Opportunities for the UK to kick-start shipping's transition to zero greenhouse gas emission fuel

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Arup and UMAS have explored energy supply and demand dynamics for early-mover zero greenhouse gas (GHG) emission shipping fuel in the UK to illustrate the factors driving supply strategy.

Decarbonising the operations of just six large ferries operating regular routes from ports in the North East or seven container vessels operating from ports in the Solent area, including Southampton and Portsmouth, could align shipping in these regions with the most ambitious international shipping decarbonisation trajectories.

While zero GHG emission fuel production costs will likely be lower in overseas locations in the long-term, countries such as the UK have an opportunity to kick-start the transition; delivering on policy commitments while making use of existing assets, supporting energy security, and realising economic opportunities.

Introduction

Meeting shipping decarbonisation targets will require significant uptake of zero GHG emission fuel by the end of the decade

The revised Greenhouse Gas (GHG) strategy agreed by the International Maritime Organisation (IMO) last summer sets an ambition for zero or near-zero GHG emission energy sources to meet between 5% and 10% of the energy used by international shipping by 2030. In practice, this will require significant infrastructure investment to enable the production, distribution, and use of millions of tonnes of scalable zero GHG emission" fuels, such as renewable ammonia and methanol.

Uncertainty is hampering the development of the necessary production and supply infrastructure

Significant investments are required in the immediate term to develop whole new supply chains covering energy generation, fuel production, distribution, bunkering infrastructure, and vessels to use the fuel. Although the revised GHG strategy provides a general, global demand signal, there remains significant uncertainty as to where the zero GHG emission fuel demand will first develop, how quickly it will scale, and how fuel production and supply infrastructure can cost-effectively be developed to meet it. This prevailing uncertainty is contributing to a lack of confidence among key actors and preventing the necessary investments from being made.

Countries like the UK can benefit from participating in early mover opportunities to kick-start the transition

Arup and UMAS have come together to jointly explore the supply and demand dynamics for early-mover zero GHG emission shipping fuels; taking supply of ammonia to vessels operating in the UK as a case study to explore the challenges. Combining the use of UMAS's first mover route identification tool with Arup's expertise in the evaluation, design, and delivery of zero GHG emission fuel production facilities and port infrastructure, we find that, while fuel production costs will likely be lower in overseas locations, over the near-term, countries such as the UK have an opportunity to kick-start the transition; delivering on policy commitments while making use of existing assets, supporting energy security, and realising economic opportunities.

Demand development

Understanding current shipping energy demand helps identify opportunities to concentrate decarbonisation efforts and reduce investment risk

Achieving a 5% to 10% uptake of zero GHG emission fuels by 2030 is a challenge that can be viewed at different levels of energy aggregation. At the most granular level, this can be done by accounting for the energy demand required from ships departing from a given port area. Using UMAS' shipping activity model, FUSE, to provide these insights, we reviewed the makeup of the fleet's activity for two dynamic port areas in the UK.

Map 1: Description of port areas considered for this work and their relative shipping energy demand.

The shipping activity of Northeast England (including the Teesside and the Humber), and the Solent (including Southampton and Portsmouth) provide a template for first mover opportunity assessment

Ships operating from the North East of England, including the hubs of Teesside, the Humber, and the Tyne River, need around 513 kilotonnes of Heavy Fuel Oil equivalent (kt-HFOe) to complete the next leg of their journeys (2023 data).' To decarbonise 10% of this energy demand using methanol or ammonia would require approximately 100 kilotonnes of either fuel, when accounting for energy density differences with HFO. As shown on Map 1, the catchment area for these ports spans approximately 200 miles (320 km) from Newcastle to Immingham, which implies the need for a suitable fuel distribution network.

Similarly, the Southampton/Portsmouth port area had a total estimated energy demand of around 751 kt-HFO, which would translate into the potential production of approximately 150 kilotonnes of ammonia or methanol if the 10% target for 2030 is maintained. This catchment area has a much more concentrated profile, with a diameter of around 50 miles (80 km), capturing the ports with the majority of demand and simplifying local distribution challenges However, the area has limited renewable energy sources, which may constrain the potential to produce electrolytic hydrogen and derivative fuels.

