



Accelerating Investment for Decarbonising UK Freight Transport

Synthesis report



**Decarbonising
UK Freight Transport**



Decarbonising UK Freight Transport

Decarbonising UK Freight Transport Network is one of the five Decarbonising Transport Networks programme funded by the Engineering and Physical Sciences Research Council (EPSRC), part of the UK Research and Innovation (UKRI). Decarbonising UK Freight Transport is a network of eleven universities and thirty industry partners, that prioritises rigorous and co-created research (academia and industry) to unleash significant investment into the freight sector's decarbonisation and guide enabling policy.

For more information and latest news visit: www.decarbonisingfreight.co.uk

Decarbonising UK Freight Transport is part of the Decarbonising Transport Networks+ programme. This programme is funded by the Engineering and Physical Sciences Research Council (EPSRC), which is part of UK Research and Innovation (UKRI).



Decarbonising UK Freight Transport is hosted by University College London. We are partnered with a further ten universities where our academic and research staff are based.



An interesting mix of industrial stakeholders and academics have been part of the Decarbonising UK Freight (DUKFT) Network. The events and studies during the three years of the Network's operation have highlighted the main decarbonisation barriers, the important transition themes, and the key post-network actions needed to accelerate the decarbonisation of UK freight.

Chicken or the Egg?

Mobilising investment for decarbonising UK freight is the objective; however, the stakeholder consultations highlighted several 'chicken-and-egg' type barriers. There were two major chicken-and-egg barriers discussed. Firstly, a debate on which should lead – investments in vehicle/vessels or energy infrastructure. Secondly, a discussion on who should lead and invest first – government or private investors and companies.

These chicken-and-egg barriers exist because of the investment risks. Indeed, as logistics chains seek to decarbonise then the following hierarchical steps can be considered:

1. **Avoid – look to move less**
2. **Shift – onto more efficient/cleaner modes**
3. **Improve – finally, seek to improve the technology (e.g. electrification)**

Therefore, investment risks can manifest at each of these three stages. Investing in current freight movements could see demand falter (e.g. fossil fuel logistics), or freight could shift onto alternative modes (e.g. from truck to train), or finally, the wrong improvements could be implemented (i.e. resulting in stranded technologies).

Risk reduction is key

During the stakeholder engagements, it became apparent that the industry and academia collectively need to overcome these risks so that acceptable investment pathways can be established and rapidly scaled. This is needed to deliver the decarbonisation required to achieve a 1.5°C aligned transition to net-zero. To accomplish this, a range of risk reduction activities and tools must be implemented and shared. The following were highlighted as important:

- Clear narratives/hypotheses on how the sector should transition – this is important to guide stakeholders through the various decisions they need to make within a complex system-of-systems. Without clear narratives/hypotheses, actors will not have the understanding, and consequently the confidence they need to act.
- These narratives/hypotheses need to be tested against models of the future freight system to generate key insights and provide narrative feedback.
- As well as inputting to the models above, stakeholders will also need quantitative data to navigate the 'Avoid, Shift and Improve' risks and drive their investment vs payback estimates.
- Complexity is the challenge, time is the enemy

Providing the transition narratives and the data to support the corresponding investment decisions is exceptionally challenging. This challenge was laid bare during the final DUKFT event, which highlighted the global scale of the logistics industry, the broad scope involved (i.e., a so-called 'system of systems' because it combines multiple major system elements like the energy system and the various transport modes), as well as many complex feedback loops and potential unintended consequences.

This means specific tools, techniques and skillsets are needed to deal with the complexity. These include complex ‘system of system’ models to help decompose the system into more manageable elements that lend themselves to deeper investigation while maintaining consideration of any important feedback loops. Such modelling efforts will need to be supported by ‘Living Labs’ that monitor large-scale pilots of the key decarbonisation approaches. These ‘Living Labs’ validate system models and, by engaging real system actors, generate an understanding of the complex stakeholder behaviours that can happen during large-scale system reconfigurations, such as the decarbonisation of the freight system. As well as the timeframe for reaching the net-zero greenhouse gas emissions milestone, the trajectory we follow is also important to the resulting global warming effect. However, insufficient investment is taking place, and critical 2030 investments are at risk. Furthermore, the absence of progress in the 2030s will slow learning rates and increase the challenge all the way to 2050.

The opportunity

What has become clear is that much of the intellectual capacity needed to deal with the complexity and therefore overcome the chicken-and-egg barriers is available from the academic community, and indeed, this is likely to be the quickest route to making it available. It requires coordination and leadership to bring it to bear, but it is either present or in development now. This capability can then be used in partnership with industry to manage the complexity, generate and validate the narratives and provide key data to drive the investment decisions at the scale needed.

DUKFT has made significant progress in demystifying the transition pathways for the different freight modes. It has been evidenced that an electrification pathway is common across all freight modes and therefore is a no-regrets low-risk investment from both public and private investors. The Network has shown that clear government direction followed by investment in the transition is necessary, and early mover action from leading private sector organisations who can act now will help to overcome the challenges of time and complexity and reduce risks for the sector at large.

Chris Thorne – Chair of Decarbonising UK Freight Transport

Executive summary

The decarbonisation of UK freight transport represents both opportunity and risk to UK stakeholders. Shipping, road freight, air freight and rail transport make up approximately 7% of UK's CO₂ emissions. The report focuses on shipping and road freight (particularly HGV's) which have some of the largest shares of UK freight activity and GHG emissions.

Operating over three years, the UKRI funded 'Decarbonising UK Freight Transport' (DUKFT) project has undertaken six research projects and two stakeholder events on how to accelerate investment that can enable UK freight decarbonisation whilst managing risk and maximising opportunity. Three inter-related key findings from the project are:

- **UK freight decarbonisation pathways can be most efficiently informed by a whole freight system, whole UK analysis capability.** This needs to couple detail on both infrastructure¹ and vehicle/vessel fleets with operational and technology specifics, resolved at granular space and time detail. Agent Based Modelling was evidenced to provide a viable and valuable platform for this objective.
- **Co-creation processes are key for future research on UK freight decarbonisation,** not only to maximise the relevance and quality of research, but also for the co-benefits of creating and enabling shared visions within stakeholder communities, framing of the challenge ahead and helping to enable a dialogue between industry and government stakeholders.
- **Ports are key nodes in the UK freight sector's decarbonisation.** They are both interfaces between the modes (road, rail and shipping), but also represent locations where infrastructure and decarbonisation solution synergies are most likely exploited. They are also likely to be hubs for wider offtake of electrification and RFNBOs², for example for decarbonising co-located industry. Port's role in the UK's transition needs to be considered broadly to help reframe them as centres for green opportunity.



1 E.g. charging, production and supply of Renewable Fuels of Non-Biological Origin (RFNBO) i.e. green hydrogen derived fuels, such as methanol and ammonia, as well as logistics infrastructure such as ports and distribution centres.

2 Renewable Fuels of Non-Biological Origin (RFNBO) i.e. green hydrogen derived fuels, such as methanol and ammonia

Why is investment needed?

GHG emissions from freight transportation can be reduced immediately by making efficiency improvement, however such advancements cannot create the scale and speed proportionate to the UK Climate Change Act (2008) objectives. Road and shipping freight transport must rapidly transition away from their reliance on fossil fuels. However, this common challenge provides an opportunity for synchronicity between freight modes, to mobilise and de-risk investment and provide common infrastructure for cleaner energy commodities and supply chains. Sustainable biofuels that could be dropped-in and used with existing fleet and infrastructure, may be used in the sector but are not considered scalable and able to achieve the decarbonisation objectives. Furthermore, drop-in biofuels may increase reliance on carbon fuels and delay transition to net zero. An understanding of the technologies and fuels for each freight transport mode is necessary; evidence compiled through DUKFT indicates that the pathways for these freight modes as follows:

- **Maritime freight** – predominantly substitution to RFNBOs, but also electrification (in ports, when at berth, and battery electrification for shorter voyages), and wherever possible direct use of wind propulsion.
- **Road freight** – predominantly electrification, which could be through battery vehicles, road electrification (e.g. through catenaries and catenary enabled HGVs), or hybrid solutions which combine these two technologies. RFNBOs may have a limited role to play in the UK for a subset of routes that cannot make an investment case for electrification infrastructure and are a significantly lower efficiency use of renewable electricity
- **Rail freight** – predominantly electrification using existing electric rail lines and expansion of an electric enabled rail freight network. This requires investment of another 800 miles of rail over the next 20 years enabling 95% of freight haulage to be travel electrically by mid-2040s. Like road freight, RFNBOs may have a limited role to play in the UK for a subset of the network that cannot make an investment case for electrification infrastructure.

What is the gap between investment deployed and what is needed in these pathways?

Investment has been limited for all freight modes and there remains a large gap between what has been deployed to the level required to be on a trajectory to zero emissions. Public spending has been minimal toward freight decarbonisation, so has private sector investment. This is of significant concern given the longevity of asset lives (fleet and infrastructure), and the timescales that are needed for renewal. Whilst road freight fleet may be able to be replaced through technologies applied to new vehicles alone, for maritime freight, the existing fleet is likely to need either early replacement or retrofit to RFNBO compatibility (which DUKFT found evidence could be achieved).

For **maritime freight** decarbonisation, it is estimated that the transition will cost ~£75 billion for the domestic fleet³ and on-land infrastructure. The majority of investment needed to enable decarbonisation of maritime freight is on land, and in the energy supply chain rather than on the vessels. This includes port electrification investment – particularly connections to grid and provision of electricity at berth for cold ironing, as well as investment in the production of RFNBO. To date, there has been limited public investment; funding has been provided to pilot projects demonstrating RFNBOs. In the private sector, investment has surfaced for hydrogen derived fuels and onboard technologies, however, this has remained within larger players in the shipping sector and large cargo owners and there is limited investment specifically for freight decarbonisation.

For **road freight** decarbonisation, it is estimated that the transition will cost ~£20 billion for fleet cost and on-land infrastructure. The nature and extent of investment that will be needed on land or on vehicles will significantly depend on whether the dominant solution is electrified – via Electric Road Systems (ERS) and/or battery electrification of vehicles – or hydrogen-based solutions. The road freight is more fragmented than the maritime freight sector and therefore is less likely to have early movers in the initial transition. This is why investments have merely come in the form of pilot and demonstration projects thus far and until clear guidance is provided from the government, private investment in charging or fuelling infrastructure will remain low. However, the urgency of decarbonisation and uncertainty of timelines for delivering energy and transport infrastructure on which freight decarbonisation is dependent on implies that there is little time for real-world demonstration projects.

³ Domestic fleet is one where voyages are made between ports in Great Britain, Northern Ireland, the Isle of Man and Channel Islands, in and out of the same port (such as travel to and from offshore oil and gas installations) and on inland waterways.

How can investment be accelerated?

From the series of studies commissioned and stakeholder events over the three-year period, DUKFT network identified actions that could address the evidenced and urgent need for accelerated investment. There were three overarching findings, which resulted in associated recommendations for future research:

1 The need for a whole system, whole UK approach to identify technology pathways

Understanding the dynamics of the freight sector is key to decarbonisation solutions. DUKFT found that clarifying the technology pathway for UK freight is critically dependent on integrating understanding of vehicle and infrastructure technology options, with a detailed representation of UK logistics. The parameters for logistics of cost, time and reliability need to be brought together in the review of any solution.

To date most efforts have been focused on techno-economic approaches. Stakeholders made clear that unless a solution is economically viable e.g. price competitive with current solutions, it will not be taken up, so such models are useful. However, DUKFT found that such models lack a holistic approach that include other critical independencies required to develop a state-of-the-art pathway. One of the DUKFT studies evidenced how the state of the art could be extended through development of a pilot multimodal agent-based freight system model. As well as the cost of technologies and future policy e.g. carbon pricing, the multi-modal framework combined supply side dynamics including infrastructural constraints and geographics, operational demands of freight modes and behavioural decisions based on carbon price changes, energy usage and technologies adopted and their financial and emissions impacts. Multi-modal modelling showed that it is necessary to consider freight modes as a whole system; failure to do so runs the risk of unexpected consequences and that models can complement and minimise more costly and time-consuming trials/pilots. The modelling also showed how larger geographical scales, including those that recognise that maritime and road freight systems have both national and international connections, could help further identify synergies beyond those that take just a technology perspective.

The role of academia and future research is therefore essential in establishing state-of-the-art pathways. But it was evident from DUKFT that more collaboration is needed between academia and industry. This was stressed in both events, as stakeholders were not confident that policy measures and regulations were likely in the short term. Multi-modal-based modelling was seen as a key area that could benefit from industry-academia collaboration; it provides an opportunity for 'digital twinning' and facilitates collaboration and the creation of business cases of solutions to real-world scenarios.

Recommendations: There remains a clear need for identifying and articulating the least-cost technology pathways for UK freight decarbonisation. Mature existing modelling techniques are limited in providing further clarification and this sector would significantly benefit from modelling capability that can integrate operations and technology, space and time characterisation of multi-modal fleet and infrastructure at fine granular scales.

