March 2023

Decarbonising Ports & Harbours: Industry Insights & Vision

Maritime & Ports Innovation Network

Contents

Authors

Mark Wray
Knowledge Transfer Manager - Buildings & Infrastructure, Innovate UK KTN

Dr Matthew Moss
Knowledge Transfer Manager - Maritime, Innovate UK KTN

01

Summary

Innovate UK

Report Outline

The Decarbonising Ports & Harbours Innovation Network's overarching objective was to raise the profile of the critical part ports and harbours need to play in Maritime transport's transition to net zero by 2050 and accelerate this transition by giving clear direction.

This report is a summation of knowledge and insights shared by our network and curated by our experts in maritime transport and clean energy systems. It's purpose is to provide focus and early planning for longer term R&D and innovation investment.

We adopted a Mission Led Approach considering the means to address this grand challenge by exploring the drivers; innovation pathways; stakeholders and systems that would be required to come together to create a route to successfully meeting the challenge. Our definition of the Decarbonising Ports and Harbour's Challenge includes the following three principle aims:

1. Reducing greenhouse gas emissions from port operations including port owned working boats and equipment;
2. Providing infrastructure services to make clean energy available to visiting transport (road freight, rail & vessels);
3. Improving localised air quality by reducing emission of gases associated with burning of fossil fuels.

This Report contains the shared learning and provides insights in to subjects related policy development, energy sources, technological solutions, stakeholders and the all important means to fund and finance the transition. Our journey through this subject has shown that there is a lot of good will and eagerness to progress, but this is marred by a lack of validated understanding and access to investment.

Foreword

Department for Business & Trade

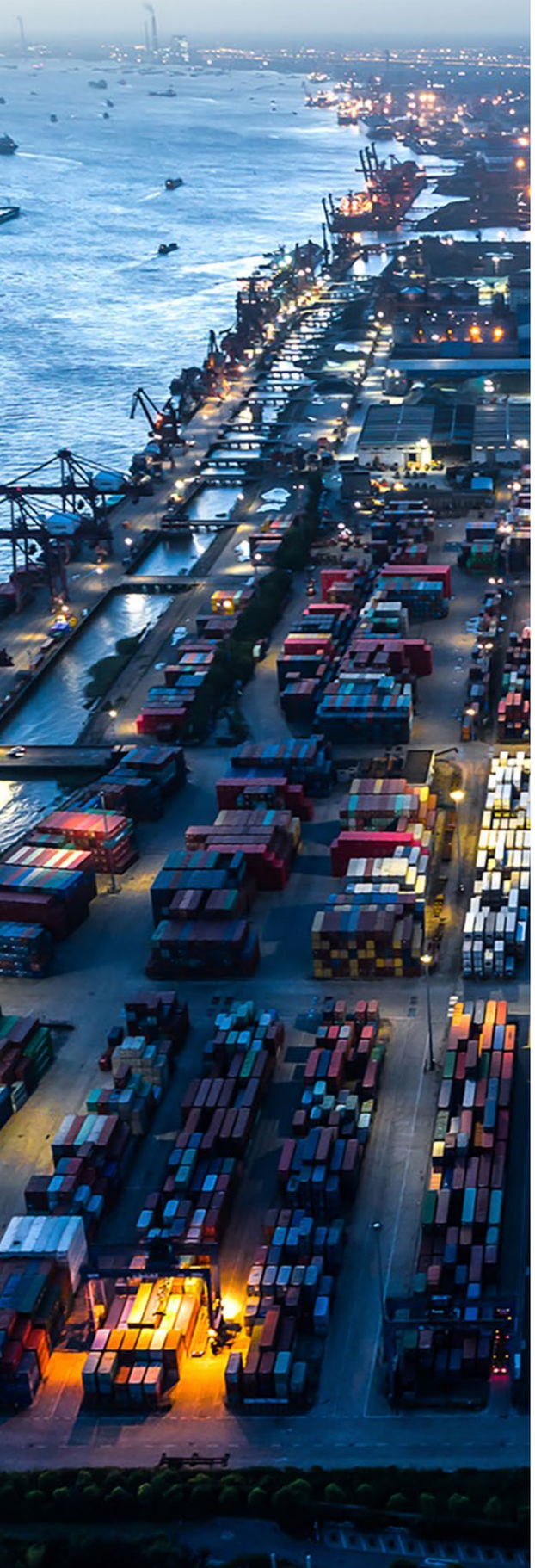
Government has set out plans to decarbonise in a Net Zero Strategy outlining measures to transition to a green and sustainable future. Decarbonisation of our ports and harbours is an essential part of this journey towards meeting our Net Zero target by the middle of this century.

Transforming our carbon emissions in and around our Ports and Harbours offers the opportunity to create and sustain jobs across our regions and in our coastal communities. This work goes hand in hand with our strategies to grow our offshore wind production, develop the hydrogen economy and decarbonise our electricity system.

The work of the Innovation Network has been instrumental in bringing together stakeholders and partners to identify how to address the decarbonisation challenge in this sector. This Roadmap sets out the direction we need to take and the tools available to make this a success.

I hope that this Roadmap will inspire you to act and give you some ideas for your next steps towards decarbonisation. I urge you to make this Roadmap your framework for change and for you to engage with the KTN and the Innovation Network as you go about implementing this urgent change.

Mark Turner
Head of Defence and Marine, BEIS



A Word from the Chairs

As an outward facing, Maritime trading nation, the UK is dependent on its ports sector to shape, support and enable the economy to flow and grow.

Never, arguably, have Ports been so vital in the success and future of the UK. The obligation to act to address the Global challenge of Climate Change is equally compelling, and the approach set out by the United Nations and seized by the UK Government in its legislating for Net Zero Carbon is amongst the toughest of the challenges that the sector will face en route to 2050. Ports are critical connectors in the transport sector, transitioning from Clean Maritime to Clean Land transport at a systems level, and an essential consideration at a systems level for success. This report details not only the challenge that Ports must understand and overcome, but some of the solutions that will need to be exploited if they are going to play their rightfully important role in our future economy.

As Chair and Deputy, we have played a small part; the Decarbonising Ports sector and community, representing Commercial and Military ports in the UK, enabled by strong and skilled leadership in The Knowledge Transfer Network, has worked together to share their understanding of the issues, the challenges they will overcome and the potential changes and technologies that will be required. Not all will fall to Ports; greening of the grid, reinforcing the power network and National Grid, greater use of digitisation and connectedness and an aligned and equally bold Maritime sector, driven by shipping owners and operators in their adoption and engagement in the role that their Ports play, will have to take their part.

UK Government leadership will be essential if this broad range of stakeholders are to come together to exploit the opportunities. Inevitably this will also involve targeted interventions from Government and local authorities if we are to sustain the centrality of Ports to 2050 and beyond. One of the primary considerations of ports is to continue to increase economic growth opportunities on a regional and national basis whilst ensuring a greener, more sustainable future for generations to come.

It has been fantastic to see the UK Ports sector come together to tackle this challenge. We offer this report for consideration and commend the conclusions. We urge those who read this report to act on its findings and look forward to seeing its impact as the transition to Net Zero continues.

Dr Jo North
Technology & Transformation Director
CHAIR

Commodore Jeremy Bailey
Commander HMNB Portsmouth
DEPUTY CHAIR

Executive Summary

The reasons behind this review

Some of the most critical sustainability issues of our time are climate change and air quality. With a target of Net Zero emissions by 2050 established within the UK's Maritime 2050 Strategy and Clean Maritime Plan, the UK has key objectives to fulfil across the entire maritime landscape in a relatively short timeframe.

The Decarbonising Ports & Harbours Innovation Network was established to showcase the essential role that ports and harbours play in achieving Net Zero 2050, with a focus on fast-tracking progress towards clearly targeted and deliverable solutions. This diverse effort examines catalysing cross-sector collaboration as well as public and private industries.

Methodology

This report on solutions road mapping for the decarbonisation of ports and harbours adopts a mission driven approach drawing on multi-stakeholder contributions. To identify a solution pathway, the Innovation Network has collated information gathered from a broad collection of shared learning, innovation insights, policy developments, energy sources and important questions asked across diverse and relevant sectors.

Challenge / Objectives

Fundamentally the challenge is to facilitate the maritime division to shift into a sector that is operationally decarbonised whereby the port structure is equally fully sustained by clean energy.

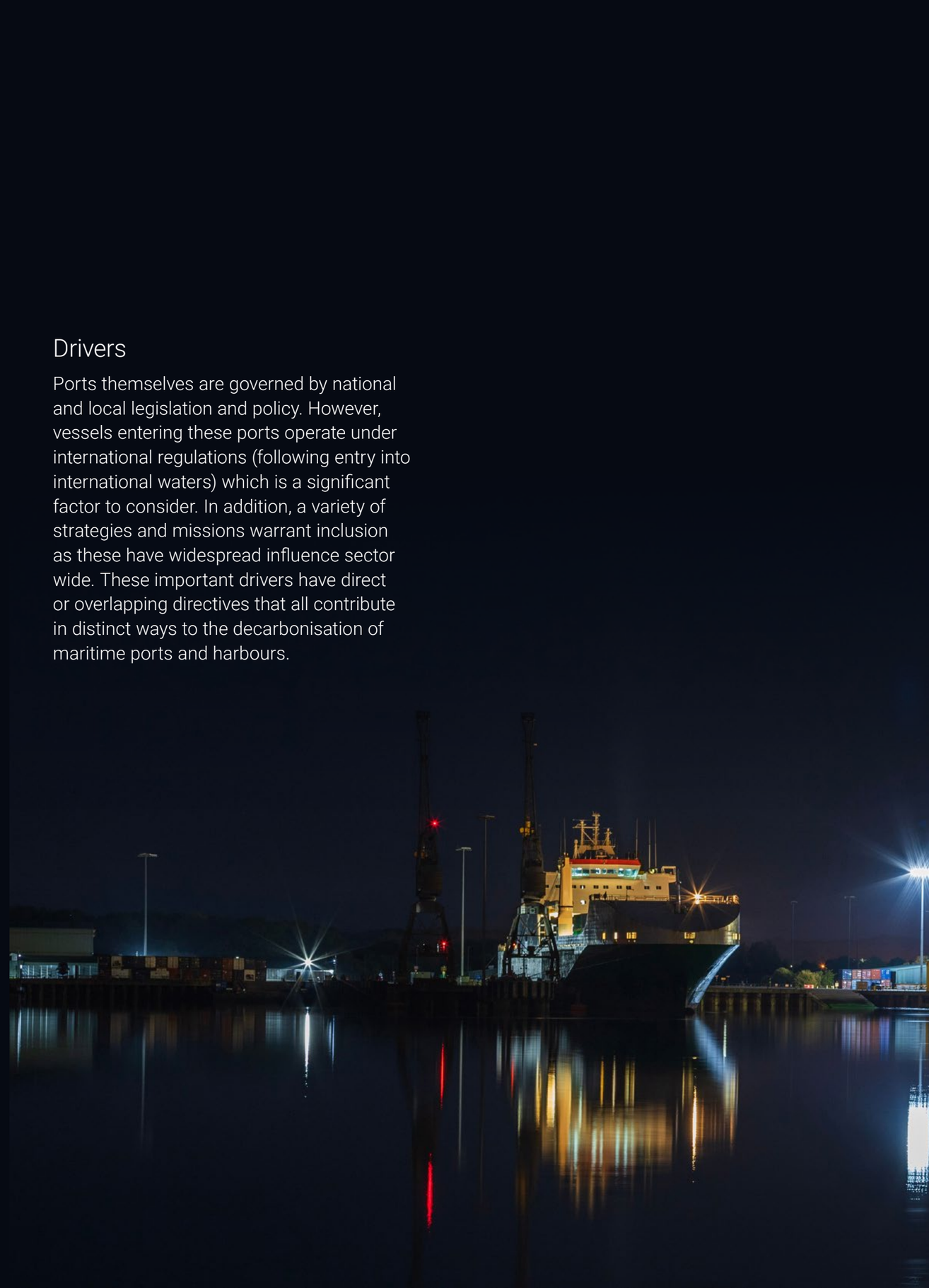
There are important objectives addressed in this challenge to decarbonise ports and harbours and establish successful green maritime infrastructures:

1. Greenhouse gas emissions must be reduced from the all-encompassing sector of port operations, which includes port-owned machinery, vehicles, equipment and working boats.
2. A radically different infrastructure system needs to be provided to facilitate services making clean energy available to visiting transport – for example road, freight, rail and shipping.
3. Localised air quality will be improved by reducing the particulates and gas emissions associated with the burning of these fossil fuels at ports and harbours.

The focus timeline for this project is 2020-2030, after which point a pipeline of R&D projects will have been completed and will require significant investment, to scale up delivery from 2030-2050 to meet UK Net Zero targets in a timely manner.

Drivers

Ports themselves are governed by national and local legislation and policy. However, vessels entering these ports operate under international regulations (following entry into international waters) which is a significant factor to consider. In addition, a variety of strategies and missions warrant inclusion as these have widespread influence sector wide. These important drivers have direct or overlapping directives that all contribute in distinct ways to the decarbonisation of maritime ports and harbours.



Innovation Pathways

This report employs innovation pathways, looking at how diverse influences and technologies can serve to grow and speed up research and development in the relevant sectors.

In order to decarbonise, the maritime sector needs to draw on science and engineering knowledge with coverage including automotive, construction, energy and rail. Ports are complex facilities with diverse civil and operational infrastructures, mixed commercial and industrial buildings, cars and road freight, non-road mobile machinery, mobile and static lifting equipment, rail freight, working boats and visiting vessels. This report focuses on two specific areas and several alternative subjects for knowledge development to support decision making. Focus is on (1.) energy generation and storage and (2.) enabling solutions.

Mains grid electricity and diesel dominate energy supply and storage in maritime. This report on solutions road mapping provides a substantial overview of the advantages and challenges for future energy directions offering low or zero emissions solutions within the port environment. It is evident that no clear and singular pathway exists, and a variety of solutions will be required, each fit for specific purpose and able to work collectively. Clean electrical energy will prevail, but as a result numerous challenges arise, particularly with a view to storage and distribution.

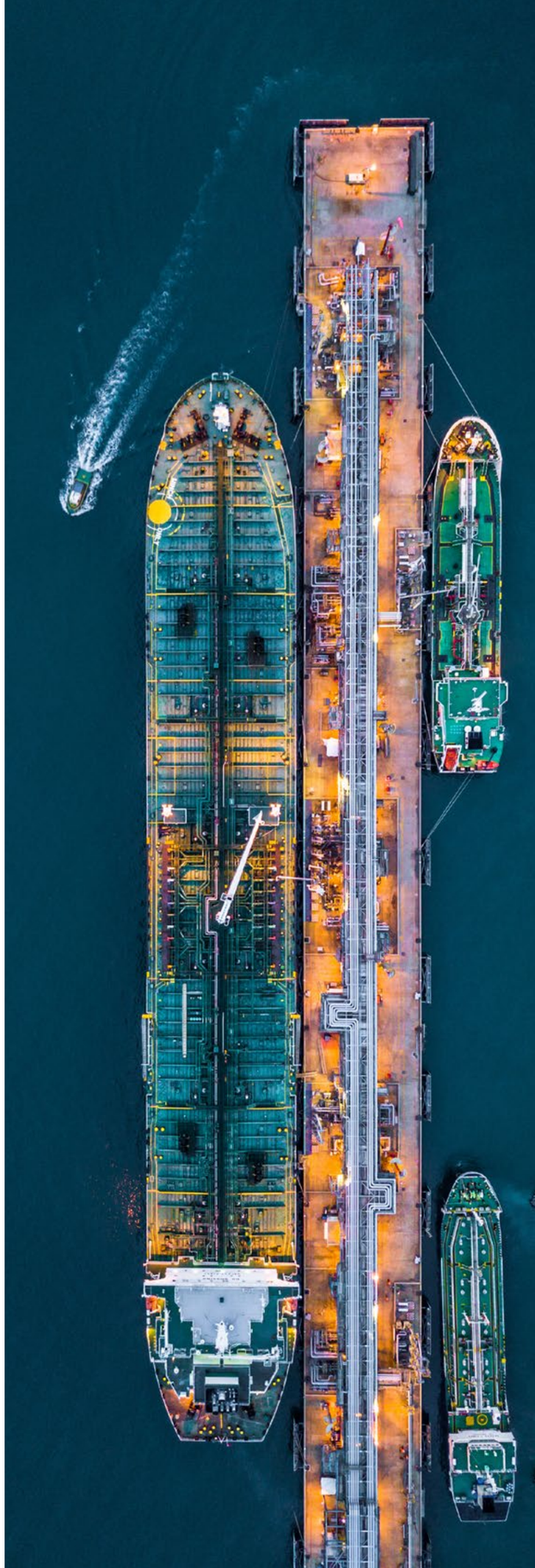
The key areas of technology for innovation are:

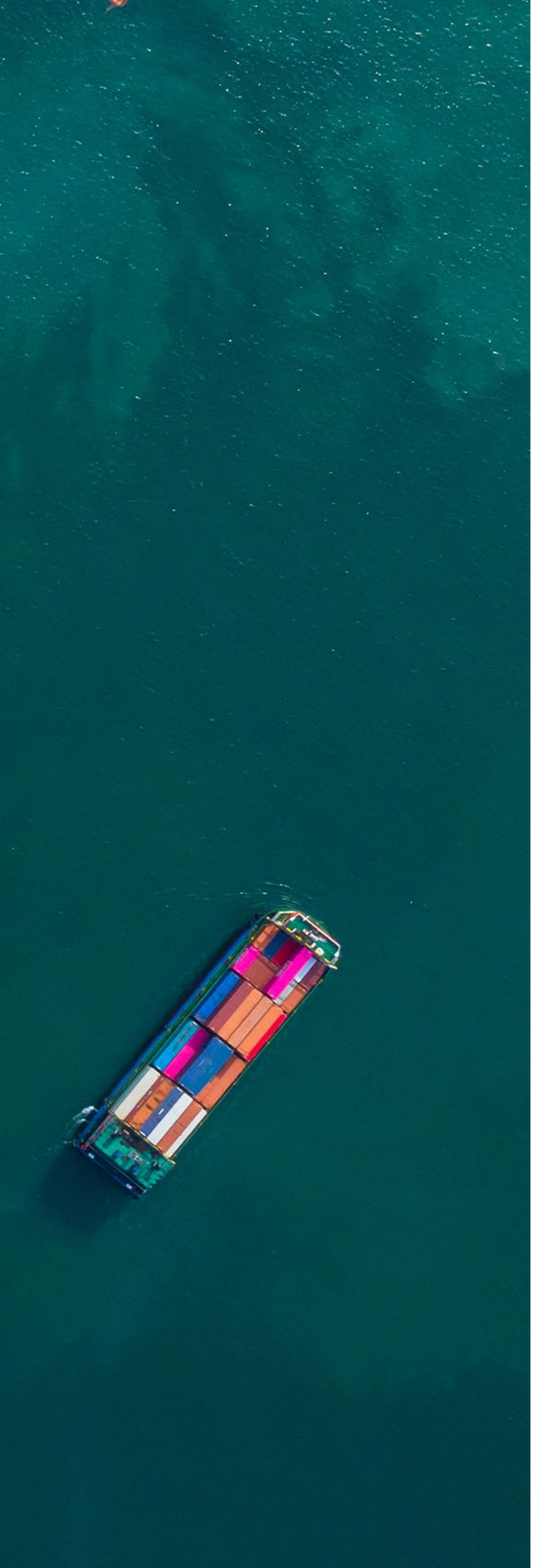
- Site-wide energy system utilizing smart grid, demand-side responses and peak shaving
- Zero carbon propulsion for leisure and work boats
- Shoreside power system to enable cold ironing – can integrate into generation and storage systems
- Resonant control electrolysis to produce hydrogen
- Hydrogen powered USV
- UK Ship Simulation Centre
- Zero emission hybrid powertrain
- Inland water charge points
- Stage marine engines
- Automated cargo handler
- Solid oxide fuel cells
- Multiple temperature-controlled storage
- Ground source heat pumps
- Hydrogen fuel cell power system
- Sustainable liquid fuels
- Software to optimise shipping movements
- Satellite mapping technology for emissions monitoring
- Hybrid and fully electric propulsion system
- Decision making model for shore power

Enabling solutions and applications

Local energy systems at ports are complex with buildings, equipment and workboats, visiting vehicles and vessels needing to be integrated with enabling solutions and applications to operate safely, efficiently and effectively in terms of decarbonisation.

