REGULATORY HORIZONS COUNCIL

The Regulation of Hydrogen Fuel Propulsion in Maritime Vessels

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Foreword

Jonson Cox CBE

The next 25 to 30 years will see substantial change across the whole economy and society as we transition towards net zero. We are talking of industrial transformation – revolution even – essential to the planet's long-term health, required at unprecedented pace.

UK maritime will be integral to this transition. Maritime vessels represent around 5% of the UK's domestic transport greenhouse gas emissions, a significant proportion of the UK's transport emissions; we are an island nation. For the sheer volume of cargo and passengers being moved, sea remains the most efficient method of moving cargo.

'Decarbonising' this essential activity is challenging. The sector is traditionally categorised as 'hard to abate', along with other heavy-duty transport sectors such as aviation and road transport. So far, emerging low-carbon technology solutions consistently carry increased cost, compared to traditional hydrocarbon technologies. However, hydrogen-fuelled propulsion is increasingly being seen to offer significant potential for the maritime sector, alongside other zero and low-carbon technologies.

The Government's net zero maritime ambitions provide a clear target to aim for, and opportunities will flow from clean growth, including in UK shipbuilding, advanced technology, equipment design, assembly, production and the UK's maritime services industries more widely. At the Port of London Authority (PLA) we set an ambitious target to reach net zero by 2040 or earlier, and have already cut emissions by 50%, against our 2014 baseline.

As part of our net zero commitment, the PLA is exploring, with a range of academic, commercial and regulatory partners, many aspects of the hydrogen opportunity through our three-year Maritime Hydrogen Highway project.[1] This covers energy diversity, trialling hydrogen-power generation in the Thames estuary, the business case for safe transport of hydrogen into central London, ship design and health & safety requirements.

Unlocking hydrogen, safely and swiftly, largely depends on getting regulation right. Whilst technologies to enable hydrogen as a fuel for propulsion in marine vessels are comparatively well-developed, there is a complex regulatory landscape which poses challenges that can impede progress. Pace is essential and will only be achieved through collaboration of manufacturers, operators and regulators. Together we must

[1] http://www.pla.co.uk/Sea-Land-and-Port-Smart-Integration-of-a-Hydrogen-Highway

establish model safety standards for hydrogen generation, storage and fuelling sites, infrastructure and approval processes. Creating this integrated, purpose-led regulation in partnership will ensure the UK can realise the climate, industrial, economic and other benefits of developing hydrogen technology solutions.

This Regulatory Horizons Council report provides a timely analysis of the UK's current regulatory framework of hydrogen as a fuel in the maritime sector. It recognises areas that are working well, elements that need to be addressed and issues in the current regulatory framework. It draws on the multi-stakeholder consultation, best international practice, and experience of the sector, to frame recommendations that are actionable and would create a hydrogen fuel regulatory framework suited to promote innovation and stimulate clean growth.

I am delighted to welcome this report and invite all relevant parties to consider, and implement, the proposals outlined.

Jonson Cox CBE

Chair of the Port of London Authority

Executive Summary

The Regulatory Horizons Council (RHC) is an independent expert committee sponsored by the Department of Science, Innovation, and Technology (DSIT) that identifies the implications of technological innovation, and provides government with impartial, expert advice on the regulatory reform required to support its rapid and safe introduction.

A great deal of focus has been given to the policy and funding structures surrounding hydrogen fuel, and its use in the maritime sector, with hydrogen-fuelled propulsion considered one of a range of technologies that offer a solution to net zero operation in the maritime sector.

The RHC set out to investigate both the technical and the economic regulatory environments to identify interventions to support the responsible uptake of hydrogen fuel technology in maritime vessels operating in UK territorial waters. The report seeks to kick-start wide-ranging discussions on the current regulation of hydrogen fuel in the maritime sector, on the part of regulators, policymakers, innovators, shipbuilders, and other stakeholders, with a view to ensuring a more proportionate and agile regulatory framework.

The RHC consulted maritime industry stakeholders operating in the UK and elsewhere in the world, covering regulators and classification societies, research and technology organisations, innovators and shipbuilders, and industry and commercial bodies. Stakeholder interviews and desk research were used to gather diverse perspectives on potential regulatory issues associated with the roll-out of hydrogen-propelled maritime vessels and associated infrastructure.

Stakeholder and Sector Assessment

The adoption of low-carbon propulsion has the potential to be an important enabler of government net zero targets. It represents an area of innovative expansion for the UK's remaining shipbuilding industry, and for ancillary industries producing advanced technology equipment for new vessels, as well as the UK's maritime services industries.

However, the lack of alignment between stakeholders and regulators and, in some cases, lack of regulatory guidance for innovators, combine to threaten the UK's ability to play a leading role in ship and technology-related design and manufacture, with benefits to the UK economy.

With an appropriate regulatory environment, a reasonable best-case scenario could see UK shipbuilders constructing hydrogen-propelled vessels over the next 3-5 years to meet the needs of wind farms, aquaculture and coastal freight and ferry transport, operating in UK territorial waters. UK ancillary services providers, such as insurers, would expand and pivot to support this growing industry.

Regulatory issues

Despite increasing interest from the relevant technology sectors, stakeholders told us that commercial and regulatory barriers are creating obstacles to the deployment of hydrogen fuel technology.

- The transition to net zero shipping and the necessary introduction of novel propulsion-fuels will require the development of guidance supporting the assessment of risks associated with these new technologies. Without these, small shipbuilders will find it difficult to develop vessels, given that they typically lack the experience and skills to develop individual risk-based analyses.
- Various industry vessel developers have cited difficulties with approval for hydrogen ship designs. The lack of a common approach for evaluating risk and complying with regulations among engineering consultancies, class societies, and the Maritime and Coastguard Agency (MCA) have caused approval delays, necessitating lengthy redesigns and reappraisals.
- Industry sources have suggested that the MCA is taking an overly cautious approach to regulation and at times these have caused delays. Class societies were also noted as unnecessarily cautious.
- There is a lack of port infrastructure to support the operation of hydrogen vessels. Many port operators do not have the incentive to make zero or low-carbon strategic investments. In addition, there is the lack of regulatory clarity around whether, and how, hydrogen storage at ports will be managed.
- A regulatory gap between shore-based and vessel-based systems was highlighted, with a desire shown by industry for regulators to agree common standards that enable interoperability of ship and shore systems.

Recommendations

The Government is advised to act quickly. There is a limited window of opportunity to put in place the regulatory environment needed to ensure adoption of hydrogen fuel, and an even narrower window to capitalise on the growth opportunities associated with hydrogen vessel supply chains.

The report recommendations could support the use of hydrogen fuel in the maritime sector by:

- Increasing the speed of approvals of zero-carbon and novel vessel designs, by appointing class societies as ‘Approved Bodies’ (ABs) for vessel design evaluation
- Providing clarity to shipbuilders and innovators, through production of better specialized guidance for the designs of hydrogen propulsion vessels

- Accelerating the build rate of hydrogen vessels, by ensuring future spending commitments are made at a scale comparable to international competitors and focus on de-risking hydrogen vessels from a technical and commercial perspective to bring private investment into the market
- Incentivising strategic planning for 'investment ahead of need' for hydrogen infrastructure at ports, by establishing guidelines for ports to plan appropriately for the required transition to zero carbon ship propulsion, and invest in the roll-out of the infrastructure
- Building investor confidence in port owners and shipbuilders to undertake hydrogen infrastructure and vessel construction, through improved governance for onshore hydrogen facilities
- Ensuring proactive resolution of evolving regulatory issues through the creation of a Centre or Taskforce for Hydrogen Maritime Propulsion

Taken together the recommendations could help support UK shipbuilders build hydrogen propelled vessels, and hydrogen systems and sub-systems, over the next 3-5 years to meet the needs of the sector and bring associated benefits to the UK's ancillary services providers. The UK has the opportunity to ensure it is creating value at each step of this roll-out of hydrogen-propelled maritime vessels and associated infrastructure.

1. Introduction

The Government recognises that it can be challenging for regulation to keep pace with emerging technical developments and set out plans to help address this challenge in its 2019 White Paper 'Regulation for the Fourth Industrial Revolution',[2] including the establishment of the Regulatory Horizons Council (RHC). The RHC is an independent expert committee set up to advise government on the regulatory reforms needed to support the rapid and safe introduction of emerging technologies, and has so far published reports on innovations including (but not limited to) drones, nuclear fusion and genetic technologies.

A great deal of focus has been given to the policy and funding structures surrounding hydrogen fuel, and its use in the maritime sector, and this focus has increased over the course of this report's research period. Hydrogen has uses as a direct fuel in both gaseous or potentially liquid form, and also as a feedstock for liquid hydrogen carriers such as ammonia or methanol. Hydrogen-fuelled propulsion is considered one of a range of technologies that offers a solution to net zero operation in the maritime sector. The UK has made international commitments to decarbonise the sector and has begun to take crucial steps towards the governance of nationwide hydrogen infrastructure.[3] At COP26, the UK pledged to launch the first zero-emission vessel by 2025 when it unveiled 'Operation Zero' alongside commercial signatories[4], as well as establishing zero-emission shipping routes through the Clydebank Declaration.[5] The British Energy Security Strategy has set out the UK's high-level plans for hydrogen pricing and transport models.[6] Now is an opportune moment to ensure that appropriate regulatory systems are in place.

This report on the regulation of hydrogen fuel for maritime propulsion arose from a scoping exercise during which the RHC noted significant government focus on the potential of hydrogen fuel in driving clean growth in the UK.[7] Initial desk research and stakeholder interviews explored a range of applications of hydrogen, including in shipping, aviation, land transport, industry, and heat and buildings, to explore the feasibility of the technology and the extent to which regulation might enable its

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[2] https://www.gov.uk/government/publications/regulation-for-the-fourth-industrial-revolution/regulation-for-the-fourth-industrial-revolution

[3] https://www.gov.uk/government/publications/uk-hydrogen-strategy

[4] https://www.gov.uk/government/publications/cop26-declaration-shipping-and-offshore-wind-operation-zero/cop26-declaration-shipping-and-offshore-wind-operation-zero

[5] https://www.gov.uk/government/publications/cop-26-clydebank-declaration-for-green-shipping-corridors

[6] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy#hydrogen

[7] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/949318/potential-priority-areas-for-the-council.pdf

expansion.[8] The RHC learnt that the technology to enable hydrogen fuel production and its use as a fuel for propulsion in maritime vessels was comparatively well-developed. However, the lack of alignment between stakeholders and regulators and, in some cases, lack of regulatory guidance for innovators, combine to threaten the UK's ability to play a leading role in ship and technology-related design and manufacture, with benefits to the UK economy. This report responds to the opportunity to inform future planning in this space and considers the full scope of regulatory interventions to promote the responsible uptake of this technology.