2 The importance of co-creation in freight research

Both stakeholder events, and several of the studies revealed the fragmented nature of the freight stakeholder space and the challenge ahead for creating a shared vision on how to decarbonise these sectors. Signals had been received by industry stakeholders that major change was expected, including from key strategies such as Transport Decarbonisation Plan, Clean Maritime Plan, however the specifics of policies that will incentivise change are not clear.

Early action from industry pioneers is therefore key to driving the emergence phase of the transition; their actions can bind relationships with governments and institutions to help forge a decarbonisation pathway through policy design and implementation. DUKFT stakeholder consultations showed that customers, cargo owners and investors were important drivers of change and there is some opportunity in catalysing some of the early movers to form private standards that kick-start the transition. However, in early consultation and studies, DUKFT found little evidence that business-to-business engagements are incentivising freight decarbonisation investment at the speed needed, and clear evidence that stakeholders are waiting on regulation to create certainty for investment to be deployed.

The stakeholder consultations showed that when effort was invested to bring stakeholders from different parts of freight value chains together (industry, academia, NGO and government stakeholders), there was benefit to identify a shared vision and co-create ideas for both public and private actions aligned with unlocking investment in decarbonisation. DUKFT primarily had the resources to explore co-creation at small-scale and regionally, which showed that even within the UK, freight decarbonisation can require place-based specialisation.

Recommendation: Research funding should deploy a sustained multidisciplinary research effort alongside stakeholder community engagement and ensure a broad spectrum of the freight sector's value chain in co-creating solutions. This can unlock multiple benefits:

- Academia, acting as an evidence-led information broker can help articulate the scale of investment and change needed, and enable a constructive discussion between industry and government about how decarbonisation can most efficiently be incentivised. Assembling a common view of the challenge ahead and building trust is a key first step.
- Enabling a shared vision through alliances (e.g. a regional version of coZEV and ZEMBA⁴ but covering all freight modes), underpinned by discussions of specific technology pathways, and potential barriers to solutions, can start to align mindsets and strategies across the supply chain and between competitors, smoothing the path for regulation and commercial action.
- Social science researchers working closely with stakeholders across policy and commercial roles have a key role to play in testing the results from engineering and techno-economic analysis and quantitative modelling, and identifying gaps between theory and solutions that might have more practical benefits.

3 Mobilising finance for ports as decarbonisation hubs

DUKFT studies found UK ports can combine multiple roles including being energy consumers, energy suppliers (including to freight vehicles calling to them), and act as energy nexuses e.g. for interconnecting energy networks, creating charging opportunities and for throughput of offshore or imported liquid energy commodities.

In particular, ports were identified as having a key role in the development of new energy supply chains associated with RFNBOs. The opportunity could vary depending on the specifics of the port, some may be used as major import terminals for RFNBO produced offshore or overseas. Some may need significant RFNBO storage infrastructure to meet the demands of shipping (e.g. bunkering). Others may be suited to local production of blue hydrogen, taking advantage of their proximity to gas and CCS infrastructure or local production of green hydrogen interconnected to large offshore wind generation. The existing co-location of ports with UK heavy industry, and increasingly distribution logistics infrastructure, mean that there are even wider opportunities than looking at their synergies with freight decarbonisation alone.

The stakeholder consultations showed that bringing stakeholders from across the supply chain together (i.e., energy suppliers, port owners, vessel/vehicle owners, logistics companies, etc) along with investors/financiers (including aggregating finance to bring institutional investors), is crucial in establishing opportunities and creating a platform to mobilise infrastructural investment. Specifically, partnerships or joint ventures between port owners and fleet operators/liners during the emergence phase were seen as a way of mobilising and de-risking investment, particularly with the creation of long-term offtake agreements of future fuel usage.

Recommendation: Further research should continue to explore how ports' opportunities in the transition can be characterised and assessed. This can not only help with the identification of synergies that occur across electrification and hydrogen investment related to the decarbonisation of the port and the UK freight modes connected to it, but also help identify their potential roles in wider UK transition, electrification and use of hydrogen. This should be part of ensuring balance of freight decarbonisation to consider infrastructure investments equally and alongside technology and investment at the vehicle/vessel level.

⁴ coZEV – Cargo Owners for Zero Emission Vessels, ZEMBA – Zero Emissions Maritime Buyers Alliance.

How to accelerate investment for UK freight transport decarbonisation

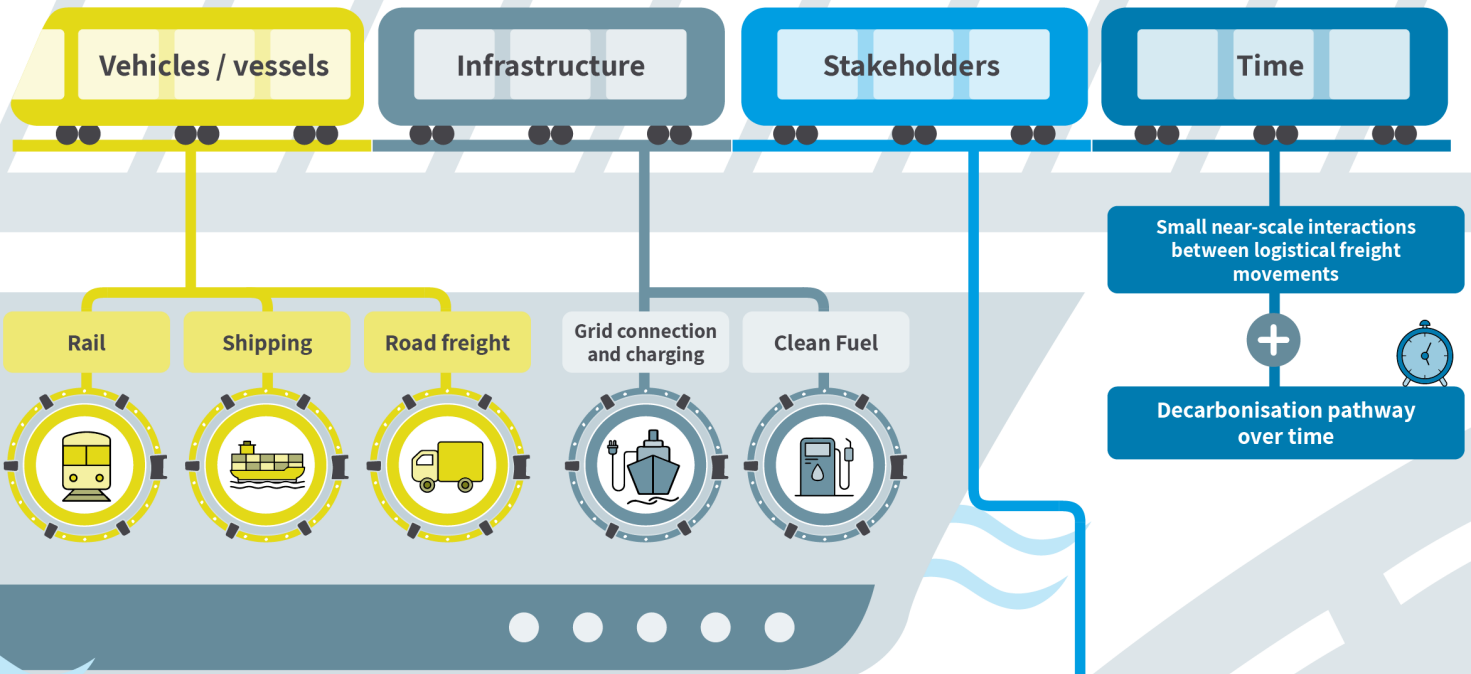
Decarbonising UK freight transport in-line with 1.5 degree goals is feasible, but requires acceleration of investment into its solutions. Academic research has a key role to play – our findings of three key topics are:

1

The need for a whole system, whole UK approach to identify technology pathways

Clarifying the technology pathway for UK freight decarbonisation is critically dependent on integrating understanding of vehicle and infrastructure technology options, with a detailed representation of UK logistics. DUKFT Whole-system modelling simulates the interaction of the following agents:

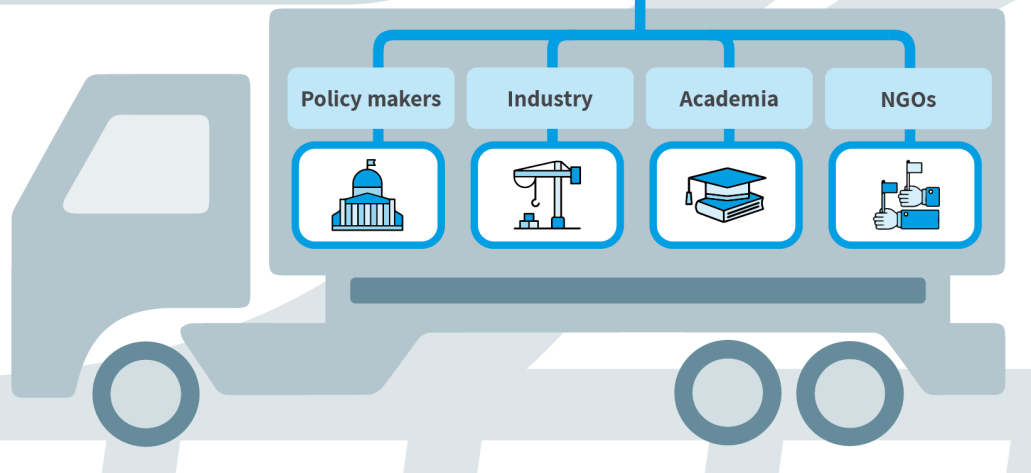
Components of Whole-system modelling



2

The importance of co-creation in freight research

Evidence showed that bringing stakeholders from different parts of freight value chains together to identify a shared vision and co-create ideas for both public and private actions aligned with unlocking investment in decarbonisation.

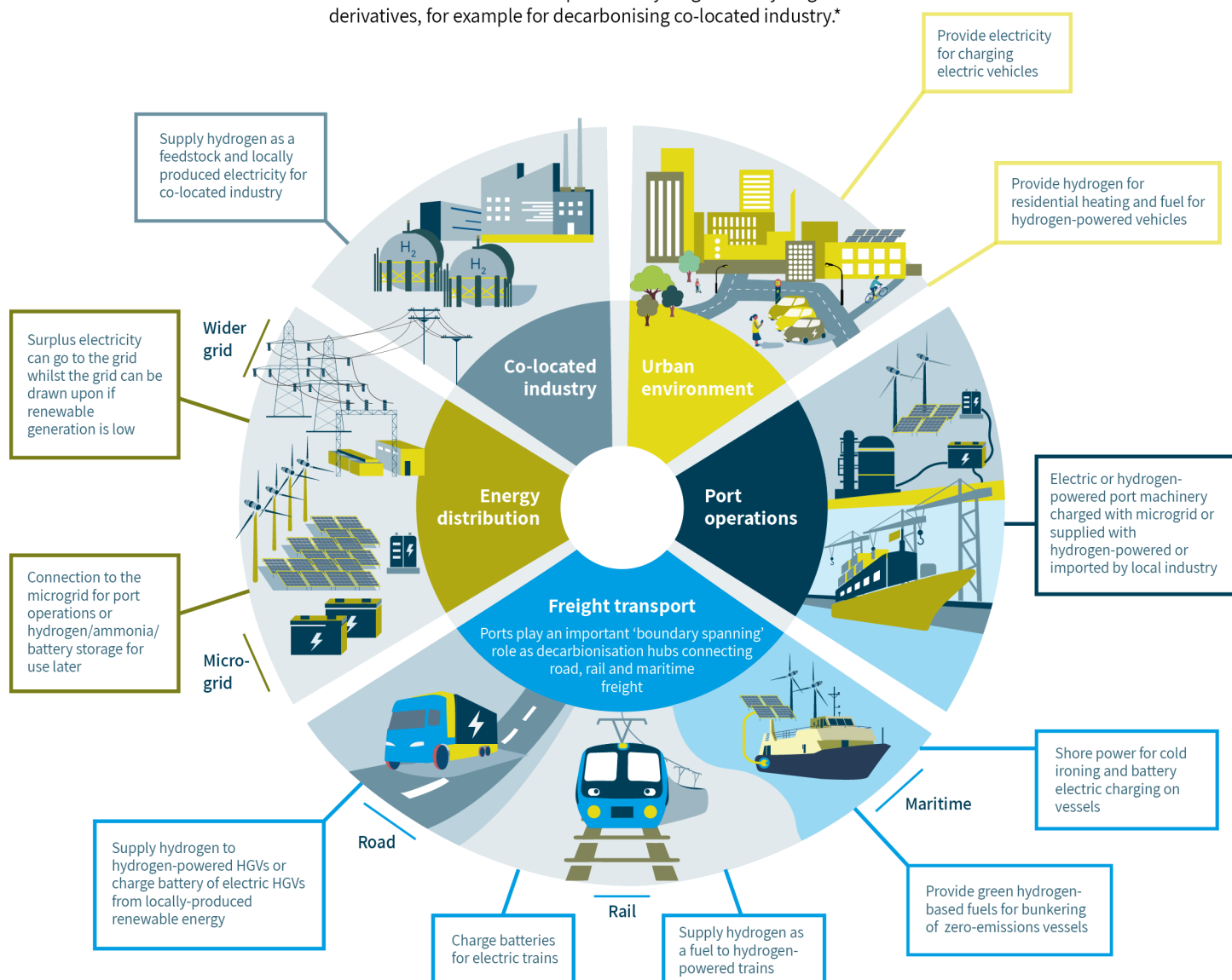


How to accelerate investment for UK freight transport decarbonisation

Decarbonising UK freight transport in-line with 1.5 degree goals is feasible, but requires acceleration of investment into its solutions. Academic research has a key role to play – our findings of three key topics are:

3 Ports as decarbonisation hubs

Ports are locations where infrastructure and decarbonisation solutions synergies can be exploited for UK freight and wider industries. They are also likely to be hubs for wider offtake of electrification and the development of hydrogen and hydrogen derivatives, for example for decarbonising co-located industry.*



*Synergies between domestic freight decarbonisation and international policies are not being addressed

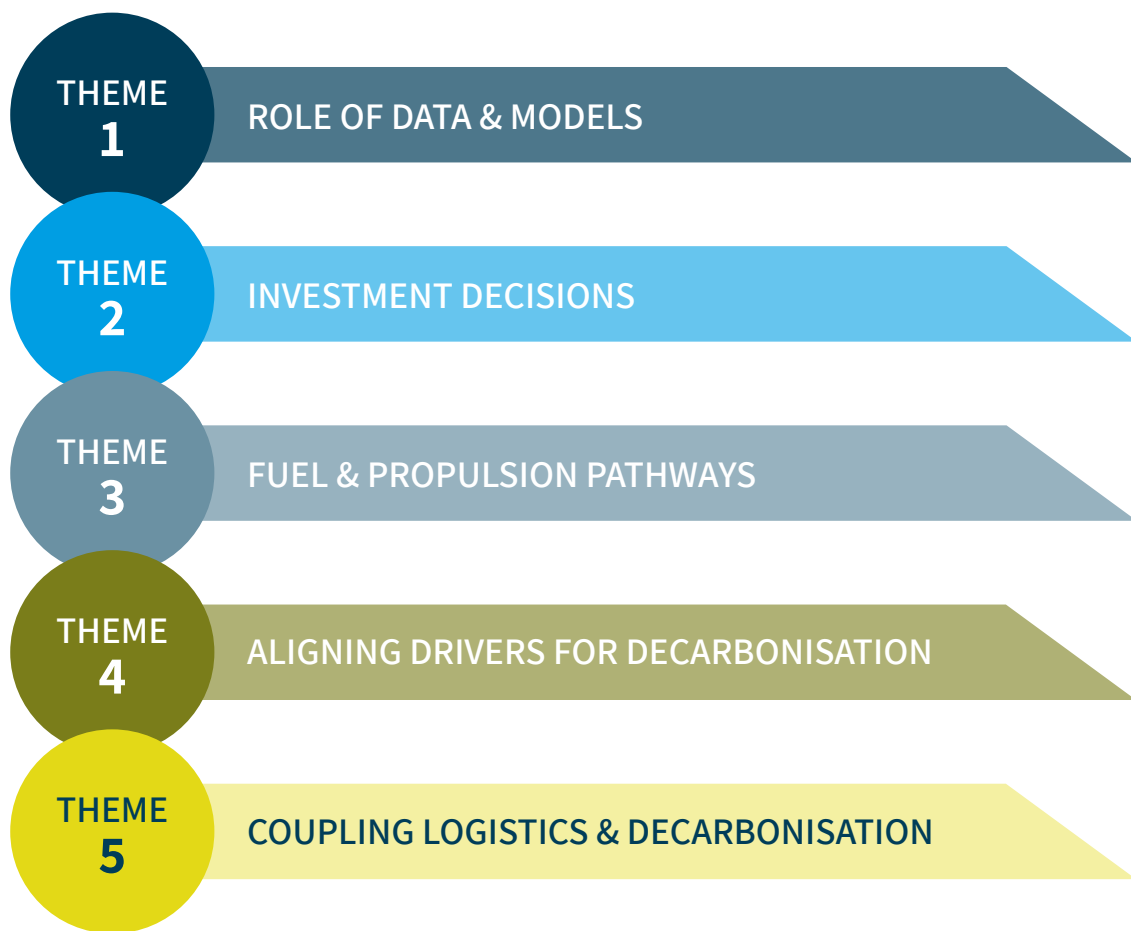
Table of Contents

1	Introduction	13
2	State of the art transitional pathways of freight modes	15
3	The gap between current levels of investment and what is required?	16
4	Unlocking investments in decarbonising freight transport	17
4.1	The need for a whole system, whole UK approach to identify technology pathways	
4.2	The importance of co-creating solutions	
4.3	Mobilising finance for clean investment and unlocking investment with ports as decarbonisation hubs	
5	Appendices	21
	Appendix A – Findings from ‘Financing the decarbonisation of freight transport’ event	
	Appendix B – Findings from ‘Mobilising investment in decarbonising UK freight transport event	
	Appendix C – Summaries of thematic projects	

1 Introduction

Starting in June 2019 and ending in April 2023, the UKRI funded ‘Decarbonising UK Freight Transport’ (DUKFT) project has undertaken six research projects and five stakeholder events on how to accelerate investment that can enable UK freight decarbonisation whilst managing risk and maximising opportunity. The network was organised in five themes which aimed to answer the research questions as shown in Figure 1. In 2020, the DUKFT network funded four small research projects that aimed to answer research questions investigating freight transport decarbonisation investment decisions. The projects explored the roles of decision makers, financiers, and the methods that characterise freight technology and fuel-based decarbonisation options. In 2021, the DUKFT network funded two more projects. The projects explored solutions to mobilise investment by using a whole systems approach to modal freight transport by employing common infrastructure and using detailed data and modelling to provide state-of-the-art transitional pathways.

Figure 1: Themes in the DUKFT network



Central to the aims of the DUKFT network, two multi-stakeholder cross-modal events that brought together stakeholders across the freight transport sector sought to understand both public and private investors, perspectives on managing risk, climate alignment, barriers and drivers to investment. The first event, titled ‘Financing decarbonisation of the freight transport sector’ took place in February 2020 and the final event, titled ‘Mobilising investment for decarbonising UK freight sector’ took place in February 2023.

This report synthesises the overall findings from the series of research projects and key messages from both events. The report updates findings from the final event and follows on from the pre-event key findings report.

DUKFT Theme	Research question	Research project
1. The Role of Data and models for unlocking implementation decision making	What effects will widespread decarbonisation of freight transport systems (particularly road freight and sea freight) have on the design, operation, costs and environmental footprint of logistics systems in the UK?	Multi-model Operations and Infrastructure Modelling
2. Managing uncertainty (macroeconomic, policy and technology) whilst mitigating climate risks in investment decisions	<p>A narrow scope analysis of financiers, including banks, institutional investors and equity investors of the factors influencing freight transport investment decisions.</p> <ol style="list-style-type: none"> 1. What approaches do investors (in general and specifically in the transport/freight sector) currently use to screen or ensure that an investment is decarbonisation-aligned? How widely/commonly used are the approaches? 2. What is missing and most difficult to capture in terms of assessing decarbonisation alignment in these approaches (specifically addressing data, tools, models, metrics and frameworks)? 3. In what ways can these approaches be improved to assist the investors in making their decisions decarbonisation-aligned? 	Transport Investment Decisions (TIDE): An exploration of climate alignment in freight related investment decisions
3. Fuel and propulsion technology pathways	<p>Methods to characterise, for decision makers, a wide range of freight technology and fuel-based decarbonisation options.</p> <ol style="list-style-type: none"> 1. What are the options and their feasibility for a method or methods to describe and characterise a diverse set of technological and fuel-based decarbonisation options for a wider range of decision makers? 	Co-produced Route-mapping to Accelerate Freight Decarbonisation (CRAFTeD): A Transdisciplinary Learning and Decision Framework
4. Aligning drivers for decarbonisation investment and policy	<p>A wide scope analysis, which includes all stakeholders including owners, government, fleet operators, ports, etc. of the factors influencing freight transport investment decisions.</p> <ol style="list-style-type: none"> 1. What are the current factors that influence investment decisions for different actors in freight transport? 2. What is the relative significance of these different factors to investment decisions? 3. Can any changes in the relative significance of these factors over time be quantified? 4. To what extent do these factors align in achieving freight decarbonisation? <p>How can ports support decarbonisation across multiple transport modes, what investment is required and how can they lead to incentives being aligned across transport modes to achieve the UK's 2050 Net Zero target?</p>	<p>Understanding Freight Decarbonisation Investment Decisions</p> <p>Examining the feasibility and investment required for ports to act as decarbonisation hubs.</p>

<p>5. Coupling the evolution of logistics and its infrastructure with decarbonising freight</p>	<p>Characterising the drivers of UK logistics' carbon footprint, and the key decision points and makers.</p> <ol style="list-style-type: none"> 1. How can we benchmark UK logistics activity and its carbon footprint (which 'parts' have the most impact? How does this compare with other countries?) 2. Who dictates the carbon footprint of UK logistics activity? – where along the supply chains are the key decisions made? What/where are the levers (locus of power, vested interests etc.)? 	<p>An Integrated System and Service Design Approach for Decarbonisation of UK Freight Transportation (INSTINCT)</p>
--	--	---

2 State of the art transitional pathways of freight modes

Freight transportation requires harmonious change to achieve deep decarbonisation. The multi-modal nature of freight (road, rail and shipping) means common challenges exist for all modes, but this can provide a springboard for synchromodality, initiating decarbonisation at the speed and scale that must happen to enable a proportionate response to UK climate change act objectives.

All modes can reduce emissions now by taking efficiency measures, however such advancements cannot create a reduction of emissions on a pathway to deep decarbonisation. They must be coupled with a shift away from fossil fuels to new energy commodities and energy supply chains. This will require significant fleet and infrastructure investment, but currently there is no direction for private and public investments to be deployed in the necessary amounts for road, rail and shipping to reach zero emissions. Research and development of clean technologies and fuels have advanced greatly since the start of this project that they are now not seen as a limiting factor. Instead, the uncertainty in a technological and transitional pathway is creating a bottleneck of investment. The evidence compiled through DUKFT projects and stakeholder consultations indicate that there are clear pathways for each mode of freight transport. For further details of the transition pathways refer to the findings from DUKFT pre-event findings report⁵.

For **maritime freight** several alternative fuels and their associated technologies are proposed to offer a transition away from fossil fuels. LNG and biofuels are currently commercially available; however, their scalability and overall emission reduction potential do not offer a pathway to zero emissions. Instead, evidence suggests Renewable Fuels of Non-Biological Origin (RFNBO) which includes hydrogen and hydrogen derived fuels such as ammonia and methanol, will be the predominant fuels in the transition, combined with electrification for shorter voyages, ships at berth and in-ports. Cleaner fuels and electrification will be coupled with wind-assisted technologies and other energy efficiency measures. Given the long life span of vessels, retrofitting of the current fleet will be a major driver in the transition and it is expected that retrofitted vessels could comprise nearly half the fleet by 2050⁶.

Evidence suggests that electrification of **road freight** will be the predominant technology in a decarbonisation pathway: either via battery electric heavy-goods vehicles (HGVs), road electrification (i.e., through catenaries and catenary enabled HGVs) or a combination of both technologies. Hydrogen HGVs are expected to play a limited role in the UK⁷, but they could be employed to move freight independently, outside of the range of electric road systems and battery ranges.

Despite an increasing proportion of the UK rail network being electrified, **rail freight** still travels predominantly on diesel trains with only around 10% of UK freight electrified. Despite this, rail freight is seen as 'low hanging fruit' and a 'no regret' option, as two thirds of the rail freight network is already electric enabled as much of the network follows the main lines. Only around 800 miles of additional electrification is required to enable 95% of UK freight haulage to be electrified by mid-2040s⁸.

5 <https://decarbonisingfreight.co.uk/resources/project-resources/>

6 Smith, T., Baresic, D., Fahrestock, J., Galbraith, C., Perico, V. C., Rojon, I., Shaw, A., (2021), A Strategy for the Transition to Zero-emission Shipping. UMAS, London

7 Ainalis, D. T., Thorne, C., & Cebon, D. (2020). Decarbonising the UK's Long-Haul Road Freight at Minimum Economic Cost.

8 The Chartered Institute of Logistics and Transport. (2023). CILT Freight electrification map

3 The gap between current levels of investment and what is required?

Investment has been limited for all freight modes and there remains a large gap between what has been deployed to the level required to be on a trajectory to zero emissions. Public spending has been minimal toward freight decarbonisation, and by association, so has private investment.

