Lowering your emissions through innovation in transport and energy infrastructure

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Transport | Energy Infrastructure | Knowledge & Enterprise

Charging Infrastructure for Near-Shore Electric Vessels

Part 1: Background to the Electric Maritime Industry and the Opportunity for the City of Plymouth

PLYMOUTH CITY COUNCIL
UKRI Innovate UK
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Contents

Documents in this Series

This document is the first of three documents in this series entitled "Charging Infrastructure for Near-Shore Electric Vessels" authored by Cenex for Plymouth City Council.

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2 The Electrification of the Maritime Sector

2.1 The Climate Crisis

As the world reacts to the climate crisis, all industrial sectors must contribute to reducing greenhouse gas (GHG) emissions if we are to limit global temperature to below 2°C, or even 1.5°C, above pre-industrial levels. These are the targets made by the Paris Climate Agreement , to which the UK government, and many other countries, are legally bound. The UK set a ‘net-zero’ greenhouse gas (GHG) target for 2050 back in 2019, a commitment that was reiterated as the UK government sought to lead by example at COP26 in November 2021.

Some industries have reduced emissions faster than others. The Department for Business, Energy & Industrial Strategy’s (BEIS) latest available figures show that as of 2019, the UK’s territorial GHG emissions – that is, the emissions produced within the geographical boundary of the UK including UK waters - were 44% lower than 1990 levels.

The energy system at its peak was accountable for 34% of UK emissions. By phasing out coal generation in favour of renewable sources such as solar and wind and other lower emitting sources such as natural gas, the sector is responsible for approximately half of the overall reduction.

In 2016, Transport became the largest emitting sector, and in 2019 was responsible for over a quarter of all UK territorial emissions. Although road transport is the largest constituent of transport emissions, shipping – both UK domestic and international shipping emissions - are a significant contributor.

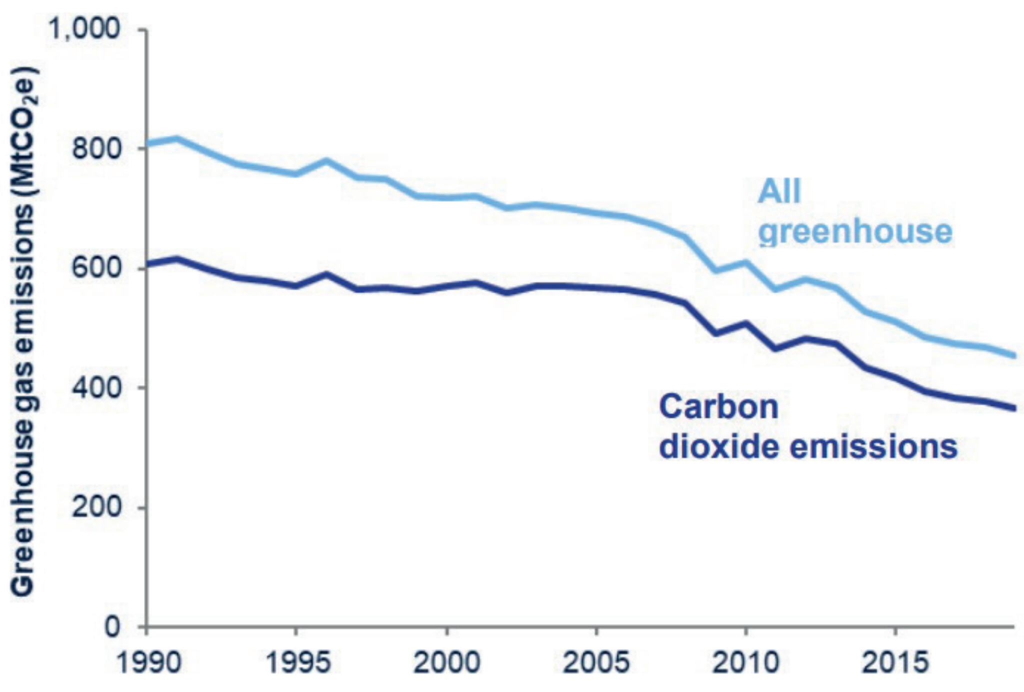

Figure 1: UK Territorial GHG emissions 1990-2019 [1]

