Net Zero Ports: Challenges and Opportunities

Department for Transport

UK National Clean Maritime Research Hub's response 24 June 2025

*The **UK National Clean Maritime Research Hub** is focusing on research at lower technology readiness levels to inform future research, development and deployment. Through collaboration with stakeholders from across the maritime sector, the Hub aims to drive forward innovation and transformation, establishing the UK's competitive advantage by setting a global benchmark for excellence.*

Website: https://www.clean-maritime-research-hub.org/

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Please note: This response was prepared over a period of time and at the time of submission was unable to match to question numbers on a later download of the form. The questions have been numbered sequentially for the purposes of this submission.

1. **Do you agree or disagree that ports will play an increased role in directly providing or enabling third parties to provide the infrastructure that helps shipping to decarbonise? Please state your reasons why.**

Ports are strategic hubs in the maritime supply chain and are well positioned to facilitate the decarbonisation of the shipping industry.

Port investment and development in infrastructure can enable the following:

- Provision of shore power facilities
- Bunkering of alternative fuels
- Provision of renewable energy sources
- Modal shift infrastructure

Ports can collaborate with third-party providers to offer services e.g. alternative fuel supply, storage, conversion and distribution. Port authorities have been working with third-party providers such as independent small businesses or subsidiaries of larger energy companies looking into entering the shore power (cold ironing) market on several projects funded by the Clean Maritime Demonstration Competition. In general, such initiatives require regulation and financial incentives to ensure commercial viability.

2. **Do you agree or disagree that there's sufficient collaboration between ports, shipping operators and infrastructure providers to decarbonise shipping? Please state your reasons why.**

UK SHORE's Clean Maritime Demonstration Competition (CMDC) rounds of funding, including the International Green Shipping Fund (IGSF), have supported the collaboration between ports, shipping operators, energy companies and infrastructure providers. Since 2021 UK SHORE have funded a range of feasibility studies and technology pre-deployment trials to decarbonising the maritime and shipping sector. Examples include ports working with an offshore wind vessel operator and energy companies, investments in shore power and alternative fuels such as LNG and HVO and in port community systems.

There are however systemic challenges. The funding for feasibility studies and pre-deployment trials are relatively short term, technological readiness is uneven, and regulation frameworks are fragmented. There is currently limited infrastructure for alternative fuels for example making longer term investment decisions on vessels challenging.

A key issue is the need for clearer business models to support collaboration with new technology providers. Some ports have partnerships with vessel operators for say a wind farm and also energy providers. If a new technology provider developing a modularised shore power supply system for the port, they will need to collaborate with all three parties. A key learning to take forward in follow up plans from CMDC projects is how interests are balanced from four or even more parties.

In summary for decarbonisation momentum to be maintained, the sector must move beyond project-based coordination and establish deeper and more integrated long-term collaboration, sharing best practices and developing cross-sector strategies that align investment, innovation, with national and international policy.

3. **Do you agree or disagree that ports have the existing powers to directly provide energy to vessels that leave the port? Please state your reasons why.**

Ports existing powers are restrictive, in that port authorities do not currently have explicit statutory powers to supply electricity to vessels beyond the port boundary, which can limit their ability to support vessels if not at berth. While ports can provide onshore power supplies (aka ‘cold ironing’) while ships are docked, their role in energy provision typically ends at the quayside. This limitation is partly due to regulatory and licensing frameworks that treat energy supply beyond the port as a utility function, requiring separate authorisation.

For example, Port of Dover have applied to the Marine Management Organisation for a Harbour Revision Order to supply electricity to vessels but understand that this application is in a slow-moving queue. A potential solution would be to introduce an omnibus power for all Harbour Authorities to be able to provide electricity to vessels at their ports.

Onshore power supply (OPS) is a key decarbonisation tool, enabling ships to power down onboard generators and plug into the local grid. However, this is often interpreted narrowly as a direct grid connection, which presents challenges, including high infrastructure costs, grid capacity constraints, and compatibility issues between ship and shore systems. The capacity at ports is variable across the UK and this will become more critical as vessels are retrofitted and built for cold ironing. The Port of Felixstowe for example is not short of power and capacity well planned for the next decade or so. At smaller ports capacity is more restricted.

One promising alternative is the use of shore-side energy storage systems that can slowly charge from the grid and then rapidly discharge to vessels. This approach can reduce peak demand on the grid, offer more flexible deployment, and potentially allow mobile or modular solutions that bypass some of the regulatory hurdles of fixed grid connections.