For **maritime freight** decarbonisation, it is estimated that the transition will cost ~£75 billion for fleet cost and on-land infrastructure⁹. DUKFT finds that the majority of investment is on-land and energy supply rather than on-board vessels. A high proportion of the costs will be for enabling electrification of ports, adding connections to the grid for battery charging and facilitating cold ironing for ships at berth. Currently UK shore power is far behind – as much as 20 years¹⁰. It requires systematic transformation instead of the singular grants supplied to individual demonstration projects. Up to ~20% of domestic emissions can be reduced by the inclusion of shore power alone⁹, but until land infrastructure is developed and ports are connected to the grid, ship owners will defer electrified solutions.

Large investments must be made to produce RFNBO and associated bunkering facilities for zero emission vessels. Demonstration projects are being funded by the UK Government's Clean Maritime Demonstration Competition (CMDC) and recently announced Zero Emission Vessel Infrastructure (ZEVI) competition totalling £206 million since 2021. A large portion of successful projects are showcasing RFNBO. Investment is surfacing for hydrogen and hydrogen-derived fuels, but there is limited investment specifically for freight decarbonisation. The UK hydrogen strategy can spur investment with recent strengthening to a target of 10GW by 2030.

Regarding the transitional investment onboard ships, activity from first movers such as Maersk and major cargo owners involved in the coZEV initiative (Cargo Owners for Zero Emission Vessels), along with green corridor development, suggests there is progressive movement, with consensus across the industry to act quickly. However, for rest of the stakeholders who have less influence on fuel of choice in their ports of operation, they will not act as quickly and require certainty in RFNBO fuel bunkering or charging infrastructure to warrant on-board spending, otherwise they are at a heightened risk of stranded assets.

For **road freight** decarbonisation, it is estimated that the transition will cost ~£20 billion for fleet cost and on-land infrastructure¹¹. The nature and extent of investment that will be needed on land or on vehicles will significantly depend on whether the dominant solution is electrified – via Electric Road Systems (ERS) and/or battery electrification of vehicles – or hydrogen-based solutions. The road freight is more fragmented than the maritime freight sector and therefore is less likely to have early movers in the initial transition. This is why investments have merely come in the form of pilot and demonstration studies and largely are in the form of desktop studies. Until clear guidance is provided to the sector from the government, private investment in charging or fuelling infrastructure will remain low. Demonstration studies commenced in 2021 over a 3-year period demonstrating multiple electrified and hydrogen solutions but a pathway will remain uncertain until 2024-25 and private investment minimal for this period.

There is concern that such demonstration studies are overshadowed by the urgency of decarbonisation and timelines for delivering energy and transport infrastructure on which freight decarbonisation is dependent on. These trials could take years to complete – time in which we can't afford to lose in the transition. The following section will provide solutions to how investment can be accelerated for decarbonising UK freight.

For **rail freight**, it is suggested that an electrification programme of 40 miles per annum with a cost of approximately £100 million per annum over a 20-year period is required to deliver electrification at the levels necessary when current diesel locomotives reach life expiry¹². Initial phases will cover cross country routes from main ports inland such as Felixstowe and Southampton and also enable modal shift from diesel HGVs.

9 MCL, UMAS & LR (2022) UK Domestic Shipping: Mobilising Investment in Net Zero <https://www.marine-capital.co.uk/ukmaritimedecarbonisationreport/>

10 UK Chamber of Shipping (2022) UK Chamber of Shipping: Mandate green shore power for ports and ships. Available at <https://www.ukchamberofshipping.com/latest/uk-chamber-shipping-mandate-green-shore-power-ports-and-ships/>

11 Ainalis, Thorne & Cebon (2023) Technoeconomic comparison of an electric road system and hydrogen for decarbonising the UK's long-haul road freight, Research in Transportation Business & Management, Vol 48. <https://doi.org/10.1016/j.rtbm.2022.100914>

12 Chartered Institute of Logistics and Transport

4 Unlocking investments in decarbonising freight transport

DUKFT combined stakeholder events with a series of studies commissioned over a three-year period with the aim to identify actions that could address the urgent need for accelerated investment. There were three overarching findings from the studies (some of which also included stakeholder consultations as part of their research methods) and stakeholder events – these were put to stakeholders in a final event in which a set of recommendations were made for each overarching theme.

4.1 The need for a whole system, whole UK approach to identify technology pathways

Understanding the dynamics of the freight sector is key to decarbonisation solutions. The INSTINCT study sought to understand the multi-levels of stakeholders in the freight sector and how this could affect investment into the freight sector. It found that the high fragmentation of the freight sector could present challenges in decarbonisation. With high division from large logistics to small fleet owners across multiple regions, it was discovered that many work in silos and subsequently are reluctant to work collectively due to confidentiality issues, competition and conflict of interest. This puts the sector at a disadvantage in establishing unison from stakeholder to stakeholder and suggests there is high importance in clarifying a technological pathway to the sector to follow and facilitating collaboration between competitors.

All parameters must be combined to bring a detailed representation of the UK freight system in order to establish a technological pathway. To date, efforts have focused on technology pathways based on techno-economic approaches, and although research into technologies and costs would be appreciated, these factors are not seen as limitations and thus such models can merely provide economical findings. A whole analysis is required, that incorporates behavioural models and detailed infrastructural descriptions to identify solutions sensitive to assumptions for a whole freight system including parameters such as logistics, time and operational reliability.

One of the DUKFT studies showed that state of the art pathways could be analysed in the development of a multi-modal agent-based freight system model. As well as the cost of technologies and future carbon pricing, the framework considered combined supply side dynamics including infrastructural constraints and geographics, operational demands of freight modes and behavioural decisions based on carbon price changes, energy usage and technologies adopted and their financial and carbon impacts.

Although at pilot scale, this modelling showed the viability and value of bringing together the specifics of infrastructure constraints alongside vehicle technology options, within a model that could consider both space and time dimensions at the scale of individual journeys. The modelling demonstrated the benefit of representing different freight modes in a single model; it gives an understanding of the synergies between modes decarbonisation solution such as the potential for leveraging shared infrastructural investment associated with electrification. The findings highlight the necessity of considering freight modes as a whole system and failure to do so runs the risk of unanticipated consequences. The pilot nature of the study meant a broader geographical perspective than a subset of UK freight was not considered, but the pilot model showed how larger geographical scales, including those that recognise that maritime and road freight systems have both national and international connections, could help further identify synergies beyond those that take just a technology perspective.

With the urgent decarbonisation agenda and the timelines for delivering energy and transport infrastructure, there is little time for real-world demonstration. Living labs can provide important data from real case studies but more could be done to scale up the results through modelling. The study highlights the impact that agent-based modelling (computer simulations used to study the interactions between people, things, places, and time) can have in determining a technological pathway soon, rather than waiting for multiple-year projects on small scales.

The economic implications of introducing new technologies and alternative fuels were an important talking point in the final event. It was clear that investors, fleet owners, operators etc within the freight sector – particularly those of smaller to medium size – would not take a solution seriously unless there is viable business case and it was price competitive with conventional solutions. Currently though, the conventional solutions are favourable as minimising cost is the priority and the lack of regulations and policy are not encouraging leaders in the industry to move first.

As stakeholders from different parts of the freight sector were not confident that policy measures or regulations were arriving in the near term, they made it clear that there is a greater need for collaboration between academia

and industry to provide state of the art technological pathways assigned to real world solution thinking (i.e., digital twinning), with essential focus on developing a business case founded on economic incentives and profitability for the end-user.

This pointed towards modelling and the role that academia can take when investigating real world decarbonisation scenario. With collaboration with industry on specific requirements, academia can provide a detailed economic assessment but also tied in with greater aspects that constitute a climate aligned investment decision. This has been demonstrated already by Agent-Based Modelling (ABM) and it was seen as the most effective approach in the event, especially when comparing the time frame and cost of demonstration trials.

4.2 The importance of co-creating solutions

The shipping and road freight sectors have received signals from policy; the Transport Decarbonisation Plan and Clean Maritime Plan released in 2021 and 2019 respectively are the latest indications of policy change. However, no specifics have been made in terms of policy to incentivise change, and thus, stakeholders cannot be clear on the direction ahead.

Forward thinking stakeholders are realising that they cannot afford to wait for guidance from government or policy makers. With increased public awareness, pressure from consumers and the latest science, the responsibility has shifted to industry to take it upon themselves and drive the agenda. Early action from industry pioneers will therefore be key to driving the emergence phase of the transition; their actions can bind relationships with governments and institutions to help forge a decarbonisation pathway through policy design and implementation.

DUKFT found little evidence that business-to-business engagements are incentivising freight decarbonisation investment at the speed needed; most stakeholders in the freight sector are taking the wait-and-see approach. The decarbonisation agenda has been growing in importance, but priorities remain high on meeting customer demands and reducing costs. Moreover, the lack of an overall sense of direction and thus lack of infrastructure/refuelling means that fleet owners are at risk of choosing a technology that will not be widespread and unusable until infrastructure is developed, consequently creating a greater risk of stranded assets.

Other factors make finding a common technological pathway even more challenging, especially as the logistics sector works in silos, are in competition with each other and therefore unlikely to share their future strategies.

Evidence from DUKFT found that there was a good potential of identifying a shared vision and co-creating ideas for both public and private actions aligned with unlocking investment in decarbonisation once effort was made to bring stakeholders from different parts of the value chain together (industry, academia, NGO, and government stakeholders). Working in collaboration usually at pre-competitive stage gives space for mutually beneficial partnerships to develop from business-to-business but allows space for government, industry and academia to work together on future freight research, identifying policy measures for innovative technological pathways that provide guidance to the sector for the overall goal of accelerating investment in UK freight decarbonisation.

Academia can act as evidence led information-broker and social science researchers can work closely with stakeholders across policy and commercial roles to test technological pathways and quantitative modelling and identify gaps between theory and solutions. This route has already proven to establish forward thinking ideas: one project found that working with start-ups in the industry can foster innovative ideas and help bring technologies to market quicker; the study also identified that the use of innovative technologies could bring stakeholder engagement together: digital platforms, blockchains and digital twins and business models can be highly effective in creating cross-compatibility in the freight sector and should be encouraged by policy makers.

The findings from the consultations largely agreed with the conclusion of the small projects: the lack of cross-sectoral stakeholder relationships is a key barrier to UK freight decarbonisation, but all stakeholders agreed that it is also a key enabler. However, “everyone is waiting for everyone else to act” and little engagement is being held. There are some examples of forward-thinking initiatives, but the vast majority are taking the ‘wait and see’ approach, mainly because various types of stakeholders do not understand what collaboration is required and who’s role is what in the decarbonisation agenda. The competitive nature of the industry is also stopping collaboration between competitors.

It was recognised that there should be encouragement to make alliances/associations that bring together competitors (in compliance with competition laws) that facilitate collaboration on decarbonisation solutions, for example, bringing together logistics operators to demonstrate system benefits by sharing data. However, it was acknowledged that it is unlikely that first movers/early adopters will provide information on solutions or best practices to accelerate the transition. Being first involves a deal of risk and there are potential rewards that are gained from being proactive; it is therefore injudicious to suggest that first movers would provide information that would diminish any benefits arose from competitive advantage, otherwise there would be no incentive to take risk.

A key question from conversations was how do we create these alliances between competitors and facilitate the necessary collaboration whilst tapping into the pioneer's knowledge without removing any competitive advantage? There is inspiration from cargo owners for Zero Emission Vessels (coZEV) which has developed the Zero Emission Maritime Buyers Alliance (ZEMBA) modelled on Renewable Energy Buyers Alliance, which aggregates and scales the demand for zero emission fuelled maritime freight services. The initiative demonstrates that through collaboration, cargo owners were able to address their own logistical need of their business whilst delivering action focused collaboration aimed at delivering economies of scale to benefit all within the alliance. It was accepted that something similar for the UK freight sector, covering all modes, would be highly valuable in bringing together a 'coalition of the willing' in the freight sector.

4.3 Mobilising finance for clean investment and unlocking investment with ports as decarbonisation hubs

To date, there has been limited investment in vehicle/vessel fleet and associated fuelling infrastructure in ports. The current lack of certainty about future provision has hindered investment, coupled with a general reluctance to be early adopters due to low profit margins and the risk of stranded assets. A few pioneers of the industry are starting to surface, particularly in the shipping sector, though this has generally concentrated on larger multinational players in the industry who have greater access to finance and can be influential on the infrastructure investment in ports.

For most vehicle/vessel owners and port operators/authorities, access to finance is made challenging from general passivity from investors/financiers. One DUKFT study found that there is a lack of evaluation of how climate aligned investments are. The study found that financiers are merely trying to understand their portfolios and taking on high-level guidance on climate progressivity instead of detailed tools assessing the climate alignment for decision making.