Clearly, the adoption of low-carbon propulsion is understood to have potential as an important enabler of government net zero targets, as an area of innovative expansion for the UK's remaining shipbuilding industry, for others to support provision of advanced technology equipment for new vessels wherever they are manufactured, and also for the UK's maritime services industries, including classification societies such as Lloyd's Register. These outcomes are not mutually dependent; it would be possible for one to proceed without the others. However, their systemic interactions mean that regulatory challenges in one area will have knock-on impacts for the success of others, and a coordinated UK approach to the overall governance of the sector would overall amplify the benefits to the UK economy and the delivery of net zero policies.

The RHC's focus in this report is on vessels operating in UK territorial waters (coastal vessels) under the jurisdiction of the Maritime and Coastguard Agency (MCA), because i) the UK's potential influence over international regulations is less direct, and ii) there is growing demand for technologically advanced coastal vessels driven by expanding wind-power and offshore aquaculture industries. There is an urgent need to bolster the UK's wind support vessel fleet and for that fleet to be carbon-neutral, with predictions that demand for these specialised vessels will outpace supply from 2024.[9] It is nonetheless important that the UK continues to attempt to influence the International Maritime Organisation (IMO), this is expanded on briefly below in section 3.6.

Industry reports and stakeholders suggest that no single technology, from batteries, hydrogen, ammonia and other fuels, will cover all the needs of shipping from inland vessels to long distance international cargo shipping. Instead, different technologies will be appropriate to different applications. Battery-powered electric vessels are already beginning to prove their value for short journeys, but the energy density of batteries is a barrier to effective use for large payloads over large distances.

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[8] Further information provided in 'Annex B – Why Hydrogen in Maritime?'

[9] https://w3.windfair.net/wind-energy/pr/39762-rystad-energy-offshore-wind-turbine-installation-crane-vessel-heavy-load-lightweight-china-global-decade-demand-jan-de-nul

Conversely, hydrogen's poor volumetric energy density relative to other fuels such as liquid natural gas renders it unviable for long distance international journeys.[10]

However, the regulatory and governance recommendations which follow form only part of the bigger picture, and will not be effective in isolation. Beyond regulation, there is much practical detail still to work through if the UK is to see development and adoption of hydrogen marine vessels; national hydrogen pricing and transport models need to be agreed, and this will inevitably impact decisions taken about port infrastructure. In addition, both fuel and vessel costs for hydrogen propulsion are likely, in the short term, to remain higher than for fossil-fuel fleets. As such, without more robust government intervention to either mandate or incentivise net zero shipping, demand is unlikely to increase.

Accordingly, the council has not sought to make detailed recommendations regarding specific regulations, but rather to write a short report pointing to **the structural changes that will be required to reassure potential investors of a stable, proportionate, easy-to-navigate future for hydrogen fuel technologies and their regulation in this space.**

What follows is based on stakeholder interviews and desk research, used to gather diverse perspectives on potential regulatory issues associated with the roll-out of hydrogen propelled maritime vessels and associated infrastructure.

[10] UMAS, E4Tech, Frontier Economics, CE Delft (2019) 'Reducing the Maritime Sector's Contribution to Climate Change and Air Pollution. Maritime Emission Reduction Options. A Summary Report for the Department for Transport' https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/816018/scenario-analysis-take-up-of-emissions-reduction-options-impacts-on-emissions-costs.pdf

2. Stakeholder and Sector Assessment

The UK Government has considered in depth the adoption of hydrogen propulsion in the maritime sector, as one of a range of technologies which offers a pathway to net zero, and has published strategies including:

- The Hydrogen Strategy,[11] which aims to support broad adoption of hydrogen power.
- The National Shipbuilding Strategy, refreshed in 2022,[12] which aims for a globally successful, innovative and sustainable shipbuilding enterprise, and established UK Shipping Office for Reducing Emissions[13] (UK SHORE) to deliver decarbonisation initiatives.
- Maritime 2050,[14] which sets out the Government's vision and ambitions for the future of the British maritime sector, and contains the Clean Maritime Plan,[15] the environment route map of Maritime 2050, which acts as the UK's national action plan on shipping emissions.

Yet UK industry has only a limited window of opportunity to capitalise on these opportunities because users need urgently to replace or expand their current fleets. Where there is clear incentive to move to low-carbon vessels, operators will look to overseas producers to fill the gap, or they will buy cheaper fossil-fuel powered vessels. Scandinavia[16] in particular has enjoyed early success in the production of specialised offshore vessels, sold at relatively high prices with which UK producers could credibly compete.[17]

Irrespective of the origin of the vessels or the provider of ancillary services, the UK will benefit if the regulatory challenges identified in this report are addressed. The lack of development of proportionate regulatory systems and related delays in infrastructure development are creating a first-mover disadvantage for companies with the capacity to build, acquire and service hydrogen-propelled vessels.

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[11] https://www.gov.uk/government/publications/uk-hydrogen-strategy/uk-hydrogen-strategy-accessible-html-version

[12] https://www.gov.uk/government/publications/refresh-to-the-national-shipbuilding-strategy

[13] https://www.gov.uk/government/speeches/uk-shipping-office-for-reducing-emissions

[14] https://www.gov.uk/government/publications/maritime-2050-navigating-the-future

[15] The Clean Maritime Plan sets out detail on how government sees the UK's transition to a future of zero emission shipping, it is due to be refreshed in late 2023. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/815664/clean-maritime-plan.pdf?_ga=2.242524162.1400715363.1667469654-818384444.1667469654

[16] UK Government's Maritime 2050 report notes that "Scandinavian countries, particularly Norway and Sweden, have been frontrunners in sustainable shipping and the use of alternative fuels."

[17] Interview, Marine Institute of the University of Plymouth

In our view, a reasonable best-case scenario could see UK shipbuilders build hydrogen propelled vessels over the next 3-5 years, operating in UK territorial waters in order to meet the needs of wind farms, aquaculture and coastal freight and ferry transport. UK ancillary services providers, such as insurers, would expand and pivot to support this growing industry.

A reasonable worst-case scenario sees UK users such as wind farm operators, replace their current fleet with fossil-fuel powered vessels which remain in use until 2050 and beyond. Not only does this directly frustrate the UK's net zero ambitions, but if government intervention penalises fossil fuels or subsidises alternative fuels, wind farm operators could face decreasing profit margins, which could curtail wind farm expansion limiting the UK's clean fuel production.

Despite increasing interest from the relevant technology sectors, commercial and regulatory barriers to deployment are having serious ramifications for the UK's ability to meet its net zero targets. Offshore support vessels account for roughly 23% of the UK's emissions from domestic shipping.[18] The operating life of vessels can be 20 to 30 years; if operators are not confident enough to invest in zero-carbon fleets now, replacement service vessels acquired over the coming years and propelled by fossil fuels could remain in operation until the middle of the century. UK-owned offshore support vessels are already, on average, older than those owned by non-UK companies (median age of 11 years compared to 7 years). As ORE Catapult forecasts, the need for these vessels will increase, with the operations and maintenance (O&M) market expected to grow faster in relative terms than any other offshore wind sub-sector market over the next decade.[19]

2.1 High-potential applications

Stakeholders were broadly optimistic about demand for hydrogen-fuelled internal combustion and fuel cell propulsion vessels making shorter journeys in UK coastal and inland waters. Alongside this shipbuilding opportunity, there is also significant opportunity in the manufacturing (and export) of maritime hydrogen systems and sub-systems. Encouragingly, this is matched by government optimism regarding the UK's industrial capability in these areas, explored in greater detail later in this section.

2.1.1 Offshore Wind farms

[18] Marine Capital 'UK Domestic Shipping Mobilising Investment in Net Zero' https://marcap.egnyte.com/dl/igIMQ6UZVs/UK_Domestic_Shipping_Mobilising_Investment_in_Net_Zero.pdf_

[19] https://ore.catapult.org.uk/?orecatapultreports=offshore-wind-operations-maintenance-9bn-year-opportunity-2030-uk-seize

There is an urgent need to bolster the UK's offshore-wind support vessel fleet, with Rystad Energy predicting that demand for these specialised vessels will outpace supply from 2024.[20] The National Shipbuilding Office (NSO) considers this a high priority and an area of significant opportunity, and as is mentioned above, the UK Government has already noted the opportunity for a zero-emission fleet to be deployed in its place, announcing Operation Zero at COP26:

> *The vision of Operation Zero is for ZEVs* [Zero Emission Vessels] *to be deployed in the North Sea's offshore wind farms by 2025 while also taking into consideration the landside infrastructure solutions needed to upscale and maintain the operation of ZEVs in the region's offshore wind sector.*
>
> *In the pursuit of these goals, members pledge to:*
>
> - *ensure that wider consideration is taken for environmental impacts and sustainability*
> - *share best practice in the decarbonisation of operations and maintenance vessels in the offshore wind sector*
> - *maintain an open dialogue between industry and government, to facilitate this transition as much as possible*
> - *explore the potential for offshore wind to be a part of shipping's future fuel mix and for the sector to play an active role in decarbonising the wider maritime industry*
> - *work collaboratively in ensuring that costs and risks inherent to the energy transition are fairly distributed and that all tiers across the supply chain will make an equitable contribution to reaching our collective ambition*[21]

Several types of vessels will be needed to support the operation and maintenance of offshore wind farms: Crew Transfer Vehicles (CTVs) and Support Operation Vessels (SOVs). Of these vessels, CTVs tend to be smaller and more standardised.

Currently, there are no SOVs serving UK wind farms that were built in the UK, nor any vessels operating using zero propulsion.[22] This is in contrast with international counterparts, at the end of 2021, a Service Operation Vessel (SOV) capable of running on hydrogen was delivered by the Norwegian shipyard Green Yard to a wind farm operator in Germany.[23] The vessel is 'almost 90m long and almost 20m wide

[20] https://w3.windfair.net/wind-energy/pr/39762-rystad-energy-offshore-wind-turbine-installation-crane-vessel-heavy-load-lightweight-china-global-decade-demand-jan-de-nul

[21] https://www.gov.uk/government/publications/cop26-declaration-shipping-and-offshore-wind-operation-zero/cop26-declaration-shipping-and-offshore-wind-operation-zero

[22] Lauren Hadnum, 'Green SOV Feasibility Study', (speech, The National Shipbuilding Office Symposium, Edinburgh, 14 March 2023).

[23] https://www.4coffshore.com/news/siemens-gamesa-celebrates-delivery-of-hydrogen-ready-sov-nid24692.html

and will be the workplace and living quarters for up to 75 offshore service technicians and 24 crew members'.[24] This ship will be powered by diesel generators, but is capable of being run on hydrogen or with batteries and offshore charging.