- Ports' energy systems represent a high demand for limited resources. Smart energy management solutions that automate energy vector selection and prioritise distribution will be required.
- To achieve decarbonising objectives, many ports will need to replace or retrofit existing plants and machinery, therefore capability needs statements must be assembled.
- Multiple fuel delivery infrastructure systems would be uneconomical and so the range of fuels offered will require an engineering solution based on needs assessment.
- A roster of further knowledge and understanding points were uncovered eg: effectiveness of short-term measures such as fuel blending, mapping capability and capacity, mapping skills and training, understanding distribution technologies and strategies for remote ports. Also creating a timeline for increased energy generation based on volume, robust accountability methods for carbon and offsetting models, solutions for rapid, local change, and granular mapping of port needs to examine areas of divergence and alignment.





Technologies

As a diverse industry within the maritime sector there is no clear one solution fits all approach. A range of technologies may be appropriate depending on the size and use case of vessels and port equipment. The incumbent diesel technology still reigns supreme but there is impetus within the sector to reduce consumption. Efficiency saving technologies such as coatings, air lubrication, voyage optimisation and wind assist technologies have grown in popularity on board vessels whilst on land, optimisation of asset usage through scheduling have proved popular. The use of diesel alternatives such as LNG, HVO and hybridisation are more commonplace among both new build vessels and retrofitted onto existing vessels.

Moving away from fossil fuel combustion the next generation of propulsion technologies will be decisive in decarbonising the sector. Wind, battery-electric, hydrogen (fuel cell and combustion of), ammonia and methanol are all potential candidates as next gen fuels which is a challenge for vessel owners on which one to back. It is a similar challenge for port owners who must have the correct fuel to refuel or sufficient energy to recharge these future vessels as well as decarbonise their own assets.

KTN, through the Decarbonising Ports & Harbours Innovation Network, conducted an industry outreach survey and workshops to gain feedback on technologies and solutions that could be utilised to decarbonise UK ports and harbours.

Industry outreach across a cross section of 19 marine organisations analysed areas including energy systems, propulsion, shore power, hydrogen power and autonomy, storage, renewable energy, emission monitoring, sustainable liquid fuels and route optimisation for shipping. Conducted across a wide target customer audience from leisure boat users to port operators, key factors identified potential barriers for adoption of required decarbonisation technology in that specific field:

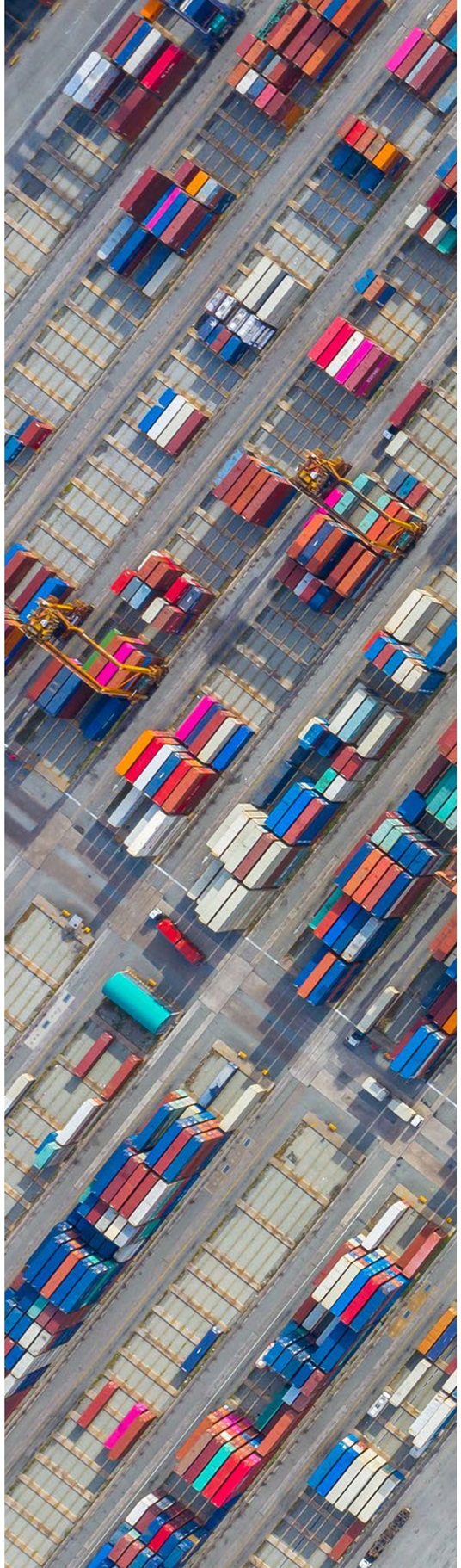
- Access to funding
- Business support
- Knowledge of regulatory landscape
- Poor market update
- Capital expenditure/production scaling

A further 23 UK-wide funded projects that could contribute to decarbonising UK ports and harbours to meet Net Zero 2025 goals, if commercially implemented, were also incorporated as a diverse array of shore-side and off-shore based organisations. This included feasibility studies and innovation solutions for decarbonisation programmes, taking into consideration technology options, speed of transition, environmental implications, potential uptake rates with volume to guide future investment and all short- and long-term operational scenarios relating to specific sectors of the overall study.

Trust and Risk Management

Having brought a sample of relevant organisations together to tackle the major challenges of decarbonisation in ports and harbours, contributors in specific workshops outlined where further trust and risk consideration could be managed:

- Mapping of maritime sector and related infrastructure plus transports sectors to understand the demands and supply chain solutions.
- Robust plan for all legacy assets to deliver guidance and confidence to avoid stranded assets
- Risk that the sector may be unable to sustain the demand and provision cycle for decarbonised energy.
- The response needs to be coordinated and co-designed across stakeholders to develop a collaborative solution.
- Recent financial and operational restrictions on ports have relegated decarbonisation down the list – look to establish priority again.
- Costs will be driven up due to restricted diesel availability and so drive-up operational costs
- Projects addressed together in a portfolio approach to manage them more efficiently and effectively within cross sector initiatives to openly share learning in a collaborative, non-competitive way.
- Ports, service sectors and stakeholders to actively put resources and leadership into developing interconnected systems solutions.
- Promotion of portfolio of work by government and local civic leaders to share learning, risk and coordinate activities.



Stakeholders

Stakeholders play a critical role in transformative change and the complex nature of ports and harbours means that the stakeholder network extends across local, regional, national and international boundaries. Principal organisations or groups must be identified and involved to support and influence decarbonisation activity and Innovation Network produced a matrix to define and determine power and levels of importance.

It is important to remember that other sectors and sub sectors have ongoing decarbonisation programmes that can provide expertise and share supply chains.

Cross sector discipline working and learning cycles sees further development of data sharing and decarbonisation strategies needed from shipbuilders and plant suppliers to work with Energy System Distribution Network Operators. Supply companies must also ensure that energy vectors match vessel solutions in terms of availability.

The way forward

Funding: For the UK to retain its position as a leading maritime nation, significant investment through both public and private funding will be required to accelerate transition towards a decarbonised future and meet the target of Net Zero 2050. Previously this funding has been sparse, especially for ports with the vast associated infrastructure systems.

To date funding for transition projects has been through a cross section of initiatives delivering both innovation and activity. With only a certain set of future funding in place the momentum for maritime decarbonisation needs to be elevated with a mixture of public funding in the next parliamentary period, including differential funding recognising the range of port ownership models - commercial, trust and public ports as well as bilateral funding with international ports to support global decarbonisation efforts.

Pilot projects demonstrating a complete ecosystem will deliver proven systems with data on performance and benefits to improve investor confidence and push solutions forward. Port wide solutions will require commissioning bodies to have access to substantive capital funds at affordable rates or compelling tax incentives, but ports are largely unfamiliar to these fund markets.

Viable opportunities for investment communities to showcase investor opportunities to be activated, for example: financial roundtables, technology showcases and model investor partnerships. The overarching necessity is to access affordable, stable and extended finance to adapt existing systems, install new systems and secure their long-term upgrades and maintenance. Despite the UK having been slow to engage financially, this landscape is changing, with specific provisions made by the UK National Infrastructure Bank, UK Green Investment Bank and the British Business Bank. Further sources of investment are available now with a view to what will be required up to 2050 and there are a number of UK government schemes, policy bodies and banking establishments open to engagement with a commitment to funding ports.

Conclusions

As gateways to international trade and supply chains, it is vital the UK ports are appropriately equipped to carry out decarbonisation and so meet Net Zero 2050 goals. It is clear that not one single organisation or trade member can address the scale and complexity of the transformation alone and therefore the expectations of strategy planning should be abundantly clear and entirely collaborative.

An acceleration on established policy frameworks set out by the government needs to occur to deliver an overall achievable and supported plan towards a clearly directed transition. Examining the potential development for extensive clean-growth technology in the UK it can be seen a gap exists between policy ambition and accessible solutions for this sector.

Industry requires a level of certainty that any investment made within the maritime infrastructure will not lead to abandoned resources. Therefore, focus is required on how to avoid stranded assets when moving away from diesel powered industrial applications, in relation to port and shipping operators, rail freight, road haulage and the like who are all experiencing the same challenges. Confidence needs to be generated that there will not be wasted investment over the lifetime of diesel driven assets and moving to green power, plus that trade will continue to flow in this transition phase.

Investigation by Innovation Networks has uncovered a promising amount of genuine willingness and enthusiasm to proceed with maritime decarbonisation overall. However, the lack of appropriately established understanding, together with lack of adequate funding and investment, have been identified as the major challenges impeding timely success without due consideration and application of pathway solutions.

The move to lower and zero emission fuels brings with it a more intricate supply and distribution picture with no single fuel of the future, which increases complexity. The greater demand for renewable generation and electrification will see an increased need for energy storage sector wide.

Encouragement to incentivise innovation, support R&D and to foster partnerships should result from positive and close collaboration between industry, government and the entire maritime supply chain. Working in this collaborative and inspiring way across port industries and the wider transport network will accelerate and motivate resolution of envisaged challenges to drive decarbonisation forward in an efficient and commercial direction towards Net Zero 2050.

Recommendations and Messaging

Government, civic leaders, industry, and the wider public recommendations.

- DEFRA to follow up on port air quality strategies – create emission reduction targets timeline.
- Refresh the Clean Maritime Plan by the DfT – targets and objectives need to be in a clearer, actionable roadmap for all sectors.
- Public financial support to port operators relating to retrofit existing equipment – “now” not “then”.
- New funding channels and access to capital for creation of a comprehensive national transitional infrastructure.
- Greater government involvement to foster links between industry and financial institutions with an urgent push for initiatives (DESNZ, DfT and DBT).
- Readily available and affordable clean electricity and renewable power with an accessible infrastructure from cooperation between distribution network operators and fuel producers.
- An overall goal to highlight freeports as an incubator for innovation, not in silos.
- Knowledge and data sharing between ports to establish prolonged collaborative behaviours.

To establish solutions that provide the best overall outcome to successfully decarbonise ports and harbours, priority actions must be established centred on extensive data and learning that combines with governmental and industry commitments that deliver sustained investment, comprehensive support and a robust timescale.

02

Introduction

Innovate UK

Purpose of the Innovation Network

The Decarbonising Ports & Harbours Innovation Network's (DP&H IN) overarching objective was to raise the profile of the critical part ports and harbours need to play in Maritime transport's transition to net zero by 2050 and accelerate this transition by giving clear direction.

This Innovation Network focused on major ports and harbours that have a cross section of usage including cargo, ferries, and containers, thus addressing a broad range of energy issues.

The DP&H IN was formed in 2019 and has convened a community of nearing 1,000 members to addresses the challenges of decarbonising, reducing emissions of greenhouse gases and improving localised air quality. The desired end-result of the Innovation Network's activity was a sector-led proposal for a government-industry partnership and stimulus package. This will include:

1. Agreed priority cross-sector challenges, informed by the current policy and solutions landscape.
2. A road-map for solution development, that offer the best overall lifecycle emission reductions, to provide focus and early planning for longer term R&D and innovation investment.
3. Agreed industry and government commitments and priority actions, including investment plan and timescales.

These objectives are now being met through pan industry and cross Whitehall initiatives capitalising on private and public investment via Government programmes including:

- Department for Transport's Clean Maritime Demonstration Programme being delivered by UKSHORE – UK Shipping Office for Reducing Emissions, £206 million to spend over the next three years (2022-2025) with back ended spending profile – see further details in later section.
- Department for Business, Energy and Industrial Strategy's £1BN Net Zero Innovation Programme and Freeport Initiative
- Department for Levelling Up, Housing and Communities Freeport Initiative

The DP&H IN was formed by the KTN in April 2020 with a founding membership and Advisory Group consisting of:

Innovation Network Community

An Advisory Group has been assembled featuring a diverse group consisting of:

challenge owners

solution providers

influencers

The IN produced a monthly newsletter which promoted relevant activity, insights and thought leadership by the members and relevant bodies.

The IN's initial outputs have included developing a Maritime and Ports Landscape Map. This interactive map is a reference tool designed to allow port owners, operators, technology providers and industry stakeholders insight into the challenge of decarbonisation in a port environment, and awareness of organisations capable of addressing this challenge.

It also serves as a showcase for the UK's world leading maritime sector and, as we transition to a decarbonised industry, will act as a directory of UK excellence in green maritime technologies.

The next output for the DP&H IN is this Solutions Roadmap Report.

Purpose of the Solutions Roadmap

This Report provides a roadmap for solution development, that offers the best overall lifecycle emission reductions, to provide focus and early planning for longer term R&D and innovation investment.

Approach taken to developing the Solution Roadmap

We adopted a Mission Led Approach considering the means to address a grand challenge by exploring the drivers; innovation pathways; stakeholders and systems that would be required to come together to create a route to successfully meeting the challenge. We broke the roadmap down into sections and ran combinations of open workshops, invitational sprint sessions and open industry surveys to gather responses and ideas, which we captured and reviewed with our Advisory Group.

The critiqued responses have been assimilated into this report which has been written by Innovate UK KTN staff members, principally Dr Matthew Moss (Maritime Transport) and Mark Wray (Clean Energy Systems).

03

Grand Challenge

Innovate UK

The Grand Challenge being addressed in part by this roadmap, is to enable the maritime sector to transition to an operationally decarbonised sector with port infrastructure being sustained by ‘clean’ energy.

We defined the scope of the Challenge to include the following three principle aims of:

1. Reducing greenhouse gas emissions from port operations including port owned working boats and equipment;
2. Providing infrastructure services to make clean energy available to visiting transport (road freight, rail and vessels);
3. Improving localised air quality by reducing emission of gases associated with burning of fossil fuels.

The Baseline for this work included key assumptions based on a starting point, January 2020, with the sectors current emissions, impacts, and consumption patterns. The horizon and focus for the work is 2020-2030, where significant investment will be required in the research and development needed to develop and test solutions, prior to scaling up delivery through 2030-2050 to meet the UK’s targets.

“Power demand in 2050 would be more than double what it is today. Production of hydrogen and biofuels would both increase more than tenfold between 2021 and 2050. Other industries, for example those that manage carbon with carbon capture and storage technologies, could also grow.”

Mckinsey Report
The economic transformation: What would change in the net-zero transition

04

Drivers

Innovate UK

Maritime and related landside industrial activity in the UK is governed by international legislation and an interrelated set of regulations, policies, strategies and missions. The UK has high ambitions for decarbonising its industrial activity based on world leading targets which are enshrined in domestic legislation.

Legislation

International Guiding Principles - The United Nations Sustainable Development Goals

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity.

At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership. The following set were deemed to be most applicable to this Grand Challenge:

G3 Good Health
Ensuring healthy lives and promoting the well-being for all at all ages is essential to sustainable development.

G7 Affordable & Clean Energy
Energy is central to nearly every major challenge and opportunity.

G9 Industry, innovation & infrastructure
Investments in infrastructure are crucial to achieving sustainable development.

G11 Sustainable cities & communities
There needs to be a future in which cities provide opportunities for all, with access to basic services, energy, housing, transportation and more.

G13 Climate Action
Climate change is a global challenge that affects everyone, everywhere.

G14 Life below water
Careful management of this essential global resource is a key feature of a sustainable future.

G15 Life on land
Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss.

G17 Partnership for goals
Revitalise the global partnership for sustainable development.

Ref: United Nations Sustainable Development Goals

Primary UK Legislation – Climate Change Act 2008

The primary legislation in the UK is the "Climate Change Act 2008", which was amended in 2019 and again in April 2021. The Act is the basis for the UK's approach to tackling and responding to climate change. It requires that emissions of carbon dioxide and other greenhouse gases are reduced and that climate change risks are adapted to. The Act also establishes the framework to deliver on these requirements.

The Climate Change Act commits the UK government by law to reducing greenhouse gas emissions by at least 100% of 1990 levels (net zero) by 2050. This includes reducing emissions from the devolved administrations (Scotland, Wales and Northern Ireland), which currently account for about 20% of the UK's emissions.

The UK government has set the world's most ambitious climate change target into law to reduce emissions by 78% by 2035 compared to 1990. The UK's sixth Carbon Budget will incorporate the UK's share of international aviation and shipping emissions for the first time, to bring the UK more than three-quarters of the way to net zero by 2050.

Other Relevant UK Legislation - Environment Act 2021

This Act was laid before Parliament by the Department for Environment, Food and Rural Affairs on 15 Nov 2021. It establishes a 25-year plan to manage the impact of human activity on the environment, creating a more sustainable and resilient economy, and enhancing well-being and quality of life. It will create a new governance framework for the environment, including an Office for Environmental Protection (OffEP) with a

- a new direction for resources and waste management
- improving air quality
- securing our water services
- enhancing our green spaces
- updating laws on chemicals (REACH)

This Act predominantly refers to England or England and Wales, NI and Scotland have their own versions to augment the national aims in the Act. This will be sense checked against other nations every two years, monitoring reports and new targets will be set every five years. All climate change legislation (including carbon budgets) will be within the enforcement remit of the OffEP. The Act builds on the 2019 Clean Air Strategy and seeks to strengthen legislation on air quality improvement, with a particular focus on fine particulate removal (PM2.5). It will also enable OffEP to recall polluting vehicles that do not meet requirements.

Policies

Current Policies

Policy is a deliberate system of guidelines to guide decisions and achieve rational outcomes. A policy is a statement of intent and is implemented as a procedure or protocol. The following are outline details on a range of policies applicable in the UK, which relate to Decarbonising Ports & Harbours:

Decarbonising Transport - A better, greener Britain

Sponsor organisations: Department for Transport

Launch date: 14 July 2021

Application period: 2020-2050

Subject focus: Transport Decarbonisation Plan, sets out the government's commitments and the actions needed to decarbonise the entire transport system in the UK.
It includes:

- the pathway to net zero transport in the UK
- the wider benefits net zero transport can deliver
- the principles that underpin the UK approach to delivering net zero transport
- Page 106, chapter 10 features Accelerating maritime decarbonisation.

Opportunities: The UK Government plan to introduce staged targets starting in 2030, with an ambition for Net Zero by 2050 for domestic and UK share of international. Clean Maritime Plan to be refreshed in 2022. The UK Government commits to exploring the establishment of a UK Shipping Office for Reducing Emissions (UK-SHORE). This is a dedicated unit within the Department for Transport focused on decarbonising the maritime sector.

Clean Maritime Plan

Sponsor organisations: Department for Transport

Launch date: 11 July 2019

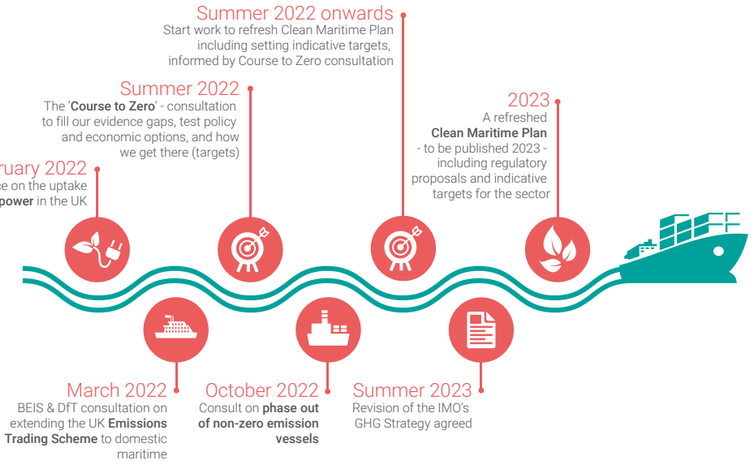
Application period: 2019-2050

Subject focus: UK's route map to clean growth for the maritime sector and pathway to zero-emission shipping. It identifies ways to tackle air pollutants and greenhouse gas emissions in parallel while securing clean growth opportunities for the UK.

