Written Submission to the Department for Transport's Call for Evidence on Net Zero Ports | Challenges and Opportunities

24 June 2025, 10.5258/SOTON/PP0130

About Us

This written contribution has been prepared by members of the Southampton Marine and Maritime Institute (SMMI) at the University of Southampton. The SMMI is a large multidisciplinary community of more than 400 ocean-facing researchers with a mission to advance knowledge and understanding of the oceans and to develop innovative solutions to tackle marine and maritime challenges by fostering collaboration between researchers, industry, policymakers, the third sector, and communities.

Our researchers investigate a spectrum of topics including maritime decarbonisation, maritime safety and security, maritime and offshore engineering, ocean acidification, marine biodiversity, marine pollution, sustainable coastal development, coastal communities, and maritime culture and heritage.

The submission has been coordinated by Nadiya Catel-Arutyunova, Specialist Policy Officer at the SMMI on behalf of the following leading researchers:

- Prof. Alan J Murphy, Professor in Maritime Engineering, University of Southampton
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Please note that the 60 questions below correspond to those articulated by the DfT in the official published call for evidence document.

SMMI has coordinated responses to the most relevant questions and would be delighted to further engage with government officials on the comments and views formulated below.

SMMI responses to the questions

2. THE ROLE OF PORTS IN ENABLING OTHERS TO DECARBONISE

1. At an individual port level, please provide us with (in MW unless specified otherwise):
    a. The number of connections that your port has to the electricity grid.
    b. The total capacity of the connections you have to the electricity grid.
    c. Whether these connections are operating at or near their maximum capacity. If you have this information, please provide at peak, mean and median capacity.
    d. The total electricity capacity that you have from the electricity grid and onsite energy generation such as wind or solar, for example.

2. At a port level, and on a monthly basis, please provide us with how much you pay in availability charges for your grid connection(s)? Has this changed over the last 12 months? If so, please provide details.

3. If you have recently upgraded your grid connection(s), please provide a breakdown of the cost of the upgrades and what was your previous grid capacity, compared to your current grid capacity?

4.Please set out whether you have a renewable energy tariff for your electricity needs and the cost difference compared to a non-renewable electricity tariff?

5.Please set out if you are planning your future electrical grid capacity and whether your current capacity at an individual port level is sufficient to meet this? Please set out your reasons why.

Planning current and future electrical grid capacity for onshore power supply is complex for many ports, with a wide range of vessel types (hence power demands), port stays and onshore freight handling equipment.

Modern numerical modelling techniques such as discrete event simulation can be used to estimate peak, annual and instantaneous requirements for port electrical capacity, but in themselves require detailed input data.

Applying such a method to the port of Plymouth, for example, yields a peak requirement of 5.95 MW and annual energy demand of 7.1 GWh [1] (please see : *https://doi.org/10.1016/j.trd.2024.104432*). This estimate includes associated freight handling. Current grid capacity in Plymouth is insufficient to meet this demand.

Demand peaks can be accommodated through installation of local energy generation using renewable energy and/or alternative fuel sources, or energy storage (such as grid-scale battery storage, charged at a slower rate from the available grid capacity) whereby the vessels can be charged at a higher rate from the energy storage.

6. If you require extra electrical grid capacity, please provide at an individual port level (in MW unless specified otherwise):

a. The extra number of connections you will need to the electricity grid.
b. The total size of the future connections to the electricity grid and whether that is 100% of the future electricity requirement at your port(s)? Please provide us with an overview of what is driving your requirement for extra electricity and what year you need it by.
c. A breakdown of the cost or quotes that you have received for the increased electrical capacity. Where possible this should include contestable and non-contestable costs, connection costs, network reinforcement costs and availability charges or your Connection Offer Expenses Letter.
d. Whether the quotes you received were before, on or after 1 April 2023.
e. The proportion of those costs in comparison to yearly revenues.
f. The year of your connection window to the electricity grid and how that compares to what you were initially seeking. Please set out if you have accepted the connection offer from your DNO.

[1] Port energy demand model for implementing onshore power supply and alternative fuels, Uzun, D., Okumus, D., Canbulat, O., Anil Gunbayez, S., Karamperidis, S., Hudson, D., Turan, O. and Allan, R., Transportation Research Part D, 136 (2024), 24pp. *https://doi.org/10.1016/j.trd.2024.104432* .

g. When it comes to onsite generation of renewable energy at ports, what is the current and future capacity of the energy that will be produced? Please provide this figure in megawatts and on a yearly basis.

7. What are the implications for port growth of any capacity constraints or long connection timeframes to secure additional electricity grid capacity?

If the UK's ports do not have sufficient onshore power supply and this becomes either mandated or a *de facto* standard, then ports will not be able to accommodate such vessels (and associated landside operations). This will lead to stagnation of ports with freight shippers and forwarders seeking alternative port locations. The likely outcome will be the UK receives break-bulk cargo (including containers, vehicles, liquid and dry bulk commodities) from ports in continental Europe, rather than directly from ocean-going vessels. This increases risks in supply chain delays and resilience.

8.Have ports, or their customers lost out on any opportunities due to insufficient grid capacity? If so, please provide details.

9.What are the advantages and disadvantages of increasing electricity capacity at ports incrementally versus installing 100% of your future electricity requirements, ahead of need?

10.Have you estimated the potential cost difference of installing future electricity grid capacity incrementally versus investing 100% of your future electricity requirements, ahead of need? If so, please provide details of any estimates.

11.When seeking new grid connections, have ports collaborated with any other energy users in their region to spread the cost? If so, how?

12.Are there any other barriers that ports face when upgrading their electricity connection?

- The high cost of UK electricity acts as a disincentive to using onshore power supplies (it is cheaper to use diesel to run a shipboard generator, for the operator of the ship).
- Additionally, one of the most important barriers towards decarbonising port activities is the lack of corresponding grid electricity infrastructure which would allow sufficient energy to be supplied at the port, without causing deficits to the cities and local regions that surround UK's major ports.
- Some of the technical barriers which come with electrification of port-related equipment have been solved, with market options, already being available (i.e.

battery powered vehicles, cranes) albeit at greater costs. Usually, port energy demands make up a large proportion of a port city's energy demand, with the possibility of completely electrifying port activities to develop further growth of energy demands, in the form of green electricity. Cold ironing (shore-power)* ports, currently available for cruise ships alone, can be enough to cause black out on a port city's grid, as cruise ships have high energy demands. The same applies for refrigerated container carrying vessels and their storage portside the energy supplied to ports needs to be generated by renewable sources to benefit from reduced carbon emissions, although there will be co-benefits from improvements in air pollution and other harmful emissions.

- Alternative approaches include greater, dedicated renewable energy generation on the port estates (and surrounds) and use of port-side energy storage (batteries but also other approaches – pumped hydro, thermal storage) that is charged during periods of low regional energy demands and used to service vessels when in port.
- High cost of capital equipment for provision of onshore power supply, including new landside machinery and charging and/or energy storage infrastructure.
- Lack of standardisation of ship and port voltage and frequency specifications (e.g. some ships use 60Hz vs ports operating 50Hz grids). Cables and connectors are not globally standardised.
- Use of high voltage electricity supply increases health and safety risks in ports.

* By "shore power" we mean that the UK should aspire to local and national grids 100% supported by renewable energy sources. This will require energy storage systems at national and regional scales, as well as full life cycle analysis to prove that the implementation of large-scale energy storage (especially batteries but also other approaches) is better than a minor contribution of gas-powdered generation (in terms of carbon).

