribution of hydrogen refuelling stations across regions.
- Explore the role of smart traffic management and real-time logistics solutions in reducing emissions.
- Analyse the policy changes required to guide infrastructural development in line with decarbonisation goals.



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