Other hydrogen-ready SOVs are being built in Spain for a Norwegian owner,[25] and as mentioned above, at least one of these (an 82m long SOV) is expected to operate at the Seagreen offshore wind farm in Scotland. Other vessels are in development and scheduled for use at other wind farms.[26] Slightly larger (90m), hydrogen-ready Commissioning Service Operation Vessels (CSOVs) are also being built in Spain and Sri-Lanka, for Edda Wind.[27] They are expected to be delivered in 2024.[28] Without hydrogen infrastructure in place at ports, these vessels will rely on diesel or marine fossil fuels.

Similar developments are taking place for hydrogen-powered CTVs, with Hydrocat 48 delivered by Windcat Workboats and CMB.TECHm,[29] using dual fuel combustion engines to reduce up to 80% of its traditional fuel usage and associated emissions.

2.1.2 Aquaculture

In the UK aquaculture sector, increasing numbers of farms are being constructed offshore to manage risks of fish disease build-up and pollution. Global trends show more farmed fish than caught fish are now being consumed[30] and 90% of wild fisheries are fished to the maximum sustainable yield or are over-fished.[31] Expansion into new inshore sites for the Scottish fish farm industry is limited and is also hampered by a tightening regulatory regime, with potential for growth coming from offshore farms.[32] As UK fisheries move towards net zero carbon emissions by

[24] https://www.siemensgamesa.com/en-int/newsroom/2021/12/211216-siemens-gamesa-press-release-vessel-rem-energy-hydrogen

[25] https://eddawind.com/edda-wind-takes-delivery-of-edda-brint/

[26] https://www.shipandoffshore.net/news/shipbuilding/detail/news/hydrogen-ready-sov-named-edda-brint.html

[27] https://workboat365.com/commercial-marine-news/ship-boat-building/service-operation-vessels/edda-wind-orders-three-additional-csovs/

[28] https://www.offshorewind.biz/2022/04/06/dnv-to-class-edda-winds-hydrogen-ready-csovs/

[29] https://cmb.tech/news/windcat-workboats-cmb-tech-present-the-first-hydrogen-powered-crew-transfer-vessel-ctv-the-hydrocat-48-ready-for-immediate-operation

[30] https://journals.plos.org/sustainabilitytransformation/article?id=10.1371/journal.pstr.0000005#abstract0

[31] Food and Agriculture Organisation of the United Nations (FAO) (2020). The State of World Fisheries and Aquaculture 2020 – Sustainability in action. Rome. http://www.fao.org/3/ca9229en/CA9229EN.pdf

[32] McGoohan, A., Tait, J., Raybould, A., Parris, S. and Hammond, K (2021) 'Fish Farming in Scotland: Optimising its contribution to climate and environmental policies'. https://www.innogen.ac.uk/media/304

2050,[33] vessels supporting the industry will need to be powered by clean propulsion methods.

The Norwegian fish farm industry has reportedly pioneered investments in offshore fish farming, including making investments in the UK. New types of vessel may be needed to support these farms, potentially larger and more robust than those used in the aquaculture industry today.[34] There is also a good, sustainability-based rationale for upgrading the existing vessels, used for inshore farms, to clean-fuel power alternatives as they come to be replaced.

2.1.3 Freight & Ferries

The classification society, DNV, have approved hydrogen fuel cell modules that have now been successfully installed on Norled's MF Hydra passenger ferry which will be the "first in the world to be powered by PEM fuel cells."[35]

More speculatively, representatives from Maritime UK raised the possibility that freight could be taken off the roads and transported using near-shore shipping in the UK, offering significant reductions in carbon emissions.[36] Carbon reductions will be furthered with the use of zero-emission ships. This is currently being trialled in Norway with an autonomous, battery-powered ship, the Yara Birkeland. Coastal freight has the potential not only to reduce emissions by taking polluting lorries off UK roads, but also to ease road congestion at the UK's major international ports.

The world's first hydrogen-powered cargo ship[37] (With Orca) and the first hydrogen-fuelled tug[38] (Hydrotug), driven by combustion engines that burn hydrogen in combination with diesel, are scheduled to be in operation within the next couple of years.

2.1.4 Ancillary Services

Commercial opportunities are not limited to shipbuilding. There are opportunities for UK ancillary service providers to pivot support towards a growing hydrogen industry, as demonstrated by the involvement of classification societies in provision of climate alignment reporting under the Poseidon Principles.[39] There is a large[40] and globally

[33] https://randd.defra.gov.uk/ProjectDetails?ProjectId=21055
[34] An example of demand for sea going aquaculture vessels from the Dutch Daman group in collaboration with Exeter based shipyard https://www.damen.com/insights-center/news/damen-shipyards-builds-aquaculture-vessels-on-stock
[35] https://hydrogen-central.com/fuel-cells-first-liquid-hydrogen-ferry-ballard-fcwave-norled
[36] https://www.marri-uk.org/zero-carbon-coastal-highway
[37] https://www.lr.org/en/latest-news/norwegian-zero-emission-bulk-carrier-with-orca-lr-aip/
[38] https://www.marineinsight.com/videos/watch-worlds-first-hydrogen-powered-tug-hydrotug-in-port-of-antwerp/
[39] Poseidon Principles provide framework for assessing and disclosing the climate alignment of ship finance portfolios.
[40] Contributing £4.4bn to the UK Economy

competitive marine services sector in the UK, including engineering consultancies, ship operators, classification societies, insurance and ship management; the UK is the most significant provider of maritime insurance in the world with a 35% share of global marine insurance premiums.[41]

A clear domestic regulatory environment would support the service sector and improve competitiveness. In addition, this could be further supported by the UK Government proactively lobbying the IMO on the regulation of international shipping. The recommendations in section 4 will support the development of hydrogen vessels and port infrastructure and will enable the UK to influence international regulation credibly.

2.2 UK Capability

Feedback from industry and academic stakeholders suggests the UK has strong areas of engineering expertise in high-value ship design (mainly defence) but also in specialist ships like the RRS Sir David Attenborough. In addition, the UK has expertise in manufacturing hydrogen fuel systems and sub-system. There is a base of engineering skills and training in naval architecture, propulsion technologies, and hydrogen-related technologies. Related skills exist in the offshore oil and gas sector, chemical process engineering, electrochemistry, internal and gas-turbine combustion engines. The UK has a strong research capability through its universities, and there is a wider hydrogen generation and supply chain components sector in the UK.

Alongside these strengths, stakeholders also cited challenges for UK industry including a fragmented UK industry structure, with unclear integration between shipbuilders, designers, classification societies, regulators and ports. The regulatory aspects of these challenges are explored in section 3. There is historically low private investment in R&D within the UK industry, which stakeholders felt had led to a long-term lack of innovation in the marine sector. Although the defence sector has invested strongly in innovation, stakeholders did not expect defence contractors to develop civil businesses, due to the drastically different business models.

Discussion with an industry stakeholder highlighted that the UK has failed to capture any meaningful value from the offshore wind-turbine supply-chain,[42] despite having a sizable market demand and a pioneering role, a structural weakness that could be replicated for hydrogen vessels.

[41] https://www.maritimeuk.org/documents/11/the-uks-global-maritime-professional-services.pdf

[42] Whitmarsh, M (2019) 'The UK Offshore Wind Industry Supply Chain Review', https://ore.catapult.org.uk/?industryreports=the-uk-offshore-wind-industry-supply-chain-review-by-martin-whitmarsh

2.3 UK's hydrogen market

In the short term, both fuel and vessel costs for hydrogen propulsion are likely to remain higher than for fossil-fuel fleets. Robust government intervention to either mandate or incentivise net zero shipping will be needed to grow demand for hydrogen fuel.

The council is encouraged by recent progress in creating frameworks for the UK's hydrogen market, including provision in the Energy (Security) Bill for the appointment of a hydrogen-production-levy administrator to oversee a levy that will provide long-term funding for the hydrogen business model. This aims to enable hydrogen producers to overcome the operating cost gap between low-carbon hydrogen and fossil fuels from 2025.[43] The council's work does not formally extend to fiscal policy, but the RHC strongly suggests that government proactively communicate these developments to the maritime sector to help inform their investment decisions. The report does make recommendations, in section 4, relating to the reprioritisation of public R&D funds, which may go some way to addressing market adoption of new technology.

Furthermore, the adoption of hydrogen propulsion at scale will depend on the development of a national hydrogen transport and storage infrastructure, which responds to the risks facing potential investors and operators such as below-capacity operation over the initial years. The maritime sector has been slow to consider the wider systems application of hydrogen alongside vessel propulsion, so there will need to be more projects like PLA's Hydrogen Highway project going forward. It is positive that the Government has consulted[44] on this. Indeed, the Department for Transport is currently reviewing responses to its own consultation on decarbonising the maritime sector,[45] and it is possible that there may be mutually useful responses.

2.4 Innovation funding landscape & international activity

Other countries, such as Norway, are experiencing greater success in trialling vessels thanks to national government support. In our view, the success of Norway is also related to its established engineering and naval expertise base in international shipping and in oil and gas industry support services. As an EEA member Norway adheres to the EU's rules on state aid under the European Economic Area agreement. Other EU members such as the Netherlands, Belgium, Spain and Portugal have also seen significant developments.

[43] https://www.gov.uk/government/publications/energy-security-bill-factsheets/energy-security-bill-factsheet-hydrogen-and-industrial-carbon-capture-business-models

[44] https://www.gov.uk/government/consultations/proposals-for-hydrogen-transport-and-storage-business-models

[45] https://www.gov.uk/government/consultations/domestic-maritime-decarbonisation-the-course-to-net-zero-emissions

The main UK mechanism for supporting hydrogen maritime development has been the Clean Maritime Demonstrator Competition (CMDC).[46] The first two rounds of the CMDC allocated over £35m to 86 projects across the UK to deliver feasibility studies and trials in clean maritime solutions. Out of a total of 86 projects, 35 focused on hydrogen or hydrogen-derived fuels, such as ammonia and methanol, and received more than 40% of the overall grant funding. A key stakeholder noted that the first two rounds of CMDC amounted to too little and funding was insufficient to meet the sector's needs and was spread too thinly to make meaningful demonstrations. It also unduly favoured research-oriented applications from universities and Research and Technology Organisations such as Catapults, despite the technology in many areas being sufficiently advanced to be more in need of later-stage translational support. This type of intervention is useful for supporting early-stage research and development but does not lend itself to whole system development.

This focus on early-stage technology development, rather than complete vessel build and operations, was also noted by one of our stakeholders. Other countries noted as moving ahead with complete vessel development were Denmark and Japan. Round 3 of CMDC launched in September 2022, allocates up to £60m for technology and system demonstrations, and may help to address the need for greater focus on later-stage research and development.[47] As may the recently announced Zero Emission Vessels and Infrastructure[48] (ZEVI) competition which provides a £77 million fund to cover the construction and set-up of close to commercial clean maritime solutions, alternative fuels and bunkering, hydrogen and its derivatives, are in scope.