13. What economic and environmental benefits would ports receiving their grid connection have on your business and customers? For example, reduced emissions, increased profits, job creation and/or retention, etc. (Please provide as much detail as possible, including details of assumptions made in the calculation of figures where applicable. For emissions figures, please refer to the guidance in Box 3.1. For employment figures, where possible please provide estimates of full time equivalent (FTE) employees by SIC code, and whether these are 'green jobs, per the ONS definition).

14. If you have installed or are exploring the installation of onshore wind turbines, solar panels, and other sources of renewable energy generation within the boundaries of a port, please provide us with the cost and details of these (e.g. installed capacity).

15.Please provide us with the use cases, the costs and the advantages and disadvantages of installing battery storage at ports.

The installation of battery storage at ports will vary depending on the level of energy storage required. We are aware that the level of energy storage for a big container ship is less than cruise (50%). For a large cruise with circa 10 MW hotel load and12 hour turnaround,120 MWh storage would be needed for one ship (assuming no grid, local renewable import).

MSE International white paper "*Energy Storage for Port Electrification"* (available at: *https://www.mseinternational.org/res/files/decarbonisation/ESSOP%20White%20Paper.2023.pdf)* suggests optimistic capital cost of £300-400 per kWh storage, so £30+ M for 100 MWh (CAPEX). At £50/MWh* in April 2025, this makes battery storage at scale expensive, hence need to optimise scale, local renewable generation and tickle charging for ports to the demands based on ship movements. Our view is that batteries need to be scaled to provide buffer to grid supply or local renewable generation.

* Note that this cost has peaked in recent years up to >£350 MWh.

16.What other options have you considered when it comes to onsite energy generation?

Case studies conducted as part of Clean Maritime Demonstration Competition showed the importance of electrifying ports, to supply ships at berth with "clean electricity", improve local air quality and reduce noise pollution. On the same topic, if each port was to be treated as future fuel bunkering hub, capable of sustaining local energy demands, then each port should be treated as an energy hub. Studies conducted by the University of Southampton for its home port, indicated that 288,000 Terajoules of energy would have to be supplied per annum to the port of Southampton for sustaining local fuelling demands, if each vessel would have to be refuelled at the next port stop.

In response to any question about the role of port in shipping decarbonisation, one should refer to IMO resolution MEPC 323 74, which invites Member States to promote the consideration and adoption by ports within their jurisdiction, of regulatory, technical, operational, and economic actions to facilitate the reduction of GHG emissions from ships. Those could include but are not limited to the provision of: (a) Onshore Power Supply* (preferably from renewable sources); (b) safe and efficient bunkering of alternative low-carbon and zero-carbon fuels; (c) incentives promoting sustainable low-carbon and zero-carbon shipping; and (d) support for the optimization of port calls.

Ports' role has been changed from their historical role "cargo hub" to "energy hub". It means that they play an important role in decarbonisation and can provide energy to both cities and the maritime industry. Considering using renewable energy they can provide the required electricity for Onshore Power System (OPS), as well as produce Zero or near Zero fuels like hydrogen and ammonia. In addition, considering the deployment of CCUS technology, ports can act as hub for CO2 transportation and can implement CCUS technology in ports and produce e-fuels, which will be back bone of maritime decarbonisations. These fuels can be used to generate electricity for onshore power systems for ships and material handling equipment as it is needed by vessels, as an alternative to battery energy storage.

17.What do you expect the energy generated onsite from wind and solar to be used for?

Energy generation onsite can be used to charge port energy storage systems (such as batteries) to supplement grid-supplied electricity. This can then be used to charge vessels, or run vessel auxiliary power, even if the local grid capacity is insufficient.

Energy generation onsite can additionally be used to power landside material handling equipment, to charge trucks and non-road mobile machinery and to make alternative e-fuels for vessel bunkering.

Based on previous Clean Maritime Demonstration Competition projects (strand 3) it was estimated that an emission reduction >35% could be achieved for high auxiliary energy demand vessels (such as cruise ships) by switching to port onshore power supply (i.e. cold ironing), with a current UK electricity grid mix that is not completely sourced by renewables.

18.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.

We agree that ports will play an increasingly significant role in directly providing, or enabling third parties to provide the infrastructure required to help the decarbonisation of shipping. When considering port decarbonisation, it is essential to account for three interlinked dimensions:

1. **Ship-Port Interface:** Ports act as a crucial interface between ships and the onshore infrastructure necessary for decarbonisation. This includes the provision of alternative fuels, such as liquefied natural gas (LNG), methanol, ammonia, and

hydrogen, and Onshore Power Supply (OPS) systems, as well as other supporting infrastructure that can significantly reduce emissions from ships during port calls.

2. **Port Activities:** Ports themselves are significant energy consumers and sources of greenhouse gas (GHG) emissions. Decarbonising port operations, such as cargo handling equipment, port vehicles, and terminal operations, directly contributes to reducing overall port-related emissions and supports the transition to a cleaner maritime supply chain.
3. **Port-City Interface:** Ports in the UK are typically located in, or near, urban areas, and their decarbonisation efforts have broader environmental and social implications for surrounding communities. Providing low-carbon infrastructure not only addresses shipping emissions but also reduces local air pollution, noise, and other externalities, aligning with wider sustainability goals.
4. **Hinterland transport of goods**: Ports are not the origin or final destination for most goods and people. Consequently, the movement of goods and people into and out of ports and port cities are major sources of pollution and congestion with consequent impacts on citizens' health, productivity and the wider environment. The movement of goods and people need to be optimised to reduce their overarching environmental footprints by maximising the use of (electrified/low-C) rail and potential other innovations such as low-carbon short seas/coastal shipping and use of inland water ways. The port can also provide energy (or fuel) to heavy goods vehicles, through charging whilst they load/unload their cargo.

Ports occupy a critical position within the maritime industry's value chain. According to the IMO's Resolution MEPC.323(74), ports are encouraged to facilitate the provision of alternative fuels and OPS systems to support the decarbonisation of the shipping sector. Furthermore, the IMO's 2023 revised GHG strategy aims to achieve a 5% uptake (with a strive for 10%) of zero- or near-zero (ZnZ) fuels in the shipping industry by 2030, further highlighting the pivotal role of ports in this transition. This underscores the need for significant investments in sustainable port infrastructure and close collaboration with shipping companies, energy suppliers, and other stakeholders.

Such investment and collaboration are crucial because, without adequate port infrastructure, ships will be unable to effectively adopt and use low- or zero-emission fuels, thereby hindering efforts to meet the IMO's ambitious decarbonisation targets. Additionally, ports are uniquely positioned to create a positive feedback loop by enabling third-party service providers, such as energy companies, technology firms, and other actors, to deploy innovative solutions that further accelerate the transition.

19.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.

The answer to this question depends on the area of investigation. Some ports around the world, particularly in Europe, have emerged as pioneers in transitioning to "energy hubs" and have made significant investments in sustainable infrastructure to support ships in their transition to zero emissions (e.g., Rotterdam). These ports have established strong collaboration and synergies between stakeholders from various sectors, successfully overcoming many of the associated barriers. However, the majority of UK ports still face challenges and are grappling with persistent barriers. The development of the associated infrastructure requires substantial investment.