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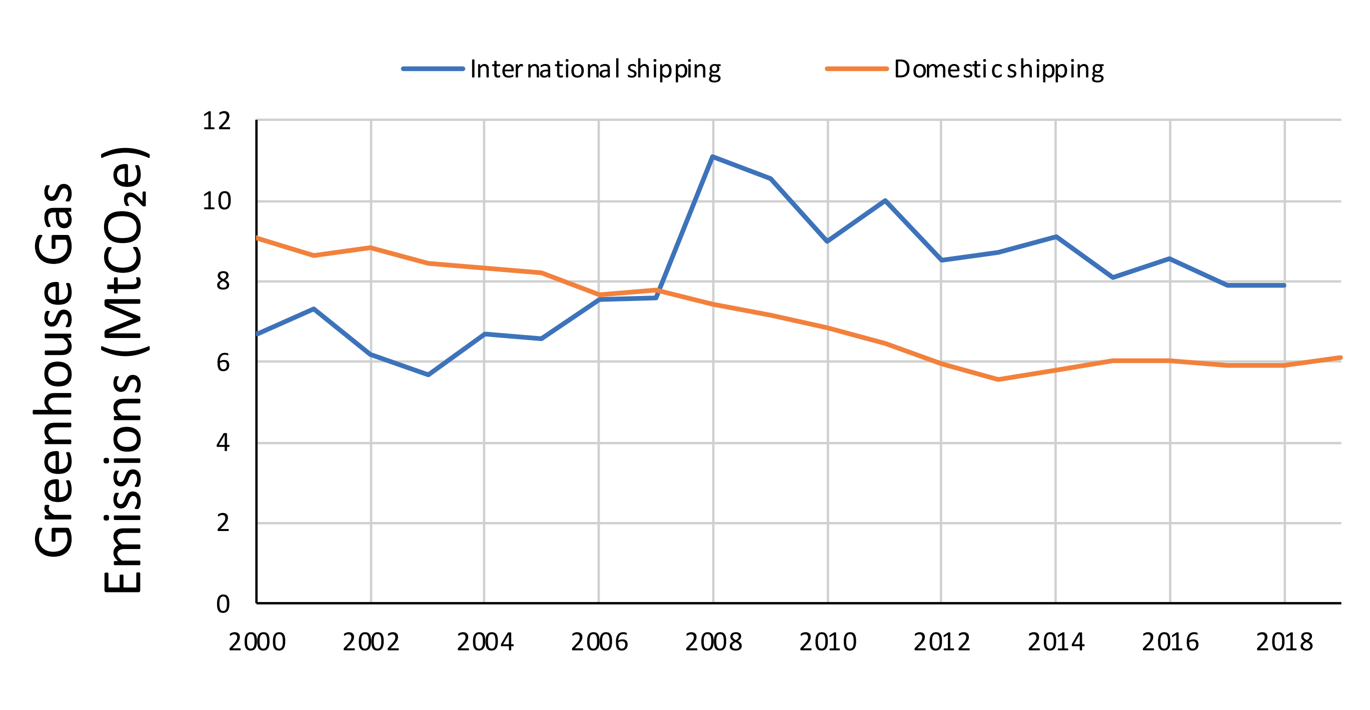

Figure 2: UK Shipping GHG Emissions [2]

Although shipping is considered an efficient means of transport, domestic shipping accounted for 5% of all UK territorial transport emissions in 2018, emitting 6 $MtCO_2e$ of GHGs. In addition, there was 7.9 $MtCO_2e$ of GHG emissions from international shipping. **Combined, domestic and international shipping accounted for 3.1% of the UK's overall GHG emissions in 2018 [2].**

