Logistics Decarbonisation Challenges

2023

Future Logistics, Technology & Environment Discussion Papers

Logistics decarbonisation challenges is part of a series of discussion papers produced by Foresion that aim to holistically explore contemporary supply chain issues and future directions, focusing on logistics, emerging technologies, and environmental sustainability. These papers are aimed at business practitioners, policymakers, and governments as a vehicle for improving integration and visibility along key supply chains.

Suggested Citation

Neagoe, M., Turner, P. (2023) "*Logistics decarbonisation challenges*". Future Logistics, Technology & Environment Discussion Papers, Foresion

Acknowledgements

This publication draws on research work currently under peer-review undertaken by an international group of researchers which includes this publication's authors. Foresion acknowledges the researchers' kind contribution and input to the research work.

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Glossary

kWh	kilowatt hour (1,000 Wh)
MWh	Megawatt hour (1,000 kWh)
GWh	Gigawatt hour (1,000 MWh)
TWh	Terawatt hour (1,000 GWh)
Alternative fuel vehicles	Includes battery electric vehicles, fuel cell electric vehicles, and vehicles not powered by fossil fuels
BEV	Battery electric vehicles
FCEV	Fuel cell electric vehicles
ICEV	Internal combustion engine vehicle
Bio-fuels	Liquid or gaseous transport fuels, such as biodiesel and bioethanol, made from biomass
Grey Hydrogen	Hydrogen produced from natural gas, generally through steam reformation
Blue Hydrogen	Hydrogen produced from natural gas, generally through steam reformation and using carbon capture and storing technology
Green Hydrogen	Hydrogen produced by using renewable electricity to split water into hydrogen and oxygen or by using syngas from renewable feedstocks
V2G	Vehicle to Grid where a BEV connects to the electricity grid through a charger and delivers electricity to the grid
t	metric tonne (1,000 kilograms)
Gt	Giga-tonne (1,000,000,000 metric tonnes)

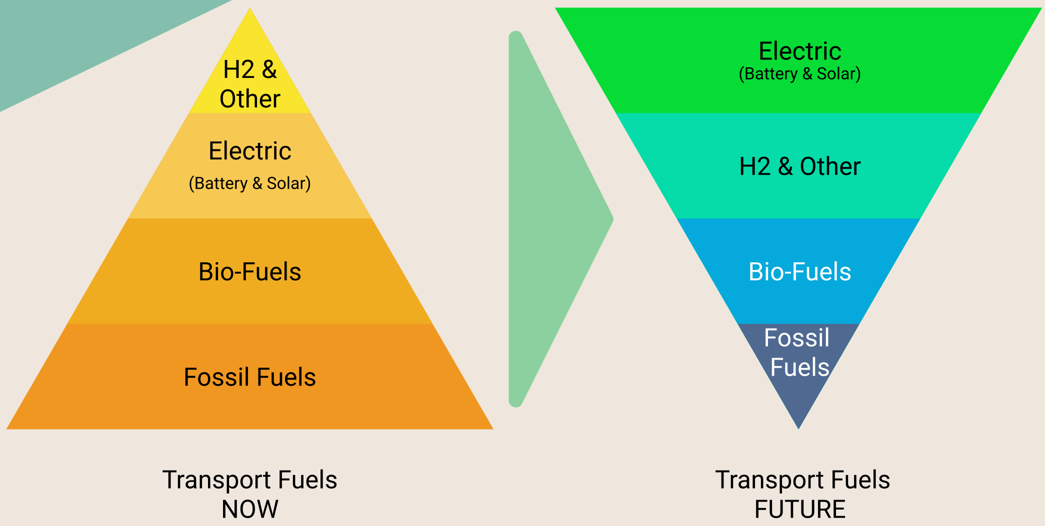

Figure 1 Current and future transport fuels (Source: Foresion, 2022)

Context

The environmental impact of human activity is evident in almost every aspect of our lives as are the implications for future sustainability and prosperity. Transport emissions totaled **7.7 billion tonnes of CO2e in 2021** (IEA 2022) and represent close to a quarter of global energy-related emissions. Tackling transport emissions is one of the pathways to addressing man-made environmental impacts.