Achieving a 50% reduction in shipping emissions by 2050 may require a substantial investment of **approximately $1.4 trillion (REF).** To provide context, the annual average investment for new fuels and engine development onboard ships ranges from $8 billion to $28 billion, with ammonia and methanol requiring the most substantial investment. Notably, the average annual investment in onshore fuel infrastructure exceeds onboard investment by a **factor of 3.5, with figures ranging from $28 billion to $90 billion.**

Given these figures, uncertainties remain about the future fuels and technologies that will enable decarbonisation of the industry, leading to significant investment risks. Therefore, the role of governments and regulatory bodies becomes crucial in reducing these investment risks and providing financial support for infrastructure development. Initiatives such as the EU Emissions Trading System (EU ETS), the UK Emissions Trading Scheme (UK ETS), and the IMO's greenhouse gas (GHG) pricing mechanism, which is expected to **generate approximately $10 to $13 billion annually**, can play a vital role in supporting investments in the required sustainable infrastructure to enable the transition to zero-emission shipping and mitigate investment risks.

20.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.

21.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?

There remains a critical shortfall in the UK's infrastructure to test and evaluate sustainable technology to decarbonise the maritime sector including ports. Together with maritime industry primes and a wide community of SMEs, the University of

Southampton has developed the concept for a national Centre for Green Maritime Innovation (cGMI) that will address this shortfall by focusing on innovation, systems integration, skills, and digital technology. The cGMI will provide the infrastructure, expertise and skills to de-risk key areas of technology, support its integration, and develop enabling regulations.

By focusing on both ship and shore-based systems, the Centre will offer technical expertise and new skills, helping our partners to adapt quickly to emerging opportunities and accelerate the realisation of zero- or low-C maritime trade. The Centre will provide a singular focus across the maritime sector to drive growth and investment in the UK maritime sector and by working with global industry players and SMEs, create UK jobs and products, benefiting industry and the nation.

The cGMI will provide the facilities and knowledge to advise industry and government on a comprehensive mix of regulatory, financial, and strategic measures to accelerate the decarbonisation of maritime trade.

To learn more about the cGMI, please access our proposal for a national facility to accelerate zero carbon technologies for the maritime sector at the following link: https://www.southampton.ac.uk/~assets/doc/cgmi/CGMIInformation.pdf

By combining the measures outlined below, governments can reduce uncertainty, build investor confidence, and ensure that port infrastructure is aligned with future trade patterns and technological developments:

1. **Long-term Port Development Strategies:** Develop and publish clear, long-term strategies and regulations outlining infrastructure priorities for ports, including timelines and expected milestones. This would ***provide certainty to investors*** and stakeholders about the government's commitment to enhancing port capacity and efficiency.
2. **Stable and live Policy and Regulatory Frameworks:** Ensure a ***predictable regulatory framework***, including environmental and safety guidance, to reduce investment risk and uncertainty. Providing transparent guidelines for port expansion and modernization can boost investor confidence. In addition, the regulations and guidelines need to be live by considering PDCA (Plan, Do, Check, Act) cycle.
3. **Targeted Financial Support and Incentives:** ***Design incentives*** such as grants, tax relief, or low-interest loans to encourage investment in port infrastructure. These support mechanisms could be specifically targeted at Zero near to Zero (ZnZ) technologies, aligning with sustainability and digital transformation goals. For example, one of the main barriers to the use of Onshore Power Supply (OPS) for vessels is the high cost of electricity. Providing incentives to both technology

providers and shipowners can help overcome this barrier and support the deployment of OPS technology at ports.

4. **Coordination with Broader Transport and Industrial Policy**: ***Integrate*** port infrastructure plans with national and regional transport networks (rail, road, coastal/short-seas, inland waterways), as well as industrial clusters and trade (potentially "green") corridors, to ensure that supply aligns with actual and forecasted demand.
5. **Engagement and Collaboration with Stakeholders:** Involve port authorities, shipping companies, logistics providers, and local communities in planning and decision-making processes to build confidence and address concerns early, thereby fostering a cooperative environment. The establishment of innovative initiatives, such as ***green corridors***, can further enhance stakeholder engagement and collaboration while facilitating the replication and scaling of these experiences in other ports.
6. "**Learning by Do-ing":** Develop and support several national and international "green corridors" of a range of scales (length and frequency of voyages) to test and de-risk decarbonisation approaches. It would be sensible to initially target freight routes where shipping is the only viable option (e.g., to islands including Ireland).
7. **Data-Driven Planning and Market Forecasting**: Su**pport** data collection and sharing initiatives to improve demand forecasting and operational planning. Governments could establish ***national maritime observatories or digital platforms*** to share insights on port capacity, demand trends, and trade forecasts. This is crucial for evaluating the significance of investments and for conducting market analysis to reduce the associated risks of investing in infrastructure.
8. **Support for Innovation and Sustainability:** Facilitate adoption of new technologies and green practices in ports through pilot programs and funding for research and demonstration projects. Clear signals of support for green port infrastructure would help align investments with environmental goals.

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

We agree that introducing an emissions-at-berth requirement will be highly effective at reducing greenhouse gas emissions and air pollutants in and around ports. When vessels are docked, they typically rely on their auxiliary engines to power onboard systems, which significantly contributes to local air pollution and carbon emissions. By requiring ships to either shut down these engines or use zero-emission alternatives, such as onshore power supply (OPS) or alternative cleaner fuels, an emissions-at-berth requirement will directly reduce these harmful emissions. This will improve air quality for nearby communities and support the achievement of climate targets.

To ensure the success of this requirement, ports must provide the necessary sustainable infrastructure, such as OPS connections and facilities for alternative fuels, to support the reduction of emissions from ships. Additionally, ports can play an active role in emission reduction efforts by adopting the "polluter pays principle" and implementing an "incentive schedule" that rewards or penalises vessels based on their environmental performance while at berth.

Evidence from ports that have already implemented OPS and similar measures, such as the Port of Los Angeles and European ports like Gothenburg and Rotterdam, shows substantial reductions in nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM) emissions. These examples demonstrate that an emissions-at-berth requirement can effectively deliver significant environmental benefits both locally and regionally. Care needs to be taken that such measures are implemented on a level playing field and additional costs don't lead to changes in behaviour (use of non-taxed ports etc). We are aware that certain companies are using carbon-offsetting approaches for freight.

Should such an emission at berth requirement be introduced it would need to be UK-wide, providing a coherent and aligned framework across all four UK nations.

23. 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.

The technological solutions that are most likely to prevail are: shore-power, upgraded grid, local renewable energy generation, energy storage (mostly likely batteries but other approaches such as thermal, pumped hydro, compressed air could also be possible).

24. 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?

Yes, we would agree with the view that Government would need to direct ports towards a certain default technological solution.

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

UK Government's approach to ensure it improves and protects air quality at ports needs to be based on a holistic systems approach, rather than compartmentalising emissions as GHG and air pollutants, which are generally associated with human health effects.

Addressing one of these without due regard to the other may have **unanticipated adverse impacts**, we recommend taking into consideration effects on emissions from road vehicles, where targets to reduce petrol use to reduce CO2 emissions resulted in uptake of diesel cars, greatly impacting NO2 and particle emissions. We recommend Government officials to consider the following scientific publications for further evidence:

1) "*The impact on passenger car emissions associated with the promotion and demise of diesel fuel*", available at: https://www.sciencedirect.com/science/article/pii/S0160412023006037
2) *"CO2-equivalent emissions from European passenger vehicles in the years 1995–2015 based on real-world use: Assessing the climate benefit of the European "diesel boom"",* available at: https://www.sciencedirect.com/science/article/pii/S1352231018307295

In addition, Government's approach will need to consider, as part of this system, emissions directly taking place within the port through port and tenant operations (i.e. Scope 1) as well as consequential emissions from activities relating to Scope 1 activities outside of the port and outside of the direct control of port operations/tenants (Scope 3). For example, consideration of mass transit development in port cities with significant numbers of passengers (dis)embarking cruise vessels or passenger ferries or delivery of freight to/from ports.