Having looked at the estimates of energy demand required to meet the 10% goal set by 2030 (based on current energy demand), the next step is to assess the opportunities within the makeup of the fleet operating from these two regions to explore the best cases for long-term offtake agreements that unlock the business cases to procure the required fuel.

Offtake agreements are key to developing e-fuel supply chains, so it is vital to identify key routes and the associated counterparties

Using the target estimates of energy demand for the two regions, we can now review routes that exhibit suitable demand profiles in terms of volume. This would help identify the parties best positioned to materialise decarbonisation efforts into offtake agreements for e-fuels.

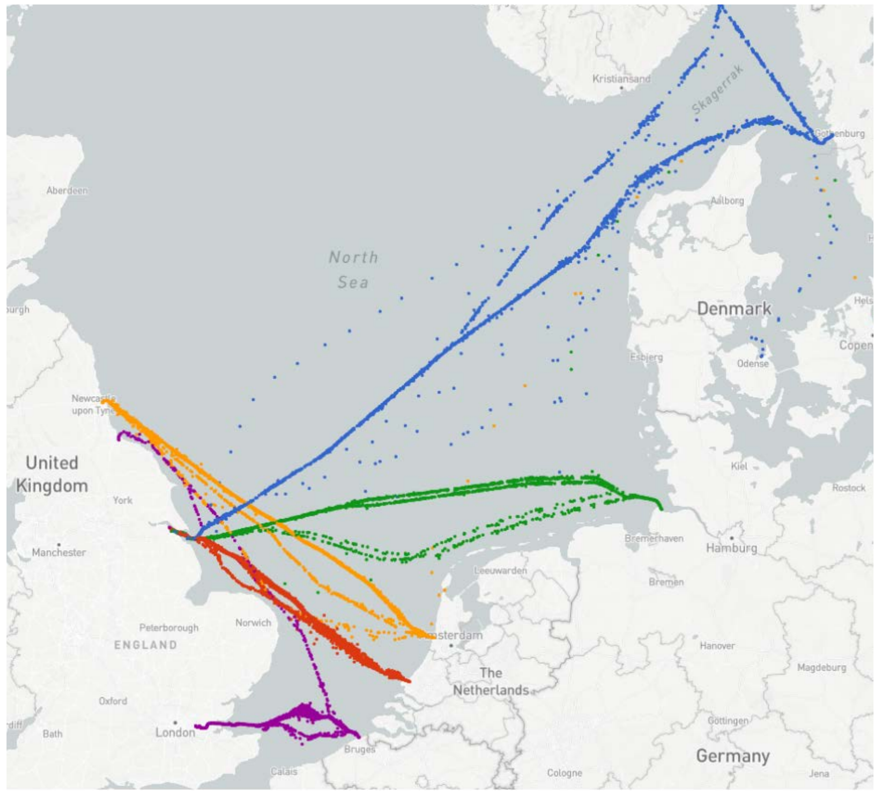
First, a review of the vessel types operating from Northeast England highlights that routes operated by large ferries offer the most immediate opportunities.

The total yearly consumption of the top six vessels in terms of energy demand that operate from the region accounts for an estimate of around 80 kt-HFOe or around 160 ktonnes of ammonia/methanol, an amount already exceeding the 100 ktonnes likely needed to meet 10% of the area's demand from shipping activity. Decarbonising the operation of these six vessels in practice means that the region would go beyond the most ambitious international shipping decarbonisation trajectory set by the IMO during last year's revised strategy.

Map 2 presents the activity of vessels identified as regular operators from the region, including those listed in the Table 1.

Table 1: General vessel details and fuel consumption estimates for ships operating from the North East of England

Ship type	Size category	Annual Fuel Consumption (HFOe, tonnes)	Visited nodes	Route color
Ferry - RoPax	20,000+ gross tonnes	18.1k	Immingham - Rotterdam	● (red)
Ferry - RoPax	20,000+ gross tonnes	17.5k	Immingham - Rotterdam	● (red)
Ferry - RoPax	20,000+ gross tonnes	14.4k	Newcastle - Amsterdam	● (orange)
Ferry - RoRo	15,000+ deadweight	15.2k	Imminghham - Gothenburg - Brevik	● (blue)
Ferry - RoRo	10,000 - 15,000 deadweight	14.8k	Immingham - Cuxhaven	● (green)
Ferry - RoRo	10,000 - 15,000 deadweight	13k	Teesside - Tilbury - Zeebrugge	● (purple)