Opportunities: It made a commitment to providing R&D grant funding for Clean Maritime Demonstration Projects. A full review of this Plan is expected in 2023, with consultations commencing in February 2022, starting with Shore Power, and with further consultations starting in February 2023. A consultation on Renewable Transport Fuels Obligation Order was called for and a draft Regulation passed to Parliament on 7 September 2021. These draft regulations are expected to deliver additional greenhouse gas (GHG) emissions savings by:

- increasing the main RTFO target to supply renewable fuels from 9.6% to 14.6% by 2032
- expanding RTFO support to new transport modes such as renewable hydrogen in rail and maritime

Transport decarbonisation plan: policy & regulation



Freeports

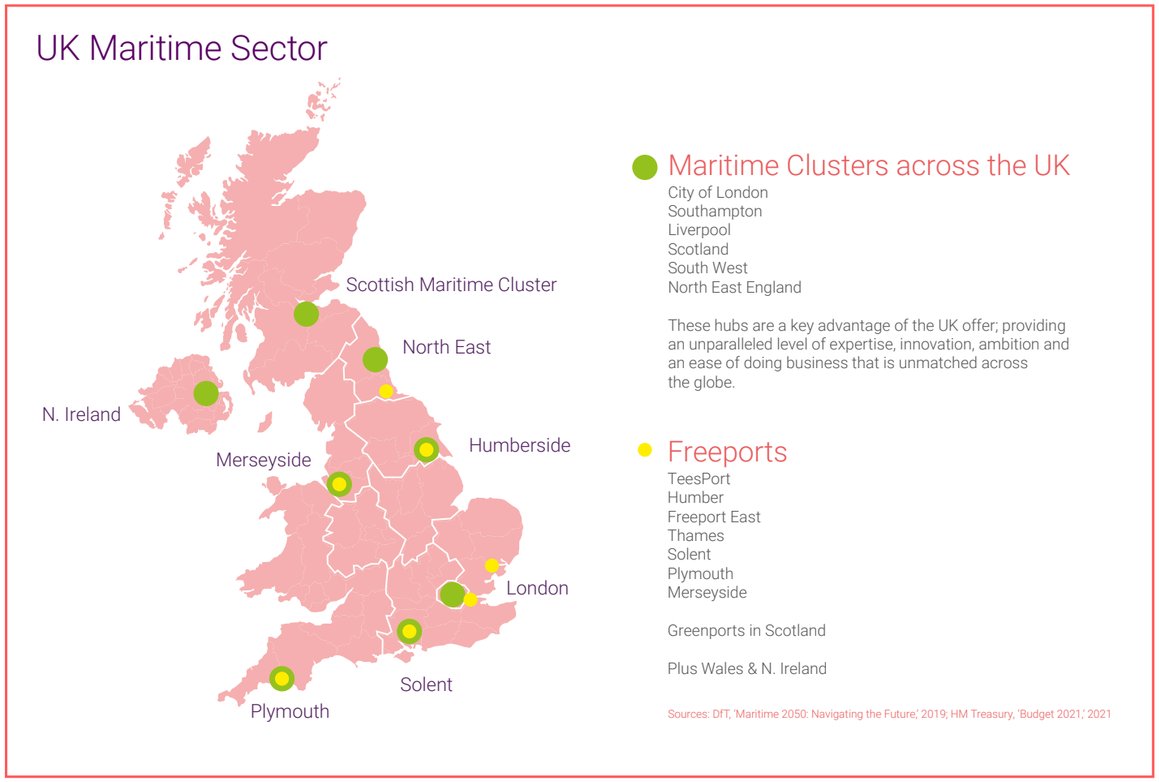
Sponsor organisations: Department for Levelling Up, Homes and Communities; Department for International Trade; Department for Business, Energy & Industrial Strategy; Department for Transport; and HM Revenue & Customs

Launch date: November 2020

Application period: 2022 - 2047

Subject focus: Freeports are special areas within the UK's borders where different economic regulations apply. Freeports in England are centred around one or more air, rail, or seaport, but can extend up to 45km beyond the port(s). The UK Freeport model Our includes a comprehensive package of measures, comprising tax reliefs, customs, business rates retention, planning, regeneration, innovation and trade and investment support.

Opportunities: Freeports are expected to be hot beds of innovation and are required to comply with UK Law, which includes delivering Net Zero. This presents great opportunities for Freeports to lead on developing and demonstrating solutions. All 8 English Freeports included low and zero carbon solution development as part of their bids.
In Scotland five 'Green Freeports', where the emphasis for selection is centred on having ambitious plans for decarbonising, were shortlisted and two were awarded Green Freeport Status in 2023 – the Firth of Forth Port and Port of Cromarty Firth.



Strategies

Strategies are general plans to achieve one or more long-term or overall goals under conditions of uncertainty. The following are outline details on a range of current strategies applicable in the UK, which relate to Decarbonising Ports and Harbours:

Strategic Innovation Fund

Sponsor organisations: OfGEM, supported by Innovate UK

Launch date: 31 August 2021

Application period: 2021-2026

Subject focus: A funding mechanism for the Electricity System Operator, Electricity Transmission, Gas Transmission and Gas Distribution sectors. The SIF aims to find and fund ambitious, innovative projects with the potential to accelerate the transition to net zero. These projects should help shape the future of the gas and electricity networks and succeed commercially where possible.

Opportunities: £450M to be invested in four Innovation Challenge areas:

- Whole system integration
- Data and digitalisation
- Heat
- Zero emission transport

Industrial Energy Transformation Fund Phase 2

Sponsor organisations: BEIS (England, Wales & NI), supported by Innovate UK and Scottish Government (Scotland)

Launch date: 16 July 2019 and updated 24 May 2021

Application period: 2019-2025

Subject focus: A funding mechanism designed to help businesses with high energy use, such as energy intensive industries, to cut their energy bills and carbon emissions through investing in energy efficiency and low-carbon technologies.

Opportunities: £315M to be invested in total, with £289M in England, Wales& NI over two Phases - Phase 1 has invested in efficiency projects and decarbonisation studies.

Phase 2 (next round runs from 31 January to 29 April 2022) will expand the scope of the Fund to include deployment of decarbonisation technologies and will make available up to £220M.

Industrial Energy Efficiency Accelerator Phase 4

Sponsor organisations: BEIS, supported by Carbon Trust and Jacobs

Launch date: April 2022

Application period: 2021-2024

Subject focus: The IEEA programme aims to increase the number of innovative energy efficiency technologies available to British industry to help reduce energy consumption and cut carbon emissions. It is designed to support partnerships between developers of efficient technologies and industrial companies willing to trial innovations on-site. It is open to projects from all UK industry sectors that can demonstrate either a novel technology (targeting Technology Readiness Level 5-8), or the use of an established technology in a novel way.

Opportunities: The third phase closed on 14 Feb 2022 and made £8M available to innovative ideas.

UK Hydrogen Strategy

Sponsor organisations: BEIS

Launch date: 17 August 2021

Application period: 2021-2030

Subject focus: This strategy sets out the approach to developing a thriving low carbon hydrogen sector in the UK to meet the ambition for 5GW of low carbon hydrogen production capacity by 2030.

Opportunities: £240M potentially to be invested up to 2025 in new hydrogen production facilities to kick start hydrogen production.

UK Transport Vision 2050

Sponsor organisations:
Innovate UK

Launch date: August 2021

Application period: 2021-2050

Subject focus: This strategic report examines the challenges and opportunities faced by the Transport Sector in the next three decades. It considers demand change, autonomy, connectivity, business models, infrastructure and energy vectors.

UK National Ship Building Strategy - Refresh

Sponsor organisations:
Ministry of Defence

Launch date: 10 March 2022

Application period: 2022-2050

Subject focus: A refresh of the 2017 Strategy, designed to reinvigorate the shipbuilding and maritime sector across the UK regions as part of the government's 'levelling up' agenda. Over £4 billion of government investment will galvanise and support shipyards and suppliers across the UK, with new measures including better access to finance, vital skills-building, and funding for crucial research and development into greener vessels and infrastructure.

Designed in partnership with industry and delivered by the recently formed National Shipbuilding Office (NSO), the National Shipbuilding Strategy Refresh will also deliver a pipeline of more than 150 new naval and civil vessels for the UK Government and Devolved Administrations over the next 30 years. The vessels will include large warships, Border Force cutters, lighthouse vessels and the new National Flagship.

UK SHORE

Sponsor organisations:
Department for Transport

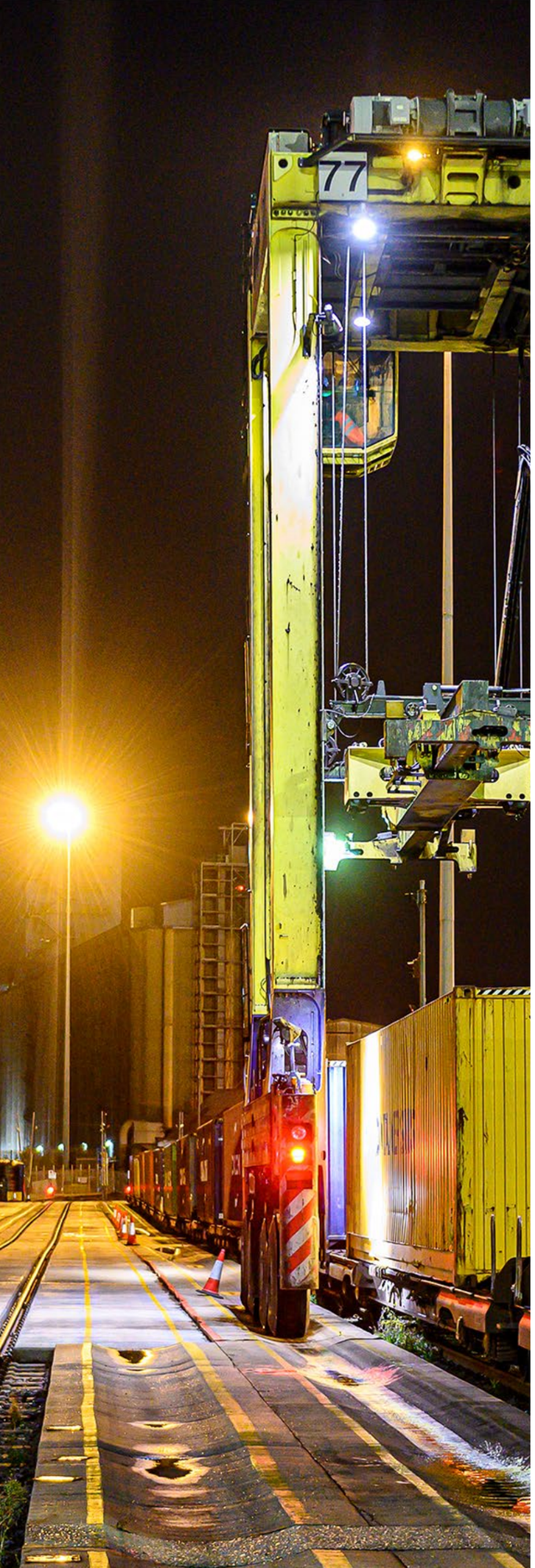
Launch date: 10 March 2022

Application period: 2022 - 2050

Subject focus: This will create the first UK Government office purely dedicated to making maritime greener – pioneering new research and development of technology that could make journeys by sea as green as they were hundreds of years ago. Known as the UK Shipping Office for Reducing Emissions (UK SHORE), the new unit will be housed in the Department for Transport, building on the success of the UK's Clean Maritime Demonstration Competition (CMDC) launched last year.

Opportunities:£206 million investment to support zero emission sailing and skilled maritime jobs, as part of the government's shipbuilding strategy.

UK SHORE will implement a comprehensive research and development programme, including a multi-year CMDC, and will help develop the infrastructure to enable zero emission technologies and the physical infrastructure needed to power these new-age vessels. The programme will include a multitude of technologies including hydrogen, electric and ammonia.



Missions

Missions are designed to focus minds on a particular ambitious activity or goal, resulting in a defined output. The following are outline details on a range of current Missions applicable in the UK, which relate to Decarbonising Ports and Harbours:

Mission Innovation

Sponsor organisations: BEIS & DfT (UK), with 24 other member states and 7 collaborator organisations

Launch date: 2015 and refreshed to MI 2.0 on 2 June 2021

Application period: 2015 - 2031

Subject focus: An intergovernmental platform addressing clean energy innovation through action-oriented cooperation, catalysing a decade of action and investment in research, development and demonstration to make clean energy affordable, attractive and accessible for all.

Opportunities: The MI currently promotes three Missions:

1. Green Powered Future - will demonstrate by 2030 that power systems can effectively integrate up to 100% variable renewable energy (VRE) in their generation mix while maintaining a cost-efficient, secure, and resilient system. [BEIS co-lead]
2. Zero Emission Shipping –with ships capable of running on zero-emission fuels to make up at least 5% of the global deep-sea fleet by 2030. [DfT member].
3. Clean Hydrogen - increase the cost-competitiveness of clean hydrogen by reducing end-to-end costs to USD 2 per kilogram by 2030. [BEIS co-lead]

Announcements on declarations in 2022 for Zero Emission Shipping.

COP26 The Clydebank Declaration

Sponsor organisations: UK Government along with 21 other nations including most of major European countries and USA, Canada, New Zealand and Australia.

Launch date: 10 Nov 2021

Application period: 2021 - 2030

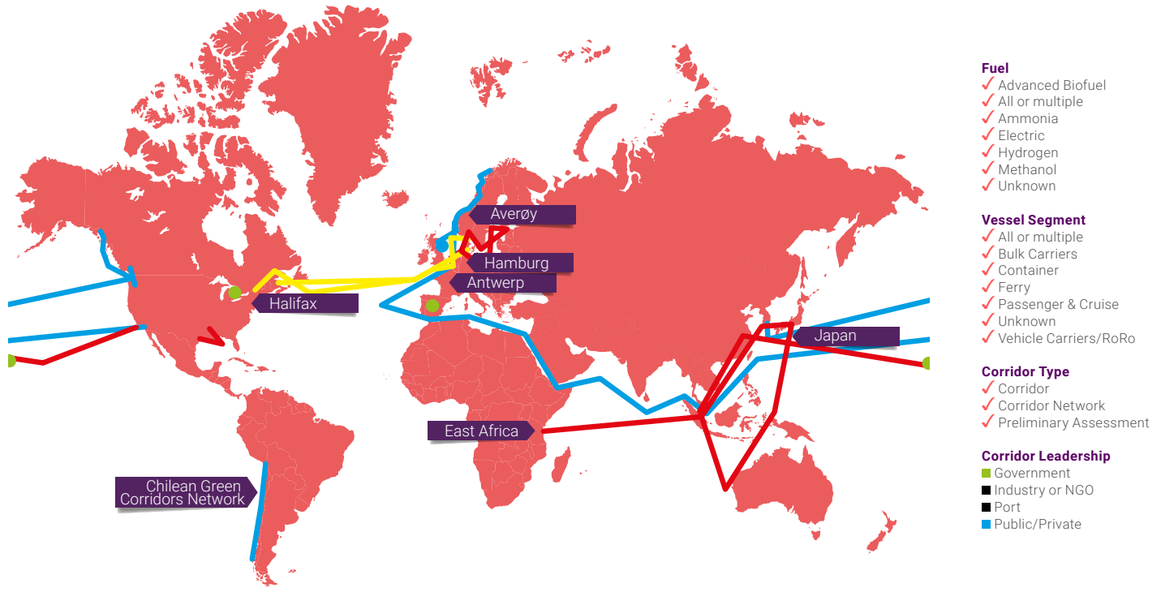
Subject focus: The signatories of the Declaration are to support the establishment of green shipping corridors – zero-emission maritime routes between two (or more) ports.

It is their collective aim to support the establishment of at least six green corridors by the middle of this decade, while aiming to scale activity up in the following years, by inter alia supporting the establishment of more routes, longer routes and/or having more ships on the same routes. It is their aspiration to see many more corridors in operation by 2030. We will assess these goals by the middle of this decade, with a view to increasing the number of green corridors. In the UK the Government is championing the establishment of an Emission Control Zone in the Irish Sea and Western Approaches.

Globally, after the first year, the following announcements for Green Shipping Corridors have been made:

Current Green Corridor Consortiums announced to date

Corridor	Geographic Focus	Segment Focus	Partners
Shanghai - LA	Trans-Pacific	Container	C40, CoZEV, PoLA, Shanghai, CMA, CGM, COSCO, Maersk
Antwerp-Montreal	Trans-Atlantic	Container	Port of Antwerp, Port of Montreal
European Ports Network	North Sea / Baltic	Port fuel supply & infrastructure	MMMZCSC, Ports of Rotterdam, Hamburg, Roenne, Tallinn, Gdynia
Nordic Region	Nordic	Ferry	Nordic Council of Ministers, DNV
Seattle - Juneau	Pacific NorthWest	Cruise	Ports of Seattle, Vancouver, City of Juneau, Carnival, RCCL, Norwegian, GMF, CLIA, Blue Sky Coalition, Washington Maritime Blue
Silk Alliance	SE Asia	Container	LR, MSC, PIL, Wan Hai, X-Press Feeders, Yang Ming Marine Transport Corp., Keppel O&M, Singfar International, Wärtsilä, Wilhelmsen Ship Management, ADB, ING.
Aus - Asia Iron Ore	Australasia	Dry Bulk	14 GtZ Companies
Chile Feasibility Study	Latin America	Dry Bulk	Chile, MMMZCSC



All routes displayed are approximate. Source data compiled by the Global Maritime Forum

And in the UK, the following projects have been instigated relating to hydrogen fuel use study in the North Sea and establishing an electric ferry crossing for the Dover Straits

Under the Clean Maritime Demonstration Competition Round 2, three feasibility projects have been funded to assess the viability of international green shipping corridors involving the following UK Ports: Aberdeen, Port of Tyne and Port of Dover.

Opportunities:

In the pursuit of these goals the signatories pledged to:

- facilitate the establishment of partnerships, with participation from ports, operators and others along the value chain, to accelerate the decarbonisation of the shipping sector and its fuel supply through green shipping corridor projects
- identify and explore actions to address barriers to the formation of green corridors. This could cover, for example, regulatory frameworks, incentives, information sharing or infrastructure
- consider the inclusion of provisions for green corridors in the development or review of National Action Plans
- work to ensure that wider consideration is taken for environmental impacts and sustainability when pursuing green shipping corridors.

COP26: Shipping & Offshore Wind – Operation Zero Declaration

Sponsor organisations: Department for Transport, Offshore Renewable Energy Catapult and including industry majors Siemens Gamesa, Orsted, RWE, Vattenfall, ScottishPower Renewables, Equinor, ABP, Lloyds Register, Bibby Marine, North Star Renewables.

Launch date: 9 Nov 2021

Application period: 2021 - 2025

Subject focus: An industry coalition, convened by the Department for Transport, to accelerate the decarbonisation of operations and maintenance vessels in the North Sea offshore wind sector.

The vision of Operation Zero is for zero-emission operations and maintenance vessels to be deployed in the region by 2025.

Opportunities: As part of Operation Zero, ORE Catapult and the Workboat Associations delivered a **technology roadmap** in June 2021 for the decarbonisation of offshore wind operations and maintenance vessels.

The roadmap suggested that the industry will build as many as 1,400 new vessels between now and 2050 just for O&M, including more than 300 SOVs, as we scale from the 25GW (iii) of European operational offshore wind we have today to 400GW by 2050 (with 100GW based in the UK), which equates to a sixteen-fold growth in less than 30 years.

World Ports Sustainability Program

Sponsor organisations: Several including the European Sea Ports Association and British Ports Association.