Consensus must be made on a best climate alignment tool. Science-Based targets are surfacing which provides a more detailed assessment of companies and financial institutions activities and investments. In the shipping industry, the Poseidon Principles (though merely aligned with current IMO policies) has attracted a large portion of the sector's finance, however there is no obligation in the direction of finance, there is just a requirement to make their activities publicly available. As such, there has been a lack of concrete impact of any financial tools on green investment decisions, and subsequently, finance that could be going towards clean investment (including port and RFNBO fuelling infrastructure and vessels/vehicles) is instead being drawn into potentially non-climate aligned investments.

Investment can also be encouraged by promoting the use of ports as decarbonisation hubs in the UK. Being cross-modal points for freight modes, their ideal location can act as a driver of green growth for the sector. They can combine multiple roles in the transition, including energy consumers, energy suppliers (including to freight vehicles calling at them) and also act as energy nexuses e.g., for interconnecting energy networks, creating charging opportunities and for throughput of offshore or imported liquid energy commodities. Domestic and international 'green corridors' have the potential to kick-start the transition by bringing together public and private entities for a narrow set of objectives and technology pathways.

Ports were identified as having a key role in the development of new energy supply chains associated with hydrogen and hydrogen derivatives (e.g., RFNBOs). The opportunity could vary depending on the specifics of the port. Some may be used as major import terminals for hydrogen/RFNBO produced offshore or overseas. Some may need significant hydrogen/RFNBO storage infrastructure in order to meet the demands of shipping (e.g., bunkering). Others may be suited to local production of blue and green hydrogen, taking advantage of their proximity to gas and CCS infrastructure or use as interconnectors to large offshore wind generation. The existing collocation of ports with UK heavy industry, and increasingly distribution logistics infrastructure, mean that there are even wider opportunities than looking at their synergies with freight decarbonisation alone.

Coupling such roles of ports across multiple sectors can create synergetic relationships, boost investment from multiple angles and in turn spread the risk of investment for infrastructure associated with future fuels and technologies.

Investment is difficult to seek individually; therefore, engagement of stakeholder groups (i.e., energy suppliers, port owners, vessel/vehicle operators, logistics) with investors/financiers is necessary to form business cases for the investment required for decarbonisation infrastructure. It was recognised that such conversations have not been happening enough within the freight sector. It was thought that the complexity of the sector and lack of understanding of roles are causing an ‘infinite loop of excuses’, but crucially this has resulted in a lack of investment in infrastructure and fleets.

Partnerships are therefore vital to facilitate ventures of realised opportunities within their operating locations. Specifically, joint ventures between port owners and fleet operators/liners were seen as a way of mobilising investment, particularly with the creation of long-term off-take agreements of future fuel use. Such agreements would de-risk investments for both parties: port owners would be sure of demand of a fuel and ports would then have invested interest and thus are more likely to secure investment for infrastructure and bunkering; whilst fleet owners would have security of supply and would therefore invest in onboard technologies for future fuels.

It was acknowledged that it is important to understand the degree of influence that liners/operators have in large ports as this would change the dynamics of these conversations. It highlights the importance of tackling this on a port-by-port basis as each port's activities and players are unique to their own circumstances, highlighting that one solution is not fit for all. Though it was also noted that collaboration is vital between port owners themselves – not only in the UK, but with international port owners where ships visit regularly. This is to ensure the availability of common infrastructure and fuel bunkering to maintain smooth operation of vessels around the UK and internationally.

5 Appendices

Appendix A – Findings from ‘Financing the decarbonisation of freight transport’ event

The event was composed of three panel discussions that shed light on issues related to investment decisions, with the view to support the building of knowledge. The objectives of the panel discussions were to explore the nature of decisions investors are making today that impinge on decarbonisation, locating the thresholds and the accuracy of evidence that investors need to make decarbonisation-aligned decisions and defining the parties that need to “buy in” to the evidence/knowledge to move forwards. The findings that arise mainly focus on the current state of the sector, the role of government, the availability and the accuracy of data and the possible solutions. Central to the aims of the DUKFT network the event sought to understand investors’, both public and private, perspectives on managing risk, climate alignment, barriers and drivers to investment. The full report can be found in the DUKFT website and the following key messages can be distilled from the event.

Call for government leadership based on academic evidence

While there is now a consensus on the necessity to decarbonise freight transportation and the market is now allegedly ready to decarbonise, investments and actions have been shy as government action is falling behind expectations from the private sector. One of the main takeaways of the event is the demand from the industry to the UK government to drive the decarbonisation of freight transportation in three main areas:

- Overall guidance and targets.
- Providing adequate market signals.
- De-risking of investments in low-carbon technologies.

Market actors are waiting for government guidelines on the technologies available for certain sectors where the technology pathway is not clear, like shipping, aviation or trucks. Fragmented sectors like road freight further needs government leadership by providing targets and setting standards, as it is nearly impossible for actors within the market to coordinate their actions. This guidance needs to be based on academic evidence to allow manufacturers and investors to make the right decisions.

The implementation of regulation, for example in the form of carbon pricing, is increasingly seen as both likely and necessary to the private sector, at least for shipping and aviation. Because most of the capital to decarbonise freight transportation is not in the public domain, the government needs to make sure that investors have adequate market drivers to align their investment strategy with the decarbonisation pathway. One of the key ways to ensure that carbon emissions are integrated into the private sectors’ decision making and improving the business case for decarbonisation is through the use of price signals which will incentivise the various stakeholders in transport and energy sectors to start cooperating and make decisions in accordance with the decarbonisation agenda.

Finally, as freight vehicles and fuelling infrastructure have long asset lives, the risk of stranded assets is a major concern for owners and investors. Therefore, the government should consider its role in providing subsidies that will de-risk investments in new technology for decarbonisation to investors who deliver the necessary capital to owners during the initial phases. Once technologies have neared maturity and the capital costs have decreased, market forces should be sufficient to drive the further uptake of clean technologies.

Building consensus rather than filling information gaps

It is clear that accuracy and availability of information are not the barriers in decarbonising the UK’s freight sector, as good enough approximations and properly evaluated options are sufficient for decisions to be made. Verifying climate alignment of investor’s portfolios and owner’s fleet is becoming possible as an increasing amount of data is being collected with the digitisation of the sectors, although the shipping industry in particular has been lagging behind in disclosing its carbon emissions.

However, building trust on these approximations across the various actors of the value chain, for example, consumers, owners, charterers and investors, is necessary and requires validation in a transparent and consistent manner. In this context, independent certification schemes are necessary for investors to have confidence, for example in the case of green bonds and offsetting schemes.

Investors and customers as drivers of decarbonisation

Change is expected to be driven from stakeholders in and around the market rather than the vehicle owners themselves. With increasing public awareness and availability of public data, consumers might drive the momentum towards green investments, pushing charterers and cargo owners to be more aggressive in their decarbonisation agenda. However, relying only on changes in demand preference is not sufficient and engagement of government and investors is absolutely necessary.

Investors in particular have a great role to play in driving the decarbonisation agenda, as they can provide the capital necessary to invest in clean technologies and have an influence on the cost of capital of assets. In the shipping sector, the 'Poseidon Principles' is an example of a coordinated initiative by the private finance community to reduce the carbon intensity of their portfolio. In addition, decreasing amounts of finance forces owners to turn to public investors with intense decarbonisation agendas or alternatively to more expensive sources of finance. Both trends mean that owners will eventually face a greater financing cost when investing in higher emissions assets, boosting the business case for low and zero carbon assets.

Appendix B – Findings from 'Mobilising investment in decarbonising UK freight transport event'

The objective of the workshop was to corroborate and test the key findings of the work done to date in DUKFT. The event was composed of three panel discussions and working groups that shed light on issues related to accelerating investment, these included; a whole systems approach – coupling vehicle and infrastructure technology with UK logistics, ports as decarbonisation hubs and other areas ripe for investment and co-creating the solutions – roadmap for unlocking investment in freight transport decarbonisation. The findings that arise mainly focus on the important role of the government, a recurring theme across all stakeholder consultations, especially around no-regrets options that appear in all freight modes such as electrification and the associated infrastructure, and the important role of early movers and private action in the emergence phase of the transition. Below is a summary of the key messages from each of the sessions.

A whole systems approach to understanding and coupling the existing vehicle and infrastructure technology with UK logistics

This session started by asking 'What collaboration should we be forming and what knowledge do we need to share?' Some of the key findings and solutions to respond to the question presented were to create alliances/associations that bring competitors together to enable collaboration on decarbonisation solutions that are beneficial to all parties e.g., demonstration of system benefits with sharing data between logistical operators. Another area of collaboration is with policy makers and government so that latest knowledge and technological solutions can be shared as independently as possible. A key challenge is that early adopters/first movers will likely be reticent from sharing their knowledge due to the risk of losing competitive advantage. One possible solution is to co-create projects where all stakeholders are involved to produce knowledge exchange forums to demonstrate the latest advancements in academia, policy and industry with the objective of creating profitable business cases, including an understanding of the consumer willingness to pay (WTP). Collaboration can also be encouraged between port owners to provide availability of common infrastructure across partnered ports around the UK and other international ports visit regularly. Another area of collaboration is around optimising freight logistics but again this is likely to be challenging due to the competition between the operators. Here there is a role for independent aggregators which could be the government or academic, to support the aims for optimising logistics. One such example that was presented in the case of Solent was the Sustainable Distribution Centre, which offers consolidation out of the city centre, reducing emissions from HGV's in the city. Stakeholders suggested the government including the different departments e.g. transport and energy, could be more collaborative in providing clarity technology/fuels, especially on no-regret options such as electrification and the associated infrastructure.

The session also delved into the most important factors in transitioning to a new whole system. It was abundantly clear from the stakeholders especially industry that they require a strong policy commitment and target to provide clarity in the direction for industry to follow. Along with this, the supporting policies should ensure there is price parity between current and future fuels (factoring in carbon pricing) – as infiltrating freight supply chains is incredibly difficult: if it costs more, the business case for investment becomes much more difficult. Trialling new technologies and investment in infrastructure is costly and risky so there was an expectation that this should be borne by some of the stakeholders e.g. government and larger players/early adopters e.g. through the various catapults, whilst academia could provide the state-of-the-art pathways (i.e., whole system modelling using agent-based modelling) for industry to utilise for real-world solutions. However the incentives to act early should be present so that early adopters/first movers are not disadvantaged, which could be in the form of customer willingness to pay and gaining market share. Therefore engaging the public/consumers in the transition is key e.g., ports involve public in talking about the safety and disruption that new fuels may cause, benefits of a greater energy resilience in their area; or including a carbon value/differential pricing when customers are buying goods (e.g. labelling of carbon free services).

The session then moved to understanding which stakeholders are best placed to accelerate the transition. The key stakeholders included energy and fuel suppliers, public facing companies, policy makers, ports and financiers. The third session then ranked the importance of the stakeholders by assessing their level of influence and interest. It is in the interest of energy and fuel suppliers to provide new fuels at the scale required. Public facing companies e.g. ports have a role to play in demonstrating the clean technologies and infrastructure and raise awareness to drive the transition. Policy makers have a critical role in setting clear, ambitious targets supported by effective policies and acting on evidence on electrification, including shore power in ports and charging infrastructure for HGVs. Financiers should use their critical role by ensuring they're using tools to ensure investments are moving away from fossil fuels e.g., Science Based Target Initiative (SBTi).

Ports as decarbonisation hubs and other areas ripe for investment

This session started by looking at what actions stakeholders must take to mobilise investment and incentivise port decarbonisation. There was agreement between the participants that there could be a first mover group 'coalitions of the willing' - to put business cases forward and unlock investment, with the help of some 'pump-prime' funding. There was a need to understand the degree of influence of operators, liners etc and their energy demand in large ports to find solutions for each port that can be unilaterally implemented in those geographies and regions, considering the different port ownership structures and bylaws.

The session then asked the working groups to understand the risks associated with port decarbonisation and how these can be mitigated. Participants suggested use of ABMs to look at the port operations at a granular level to feed into the design of a demonstration of zero carbon at the port level – part of this could be scenario planning. Identification of clusters of ports and businesses operating in the vicinity with a business case for decarbonisation around a port. One way to do this would be to look at international green corridors and how they can contribute to regional clusters. Many stakeholders agreed that there is a lack of clear demand for zero emission fuels and this needs to change to create a business/investment case. In the absence of regulations, this could be done through off-take agreements i.e., establishing long term demand from customers; aggregate demand and provide production certainty of fuels and zero emission services (this could come from a coZEV/ZEMBA book and claim type approach).

The working groups agreed that there was a need for a public relations drive to improve the image of the ports and the perception of new zero emission fuels especially around safety and the environment. The last session, therefore, looked at how the general public could be engaged to drive investment by the industry and government. Some of the key points from this session are summarised as follows. Ports should build on their cultural history and the value of ports to the local community, to engage in discussion around the future; highlight that ports have always changed and adapted. The ports should communicate and raise awareness of the benefits of zero emission fuels to local pollution and public health. Efforts should also be made to connect this with the carbon footprint impact on consumer goods.