Just as all countries must contribute to global emissions reductions, all sectors must play their part. Although shipping is only 5% of total emissions, as other sectors reduce their emissions, the maritime industry must do the same if the UK is to meet its legal obligation to reach net zero emissions by 2050. As a result, the UK government has included shipping under "Point 6: Jet zero and green ships" in its ten-point plan for a green industrial revolution which includes a modest reduction target of 1 MtCO2e between 2023 and 2032. However, the stated ambition for the UK to be at the forefront of reduced maritime emissions should lead to more ambitious maritime CO2e restriction.

There are limited existing policies to reduce maritime emissions . In 2018 the UK led the call for the International Maritime Organization's (IMO) to target a 50% reduction in emissions by 2050 with respect to 2008 levels. The Department for Transport's (DfT) Clean Maritime Plan [3] (building on Maritime 2050 [4]) stated that the UK, with a proud maritime history and substantial maritime sector, can lead the transition to a zero-emission maritime industry. Although disappointing that the Clean Maritime Plan did not make more ambitious emissions reduction commitments than the IMO target, the ambition to transition to a zero-emission maritime industry is welcomed.

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2.2 Air Quality

With the ongoing coronavirus pandemic, it is easy to neglect other major public health risks. One such risk, shown to increase the mortality rate from diseases such as COVID-19, is poor air quality due to pollutants [5]. As we exit the pandemic or learn to live with coronavirus, air quality will return to the top of the list of environmental risks for public health [6]. The impact of pollutant emissions from shipping has only recently started to be understood. According to the DfT, domestic shipping in the UK accounted for 11% of the UK's total NOx emissions, 2% of primary PM2.5 and 7% of SO2. This excludes the impact of international shipping, which a study by Imperial College has estimated to be three times higher than domestic shipping [3].

Air quality improvements have primarily focused on road transport pollutant emissions in urban areas, and significant progress has been made in response to the DfT's Road to Zero strategy [7]. The UK has 51 major shipping ports which handled 27 million passengers in 2017 [8], many of which are close to densely populated urban areas. Whilst the exact impact is not known, it is safe to say that **pollutants from the maritime industry have an adverse impact on public health in the UK**.

The issue of maritime air pollution can be addressed by international, regional and local regulations. The UK is involved with the North Sea Emissions Control Area (ECA), which was designed to reduce the impact of air pollution resulting from busy shipping lanes in the North Sea. The ECA focuses on the NOx emissions from new vessels and is an international regulation implemented by the IMO. At a domestic level, the Clean Air Strategy is investigating the possibility of extending the North Sea Emissions Control Area or creating new ECAs around the UK coast. At the municipal level, the Clean Air Thames (CAT) project (2019-2022) is an example of a project designed to reduce pollutants from maritime operations in an urban area. CAT contributes to the overall aims of the Port of London Authority's Air Quality Strategy, providing funding for emission-reducing retrofits of commercial freight and passenger boats [9].

2.3 Electrified Maritime

The emissions reduction proposed by the IMO will require a number of technological, operational, and policy changes to be realised. Low carbon fuels, including electrification, are planned to contribute 22% of the overall shipping emissions reduction by 2050 as shown by the scenario of Figure 3. This will also have a positive impact on air quality as less pollutants are emitted in port.

View Figure 3 on next page.