As a comparison, the Norwegian state-run enterprise Enova SF, has awarded USD 112 million in financing for a green hydrogen hub and vessels alone.[49]

The International Partnership for Hydrogen and Fuel Cells in the Economy, at a conference in 2021, identified the need for R&D to address vessel-related issues, for example hydrogen storage rather than component development.[50] There has hitherto been limited development of hydrogen storage and fuelling infrastructure at UK ports. The Health and Safety Executive shared that they had been approached for early demonstration projects and trials, but not for any work at scale or which demonstrated significant intent to invest in hydrogen infrastructure. They added that

[46] https://www.gov.uk/government/publications/clean-maritime-demonstration-competition-cmdc
[47] The winners of CMDC round 3 were announced in February 2023, and include a small number of hydrogen-focussed projects at higher technology readiness levels (TRLs). The RHC will follow the outcomes with interest.
[48] https://www.gov.uk/government/publications/zero-emission-vessels-and-infrastructure-zevi-competition
[49] https://renewablesnow.com/news/norways-enova-awards-usd-112m-to-maritime-hydrogen-hub-ship-projects-789342/

[50] The International Partnership for Hydrogen and Fuel Cells in the Economy (Regulations, Codes and Standards, and Safety), Pietro Moretto, (European Commission, JRC) and Laura Hill (U.S. DOE) Co Chairs, ICHS 2021, Safe Hydrogen for Net Zero, September 22, 2021].

there was uncertainty around a number of key elements of this infrastructure, including how the fuel might be transported to the ports in the first place.

2.4.1 Public funding

Public spending has been focused on early-stage research, with a greater emphasis on components than complete vessels and port infrastructure. This has not yielded private investment at scale. Indeed, some stakeholders have suggested that hydrogen-enabling technologies are already viable, and that complete vessels could be built, as has been the case in other countries. A shift in focus to the construction of complete vessels, and greater focus on enabling infrastructure at ports, could be the key to greater investor confidence.[51]

A) UK Shipping Office for Reducing Emissions (UK SHORE)

In March 2022, the Government allocated £206m to UK Shipping Office for Reducing Emissions (UK SHORE), a new programme within the Department for Transport focused on accelerating the technology necessary to decarbonising the domestic maritime sector. The UK SHORE programme is delivering a suite of interventions aimed at addressing different barriers to maritime decarbonisation across a range of technology readiness levels including the CMDC, which delivers up to £95 million for a range of clean maritime solutions and the ZEVI competition which will award £77m to support near-commercial zero emission shoreside and vessel technologies. Innovate UK are the delivery partner for these competitions. It should be noted that the Department for Transport (DfT) has not provided a funding commitment for UK SHORE beyond the year 2025.[52]

B) European Union

In addition to UK SHORE, the Horizon Europe programme has funded technology and hydrogen vessel development. Projects include HySeas III which aims for the development of a hydrogen ferry between Shapinsay and Kirkwafll in Orkney.[53]

C) Scottish Enterprise

The Scottish Government has a number of public funding streams, some of which are delivered through Scottish Enterprise.[54] The precursors to HySeas III, the HySeas I and II projects, were Scottish funded projects.

[51] Clean Maritime Demonstration Competition (CMDC) Round 4 was launched immediately prior to publication of this report, with a focus on funding real world demonstrations, pre-deployment trials and feasibility studies into clean maritime technologies that reduce greenhouse gas emissions.
[52] https://committees.parliament.uk/committee/153/transport-committee/news/195900/dft-promises-to-sort-muddle-of-maritime-policies-in-response-to-major-transport-committee-report/
[53] https://www.hyseas3.eu/the-project/. A related project Big Hit is also EU funded, and has demonstrated integrated hydrogen production, storage, transportation in Orkney https://www.bighit.eu/
[54] https://www.gov.scot/publications/emerging-energy-technologies-fund-hydrogen-innovation-scheme-form-and-guidance/

D) Department for Energy Security and Net Zero (DESNZ)

The Net Zero Innovation Portfolio has supported a number of hydrogen demonstrator projects, not involving marine vessels. The first competition closed in July 2022 and represented £26 million of funding to demonstrate end-to-end industrial fuel switching to hydrogen. This has included procuring complete hydrogen production systems and demonstrating hydrogen applications. Marine applications are not covered.[55]

A Contracts for Difference (CfD) approach to provide revenue support for hydrogen projects was announced in August 2022. Not specifically for the marine sector, the programme aims to develop an initial 1GW of green and blue hydrogen projects, with 10GW by 2030.[56]

A separate £240 million of grant funding from the Net Zero Hydrogen Fund (NZHF) was also announced in June 2022 'to support the upfront costs of developing and building low-carbon hydrogen production projects'.[57] This does not represent funding for vessels but is nonetheless a useful support for infrastructure.

In January 2023, DESNZ launched the second phase of the Red Diesel Replacement (RDR)[58] competition, which aims to encourage the development of alternative fuels and/or energy capture and storage technologies. Hydrogen as a fuel will be considered in its application for construction and mining, which may provide transferable insights for the maritime sector.

E) Department for Transport (DfT)

The Renewable Transport Fuel Obligation Order regulates renewable fuels used for transport. Under the RTFO, suppliers of relevant transport fuel in the UK must be able to show that a percentage of the fuel they supply comes from renewable and sustainable sources. As of January 2022, green hydrogen (non-biological origin) has been eligible for support under the RTFO.

F) Department for Environment, Food, and Rural Affairs (DEFRA)

The Infrastructure Scheme round of the UK Seafood Fund[59] will provide up to £2 million in grant funding to modernise the small-scale coastal fleet with replacement engines, such as covering the replacement and fitting costs of new hybrid engines.

G) Department for Business and Trade (DBT)

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55 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1067402/beis-hydrogen-funding-landscape-infographic.pdf

56 https://www.gov.uk/government/news/uk-government-launches-plan-for-a-world-leading-hydrogen-economy

57 https://www.gov.uk/government/publications/net-zero-hydrogen-fund-strand-1-and-strand-2

58 https://www.gov.uk/government/publications/red-diesel-replacement-competition-phase-2

59 https://www.gov.uk/guidance/apply-for-the-uk-seafood-fund-infrastructure-scheme-round-3

The Home Shipbuilding Credit Guarantee Scheme (HSCGS)[60] has been proposed to give UK shipyards access to finance for underwriting domestic contracts. If launched, the objective of the scheme is to level the playing field with competitors' export credit guarantees, to help UK shipbuilders have a fairer chance of securing valuable contracts.

2.5 Conclusions

There is a large and growing market in the UK and the North Sea for offshore wind support vessels that could potentially be furnished by hydrogen-powered ships, which we now know to be technically viable.

However, the UK's considerable investment in R&D has not yet led to significant private sector investment in either vessel development or port infrastructure, despite the viability of the technology for the former having been demonstrated. This is symptomatic of a broader challenge in the UK, whereby technically innovative businesses flourish at early stages, and then struggle to scale. Whilst this is largely related to the nature of grants made available, clear regulatory environments do of course play a role in building investor confidence.

The Government needs to act quickly. There is a limited window of opportunity to put in place the regulatory environment needed to ensure adoption of hydrogen-fuel, and an even narrower window to capitalise on the growth opportunities associated with hydrogen-vessel supply chains. Regulatory challenges associated with hydrogen maritime fuel, and associated recommendations, are set out in the final chapters of this report.

[60] https://www.gov.uk/government/news/new-uk-shipbuilding-vision-launched

3. Key Regulatory Issues

The issues set out below were prominent in the consultations undertaken for this report, and take account of the principles of good regulation (the importance of **collaboration**, being **balanced, proportionate and adaptable**, being **outcomes-focused and future-facing**) and, beyond that, address a range of focal points for regulators to address in overcoming unnecessary regulatory barriers to innovation.

Further to this, the council's report on "Closing the Gap"[61] offers cross-cutting analysis on how regulation and regulators can balance support for innovation with high standards of safety, quality and efficacy.

3.1 Risk-based design

Traditional shipbuilding has not involved significant innovation for a number of years and many industry stakeholders described today's ship design as being based on prescriptive, or checklist regulation. The innovative transition to net-zero shipping and the necessary introduction of novel propulsion-fuels and technology will require the development of new checklists or guidance derived from evaluation of the specific risks presented by the new technologies.[62] The intervening period will be difficult for small shipbuilders to negotiate, given that they lack the experience and skills to develop individual risk-based analyses.

The DNV report, The Maritime Forecast to 2050, 2022 edition,[63] notes that:

> "A shipbuilder will have to demonstrate through extensive risk evaluations that the chosen fuel system design […] meets the intent of the goal and functional requirements of the IGF Code [International code of safety for ships using gases or other low-flashpoint fuels], and that it is as safe as a conventional oil-fuelled ship. This is not a process that most shipbuilders and designers are used to working with. It requires more time and resources, and is creating uncertainty and an additional business risk for the project since acceptance of design premises are not necessarily a given outcome."

61 https://www.gov.uk/government/publications/closing-the-gap-getting-from-principles-to-practice-for-innovation-friendly-regulation

62 This guidance provides an example of how to bridge risk-based and check-list based regulation, in the context of wood fuel. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/594145/Woodfuel_Risk-based_Regional_Assessment_v2_Feb2017.pdf

63 DNV, The Maritime Forecast to 2050, 2022 edition, p40

3.2 Differences in risk-based evaluations by various bodies

Various industry vessel developers have cited difficulties with approval for hydrogen ship designs. Lack of consistency between engineering consultancies, class societies and the MCA have led to delays in approval, including the need for time-consuming redesign and reappraisal. The issue lies in the differences in interpretation between the various engineering consultancies, class societies, and the regulator. An example of this was reported to the RHC by a CMDC participant, where a different interpretation of guidance on vessel hydrogen storage resulted in the reworking of designs, leading to an increase in time and budget required to complete the work. This has also been cited as an issue within class societies. Most class societies maintain fully independent consultancy and regulatory functions, and delays were noted to have occurred when a class society acting as consultant to a project developed a design, which the regulatory function of the same class society did not subsequently approve.

The RHC also found consensus among industry interviewees that there is no clear pathway for the approval of new technology. There is also some concern that although the different classification societies work to common standards, there are mixed messages on how they respond to new technology.

The MCA published a high-level guidance document in March 2022, MGN 664[64], which was welcomed as a step forward by some stakeholders; but industry stakeholders offered feedback that a follow-up, more detailed document, would be warmly received as it would provide yet greater clarity and certainty. It should be noted that the MCA is responding to stakeholder feedback on the use of MGN 664 and is working towards updated version in the spring of 2023 to enhance its usability[65], the RHC hopes it takes into consideration the findings of this report.