Co-creating the solutions – roadmap for unlocking investment in freight transport decarbonisation

Participants identified key stakeholders who have the power to unlock investment for decarbonising UK freight transport. In particular, they believe that the most powerful stakeholders (in terms of influence) are from the ‘Policy’ system, including Central Government, politicians, policy makers in the UK, as well as international bodies (e.g., IMO). Key influential industrial stakeholders include the electricity grid and network operators, and energy/fuel suppliers. In addition, most groups of participants identified the general public and end-consumers as one of the most interested and influential stakeholder groups. Many groups found that investors/financiers had a high influence – interest was lower at the moment but with rising public awareness and the rise of clean investment tools, investors will have to be forward thinking in terms of green assets. Logistics operators were identified as the least influential stakeholder group, even though highly interested.

Through a driver mapping exercise, participants identified drivers shaping the future of UK freight decarbonisation. In particular they were asked to identify the most important and uncertain factors to drive investment for decarbonising UK freight. In particular, stakeholders identified appropriate regulations (e.g., legislation) and policies (e.g., demonstrations, pilots, funding) as important drivers. Technology certainty, both in terms of what kind of technology would be more appropriate/effective and when each technology should be implemented to efficiently reach net zero, was identified as the most important driver, but also the most uncertain. This highlights the need for more academic and industrial research, but also for clearer directions from Central Government in order for industrial stakeholders to invest in the ‘right’ technology at the ‘right’ time, avoiding (or reducing) the risk of investment.

The most important and most uncertain factors to unlock investment in UK freight transport decarbonisation were used to create a series of preliminary roadmaps that are presented in the next section. Participants identified the actions that need to be undertaken in order to make sure the most important factors are unlocked (e.g., back-casting method). This exercise helped to understand what kind of dependencies exist (or might exist in the future) and underlines the uncertainty and complexity of future planning and policy, as well as the key factors that might affect the timing or scale of change. The result of this exercise was a series of roadmaps (or ‘sequences of actions’) to unlock the drivers of change. The roadmaps provide a first attempt to understand areas of action and co-creation, and require further discussion. The roadmaps can be clustered toward three main themes:

CLUSTER 1 – Driving the technological development

Certainty towards the type of technology and the timing of implementation of each technology were identified as key factors to unlock investment in decarbonising UK freight. In particular, stakeholders feel that at the moment there is a lack of clarity towards the type of new and clean technology (and fuel) that will be more efficient and cost-effective.

Another key challenge identified by participants was the need for understanding when to implement which type of technology. This would require research on effective and available technological solutions, in conjunction with feasibility studies for different use cases and business models. It would also require appropriate regulations and public/stakeholder consultation. Stakeholder engagement (including from transport and energy sectors) was seen as a key requirement for this road map.

CLUSTER 2 – Driving behavioural and organisational change

This cluster includes four road maps, including interventions on the demand/consumer side, collaborative schemes, and carbon price. Stakeholders thought that politicians and companies should encourage consumers to understand what the impact of their consumption is. This could be achieved through soft and hard measures, including, for example, education and communication campaigns, incentives to invest in reducing emissions or sustainable options, as well as appropriate regulations.

This roadmap is strongly in line with Roadmap 4, which suggests increased awareness among end-consumers, supported by stronger measures, such as increase prices of non-sustainable options, to reduce the demand. This would also require strong engagement of the public and end-consumers.

In addition to solutions targeting end-consumer's behaviour change, stakeholders suggested collaborative schemes and data sharing could drive an organisational change to unlock investment in freight decarbonisation. They believe that this would require active participation of the public, for example through the establishment of a citizen parliament, which will inform industry about public perspective. It will also require clearer directions from central government (especially about upcoming regulations, such as mandatory data collection to be 'centrally' collected and managed). Strong collaboration among stakeholders, including public-private partnerships, would be key for this road map. Whilst participants agreed that collaboration is required the real question is how it should be undertaken and how do we get competitors to speak to each other. Without an approach, they will remain hesitant to collaborate. The final roadmap of this cluster includes a stronger measure, which is a price on carbon/emissions. Stakeholders believe that this is needed to drive freight decarbonisation and would require the definition of appropriate price of fuels, as well as a clear and fair inter-Government taxation method. Freight stakeholders will need to establish long-term agreements to facilitate the uptake of low carbon fuel choices.

CLUSTER 3 – Clear government direction

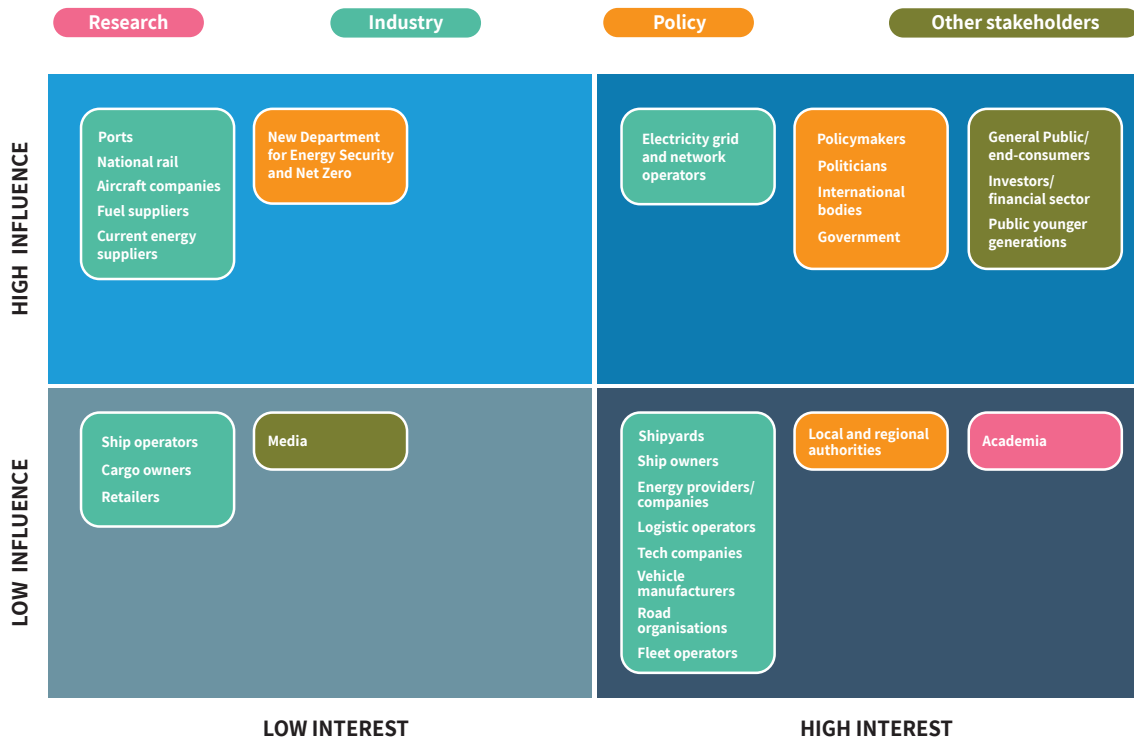
The final cluster includes directions and regulations from central government. Stakeholders believe these are needed to accelerate freight decarbonisation and drive investment for decarbonising UK freight transport. It includes two key components: (i) legislation; and (ii) clear government directions. The roadmap designed in this session suggests that specific legislation is needed to accelerate decarbonisation, including Carbon Pricing e.g. a carbon tax, on the one hand, as well as incentives to reduce carbon emissions on the other hand. This would also require (i) a favourable planning environment, with local governments providing appropriate planning directions; (ii) pilots from fuel suppliers, in order to understand the best/most sustainable alternatives; (iii) modal shift from road to rail for specific trunk of delivery networks. However, in order to be able to design and implement the appropriate legislation, political support will be needed. It was clear that if a solution has not got a business case it won't be considered for implementation. Industry made clear that price parity was vital in any uptake of technology. For this to have broad acceptance, the participants agreed there must be collaboration with other governments or groups of nations (e.g. EU) to provide a similar pricing structure to ensure smooth operation. The level of carbon price required to bridge the gap between existing and zero emission fuels should be evidenced by academic studies.

In addition to appropriate legislation, participants believed there is a need for clear government direction towards what new/clear technologies and fuels should be used and when. This will require academic and industrial research and demonstrations, in order to reduce risk of investment and technology operational visibility. In addition, confidence in the stakeholder community is seen as key to upscale decarbonisation solutions. From a Central Government perspective, participants also suggested that there should be a cross-Government collaboration, including, for example, Department for Transport (DfT), Department for Business, Energy and Industrial Strategy (BEIS), and Treasury, in order to adopt a more holistic perspective to drive UK freight transport decarbonisation.

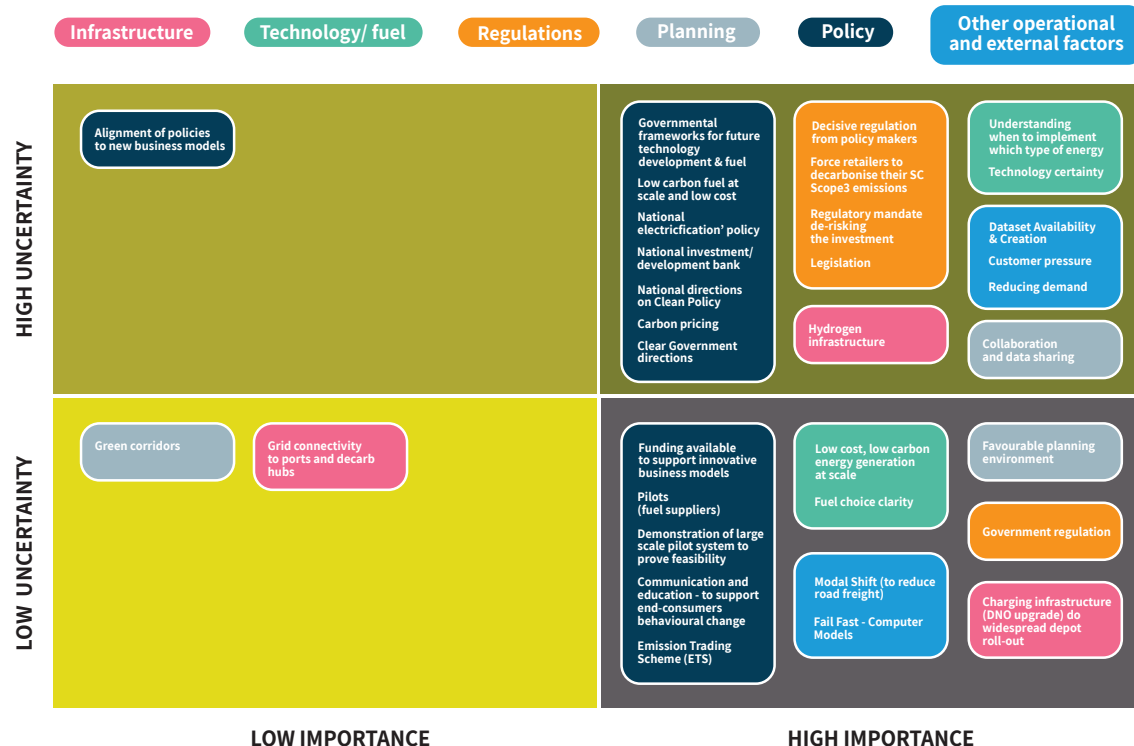
Co-produced Route-mapping to Accelerate Freight Decarbonisation: a transdisciplinary learning and decision framework.