To fully unlock the potential of OPS and support decarbonisation beyond the berth, the UK needs to consider existing regulatory frameworks, encourage battery-based or hybrid solutions, and clarify the role of ports as energy hubs, as part of a broader clean maritime energy ecosystem.

4. What measures could government take to increase certainty in terms of ensuring adequate supply of infrastructure at ports and the subsequent demand for use of that infrastructure?

Coordinated and collaborative approach is needed between government, ports, shipping companies, energy providers, coastal communities, and investors – it is not just infrastructure but also the safe use of alternative fuels so appropriate regulations of these are required.

Long term policy commitments and clear roadmaps for port infrastructure upgrades, cold ironing readiness and alternative fuel availability (e.g., hydrogen or ammonia). Clarity around port decarbonisation policy in the UK needed as the implementation on measures elsewhere are taking effect e.g. FuelEU and the EU ETS. A commitment to technology neutrality where appropriate, while outlining clear regulatory expectations (such as shore power mandates). There could be further targeted funding to offer co-fundings and grants for port upgrades, cold ironing infrastructure, and demonstrations. An area that could be explored is maximising surplus electricity generation from offshore wind farms for hydrogen production or port use.

To increase certainty around ensuring adequate infrastructure at UK ports and the demand for its use, the government could consider several measures:

(i) Establish clear regulations and policies that encourage private investment in port infrastructure and reduce uncertainty for investors and operators.

(ii) Implement comprehensive data collection and forecasting systems to monitor port-related activities and predict future demand. Sharing this information transparently with stakeholders can help align infrastructure development with actual needs.

(iii) Simplify and expedite planning and permitting procedures for port infrastructure projects to reduce delays and encourage timely development.

(iv) Incentivize the adoption of new technologies and support first movers.

(v) Foster collaboration between government agencies, port authorities, shipping companies, and local communities to ensure that infrastructure development aligns with economic and environmental goals.

To give investors and developers more confidence in building hydrogen and ammonia storage and bunkering infrastructure, there are some regulatory issues to be addressed. There are technical challenges in making hydrogen safe to use on ships. The IMO’s International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels (IGF Code) does not currently appropriately address hydrogen safety challenges. The use of “alternative design” is more theoretical than realised in practice. Need to ensure that any hydrogen-powered ships brought into service are designed to be safe in a way that is reliable and minuses costs. This creates uncertainty for shipowners and port operators.

It should be noted too that shore power system safety regulations are not covered by ship classification societies. Separate safety regulations are required too where using alternative fuels for shore power technologies for cold ironing services.

Government can play an important role by supporting stronger collaboration. At the moment port authorities, regulators/classification societies, naval architects and technology developers sometimes, if not often, work separately. If governments help bring these groups together, the planning and approval process can become faster and more organised. Importantly, hydrogen and ammonia projects should be treated as a key part of the wider shift of the country towards cleaner energy.

5. Do you agree or disagree that introducing an emissions at berth requirement will be effective at reducing at berth GHG emissions and air pollutants surrounding ports?

Introducing an emissions at berth requirement can be an effective measure to reduce GHG emissions and air pollutants surrounding ports. Such requirements can limit emissions from ships while they are docked. As a result, vessels will be encouraged to adopt shore power or cleaner fuels. This can significantly decrease local air pollution and GHG emissions in port areas, improving air quality and health outcomes for nearby communities. However, the effectiveness of such requirements depends on proper implementation, enforcement, and the availability of appropriate solutions like shore power infrastructure and equipment.

Note that the success of implementing such a requirement would depend on the cost of the penalty relative to the cost of UK electricity. UK electricity considerably more expensive than EU and shipping owners may find it cheaper to use conventional fuels for auxiliary services at berth and pay a penalty rather than pay for electricity.

If the penalty was sufficiently steep, or there were financial incentives to use UK electricity while at berth, this would reduce emissions at berth and improve the air quality in the area. All subject of course to the ships themselves being cold ironing enabled and there being an appropriate connection while at berth. A port decarbonisation plan with a clear timeline would provide the industry with direction to begin transitioning. However, early penalties could pose significant challenges for some businesses, so such measures should be applied cautiously.

Note that ships could use carbon free fuels for auxiliary instead for example ammonia, hydrogen or methanol. But such fuels while carbon free pose safety challenges and need to address risk of toxicity and other hazards.

In addition, emissions from vessels when they are in port areas but not docked should not be ignored. While introducing emissions-at-berth requirements may significantly reduce greenhouse gas emissions and air pollutants in port areas, this approach addresses only a small part of the maritime emissions profile. At-berth emissions primarily come from auxiliary engines, which are relatively low compared to the emissions produced during vessel approach, manoeuvring, and departure, where main engines are often in use. These phases commonly go unregulated at the port level, despite their substantial contribution to overall emissions and their impact on air quality in surrounding communities.