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Figure 3: IMO Beyond 2 Degrees Emissions Reduction Scenario [10]

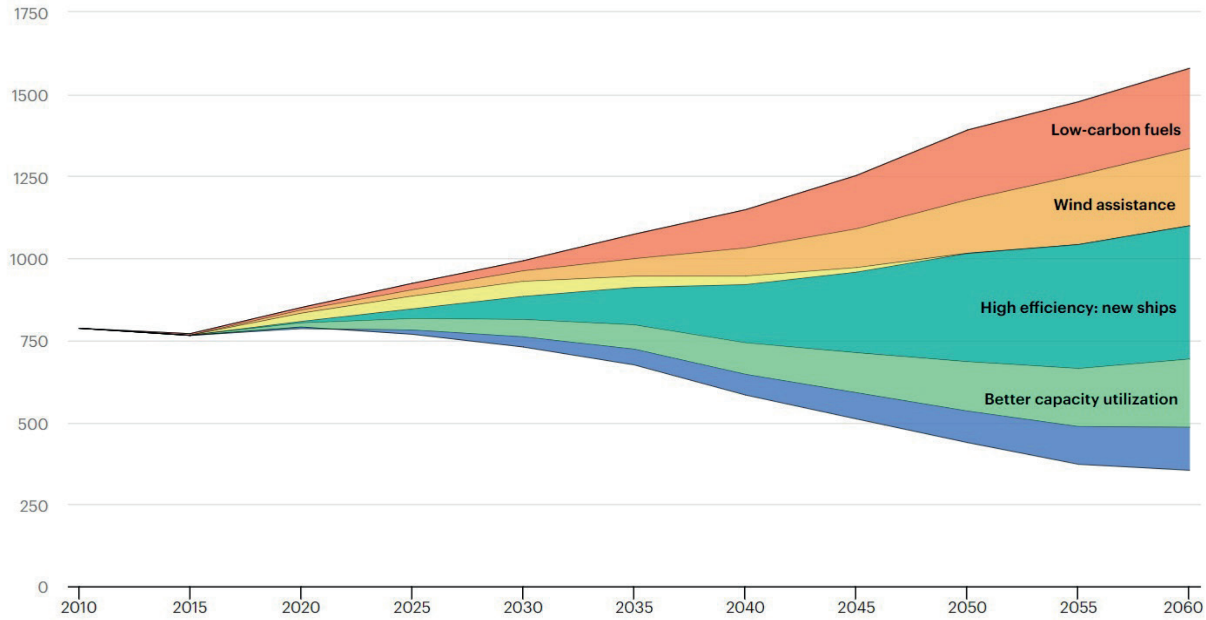

Figure 4 shows that rechargeable batteries are expected to play a significant role in the transition to a more sustainable maritime industry. Fully battery electric or hybrid-electric propulsion (where battery electric systems are paired with another powertrain technology) are being actively researched and demonstrated worldwide. Battery and hybrid-electric auxiliary systems to power maritime 'hotel loads' are also being demonstrated. Electrification is feasible for smaller vessels, especially those that perform operations where total energy requirement is low, or that make short trips allowing the batteries to be recharged frequently.