3.3 Overly cautious approach to regulation

A high-profile Orkney-based ferry project has been quoted publicly as experiencing delays:

> "We've encountered some regulatory challenges with the Maritime and Coastguard Agency (MCA), which has meant we've got to the point where we can't complete that project." [66]

[64] https://www.gov.uk/government/publications/mgn-664-mf-certification-process-for-vessels-using-innovative-technology

[65] Additionally, in a public response to stakeholder comments on the Workboat Code, MCA has indicated that it will consult on regulations on alternative fuels and power sources (including hydrogen), to supplement the processes set out in MGN 664.

[66] https://hydrogen-central.com/scotland-hydrogen-powered-ferries-northern-isles/

Industry sources have suggested that the MCA is taking an overly cautious approach to regulation and at times these have caused major delays. Beyond hydrogen propulsion, an example was provided by a stakeholder of the MCA taking a conservative approach to the regulation of autonomous marine vessels and effectively preventing their plans to introduce them. This suggests a general over-precautionary tendency at MCA given that stakeholders claimed that marine robotics could be safer than current arrangements given appropriate regulatory adaptation.[67]

The RHC heard several times that the engineering expertise base at the MCA has been eroded over time. There are fewer staff, with less engineering experience, leading to a lack of self-confidence in decision making and a cautious approach. This engineering expertise is more commonly held in engineering consultancies including class societies. Where the technology teams of the MCA were seen to be more receptive, they were described as ‘not on the same wavelength’ as the regulatory function of the MCA.

There was some discussion among stakeholders that class societies themselves were also unnecessarily cautious. However, in the past year, it was reported that Lloyd’s Register has been further developing its approach to the adoption of new propulsion fuels.[68]

3.4 Port infrastructure

There is a lack of infrastructure available to support the operation of hydrogen vessels. Many port operators in the UK are private businesses and have a property developer’s business model and, according to several stakeholders, they rent space to tenants who are then expected to build any necessary infrastructure. In contrast, a greater number of continental ports are publicly owned and have longer term infrastructure plans, and as a result are ahead of the UK in the development of sustainable fuel propulsion systems. Ship designers and operators need certainty that the necessary shore infrastructure will be in place to service their ships.

This lack of strategic investment is a weakness in the UK in many renewable energy transition scenarios. For example, the British Energy Security Strategy (2022) recognises the value of investment ahead of need: over the long term, good value for money may entail paying more in the short term for an asset that will not be

[67] The RHC commends the collaborative efforts between Plymouth County Council and the MCA to develop testing plans for autonomous marine vessels in 2023-24, as a positive step in the right direction.https://www.gov.uk/government/publications/projects-selected-for-the-regulators-pioneer-fund/projects-selected-for-the-regulators-pioneer-fund-2022#month-projects-1

[68] https://www.lr.org/en/shipright-procedures/#accordion-riskmanagement

efficiently used immediately, but that reduces the need for repeated works to upgrade the system and whose operating costs will diminish significantly over time.[69]

An example from the maritime sector is presented in a report from the Tyndall Centre, University of Manchester, on shore-power. It states that it is long-understood that there is a 'chicken and egg' problem for shore-power – ports will not invest in shore- power until they know that ships are equipped and willing to use it; ship owners will not invest until they see that there are ports where they can connect. This case study highlights a similar issue affecting hydrogen fuel infrastructure at ports, and more broadly reflects a common problem across many areas of environmental policy, which is overcome by actions on both supply and demand sides, and collaborative working.[70] [71]

One issue is the lack of regulatory clarity around whether, and how, hydrogen storage at ports will be possible. A maritime stakeholder said:

> "As well as the question of regulation in the maritime space, there is also the need to consider the existing regulations that would apply to storage of these fuels, on land and in bulk, and the supply chain involved in that. The handling, storage and use of these fuels will need very careful consideration to ensure they are done safely with the appropriate checks and balances. Due to their potentially hazardous nature, it is likely that some places will be unable to handle these fuels and potentially vessels fuelled by them."

A point echoed in the MCA's report 'Supporting the ports ecosystem in decarbonisation'[72] which reports stakeholders' views that "no further port regulation was required nor any significant change to the regulatory framework but that government guidelines need to be updated significantly to be clearer about the management of the new more dangerous fuels within the port environment."

Hydrogen storage oversight is multifaceted and differs depending on volume. At lower storage inventories, the Planning (Hazardous Substances) Regulations 2015[73] apply, which is local authority regulation where HSE is a statutory consultee. At higher storage inventories, the Control of Major Accident Hazards (COMAH) 2015[74] regulations apply and are enforced by HSE.

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[69] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

[70] Bullock, S. (2021, Mar 1). Barriers and solutions for UK shore-power https://www.research.manchester.ac.uk/portal/files/188647824/Shore_power_Tyndall_FINAL_EMBARGO_1st_MARCH_2021.pdf

[71] The Zero Emission Vessels and Infrastructure (ZEVI) competition promotes collaborative working, projects require development of on-vessel technology and shoreside infrastructure, and partners must include both ports or infrastructure owners and operators, and vessel owners and operators.

[72] Maritime & Coastal Agency, Supporting the ports ecosystem in decarbonisation, 2023 (p10)

[73] https://www.hse.gov.uk/landuseplanning/hazardoussubstances.htm

[74] https://www.hse.gov.uk/pubns/books/l111.htm

HSE state they have carried out initial pre-normative research into the risks associated with storing hydrogen in confined and semi-confined spaces and undertakes international research and evidence gathering relating to hydrogen. There are several statutes that apply to the use of hydrogen at ports and the HSE have noted 8 of them. It is clear that the hazards posed by hydrogen storage and fuelling need careful consideration and will need to take into account diverse location-specific factors.

The HSE have told the RHC that they are engaging early with industry on the topic of hydrogen-fuelled vessels. However, currently there appears to be a stalemate in that regulators and commercial actors are each waiting for the other to make the first move, regulators in developing guidelines or commercial actors in investing in infrastructure. The onus seems to be placed on commercial actors to produce management plans to demonstrate the safety of their work environments and the lack of guidance may be explained by a reluctance to provide this for specific port environments - London and Orkney present very different risks - nevertheless some stakeholders perceive this situation as creating a first-mover disadvantage that is serving as a blocker to private-sector investment.

A similar issue that arose for the use of liquid natural gas as a fuel has led to ship-to-ship refuelling as port storage issues could not be overcome, despite this being an inefficient compromise for operators.

As aspects of port and planning policy are devolved matters, both the devolved authorities and the UK Government will need to consider new approaches to encourage the development of hydrogen port infrastructure.

3.5 Mismatch between onshore and offshore regulations

A regulatory gap between shore-based and vessel-based systems was highlighted. Some stakeholders, such as the PLA, have taken their own initiative to bring regulators together to agree common standards that enable interoperability of ship and shore systems. However, these initiatives are localized and have not been easy to arrange. One stakeholder suggested exploration of the application of common standards, and there may indeed be benefits associated with a British Standards Institution review.[75]

3.6 International engagement

Finally, although the recommendations below focus on activity in domestic waters; international engagement also remains important.

[75] https://www.gov.uk/government/publications/future-of-transport-data-standards-scoping-study

One stakeholder noted that “many UK maritime businesses are regulatory driven – they exist so ship owners/operators can safely run their vessels with the various rules. It is very important for UK companies to be at the forefront of discussions on regulations and leading the way they are shaped. International competition and self-interest do come into play when generating guidelines and it is important for the UK that the large state-owned and state-funded entities of Asia and Europe don’t write the rules to favour their local industry.”

Another UK maritime stakeholder highlighted that they considered “it paramount that the UK leads and speeds up the regulatory framework at the International Maritime Organization (IMO) to ensure a uniform application that will encourage early movers to build zero-emission vessels.” It is important that international consensus does not become tilted towards non-UK companies, with potential export disadvantage to shipbuilder and component suppliers. It will be easier to do that if we have already successfully adapted our domestic regulatory system.

This is a view shared in the Review of Net Zero[76], the independent review of the Government’s approach to delivering its net zero target, which advocates government to take a leading role in IMO negotiations to decarbonise the maritime sector.

Reassuringly, the HSE is already engaged in pre-normative hydrogen research projects in an international setting, although they clarify that policy activities are not covered. However, it will be the development of hydrogen infrastructure and deployment of hydrogen vessels that lends the UK real credibility on the international stage, without which UK industry risks being disadvantaged.

The following sections describe our recommendations for addressing the issues noted above, relevant to the operation of the vessels themselves, the onshore infrastructure, and the ship-shore interface.

[76] https://www.gov.uk/government/publications/review-of-net-zero

4. Governance of hydrogen propulsion vessels operating in UK waters: recommendations and rationale

Recommendation 1. Classification societies as approved bodies

The MCA should appoint one or more class societies as 'Approved Bodies' (ABs) for the approval of zero-carbon and novel vessel designs using risk-based assessments.

The MCA is perceived to have suffered from a gradual decline in its engineering expertise base. The stakeholders the RHC spoke to feel that it no longer has the skills to make engineering judgements with confidence. With an absence of a long-term strategy to upskill in the MCA, the use of suitably vetted external bodies would bridge this gap.

This recommendation follows a similar rationale to the arrangement in operation for the regulation of medical devices by the Medicines and Healthcare products Regulatory Agency (MHRA).[77] MHRA has general oversight of the regulatory system and is empowered to designate Approved Bodies (ABs) as competent to assess whether manufacturers and their products meet the requirements of the relevant regulations and to approve the placing of new products on the market. MHRA has a dedicated team that fulfils its obligations regarding designation and monitoring of ABs and monitors their performance through regular audits.

Arrangements that could form the basis of this seem to be in place already, however, delegation of authority should be based on a rigorous consideration of the hydrogen-specific experience and capability of that society.[78] Classification Societies play an international role in developing vessel standards and are part of the regulatory framework. This role seems similar to that of the British Standards Institution (BSI), one of the ABs appointed by the MHRA for the approval of medical devices.

Class societies are widely recognized as having the technical skills, experience and established credibility to perform the role of an AB. However, consideration should be given, where necessary, to revising existing arrangements for managing

[77] https://www.gov.uk/government/publications/approved-bodies-for-medical-devices/approved-bodies-for-medical-devices

[78] There are 6 classification societies MCA authorise as Recognised Organisations for the survey and inspection of UK ships: American Bureau of Shipping (ABS), Bureau Veritas SA (BV), Nippon Kaiji Kyokai (ClassNK), DNV, Lloyd's Register (LR), RINA Services S.p.A (RINA)

conflicting interests between the commercial engineering consulting roles and the role of an AB.

Recommendation 2. Guidance documents on regulation of hydrogen-powered vessels

Further guidelines should be produced for the designs of hydrogen propulsion vessels, which will provide confidence that appropriate regulations will be met.

Guidelines should be developed by MCA in consultation with the appropriate industry expertise, including classification societies, standards bodies, other regulators and appropriate academic and commercial engineering expertise. The issue of how such coordination could be achieved is expanded upon in Recommendation 6.