Launch date: 12 May 2017

Subject focus: The signatories of the Declaration are to enhance and coordinate future sustainability efforts of ports worldwide and foster international cooperation with partners in the supply chain.

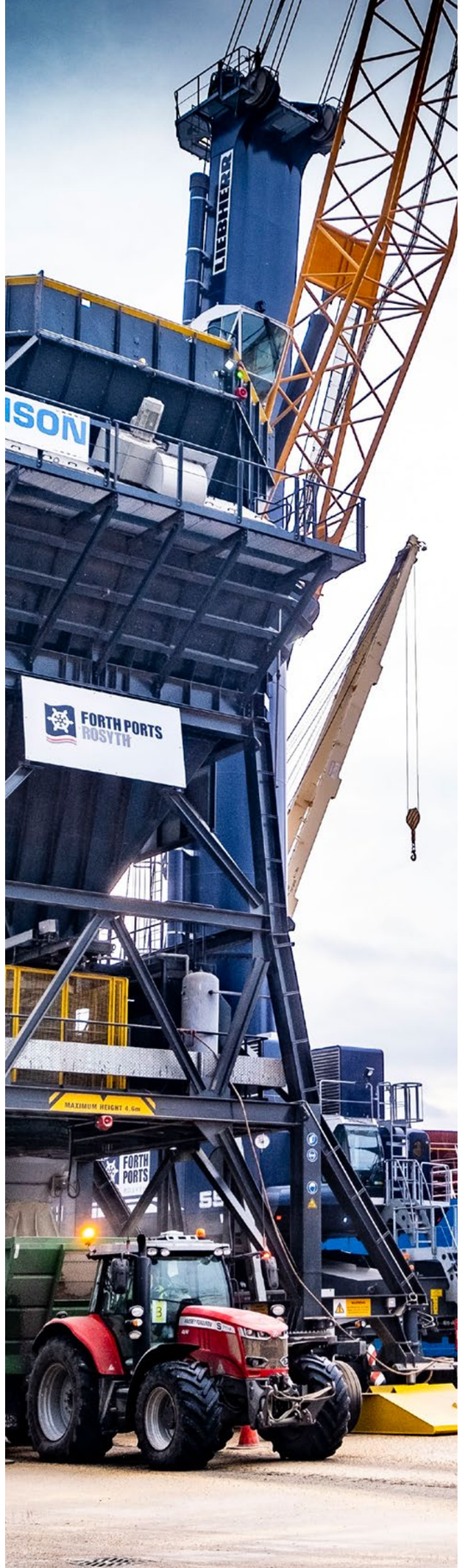
05

Innovation Pathways

Innovate UK

Solution roadmaps are not merely lists of technologies and delivery periods. To be effective they should examine how a set of influences and technologies can evolve to accelerate R&D. These often occur in parallel and come together either in incremental innovations or larger disruptive solutions. In this section we have examined the following pathways:

- Science – What knowledge or understanding do we need to access and develop?
- Technologies – What technologies are emerging and do we need to accelerate their development?
- Innovation (non tech) – What systems or process innovations do we need, what support or enabling solutions are required (incl. skills)?
- Trust – What means or measures need to be introduced to create trust and assurance in the solutions to drive investment?
- Risk - Major risk items which needed to be mitigated or avoided.
- Portfolios – What items or approaches need to be out in a portfolio to enable them to come forward or to mitigate risk?
- Learning cycles – What solutions are required to assist knowledge transfer and learning across disciplines?



Science

To decarbonise our Ports and Harbours the maritime sector will need to access science and engineering knowledge developed within maritime and drawn from various sectors including automotive, construction, energy and rail.

Ports are complex facilities with substantive civil and structural infrastructure; mixed commercial and industrial buildings; cars and road freight; non road mobile machinery; mobile and static lifting equipment; rail freight; working boats and visiting vessels.

In the last decade there has been a sizeable focus on improving energy efficiency and powering of the built environment from low and decarbonised solutions and facilities and organisations like the Construction Innovation Hub, Active Building Centre, Construction Wales Innovation Centre, Construction Scotland Innovation Centre and Infrastructure Industry Innovation Platform – i3P host resources and networks to support Ports seeking knowledge and guidance. The infrastructure and buildings which make up the built environment therefore do not feature further in this report.

Certain Ports, like many industrial complexes, have taken early steps towards decarbonising by addressing their buildings footprints, two examples both from Portsmouth is the Forward Logistics Supply Centre at HMNB Portsmouth and the Terminal Building at Portsmouth International Port.

For this report we chose to focus on two specific areas and a host of other areas for developing knowledge to support decision making around decarbonising. In the context of this report, we are considering where the sector needs to develop knowledge over the next few years to mid-decade (2025) to develop solutions in this decade ready for scaling up and roll out across the sector to meet the Net Zero requirements by 2050, or sooner. The two areas of specific focus are energy generation and storage; and enabling solutions.

Construction Innovation Hub - constructioninnovationhub.org.uk
Active Building Centre - activebuildingcentre.com
Construction Wales Innovation Centre - cwic.wales
Construction Scotland Innovation Centre - cs-ic.org
Infrastructure Industry Innovation Platform - i3p.org.uk

Case Study: Portsmouth International Port

Portsmouth International Port is on target to become the UK's first net carbon neutral port ahead of Portsmouth City Council's 2030 target.

Portsmouth City Council are determined to provide the country's most environmentally advanced facilities through collaboration, shared knowledge and innovation.

Portsmouth International Port is leading the way in sustainable innovation with a carbon-neutral terminal extension, energy prototypes and the UK's largest installation of solar PV canopies in a port. The port also piloted the Port Energy Systems Optimisation (PESO) project which demonstrated how ports can decarbonise their activities and reduce their adverse impact on air quality by using smart grid technology and energy storage. Co-funded by InnovateUK this pilot scheme has shown how port infrastructure can meet the UK government's 'Clean Martime Plan' cost effectively.

The PESO technical capability has been demonstrated in a pilot system comprising a novel dual chemistry battery and a multi-level control system. The control system includes an AI-based capability that learns from historic energy consumption profiles to ensure that the battery can deliver as much energy as possible when demand is high. The technology has been extended further by engineering a predictive 'digital twin' model that can ensure the battery has storage capacity to fully utilise energy generated by on-site renewable generation or procured from the grid at times of low price.

The prime 'early adopter' ports are likely to be in locations where vessels are obliged imminently to electrify in order to comply with policy developments in carbon emissions and air quality. Examples include passenger ferries and water taxis operating in cities where traditional fossil-fuelled combustion engines are not permitted.

Berths supporting shore powered ships will help reduce harmful engine emissions and allow Portsmouth to supply the cruise industry with shore power ready berths by 2026 as the industry trade body expects that all cruise vessels will need to be shore power compliant by 2030. PESO will also help to ensure that popular recharging times, such as weekends in summer, do not overload the grid and minimise the cost of energy to the port.

An agreement with Scottish and Southern Energy Network (SSEN) will provide the extra capacity to support shore powered vessels and installation of these berths will be complete by 2025 in time to supply Brittany Ferries two new hybrid ships, with the remaining fleet due to be converted by 2027.

This agreement will cost approximately £3m to secure, with further funding required to complete the process. Cllr Gerald Vernon-Jackson, Leader of Portsmouth City Council is hopeful that this additional funding can be secured by working closely with the government.

Mike Sellers, Port Director at Portsmouth International Port said: "Our aim is to turn the port into a living laboratory of green technology. We were delighted to collaborate with partners on the PESO project, which has so much potential for the wider ports and shipping industry. Combined with other sustainability initiatives, the findings from the PESO project will help us achieve our ambition of reaching net-carbon zero by 2030, and becoming one of the UK's first zero emission ports by 2050."

Energy Generation, Storage and Supply

Current energy supply and storage in the Maritime sector is dominated by mains grid electricity and diesel either in internal combustion engines or generators. Whilst we have reliable and extensive data on goods and fuel passing through UK Ports, we have very little public information on the energy being used in them. Anecdotally Port operators advise that their energy sources mirror those in the wider maritime industry and are dominated by diesel consumption in internal combustion engines (+95%).

KTN and Innovate UK published a report in August 2021, exploring challenges and opportunities faced by the Transport sector in the next three decades. Changes to energy vectors was a significant section of the report, which examined changes across different transport modes, with varying degrees of certainty across the 30 year horizon.

Energy Vector Pathways for Transport Modes in Port Locations

CERTAINTY High Med Low Speculative

Transport	Elements	2021 position	by 2025	by 2030	by 2040	by 2050
Air	Policy Enablers	Early dev of alt. energy vectors	UK SAF mandate implemented	All aircraft certified for 100% SAF	SAF industry established	
			CORSIA mandatory for all UK int flights	Sufficient SAF for domestic flights		
			PtL Strategy 2023			
	Advanced Air Mobility (AAM)		>99% battery electric or hydrogen			
	Fuel Mix [36-41]	>99% kerosene	>99% kerosene	90% kerosene	70% kerosene	43% kerosene offset
		1% SAF	1% SAF	10% SAF	20% SAF	32% SAF (including some PtL)
			Development of hydrogen powered aviation	ZE flight demonstrator 2026	10% hydrogen	25% hydrogen for commuter to short-range
	International & domestic		Transatlantic flight 100% SAF demonstrator by 2025	All aircraft certified for 100% SAF by 2030		
			Domestic flight 100% SAF demonstrator by 2023		2031 UK domestic aviation 100% SAF	
			At scale SAF plant by 2025	SAF significant increase in production	Zero-E planes enter into service in 2035	Sufficient SAF to meet >30% UK domestic demand
Maritime	International	Marine diesel & heavy fuel oil (HFO)	BEV for short journeys only	All new ships to be ZE capable		
			TRL3-7 hydrogen & ammonia projects	Wind, biofuel, electro-fuel and H2 demonstrators	Large shift in take up of ZE energy sources from 2030s	All zero emission
	Domestic			40% marine diesel	18% marine diesel	1% marine diesel
	Fuel Mix	52% marine diesel	52% Marine diesel	47% low sulphur & heavy fuel oil	33% low sulphur and heavy fuel oil	0% low sulphur and heavy fuel oil
		48% heavy & low sulphur fuel oil	48% low sulphur & heavy fuel oil	4% methanol	10% methanol	26% methanol
				3% shore power	5% shore power	6% shore power
				4% ammonia	30% ammonia	62% ammonia
				2% hydrogen	4% hydrogen	4% hydrogen
Micromobility	Policy Enablers	Encourage more active travel	Develop micro-consolidation hubs	Large-scale urban freight consolidation		
		Provide infrastructure		Electric-powered last-mile delivery		
	All modes	E-scooter & e-cargo bike trials ongoing	>99% BEV & active travel modes		100% BEV & active travel modes	
Rail	Policy Enablers	Develop hydrogen & battery solutions	Hydrogen & battery electric trials	Increased electrification of network	Diesel trains removed by 2035-2040	Wholesale integration with energy system
			Manufacture of diesel trains ends	Manufacture of ZE trains only		Net zero rail network
	Fuel Mix	71% electric	75% electric	80% electric (inc direct electric & electric diesel hybrids	85% direct electric	
		25% diesel	29% diesel	15% fossil fuels	Electric diesel hybrids phased out	
				2% hydrogen	5% hydrogen	
				2% battery electric hybrids	5% battery electric hybrids	
				1% battery	5% battery	
Road	Policy Enablers	ICE sales end 2030, hybrids 2035	ICE de-incentivised	ZEV capability & affordability increased	Shift to ZEV for HGVs	Circular economy for ZEV established
	Cars (2020: 32.9m)	97.6% ICE	84% ICE	57% ICE	8% ICE	
		2.1% hybrid	7% hybrid	9% hybrid	5% hybrid	
		0.3% BEV	9% BEV	34% BEV	87% BEV	100% BEV
	Vans (LCVs) (2020: 4.3m)	99.8% ICE	84% ICE	57% ICE	8% ICE	
		0.2% BEV	9% BEV	34% BEV	87% BEV	100% BEV
			7% hybrid	9% hybrid	5% hybrid	
	Motorcycles (2020: 1.4m)	99.8% ICE	84% ICE	57% ICE	8% ICE	
		0.2% BEV	9% BEV	34% BEV	87% BEV	100% BEV
			7% hybrid	9% hybrid	5% hybrid	
	Bus & coaches (2020: 144k)	99.6% ICE	98% ICE	85% ICE	33% ICE	50% BEV
		0.4% BEV	1% BEV	7% BEV	33% BEV	
			1% H2	7% H2	33% H2	50% H2
	HGV (2020: 508k)	99.9% ICE	98% ICE	85% ICE	33% ICE	
		0.1% BEV	1% BEV	7% BEV	33% BEV	50% BEV
			1% H2	7% H2	33% H2	50% H2

SOURCE: UK Transport Vision 2050: Investing in the future of mobility p20 - https://www.ukri.org/wp-content/uploads/2022/01/IUK-110122-UK-Transport-Vision-2050.pdf

This report concluded that:

Overall

- The energy vector pathway will have a variety of solutions and sources of energy, to be matched against the demand of the transport mode; the availability and cost of the energy; and policy enablers.
- Diesel and fuel oil demands will continue, particularly in rail and road based heavy goods movement, in significant quantities for the next two decades but overall, at substantively reduce levels, because of the drop in demand for light weight land travel from cars and vans, which dominate the market for diesel. This will have implications for the cost per unit for diesel, where fewer consumers will bear the cost of the processing, storage and distribution.

Maritime

- 2021 – Diesel and heavy fuel oils dominate at 99%+
- 2025 – demonstration scale electric vessels and hydrogen R&D projects emerge
- 2030 – all new vessels to be low emission capable; diesel and heavy fuel oil based units falls below 90%; demonstrators and early market penetration for a wide variety of energy vectors including wind, biofuel, methanol, electric, hydrogen and ammonia
- 2040 – diesel and heavy fuel oils drops below 50%; replaced by combinations of alternatives which begin to scale. Methanol and ammonia dominate in global transport, whilst electric and hydrogen take greater share in domestic.
- 2050 – diesel and heavy fuel oils now down to 1% as nearly all vessels are ZE. Alternatives continue trend of 2040.

Rail

- 2021 – 70%+ is already electrified with the remainder being diesel. Within Ports however, which are often at the end of electrical energy grids, anecdotally the percentage served by rail freight where loads and access to electricity is different to the passenger services or main lines, then diesel is more prevalent.
- 2025 to 2050 – steady progression to near dominance of direct electric with the remaining demand met by batteries and hydrogen.

Road

(and most likely non road mobile machinery)

- 2021 – internal combustion engines running on petrol and diesel dominates; with diesel dominating larger vehicles.
- 2025 – Electric vehicles make up near 15% of cars but are only emerging along with hydrogen in larger vehicles.
- 2030 – low / zero emission cars approaching 50%, but larger vehicles are below 10%
- 2040 – low / zero emission cars approaching 90%, and larger vehicles are over 30%
- 2050 – smaller vehicles are all electric and larger vehicles are a split between electric and hydrogen.

Energy Vector Advantages and Challenges

The following table provides a view of the commonly held views on the advantages and challenges of a range of future energy vectors which offer low or zero emission solutions applicable in the Port environment.

Energy Vector	Advantages	Challenges
Petroleum with carbon capture	• High energy density • Readily available fuel source • Drop into existing equipment • Established supply chain for fuel supply & propulsion systems • The carbon, can depending on its purity, be used in a variety of industrial applications.	• Carbon Capture technology is in its infancy and has had a troubled start • You need a readily available and economically attractive location to store or use the carbon dioxide • Expense – current abatement costs and as petroleum sources become depleted the costs will rise
Biofuels and Electrofuels	• Can be produced from waste resource streams • High energy density • Can be dropped into existing equipment with little modification • Wide range of fuels can be produced	• Existing processes are inefficient and take time to create fuel • Many competing high value demands particularly in aviation and heavy road transport
Ammonia	• Easy to store and transport, with readily established supply lines • Can be used in existing engines or in fuel cells • Wide range of applications	• Highly toxic • Inefficient to produce and requires plentiful supply of energy (clean) • Competing demands for use including transport, agriculture and industrial processes
Methanol	• Easy to store and transport • Can be used in existing engines or in fuel cells • Wide range of applications	• Highly toxic • Low energy density • Not favoured by other sectors
Hydrogen	• Significant investment being directed at hydrogen generation and distribution • Can be used in existing engines or in fuel cells • Wide range of applications	• Highly toxic • Needs to be stored under pressure to be efficient, which presents an additional hazard • Low energy density compared to ammonia or synthetic fuels • Inefficient to produce and requires plentiful supply of energy (clean) • Competing demands for use including transport, domestic heating and industrial processes
Liquified Natural Gas and Compressed Natural Gas	• Widely used in vehicle propulsion and heating systems • Can be used in existing engines or in fuel cells • Wide range of applications • Highly efficient • Lowest CO2 footprint of fossil fuels	• It is a lower emission fuel compared to diesel, but to be low or zero it will require additional treatment of exhaust gases • Requires a lot of space to store and needs to be stored under pressure to be efficient, which presents an additional hazard

Energy Vector	Advantages	Challenges
Compressed Air	• Can be used in existing engines • Wide range of applications • Highly efficient • Is not toxic • If generated from renewable or zero emission energy sources then it has a ultra low / zero emission profile.	• Requires a lot of space to store and needs to be stored under pressure, which presents an hazard
Electricity – direct	• Is readily available and widely understood • Highly adaptable and can be used to augment or replace engines in existing assets • Can be sourced from renewable sources • Zero emissions and silent	• Needs specialist trained fitters to install and modify • Capacity is limited in many locations with competing demands for power • Tethering equipment can present restrictions on activity, particularly for non-road mobile machinery

Energy Vector	Advantages	Challenges
Electricity – batteries (Lion / Flow)	• Zero emissions at point of use • Near Silent running • High energy conversion efficiency at point of use • Rechargeable – potential for reduced through life cost and logistic burden	• Low energy density relative to gasoline and other energy storage vectors • Discharging / Charging time • Performance diminishes over time • Longer term recycling will need to be addressed
Electricity – super capacitors	• Able to provide high energy density • Near instant power output • Low mass, relative to batteries • High cycle life • Does not typically contain toxic / harmful metals	• Low energy density relative to batteries • Currently high cost relative to batteries, but significant development is being undertaken

Areas identified as needing development of further knowledge and understanding

1. Electricity generation & distribution capacity models

The energy sector in the UK is fragmented and much of the generation and distribution infrastructure is owned by private companies, which makes access to data problematic. Without access to good data on availability of energy, it makes forward planning for Ports (and other heavy users) very challenging and largely based on imperfect data.

Furthermore the energy models available tend to be generated from single source or single vectors such as gas, or electricity. The sector and other energy intensive sectors would benefit from integrated and extended models to include other vectors such as co-generation models for hydrogen etc., and including economic models. This would help identify where Ports feature in the priority rankings for national energy networks.

2. Understanding alternative fuel options

Whist alternative fuels like biofuels, or ammonia & methanol have been in use for some time, there is little available evidence of their impact & effectiveness in reducing pollutants. In particular, there is very little data on retrofit solutions. Ports will be keen to maximise the value of their assets and will be interested in retrofit and conversion solutions.