Contemporary debates around what actions to take to address production, power and sustainability in Western societies are increasingly focused on responses to climate change through electrification of transport and increasing use of renewables. This future vision entails diminishing the role of fossil fuels in favour of batteries, hydrogen, and other renewable fuel sources.

While these standalone initiatives appear to be a step forward towards a more sustainable future, most lack integrated perspectives on their impacts on supply chains and how sustainability will be realized over the long term. In looking at these supply issues, this paper aims to highlight key problems and potential approaches that could improve sustaina-bility, without sacrificing global supply chains' integrity and incurring the risks of dramatic reductions in citizens' physical and social mobility due to a lack of integrated planning and implementation.

In this context, this paper examines the transition challenges from the **NOW** to the **FUTURE**, specifically focusing on the transition of transport logistics through alternative fuel vehicles and the challenges, risks and opportunities that need to be addressed in an integrated manner to avoid major disruption to global supply chains.

Executive Summary

The logistics sector is under pressure to decarbonise operations as the net zero goal is increasingly adopted by Governments worldwide. Innovations and new technologies have elevated alternative fuel vehicles to genuine contenders to the traditional fossil fuel-powered internal combustion engine. Consequently, alternative fuel vehicles have become a prime contender for decarbonising logistics. However, decarbonising operations is not without its challenges. Failure to understand, prepare and address these challenges could negatively impact the speed at which the logistics sector decarbonises.

To explore the logistics decarbonisation challenges, risks, and opportunities this paper examines five technical, economic and environmental factors identified in evidence being produced by industry and academic research.

The five aspects are:

1. Alternative fuel vehicles performance
2. Alternative fuels delivery
3. Renewable energy availability
4. Return on investment
5. Emissions modelling and reporting.

Given the dominance of vehicle electrification, many of the examples discussed in this paper pertain to battery electric vehicles (BEVs). However, it is important to realise that many of the issues identified with BEVs are equally applicable to other alternative fuels.

Similarly, while forecasting any new alternative fuel vehicle technological breakthrough is difficult, businesses can focus on two key dimensions of their existing value chains to better prepare for and/or commence decarbonising their logistics operations: the low rather than no and the course to zero.

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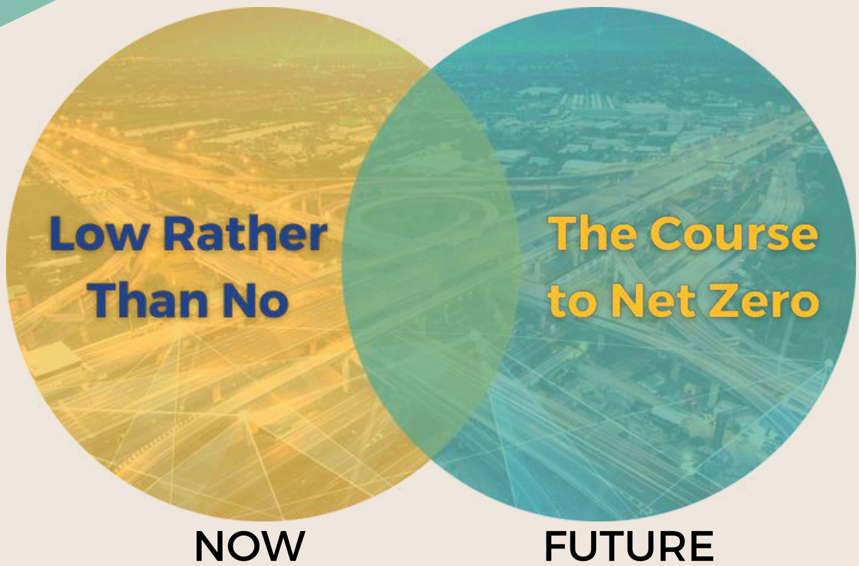

Low Rather Than No

Start decarbonisation now at operational and tactical levels by enhancing logistics efficiency and the way in which existing assets are used:

1. Understand your logistics and supply chain energy consumption and emissions
2. Examine logistics data and emissions under Scope 1, 2 and 3 and identify areas were efficiency improvements are most achievable
3. Investigate low emissions vehicles or lower emissions fuel alternatives (including biofuel blends, hybrids) to generate an immediate impact on logistics emissions

Chart the Course to Zero

Build your future strategy towards no emissions:

1. Determine a transition timeline and plan for gradual change. Planning should consider the routes, energy and fuel availability, operations management changes
2. Balance alternative fuels across fleet with other emissions reduction measures
3. Employ data analytics, reporting and management across carbon emissions and other emissions (e.g., particulates) to be prepared for the next generation of environmental legislation

Introduction

Worldwide, transport emissions accounted from 5.86 Gt CO2 in 2021 and over 6 Gt in 2019 prior to the COVID-19 pandemic (IEA 2021). As net zero aspirations and targets are increasingly adopted by Governments, the pressure on the logistics sector to decarbonise its operations has increased (Zhang et al. 2022). Decarbonisation in this report refers to "*a reduced use of fossil fuels*" (Andersson et al. 2020). Governments have implemented several policy levers to decarbonise road transport including subsidies, emissions, efficiency and modal shift targets. Charting a path to adhering to emissions policies and targets falls however on the back of organisations.

The key emerging decarbonisation strategy is the transition from fossil fuel powered vehicles to **alternative fuel vehicles**. Although battery electric vehicles (BEV) are leading the pack and are heavily promoted, other types of vehicles, such as fuel-cell electric vehicles (FCEV) using hydrogen are also seen as potential alternatives. As many expected, and some early adopters are reporting, transitioning from fossil fuels can be challenging. Alternative fuel vehicles are typically more expensive (LeBeau 2022), have their own set of performance attributes and can increase organisational exposure to electricity distribution and generation issues (CBS News 2022).

This paper identifies and maps five key logistics decarbonisation challenges organisations should consider when transitioning their operations and supply chains away from reliance on fossil fuels.

Logistics Decarbonisation Challenges

Future Vehicles Performance

Alternative fuel vehicles entail performance trade-offs including fuelling time, transport range and payload capacity. These must be evaluated against the anticipated logistics tasks. One type of alternative fuel vehicle is currently unlikely to be optimal for all types of logistics tasks

Alternative Fuel Delivery

Alternative fuels will require delivery infrastructure. Hydrogen, ammonia, methanol or biofuels can use similar infrastructure as fossil fuels. However, battery electric vehicles require grid and charging infrastructure improvements which although already started, may take time to come online

Renewable Energy Availability

Renewable energy sources may prove to be in short supply as more logistics chains transition to alternative fuel vehicles. This issue is likely to be compounded as other industrial sectors also transition to renewable energy sources to decarbonise

Return on Investment

The relatively high upfront cost of alternative fuel vehicles combined with energy prices uncertainty, energy storage replacement requirements and pricing structures (especially for BEVs) raise return on investment uncertainty for alternative fuel vehicles

Emissions Modelling & Reporting

Understanding and reporting on logistics emissions may prove to be costly and complicated. Validating emissions can be difficult given the complex web of ownership structures for operations and data, the range of indirect and direct emissions estimations and difficulty in assigning emissions for non-value-adding tasks.

Figure 2 Logistics decarbonisation challenges (Source: Foresion, 2023)

Future Vehicle Performance

Organisations operating alternative fuel vehicles are likely to be faced with a series of trade-offs compared with traditional vehicles. These trade-offs relate to **vehicle payload capacity, range, fuelling time, and other abilities** (such as vehicle-to-grid interactions). Adequately managing these trade-offs will likely make the difference between the success of failure of logistics decarbonisation journeys.

The vehicle range may vary depending on the fuel characteristics - ammonia or methanol have lower energy densities than fossil fuels (NIST 2022) hence requiring larger fuel tanks for similar ranges. Similarly, BEVs may face range limitations due to the battery technology and environmental factors. BEVs' range can be particularly affected by battery degradation and the ambient temperature.