Two issues within the industry would need to be resolved:

- Ship builders are typically familiar with a prescriptive approach to regulation. Compliance with the required risk-based approach demands skills and expertise that are found mainly in external engineering consultancies, creating an additional layer of contracting and cost to shipbuilder, which can be prohibitive for small companies.
- There is occasionally a lack of consensus between the classification societies, engineering consultancies and the MCA.

As described in section 3, the RHC was informed of occasions when engineering analysis and design have indicated that certain vessel architectures are safe and viable, but the MCA has not approved and has required some rework of design. The arrangement proposed in Recommendation 6 could provide a solution to the issue of consensus, with a district centre coordinating different stakeholders and agencies, to cohere different approaches to regulation.

Recommendation 3. Public R&D investment

Ensuring future spending commitments are made at a scale comparable to international competitors and focus on de-risking hydrogen vessels from a technical and commercial perspective to bring private investment into the market.

The first two rounds of the CMDC allocated over £35m to 86 projects across the UK to deliver feasibility studies and trials in clean maritime solutions. As described in section 3, stakeholders considered this to be too little and spread too thinly to make for meaningful demonstrations. The barrier to developing hydrogen vessels is probably not the requirement for R&D investment, but rather the fragile state of a market exasperated by uncertainty in fuel costs, market regulations and technical regulations. Decisions made by DfT over the course of the RHC preparing this report are positive in this respect; CMDC round 3 has awarded £60m to 19 projects to deliver large scale technology and system demonstrations, and ZEVI competition will award £77m for large projects supporting close-to-commercial clean maritime solutions. **The RHC strongly supports this shift in focus, and would also welcome clarification of the strategy on how public funds are being used to accelerate the adoption of hydrogen (and zero) technologies in the marketplace.**[79]

More broadly, HMT, DfT, NSO, DESNZ, and other public funding bodies should ensure **future spending commitments are made at a scale comparable to international competitors and focus on de-risking hydrogen vessels from a technical and commercial perspective to bring private investment into the market.** The issue of how to coordinate public funding is expanded upon in Recommendation 6. Devolved authorities are advised to cooperate with UK agencies and give due regard to these findings.

The existence of R&D competitions and the involvement of regulators, may also lead to a focus on the supposed immaturity of the technology, expected to entail many years of development, rather than encouraging rapid resolution of regulatory issues and thereby supporting more rapid development of the technology. This issue was noted in the RHC's Drone report as affecting the Future Flight programme.[80] The experience of other countries such as Norway where fully functioning hydrogen-powered ships are already being trialled supports the case for greater urgency in regulatory adaptation in the UK. Norwegian advances in innovation capacity can be attributed to a more holistic approach to encouraging innovation that includes strategically targeted investment alongside an enabling regulatory environment.

Another approach would be **to encourage direct public procurement and operation of zero carbon vessels.** Norwegian ship designers involved in building such vessels are supported by Norwegian government and commercial procurement incentives. Repurposing some or all of the funds allocated to public R&D to procurement of vessels on a competitive tendering basis would compress several years of technology development and focus attention on what can be delivered now, also prompting regulatory authorities to resolve any issues quickly rather than focus on the development of technology roadmaps.

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[79] CMDC Round 4 was launched prior to the publication of this report. The RHC acknowledges and welcomes the competition's emphasis on funding real-world demonstrations and technologies with higher Technology Readiness Levels (TRL).

[80] https://www.gov.uk/government/publications/regulatory-horizons-council-the-regulation-of-drones

Recommendation 4. Incentivise strategic planning for 'investment ahead of need'

To incentivise strategic planning for 'investment ahead of need' for hydrogen infrastructure at ports, DfT should announce an intention to establish guidelines for ports, firstly to plan appropriately for the required transition to zero carbon ship propulsion, and secondly to invest in the roll-out of the infrastructure within a given time period

The lack of port infrastructure was often cited as a barrier to adoption of zero-carbon vessels in the UK. Clearly, no deployment of hydrogen vessels is possible without the availability of hydrogen fuelling infrastructure and several industry stakeholders described how some of the UK ports that are privately owned appear to act more like property developers, with short time horizons. This was contrasted with continental ports, which are typically municipally owned, and which have long-term plans to accommodate net-zero shipping, enabling investment in future port facilities and the wider support ecosystem. Examples include the Port of Antwerp-Bruges, which through the Hydrogen Import Coalition[81] – a partnership between industry and public stakeholders – is mapping the financial, technical and regulatory aspects of the hydrogen import chain, from production to distribution. Additionally, it already operates a multimodal hydrogen refuelling station[82] that services vessel bunkering and has plans to become a Multi Fuel Port[83] by integrating LNG, methanol, hydrogen and electrical power into their bunker market by 2025.

A barrier for the UK to overcome, is adopting the economic concept of 'investment ahead of need' which is commonly faced in energy transition situations. A port will not want to invest in infrastructure assets without being certain there is a market need, but there can be no market demand without the requisite infrastructure being in place. Ports will need to be incentivized, firstly to plan appropriately for the required transition to zero carbon ship propulsion, and secondly to invest in the roll-out of the infrastructure.

The RHC recommends that the **DfT announce their intention to establish guidelines for ports in England, incentivising strategic planning for investment in hydrogen infrastructure ahead of need. These guidelines should ensure that i) ports effectively plan for the necessary transition to zero carbon ship propulsion, and ii) invest in infrastructure roll-outs within a specified timeframe.** The DfT should notify relevant counterparts in the devolved

81 https://flux50.com/news-events/news/the-hydrogen-import-coalition-is-ready-to-take-the-next-step-towards-the-belgian-hydrogen-economy
82 https://cmb.tech/news/cmb-tech-opens-worlds-first-multimodal-hydrogen-refuelling-station-and-presents-the-hydrogen-truck
83 https://sustainableworldports.org/clean-marine-fuels/about-our-cmf-working-group/cmf-members/port-of-antwerp/

administrations of this work.[84] The process of implementing this government policy should be accompanied by a consultation with port authorities and shipping operators to inform development of the most effective and agile/adaptive incentive structure.

The RHC would expect the resulting policy to cover the following aspects:

1. In areas where there are expected to be opportunities to use hydrogen-powered vessels, **ports should be encouraged to produce strategic plans to accommodate them, with clear frameworks and timelines to provide greater certainty to shipbuilders and ship operators on future access to hydrogen bunkering**. This will improve the expected viability of hydrogen-propelled vessel projects.

2. To drive delivery of hydrogen development and use projects, **consideration should be made for the set-up of private-public partnerships led by ports authorities and including local authorities, HSE, hydrogen producers and hydrogen end-users**. An example of this is the PLA's Hydrogen Highway project,[85] establishing a national hydrogen highway network, integrating land, sea and port, which is a consortium of eight organisations including OS Energy, University of Strathclyde, University of Kent, HSE, ORE Catapult, University of Birmingham and Newcastle Marine Services, and supported by a number of other ports, operators and trade associations.

3. To consider different models that are relevant to different circumstances across the UK. For instance, the Orkney Islands Council is coordinating and accelerating the development of hydrogen infrastructure, which is designated as the 'Hydrogen Islands.' They are utilizing excess electricity from wind generation, which exceeds the carrying capacity of the local electricity grid, to generate and store green hydrogen. This green hydrogen is then used to power local shipping needs and other purposes.

   Governing onshore support facilities in the Orkney Islands will be very different from governing facilities in a busy port environment surrounded by major housing developments and other industrial operations. Therefore, **the RHC recommends that governance requirements for these different circumstances need to be specified to ensure that regulatory requirements are met and these initiatives can capitalize on the innovation trajectory.**

[84] Aspects of port and planning policy are devolved matters. The effectiveness of this recommendation will be maximised by coordinating policy making across administrations.
[85] https://www.pla.co.uk/PLA-led-consortium-wins-funding-for-Hydrogen-Highway-project

Recommendation 5. Integrated governance approaches for onshore hydrogen facilities

HSE should be tasked with delivering an internally coordinated approach to safety of onshore hydrogen facilities, that is better able than current arrangements to give ports and port-fuelling companies paths to develop hydrogen infrastructure and the shipping industry the confidence to proceed at pace with vessel construction.

Given its complex internal structure and array of responsibilities, HSE should be encouraged and supported to establish an internal initiative which will first review the appropriateness of existing guidance, which is currently disparate and may be challenging to navigate, and also consider whether further integrated standards, guidance, and frameworks are necessary to enable construction of hydrogen fuelling facilities at ports and possible future initiatives such as offshore renewable power production or ‘energy islands’.[86] This should be done bearing in mind Recommendation 6, requiring coordination with other regulators including MCA in particular.

Additionally, as noted in the Regulators Code (2014), early-stage engagement with industry is to be encouraged by regulators. Mechanisms exist in a variety of sectors to do this, ranging from guidance documents to formal Generic Design Assessments. However, whether early engagement itself is able to deliver the necessary support will depend on the nature of the engagement and the issues it is designed to address. The adoption of infrastructure at ports specifically for the application of hydrogen fuelling is a relatively recent challenge and developers would value early-stage guidance in order to develop plans. However HSE is not in a position to provide further guidance without plans being submitted for review.

The RHC suggests that the following elements should be part of this process.

- Engaging with commercial stakeholders to establish feasible timelines and targets for the safe adoption of hydrogen powered vessels operating within UK territorial waters, given an enabling governance environment, and to commit to working to these timelines. The development of the HSE’s Net Zero Hub is indication of progress in this direction.

- Establishing accountability for facilities and operation of hydrogen fuelling systems at ports, including a clear point of contact for industry to raise concerns and contribute new ideas at early, often pre-investment stages.

[86] https://www.dnv.com/energy-transition/offshore-energy-islands.html

- Continuing to work with industry partners to help support the development of standards that are proportionate and adaptive to current and future technology developments and the context of use, bearing in mind the differences between ports. Where stricter standards are required when additional hazards are present, this should not be allowed to restrain safe developments unnecessarily in other locations. DNV's Joint Industry Project on green hydrogen production systems[87] offers an exemplar of best practice.

- Continuing its international engagement, and using evidence from other countries and companies that are ahead of the UK in building hydrogen facilities at ports and related national and international organisations, e.g. the US Hydrogen and Fuel Cells Technology Office, the Centre for Hydrogen Safety, and HySafe (the International Association for hydrogen Safety).

- Sharing HSE's research and evidence with the Department for Energy Security and Net Zero, and continuing their collaborative work with other government departments and industry networks.

[87] https://www.dnv.com/article/certification-of-green-hydrogen-production-systems-211452

5. Gaps and Discontinuities: recommendations and rationale

Recommendations 1 – 3, relevant to vessels, and 4 – 5, covering onshore facilities, are all needed to facilitate the rapid development of this sector.