To achieve meaningful decarbonisation, the UK should adopt a more comprehensive strategy that includes emissions across all phases of vessel activity. This would involve empowering port authorities with the regulatory tools to influence emissions beyond the berth, for example through differentiated harbour dues, operational incentives for cleaner approaches, or integration into green corridor frameworks. By broadening the scope of emissions control and enabling ports to act as active energy and environmental stewards, the UK could better align its maritime decarbonisation efforts with its net-zero ambitions and aspirations for international leadership on green shipping.

6. **What are the technological solutions that will most likely prevail if a requirement for zero or near zero emissions at berth is implemented? Please state your reasons why and any evidence that supports it.**

There are a range of technological solutions such as shore power, cleaner fuels and emerging electric vessel technologies that are likely to prevail if zero or near-zero emissions at berth become a requirement in the UK. However, different ports may have different preferences and constraints to adoption.

Hydrogen and ammonia are alternative fuels that could be used not only in propulsion but in the supply of auxiliary power while ships are docked, as ports and vessel operators look for ways to reduce emissions from diesel generators on board.

Hydrogen is already being used for both propulsion and auxiliary systems, most commonly in the form of compressed gaseous hydrogen (CGH2). 82% of hydrogen-powered vessels built between 2000 and 2024 used CGH2 stored at pressures from 200 to 700 bar depending on how much energy was needed and the required sailing distance. For hydrogen systems to be used safely while ships are docked, ports and vessels will need proper infrastructure, including valves that control the flow, ventilation systems with required air changes per hour (ACH) and advanced detectors that can quickly identify gas leaks.

Ammonia is attracting attention for its higher energy density and ease of storage as a liquid compared to hydrogen. However, ammonia brings different safety challenges mainly due to its toxic and corrosive nature. The systems must include fully sealed storage tanks, materials that can resist corrosion, ventilation systems that stop toxic gas from building up and fire suppression systems designed to deal with chemical fires and in handling ammonia safely overall. Ammonia slip, i.e. when unburned ammonia escapes during combustion or venting, must be carefully controlled to avoid harming both the environment and human health.

We outline below some further technological solution examples:

- MW scale battery system to store electricity during the demand valley and use for peak hours e.g. Fortescue 3MW containerised battery system for mobile power supply.
- Green methanol/HVO engine gensets. HVO has been used on shore power gensets at ports already. Green methanol is a promising alternative fuel with multiple methanol engine models are available on the market. Green methanol may have a large production capability

compared to HVO in the long run. Maersk for example the global containership owner has chosen methanol as the future fuel for their fleet.

- Ammonia engine gensets. There is potential for cheap ammonia fuel available for import in a near future from the Middle East and Australia. Instead of cracking ammonia for purified hydrogen production and fuel cell use, it is more economically viable to burn ammonia in new engine models. It is anticipated that some ammonia/dual fuel engine models will be available on the market within next five years.
- Green hydrogen from surplus renewable electricity say from offshore wind farms may play a role if commercially viable. Fuel cell costs are still too high for shore power applications at the moment. The materials used in fuel cells may cause potential supply chain issues if wide adoption across different industry sectors such as in the demand for platinum[1].
- Ocean energy near ports, such as tidal and wave energy has potential as can provide a land-saving approach to generating additional renewable electricity compared with solar and onshore wind.

7. In your opinion, does the government need to direct ports towards a certain default technological solution (e.g. electrification) to achieve zero or near zero emissions at berth, whilst enabling other technologies where appropriate through exemptions?

At this stage a technology agnostic approach would be most effective, as many low carbon fuels and corresponding propulsion systems are still in development.

Electrification is suitable for certain applications, such as electrifying cranes, trucks or other equipment, but it is not the only solution for cold ironing.

It could bring greater certainty if the government directs ports toward electrification as the default solution for achieving zero or near-zero emissions at berth, but while allowing the development of other technologies through exemptions. Such a strategy could promote a clear and effective pathway to decarbonization, supporting practical implementation across diverse port environments. However, this approach may face challenges due to the diversity of decarbonization pathways and concerns about the capacity of the electricity supply.

While the UK government has a clear role in setting emissions reduction targets and enabling infrastructure investment, mandating a single default technological solution (i.e. electrification at berth) risks stifling innovation and limiting flexibility. Ports vary widely in their operational profiles, vessel types, energy access, and local constraints. A one-size-fits-all approach could inadvertently penalise ports or operators that are better suited to alternative solutions, such as hydrogen, ammonia, biofuels, or hybrid battery systems.