The **payload capacity** of alternative fuel vehicles will vary depending on the type of powertrain. BEVs and FCEVs to a lesser extent are at somewhat of a disadvantage due to the weight of the power packs - it is estimated that electric trucks require an additional tonne in battery for an increase of 100 km in range (Nilsson 2022; Transport & Environment 2020). However, not all types of cargo require high payload capacity, think consumer goods, electronics or parcels. Hence, aligning the alternative fuel vehicle with the cargo features will be critical.

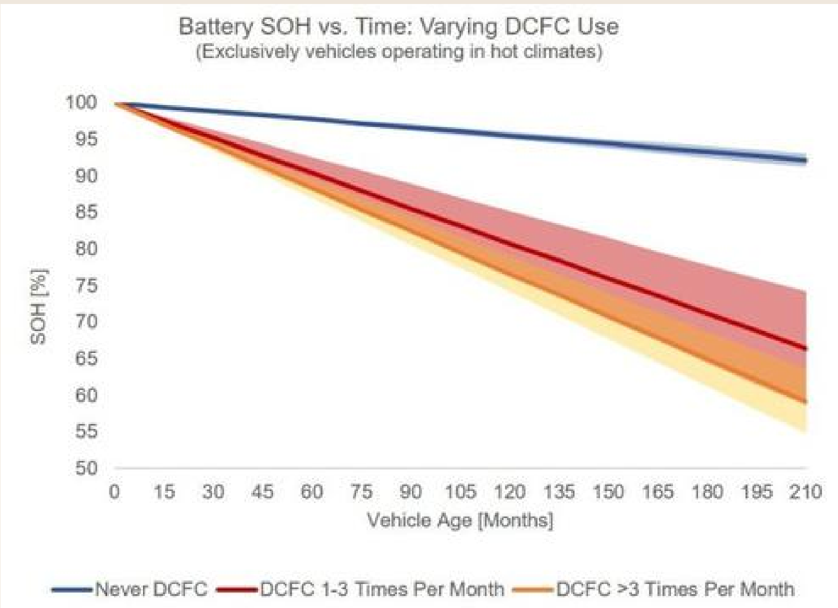

Figure 3 Direct current fast charging (DCFC) impact on electric car battery degradation (Source: GeoTab, 2022)

Fuelling time is an important efficiency indicator as it determines the duration a vehicle is unavailable. It is anticipated that FCEVs, ammonia or methanol powered vehicles will require similar times for fuelling as ICEVs. Depending on the charging capacity, charging BEVs may be just as rapid, or may take up to several hours. Fuelling time management will become an important part of organisational logistics planning to limit vehicle down time and associated costs or lost opportunities.

Most vehicles only allow one-way fuelling interactions. BEVs are somewhat unique in that they allow **vehicle-to grid (V2G) interactions**. When electricity prices are high, BEVs can become a mobile battery that plugs into the grid and delivers power and additional revenue. During V2G interactions, BEVs can no longer fulfill their traditional transport role and the releasing electricity to the grid also depletes their energy storage. Organisations stand to benefit from selling electricity to the grid but will need to carefully weigh the benefits and costs of V2G.