Map 2: Regular routes operating from the Northeast of England

An analysis of active routes operating from Southampton/Portsmouth also illustrates the presence of ferries, among other vessel types like cruise, tanker and container ships. From the alternatives reviewed, one route with an interesting opportunity for the region is that of transatlantic container movements. With a total energy demand of around 95 ktonnes of HFOe or around 190 ktonnes of ammonia/methanol, the seven container ships shown in the Table 2 would also exceed the required demand to hit the 10% fuel uptake target for 2030 for this port area. However, it is worth noting that these are relatively long transatlantic journeys with multiple stops where single-point refuelling is unlikely.

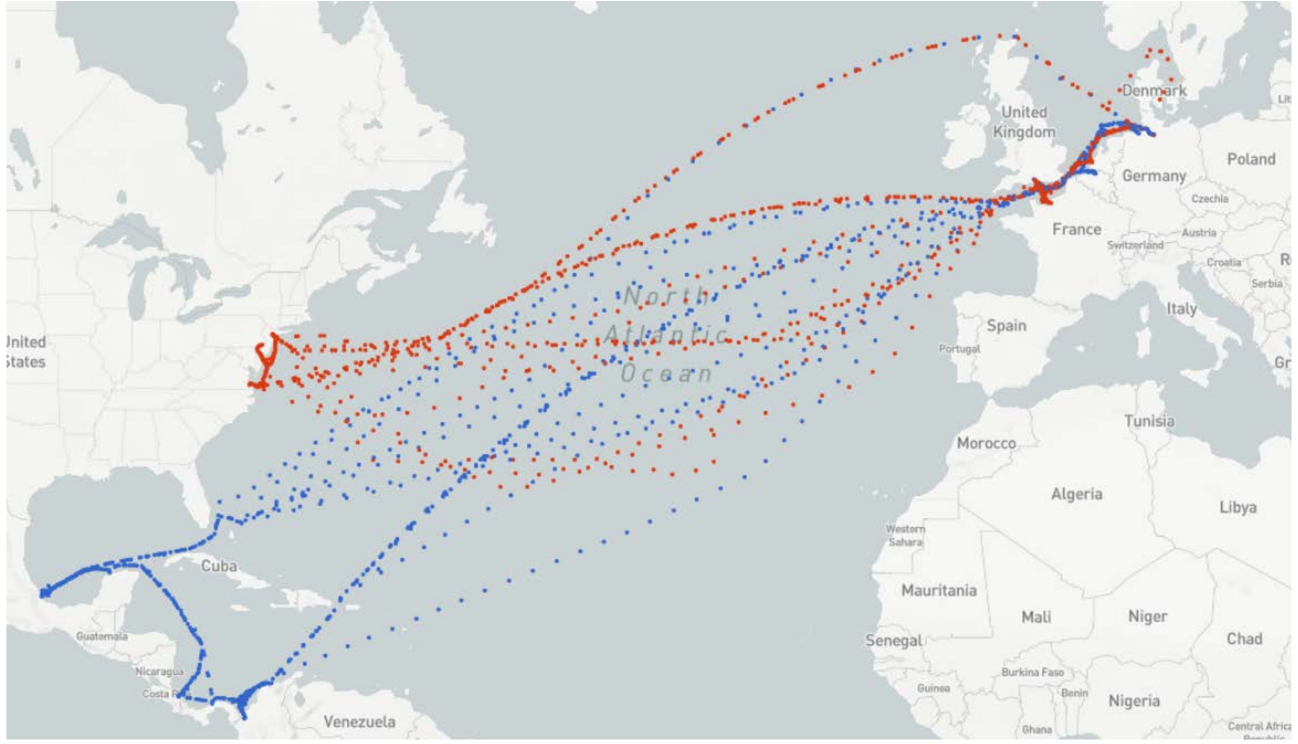
As shown on Map 3, when travelling from the Americas, these vessels have Southampton as their first stop on the east side of the Atlantic,, catering for one route that directly connects to North America and a separate route that loops around the Gulf of Mexico and the Caribbean.