We would recommend considering a comprehensive monitoring of GHG and air pollutants in real world setting at ports. This monitoring should be a hybrid approach consisting of satellite measurements, emissions modelling using shipping databases as well as emissions inventories, and on-site monitoring stations. This approach will facilitate optimal measurement/prediction of air quality at different spatial and temporal scales. We recommend Government officials to consider the following scientific publication for further information: *"Innovations and insights in environmental monitoring and assessment in port areas",* available at: https://www.sciencedirect.com/science/article/pii/S1877343524000599

This monitoring will facilitate evaluation of key impacting factors, source apportionment, and temporal trends in pollutants, allowing the necessary degree of evaluation of interventions aimed at improving air quality.

It will also provide evidence for health impact assessment of emitted air pollutants not only in scope 1 and 2 but also scope 3 (see above). We recommend Government officials to consider the following publication for further information: *"Health impact assessment of port-sourced air pollution in Barcelona",* available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0305236

Most importantly, we believe that regulations need to be timely implemented and enforced nationally, to avoid situations (which currently exist) where emissions regulations differ between ports, therefore creating incentives for use of areas with less stringent regulations. We are aware and supportive of the proposal to extend the North Sea ECA).

There is a need for full economic cost-benefit analysis utilising "well-to-wake" analyses so that (1) the burden on environment and health of shipping and shipping-related emissions can be quantified, and (2) the economic benefits of proposed interventions can be evaluated. This will allow financial benefits to be conveyed to the public and stakeholders, as well as allowing for financial planning across government departments.

There also needs to be a comprehensive assessment of emissions from proposed alternative fuels from an environmental point of view. This includes slip of GHGs (e.g. from LNG, ammonia) and other emissions which may either act as air pollutants/GHGs themselves or participate in formation of secondary pollutants with these properties. This should include, but not necessarily be limited to, release of NOx/NO2 from combustion, VOC emissions, and an evaluation of particle size distributions, given that "cleaner" fuels may produce particles with a smaller median aerodynamic diameter, with potential implications for health.

We recommend Government officials to consider the following publications for further scientific information:

- *"Real-Time Gaseous, PM and Ultrafine Particle Emissions from a Modern Marine Engine Operating on Biodiesel",* available at: https://pubs.acs.org/doi/full/10.1021/es1026954
- *"Particle Emissions from Ships: Dependence on Fuel Type",* available at: https://www.tandfonline.com/doi/abs/10.3155/1047-3289.59.12.1391
- *"Chemical composition and size distribution of particulate matters from marine diesel engines with different fuel oils"*, available at: https://www.sciencedirect.com/science/article/abs/pii/S0016236118314509

Shoreside electrical power offers clear potential benefits to port air quality through reducing at berth emissions. However, there are infrastructural considerations which require thorough investigation, including the cleanliness of electricity generation,

location of electricity generation (with implications for how the energy reaches the port), and environmental impact of infrastructure installation and maintenance. We recommend Government officials to consider the following publication for further scientific information:
https://www.sciencedirect.com/science/article/abs/pii/S1361920923003954

Shoreside power not only requires landside and ship-borne infrastructure – it also requires accompanying economic incentives or legislative mandates in order to optimise adoption, and thus potential benefits to air quality. Such approaches should be evaluated to ensure that uptake is optimal for port air quality. We recommend Government officials to consider the following publication for further scientific information:
https://www.sciencedirect.com/science/article/abs/pii/S1361920923003954

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

We agree with the view articulated by the Society of Maritime Industries that any future regulatory regime designed to decarbonise at-berth emissions would need to balance clarity, flexibility, and enforceability while creating the right market conditions for investment and innovation.

The regulatory regime should also be underpinned by up-to-date, objective scientific evidence that has been adequately peer reviewed.

Shoreside power not only requires landside and ship-borne infrastructure – it also requires accompanying economic incentives or legislative mandates for its use, to optimise potential benefits to air quality. Such approaches should be evaluated to ensure that uptake is optimal for port air quality. Finally, it is also necessary, of course, to ensure that decarbonisation at berth does not result in "recarbonisation" elsewhere i.e. through generation of electrical shoreside power by fossil fuel combustion.

27.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 services with short turnaround times at ports should be individually defined for each port of interest around the UK. For ports which are predominately visited by smaller vessels, high frequency visits could be considered as ones which occur on a daily or weekly basis. This can include vessel types such as passenger ferries, sea taxis, pilot boats and tugboats, which although are not considered as deep-sea operating vessels, do still contribute towards port and local emissions.

On the other hand, according to the Fuel EU directive, frequent port calls could be vessels which visit the same port for 5 or more times each year and a short turn around. This could be a more effective way for planning on infrastructure investments regarding each port, yet this will prioritise larger vessels with higher energy demands than smaller vessels, even though the latter can have significant local impacts in terms of emissions, again depending on each individual port's traffic. A representative example would be shore-power, where larger vessels would require their own dedicated port grid due to higher voltage and amperage requirements.

Port call data can be obtained using satellite AIS data and the resulting frequency histograms derived. An example for the port of Plymouth is provided in: https://doi.org/10.1016/j.trd.2024.104432 .

28.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, we agree that high-frequency services with short turnaround times at ports should be included in any future emissions-at-berth requirements. Although these vessels may spend less time docked, their cumulative emissions, given the frequency of port calls, can have a significant impact on local air quality and environmental health. Including them ensures a level playing field across all types of shipping operations and incentivises the adoption of emission-reducing technologies, such as onshore power supply or alternative fuel use such as hydrogen fuel cells, even for short port stays.

However, practical considerations must also be considered. These services often have tight operational schedules and may require tailored solutions, such as faster connection times for OPS or hybrid power options, to ensure that compliance with emissions-at-berth requirements does not unduly disrupt service schedules or economic viability. As an example, the world's fastest-charging electric ferry that operates between Helsingborg, Sweden and Helsingør, Denmark, can fully charge its **batteries in 7 minutes thanks to a megawatt-scale OPS system**. This is a key example of how rapid charging infrastructure can support the decarbonisation of short-sea shipping and demonstrate the viability of electric propulsion for frequent and high-intensity ferry services.

29. 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.

30. 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.

Ports face several multi-disciplinary barriers to becoming near-zero or zero GHG emission refuelling "energy" hubs. These barriers include:

1) **Infrastructure and Investment Costs:** Transitioning to zero-emission refuelling (such as for hydrogen, ammonia, methanol, or electricity-based fuels) requires significant upgrades to port infrastructure, including storage, bunkering facilities, and safety systems. The high capital investment needed for these upgrades can be a barrier, particularly when port revenue models are already constrained.
2) **Uncertainty in Fuel Demand: There** is uncertainty regarding which alternative fuels will emerge as the dominant choice in the coming decades. This lack of clarity makes it difficult for ports to justify large-scale investments in dedicated infrastructure for any one fuel. There remain high levels of risk in early adoption of a specific future fuel.
3) **Regulatory and Policy Gaps:** Inconsistent or unclear regulatory frameworks at national and international levels hinder investments. Ports and private operators require clear guidelines on safety, technical standards, and liability issues for new fuel types, which are often still in development.
4) **Safety Concerns**: Handling and storing alternative fuels such as hydrogen, ammonia or methanol introduces new safety challenges, including flammability, toxicity, and explosion risks. These safety barriers necessitate new protocols, training, and investments in risk mitigation measures. Shipping has never used a toxic fuel before. This will require major, systemic changes in the shipping safety culture. With ports being located in, or around, urban areas in the UK, this presents risks to surrounding populations that do not exist at present.
5) **Technology Readiness and Supply Chain Maturity:** Many zero-emission refuelling technologies are not yet at full commercial maturity (TRL 7-8 and above) or lack reliable and affordable supply chains. This limits confidence in long-term operational viability. All fuel fuels are likely to be much more expensive than marine diesel and heavy fuel oil, and there will be competition for high-end manufactured products (e.g., green ammonia) from other industries who add substantial value to base commodities (e.g., ammonia to fertilisers). Shipping does not pay high prices for fuel at present, so this represents an economic and cultural shift that is required.