Aim: to explore multi-stakeholder perspective towards factors that can drive investment for decarbonising UK freight transport
N. of participants: 38 from industry, policy and academia (23 from academia)

Key stakeholders who have the influence and interest in decarbonising UK freight transport



Factors to drive investment for decarbonising UK freight transport



Roadmaps: the role of policy makers, academia and industry to unlock the drivers of change

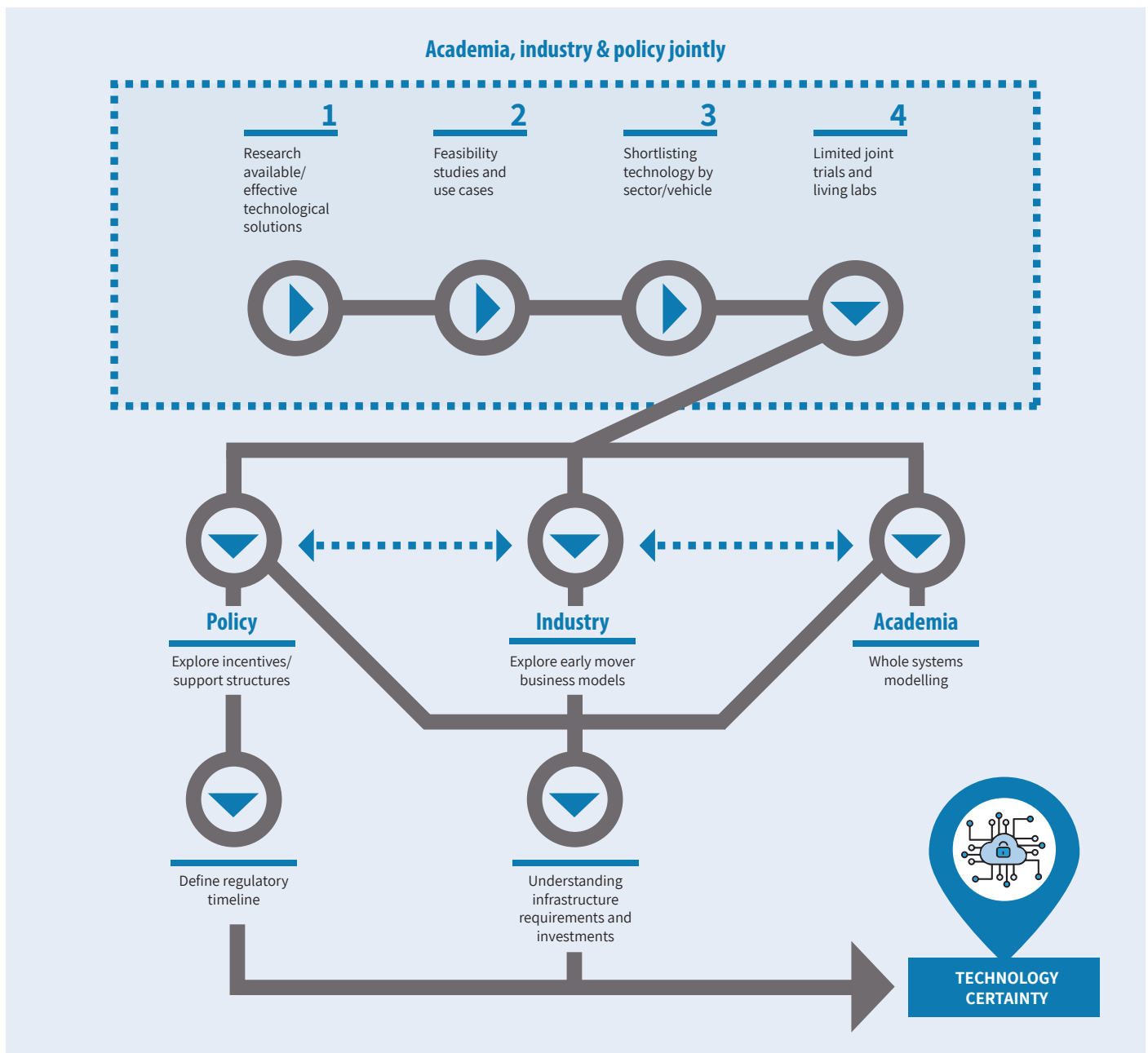
Actions that need to be undertaken in order to make sure the most important factors are unlocked

CLUSTER 1 – Driving the technological certainty

Roadmap 1

Technology centrainty

Certainty towards the type of technology and the timing of implementation of each technology were identified as key factors to unlock investment in decarbonising UK freight. In particular, stakeholders feel that at the moment there is a lack of clarity towards the type of new and clean technology (and fuel) that will be more efficient and cost-effective.

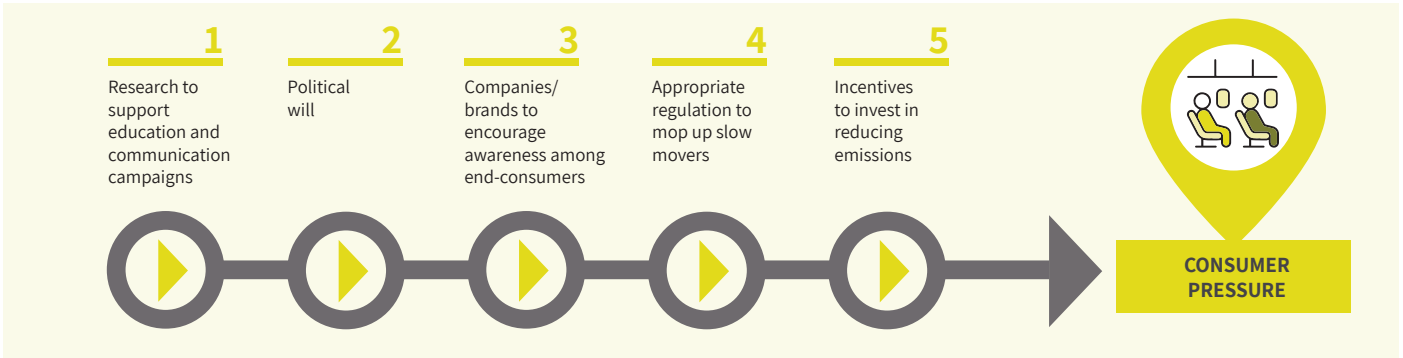


CLUSTER 2 – Driving behavioural and organisational change

Roadmap 3

Consumer pressure

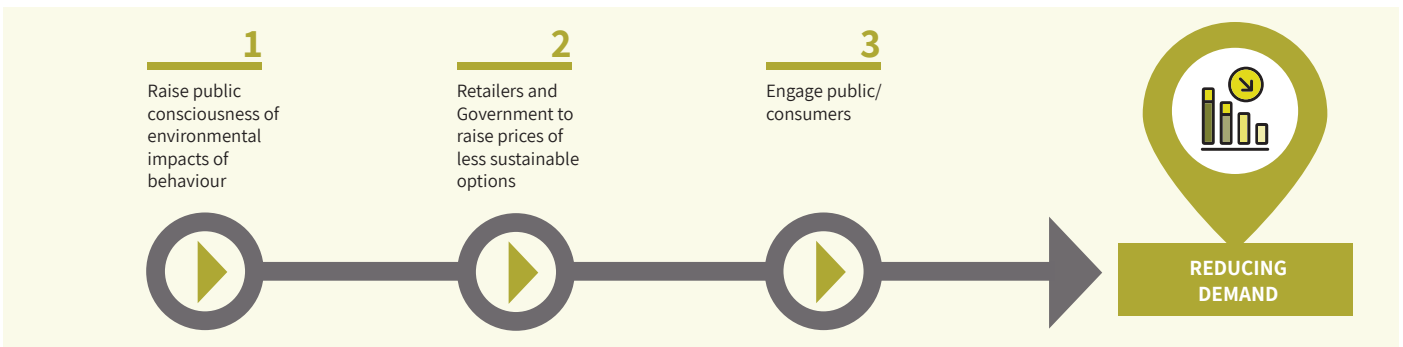
Stakeholders thought that politicians and companies should encourage consumers to understand what the impact of their consumption is. This could be achieved through soft and hard measures, including, for example, education and communication campaigns, incentives to invest in reducing emissions or sustainable options, as well as appropriate regulations.



Roadmap 4

Reducing demand

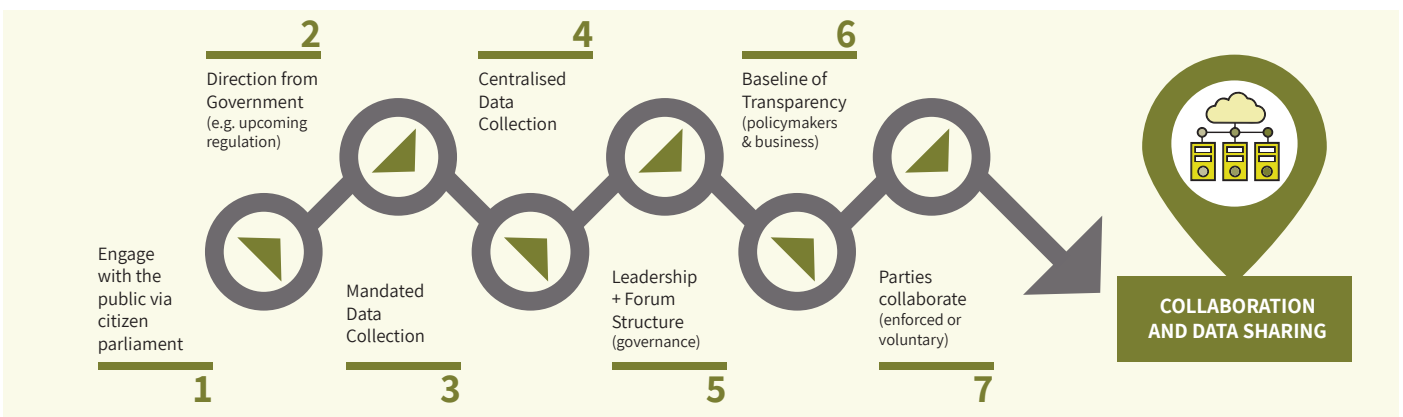
This roadmap is strongly in line with Roadmap 3, which suggests increased awareness among end-consumers, supported by stronger measures, such as increase prices of non-sustainable options, to reduce the demand. This would also require strong engagement of the general public and end-consumers.



Roadmap 5

Collaboration and data sharing

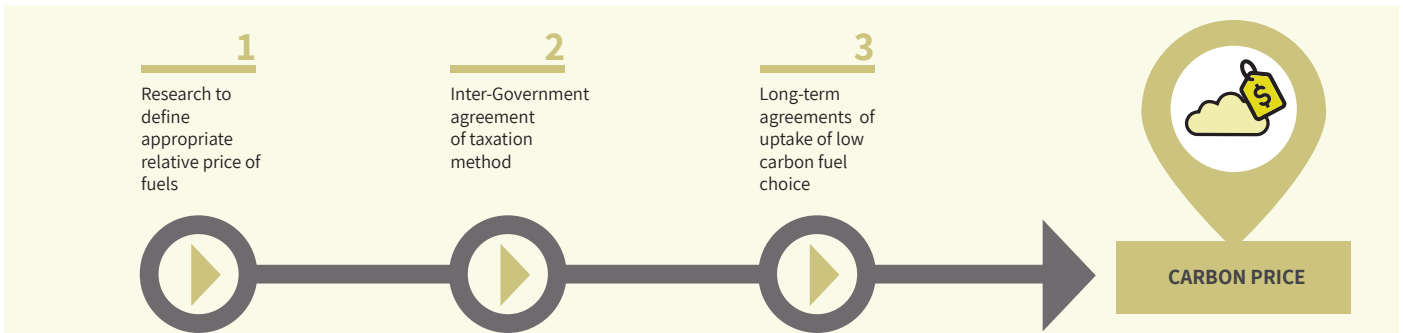
In addition to solutions targeting end-consumer's behaviour change, stakeholders suggested collaborative schemes and data sharing could drive an organisational change to unlock investment in freight decarbonisation. They believe that this would require active participation of the general public, clearer directions from central government, strong collaboration among stakeholders would be key for this road map.



Roadmap 6

Carbon price

This roadmap is strongly in line with Roadmap 4, which suggests increased awareness among end-consumers, supported by stronger measures, such as increase prices of non-sustainable options, to reduce the demand. This would also require strong engagement of the general public and end-consumers.