3. Offshore H2

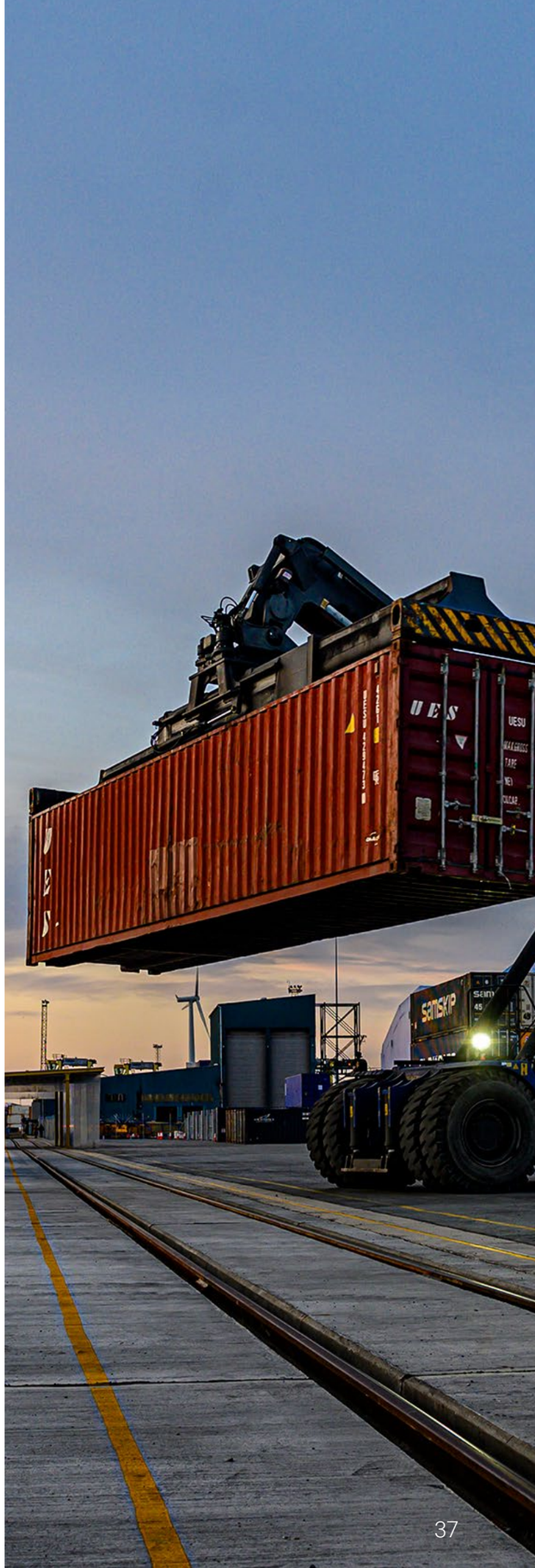
Offshore wind farms and oil / gas rigs present an opportunity to generate and store hydrogen from the electrolysis of seawater using wind energy. There are example projects in the DfT Clean Maritime Demonstration Competition (2021/2). With the increased demand for shipping and with vessels transitioning to new energy sources, which based on current technology, will take longer to re-energise there is an increased potential for queuing at Ports. Also as vessels transition to alternative energy sources, Ports will need to provide a range of fuel and energy sources. Space is very much at a premium in the majority of Ports. Being able to store fuel and energy offshore and re-energise there will avoid congestion in Ports, improve logistics and, for the benefit of the energy companies, reduce edge demand.

4. Safe storage and distribution / transport of volatile or toxic energy

The potential new fuels like hydrogen, ammonia and methanol are toxic and volatile. They will need careful handling and control to safely store and transport or distribute them. The Ports sector is largely unfamiliar with the use of these chemicals and will need expert knowledge to safely integrate them into their industrial facilities. Furthermore, batteries containing Lithium Ion will need special precautions for storing and moving them. Lithium batteries can be very dangerous if punctured, resulting in intense fires or explosions. Specialist knowledge is required to safely use them.

5. Improving energy density

Some of the alternative fuels like hydrogen, ammonia and methanol and electrical storage devise like batteries and super capacitors have low energy density compared to fossil and synthetic fuels. With space at Ports and on vessels at a premium, improving the energy density of these fuels will improve their appeal and take up.



Enabling Solutions & Applications

The Ports buildings, equipment and work boats, visiting vehicles and vessels all form part of the Ports local energy systems. These need to be integrated and enabled to ensure they function safely, efficiently and effectively. To do this they will need to be underpinned by enabling solutions and applications. Some of these are currently emerging in other sectors and require adapting for use in port environments. These include:

1. Smart energy management

Localised energy systems in Ports will be highly complex energy systems with multiple energy vectors and competing demands on limited resources. Solutions will be needed which can automate energy vector selection and prioritise energy distribution to those items in higher need.

2. Emergency response

Future energy systems will utilize fuels and chemicals which are not currently commonplace and in the case of items such as hydrogen or methanol are extremely dangerous if not controlled. These will need careful handling and in the event of fire or spillage they will require new solutions for containment, control and making safe / good.

3. Artificial intelligence and data analytics

As ports become serviced with new sensors and data gathering devices, then it is likely that a range of applications for AI could be spawned to enable greater understanding of complex needs and providing control recommendations. Understanding the potential use cases will help accelerate take up, which is likely to initially materialise in optimising operations and improving safety.

4. Capability Needs Statements

To achieve decarbonising ambitions, many ports will need to either replace or retrofit their existing plant and machinery. There is a substantive and diverse mix of plant and machinery working on Ports both on land and in the water. To assist OEM's and specialist retrofit companies develop low / zero emission solutions, the maritime operators should assemble capability needs statements for the range of larger equipment, working boats and visiting vessels.

5. Fuel switching systems

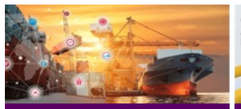
It is highly plausible that Ports will in the future need to offer a range of fuels potentially including diesel, biofuels, synthetic fuels, ammonia, hydrogen and methanol. These fuels have very different properties and usage parameters and mixing would not be advisable. However it would be uneconomical for Ports to install multiple delivery infrastructure systems to suit each fuel. They are likely to want to use a common distribution infrastructure, as airports are starting to explore with jet fuel and synthetic fuels. In Ports however the range of fuels is greater and will need particular scientific understanding and engineering solution.

Other

In the process of exploring the need for further knowledge and understanding, the following areas were identified:

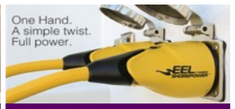
- Effectiveness of non-engineering measures such as behavioural change, variable pricing or taxation
- Effectiveness of short term measures such as fuel blending
- Understanding the potential for using second life batteries for energy storage, peak lopping or transfer of energy, to include an understanding of the circularity potential and how redundant / end of life batteries might be disposed of.
- Understand the effectiveness of approaches to transition of existing plant, machinery and working boats through case studies on replacement of drive trains / augmentation with electrical motors for partial loads or auxiliary loads / and retrofit of components for greater efficiency or introduction of replacement fuels
- Granular mapping of port owner and tenant needs on a range of ports to demonstrate areas of alignment and divergence to better inform benefit mapping.
- Mapping of manufacturing capability and capacity, particularly for shorter term transition approaches and provision of energy systems i.e. shore power.
- Mapping skills and training capacity and developing a plan for upskilling and to inform potential regulations and standards.
- Understanding implications of Ports becoming Energy Companies or for offering Energy as a Service (reputational risk if not available)
- Explore options and implications for in-port emission capture systems for vessels not converted – potential to link to BEIS NZIP CCS programme. Will this be efficient in remote areas far from potential use or long term storage.
- Develop master planning tools based on evidence for future investment decisions, enabling large scale energy transition and retrofit of port assets. Tools should be robust and trusted, encourage best practice and show prioritisation of upgrades needed in ports and infrastructure systems. They need to be flexible to understand capacity and growing demand.
- Fuels / energy vector review – including pro's & con's points of consideration (feedstock resilience / energy infrastructure upgrades)
- Understand the process and ecosystem of making chemicals and other resources needed to include an understanding of economies of scale or opportunities to link to other sectors.
- Understand distribution technologies and strategies around how to transport, store and distribute safely and efficiently. For example if Scotland is to repurpose its oil refineries to hydrogen production, how will this be distributed to remote ports?
- Create a timeline for increased energy generation and new fuels based on volume needed. Explore how this compares against other industrial clusters; and in the face of competing demands and limited resources, what ports should be prioritised.
- Explore what potential role small nuclear power might have in meeting localised energy demand along with other yet unrealised energy sources have, and how might these overtake current approaches. Could this lead to Stranded Assets.
- Explore opportunities to capture waste energy generated in ports, particularly heat and how to efficiently use either to generate electrical energy or as heat in the local area.
- Develop robust and usable port specific means to account for carbon – particularly in shipping where they transition between ports / countries. Explore Offsetting models for carbon that are robust and trusted.
- Understand target setting & implications of doing so. Perhaps use KPI's instead and avoid race to the bottom through using standards and regulation. Develop solutions able to recognise local factors and ability to rapidly change. Select those with 'decarb readiness' appeal for demonstrators. Develop a national reporting system and a league table with details on energy use which uses industry best practice and bespoke measurement.
- Develop a means to share academic and industry learning along with regulatory systems to prompt demand side requests and supply side engagement.

Running concurrently with the Solutions Roadmapping work, the Department for Transport developed a bid for the Autumn 2021 Spending Review. This promoted the creation of a UK Shipping Office for Reducing Emissions (UK SHORE) which is responsible for the delivery of the following funding schemes and focuses on creating science and engineering understanding.



Clean Maritime Demonstration Competition

A multi-year version of the current CMDC, to match-fund industry investment in technology demonstrations across the UK, including the Teesside Hydrogen Hub and Orkney.



Zero Emission Infrastructure Funding Scheme

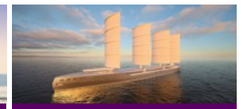
Match-funded industry investment in technologies including shore power and vessel chargepoints, revitalising existing ports infrastructure, enabling the uptake of zero emission vessels and reducing emissions.

Zero Emission Vessels Development Grant

Grants to manufacturers supporting the R&D content of shipbuilding projects, placing the UK at the forefront of the design and manufacture of zero emission vessels.

Zero Emission Ferries Grant

Match-funding scheme to enable the replacement of ferries used for public transport across the UK with low and zero emission solutions, similarly to the ULEB scheme implemented in the buses sector.



Centre for Smart Shipping

A small taskforce within UK_SHORE aimed at providing a coordinating function in the field of smart shipping and autonomy, leading targeted R&D programmes.

Technology focus

Clean Maritime Demonstration Programme

UK **existing strengths in advanced manufacturing, green energy and technologies, and cutting-edge R&D** can be used to foster clean maritime businesses.

Round 1

The UK has invested £23m into the Clean Maritime Demonstration Programme to develop clean maritime technology.

Competition oversubscribed: DFT received 114 eligible bids, from across the UK, with £45m funding sought in total (225% of the available budget) and a total investment proposed of £70m..

Innovate UK independently assessed these bids and identified 55 projects for funding. Ministers have agreed to the proposed approach, for a total of £23.259m grant awarded and a total investment of £33.5m.

This investment is spread across the Union. The UK is also running hydrogen ferry trials in Orkney and are due to launch a hydrogen refuelling port in Teesside.

Round 2

A further £12m of R&D funding was allocated to a second round of the CMDC building upon the success of the initial round of funding. 31 projects were successfully awarded funds to conduct a series of feasibility and pre-deployment trials between January 2023 and August 2023.

For Round 2 of the CMDC a total investment of £20.8m was made and £14.9m of grant awarded to 121 organisations.

Round 3

Round 3 of the CMDC was launched in September 2022 and allocated £60m for technology and system level demonstrations to 19 successful projects. An additional £29.9m of private investment was leveraged alongside the £60m grant awarded

A fourth round of the competition is also planned for summer/autumn 2023.

These later competition rounds target intervention at a higher TRL to bring clean maritime solutions closer to commercialisation.

Zero Emission Vessel and Infrastructure

The ZEVI competition is another high TRL intervention from UK SHORE focusing on near commercial clean maritime solutions. This £77m competition was launched in February 2023 and projects will operate until March 2028. Funding for these projects can be claimed from project initiation until March 2025, after this point projects will undergo a 3 year unfunded demonstration period and the data collected will be used to inform future policy and regulatory decisions.

KTN, through the Decarbonising Ports & Harbours Innovation Network, conducted a survey and ran a workshop to ascertain from industry feedback the types of technologies and solutions that could be utilised to decarbonise UK ports & harbours.

The following information summarises the results from that industry outreach:

Moixa Technologies

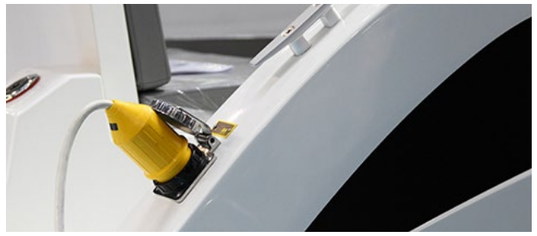
Technology
Site-wide energy system utilizing smart grid, demand-side response and peak shaving

Theme
Energy systems

Target customer
Site operator, Charge point operator, Fleet manager

TRL & Time to market
TRL7, 2 months

Cost to market
£250,000



Pixii Electric Boats

Technology
Zero carbon propulsion for leisure & workboats

Theme
Propulsion

Target customer
Workboat & leisure boat users

TRL & Time to market
TRL4, 2 months

Cost to market
£600,000

Barriers to adoption
Access to funding

MJR Controls

Technology
Shoreside power system to enable cold ironing. Can integrate into generation and storage systems

Theme
Shore power, energy systems

Target customer
Ports & Harbours

TRL & Time to market
TRL6, 6 months

Cost to market
£0

Barriers to adoption
High CAPEX, standardization of ship connection

PinkH2 Maritime

Technology
Resonant control electrolysis to produce hydrogen

Theme
Hydrogen

Target customer
All transport modes

TRL & Time to market
TRL4, 18-24 months

Cost to market
£8m

Barriers to adoption
Access to funding

ACUA Ocean

Technology
Hydrogen powered USV

Theme
Hydrogen, autonomy

Target customer
Port operators

TRL & Time to market
TRL4, 9 months

Cost to market
£1m

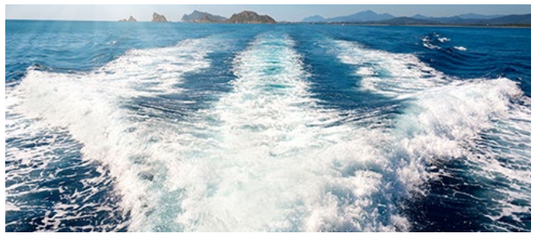
HR Wallingford

Technology
UK Ship Simulation Centre

Theme
Digital

Target customer
Port and ship operators

TRL & Time to market
TRL9



ML Power Systems

Technology
Stage marine engines

Theme
Propulsion

Target customer
All vessel operators up to 1000hp

TRL & Time to market
TRL8, 6-18 months

Barriers to adoption
Access to funding, Business support

FluXXWorks

Technology
Automated cargo handler

Theme
Automation

Target customer
Port operators, cargo owners and shipping lines

TRL & Time to market
TRL2, 24-36 months

Cost to market
£25m-30m

Barriers to adoption
Access to funding

Denchi Group

Technology
Zero emission hybrid powertrain

Theme
Propulsion

Target customer
Vehicle/vessel OEMs

TRL & Time to market
TRL3, 18 months

Cost to market
£1.5m

Barriers to adoption
Knowledge of regulatory landscape

Oxfordshire County Council

Technology
Inland water charge points

Theme
Shore power

Target customer
Inland waterway users and marinas

TRL & Time to market
TRL2, 24 months

Cost to market
£2m-4m

Barriers to adoption
Access to funding, lack of resources

G-volution

Technology
Solid oxide fuel cells

Theme
Shore power, propulsion

Target customer
Power generation on land or vessels

TRL & Time to market
TRL7, 6-12 months

Cost to market
£500,000

Barriers to adoption
CAPEX, production scaling

Hubl Logistics

Technology
Multiple temperature-controlled storage

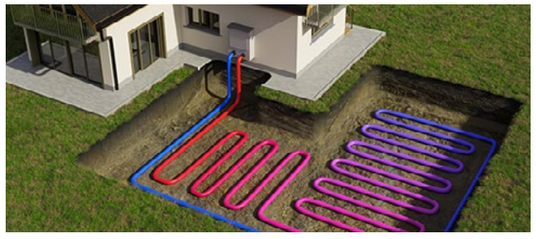
Theme
Storage

Target customer
3rd party logistics, food producers, wholesalers

TRL & Time to market
TRL8, 3-6 months

Cost to market
£300,000

Barriers to adoption
Lack of market pull



Kensa Contracting

Technology
Ground source heat pumps

Theme
Renewable energy

Target customer
Homes, offices, warehouses

TRL & Time to market
TRL9, 3-6 months

Barriers to adoption
Poor market uptake

Hydrogen Afloat Ltd.

Technology
Hydrogen fuel cell power system

Theme
Hydrogen

Target customer
Wealthy boat owners and high-end boat builders

TRL & Time to market
TRL7, 6-12 months

Barriers to adoption
High market price of hydrogen

Rightship

Technology
Satellite mapping technology for emissions monitoring

Theme
Emission monitoring

Target customer
Ports, Terminals, and Harbours

TRL & Time to market
TRL8, 4 months

Cost to market
$600,000

Barriers to adoption
Access to funding

Ecospeed Marine Ltd

Technology
Hybrid and fully electric propulsion system

Theme
Propulsion

Target customer
Vessel owners and operators

TRL & Time to market
TRL8, 6 months

Cost to market
£500,000 to £2m

Barriers to adoption
Access to funding, lack of resources

Coryton Advanced Fuels

Technology
Sustainable liquid fuels

Theme
Fuel

Target customer
Fuel users and distributors

TRL & Time to market
TRL9, 1 month

Barriers to adoption
Lack of support for liquid fuels

Leidos

Technology
Software to optimise shipping movements

Theme
Route optimisation

Target customer
Shipping Lines or Ship Management companies

TRL & Time to market
TRL4, 12-18 months

Cost to market
Not specified

Barriers to adoption
Lack of client engagement

Ricardo

Technology
Decision making model for shore power

Theme
Shore power

Target customer
Port operators, DNOs, legislators

TRL & Time to market
TRL6, 5 months

Cost to market
£75,000

Barriers to adoption
Access to funding

Further examples of projects that, if commercially implemented, could contribute to decarbonising UK ports & harbours are summarised :

Freeport East Energy Hub Feasibility Study

This feasibility study project will explore the potential decarbonisation options available to Freeport East to become both a net-zero port and a net-zero energy hub. Technology options, speed of transition, potential uptake rate and volumes required will be evaluated laying out a clear plan for future investment.

Funding Received
£260,310

Partners Involved
Felixstowe Dock & Railways Company (Lead)
EDF Energy
NNB Generation Company
Cranfield University

Target Customers
Port operators

Theme
Energy systems

Shipping, Hydrogen & Port Ecosystems UK (SHAPE UK)

The 'Shipping, Hydrogen & Ports Ecosystems UK project aims to demonstrate an achievable modular green hydrogen generation system within Portsmouth International Port delivering a decision support tool that will enable port managers to determine the environmental and economic use cases for hydrogen generation and utilisation.

Funding Received
£1,507,063

Partners Involved
University of Portsmouth (Lead)
Cox Powertrain
Lloyd's Register
University of Brighton
Portsmouth International Port
Barter for Things
Connected Places Catapult
Engas Global
Iotic Labs
Knownow Information

Target Customers
Port operators

Theme
Hydrogen

Vertically integrated cloud based ports

This project proposes a cloud-based industrial microgrid for ports deep electrification that simultaneously reduces costs and emissions, and hence reduces the impact of ports and shipping sector on the environment. The technology combines the smart microgrid technology with a higher-level cloud-based services platform that allows third party integration and add-on services. In the feasibility stage an emulated port platform will be produced to measure the environmental impact and business and environmental benefits of both short-term and long-term port operational scenarios.

Funding Received
£285,420

Partners Involved
GE Power Conversion (Lead)
PD Teesport
Connected Places Catapult
Teesside University

Target Customers
Port operators

Theme
Digital

Plymouth's Marine e-Charging Living Lab (MeLL)

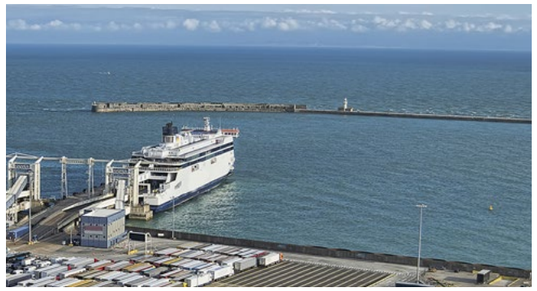
This project will offer a network of shore-side charging facilities for electric marine vessels operating in Plymouth Sound. The project aims to create a blueprint for rolling out shoreside charging on a national level.

Funding Received
£572,686

Partners Involved
University of Plymouth (Lead)
Princess Yachts
Plymouth City Council
Aqua Superpower

Target Customers
Marinas
Harbour authorities
Port operators

Theme
Shore power



Dover Clean Ferry Power (DCFP):

Techno-Economic Feasibility Analysis of Electric Power Solutions for Port of Dover Ferries

The Dover Clean Ferry Power project focuses on the development of innovative solutions to accelerate the adoption of (plug in) hybrid or fully electric propulsion vessels by identifying the current and future electrical power demands of the ferries operating at the PoD. It will find viable, sustainable emissions-minimising pathways for the on-shore supply of the required demand.