It’s worth noting that high volumes of aggregated fuel demand result from medium to large-size vessels operating these routes. It’s due to this factor that a relatively low number of vessels and shipping actors would be needed in defining the projects that could deliver the operation of zero GHG emission shipping.

Setting 2030 short-term goal means that some vessel types and available technology will define the fuel mix at a local level

Parallel factors to consider when exploring the outlook of the short-term transition are technology readiness and availability of engines, safety measures, and accumulated operational experience with e-fuels. Methanol is liquid at ambient temperature and has already been used extensively as a shipping fuel. However, its production pathway requires sourcing sustainable CO_2, which could translate into logistical issues for its production. Conversely, ammonia doesn’t contain carbon, so its feedstock supply is less constrained, but it is a toxic chemical that needs to be handled with extra safety measures, and to be refrigerated to be kept in liquid form. Engines operating on ammonia are still under development with an expected commercialisation around 2026 for both new builds and retrofits. Industry standards for the operation of this fuel are also being developed rapidly.

Map 3: Transatlantic container routes operating through the Solent Strait



Due to these fuel characteristics, some ship segments are showing a preference when considering the placement of new-build orders. Passenger carriers such as cruise and ferry operators are expressing greater interest in Methanol, while the accumulated experience of transporting ammonia as cargo is attracting the interest of tanker operators seeking to replicate LNG’s transition from being solely a cargo to also providing fuel for the vessels propulsion. Other segments like containers have placed orders for both fuels, although for now, methanol is leading the order book for this vessel type. There is enough room for a shift in fuel preferences in the long term, and these will largely depend on the availability and the relative pricing of fuels. However, looking at the 2030 goal heavily hinges on the consideration of the factors previously presented. One thing that appears to be clear is that clean hydrogen production will be needed as both fuels will require it as a feedstock.

Table 2: General vessel details and fuel consumption estimates for ships operating from the Solent strait.

Ship type	Size category	Annual Fuel Consumption (HFOe, tonnes)	Visited nodes	Route color
Container	8,000-12000 TEU	16k	Southampton - LeHavre - Rotterdam - Hamburg - Odense - Norfolk - Philadelphia - Newark	🔴
Container	8,000-12000 TEU	15.3k	Southampton - LeHavre - Rotterdam - Hamburg - Odense - Norfolk - Philadelphia - Newark	🔴
Container	8,000-12000 TEU	15.2k	Southampton - LeHavre - Rotterdam - Hamburg - Odense - Norfolk - Philadelphia - Newark	🔴
Container	8,000-12000 TEU	14.7k	Southampton - LeHavre - Rotterdam - Hamburg - Odense - Norfolk - Philadelphia - Newark	🔴
Container	2,000-3,000 TEU	12.3k	Southampton - Antwerp - Bremerhaven - Hamburg - Veracruz - Moin - Colon Santa Marta	🔵
Container	2,000-3,000 TEU	11.3k	Southampton - Antwerp - Bremerhaven - Hamburg - Veracruz - Moin - Colon Santa Marta	🔵
Container	2,000-3,000 TEU	10.6k	Southampton - Antwerp - Bremerhaven - Hamburg - Veracruz - Moin - Colon Santa Marta	🔵

Fuel production & supply

Meeting early mover zero GHG emission fuel demand will require the simultaneous scaling up of production facilities and supply chain infrastructure. Taking renewable ammonia as an example fuel to meet the identified first mover demand in Southampton, this section explores the relative merits of utilising domestic UK production or low-cost fuel imports.

Fuel production costs

The cost of renewable energy generation is the key driver impacting the competitiveness of hydrogen-based fuel production locations. Although the UK has been a leader in the development of offshore wind in the North Sea, the inherently lower cost of solar and onshore wind generation in locations such as North Africa, the Middle East, Western Australia, and Chile, suggest that the UK may have a limited role as a producer of zero GHG emission fuels in a cost-optimised, connected and competitive global market.

To illustrate the magnitude of this cost differential, Arup has modelled the Levelised Cost of Ammonia (LCOA) for two cases:

1. Produced from a MW-scale green ammonia production facility in the Northeast of the UK and transported to a terminal in Southampton by a 20,000 m^3 gas-carrier.
2. Produced from a GW-scale facility in Morrocco and transported to a terminal in Southampton by an 80,000 m^3 capacity gas-carrier.