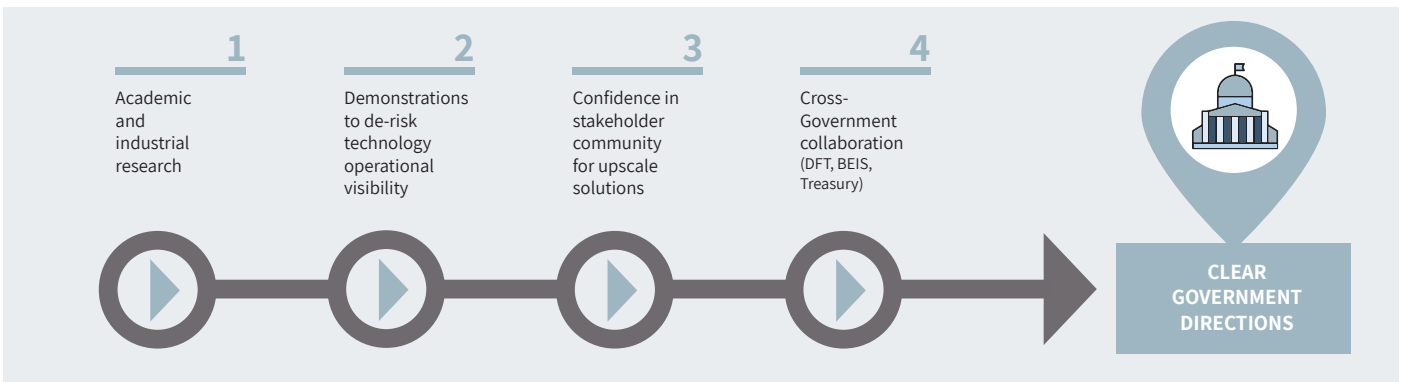


CLUSTER 3 – Clear government directions

Roadmap 7

Clear government directions

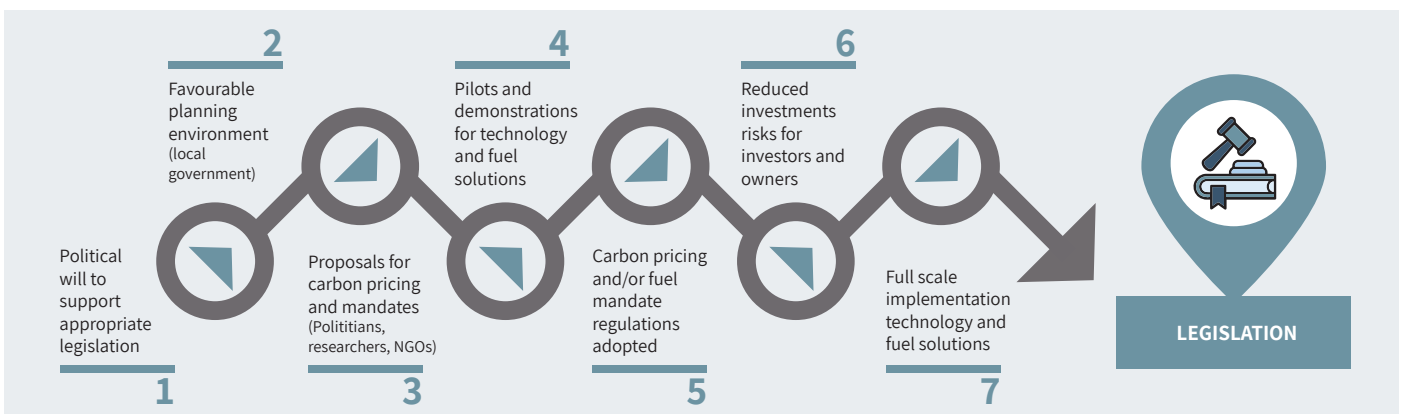
In addition to appropriate legislation, participants believed there is a need for clear government directions towards what new/clear technologies and fuels should be used and when. This will require academic and industrial research and demonstrations, in order to reduce risk of investment and technology operational visibility.



Roadmap 8

Legislation

The final cluster includes directions and regulations from central Government. Roadmap 7 suggests that a specific legislation is needed to accelerate decarbonisation, including carbon pricing and mandates on the one hand, as well as incentives to reduce carbon emissions on the other hand.



Appendix C – Summaries of thematic projects

Understanding Freight Decarbonisation Investment Decisions

Project team: Fraser McLeod (University of Southampton), Anthony Velazquez Abad (TRL), Marina Garyfalou (TRL)

This project aimed to undertake a wide scope analysis, including all stakeholders, of the factors influencing freight transport investment decisions. Specifically, it aimed to identify the key drivers and enablers or barriers associated with freight decarbonisation investment decisions, and the relative importance of these for each mode of transport. The project team carried out a literature review, conducted several focus groups and AHP interviews, their analysis of the data they collected led to the following results.

Whole life cost was ranked highly by each sector and was needed to justify investments in vehicle fleets. For road vehicles it was considered easy to calculate, as many low carbon options are commercially available, however for rail freight it was currently considered impossible to calculate due to the immaturity of the market. For maritime the whole life cost of low carbon fuels is not yet fully understood, and the cost of low carbon fuels compared with alternatives currently in use was considered a barrier to adoption.

The current **lack of recharging/refuelling infrastructure**, and uncertainty about future provision were considered barriers to adopting low carbon vehicles at this stage. However, where infrastructure is more widespread low carbon vehicles are becoming more commonplace, and local authority participants felt they had a responsibility to aid the deployment of infrastructure to support the uptake of low carbon vehicles.

Vehicle range, payload capacity and efficiency were identified as key factors for the road, rail and maritime sectors. Due to the current lack of infrastructure, range anxiety is an issue for all. For long haul road freight long downtimes reduces operational efficiency, and suitable options are not available at present. For rail freight Infrastructure would need to be upgraded to support heavy axle loads to allow heavier freight trains access across the whole rail network. For maritime the ability of a vessel to move freight at a speed, and capacity, that meets the time restrictions of the charterparty is vital and it is not clear which alternative fuel will meet the requirements.

Subsidies or incentives were identified by maritime freight operators as being necessary due to the cost differences between alternative fuels and the fuels currently in use. Road freight operators stated that subsidies or incentives would increase the uptake of low carbon vehicles but did not consider this as one of the most important key drivers.

Reliability was identified as the most important factor for the road freight group. Low carbon vehicles are currently considered less reliable than existing models, and there was concern that many service stations are not equipped to service alternatively fuelled vehicles.

Vehicle suitability/capability was considered a priority for the public sector and rail freight groups. For the public sector the variation in vehicles used, from small vans to refuse collection vehicles meant that there is currently no simple solution across different fleets. The rail freight group noted that no viable solution had yet emerged with the same capability as diesel engines.

Vehicle emissions were given as a key driver only by the public sector group. Many local authorities have air quality targets and want to set a good example with their fleets. The private sector does not currently have the same pressures or priorities.

Transport Investment Decisions (TIDE): An exploration of climate alignment in freight related investment decisions

Project team: Nadia Ameli (UCL), Nishatabbas Rehmatulla (UCL), Julian Allen (University of Westminster), Sophie Parker (UMAS), Marie Fricaudet (UCL).

This project aimed to undertake a narrow scope analysis of financiers, including banks, institutional investors and equity investors of the factors influencing freight transport investment decisions. Specifically, it aimed to provide a better understanding of the existing initiatives and tools available to financiers to measure the alignment of their investments and portfolio to a decarbonization trajectory, and how they compare to each other. It also aimed to provide some insights on the approaches financiers currently use to screen their investments against climate alignment, and the barriers they face in their implementations. The project team carried out a literature review and conducted several interviews to collect their data.

The project found that *awareness and use of such tools by financiers vary widely depending on the institution*. A few financiers use a wide variety of tools conjointly and are proactive in developing them. Many others are lagging and are found to use no climate alignment tool outside of high-level commitments and guidance. Many of the stakeholders that were interviewed were just starting the process of understanding the alignment of their portfolios and, currently, the emphasis is on first understanding their emissions and disclosing rather than on screening investment decisions and checking for future alignment. This explains why the project found the uptake of high-level guidance and commitments among freight financiers to be higher than the uptake of assessment tools, and as yet it is hard to see any concrete impact of this on investment decisions.

The increased interest in climate change in finance has resulted in a *large range of initiatives, often targeting different types of financiers, sectors and regions and therefore appear fragmented*. Shipping is an exception in this regards, as the Poseidon Principles provide a harmonized and coherent methodology to its signatories and managed to attract enough signatories to cover a large share of the sector's finance. In the other sectors however, this suggests that climate alignment methodologies might not be comparable across financiers, but also that methodologies are used for complementary activities.

Many financiers are lagging and are found to use no climate alignment tool outside of the high level commitments and guidance. The project found that sectoral methodology and the PCAF (Partnership for Climate Accounting Financials) in the US are increasingly popular for banks while asset managers are looking for portfolio alignment tools with increasing attention on forward looking pathways, typically the SBT-FI (Science Based Targets for Financial Institutions) tool. Moreover, some tools are better used to understand the present situation of the financier while others are forward-looking tools (e.g. PACTA, Paris Agreement Capital Transition Assessment). This explains why we found that in some cases a single freight financier can be using several tools conjointly.

Firms at the beginning of the process face *institutional/organizational barriers*, where change is difficult and a slow process. They also lack a clear view on which is the best climate alignment tool. On the other hand, the main barrier which more advanced financiers have noted is the *lack of comparability of results, resulting from a lack of comparability of the climate alignment methodologies* and the lack of comparability of the corporate data provided by external providers.

An Integrated System and Service Design Approach for Decarbonisation of UK Freight Transportation (INSTINCT)

Project team: Alok Choudhary (Loughborough University), Edward Sweeney (Aston University), Tracy Ross (Loughborough University), Fahham Qaiser (University of Huddersfield), Amritha Sasankan (Aston University), Sube Singh (Loughborough University).

This project aimed to characterise and benchmark logistics activity and its carbon footprint for decarbonisation of freight transportation and identify the key drivers and barriers, key decision points and key decision-makers in the supply chain for decarbonisation of freight transportation. To collect their data the project team organised a series of activities to engage with key stakeholders from 63 organisations across the UK and internationally.

The project identified the following **key barriers**, the logistics sector not prioritising the decarbonisation agenda, a lack of information flow creating uncertainty e.g. around which technologies to adopt, the high degree of fragmentation in the freight transport industry, green initiatives that are often only relevant and prominent among bigger organisations, and the imbalance of fleet technology developed to infrastructure implementation.

The project identified the following **key drivers**, the opportunity to make use of pandemic recovery funds for decarbonisation initiatives, customer expectations and demand for greener alternatives, employee level initiatives and the need to be seen to be working on decarbonisation in order to attract the best young talent, potential collaboration between leading organisations and smaller companies, and the use of technologies such as telematics for fleet management, vehicle tracking, maintenance, dynamic routing, and driver performance

The project identified the following **key decisions**, redesigning the existing supply chain and its operations, the development of fleet technology e.g. telematics, innovative vehicle design and new technology vehicle trials, infrastructure implementation e.g. smarter mode switch, smart motorways and electrification of road and rail networks, the positioning of warehouses and greater warehouse automation and storage density, long term partnerships and collaboration involving small companies and start-ups, and investment decisions that take into account vehicles and assets life cycle, the vehicle technology and infrastructure.

The project identified the following possibilities with regards to **decision makers**, the expansion of decision making to include shareholders and technology providers, and a growth in the role of consumers in decision making that impacts on decarbonisation of freight.

The project identified **25 KPIs to focus on investments to inform the benchmarking framework**. These were categorised into technology, behaviour and infrastructure, which focused on both private and public investment. The project concludes that supply chain and logistics activities should be viewed as an integrated chain rather than a collection of subsystems. A collaborative effort including players from the entire value chain irrespective of the organisation size and maturity is essential for the decarbonisation of freight transportation pathway. More initiatives from government and policymakers are required to provide guidelines, create policies and regulations, and enable more investments in infrastructure, technology, and training to maximise the investments in the decarbonisation of freight transportation initiatives.

Co-produced Route-mapping to Accelerate Freight Decarbonisation (CRAFTeD): A Transdisciplinary Learning and Decision Framework

Project team: Graham Parkhurst (UWE), Daniela Paddeu (UWE), Ges Rosenberg (University of Bristol), Neil Carhart (University of Bristol), Colin Taylor (University of Bristol).

This project aimed to identify what kinds of methods and tools would most effectively support decisions that would contribute to the design of a pathway to decarbonise the future UK freight system, considering local, regional, and national scales and international implications. To collect their data the project team convened an expert panel and carried out a scoping workshop and several stakeholder workshops and small discussion groups.

Significant uncertainty is a major challenge for freight service operators and local government as they seek to plan a long-term investment strategy and develop net zero carbon policies. Principal areas of concern remain around i. the lack of transparency and clarity in terms of the direction and timeliness of national regulations and standards, ii. the feasibility of timelines for delivering the energy and transport infrastructure on which freight decarbonisation is dependent, iii. the maturity and roles for energy carriers such as battery, fuel cell, hydrogen and e-fuel technologies.

Behavioural change in consumers, producers and retailers is frequently overlooked when forming policy for the freight sector due to the widespread perception that decarbonisation as a purely technical challenge. Although consumers and organisations make decisions which contribute to freight sector emissions, they seldom take responsibility being either unaware of the impacts or seeing decarbonisation as ‘outsourced’ to freight providers.

The **regional level is a relevant one for stakeholder engagement around freight decarbonisation**, offering a viable scale for coproducing a route-map, coordinating and organising public and private action, including testbeds and living labs. Creating alignment with national guidance, fiscal and regulatory measures, was identified as vital for effective regional transition planning. Of concern, regional governance and leadership of freight decarbonisation in the largely absent. In this vacuum, the formation of other regionally oriented interest groups, such as the South West Infrastructure Partnership (SWIP), could be helpful to build future regional governance, leadership and citizen engagement.

Segmentation of the freight sector could present significant challenges in the drive to net zero, with conversations and planning of decarbonisation still taking place in sub-sector siloes. Whilst aviation and maritime subsectors are predominantly focused on global or national scales, the domain of road and rail subsectors has a distinctly local to regional focus. Notably, airport and ports could play an important ‘boundary spanning’ role, bringing global airfreight and shipping perspectives to regional infrastructure planning.

Stakeholders generally identified changes of regulation, governance, and organisation as more significant for successful decarbonisation than a particular ‘breakthrough’ technology. Hence, there was a **call for clear national policy guidance which is needed urgently from central government** to empower businesses and devolved administrations to take action to speed up freight decarbonisation. National targets, incentives and regulations will be essential if decarbonisation is to be prioritised above the other demands the organisations face in delivering their primary outputs efficiently in either a competitive business or public sector environment.



Decarbonising UK Freight Transport