6) **Grid Capacity and Energy Availability:** For fuels like electricity and green hydrogen, the availability of sufficient, reliable, and renewable power sources is a major challenge. Ports often rely on local energy infrastructure, which may not be capable of meeting the increased power demand of large-scale zero-emission fuel production or supply. Ammonia - which some consider a 'front runner' alternative fuel - requires significantly more energy to produce than hydrogen (that for hydrogen as feedstock and that to then produce ammonia). The renewable energy challenge of any alternative fuel is significant.
7) **Commercial Viability and Cost Competitiveness:** Alternative fuels are currently more expensive than conventional fuels, particularly without significant government support or carbon pricing mechanisms. This limits demand from shipowners, reducing the economic viability of building near-zero or zero-emission hubs.
8) **Coordination Across Stakeholders:** Ports are complex ecosystems involving many actors (port authorities, terminal operators, shipping companies, fuel suppliers, local authorities). Achieving consensus and coordinated investment for zero-emission refuelling is often a lengthy process.

To help ports with the barriers they're facing in becoming near-zero or zero GHG emission refuelling hubs, the University of Southampton has developed the concept for a national Centre for Green Maritime Innovation (cGMI) that will address these challenges by focusing on innovation, systems integration, skills, and digital technology. The cGMI will provide the infrastructure, expertise and skills to de-risk key areas of technology, support its integration, and develop enabling regulations. The Centre will operate at TRLs 4-6, providing the critical acceleration of infrastructure and regulations required for alternative fuels.

By focusing on both ship and shore-based systems, the Centre will offer technical expertise and new skills, helping all stakeholders to adapt quickly to emerging opportunities and accelerate the realisation of zero- or low-carbon maritime trade. The Centre will provide a singular focus across the maritime sector to drive growth and investment in the UK maritime sector and by working with global industry players and SMEs, create UK jobs and products, benefiting industry and the nation.

To learn more about the cGMI, please access our proposal for a national facility to accelerate zero carbon technologies for the maritime sector at the following link: https://www.southampton.ac.uk/~assets/doc/cgmi/CGMIInformation.pdf

31.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.

This depends on many factors and cannot be generalised; a feasibility study is needed for each individual case. It is expected that every refuelling hub built will have to meet each port's individual energy demands. These energy demands are the result of a port's traffic characteristics such as vessel types visiting this port, their visiting frequency, their size and the expected bunkering intervals for each (i.e., refuelling at every port call or every other port visit). All these factors significantly affect the refuelling capacity of each fuelling port, therefore, the size of energy source expected to be used for fabricating fuels.

For the case of the port of Southampton, which is one of the UK's busiest ports, the annual refuelling energy requirement is expected to be a minimum of 288,000 Terajoules, requiring a proportional investment in electricity grid infrastructure (REF). Aside from a dedicated fuel fabrication plant, it is expected to invest a renewable electricity farm (Wind, Solar etc.), with its power output (180MW for solar park or 60MW for Windfarm) being several times larger than Southampton's electricity grid's current provision. Although no relevant cost estimation case studies have been conducted for the port of Southampton, it is expected that the total cost for it become a refuelling hub, which will also require an accompanying green electricity grid will reach into the scale of 10s of billions. For Southampton, re-engineering of the Fawley Refinery, coupled with carbon capture and storage (Vahid's CO2 paper) could be a transitional approach to provide low carbon "blue" hydrogen and possibly other low-C fuels.

We recommend government officials to consider the case study for the port of Plymouth, provided in *https://doi.org/10.1016/j.trd.2024.104432* which estimates the energy and alternative fuel requirements for vessels and shoreside machinery handling equipment.

32.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.

There are opportunities both domestically (ferries, in-port vessels and other short-sea shipping, including the support of the offshore wind industry) as well as internationally, selling fuels to vessels calling in the UK such as vehicle, container and liquid and dry-bulk vessels. At present the LNG to fuel cruise ships in Southampton comes from Rotterdam in specialist bunker vessels, since the UK has no port-side infrastructure to re-fuel vessels with LNG. Whilst this represents a 'missed opportunity' 15 years ago, the same could happen with new alternative fuels, delaying their uptake in the UK for domestic vessels.

A key domestic sector is the support of the growing offshore wind industry. Vessels for installation and maintenance of windfarms operate domestically in the UK EEZ and are thus candidates for near-zero or zero GHG fuels. How does it look if this sector is supported by fossil fuels, whilst providing critical support to the UK becoming a clean energy superpower?

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

As evidenced from case studies published in the past (see scientific publication available at *https://www.sciencedirect.com/science/article/pii/S0360319924030659*), it is expected that significant investments will have to be put forward in terms of renewable energy infrastructure development, to sustain shipping industry's energy demands once the transition towards renewable fuels occurs.

At the same time, economies of scale will play an important role in producing sustainable future fuels, meaning the larger the production plant and its energy source, the lower will be the final cost per unit of energy of fuel produced. Each vessel's energy demand is approximately 3 times the direct energy contribution from renewables, when all energy losses during each renewable fuel's lifecycle is considered.

As such, transitioning into renewable fuels will provide ports serving as energy hubs the opportunity to produce fuels with the lowest cost that could potentially yield high profit margins for the port itself as well as the surrounding communities.

There are growth opportunities for the UK to become a major bunker port for new and alternative fuel types, leveraging investments in other key components of the shipping energy supply chain – namely a leading position in renewable generation and hydrogen. Whilst the UK is not a significant actor in the global bunkering industry at present, it has the potential to be in the future. This is especially the case when it is highly likely that ships will need to bunker more frequently with alternative fuels (due to their lower energy density per unit volume compared to diesel/HFO) and this during more port calls than at present, where they can simply seek the cheapest fuel and carry ~3 times fuel needed for a single voyage.

34.What bunkering facilities does your port currently offer and what types of services use these facilities? If not available, are the users aware of where bunkering takes place?

The UK has a number of bunkering facilities located in several bunkering ports across the country. These are in direct competition with major European bunkering facilities which may offer competitive pricing power, infrastructure and fuel variety/availability/volume and benefit from incentivising policy frameworks like Fit For 55 and FuelEU Maritime. The choice of the bunkering destination remains price/cost-driven for many operators.

The UK has potential to become a global bunkering destination, the opportunity is available, especially in the light of the UK's objective to establish at least six green corridors by mid-2026 (cf. official endorsement made at the COP26 in November 2021). For example, certain UK ports could become fuel bunkering centres due to shortened bunkering intervals resulting from all alternative fuels (WtW).

This question is more relevant for the ports themselves to answer. However, if we consider the English Channel region, specifically the Port of Felixstowe and the Port of Southampton, most international shipping currently receives its fuel from Rotterdam, which is a well-established energy hub in Europe and globally. The Port of Rotterdam has made significant investments to maintain its position in the global energy value chain. Singapore is similarly investing to maintain its position as a global bunkering hub.