Funding Received
£438,326

Partners Involved
University of Kent (Lead)
University of Warwick
Schneider Electric
P&O Ferries
Dover Harbour Board

Target Customers
Port operators
DNOs

Theme
Shore power
Energy systems

Northern Ireland Green Seas

The Northern Ireland Green Seas project will assess 3 use case scenarios for developing the optimal decarbonisation strategy in each location. The main outputs of this assessment will be fully costed plan for a large-scale demonstration of the solutions, including any barriers to adoption, and an investigation into the potential reduction of lifecycle emissions of the solutions.

Funding Received
£551,386

Partners Involved
Energia NI (Lead)
Belfast Harbour
Artemis Technologies
Mott Macdonald
NI Electricity Networks
Queen's University Belfast
University of Ulster

Target Customers
Port operators
Harbour authorities

Theme
Energy systems

Mayflower - The Feasibility Study

The aim of the project is to create a replicable and scalable solution to supply green hydrogen initially to the Port of Immingham and then afterwards other port locations. The study will assess the technical and economic feasibility of a green hydrogen supply to the PoI, incorporating the full hydrogen value chain from production through to end use.

Funding Received
£140,438

Partners Involved
Uniper Technologies (Lead)
Siemens Transmission and Distribution
Toyota Tsusho UK
Uniper Hydrogen
Associated British Ports

Target Customers
Port operators

Theme
Hydrogen

NEPTUNE

NEPTUNE aims to facilitate the Net Zero transition in the Shetland Islands by developing a desk-based Decision Modelling and Support System digital tool to help analyse, scope and develop plans for supporting the maritime eco-system's transition to zero emission.

Funding Received
£478,452

Partners Involved
University of Strathclyde (Lead)
Ricardo
Rosyth Royal Dockyard
Shetland Island Council
University of Strathclyde

Target Customers
Stakeholders looking to enact Net Zero plans

Theme
Digital

Hydrogen in an Integrated Maritime Energy Transition (HIMET)

HIMET will demonstrate maritime decarbonisation enabling technologies, encompassing the design, development, and demonstration of four solutions: 1.Hydrogen systems and future micro-grid architectures for resilient shore-side power; 2.Combustion of hydrogen in a marine propulsion engine; 3.Containerised and marinised hydrogen storage on board a vessel; 4.and the supply of vessel on-board auxiliary power using a hydrogen fuel cell.

Funding Received
£2,284,122

Partners Involved
EMEC (Lead)
Aquaterra
Eneus Energy
Oak Technical Services
Orcades Marine Management Consultants
Orkney Islands Council
Ricardo
Rina Consulting
Schnieder Electric
ULEMCo
Urban Foresight

Target Customers
Port operators,
Ship owners
Bunkering facilities

Theme
Hydrogen

Green Hydrogen Production Barge

To overcome the barrier of hydrogen availability and large costly infrastructure it is proposed that a floating hydrogen production and storage barge would provide a quick and cost-effective way to provide in-port hydrogen without the requirement for significant shoreside infrastructure or the large-scale transport of hydrogen. This innovation would lower the barriers to adoption of green hydrogen as a Marine Fuel and encourage vessel owners, operators and designers to utilise hydrogen in their vessels.

Funding Received
£144,493

Partners Involved
London Offshore Consultants (Lead)
Green Hydrogen Solutions
Poole Harbour Commissioners
Longitude Consulting Engineers Limited

Target Customers
Port operators

Theme
Hydrogen

Clean Tyne - UK Blueprint for Decarbonisation Demonstrator

Clean Tyne will consider the justification and investment case for an integrated, multi-vector digital energy platform to manage the balance of supply and demand in the maritime sector, ensuring the optimisation and resilience of clean energy supplies for shore power, land-based infrastructure and other use cases. The project will establish future use cases and explore the potential for analytical functionality built on the digital foundation and smart port technology to reduce energy costs at the port and support decision making in future infrastructure.

Funding Received
£842,847

Partners Involved
Port of Tyne (Lead)
Siemens Public
Newcastle University
Connected Places Catapult
North East LEP

Target Customers
Port operators

Theme
Digital & Energy Systems

Feasibility Study for Shore Power in Aberdeen Harbour

This project will undertake a Feasibility Study for a next-phase demonstration project for a green shore power scheme in Aberdeen's existing North Harbour. Key outputs will be an Outline Business Case for the scheme and plans for the demonstration project.

Funding Received
£539,582

Partners Involved
Connected Places Catapult (Lead)
Port of Aberdeen

Target Customers
Port operators
Harbour authorities

Theme
Shore power
Energy systems

National Clean Maritime Demonstration Hub

The project will conduct a high-quality feasibility study that, informing a business case for infrastructure-investment in Zero-Emission(ZE) Fuels/charging-infrastructure at the Port of Grimsby, at the same time as investment in operational programmes of work that will establish Grimsby as a national Clean Maritime Demonstration Hub (CMDH).

Funding Received
£411,776

Partners Involved
Offshore Renewable Catapult (Lead)
Associated British Ports
Infrastrata; Lloyd's Register
MJR Controls
Rix Shipping Company
Wood Group
Zero Emissions Maritime Technology
TPG Maritime

Target Customers

Port operators
Bunkering facilities

Theme
Hydrogen

Energy Systems

SUPPORTIVE-SUPercapacitors for zero emission PORT-sIde VEhicles

Westfield and 2-DTech (collaborating with CPI and the Graphene Engineering Innovation Centre (GEIC) are jointly developing new high-performance energy storage system (ESS) technology specifically aimed at enabling the electrification of port vehicles/vessels based on the use of novel high-power, high-energy density **supercapacitors.**

Funding Received
£837,683

Partners Involved
Westfield Sports Cars (Lead)
Centre for Process Innovation
Milford Haven Port Authority
2-Dtech

Target Customers
Port operators
Vehicle OEMs

Theme
Vehicle electrification
Energy systems

Port of Aberdeen - Port Zero Project

A Feasibility Study to understand how Port of Aberdeen can decarbonise day-to-day operations to support organisational and UK net zero goals by 2040 and 2050 respectively will be conducted

The project will look to understand future power demands, low carbon energy supply sources and will develop a roadmap for implementation to decarbonise port operations which will improve conditions for port users and the wider Aberdeen City region.

Funding Received
£288,829

Partners Involved
Aberdeen Harbour Bord (lead)
Energy Systems Catapult
Connected Places Catapult

Target Customers
Port operators

Theme
Energy Systems

Green Shipping Corridors:

Feasibility of the world's first hydrogen powered North Sea crossing

This feasibility study develops a detailed project plan for the world's first hydrogen-powered zero-emission crossing demonstration from the Port of Aberdeen in the UK, to Norway in 2024, an economically important potential green shipping corridor route.

The project furthers baseline research conducted by the Port of Aberdeen entitled "Hydrogen Port" by developing new hydrogen risk and regulatory assessments, technical blast and bunkering analysis and expanding use-cases for the safe operation of hydrogen fuels in the Port.

Funding Received
£162,145.90

Partners Involved
Acua Ocean (lead)
Aberdeen Harbour Board

Target Customers
Port operators
Vessel designers
Ship owners

Theme
Green Shipping Corridor

Floating Fuel Depots for Offshore Wind

A system of Floating Fuel Depots (FFDs) is proposed as a means of facilitating the supply of fuels to this fleet, while optimising transit distances, reducing emissions and easing pressures on port facilities. Through this project, Apollo, EMEC and Aquatera will thoroughly explore the technical and economic potential of the FFD concept, while investigating the environmental, societal and economic opportunity that they present.

Funding Received
£318,532.20

Partners Involved
Apollo Offshore Engineering (lead)
Aquaterra
EMEC

Target Customers
Ship owners
Bunkering facilities,
Fuel providers

Theme
Energy systems
Hydrogen

Virtual Bunkering for Electric Vessels - VBEV

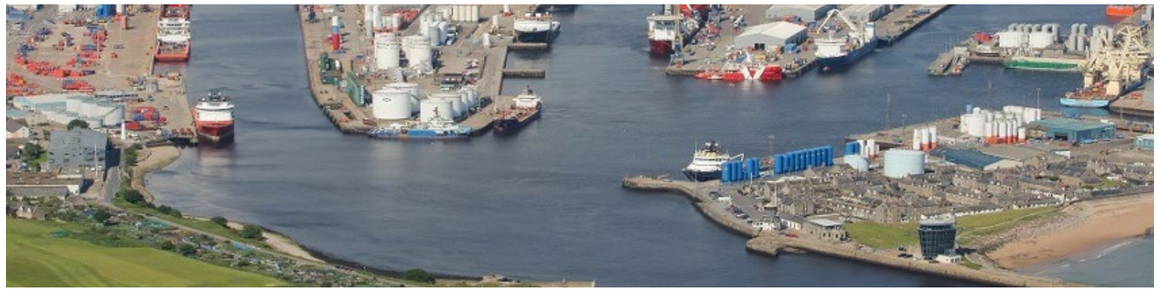
Virtual bunkering enables aggregated electric boat batteries to provide additional value when not being used for propulsion. With the transition to electrically powered recreational and commercial craft, harbour and mariner charging infrastructure will be required. The provision of sufficient power at an affordable price to harbours and marinas represents one barrier to the widescale adoption of electric boats, the high upfront cost is another as well as potential battery degradation from infrequent use in leisure craft another.

Funding Received
£259,946.40

Partners Involved
Aqua Superpower (lead)
University of Plymouth
Cenex
Indra Renewable Technologies

Target Customers
Harbour/marinas

Theme
Energy systems



Green Corridor at Short Straits (GCSS):

Feasibility study into establishing a Green Corridor between Port of Dover and the Ports of Calais and Dunkirk

In this project the Dover-Calais/Dunkirk Green Corridor consortium focuses on the development and feasibility of implementing a green corridor between the Port of Dover and the Ports of Calais and Dunkirk. The GCSS project partners will collaborate for eight months to identify and analyse the full value chain and determine viable energy pathway options for both marine and landside vessels and vehicles. The project will ultimately produce a GC business case and route map that can be used to both scale up the number of zero-emission vessels and corresponding landside infrastructure, but also to attract private sector investment and replicate the corridor elsewhere.

Funding Received
£595,162.40

Partners Involved
Dover Harbour Board (lead)
JG Maritime Solutions
Sea Utilities Solutions
University of Warwick
Irish Ferries UK
Schneider Electric
DFDS
ABB
University of Kent
Ikigai Capital

Target Customers
Port operators

Theme
Green Shipping Corridor

HyBunk

H2GO Power have joined forces with Waterwhelm, to develop an energy efficient proposition towards the decarbonisation of ports. Through this proposed feasibility study, the technical and economic feasibility will be assessed prior to proceeding into a full-scale demonstration of the proposed solution at a port.

The entire solution's feasibility will be assessed by using H2GO's novel AI-enhanced software platform (HyAI) for the optimisation of hydrogen systems in terms of cost and environmental footprint. HyAI will be collecting a large amount of real-time data sets from Port of Leith in order to accurately simulate the proposed system's operation.

Funding Received
£452,421.20

Partners Involved
H2GO Power (lead)
Waterwhelm

Target Customers
Bunkering facilities
Port operators

Theme
Hydrogen
Digital

Smart Shore Power System with energy storage for self-discharging commercial vessels supporting Whole Vessel Efficiency

The objective of this project is to undertake a study to determine the feasibility of developing, in a practical, environmentally and economically sustainable manner, a shore-based store and release electrical energy solution; capable of meeting the fluctuating electrical load demands of commercial cargo vessels operating, in addition to vessel base loads, ship-mounted self-discharging cargo equipment drawing frequent high peak transient electrical loads throughout extended duration cargo operations.

Funding Received
£435,629.30

Partners Involved
Independent Control Systems (lead)
University of Warwick
Cemex

Target Customers
Any stakeholder looking for energy storage solutions

Theme
Energy systems

Clean Tyne Shipping Corridor

This Clean Tyne Shipping Corridor consortium aims to support this transition by undertaking a feasibility study to establish a green shipping corridor from the UK north-east shore with the vision to join up with the Europe Green Shipping network and accelerate uptake through diffusion.

The consortium will undertake an analysis of the innovative green shipping technology requirements for both vessel and landside infrastructure. It will also produce the roadmap for implementation based on identified barriers such as the regulatory framework, information sharing, and infrastructure investment, as well as possible actions to address them.

Funding Received
£398,217.40

Partners Involved
Port of Tyne (lead)
Newcastle University
North of Tyne Combined Authority
EDF Energy R&D UK Centre
Ove Arup & Partners
Connected Places Catapult
Lloyd's Register

Target Customers
Port operators

Theme
Green Shipping Corridor

Zero-Emission Multi-Fuel Station (ZEMFS) for Hydrogen and Electric Small Craft

To decarbonise the operation of waterborne small crafts, the following had to be addressed.

- The safety of storage of hydrogen and ammonia onboard vessels
- The continuous availability of zero carbon fuel for bunkering (LH_2) or (LNH_3)
- The willingness of vessel owner to convert to zero-carbon fuels

This study will lead to the development of a Zero-Emission Multi-Fuel Station (ZEMFS) that uses a single source of liquid hydrogen (LH_2), to provide zero-emission fuelling of Liquid hydrogen (LH_2), compressed gaseous hydrogen (CGH_2) and electric charging options, at the port or harbour.

Funding Received
£233,176.60

Partners Involved
Unitrove Innovations (lead
Acua Ocean
University of Strathclyde
Zero Emission Maritime Technology

Target Customers
Port operators
Vessel owners
Bunkering facilities

Theme
Energy Systems

Trust & Risk

Bringing diffuse organisations together to tackle major challenges requires the means to develop trust and manage risk to facilitate efficient and significant change.

Trust

Trust helps build relationships and is a great enabler of collaboration, which helps to bring together creative responses and encourage parties to work together on common challenges.

In the workshops our contributors considered the following would have the most benefit in creating trust in the solutions emerging:

Establish and maintain a curated map of the supply chain for decarbonised solutions suitable for ports (potentially utilising the Networks Landscape Map. This would help develop a credible indicator of capability and capacity providing confidence to invest in solutions. This would also help solution developers reach investors and customers.

Develop a credible supply chain through a range of coordinated initiatives to include the robust demonstration of technology solutions, with standardised testing / assurance to allow for comparison of approaches and validate claims on performance.

Develop a common understanding of the ecosystem not solely from the maritime sector but wider supporting/interconnecting sectors. Establish a thorough understanding of the priorities and needs of the diverse range of stakeholders – see later section on stakeholders.

Some of the assets within and visiting ports, such as lifting equipment, work boats, road and rail freight, that will be operating in 2050 already exist, and those that will be purchased in the next decade are unlikely to be low or zero emission ready, as the market for equipment and plant mobilises to provide them, which is unlikely to be before 2030 at scale. These ‘legacy assets’ will need to have a robust plan in place to address them and prevent them from becoming ‘stranded’ assets. Developing a robust plan now will provide guidance and confidence to purchasers to avoid stranded assets.

Risk

Risk is the potential for something bad or unwanted to happen, which can have a detrimental effect on a project or not realise all of the benefit of change.

In the workshops our contributors considered the following would have significant potential to reduce the benefit of emerging solutions:

When it comes to demand and provision for decarbonised energy, there is anecdotal evidence of a chicken v egg scenario playing out. The maritime operators are unwilling to invest in low emission technologies if they are unable to secure robust supplies of the energy or fuel required to power them. Low or zero emission energy and fuel providers are unwilling to invest in supply solutions that have insufficient or highly fragmented demand. There is a risk that the sector may be unable to break this cycle of demand & provision (chicken v egg).

Demand for decarbonised solutions is growing with several ports developing net zero transition plans and a handful implementing early-stage solutions. If this transition accelerates and diversifies it will quickly exceed capability of the energy and transport sector to meet the demand and momentum will be lost. The sector should look to co-develop a transition plan and map demand to allow the supply chain to mobilise.

As discussed in the Trust section, as the sector continues to invest in fossil fuel based assets, there is a risk that these will become 'stranded' as carbon based fuel sources become unavailable or uneconomical to procure whilst the asset retains a service life. This is likely to lead to investment in low demand solutions which offer a reduction in use of fuel, but which are less effective solutions in reaching low or zero carbon whilst tying the user to this asset.

Whilst significant progress has been made by the International Maritime Organisation and the UK Regulators / Government Departments and trade bodies, there is a perception of a fundamental lack of domestic and international coordination. This is leading to trend setters 'ploughing their own field' and developing solutions which suit their specific needs which are not readily scalable. Original Equipment Manufacturer's (OEM) developing solutions that are serving non UK specific country needs or markets, where for example a readily available energy source might dominate.

System change which is catalysed by Government investment can be disrupted with little forewarning in the wake of prioritisation of other challenges – recent examples include Covid 19 Pandemic and Brexit.

Maritime sector and in particular ports and harbours are widely distributed about the UK with responsibilities for regulation and taxation being devolved. This fragmentation could lead to a local disconnect and poor communication between groups and organisations. This in turn can lead to silos of no/slow change. This may cause gaps in the supply chain preventing positive change from occurring efficiently and effectively.

As demand for new energy vectors for port users grows and if mainstream energy providers are unable to meet the demand, this might create new roles for ports as an energy generators / distributor which is unfamiliar territory. Ports may not be able to adapt to this new role or want to be in this position? Greater collaboration between ports and the local DNO may help mitigate this or open new opportunities for energy service companies?

Ports are dynamic places of operational and industrial activity. There are many conflicting priorities within a port. Lately managing the post-Covid and post-Brexit situations have placed considerable financial and operational restrictions on ports, on top of business as usual activities, which has for many, relegated decarbonising to a lower priority in the short term.

Energy and Fuel prices in the last year has been volatile with diesel prices rising dramatically, coupled with the suspension of 'red diesel' reduced tax fuel. This has rapidly driven up operational costs reducing ability to invest in new solutions. There is growing concern, that as diesel usage is dominated by land transport usage – 80- 90%, that with the banning in the UK of new diesel car and van sales after 2030, suppliers of diesel will restrict availability and with the loss of scale, be forced to drive up costs. There are early signs of this happening now, and there is expectation that this risk might materialise earlier as consumers switch to EV's.

Portfolios

Portfolio is an approach whereby different aspects of a project are addressed simultaneously or brought together to manage risk in them more efficiently or effectively.

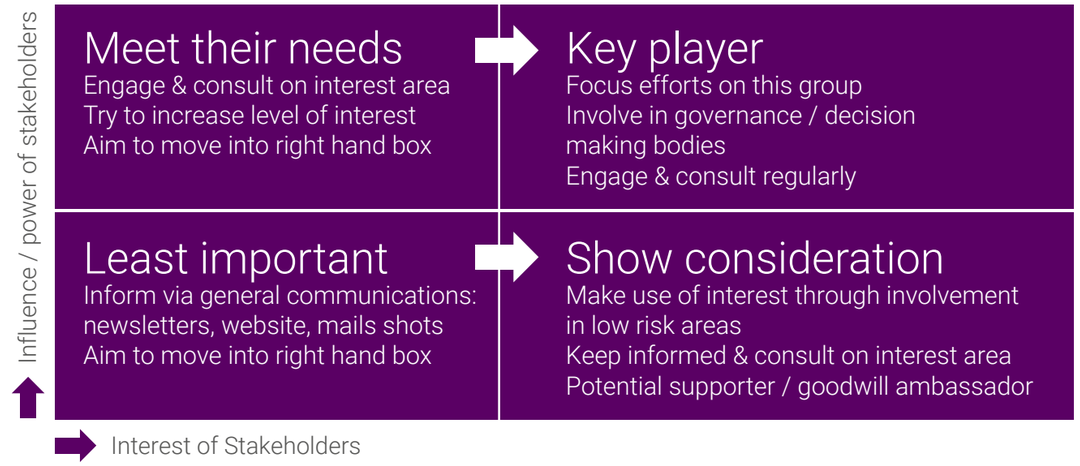
In the workshops our contributors considered the following would have the most potential to reduce risk through a portfolio approach:

- Collaborate with cross sector initiatives and openly share learning (non-combative). Ports work in a commercially aggressive arena and are by their nature highly competitive, that can make them combative over aspects of their operation. Decarbonising presents a risky and substantive challenge to their operations. This risk can be greatly reduced by sharing the burden of R&D and innovation development, developing common approaches, sharing best practice and offering a wider market for solution adoption. As working practices and funding has started to appear, there has been a marked desire for means to collaborate and an eagerness to show progress.
- Many of the solutions being developed and particularly those needed will be interconnected and cut across systems. This will lead to the development of a systems of systems approach (internally within Ports and their external services and infrastructure). This needs Ports, their service sectors and their stakeholders to actively put resources and leadership in to developing these, and not just warm words.
- The Government and Local Civic Leaders have a strong role to play in promoting a portfolio of work across the port and the localised areas. This might include promoting Localised Leadership groups working across sectors, and consider developing Codes of Practice – for example Heat Networks developed a Civic lead Code of Practice to encourage industry to work together and across technical and physical boundaries.
  As decarbonising Ports cuts across a number of systems consideration should be given by Leaders and Regulators around consolidating existing networks by geographic areas to share risk, learning and coordinate activity.
- Moving towards coordinated cross sector activity will draw upon an extensive range of Government Departments and their Agencies. They should be encouraged to improve coordination of their activity. In particular DfT & BEIS, DIT, DEFRA MCA, EA, UK SHORE and HMT should be encouraged to develop improved ways of Cross Whitehall working and open engagement with industry. The Freeport Initiative is seen as a good example of ambition and with the formation of cross Whitehall teams through groups such as the Freeport Regulatory Engagement Network from the Better Regulation Executive these could become working models for a wider coordinated engagement approach. This takes commitment from the Executive level and dedicated resources, which are too often in short supply.