This shore-to-ship interface was of particular concern to several key stakeholders. The gap between ship-based systems, governed by the MCA, and shore-based systems, governed by the HSE, has yet to be bridged. There is wide agreement that this gap exists, but seemingly no common understanding of the exact nature of the problem and a lack of initiatives to address it. If this is not more widely recognised and addressed, it could lead to major delays in the UK adoption of this technology and to our inability to innovate independently of other nations.

Recommendation 6. Centre for Hydrogen Maritime Propulsion

Department for Transport, Department for Energy Security and Net Zero, National Shipbuilding Office, HSE and MCA to decide how to manage the implementation of Recommendations 1 – 5.

Given the limited window of opportunity for the UK to capitalise on its wide-ranging expertise in this area, and the need for urgent resolution of the regulatory gaps and discontinuities, the RHC proposes a Centre or Taskforce for Hydrogen Maritime Propulsion to address this and bring hydrogen maritime key players together in a decision-making forum.

The regulatory initiatives described in Recommendations 1 – 3 for vessels and 4 – 5 for onshore facilities will be internally coordinated, as described above, by the MCA and the HSE, respectively, and the management approach must meet the need for careful orchestration of these parallel initiatives to ensure smooth delivery of the technology. It should act as an aggregator of expertise and opinions from all involved parties and a generator of consensus around optimal solutions, rather than seeking to act as a 'gate keeper' or 'thought leader'. Whilst existing groups such as Maritime UK's Maritime Hydrogen Fuels Group exist, a Centre or Taskforce would be distinguished by a focus on standards and infrastructure delivery.

The management approach should also link these regulatory initiatives to the related need for revision of government initiatives for direct funding support of innovation, addressed in Recommendation 3. It should target the need to focus public investment on rapid delivery of proven technologies through downstream translational initiatives, rather than investing in upstream research projects. Targeting of these downstream funding initiatives should be guided by questions relevant to the necessary regulatory requirements for the sector.

The management approach (or Centre) should enable two primary areas of activity:

1. **An integrated governance environment covering both shipping and onshore facilities.**

The Centre should facilitate the HSE and MCA in working jointly with ports, local authorities, and other shipping, industry and onshore stakeholders to support the creation of integrated sets of standards, guidelines and, if necessary, regulations. The aim should be to enable the development of a UK hydrogen-fuelled fleet operating in UK territorial waters, along with the necessary onshore servicing facilities from major ports to more remote locations. The MCA have themselves recently recommended the creation of a Port Regulator Steering Group with the aim to ensure a macro view is taken by government to create a deeper shared understanding of sector issues to support the port industry in achieving net zero commitments.[88]

A minimum requirement of this recommendation will be common, or at least interoperable, standards on each side of the ship-shore gap, perhaps drawing on HSE's experience of handling hydrogen as cargo, rather than a fuel. The BSI could be appointed to oversee the delivery of these standards, and could build on existing work being undertaken by DfT, MCA and BSI to develop a standards roadmap framework for clean maritime, to ensure a cohesive approach across the market. Another requirement will be the development of full-system demonstrators in realistic conditions. Here, the UK could build on the experience of the PLA in setting up a stakeholder committee to resolve hydrogen development issues. The Centre should also seek to learn from similar initiatives in other countries. One such example is the Norwegian Maritime Authority, which as a "Centre for new technology" helps innovators and shipbuilders navigate guidance and legislation on novel ship design requirements.

2. **Public funding support for innovation**

The Centre should have a role in directing innovation funding strategies designed to accelerate deployment of hydrogen-related technology, but it should not itself become a funding body. It should also contribute to defining the objectives, scope and timelines of publicly funded demonstrator and research programmes, advising on how innovation funding can be used to support market creation for hydrogen vessels rather than focusing on early-stage R&D.

Several working groups, initiatives or agencies have been set up to resolve innovation support and/or regulatory challenges to the deployment of hydrogen

[88] Maritime & Coastguard Agency, Supporting the ports ecosystem in decarbonisation, 2023 (p19)

maritime technologies, led by various public agencies, but none has the remit or breadth of coverage needed to deliver the required comprehensive approach.

- The MCA Maritime Future Technologies team aims to facilitate and support innovation, regulation and policy.[89] However the Future Technologies team to date has a focus on R&D and less on resolving regulatory issues with existing technology. Ultimately, this team will also be limited by the perceived limitations of the MCA identified earlier in the report. The MCA has announced the movement of resource within the MCA to the Technical Services Operations team, which is more closely aligned with the delivery of regulatory functions. This may be a step forward.
- In general, industry stakeholders the RHC consulted were not aware of this team, perhaps due either to its relatively recent appointment or to an arm's length relationship with industry.
- The Offshore Renewable Energy Catapult has a role in delivery of the Clean Maritime Demonstrator Programme and is a hub for the development and demonstration of technologies. It is also an active participant in the Clean Maritime Demonstration Competition.
- The PLA has taken the initiative to work with HSE, MCA and other stakeholders to resolve challenges such as the need for shore to ship standards. Their approach appears pragmatic, targeted at near-term full vessel demonstration, and has received high-level support. A similar approach at national level could bring benefits to more regions and accelerate demonstrator projects, leading to earlier deployment of hydrogen powered vessels.
- The UK Shipping Office for Reducing Emissions was established by DfT in March 2022 to work in partnership with industry to 'help develop the infrastructure to enable net zero emission technologies […] including hydrogen', and 'implement a comprehensive research and development programme'. Its initial ambitions appeared to have focussed largely on small-scale, early-stage development research.

The Centre for Hydrogen Maritime Propulsion will be responsible for coordinating existing working groups and initiatives at a high level, while many working groups will continue to play an important role in policy delivery. The Centre's main focus will be on commissioning or coordinating work, rather than undertaking it directly. In certain cases, the Centre may eliminate the need for some working groups, which could simplify and enhance the efficiency of the innovation ecosystem.

[89] https://www.gov.uk/government/collections/maritime-future-technologies

6. Conclusion

The RHC hopes that this report will kick-start wide-ranging discussions on the current regulation of hydrogen fuel in the maritime industry, on the part of regulators, policymakers, and the maritime industry, with a view to ensuring a more proportionate and agile regulatory framework.

The Government needs to act quickly. The lack of development of a proportionate regulatory system and related delays in infrastructure development will have ramifications for the UK's ability to meet its net zero targets. The delay is creating a first-mover disadvantage for companies with the capacity to build, acquire and service hydrogen-propelled vessels, with international peers making the most of opportunities.

The report recommendations, if implemented, could support the use of hydrogen fuel in the maritime sector by:

- Increasing the speed of approvals of zero-carbon and novel vessel designs, by appointing class societies as ‘Approved Bodies’ (ABs) for vessel design evaluation
- Providing clarity to shipbuilders and innovators, through production of better specialized guidance for the designs of hydrogen propulsion vessels
- Accelerating the build rate of hydrogen vessels, by ensuring future spending commitments are made at a scale comparable to international competitors and focus on de-risking hydrogen vessels from a technical and commercial perspective to bring private investment into the market.
- Incentivising strategic planning for ‘investment ahead of need’ for hydrogen infrastructure at ports, by establishing guidelines for ports to plan appropriately for the required transition to zero carbon ship propulsion, and invest in the roll-out of the infrastructure.
- Building investor confidence in port owners and shipbuilders to undertake hydrogen infrastructure and vessel construction, through improved governance for onshore hydrogen facilities
- Ensuring proactive resolution of evolving regulatory issues through the creation of a Centre or Taskforce for Hydrogen Maritime Propulsion

Taken together the recommendations could help support UK shipbuilders build hydrogen propelled vessels over the next 3-5 years to meet the needs of offshore wind farms, aquaculture and coastal freight and ferry transport, bringing associated benefits to the UK’s ancillary services providers. The UK has the opportunity to ensure it is creating value, at each step of this roll-out of hydrogen-propelled maritime vessels and associated infrastructure.

Annex

Annex A – Methodology

The RHC takes a multidisciplinary and agile approach to developing its recommendations. The RHC conducted this enquiry by asking the following question, which we developed and sense-checked with stakeholders across industry and government actors including the Department for Transport and the Maritime Coastal Agency.

How can the regulatory system further support the development of a hydrogen vessel market needed to support offshore wind and other UK domestic maritime projects?

The RHC followed the following process to develop recommendations:

1. A **scoping process** to decide the area of focus within zero-carbon fuels in transportation.
2. **Refinement** in consultation with the Department for Business and Trade (DBT) maritime policy team and Department for Transport (DfT) maritime team, the RHC narrowed our focus to the use of hydrogen fuel in maritime sector, and a focus on domestic vessels such as those supporting offshore wind-energy production.
3. **Evidence gathering** through stakeholder engagement with relevant regulators and key parts of industry. This was supplemented by complementary evidence from published sources.
4. Used key sources on innovation-friendly regulation to help **develop recommendations**.
5. **Testing findings and recommendations** – Further stakeholder engagement conducted to test findings and recommendations, with recommendations further developed in an iterative process following input from stakeholders.

The RHC engaged with the below stakeholders to obtain their views on regulation of hydrogen vessels in the maritime sector in the UK and abroad.

Regulators and classification societies

- Maritime and Coastguard Agency (MCA)
- Health and Safety Executive (HSE)
- British Standards Institution (BSI)

- Lloyd's Register

Government and local authorities

- UK SHORE, Department for Transport
- Transport Decarbonisation, Department for Transport
- Hydrogen Economy, Department for Energy Security and Net Zero
- Manufacturing, Marine and Defence, Department for Business and Trade
- National Shipbuilding Office, Ministry of Defence
- Orkney Islands Council

Innovation and research organisations

- Marine Institute of the University of Plymouth
- European Marine Energy Centre (EMEC)
- Innovate UK KTN
- Offshore Renewable Energy Catapult
- Royal Institution of Naval Architects

Hydrogen-propelled vessel projects

- HyDIME (Hydrogen Diesel Injection in a Marine Environment)
- Clean Maritime Demonstration Competition (CMDC) participants

Commercial and industry

- Caledonian Maritime Assets Ltd (CMAL)
- Auriga Energy
- UK Chamber of Shipping
- Scottish Hydrogen and Fuel Cell Association
- Maritime UK
- Associated British Ports
- Windcat Workboats
- Bibby Marine
- Norwegian Ship Design
- Harland and Wolff

- Port Authority of London (PLA)

Annex B – Why Hydrogen in Maritime?

In scoping a potential report, the RHC undertook early desk research and engaged with policy teams and stakeholders interested in hydrogen applications including shipping, aviation, land transport, industry, and heat and buildings, to explore the feasibility of the technology and the extent to which regulation might enable its expansion.

- There was significant uncertainty around the potential value of hydrogen in decarbonising heat and buildings, and policy teams also indicated that consideration of the regulatory environment around domestic and industrial heating was already in train, meaning that the value added by the RHC might be limited.