Nevertheless, as the shipping industry transitions towards zero- and near-zero (ZnZ) emission fuels, there is a clear opportunity for English ports to position themselves as emerging energy hubs. Given the increasing demand for alternative fuels and the shortage of such fuels in the region, timely and targeted investments in the necessary maritime infrastructure could enable the Port of Southampton, for example, to cater to specific shipping segments—such as cruise and container vessels.

To fully understand this potential, a detailed feasibility study is essential. Such a study should assess the number and type of vessels using these ports, their fuel requirements, and the demand and potential supply of various ZnZ fuels. This would inform a robust investment strategy and help mitigate associated risks and uncertainties for potential investors.

Furthermore, linking this opportunity to the development of green corridors—designated shipping routes that prioritise zero-emission fuels and practices—could strengthen the case for investing in bunkering facilities for ZnZ fuels. Green corridors can provide a reliable market for sustainable fuels, enhancing the confidence of both investors and users while supporting the UK's maritime decarbonisation goals.

35.What is the estimated cost of installing electric charging infrastructure for vessels (boats or ships)?

36.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?

Transport and storage infrastructure for new alternative fuels and new 'waste products', such as CO2, will all need to be new. It is simply not feasible to re-purpose storage tanks, handling or transport infrastructure for e.g. diesel to new zero or near-zero alternative fuels.

37.Please provide us with the number of tenants and entities that operate within the landward and seaward boundary of your port(s) and their economic activities.

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

As mentioned above, ports are energy hubs with multifaceted environmental impacts and interconnected links with the city, its local coastal communities and the wider transport networks like road, rail and aviation. Our response to Q38 is specifically focusing on shipping as an important part of decarbonising the industry, ports and major regional industries.

UK ports are strategically located near major industrial clusters, which are responsible for a significant share of the country's greenhouse gas emissions (industrial clusters account for about half of all UK industrial emissions). Many port tenants operate in hard-to-abate sectors and are under increasing pressure to decarbonise, particularly as the UK advances its Carbon Capture and Storage (CCS) agenda.

Ports can play a transformative role in supporting tenant decarbonisation and reducing environmental impacts by:

- **Providing critical CCS infrastructure:** by developing safe and flexible temporary storage facilities for captured CO_2, ports can enable tenants to efficiently transfer emissions to permanent offshore storage. This is especially important as shipping becomes a key non-pipeline transport (NPT) solution for CO_2 in the UK's CCS strategy (ref IDRIC CCS transport frontiers reports).
- **Tailoring port operations for CCS:** ports should adapt operational protocols to safely manage increased volumes of liquefied CO_2, ensuring that infrastructure

and safety measures are robust enough to handle new risks associated with CO_2 shipping and storage.

- **Facilitating shared CCS infrastructure:** ports can coordinate with multiple tenants to develop and operate centralised temporary CO_2 storage facilities. By providing shared storage infrastructure, ports enable tenants to efficiently aggregate, condition, and transfer captured CO_2 for onward shipping to permanent offshore storage. This collaborative approach reduces duplication of infrastructure, lowers overall costs, streamlines logistics, and accelerates the decarbonisation of entire industrial clusters.
- **Supporting innovation and collaboration:** ports can act as hubs for innovation, fostering partnerships between tenants, technology providers, and regulators to pilot and scale new decarbonisation technologies, including CCS, hydrogen, and electrification
- **Enabling transparent reporting and best practice sharing:** ports can facilitate the collection and sharing of emissions data and best practices among tenants, supporting compliance and driving continuous improvement across the cluster

By taking these actions, ports not only help their tenants meet regulatory and societal expectations but also position themselves as central enablers of the UK's net-zero transition.

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

Despite their potential, UK ports face several regulatory and operational challenges in supporting tenant decarbonisation efforts, particularly in the context of CCS and CO_2 shipping:

- **Regulatory gaps in major accident prevention:** The Control of Major Accident Hazards (COMAH) Regulations 2015 currently exclude temporary CO_2 storage in ports, leaving a significant gap in the regulation of activities that pose real risks to port workers, tenants, and surrounding communities. This gap can be addressed by amending the regulations to include CO_2 as a named substance and by removing exclusions for transport and temporary storage, thereby extending COMAH's safety requirements to port-based CO_2 storage activities.
- **Lack of environmental permitting clarity:** The Environmental Permitting (England and Wales) Regulations 2016 (EPR) do not adequately cover liquefied CO_2 storage in ports, especially when storage is not directly associated with capture activities on the same site. This creates legal uncertainty and fragmented oversight, undermining environmental protection and complicating compliance for operators. To resolve this, the EPR should be amended to explicitly include

CCS-related activities such as CO_2 conditioning, liquefaction, and temporary storage within its permitting framework, while excluding CO_2 from waste and water discharge provisions to avoid regulatory overlap.

- **Operational and safety challenges**: the anticipated increase in CO_2 shipping will require port authorities to manage new safety risks. While existing powers under the Dangerous Goods in Harbour Area Regulations 2016 provide a foundation, there is a need for updated guidance, such as a Marine Guidance Note (MGN) developed in collaboration with the Maritime and Coastguard Agency (MCA) and CCS stakeholders, to address the specific implications of increased liquefied CO_2 movements.
- **Policy and regulatory misalignment: the** current regulatory framework in the UK has not kept pace with the complexity of CCS project configurations, particularly those relying on shipping as a non-pipeline transport option. This misalignment risks undermining the UK's ambitions for flexible, accessible CCS deployment and could delay the decarbonisation of hard-to-abate sectors, including within the boundaries of ports.

These reforms would establish a coherent, fit-for-purpose regulatory framework, enabling ports to fully support tenant decarbonisation and the broader transition to net zero. **To achieve this, we recommend:**

- Amending COMAH to include CO_2 and temporary storage in ports within its scope.
- Expanding the EPR's CCS-specific regime to cover all relevant activities, including port-based temporary storage, and exclude CO_2 from waste and water discharge provisions.
- Developing sector-specific guidance for port authorities and operators to manage the unique risks of CO_2 shipping and storage.
- Ensuring that regulatory reforms are tailored to address the specific risks and operational realities of ports, providing legal certainty and robust environmental protection in support of the UK's net-zero goals

40.From the perspective of a tenant at a port, how can your landlord(s) help you to decarbonise?

3. DECARBONISING PORT OPERATIONS

41.Are there any sources of direct GHG emissions at ports that have not been mentioned in the examples above?

The GHG Protocol is a helpful framework to consider in relation to GHG emissions mapping. GHG emissions emitted / embedded in the list below are particularly relevant to include and allocate to the most appropriate scope bucket.

- Emissions from non-road mobile machinery (NRMM) located on the premises of a port
- Emissions from delivery trucks, pilot boats/workboats/tugboats, as well as any on site buildings, static cargo, hoppers, conveyors and filters
- Emissions from parking activity (for example due to increased visitors traffic during summer holiday)
- Emissions associated with port bunkers
- Emissions from any rail-related activity directly connected to the port and its premises.
- Emissions from road transport of goods and people to and from ports including emissions from congestion in port-cities and local environments
- Emissions associated with biofouling removing activity / hull cleaning on-site

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

Many of the port activity-related equipment can be electrified, as current market options show that most previously diesel-powered equipment has been converted to be battery powered. However, even if ports were fully electrified at a short time, this would have a significant impact on local grid capacities, since port energy demands make up the majority of a port city's electricity demand. As such, the biggest challenge for decarbonising port activities would be the requirement for investing in renewable energy grid infrastructure to accompany port demand.