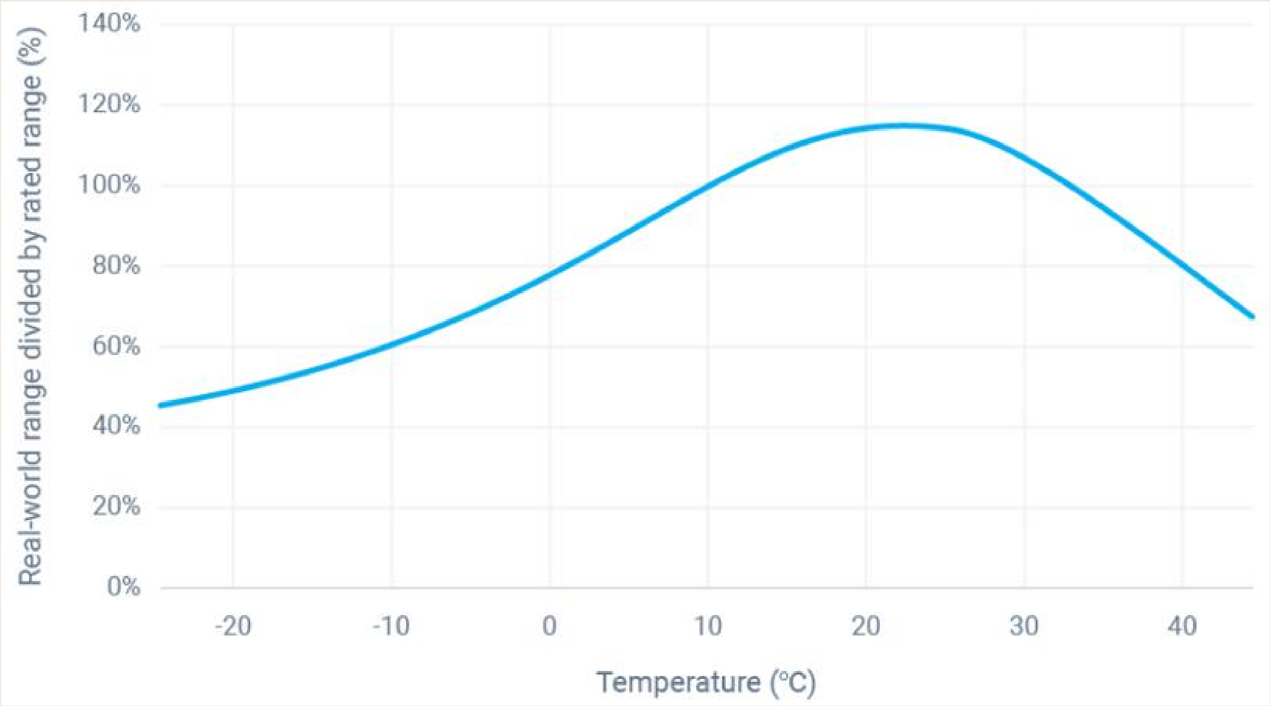

Figure 4 Rated vs real world range of BEVs depending on temperature (Source: GeoTab, 2022)

Alternative Fuel Delivery

The alternative fuels delivery infrastructure and supply chains may represent an increasingly important decision factor in the way and the speed at which logistics can be decarbonised.

Liquid fuels such as ammonia, methanol and biodiesel are likely to be handled in a similar way to traditional transport fuels. The high pressure and low temperature requirements for storing hydrogen will likely require additional infrastructure investments. However, hydrogen fuels supply chains are likely to resemble liquid fuels delivery.

The infrastructure required to electrify logistics is likely substantial. It is estimated that the U.S. will require 16 million public chargers to cater for an all-electric light vehicle and truck fleet (from roughly 109,000 currently) and Canada would require 1.7 million public chargers just for light vehicles (Booth 2022).

Trucks are unlikely to use slower 7 or 22-kW chargers given the size of their batteries. Fast DC chargers, especially for larger fleets will likely require significant electricity infrastructure investments to cater for the increased use.

Smart charging (Barthel et al. 2021; Moolenburgh et al. 2020) and vehicle-to-grid operations (V2G) (Jiao et al. 2021; Ahmadi et al. 2020) may provide an intermediary solution for logistics operators as charging infrastructure capacity is increased as well as some interesting incentives. V2G allows logistics operators to use trucks as mobile batteries and sell to the grid while electricity prices are high at the cost of transport capacity.

Renewable Energy Availability

The carbon emissions associated with alternative fuels and alternative fuel vehicles is heavily dependent on the availability and use of renewable energy. Renewable energy in this context refers mainly to wind, solar and hydro generation. Electric vehicles are only as clean as the electricity used to power them. Green hydrogen (produced from renewables) has a significantly reduced carbon footprint when compared with grey (produced from natural gas) or blue hydrogen. Ammonia or methanol, two liquid hydrogen carriers, should also be produced using renewable energy to ensure a reduced carbon footprint during production and subsequent use. As a result, renewable energy generation will need to significantly increase to power future vehicles.