It should be noted too that cranes, trucks and other equipment may have substantial remaining working life and it could be financially onerous if needing to replace relatively young equipment.

The government could instead focus on the application of performance-based standards. For example, requiring zero or near-zero emissions at berth, while allowing ports and operators to

[1] https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/mineral-requirements-for-clean-energy-transitions

determine the most appropriate technologies to meet those standards. This approach encourages innovation, supports emerging technologies, and enables tailored solutions that reflect local conditions.

Where electrification is the most viable option in many cases, it should be supported through funding and planning reform but not enforced as the only route. Exemptions or alternative compliance pathways should be built into the regulatory framework to ensure inclusivity and adaptability. The goal should be to create a technology-neutral policy which rewards emissions outcomes, not specific methods or pathways. This will better align with the UK's broader innovation and decarbonisation goals, while empowering the maritime sector to lead in developing diverse, scalable solutions.

8. When developing the requirement, what can the government do to ensure it improves/protects air quality at ports?

To ensure that any requirement genuinely improves air quality, the government could go beyond simply mandating a specific technology. A preferable approach would be to focus on setting clear, measurable air quality outcomes, such as reductions in nitrous oxides (NOx), sulphur oxides (SOx), particulate matter, and greenhouse gas emissions such as carbon dioxide (CO_2). Allowing ports and operators the flexibility to choose how they meet those targets. This performance-based approach encourages innovation and ensures that solutions are tailored to the unique operational and environmental conditions of each port.

A technology-neutral framework would enable the adoption of a range of solutions, including shore power, battery-based systems, and alternative fuels, while still achieving the desired air quality outcomes. To support this, the government could invest in enabling infrastructure, including grid upgrades and clean energy supply chains, and streamline planning and permitting processes. Transparent emissions monitoring and public reporting should also be mandated to ensure accountability and track progress over time.

Port emissions policy could be aligned with broader environmental and public health goals. Engaging with stakeholders will help ensure that the requirement is both effective and practical. By focusing on outcomes rather than prescriptive methods, the UK can protect air quality, support innovation, and accelerate maritime decarbonisation in a way that is inclusive and future-proof.

In summary the government could

- Set emissions standards not only for greenhouse gases but NOx SOx and particulates and also set safety and security standards
- Implement monitoring and reporting to track pollutant levels and ensure compliance with emissions standards
- Introduce enforcement regulations and penalties for non-compliance.

9. What features of a regulatory regime would support the decarbonisation of at berth emissions from shipping?

Needs to be coordinated across energy provision, infrastructure investment, safety regulations and all in consultation with ports and coastal communities. A regulatory regime could include several features such as:

(1) clear enforceable standards with penalties for non-compliance

(2) monitoring, reporting, and verification;

(3) incentives and support measures

To enable the safe use of hydrogen and ammonia at berth, the regulatory regime must in particular be strengthened with safety focused features that reflect the unique hazards of both fuels. Current frameworks such as IMO's IGF Code do not yet offer specific or adequate guidance for hydrogen or ammonia systems in areas like ventilation, gas dispersion, or fire suppression. Leak and flame detection systems must be required for all hydrogen and ammonia operations. For hydrogen, this includes sensors that can detect invisible flames and rapidly accumulating concentrations in confined spaces.

Hydrogen's buoyancy and high diffusivity make it especially prone to accumulating near ceilings or in ducting. For ammonia real-time toxic gas detectors are needed to trigger immediate ventilation or shutdown responses in the event of a leak, since even small concentrations can pose serious health hazards. Another important requirement is improved ventilation. The current IGF Code minimum of 30 air changes per hour (ACH) may be too low during high-flow releases. Especially for hydrogen where high-pressure venting can lead to the pressure peaking phenomenon. IMO regulations should require designs using developed computational fluid dynamics (CFD) modelling to evaluate scenarios, ventilation effectiveness and suggest engineering tools or correlations.

A regulatory regime that supports the decarbonisation of at-berth emissions from shipping should be performance-based, technology-neutral, and outcomes-focused. It should set clear emissions reduction targets, while allowing flexibility in how those targets are achieved, whether through shore power, battery systems, alternative fuels, or other means. The regime should include robust monitoring and reporting requirements to ensure transparency and accountability and be supported by aligned government investment in enabling infrastructure upgrades and clean energy supply.

In parallel planning and permitting processes should be streamlined to accelerate deployment, and the regime should be aligned with broader environmental and public health goals. Crucially, it should be developed in consultation with ports, shipping operators, and local communities to ensure practicality, fairness, and long-term effectiveness.