- The Hydrogen Strategy indicated that the technology and infrastructure required to integrate hydrogen into our power system needs was not at a point at which the application would benefit from regulatory review

  > *"Our analysis indicates that by 2030, we could see a small but important role for low-carbon hydrogen to generate power, with demand for hydrogen in power ranging from 0-10TWh. We expect to see further ramp up beyond 2030: hydrogen demand could increase to 10-30TWh in 2035, and 25-40TWh by 2050"* [90]

- Again, the Hydrogen Strategy suggests that reducing CO2 in industry would have a large impact on reducing greenhouse gas emissions, citing that 'industry produced 16 per cent of UK emissions in 2018, and hydrogen will be critical to decarbonise industrial processes that would be hard to abate with carbon capture, usage, and storage or electrification. However, the council opted not to take forward this work on the basis that it had more limited expertise on industrial hydrogen, and also that the scope of the report might be overly large.

- Whilst hydrogen's application in aviation has the potential to be a major part of the future propulsion technology mix in the sector, there is a significant lead-in time, with hydrogen powered short-range aircraft targeted by 2035.[91] From present day to commercialisation and certification of hydrogen aircraft, it is expected to take more than 10 years, with any substantial fleet replacement

[90] https://www.gov.uk/government/publications/uk-hydrogen-strategy/uk-hydrogen-strategy-accessible-html-version

[91] Fuel Cells and Hydrogen 2 Joint Undertaking, Hydrogen-powered aviation: a fact-based study of hydrogen technology, economics, and climate impact by 2050, Publications Office, 2020, https://data.europa.eu/doi/10.2843/471510

another 10 years. A regulatory assessment of the application of hydrogen in aviation was deemed to have more limited value at present.

- There is a growing consensus that hydrogen will not play a significant role in land transport for light-duty and passenger cars.[92] Battery electric cars have seen improvements in vehicle real-world range and charging speeds, resulting in the establishment of a global market, with almost all manufacturers producing battery electric and plug-in hybrid vehicles. The limited scope for hydrogen cars to compete for a share of the car market dissuaded the RHC from undertaking an assessment of this application.

- Even for vehicles designated for long-haul logistic operations and transportation of heavy goods such as for trucks, where high energy density is better suited, widespread commercial application of hydrogen is currently uncertain. Improvements in charging speeds and the construction of megawatt charger networks, are expected to arrive earlier than the production of commercial hydrogen fuel-cell trucks. As with cars, the uncertainty around the market share for hydrogen heavy-duty vehicles deterred the undertaking of analysis of this application.

- Unlike other applications, the use of hydrogen fuel in the maritime sector is deemed a viable solution to decarbonisation in the near future. This is in part due to the comparatively well-developed state of the technology compared with its application in other transportation sectors. Unlike with land transportation, electrification of large payload and long-distance maritime vehicles is not currently viable, with hydrogen deemed a more viable fuel energy source. In addition, there is already a burgeoning market for hydrogen fuelled vessels globally, and a need domestically for low and zero carbon vessels to support the UK's growing offshore wind generation market. As such it was considered that there was value for the RHC to assess how regulation might enable the adoption of hydrogen fuel propulsion vessels in the UK.

[92] Plötz, P. Hydrogen technology is unlikely to play a major role in sustainable road transport. *Nat Electron* **5**, 8–10 (2022). https://doi.org/10.1038/s41928-021-00706-6

Annex C – Terms & key stakeholders

Terminology

The RHC have elected to use the terminology adopted by the Marine Management Organisation (MMO), an independent UK marine environment regulator established in 2010,[93] because the activities licenced by the MMO map approximately onto the high-potential applications of hydrogen vessels that the RHC identify in section 2. Other stakeholders used slightly different terms, many of which also had bases in legislation and regulatory guidance; for example, 'territorial sea' is used in some legislation to refer to the sea extending 12 nautical miles from the baseline coast[94] which is usually the low water mark.[95] To avoid confusion, the RHC have sought to use consistent terminology throughout the report.

Terms used frequently in this report include:

Maritime terminology

Inshore waters: the sea extending 12 nautical miles from the baseline coast.

Offshore waters: the sea beyond inshore waters and within the UK's exclusive economic zone, which can extend up to 200 nautical miles from coast or to the limits of the continental shelf;

International waters: waters outside of this space.

Inland waters: any area of water not categorised as 'sea' - e.g. canals, tidal and non-tidal rivers, lakes, and some estuarial waters (an arm of sea that extends inland to meet the mouth of a river).[96]

The MMO offers a useful diagram to depict these areas, which illustrates the complexity of the legislative and enforcement landscape; hydrogen vessels and port infrastructure themselves would be subject to slightly different regulations to those set out below, and this is explored in greater detail in section 3.

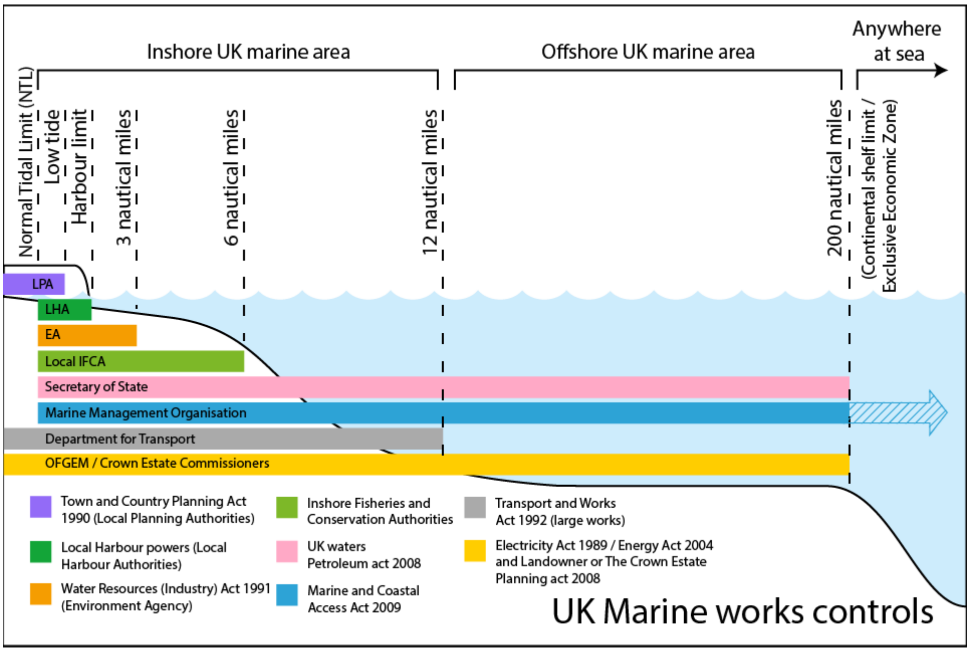
[93] https://www.gov.uk/government/organisations/marine-management-organisation/about

[94] Territorial Sea Act 1967 ch1a. To note, where UK territorial waters adjoin that of another state, the English Channel, the Territorial Sea (Limits) Order 1989 (SI 1989/482) sets out different limits in accordance with an agreement between France and the UK.

[95] Marine and Coastal Access Act 2009, Explanatory Note 24

[96] https://www.gov.uk/guidance/inland-waterways-and-categorisation-of-waters

Figure 1 - MMO Marine Licencing Definitions[97]



Key regulators & non-commercial actors

The following regulators and non-commercial bodies will play key roles in the implementation of our recommendations (sections 4-5)

Ship Classification Societies: Ship classification is an important aspect of marine vessel regulation. Classification societies, such as Lloyds Register, perform audits of ship designs and operation, and have a quasi-official role in regulation. The use of hydrogen fuel is not currently within classification but at the time of drafting, Lloyd's Register is preparing a first draft of 'Hydrogen Rules' covering some aspects of hydrogen deployment.

Maritime and Coastguard Authority (MCA): The MCA is an executive agency of the Department for Transport with broad responsibilities relating to maritime safety, including:

- promoting and enforcing compliance with maritime rules, regulations and best practice, making sure that legislation is proportionate for business
- undertaking the survey and inspection of United Kingdom registered ships and for Port State Control inspections of foreign flagged ships calling at UK ports.[98]

Ports: There is a variety of types, sizes and functions of ports and harbours across the UK. Ports policy is devolved, although devolved administrations tend to manage

[97] https://www.gov.uk/guidance/marine-licensing-definitions
[98] https://www.gov.uk/government/organisations/maritime-and-coastguard-agency/about

ports policy following the same processes.[99] The Department for Transport Port Freight Statistics estimate there are 51 'major' ports each handling more than 1 million tonnes of cargo per annum, and a further 63 'minor' ports.[100] In addition, there are a further 800 locations along the coast and inland offering facilities for domestic and short sea fleets.[101] The UK has the following 4 main ownership models for port facilitates:

- around two-thirds of major ports are privately owned commercial entities (generally larger ports or port groupings);
- around a quarter of major ports are established as public trusts, independent statutory bodies with no shareholders or owners and where surplus is invested back into each port for the benefit of its stakeholders such as the Port of London Authority;
- a small number of major ports are owned by local authorities, such as Plymouth and Portsmouth ports[102] [103] and;
- a handful are smaller ports owned by the Ministry of Defence.

According to Innovate UK's Decarbonising Ports and Harbour's programme, local authority-owned ports tend to have made the most significant progress toward decarbonisation. This was due to a combination of their recognising their responsibilities on air quality towards households in the vicinity, and commercial pressures, for example from channel ferry operators who had decided to move to hybrid ferries.

Health and Safety Executive (HSE): The HSE is Britain's national regulator for Health and Safety in the workplace, and is the responsible regulator for port safety, and the safety of workers on installations up to 12 miles from the coast (on inshore waters). HSENI provides the same functions in Northern Ireland.

Local Authorities (LAs): Local authorities provide permission for hydrogen storage sites under their responsibilities relating to the storage of hazardous substances, and in some cases they are also port operators. To date, no docks or ports have been classified as storage sites for hydrogen fuel for vessel propulsion, and any future processes may be complicated by housing and industrial developments in the vicinity of the port.

International Maritime Organisation (IMO): The IMO is a United Nations (UN) agency which provides the mechanism to allow governments to cooperate in relation to

[99] https://commonslibrary.parliament.uk/research-briefings/cbp-9576/
[100] Department for Transports Port Freight Statistics 2020: notes and definitions https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1002364/port-freight-notes-and-definitions.pdf
[101] UMAS FUSE (Fuse Use Statistics and Emissions) Model https://www.u-mas.co.uk/products/fuse/
[102] https://ktn-uk.org/programme/decarbonising-ports-harbours-landscape/
[103] https://marcap.egnyte.com/dl/igIMQ6UZVs/UK_Domestic_Shipping_Mobilising_Investment_in_Net_Zero.pdf_

technical matters of all kinds affecting shipping of international trade to facilitate the highest practical standards in relation to safety, efficiency of navigation and prevention of and control of pollution from ships.