Modelling previously conducted by Foresion indicated that electrifying all light vehicles in Australia alone would require 60% more renewable energy generation than currently available assuming that **all** renewable energy is diverted for vehicles (Foresion 2022).

Simultaneously, other sectors are currently on a journey for decarbonisation, not the least which electricity generation. This trend increases the pressure on renewable energy availability as fossil fuel generation is expected to be gradually withdrawn and an increasing suite of industries are aiming to rely more heavily on renewable energy.

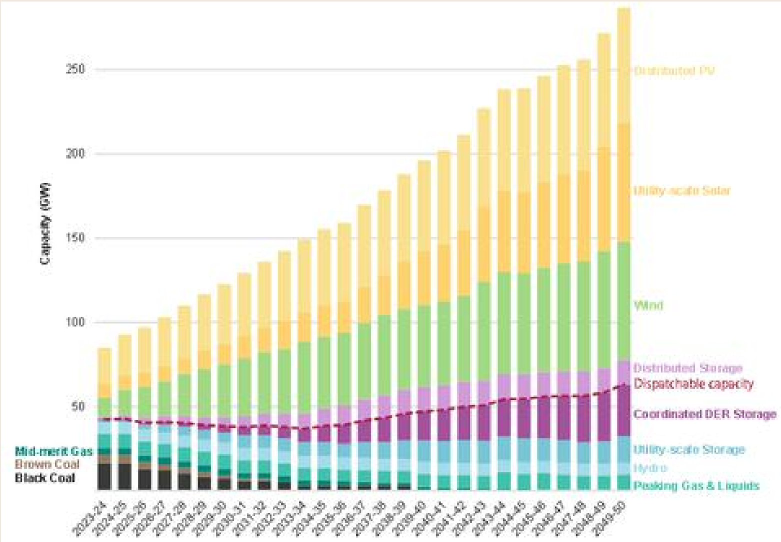

Figure 5 Australia's (Draft) Integrated System Plan (ISP) projected energy capacity generation 2050 (Source: AEMO 2022)

Australia's Draft Integrated System Plan projections for energy generation by 2050 consider an increase in required capacity by 150% with an associated increase **900% in utility-scale renew-able generation and a 500% increase in distributed pho-tovoltaic generation** while projecting the elimination of coal-fired generation by 2040.

The UK's projections for 2050 indicate a similar trajectory to Australia, with a required **2-fold increase in generation capacity and a 10-fold growth in renewable ener-gy generation.**

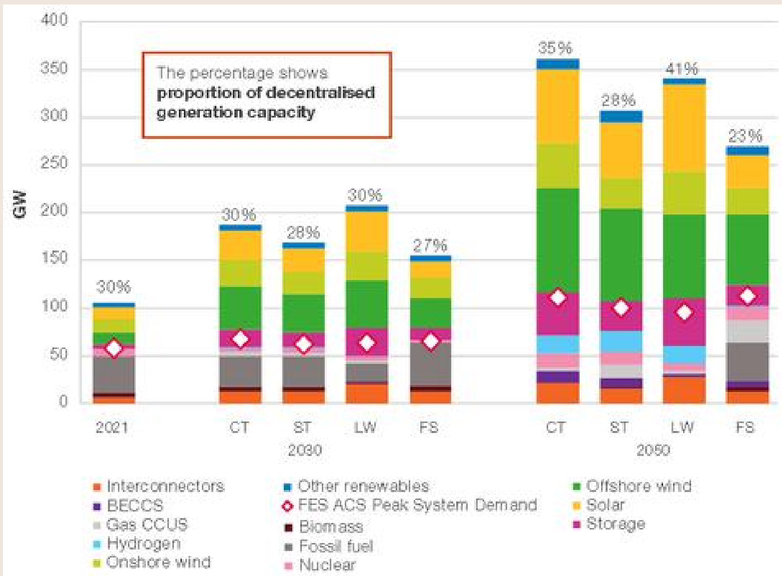

Figure 6 UK's National Grid ESO projected energy capacity generation 2050 (Source: FFS 2022)

While these projections are certainly ambitious and admirable, it is worthwhile to take a moment to appreciate the magnitude of the transition to renewable energy for the Wes-tern world, its emissions foot-print and the implications of a renewable energy shortfall on future logistics.