As the EU is a first mover, lessons from their implementation of measures such as the FuelEU Maritime Regulation and the EU ETS could be drawn upon. Building on these insights, the UK should develop tailored regulatory approaches to decarbonise its ports—while ensuring support for local businesses operating within the port sector.

10. **How should government define high frequency services with short turnaround times at ports for the purpose of an at berth requirement? Please explain your rationale and any supporting evidence.**

High-frequency shipping services may be defined as those that operate with a minimum number of departures or arrivals per week on a specific route, combined with an average port turnaround time below a defined threshold. The specific values of the thresholds may need consultation with industry as to what is most appropriate.

For example, ferries could be considered as operating at high frequency services where they are at berth for only 30-45 minutes before their next voyage. Cruise ships however will be at berth for 7-8 hours or in some cases a couple days. Offshore service vessels have duty cycle of 10-12 days at sea and 5-10 hours or several days at berth before next duty cycle.

Short turnaround times as those operating multiple daily port calls (e.g. 3 or more per day) with berth durations typically under 2 hours (current government definition).

11. Do you agree or disagree that high frequency services with short turnaround times at ports should be captured in any future emissions at berth requirement?

Yes, high-frequency services with short turnaround times should be included in any future emissions-at-berth requirement. Excluding these vessels would create a significant loophole, particularly at ports with high volumes of ferry traffic or short-sea cargo operations, where these vessels contribute substantially to local air pollution and greenhouse gas emissions. While operational constraints may make traditional shore power connections challenging, this should not exempt these services from emissions reduction obligations. Instead, the regulatory framework should allow for alternative compliance pathways, such as battery-based solutions or hybrid systems, while still holding all vessel types accountable for their environmental impact.

12. Please provide us with a) any current examples of and b) any examples of future plans for zero and near-zero GHG emission refuelling production, storage, import and export terminals at ports for alternative fuels such as hydrogen and hydrogen derivatives (e.g. ammonia or methanol)? Please provide as much information as possible, including distinguishing between the different fuels where possible, and providing details on where any infrastructure is/will be located, and the companies with which you are working.

Some examples:

- Stanlow Terminals: This is a leading biofuels hub, offering solutions to support the UK's ongoing adoption of sustainable fuels for transport.
- HyNet North West: The HyNet project aims to develop a regional low-carbon energy system, including: Green hydrogen production via electrolysis powered by offshore wind; Infrastructure for hydrogen storage and distribution; Potential export of green hydrogen or derivatives like ammonia. Note that HI-ACT website gives detailed hydrogen production sites in the UK https://hi-act.ac.uk/hydrogen-map/
- Statkraft: Advancing a green ammonia production facility in the UK, centred on its Scatsta project in Shetland. A 350 MW electrolytic green hydrogen-to-ammonia plant is planned near the former Scatsta Airport in Shetland. Received £270,500 in Scottish Government funding to progress feasibility and lease arrangements

- Seal Sands green methanol terminal in the North East
- Port of Tyne is investigating becoming a green energy hub

Safety considerations:

Ports aiming to become hydrogen or ammonia refuelling hubs face several critical safety barriers, which must be addressed through design, regulation and operational practice. One of the most significant risks is the potential for fire and explosion. Hydrogen is highly flammable, with a wide flammability range and extremely low ignition energy, while ammonia is toxic and can form flammable mixtures under certain conditions. Both fuels introduce risks that differ from traditional marine fuels and require fundamentally different approaches to hazard management. Ports face challenges in emergency response preparedness. Standard fire protection or suppression systems may be ineffective against hydrogen jet fires and current training for port staff does not typically include managing gas dispersion or dealing with toxic releases. This knowledge gap is a barrier in itself as ports cannot safely operate as bunkering hubs without first ensuring that their personnel are equipped to manage emergencies specific to hydrogen and ammonia. The absence of clear and specific regulations for hydrogen and ammonia in maritime applications makes project planning and approval more difficult. Since the IGF Code only covers these fuels partially and guidance from classification societies varies, port authorities may be reluctant to invest in infrastructure that yet need consistent and well-established safety standards.

13. What are the barriers that ports face in becoming near-zero or zero GHG emission refuelling hubs? Please state your reasons why, including any safety barriers.