Onward transport of goods and people to and from the ports by road and diesel-rail transport will continue to be a major source of related emissions and pollution. Electrified rail freight should be prioritised, but ZnZ-carbon short-seas and coastal shipping could be an innovative trajectory to reduce freight distribution emissions and there are good models from other island nations (e.g., Japan).

Workboats in ports (e.g. pilot vessels and tugs) often have operational profiles that are challenging to electrify completely due to the 'demand driven' nature of their roles.

Large non-road mobile machinery or materials handling equipment can be challenging to electrify due to size of demand vs operational profile. Hydrogen may offer an alternative solution for this equipment.

43.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.

Renewable electricity support (shore power) for larger vessels can be an option for directly decarbonising port related activities by utilising cleaner energy sources, coming from the UK electricity Grid. For ports which are regularly visited by large vessels with significant onboard energy demand, the option of having on shore power can directly benefit local air quality, while the provision of power from the port side, could be charged as a service by the port. In general, electrification of most port related activities relative to onsite operations, can be very beneficial not only in terms of local emissions, but also from a long-term maintenance perspective. Studies have shown (CMDC work on zero carbon baseload for large vessels) that shore power can reduce total vessel emissions by more than 25%, while in-port emissions are expected to be reduced by 75%. This number is strongly dependent on the Electricity Grid carbon footprint, with the results stated being based on the UK's average 190 g CO2equiv/kWh.

Use of electrical energy storage, or local electricity generation (including from alternative zero or near-zero fuels) may be a good way to supplement peak capacities if local electricity grid constraints are not sufficient.

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

Organisations directly involved in the port operations will be able to supply Government with detailed outlined of barriers and incentives that help them to reduce direct GHG emissions. However, from an overarching perspective, a UK-wide approach is currently missing, and it is unclear whether the four UK Nations fully aligned on the policy and incentives. It's also important to underline that in the absence of a clear coherent government policy with mandatory reduction targets in place, one is de facto exposed to a patchwork landscape. There is no level playing field in place and any actions undertaken is done on a voluntary basis, in the context of fragmented port governance. This is prone to inconsistency but is also further exacerbated by the fact that the different stakeholders involved (shipping companies, terminal operators and port authorities) have different financial interests and not always aligned priorities.

One of the main barriers remains the lack of certainty and visibility over the demand which make investments hard to secure. The first mover risk is incredibly high and there are currently no frameworks in place that would incentivise or reward those who may consider investing in future tech. In some instances, the timeline for investors return on investments may also differ from the timeline needed to unlock and operationalise the infrastructure at port operations level.

In addition, the following barriers and incentives should be taken into account:

- Port operators require a high capital expenditure to build and maintain shore structures for OPS implementation.
- Shipowners incur high capital costs when retrofitting vessels with OPS systems, which may not be financially viable.
- Ships do not have standardised voltage and frequency specifications. While some ships use a 60 Hz frequency, most ports operate on a 50 Hz grid.
- The cost of electricity on the shoreline is higher than the cost of energy generated by auxiliary engines, which may discourage shipowners from using OPS.
- OPS supply is still limited worldwide (Ssali, 2018).
- Connectors and cables used in OPS are not standardised globally.
- Proper policies for OPS implementation have not been established.
- The use of high voltage electricity supply poses health and safety issues and requires load requirements around ports.
- The primary obstacle is the high capital cost, necessitating public support to help meet the prohibitive costs, especially concerning energy networks and generation, especially electricity network capacity, which needs to be quantified.
- The electricity price must be competitive for UK ports since it is considerably higher than in other countries that offer shore power at their ports.
- The British Ports Association identified demand as a risk, claiming that vessels calling in the UK do not consistently demand shore power. Unlike the EU directive, the UK does not have a policy or similar directive on shore power implementation. This increases the investment risks.

A more comprehensive discussion is available in:

- British Ports Association (2019) reducing emissions from shipping in ports examining the barriers to shore power (available at: *https://www.britishports.org.uk/content/uploads/2021/10/BPA_Shore_Power_Paper_May_2020.pdf*)
- *https://research.manchester.ac.uk/en/publications/barriers-and-solutions-for-uk-shore-power*

45.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?

Opportunities:

- There is a need to increase availability of electricity within ports for shore-side power. In delivering this it is recommended to consider establishing local renewable/low carbon energy generation infrastructure.
- For passenger heavy ports, it may be useful to consider ways to increase transport of passengers by mass transit or park and ride/train and ride schemes to reduce the number of passenger road cars entering port towns and cities, thus reducing shoreside emissions from these journeys. Electric options should be of especial consideration.

Challenges:

- If alternative shipping fuels are to be used as part of a decarbonisation strategy, there needs to be careful consideration of minimising ammonia slip as a fuel if this is to be a viable shipping fuel owing to its corrosive nature, atmospheric and marine toxicity and role as a secondary particulate pollutant (i.e. it is able to react with other pollutants to form new pollutants, such as reacting with NOx to form ammonium nitrate particles).
- We recommend DfT officials to consider:
    - the following scientific publication: "*Green ammonia adoption in shipping: Opportunities and challenges across the fuel supply chain*", available at: https://www.sciencedirect.com/science/article/pii/S0308597X24004445
    - DEFRA's report from November 2024 "*Air pollution horizon-scanning: Seven potential risks of relevance to the UK*", available at: https://uk-air.defra.gov.uk/library/reports?report_id=1161
- Similar concerns apply to the carbon-based fuels LNG and methanol, while combustion of any of these will also generate NOx as a by-product, and LNG may suffer from significant methane-slip, a more powerful greenhouse gas than CO2.
- Owing to the long-life cycle of maritime vessels, decisions made with respect to fuel choice, powertrain etc. are likely to have impacts over a long time period (a typical lifespan of a ship is around 20 years) and so anticipating unintended consequences (such as those occurring with the switch from petrol to diesel in road vehicles) are of upmost importance. We recommend Government officials to consider the following scientific publication: "*Critical evaluation of the European diesel car boom - global comparison, environmental effects and various national strategies*", available at: https://link.springer.com/article/10.1186/2190-4715-25-15

46.If you are, for example, a technology, equipment, services, fuel, or energy provider, what growth or other opportunities are presented by ports addressing their direct GHG emissions?

Please see above answer, in particular Q33.

47.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?

UK universities like Southampton educate the future workforce of engineers, scientists, and legal specialists at undergraduate, postgraduate and doctoral levels that will help the industry, including ports, to decarbonise. Our maritime engineering expertise is a cornerstone to the legal, insurance and finance sectors centred in London and is essential to so many businesses looking to unlock R&D and innovation decarbonisation opportunities for ports and shipping.

There will be a need to provide skilled people working with all possible alternative fuel systems, as well as associated equipment and supply. In collaboration with industry stakeholders the UK government should invest in new and upskilling the workforce for the maritime industry of the future.

The UK is already a world-leader in provision of skills to the maritime industry globally, from universities to nautical training colleges (such as Warsash Maritime Academy) and commercial training provision (e.g. LR) as well as the training provided by naval shore establishments (e.g. HMS Sultan). The UK also has a well-respected flag-state regulatory regime in the Maritime and Coastguard Agency, with significant influence (e.g. the Red Ensign Group). This provides the UK – and in particular the Solent region – with an opportunity to be a centre for new skills provision for a global market.

48.Do you monitor your direct emissions in your port? If yes, how? In tonnes of CO2 equivalent (CO2e), please provide evidence to quantify the current level of annual direct GHG emissions in your port. Please disaggregate this information as much as possible to cover the different sources of direct GHG emissions, for example, the emissions from specific types of equipment used in port operations.