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Return on Investment

The return on investment of alternative fuel vehicles is still somewhat uncertain. A key factor contributing to this uncertainty is the high, real or perceived, **upfront vehicle costs** (Ziegler and Abdelkafi 2022). Some vehicle power-trains have yet to be commercially released, casting doubt over their potential purchase costs. Both BEVs and FCEVs rely on Li-Ion batteries for energy storage. Energy metals prices such as Lithium, Cobalt or Nickel have all significantly increased in the recent past. Lithium prices have increased by 240% in 2021 (Koehler 2021), while Cobalt prices increased by 119% (Ellis 2022).

Operating costs for alternative fuel vehicles are also somewhat uncertain. The key source of uncertainty is the cost of fuel. Electricity prices have skyrocketed in much of the European Union (EU), US, Australia and the UK which has increased not only the running costs for BEVs but also the fuel production costs for FCEV, methanol or ammonia powered vehicles (which all ultimately rely on electricity for electro-lysis of water to produce hydrogen). The target price for hydrogen of 2 EUR/kg in the EU or 2.8 AUD/kg in Australia seem a far cry from the current production costs 3.5 to 7 EUR/kg in the EU (Aurora ER 2022) and the 8.6 AUD/kg in Australia (DPIE 2022). Given that fuel can repre-sent more than 60% of logistics costs the magnitude of operating cost uncertainty becomes clear.

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Emissions Modelling & Reporting

What data should be used for emissions modelling? Using industry average data provides a relatively straightforward way to report a compre-hensive emissions figure. The disadvan-tage that comes with using these data is that they are not necessarily represen-tative of businesses' footprint. Beyond reporting emissions figures, reporting on emissions reduction is practically impossible. Using primary data from the business or close proxies (fuel consump-tion, driving distances) can provide a more comprehensive view of emissions. Often these data are collected and owned by several companies in supply chains which may be reluctant to share it.

How should emissions be distributed across customers? This deceptively simple question has a complex answer. Emissions should be assigned proportionately to the distance and cargo weight per customer. However, assigning emissions for empty kilometres, repositioning or non-productive moves is not as straightforward as it may seem.

This question ties in with **emissions forecasting**. Currently, emissions are generally reported after a logistics task was completed. Yet, increasingly, custo-mers require emissions estimations prior to choosing a particular logistics provider. If emissions estimations make the diffe-rence between a secured or lost con-tract, emissions forecasting becomes paramount.

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Looking to the Future

Figure 7 Now and future steps for logistics decarbonisation (Source: Foresion 2023)

Resolving logistics decarbonisation challenges will take time and may require technological progress and innovations. Businesses and Governments can however already take steps towards addressing the decarbonisation challenges in order to be better prepared to act when such innovations arrive.

Low Rather Than No

Decarbonisation can commence now at operational and tactical levels by enhancing logistics efficiency and the way in which existing assets are used.

Businesses should implement tools and technology to **track and analyse energy consumption**, as much as possible using primary data sources, or close proxies such as fuel. This ensures that energy consumption is well understood and that sources of inefficiency may be addressed prior to the adoption of alternative fuel vehicles or other decarbonisation measures.

Emissions reporting should be undertaken using a consistent set of assumptions within sectors and industries to ensure benchmarking within and between businesses is possible.

Businesses will need to clearly map and identify logistics task types using telematics to **target the right alternative fuel vehicle** to the type of logistics task which maximizes the vehicles' impact on the business.

Chart the Course to Zero

Beyond net zero targets and aspirations, businesses should elaborate emissions reduction strategies and the potential zero emissions future considering existing supply chain limitations for alternative fuels and vehicles.

Businesses should determine a transition timeline and plan for **gradual change**. Planning should consider the routes, energy and fuel availability and operations management changes.

Logistics operators should **balance alternative fuels** across fleet with other emissions reduction measures.

Business leaders should employ data analytics, reporting and management across carbon emissions and other emissions (e.g., particulates) to be prepared for the **next generation of environmental legislation**.

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