- Safety regulations / skills and training in handling alternative fuels
- Infrastructure investment and when shipping companies make investment decisions new ships or retrofit

To become near-zero or zero GHG emission refuelling hubs for alternative fuels such as hydrogen, ammonia, and methanol, ports face a range of barriers such as infrastructural and supply chain barriers (lack of dedicated facilities for production, storage, and distribution of low-carbon fuels); economic barriers (high capital costs, uncertain market demand); regulatory barriers (lack of clear regulatory frameworks, lengthy permitting processes); safety barriers (flammability/toxicity hazards, risk management complexities); and operational barriers (workforce skills gap; operational safety concerns).

Human safety and workforce readiness being among the most critical. Many ports lack the established protocols and emergency response systems needed to manage these hazards, and current regulations were not designed for these emerging technologies. Without clear standards and liability frameworks, ports may be hesitant to invest in the necessary infrastructure.

Equally important is the need for education and training across the sector. The transition to clean fuels and advanced energy systems demands a skilled workforce capable of safely operating, maintaining, and responding to incidents involving unfamiliar technologies. However, many port workers and operators have limited exposure to these systems, creating a significant skills gap. Addressing this requires targeted training programmes, updated certifications, and cross-sector collaboration to build operational confidence. Combined with infrastructure investment and regulatory reform, these measures are essential to enabling ports to become safe, effective hubs for low-emission maritime refuelling.

14. What are the estimated costs and timeframes for building near-zero or zero GHG emission refuelling hubs? Please provide us with the evidence and assumptions that you have used in this response.

Costs and timeframes vary with ports. The Port of Dover is implementing a phrased transition plan towards 2050. However, the pace in power grid upgrade may become a barrier for the phased transition. According to their CMDC2 report (the Port of Dover, 2023), the capex cost for various stages of power upgrades at the Port of Dover are:

Upgrading from 4.2 MVA to 20MVA, overall capex £17.8 million

Upgrading from 20 MVA to 50MVA, overall capex £59 million

Upgrading from 50 MVA to 80MVA, overall capex £92 million

Figures taken from: The Port of Dover (2023): Green corridor at short straits (GCSS): feasibility study into establishing a Green Corridor between Port of Dover and the Ports of Calais and Dunkirk

15. What are the potential markets and end use sectors that can be supplied when a port becomes a near-zero or zero GHG emission refuelling hub? Please set out whether these are domestic and/or for international export markets.

Various depends on geographic location if near zero carbon fuel production sites or a strategic node for foreign energy importer to transport green hydrogen or ammonia.

The end use sectors may include maritime (shipping, ferries, port logistics); road transport (trucks, buses, vans); industry (manufacturing processes, chemical production, power generation); aviation; export markets (international energy markets). However, this may depend on the type of near-zero or zero GHG fuels.

16. What are the potential growth opportunities of ports becoming near-zero or zero GHG emission refuelling hubs?

Depends on other things such as UK ETS vs FuelEU measures and relative competitiveness more generally (especially with large fairly local international hubs such as Rotterdam).

Transforming ports into near-zero or zero GHG emission refuelling hubs would offer substantial growth prospects across economic development, environmental sustainability, technological innovation, and strategic positioning.

However, since ports vary significantly, a careful supply and demand analysis is essential.

17. What transport and storage infrastructure for fuels are available at ports and what do you see as the barriers to safely repurposing this infrastructure for alternative fuels such as hydrogen, methanol, and ammonia?

UK ports currently possess a range of transport and storage infrastructure primarily designed for traditional fuels such as oil, petroleum products, and liquefied natural gas (LNG). While existing infrastructure provides a foundation, several barriers (technical, safety, regulatory, infrastructure, and economic barriers) must be addressed to safely adapt it for alternative fuels like hydrogen, methanol, and ammonia.

Considerations include consumer demand for fuel types, the availability of barge bunkering, the cost of hydrogen storage tanks and safety of ammonia particularly where ports are close to residential areas. Note that some industrial ports are familiar with the handling and storage of ammonia for the agricultural sector. However adequate safety measures are required when storing and handling alternative fuels.

18. What actions can ports take to help their tenants decarbonise and reduce wider environmental impacts?

By implementing targeted actions (proactively investing in infrastructure, incentivizing sustainable practices, fostering innovation, sharing information, and engaging stakeholders), ports can support their tenants (such as shipping companies, logistics providers, and industrial operators) in reducing their carbon emissions and minimizing broader environmental impacts.

19. What barriers do ports face in helping their tenants to decarbonise?

The barriers that ports face may include the following: high capital investment costs for upgrading infrastructure; uncertain market demand which makes it difficult to justify investments; lack of regulatory incentives or mandates at national or local levels; technical and operational challenges as existing port infrastructure is often designed for traditional fuels; safety and risk management concerns as handling new fuels involves unfamiliar risks; long payback periods as many green investments have long payback periods.