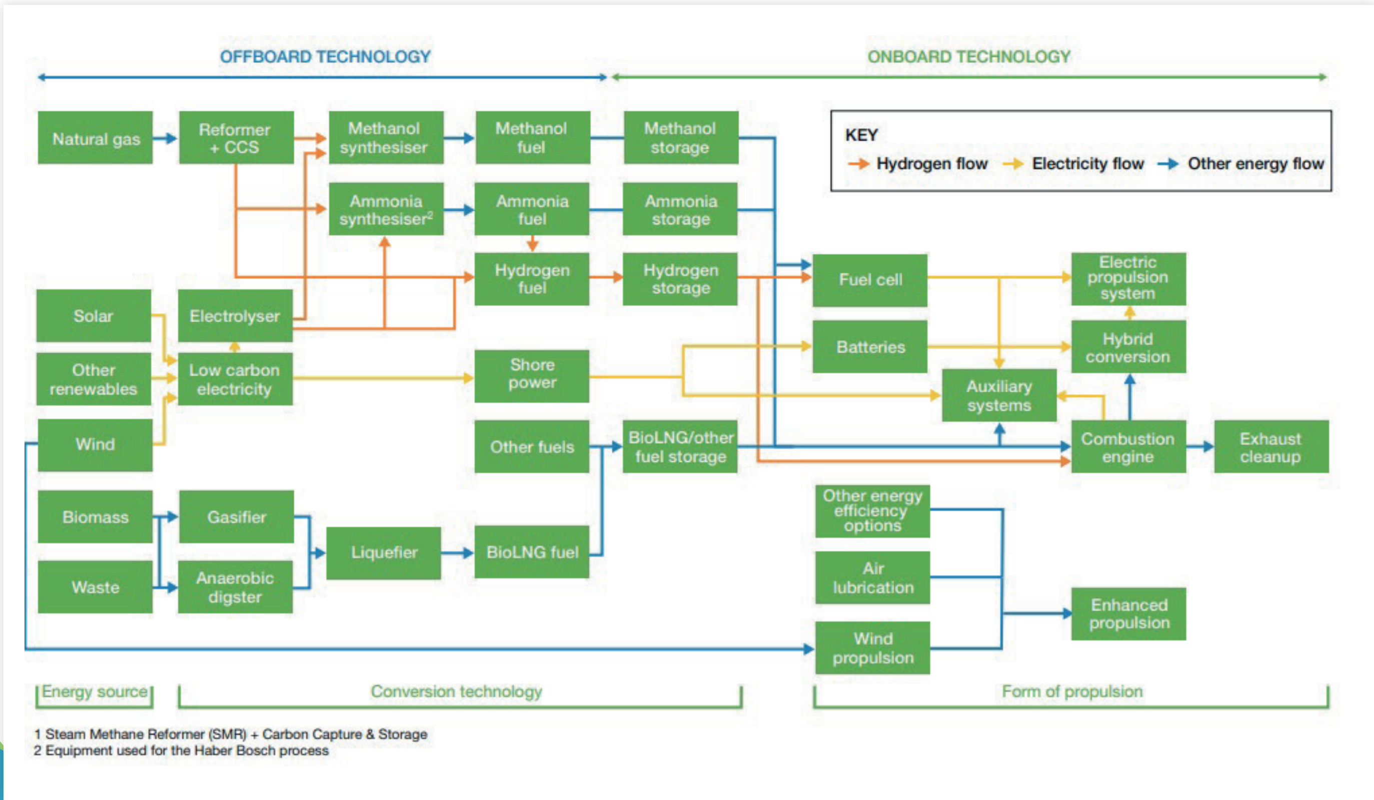

Figure 4: Technologies and fuels for zero-emission shipping [3]