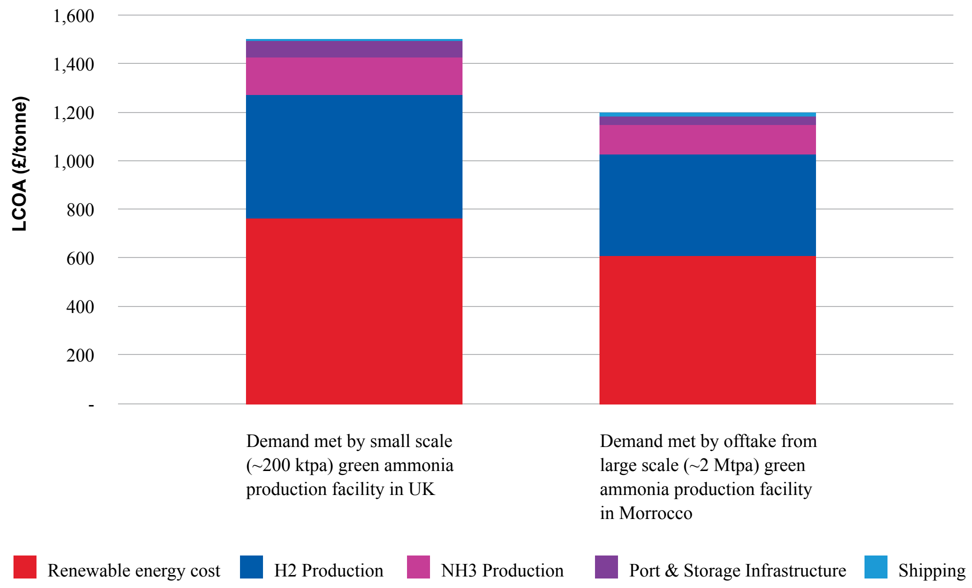
The cost premium associated with UK production may be clear, however commercial barriers to the development of production facilities in international locations, as well as the need for infrastructure development to export and ship the fuel, may mean there are opportunities for the UK to play an active role in the early stages of the transition while showing leadership in maritime decarbonisation.

Export and shipping costs

Transporting zero GHG emission fuels over large distances from low-cost production locations to the major demand centres in North America, Europe, and East Asia requires investment in new export and storage facilities, ports, and ships. While these costs will only make up a fraction of future LCOA for major export projects, significant investment and development challenges could present a barrier to the delivery of early-mover projects.

Experience shows that development of a greenfield port for ammonia export could require between £100 and 200 million in capital investment and potentially twice this amount in areas with less favourable marine conditions. Additional investment for ammonia storage will be significant and are highly dependent on the ability to optimise capacity as well as the site conditions. Furthermore, unlike renewable energy and electrolysis, the cost of liquid bulk terminals generally does not scale linearly with demand, since the jetty and storage facilities must be sized to accommodate typical gas carrier vessels, regardless of how often it is used. An export jetty sized to accommodate large gas-carriers could support between five and ten million tonnes of ammonia throughput each year. Only the largest green ammonia plants, or multiple production facilities sharing the same export port, would make this level of investment viable.

Chart 1: LCOA delivered from fuel terminal in Southampton



Levelised Cost of Ammonia (LCOA) has been modelled based on 2023 costs and following the same modelling approach as applied in recent Arup research.

Reasonably conservative assumptions are applied for renewable energy and electrolyser costs, reflecting the latest announced hydrogen project costs, to provide a realistic outlook for early mover projects.

Key assumptions:

- Renewable LCOE from IEA and BloombergNEF with 5% discount applied for economies of scale in multi-GW project;
- Electrolyser, Ammonia synthesis, and ASU costs based on Arup internal benchmaks;
- Port and storage costs based on Arup internal benchmarks considering re-purposed UK infrastructure and greenfield infrastructure in Morocco;
- Shipping costs are based on chartered vessels operating on round-trip voyages from Morrocco (2750km) and North East UK (750km).