49.In tonnes of CO2 equivalent (CO2e), please provide evidence to quantify any savings you have achieved in your annual direct GHG emissions. Please disaggregate this information as much as possible to cover the different sources of your emissions, for example, the emissions from specific types of equipment used in port operations.

50.Do you monitor the additional environmental impacts such as air quality, noise, and biodiversity from the sources of your direct emissions at your port? If yes, please provide details of these environmental impacts. Please disaggregate your response as much as possible.

As researchers at University of Southampton, we have a strong interest in port and port city air quality. We have carried out long-term sampling and monitoring of size-segregated particulate matter concentrations, including particle elemental characterisation at various locations within the Port of Southampton. Each of these locations was adjacent to specific distinct activities, each releasing particles with different physical and chemical characteristics. Submission of papers is envisaged within 1-3 months, although conference abstracts relating to aspects of this work are already published and are accessible via the following links:

- *"Source-related composition and toxicological effects of shipping-associated particulate matter",* available at: https://doi.org/10.1183/23120541.LSC-2022.206
- https://meetingorganizer.copernicus.org/EGU25/EGU25-7152.html

[NB – this data and conclusions are for publication shortly, do not disseminate publicly]. Our findings in the Port of Southampton: we have undertaken a PM source apportionment on a set of PM samples collected at the Port between 2017 and 2020, looking at PM10-2.5 and PM2.5-0.1 separately. This identified 5 factors, including shipping fuel (HFO and desulfurised HFO) combustion (15% average in PM2.5-0.1, <1% in PM10-2.5). This showed a strong seasonality aligning with cruise shipping activity, with concentrations of shipping PM2.5-0.1 peaking at 3.9 μg m-3. This is notable because (1) the figure of 15% is at the high end of what other studies have found in other ports in Europe (see "*Impact of harbour activities on local air quality: A review*" available at: https://www.sciencedirect.com/science/article/abs/pii/S0269749119326922) ; and (2) 3.9 μg m-3 represents over 25% of the WHO guideline value (see source here: https://www.who.int/publications/i/item/9789240034228) for 24 hour PM2.5 concentrations (and almost 80% of the annual average guideline), suggesting that future aims to comply with these values may be frustrated without reductions in shipping emissions.

Other factors identified, including sea spray, road vehicle non-exhaust emissions, crustal erosion/resuspension, and mixed road vehicle fuel and biomass combustion, may well originate in part within the port, but also likely originate outside of the port from non-port-related sources. We also established a strong elemental signature for shipping HFO-associated PM emissions, which could be used to identify, trace, and quantify these in future. We have used this emissions signature to evaluate the spread of emissions in the local area, using novel techniques. This suggests that long-term average air quality from shipping alone (i.e. tier 1 emissions) is impacted to a distance of at least 3 km from the port, although given that this technique is less powered to identify transient spikes, individual emissions episodes likely travel further.

The literature shows that emissions from the English Channel can be detected in London, please consider the following scientific publication for further information: *"Receptor modelling of both particle composition and size distribution from a background site in London, UK*", available at: https://acp.copernicus.org/articles/15/10107/2015

Our in vitro toxicology experiments have indicated that there may also be a need to address the unregulated ultrafine PM fraction, which appears able to escape the emissions abatement mechanisms used to achieve compliance with sulfur emissions regulations as an alternative to lower sulfur fuel combustion.

51. If you have a decarbonisation goal, what goals have you set? Please include details of any interim goals and the associated timeframes for achieving these goals. Additionally, please specify if your decarbonisation goal aims to achieve net zero with some residual emissions, or close to or absolute zero emissions.

a. If your decarbonisation goal aims to achieve net zero with some residual emissions, how do you plan to address the residual emissions? Different methods of addressing residual emissions include, but are not limited to, carbon capture, usage and storage and carbon offsetting.

52.What considerations have you taken to set your decarbonisation goal(s)?

53.What are the costs or investment required to achieve your decarbonisation goals? Please provide any calculations used for your cost and/or investment estimates.

54.What are the economic and environmental benefits of achieving your decarbonisation goals, including co-benefits through the reduction of air quality, noise, biodiversity and adapting to climate change impacts?

Reduced health burden on port cities – emissions from ships, portside sources, and "associated" sources such as passenger and freight movements landside, contribute to air pollution. Exposure to air pollution in general is the leading risk factor for ill health and premature death worldwide, and therefore and initiatives which reduce emissions, and thus air pollution concentrations, may be expected to have health benefits.

In particular, reduced traffic congestion and associated air quality – in Southampton two of the Air Quality Management Areas (AQMAs) for exceedances in NO2 concentrations are attributed to “access to IOW ferries, cruise ship terminals”[AQMA 4 – Town Quay] and “road into container port, high number of HGVs” [AQMA 5 – Millbrook Road and Redbridge Road]. Source: *https://www.southampton.gov.uk/our-green-city/council-commitments/clean-air/air-quality-management-areas/*

55.If you are, for example, a technology, equipment, services, fuel, or energy provider are there any additional growth benefits of supplying ports with equipment or services that helps them meet their decarbonisation goals?

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

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

There is insufficient guidance at present. It should be emphasised that the ports alone cannot achieve this transition and industry-wide collaboration is required, supported by government incentives. However, these incentives and regulations are currently lacking, and the funding provided is not at the required level. This is further complicated because, unlike most of the ports in the EU and USA, which local or national governments own, most UK ports are privately owned by commercial companies.

In addition, as the major maritime engineering institution based in a port city, the University of Southampton and its multidisciplinary research community are inherently interlinked and connected to the decarbonisation activities linked to Southampton’s port. More generally, this means that helping ports to decarbonise is not solely dependent on sufficient government or industry-led guidance. Meaningful and impactful change entails bringing on board higher education institutions and local government. UK universities like Southampton educate the future workforce of naval architects at undergraduate, postgraduate and doctoral levels that will help the industry, including ports, to decarbonise. Our maritime engineering expertise is a cornerstone to the legal, insurance and finance sectors centred in London and is essential to so many businesses looking to unlock R&D and innovation decarbonisation opportunities for ports and shipping. Therefore, we believe that higher education/academia has an equally important role to play in the discussions, immense knowledge to share and an opportunity to act as a pivotal collaboration partner to help ports in their decarbonisation journey, especially if like University of Southampton, there is an equivocal proximity to the port and the English Channel.

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

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

60. 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?

There remains a critical shortfall in the UK's infrastructure to test and evaluate sustainable technology to decarbonise the maritime sector including ports. Together with maritime industry primes and a wide community of SMEs, the University of Southampton has developed the concept for a national Centre for Green Maritime Innovation (cGMI) that will address this shortfall by focusing on innovation, systems integration, skills, and digital technology. The cGMI will provide the infrastructure, expertise and skills to de-risk key areas of technology, support its integration, and develop enabling regulations.

By focusing on both ship and shore-based systems, the Centre will offer technical expertise and new skills, helping our partners to adapt quickly to emerging opportunities and accelerate the realisation of zero- or low-C maritime trade. The Centre will provide a singular focus across the maritime sector to drive growth and investment in the UK maritime sector and by working with global industry players and SMEs, create UK jobs and products, benefiting industry and the nation.

To learn more about the cGMI, please access our proposal for a national facility to accelerate zero carbon technologies for the maritime sector at the following link: https://www.southampton.ac.uk/~assets/doc/cgmi/CGMIInformation.pdf

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