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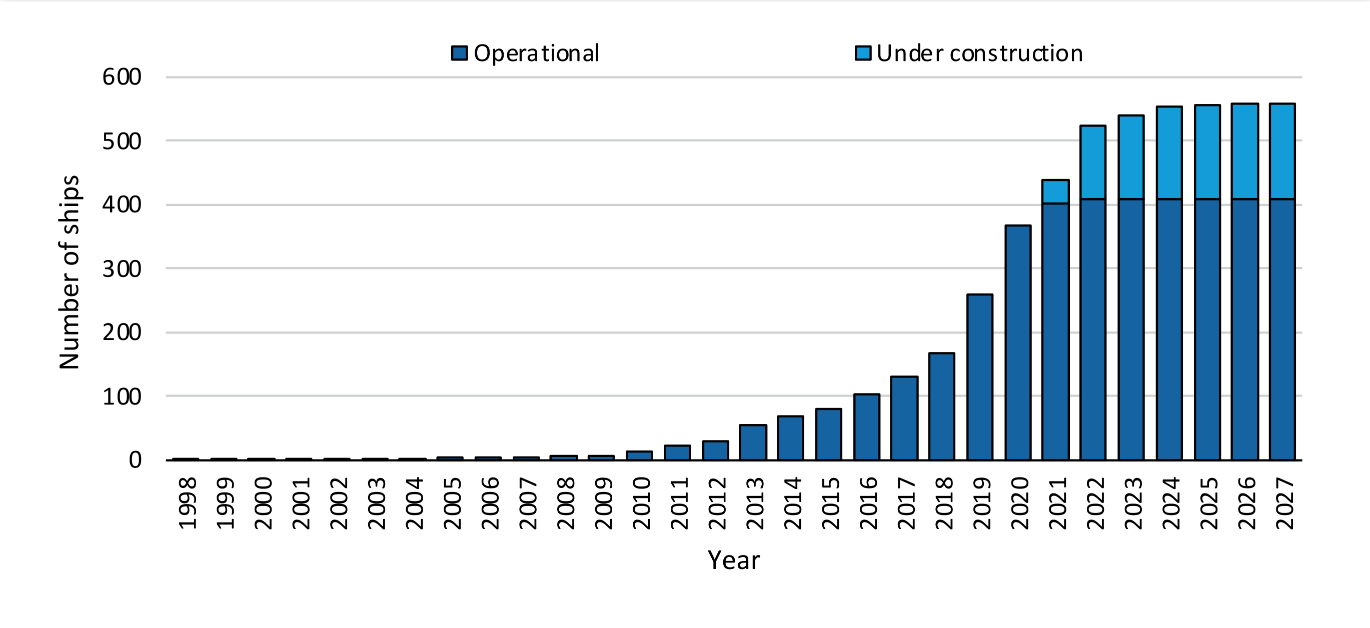