The 'last-mile' delivery challenge

The modelled LCOA in both cases includes logistics costs for delivering the fuel in bulk to a terminal in Southampton. This overlooks the cost of the 'last-mile' delivery of the fuel from terminal to receiving vessels; a key challenge to early mover uptake that is present for both imported as well as locally produced fuel.

The cost of small-scale storage facilities, bunker barges, and road tankers may seem small in the context of the production facilities. However, at low levels of demand in the early stages of the transition, the utilisation of such infrastructure is low, making the cost per tonne of fuel supplied significant and the investment decision highly challenging for operators. Consolidating early mover demand in a single port or region can help overcome this challenge while supply chain infrastructure scales.

Delivery timelines

Major renewable generation and green ammonia production projects typically take between 3 and 6 years of procurement, construction, and commissioning once a Final Investment Decision (FID) is made, before they are ready to start producing fuel. Furthermore, it can take several years of project development, consenting, and commercial negotiations before FID is reached in the first place and, in remote locations, initial development of port facilities is required to deliver materials and components for the construction of renewable energy and fuel production facilities.

Considering these timelines, major GW-scale projects would need to be in development already if they are to realistically contribute to meeting early mover zero GHG emission shipping fuel demand by 2030. Although there may be several million tonnes of low or zero GHG emission ammonia production capacity scheduled to be available by 2030, many of these projects have yet to reach FID, while much of the capacity of those that have is already earmarked for export and use in large-scale energy exports.

The UK's potential role

Delivery of a small-scale green ammonia facility in the UK could present a route to meeting the identified demand by 2030, helping to kick-start the maritime fuel transition and secure the UK's position as a climate leader. Furthermore, it may be achievable at a similar cost to an offtake agreement from a early mover GW-scale facility in a low cost renewables location such as Morrocco.

Considering a scenario where there is a significant 25% risk premium on the cost of capital to deliver the Morocco project and development of greenfield export infrastructure approaches £500m Capex, then an increase of 12.5% to the LCOA to the base estimate could be experienced. Meanwhile, if the UK project is able to revamp existing ammonia production facilities, replacing grey hydrogen with locally produced green electrolytic hydrogen, the LCOA could be reduced by 10% from the base assumption, effectively closing the cost gap between the two projects. Re-use of existing production and port facilities could also support an accelerated delivery timeline towards first production, ready to meet the early mover demand in 2030.

Realisation of such a project would help meet policy commitments across multiple areas of the net-zero transition, supporting the UK hydrogen and clean maritime sectors, taking advantage of existing government financial support provided though the Hydrogen Allocation Rounds, as well as supporting energy security with a reliable domestic supply of zero GHG emission maritime fuel.

Summary

The fossil bunker fuel market is highly developed, fully globalised, and cost-optimised through market forces whereas the zero GHG emission fuel supply chain could take decades to reach a similar state, with the transition requiring development of new production facilities and supply infrastructure for multiple different fuels. What makes most sense in the short to mid-term may not be the most-cost effective solution in the long-term so its important to take a holistic view of the technical, commercial, and regulatory considerations across the whole value chain to shape first-mover zero GHG emission shipping fuel projects and unlock the necessary investment.

Both the Northeast of England and the Solent area present compelling cases of consolidated energy demand from established shipping routes. These scenarios offer potential opportunities to establish the fuel supply chains necessary for achieving the ambitious industry targets set for 2030. Additionally, they could help address the challenges related to the utilisation of capital-intensive storage and distribution assets at the beginning of the transition.

Reviewing the alternative approaches to meet this demand offers some insights into why there may be a case for supporting local production over imports. Large production projects abroad are encountering challenges in securing sufficient offtake agreements to support their business case. This leads to increased investment risk, which in turn raises the cost of capital for deployment. On the other hand, strategic planning for the reutilisation of existing production and distribution infrastructure in the UK may present a time-limited opportunity for establishing a financially viable business case for local production and provision of fuels. This approach could help bridge the cost gap compared to utilising a large-scale plant abroad.

Contact:

Sally Prickett
Hydrogen Advisory Lead, Arup
e: sally.prickett@arup.com

Chris Thorne
Director of Strategy and Operations, UMAS
e: chris.thorne@umas.co.uk

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Global Maritime Forum, GMF

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