06

Stakeholders

Innovate UK



Transformative change programmes are delivered by people, and large scale programmes and initiatives involve complex networks of people and organisations, referred to as 'stakeholders'.

Ports & Harbours are often complex multi modal transport hubs with numerous organisations operating, servicing, monitoring, controlling or financing activity within them. The stakeholders form complex and extensive networks across local, regional, national and international boundaries. In this section we want to identify principal stakeholder organisation or groups whom need to be engaged with to support the decarbonisation activity and identify their potential level of influence and interest.

Stakeholders will have varying levels of influence or power over a project and varying levels of interest. These will vary over time and at different stages. It is often useful to analyse and categorise these stakeholders to help manage communication and engagement. Using a simple matrix tool might help manage their inputs.

Through our work in this Innovation Network we workshopped a stakeholder matrix and identified a vast number of stakeholders whom will exert influence of varying degrees over the route to a decarbonised sector. We have attempted to distil these workshop outputs into the following key messages:

Those with the **least level** of direct influence, although one might argue they have a substantive indirect influence, would be the popular media, trade unions and the public at large. Communication and engagement with these groups might be through broadcast solutions such as general podcasts, general update mailshots, awareness raising events.

Those who should be **shown consideration**, would include adjoining areas of economic and industrial activity, but which are not directly connected to the Port. This might include other international ports. Communication and engagement with these groups might be through targeted mailshots, dedicated engagement events, specific meetings.

Those who should have their **needs met**, who should be engaged with and consulted to raise or maintain their interest in the subject will include:

- Port Operators – specifically those organisations responsible for current fuel bunkering and energy provision services
- Policy makers & funders – whilst these will predominantly feature in the Key Player section, there is a place here for influential peripheral organisations such as conservation groups, Chambers of Commerce
- Solution providers - business support services, energy network providers, fuel or energy developers in other related sectors such as rail or road
- Trade bodies and lobbyists - road and rail freight organisations, local community groups such as LEP's etc., fishing associations

Communication, engagement and collaboration with these groups might be through targeted mailshots, specific meetings, engagement / discussion events, round tables, presenting at conferences of mutual interest, potential for joint consultation and funding calls.

Those who are **key players** and who should be the focus of engagement activity. They should be consulted with early and communication should be planned and maintained. They will have influence over governance and decision making in relation to decarbonising solution deployment. This group would include the likes of:

- Port Owner / Operators – engagement with this group should be mindful of the three mainstream ownership models in the UK, private, local authority, and trust ports. All of which, pretty much, operate as commercial entities but they do have different motivations and clients. There are a growing number of major ports who have developed decarbonisation strategies with a handful commencing limited installations and transformation – see case studies and solutions sections of this report for examples. Many of the major ports have decarbonisation as a key challenge and opportunity in their future business plans.
- Solution Providers – with decarbonising ports and harbours being an expansive subject there are a wide number of solutions both technical and non-technical which we have explored earlier in this report. These might be grouped into categories including mobility systems (road, rail and water), building systems, handling systems, and enabling systems. The Distribution Network Operators (DNO's) are
- Policy makers and funders – there is a wide cross section of key players in this subgroup, drawn from international, national, regional and local spatial scales. Decarbonising ports and harbours will straddle a number of government departments most prominently Transport; Levelling Up and Homes and Communities; Business, Energy and Industrial Strategy and Treasury. Transport and Energy are devolved responsibility areas and so the equivalent sections of Devolved Administrations in Northern Ireland, Scotland, and Wales should be engaged. Government executive agencies also have a regulatory role to play, and this would include the Maritime and Coastal Agency (DEFRA), Office of Gas and Electric Markets (BEIS), Better Regulation Executive (BEIS) and UKSHORE (Transport). Local Authorities, whether as owners, regulators, economic development drivers or spatial planners will have a strategic role to play in the future development of ports. And at an international scale the International Maritime Organisation, which is based in London, will have a pivotal role driving international efforts at decarbonisation in this global industry.
- Trade bodies and lobbyists – these groups have a substantive role to play in engaging with disperse and sometimes peripheral groups and formulate an industry voice to a wide range of topics. Major ports are well represented by the British Ports Association and the UK Major Ports Group; the vessels have representation from bodies like the Working Boats Association and the UK Chamber of Shipping; and there are umbrella groups like Maritime UK and the Society for Maritime Industries..
- Academia – is represented by MarRi UK and a host of specialist RTO's and Universities in key locations including: Glasgow, Hull, Liverpool, Newcastle, Plymouth, Southampton, and UCL.

Communication, engagement and collaboration with these groups might be through targeted mailshots, specific meetings, engagement / discussion events, round tables, bespoke conferences, potential for joint consultation and funding calls, establishing working groups and innovation platforms.

07

Systems

Innovate UK

Ports and Harbours are complex zones of industrial, business and transport activity with complex needs for resources.

As multi modal transport hubs they are surrounded with a range of facilities housing a wide variety of commercial and industrial activity, all of which consumes large and fluctuating quantities of energy, with its associated emissions. Transforming these facilities from dependency on fossil fuel derived energy, principally diesel, gas and grid electricity to a low carbon or net zero solution will require drawing upon expertise and inputs from a suite of systems to enable timely and efficient transformation.

Instigators of change will need to draw upon technical expertise and inputs for a wide cross section of disciplines and sectors. Complex interconnections between disciplines or supply chains, new or existing which may need reinforcing with new relationships. New capabilities may need to be integrated into existing supply chains and the commissioning body.

Commissioning bodies will similarly need to draw upon capabilities new and existing in benefits and financial management. Spillovers are benefits that could be captured from or delivered to other sectors through creating new solutions in Ports & Harbours. Ports and Harbours tend to be located in dense commercial or urban settings and any decarbonised energy system will have potential to create benefits in adjoining areas. And we recognise that major innovative infrastructure projects require significant financing and thus commissioning bodies must have a strong understanding of sources of public funding and stimulus initiatives; and sources of private finance & investment.

Cross Sector Discipline Working & Learning Cycles

The ecosystem around decarbonising any industrial facility can be complex, but Ports and Harbours have potential to be extra ordinarily complex multi modal transport hubs in extensive commercial and industrial complexes. As such they draw on an extensive network of parties in particular linkage between government departments to use public levers in the domestic arena (DfT (UKSHORE), BEIS (OfGEM), DEFRA (EA) & MoD (RN) and DLUHC) and then the International Maritime Organisation for international arena, Local Authorities, academia, industry, standard bodies, trade bodies and a host of disperse regulators. One sub area that is oft overlooked but which does require integrating in decision making relates to navigating inland waterways.

From industry other sectors and sub sectors have ongoing decarbonisation programmes and can provide expertise and share supply chains. There is a growing mass of expertise in key relatable sectors such as airports, road haulage, rail freight handling, construction and LA service providers.

At present, two disciplines stand out as ones whom need to develop a working network to share data and strategy for decarbonising. The Shipbuilders and plant suppliers / OEM's need to co-develop strategies with the Energy System Distribution Network Operators' and Supply companies, to ensure pace of development of decarbonised vessel solutions match the pace of availability of decarbonised energy vectors.

Spillovers

Ports and Harbours are by their nature, located in coastal and remote locations in relation to the largely centralised energy system in the UK. Being at the edge of the system and creating a potential substantive increase in energy demand can provide impetus for upgrade to the system. Or conversely, if their solution has significant energy generation or storage this may contribute to offsetting grid reinforcement. Both of these scenarios provides benefits to the DNO and other users in the vicinity.

Because they are likely to be large projects delivered over many years and with several sub projects they provide for a stable base load for capabilities development and financing. This is likely to stimulate a prolonged need for skills and training in deploying and operating decarbonised solutions and a market for investment in people, facilities and equipment.

Funding

To meet the target of achieving Net Zero by 2050 the maritime sector needs significant investment through the 2020s and 2030s to accelerate the transition towards a decarbonised future.

A range of funding mechanisms will be required to support this transition including both public and private funding. Since the UK committed to achieving Net Zero by 2050 the funding for the maritime sector has been sparse, especially for ports. If the UK is to achieve the aim within Maritime 2050 of retaining its position as a leading maritime nation investment in the sector comparable with other leading nations such as Norway, The Netherlands and Singapore is required.

Recent funding opportunities

Ports Infrastructure Fund (2020) - £200m to enable maritime ports, airports and international rail termini currently handling goods imported from the EU to access funds to build the necessary infrastructure and facilities to enable customs and sanitary/ phytosanitary checks to be carried out at ports following the end of the Brexit transition period.

Levelling Up Fund (2020-25) - £4.8bn to invest in high value local infrastructure. Aim to focus on high priority local projects rather than narrow technology focused funding pots. For example, East Cowes Marine Hub were a Round 1 recipient.

Strength in Places Fund (2021) - £316m allocated. A UKRI programme that helps areas build on areas of existing strengths in research and innovation to deliver benefits for their local economy. For example, Artemis Technologies were awarded £33m to decarbonise a commuter route between Belfast and Bangor in NI.

Clean Maritime Demonstration Competition (2021) - £23m of R&D funding awarded to 55 projects to provide a springboard for the maritime sector's journey transition towards a cleaner smarter maritime future. 14 projects include port owners/operators as part of the consortium.

Clean Maritime Demonstration Competition Round 2 (2022) - £12m of funding awarded to 31 projects to develop more feasibility studies and pre-commercial trails of clean maritime technologies.

Clean Maritime Demonstration Competition Round 3 (2022) - £60m announced to focus on high TRL demonstrations of clean maritime solutions. Winners to be announced in 2023.

The Niche Vehicle Network runs three competitions annually, providing match-funding for niche vehicle technology organisations to accelerate the development of zero emission and low carbon vehicle technology from concept through to production. Previous winners include a consortium led by Hypermotive working on fuel cell hybrid vessels.

Ofgem Strategic Innovation Fund - £450m (2021-2026). A partnership between Ofgem and Innovate UK the Strategic Innovation Fund will unlock greener ways to travel and to heat and power homes and businesses, by harnessing a new approach to energy network innovation.

Transport Technology Research & Innovation Grant (TRIG) (2014-Present) - Delivered by the Connected Places Catapult, supports future leaders in transport innovation by awarding 100% funding for the development of new technology, allowing innovators to either succeed or fail fast. The programme also provides a collaborative space for innovators, including academics, SMEs and large businesses to work with DfT's policy teams on realising shared goals.

Since 2014, TRIG has awarded £10.3m for 294 innovation projects and our alumni of successful innovators is growing! If you have an idea that could make the UK's transport systems safer, greener, more resilient, and more accessible we want to hear from you. For the past 2 years there has been a dedicated funding strand associated with maritime decarbonisation.

MarRi-UK, an innovation vehicle between maritime industry and academia, has hosted 3 funding competition to-date with a total value of £3.35m. All competitions revolve around clean and smart maritime operations. Previous winners include a consortium led by the Port of London Authority to develop a national hydrogen highway on land, sea and within port.

Through the EU Green Deal, the first round of call under the Horizon Europe framework, the Zero Emission Waterborne Transport Partnership has approximately €100m to spend on innovative projects tackling the challenge of decarbonisation in 2021-2022.

Future funding

The UK Shared Prosperity Fund, a fund in a post-Brexit UK that replaces European Regional Development Funding (ERDF) is set to be worth £2.6bn during 2022-2025. The aim of the fund is to reduce inequalities between communities and to help deliver sustainable, inclusive growth.

Net Zero Innovation Portfolio. Launched in 2021 this £1bn fund will enable low-carbon technologies and systems. Decreasing the costs of decarbonisation, the Portfolio will help enable the UK to end its contribution to climate change. Tranches of this fund include carbon capture usage and storage, energy storage, offshore wind and hydrogen.

Multi-year Clean Maritime Demonstration Competition. Announced in the 2021 Spending Review and following on from the success of the CMDC a multi-year programme to continue the work in developing clean and smart innovative maritime technology was announced. £206m has been committed to future rounds of the CMDC. Round 2 launched in Spring 2022, with Round 3 in Autumn 2022 and Round 4 expected late 2023.

The funding provided to date has been substantive and disperse and has provided a great impetus for innovation and activity. To maintain this momentum a mixture of public funding will need to be available in the next parliamentary period, including differential funding recognising the range of port ownership models - commercial, trust and public ports.

The sector would welcome the opportunity for bilateral funding with international ports (where many decarbonised ports are publicly funded / supported like Baltics, Barcelona, Rotterdam, or Singapore). The UK has a long standing history of innovation led bilateral funding programmes, and there are already a few small examples in place with Singapore around autonomy which could be built upon to address the common challenge of green shipping and decarbonising port operations.

Public funding could be directed to pilot projects demonstrating a complete ecosystem, not just compartmentalised. Recent funding packages from DfT (hydrogen in road Freight) and BEIS (Red Diesel replacement in construction and mining) have been directed to system or well to work projects. Commissioning bodies are expressing concerns over investing in unproven whole systems without seeing verified data on performance and benefits. Demonstration projects will greatly improve investor confidence and drive refinement in solutions.

Port wide solutions will require commissioning bodies to have access to substantive capital funds at affordable rates or compelling tax incentives. Ports are largely unfamiliar to these fund markets, where they need capital fund to provide attractive loans to support scale up as in Baltic, Barcelona and Rotterdam.

The maritime sector is keen to explore opportunities to draw in people with funding & investment expertise, to showcase opportunities, present perspectives of solution providers / asset owners. This will aim to bring viable opportunities for investment to them and build a community within investors. This might include:

- Round tables - setting up a set of round tables on different types of finance; what investors want to see; what R&D funding has been spent; how to finance long duration investments.
- Showcase – technologies around decarbonising haulage / freight; decarbonising plant and vessels; and energy systems, and how the sector has made good use of funding to date through examples like Southampton and Portsmouth, Port of Tyne, Plymouth, Teesside and Humber who offer a range of solutions deployed as pilot projects on aspects of decarbonising.
- Models – develop model investor partnerships, perhaps through segmentation around investment in new / retrofit or in lifting v movement etc., or versions for multi owners / responsible parties or low and high-risk items.

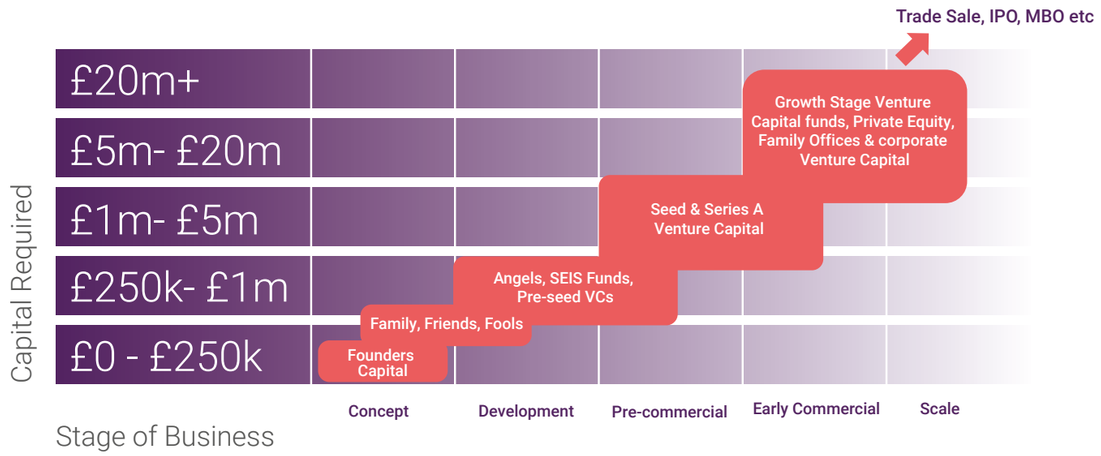
Finance

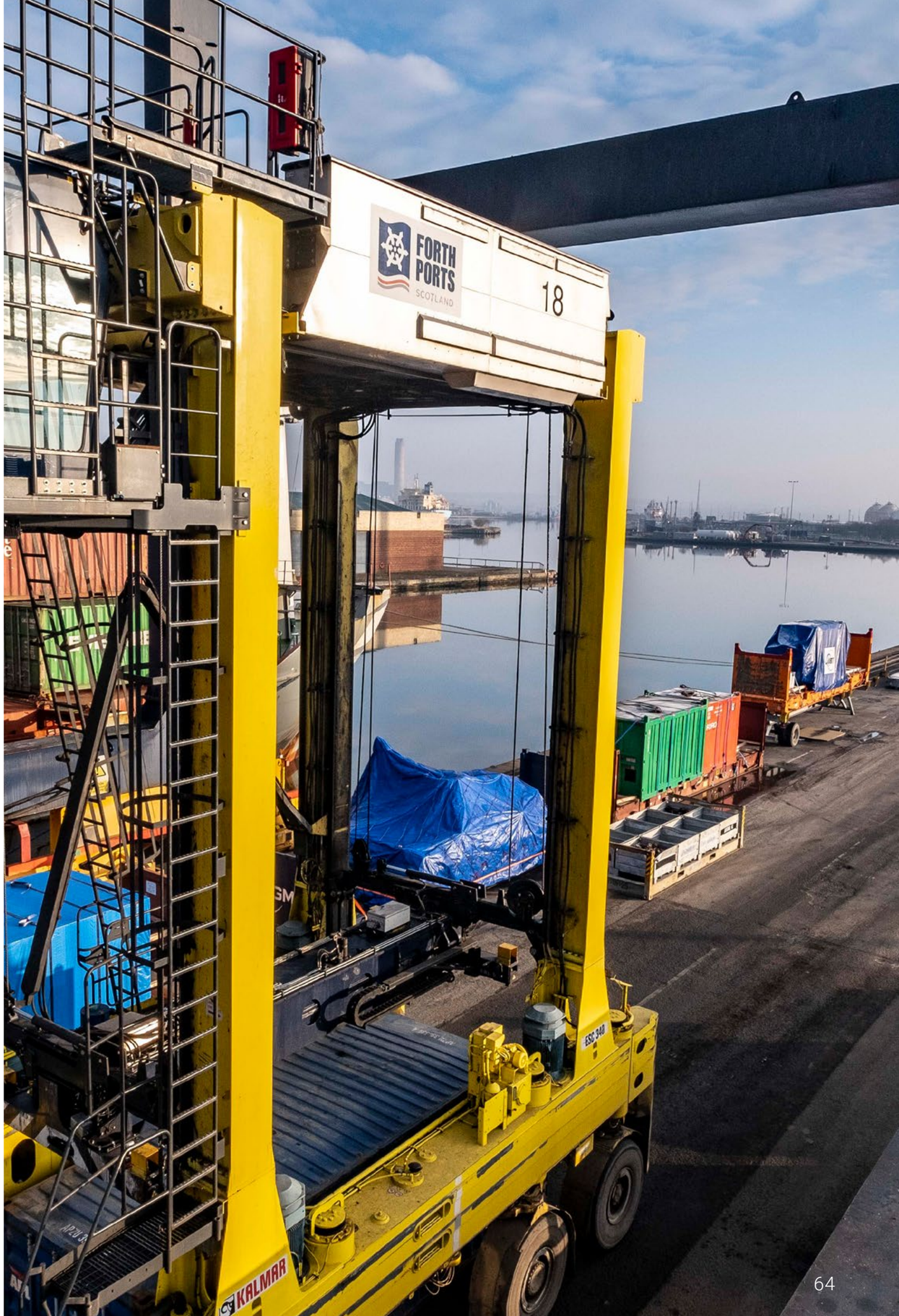
Unquestionably the most frequent question or statement posed when discussing transformational change projects in infrastructure systems, is one of finance. How to access affordable, stable, long term finance for adapting existing systems, installing new systems and the long term maintenance and upgrade.