At some ports there are listed buildings, and these are particular challenging to decarbonise heating.

Note that there can be limited interest from shipping lines due to the higher cost of using cold ironing services compared with using onboard power systems.

20. What sources of direct GHG emissions at ports (e.g. specific types of vehicles and equipment) are particularly challenging to decarbonise?

Engines that run on fossil fuels will emit carbon dioxide and even those running on LNG may have methane slip. Any combustion engine may emit N_2O that has a high global warming factor.

Some types of refrigerants used on vessels, such as fishing vessels may cause GHG effect as well. There are many types and these need to be examined on a case by case basis.

Harbour craft (e.g., tugboats and workboats); Heavy goods vehicles and terminal tractors; High-power cargo handling equipment such as gantry cranes; On-site diesel generators used as backup power or to power non-electrified equipment.

The most challenging sources of direct GHG emissions at ports include heavy-duty diesel vehicles, cargo handling equipment, tugboats, and backup generators. These systems often operate under high power demands, in continuous or stop-start cycles, and require rapid refuelling or high reliability, conditions that current zero-emission technologies will struggle to meet. Electrification is limited by infrastructure, cost, and performance constraints, while alternatives like hydrogen or methanol are still emerging and face safety and logistical hurdles.

Buildings at the port that are listed and therefore have planning conditions around the extent can retrofit are challenging to decarbonise the heating system.

21. What are the main options for reducing direct GHG emissions at ports? Please provide evidence of technological readiness and financial costs and benefits of these options.

Some examples along with citations:

- Shore power for vessels (proven technology; requires port infrastructure and vessel retrofits)
- Electrification of port vehicles and equipment (proven technology; requires vehicle and equipment replacement, and installation of recharging stations);
- Hydrogen-powered equipment (pilot-stage technology; requires significant infrastructure investment);
- Modal shift to rail freight (proven technology; requires high initial investment);
- Operational measures such as AI-enabled operations and energy management systems to reduce waiting times of vessels and trucks, reducing congestion [technologies range from readily applicable (machine learning, simulation and optimisation) to emerging pilots (digital-twin, smart grid), with financial costs ranging from low to high].
- Floating power platform

Ibrahim, K.A., Le Maréchal, T., Luk, P., Qin, Q., Huang, L., Xie, Y., Verdin, P. and Luo, Z., 2025. Floating solar wireless power transfer system for electric ships: Design and laboratory tests. *Energy Conversion and Management*, *332*, p.119738.

Jahangard, M., Xie, Y. and Feng, Y., 2025. Leveraging machine learning and optimization models for enhanced seaport efficiency. *Maritime Economics & Logistics*, pp.1-42.

22. What are the current main barriers and incentives to reduce direct GHG emissions from port operations?

- High capital costs for investments such as shore power infrastructure, hydrogen infrastructure, grid upgrades, rail service infrastructure, and vehicle and equipment replacement.
- Regulatory uncertainty due to the lack of binding national mandates, emissions caps for ports, or clear green fuel regulations.
- Grid connection delays

- Market uncertainty around future carbon pricing, electricity costs, energy demand and availability of alternative fuels.
- Operational complexity and risk-averse behaviour, as port operations have limited tolerance for downtime caused by charging or refuelling, and operators are reluctant to adopt new technologies that might affect reliability.

23. In addition to GHG emissions, there are likely to be additional environmental impacts at ports, such as air quality (for example from emissions of nitrogen oxides and particulates), noise and biodiversity impacts. What opportunities and challenges are there to reduce these impacts as ports decarbonise?

Some port decarbonisation measures have positive impacts on broader environmental issues. For example, replacing diesel with electricity can significantly reduce emissions of NO_x, SO_x, particulate matter, and noise. However, port decarbonisation may also present environmental challenges. New infrastructure can generate significant construction-related emissions, dust, and noise. While decarbonisation efforts often focus on carbon and air pollutants, the impact on biodiversity is also a concern. Additionally, ports may face regulatory complexity, as environmental issues are governed by multiple overlapping regulatory frameworks.

Electrification of port operations can significantly reduce airborne pollutants like nitrogen oxides (NO_x) and particulate matter (PM), which are harmful to both human health and the environment. Note that ship engines fitted with DeNOx i.e. a selective catalytic reduction (SCR) system reduces NOx the requirement could be in port decarbonisation regulations.

Shore power systems allow ships to shut down diesel generators while docked, cutting emissions and reducing noise pollution, which would benefit nearby communities and port workers. Similarly, replacing diesel-powered cargo handling equipment with electric or hybrid alternatives can lower both emissions and operational noise.

Infrastructure upgrades, such as installing high-capacity electrical systems, battery storage, or alternative fuel bunkering, require substantial investment, long planning horizons, and coordination across multiple stakeholders. There are new environmental risks to manage, for instance, hydrogen and ammonia fuels pose important safety concerns, while battery systems raise questions about lifecycle impacts and recycling.

Additionally, ports located near sensitive ecosystems must carefully manage construction and operational changes to avoid harming local biodiversity, including through increased light, noise, or water pollution. To navigate these complexities, ports will need integrated environmental management plans, robust monitoring systems, and strong collaboration with regulators, local communities, and environmental experts.

24. What skills (both in terms of capacity and capability) does the maritime workforce need to develop in order to enable ports to decarbonise their operations? What new jobs will be created as maritime decarbonise?

Port and maritime workforces will require a broad set of new skills to ensure safe, efficient, and sustainable operations. Increased technical expertise will be essential for installing and maintaining shore power systems, battery storage, and alternative fuel infrastructure, including hydrogen or ammonia bunkering. Training in hazardous materials handling, environmental monitoring, and emergency response tailored to the risks of new fuels and energy systems will also be required. In addition, digital literacy and data analysis skills will become increasingly important for managing smart systems, emissions tracking, cybersecurity and automated equipment(s). Strategic capabilities in project management, sustainability leadership, and regulatory compliance will also be critical to guide the transition and align port operations with national and international climate goals.

To meet these demands, ports will need to invest in targeted training programmes, collaborate with educational institutions, and create upskilling pathways for existing staff.

25. In your opinion, are both large and small ports adequately planning their approach to reaching net zero?

Some of the larger ports are more actively planning for net zero, though progress is uneven and challenges remain across the sector.

26. Is there sufficient government or industry led guidance to help ports to decarbonise?

There is a growing body of government and industry-led guidance to support UK ports in decarbonising, but it is not yet sufficient. Government-led guidance provides a high-level vision and direction but lacks practical, standardised implementation pathways for ports. The very late publication of the Maritime Decarbonisation Strategy has exacerbated uncertainty in the sector.

While several government funding schemes support maritime decarbonisation innovation, including the funding of the UK National Clean Maritime Research Hub, more is needed to encourage widespread technological deployment or retrofitting for example. There is a need of regulatory clarity regarding future fuel standards, emissions caps, or carbon pricing. There is also insufficient coordination with energy grid upgrades, hydrogen logistics, and modal shift planning.

27. Of the measures listed in paragraphs 3.18 – 3.20, which measure(s) would enable ports to decarbonise most effectively?

Many of the larger ports already develop masterplans. The measures to be taken to decarbonise ports vary according to a whole range of factors and therefore it could harm decarbonisation progress by being too prescriptive.

Where there is decarbonisation planning activity this will be most effective if this is in tandem with and through collaboration and coordination with regional and local decarbonisation planning activities as well as regional energy providers and relevant stakeholders.

Combining regulatory standards with financial support certainty can be an effective way to enable ports to decarbonise.

28. Of the measures listed in paragraphs 3.18 – 3.20, would any measure(s) adversely affect port's ability to effectively decarbonise?

Where there are no requirements for ports to develop spatial plans to decarbonise and that those that do don't coordinate and collaborate with local authorities, energy providers and local communities.

Local planning authorities need to not create an unnecessary barrier to decarbonisation efforts and there needs to be consistency of interpretation of national planning framework and local development plans and initiatives.

Regulatory uncertainty may delay the investment in long-term decarbonisation projects. Applying the same decarbonisation requirements to all ports, regardless of size or function, can disproportionately burden smaller ports.

29. In addition to the measures listed above, are there any government or industry led measures not mentioned here that would incentivise the sector to decarbonise?

A national planning framework that recognises the need for infrastructure changes and investments at ports to realise decarbonisation ambitions. Though this should not be without taking consideration of the concerns of local coastal communities.

Coordinate infrastructure planning and investment at the national level, e.g. (i) Work with energy grid operators to ensure grid capacity upgrades align with port electrification timelines. (ii) Support the development of national hydrogen and alternative fuel infrastructure, including safety standards and bunkering regulations. (iii) Integrate ports into multi-modal freight strategies to support modal shift.

Enable collaboration and accountability, e.g. (i) Incentivise port-user collaboration platforms involving port authorities, shipping lines, logistics firms, and local government. (ii) Encourage regional port clusters to pool investment and coordinate decarbonisation efforts. (iii) Track progress through a national port decarbonisation dashboard.