Whilst the UK enjoys a diverse range of financial instruments, they have been slow to engage with the maritime sector beyond vessel finance. But this is changing with a strong recognition of the need to finance decarbonisation of our maritime infrastructure, with the UK National Infrastructure Bank, UK Green Investment Bank and the British Business Bank making specific provisions.

Looking wider afield, there are examples of co-dependant organisations delivering JV projects with co-financing, for example Maersk in the Baltic Seas co-financing installations with the Port Owners.

Investment Journey





What sources of investment are available now and what will be required for 2050?

What's available now?
Who to engage with? Examples...

In the UK:

Green Finance Institute
- Policy body which advises industry and government on green infrastructure projects

Green Investment Group

UK Government - Green Bond Scheme
- Scheme is set to help finance Green Infrastructure projects - can this be leveraged to support ports and other actors in de-carbonisation projects and step change shifts industry.

British Business Bank
- To support the UK economy through increased business investment, growth and jobs.
- The Finance Hub has been built to help businesses understand and find the finance options best suited to them

UK Infrastructure Bank
- Partners with the private sector and local government to finance a green industrial revolution and drive growth across the country.
- Help crowd in private investment alongside public money across a Net-Zero portfolio.
- Could be very useful for bringing together the various private and public actors involved in ports.

Traditional and investment banks
- JP Morgan, Goldman, Barclays and the like.
- Lloyds have made a strong commitment to ports.
- Often will be offering debt instruments. These are favourable to large private organisations but do not seek to directly address the how to engage a multi stakeholder approach

Private Equity & Venture Capital
- Private Equity - may hold positions in privately held ports and various companies across the value chain.
- Venture Capital will be interested in investing in the core technologies supporting the transition. Whether digital or hardware to solve energy crisis.
  - o See www.signol.io/

Project Finance
- Mix of debt and equity to support long term infrastructure.
- Multi-stakeholder - may be an avenue for larger project post demonstration and to scale up.
- Good for those technologies with low technical risk or those already at TRL-9.

Asset Finance
- Needs to be looked at for financing costly assets.

Outside of UK:

Green Shipping Fund
- The Green Shipping Fund is a €420 million private debt fund that provides shipowner loans for new and existing vessels or retrofits that comply with our ESG criteria and lower their emissions in order to meet the IMO's 2030 and 2050 goals and the EU Green Deal.

What will be required in the future?

Green Maritime Fund - British Ports

- Called for a Green Maritime Fund to help support ports with the transition to net-zero in a manner which can deliver

A mixture of legislative pressures such as removing tax incentives on fossil fuels and a mixture of innovative government backed investment vehicles to stimulate innovation across stakeholders and assets requiring decarbonisation.

Adoption of new technologies is difficult and prolonged due to long term pre-existing assets held under contract restricting new innovation. What incentives can be provided to ensure future contracts have green considerations at their core?

- Tax?
- Levies?

Innovate UK / Department for Transport / BEIS could pull together a collaborative fund, with a matched private investment pot, with a targeted roadmap which incentivises consortium building across stakeholders and fund demonstrator projects to be scaled up.

- A similar approach is being explored in relation to the aviation sector through its vision for Future of Flight
    - Both sectors will need to engage with multiple stakeholders, regulators, high public interest and expensive long term assets.
    - Future flight brings together infrastructure providers, technologists, local governments, private enterprise to build consortia to scale up technologies.

As support and investment services are developed they should recognise the need for continued multi-billion pound commercial investment in maritime infrastructure that makes the UK a globally attractive destination for all maritime business.

Close collaboration between industry, government and different parts of the supply chain, will enable lessons to be learned from other sectors, ensuring new regulation is appropriate and helping maritime companies realise the benefits of research and investment. Ultimately this will lead to the development and swift uptake of clean technologies.

The government is and should be encouraged to continue to incentivise innovation, working with ports to support R&D, foster beneficial partnerships with SMEs and create conditions conducive to testing of new technologies. New transport modes and models of use such as drones, autonomous vehicles, platooning of trucks and their impact on the distribution of freight, will need to be incorporated into investment programmes. DfT through UK SHORE provides a backbone for this engagement but this needs to be augmented with a cross Whitehall response. The Freeport Initiative currently being rolled out across Great Britain provides a catalyst and pilot for such an arrangement, but this needs to be extended to be available beyond the dozen or fewer Freeports being implemented.

Stronger links will help leverage the maximum benefits from government and industry investments alike. Close collaboration between industry, government and different parts of the supply chain, will enable lessons to be learned from other sectors, ensuring new regulation is appropriate and helping maritime companies realise the benefits of research and investment. Ultimately this will lead to the development and swift uptake of clean technologies.

Government could consider implementing a targeted programme of Port Economic Partnerships, for ports meeting specific scheme and success criteria, leveraging the maximum benefits from both government and industry investments.

Shipping is currently responsible for 3.4% of the UK's overall greenhouse gas (GHG) emissions and it emits a range of pollutants that are harmful to human health (DfT, 2019). National and international commitments have been made to reduce emissions. Fulfilling these commitments requires the widespread adoption of abatement options and changes in behaviour.

In addition, shipping emissions (GHGs and air pollutants) impose costs on society that the sector itself does not have to bear (e.g. the costs to human health associated with air pollutant emissions) (Brown, 2001).

Market failures can also occur due to split incentives: ships are often owned by one set of organisations and leased to others to operate them. The incentives for owners to invest in abatement options which reduce emissions (e.g. by increasing energy efficiency) are minimal given that it may be the operator (and wider society) that would benefit from lower energy use (IEA, 2007; Rehmatulla, 2014; Faber et al., 2012). An option might be to develop Multi-stakeholder finance incentives. By building a consortia of both partners incentives and tax breaks could be developed for both to benefit from.

Finally, vessels themselves have long lifespans, which can mean that existing designs and technologies persist even when new options are available (EEA, 2017). Adoption of new technologies is hard due to long term pre-existing assets held under contract restricting new innovation.

Perceived barriers to investment:

The following is a summary of key barriers to investing as perceived by the investment community at present. Much of this relates to poor availability of information and communication between the investment community and the maritime sector.

Barrier categorisation

Barrier typology	Barrier Subcategory	Impact of Barrier
Economic	Negative externalities	High
Economic	Split incentives to invest	High
Economic	Imperfect information on abatement options	High
Economic	Imperfect information between owners and charters	High
Economic	Variation in characteristics	Low
Economic	Cost of capital	Medium
Economic	Hidden costs of investing (capacity reductions etc.)	Medium
Structural	Existing infrastructure and onboard technologies	High
Structural	Long life of existing assets	Low
Structural	Market operations	Medium
Policy / regulatory	Existing policy	Medium
Policy / regulatory	Regulatory constraints	Low
Organisational	Intra-organisational co-ordination failures	Medium
Organisational	Inter-organisational co-ordination failures	High
Behavioural	Bounded rationality	Medium
Behavioural	Myopic outlook	Medium

Source: Frontier / UMAS

Decarbonising Ports: Issues in investment

Existing infrastructure and onboard technologies can act as a lock-in to the introduction of new/green operations or abatement technologies. Therefore, certain abatement options may not be adopted since ports and shipyards are currently configured in a certain way. This configuration may not be compatible with some abatement options.

Some areas will develop faster than others, and some abatement options will only be feasible at some ports, with others needing significant infrastructure investment.

Use of shore power when at berth is likely to be affected by this barrier as significant investment is required in order to provide plug-in facilities at port. Without changes to existing infrastructure, the uptake of these options could be very limited. It is also important to consider that changes to infrastructure will need to be widespread and consistent. If there is a difference in the infrastructure offered at certain ports, then ships which feature abatement options could be restricted in terms of which routes they operate. This in turn could hinder investment and uptake of these options by ship operators.

To address this the government could consider the case for offering tapered financial support to ports that may not otherwise invest due to uncertainty regarding future demand which may not be sufficient to reach minimum efficient scale. Alternatively, government setting a clear policy direction for shipping fuels could provide more certainty and mitigate some of the risk of investment.

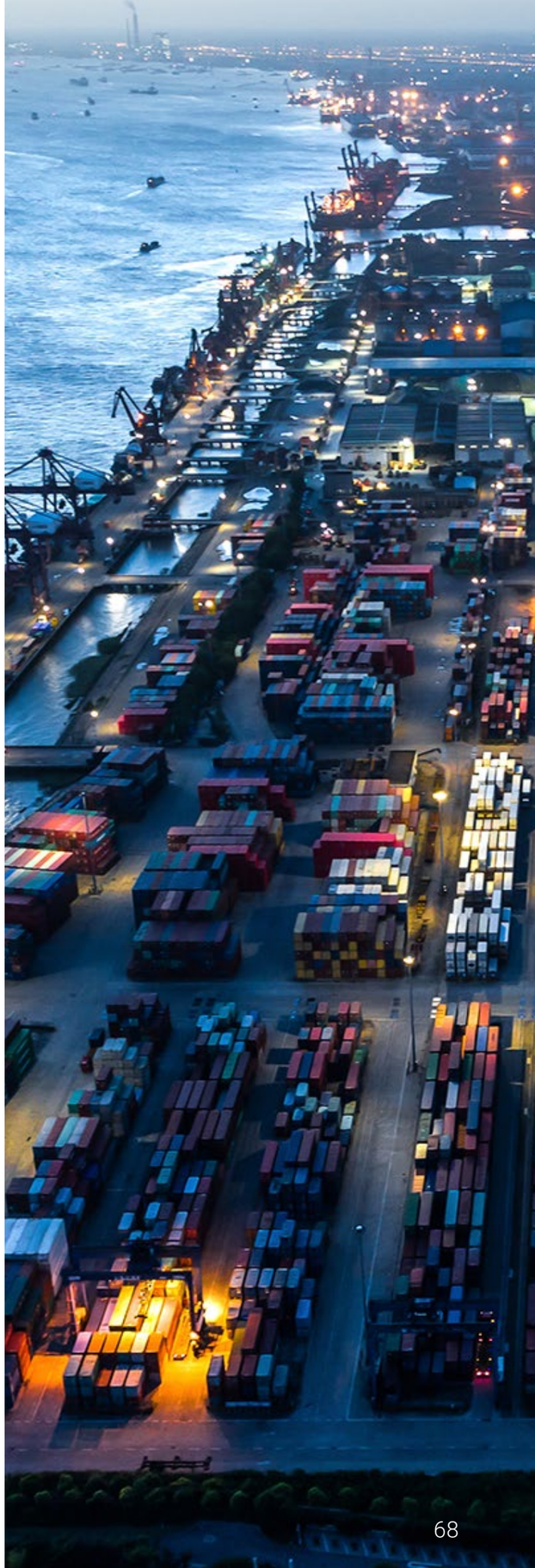
However, some retrofits are only feasible when a ship is already undergoing large-scale maintenance. This typically occurs at regular five-year intervals (Faber et al., 2011). Retrofitting financing options for vessels might be required to encourage dual propulsions systems or adaptable propulsion systems to be installed.

Current policy may inadvertently encourage continued use of existing technology due to a favourable tax regime or subsidies. This could make new, more energy-efficient technologies or sustainable fuels relatively less cost effective.

For example, OECD analysis has shown that fossil fuel subsidies across all sectors in OECD countries and partner economies totalled $151-249 billion annually over the 2010-16 period (OECD, 2018). There is currently tax relief for fossil fuels used in marine voyages in the UK, giving further incentive for the use of these fuels. This could limit the uptake of certain abatement options.

Existing evidence (EEA, 2017) refers to a ‘chicken and egg’ problem whereby no ship owner wants to invest in abatement options, such as alternative fuel technologies, until other actors, such as ports, put in place the supporting infrastructure. However, ports may not want to invest in the supporting infrastructure until the demand can be credibly demonstrated. This affected the development of LNG-bunkering infrastructure in northern Europe where uptake of LNG was hindered by the lack of bunkering facilities linked to uncertainty of future demand (Aronietis et al., 2016).

These coordination issues could be partially overcome if governments, trade bodies or international representative groups could organise, promote and facilitate the diffusion of alternative technologies, especially through an inter-governmental body like the International Maritime Organisation.



Options for energy-efficient and abatement in Maritime Sector:

Feedback from the investment community suggests these options can be considered in four categories:

- Technologies that can increase energy efficiency;
- Operational or behavioural change that can increase efficiency;
- Technologies specific to the capture/ treatment of exhaust emissions (GHG and air pollutant emissions); and
- Alternative fuels and energy sources and related machinery or propulsion.

The government could consider building a funding and tax program wrapped around these four areas to incentivise and provide financing options to kick start and accelerate the development and adoption of these innovations in ports. Existing funding has been targeted at specific aspects of these and the maritime sector and other enabling sectors have been agile to respond with an impressive range of innovation R&D and demonstration projects – see technologies section for details.

The following is summaries from analysis by the investment community expressing their perception of readiness and impact of technologies for energy efficiency and exhaust capture.

Technologies that increase energy efficiency

Options	Impacts / benefits			Commercialisation		
	GHG abatement	Local air pollutant abatement	At sea air pollutant abatement	TRL	Expected commerc. date	Future cost reduction potential
Propulsion devices, including modifications to the propeller and adjacent area (ducts, fins etc.)	Low	Low	Low	TRL9	Currently available	Low
Ship design (changes in the shape of the hull, addition of bulbous bows etc.)	Medium	Low	Medium	TRL9	Currently available	Medium
Main machinery and engine modifications (design improvements to the diesel engine, energy recovery from waste heat etc.)	Low	Low	Low	TRL7-9	Up to 10 years	Medium
Auxiliary (energy management and recovery systems, design improvments and control systems for machinery such as pumps etc.)	Low	Medium	Low	TRL7-9	Currently available	Medium

Technology specific to the captive / treatment of exhaust emissions

Options	Impacts / benefits			Commercialisation		
	GHG abatement	Local air pollutant abatement ***	At sea air pollutant abatement ***	TRL	Expected commerc. date	Future cost reduction potential
NOx emissions control: Selective catalytic reduction (SCR) and Exhaust gas recirculation (EGR), exhaust gas technology, water in fuel (emulsion fuels)	Negative - Low	High	High	TRL9	Currently available	Medium
SOx emissions control: Exhaust gas cleaning systems	Negative	High	High	TRL9	Currently available	Medium
Particulate matter (PM) (including black carbon (BC)) control: diesel particulate filters for reducing PM and BC, diesel oxidation catalyst for reducing SOx, PM and BC, electrostatic precipitator	Negative - Low	High	High	TRL8*	Currently available**	Low
Methane catalysts for removal of methane (CH4) in exhaust	High	Low	Low	TRL5	Approx 5 years	Medium
On board carbon capture, for storage and sequestation (CCS)	High	Low	Low	TRL4	Approx 10 years	Medium

Note:
* for 4-stroke engines.
** Applications in smaller vessels, more devloped applications in trains and tractors, which can be marinised (made suitable for the marine environment).
*** The abatement estimation is specific to the emissions that the technology is designed to abate (as specified in the row header).

imo.org/en/OurWork/Environment/Pages/Technical-and-Operational-Measures.aspx
icaew.com/insights/viewpoints-on-the-news/2021/feb-2021/investment-in-ports-a-key-enabler-of-growth
assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/974603/20201002-Prospectus-PIF-Port-Prospectus-vFINAL.pdf
britishports.org.uk/uk-ports-look-to-green-investment-and-freeports-as-part-of-economic-recovery/
marri-uk.org/projects-we-funded/clean-maritime-grant-awardees
greenfinanceinstitute.co.uk/wp-content/uploads/2020/12/GREEN-FINANCE-INSIGHTS-PAPER.pdf

08

Key Messages & Recommendations

Innovate UK

The following were key messages and recommendations to Government, Civic Leaders, Industry and the wider public:

01

The government (DEFRA) should follow up on port air quality strategies and obtain them from ports who have not yet submitted one. These should be used to create emission reduction targets and a timeline for those who have already provided a baseline. All major ports should be encouraged to install means of monitoring air quality within their site boundaries, and work with Local Authorities to monitor air quality in the surrounding area. This data should be reported on a regular basis, at least annually.

02

The refresh of the Clean Maritime Plan by the DfT in 2023 is welcome, but this must include stretching intermediate targets and objectives for stepped reductions before 2050, to encourage continued action from across the sector. A clearer roadmap is needed, hopefully informed by the ongoing consultations in 2023, that narrows down the technology pool and focused support provided to back the “winners” – needed for both vessels, NRMM and infrastructure.

03

There needs to be some public financial support to port operators for deploying retrofittable technologies to reduce the emissions of longer life assets within a port. It is not economically feasible to scrap these and buy the newest greenest lifting or mobility machine. A deeper understanding of what can be done with the existing equipment is required, including sharing learning from other sectors such as construction or mining. It is not a priority topic within government and frequently gets side-lined in favour of investing resources in the next ‘shiny’ new thing.

04

New funding channels and access to capital is needed for the large and expensive infrastructure required to make the Net Zero transition. Government investment at an earlier stage could help de-risk the technology to the point where private capital can be more easily leveraged. Investor partnerships could be a way of achieving this, and the role of ports as part of our national infrastructure should be given a higher rating by the National Infrastructure Commission and the UK Infrastructure Bank.

05

Following on from the above point, greater involvement and links between government, industry and financial institutions should be created. Initiatives across Whitehall should be coordinated in particular between BEIS, DfT and DIT. Government Executive Agencies such as the Intellectual Property Office and Better Regulation Executive should be thoroughly consulted when developing policy along with investment institutions such as the UK Infrastructure Bank, British Business Bank and Clean Growth Fund.

06

Readily available and affordable clean electricity and renewable fuels will be essential to enable a transition away from fossil fuels. Access to clean energy is often cited as a significant barrier, due a lack of accessible infrastructure. Greater collaboration with the Distribution Network Operators and renewable fuel producers is needed to ensure when the vehicle/vessel is ready to make the switch to alternative power source the infrastructure and grid/fuel availability is there.

07

Freeports present a key opportunity to provide an incubator for innovation but this work must not be done in silos. BEIS, DLUHC and DIT are working together to ensure they are a hot bed of innovation, but this needs greater linkage across Whitehall to maintain engagement with future opportunities.

08

Ports in general need to be better at sharing knowledge, ideas (open innovation) even data to collectively decarbonise the sector. The sector should work collaboratively and with industry bodies like Maritime UK to produce case studies on impact, and undertake post project, peer assessed reviews for publicly funded R&D projects?

Discover More

Find out more about the Maritime & Ports Innovation Network website by visiting this programme page on Innovate UK KTN website:
iuk.ktn-uk.org/programme/maritime-ports-innovation-network/

Contact Us

Innovate UK KTN Transport team
transport@iuk.ktn-uk.org

Innovate UK KTN Clean Energy & Infrastructure team
infrastructure.team@iuk.ktn-uk.org

Innovate UK drives productivity and economic growth by supporting businesses to develop and realise the potential of new ideas.

We connect businesses to the partners, customers and investors that can help them turn ideas into commercially successful products and services and business growth.

We fund business and research collaborations to accelerate innovation and drive business investment into R&D. Our support is available to businesses across all economic sectors, value chains and UK regions.

Innovate UK is part of UK Research and Innovation.

For more information visit ukri.org/councils/innovate-uk/

Follow us

Telephone: 01793 361000
Email: support@iuk.ukri.org
ukri.org/councils/innovate-uk/