Figure 5: Number of Ships with Batteries [12]

The Maritime Battery Forum [11] (MBF) has been created to promote the use of batteries in shipping and off-shore applications. The forum provides updates on technology developments, and knowledge transfer on the technical and economic aspects of using battery technology in maritime applications. Since 2016, the MBF has maintained the Battery Ship Register to track ships (both planned and operational) using batteries either in a hybrid or pure electric propulsion system. Figure 5 shows the exponential increase in numbers of ships with batteries in recent years.

At the time of writing there were 410 ships with batteries in operation and a further 149 on order. These were evenly split between hybrid, and both plug-in hybrid and pure electric propulsion types combined, as shown by Figure 6:

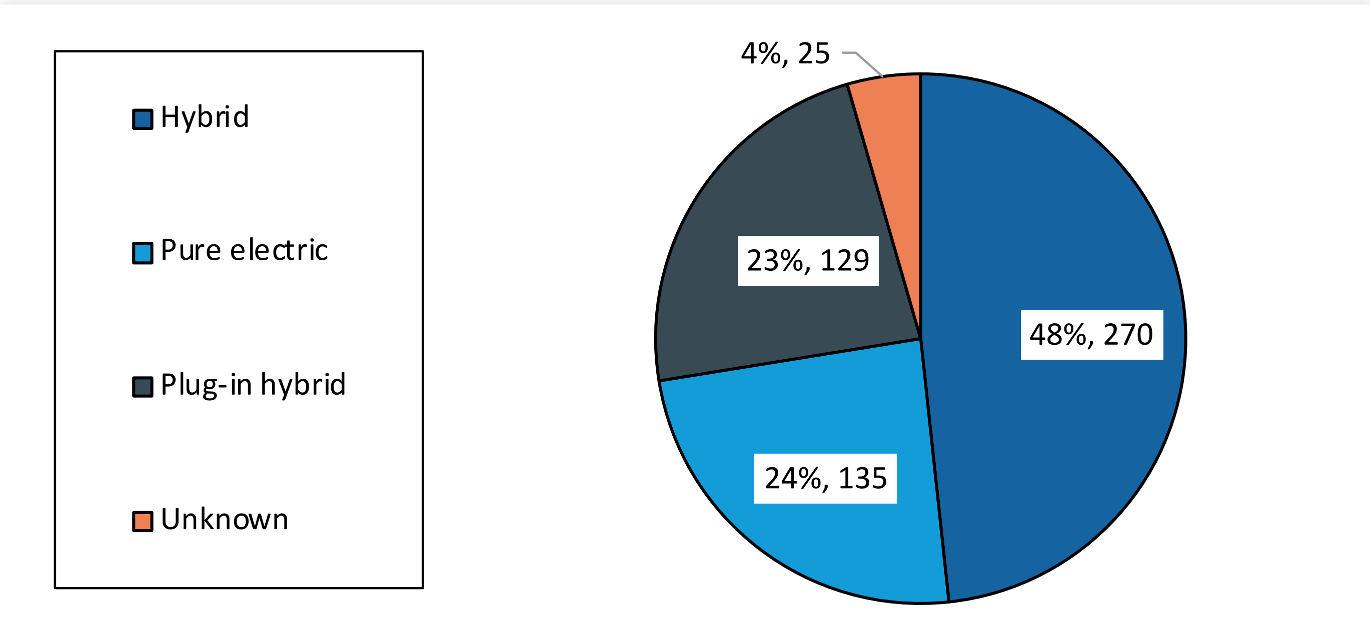

Figure 6: Battery Ship Propulsion System Type [12]

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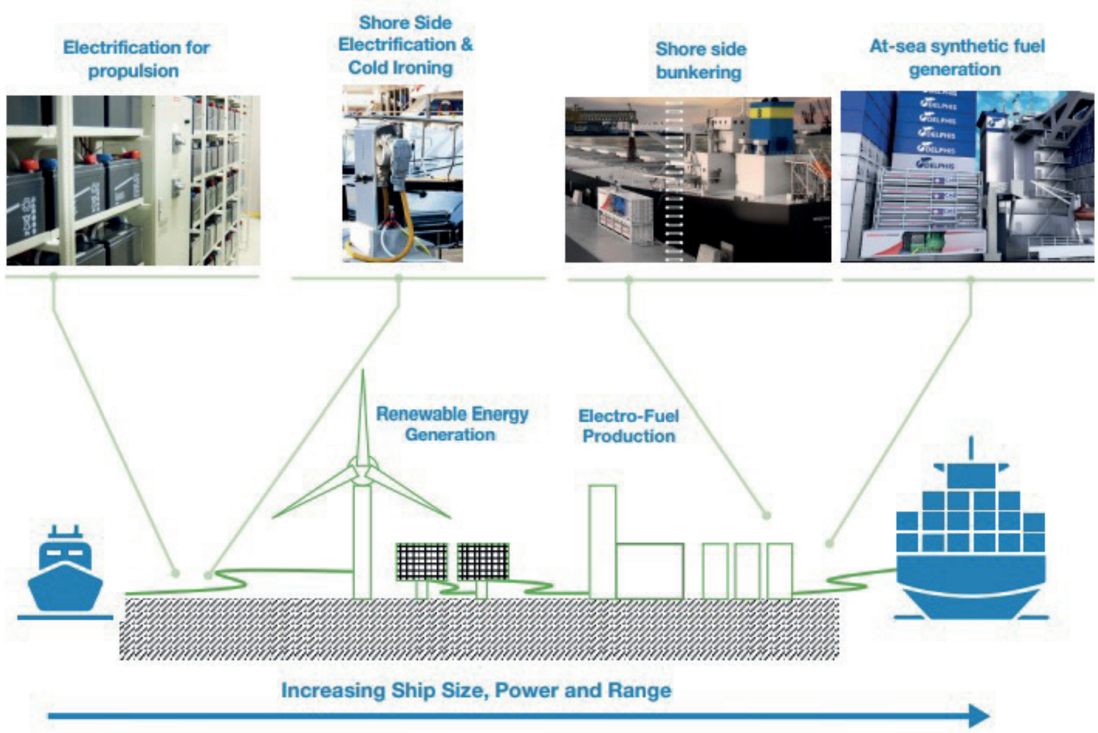
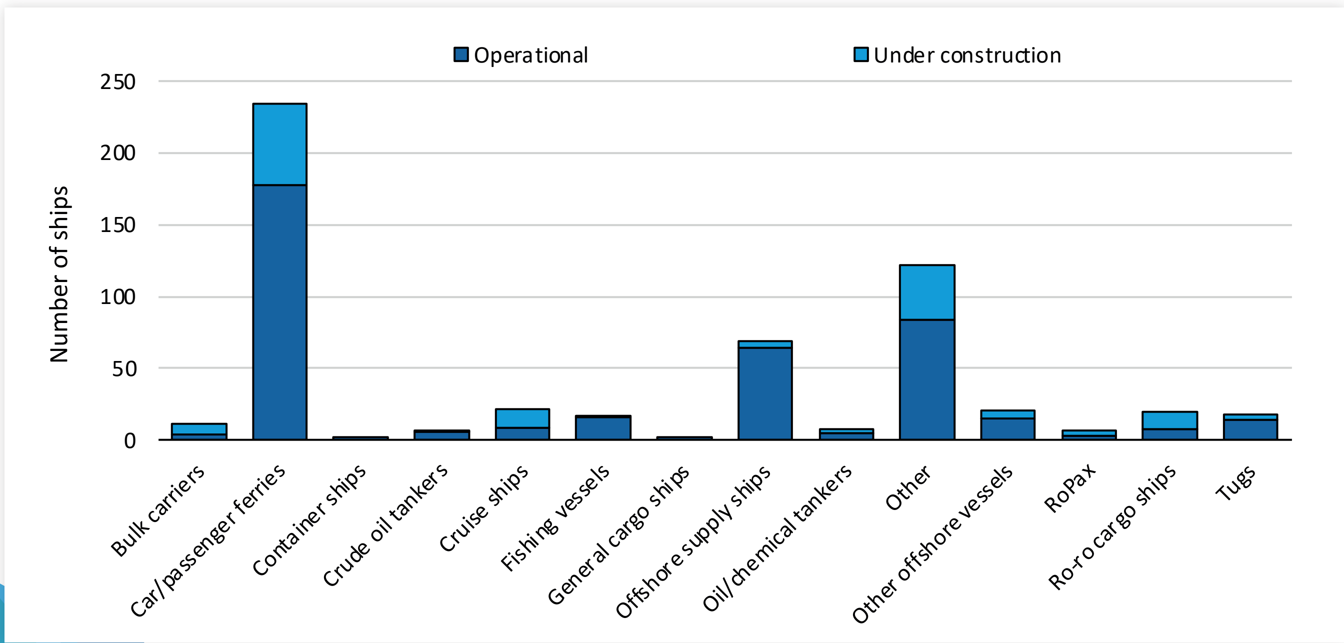
Figure 7: Landside infrastructure for a zero-emission maritime sector [3]



Pure-electric and plug-in hybrid electric propulsion systems (when operating in electric mode) create zero-emissions at the point of use. When charged with renewable electricity, battery propulsion is a fully zero-emission system during operation. The Clean Maritime Plan recognised the importance of, and opportunity for, electrification for smaller ship sizes with shorter ranges conducting near-shore operations, as shown in Figure 7.

The opportunity presented by battery propulsion in the maritime industry is already being demonstrated by the numbers of ships with batteries already in operation or under construction, as shown by Figure 8 grouped by vessel type.

Figure 8: Battery Ships by Category [12]



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The dominant vessel categories are:

1. **Car/passenger ferries (178 operational, 56 under construction, 234 total)**
Ferry operations typically include short, regular trips such as river crossings, channel crossing and island hopping. This point-to-point operation gives regular opportunity for batteries to be recharged (either fully or top-up charging), whilst the low speeds allowable for near-shore journeys made in and between ports and marinas mean that energy usage is often low enough for pure electric drivetrains to be viable.

2. **Other (84 operational, 38 under construction, 122 total)**
Within this other category there are leisure operations which may share similar types of usage with ferries – shorter journeys with regular charging opportunities. Hence this sector is already seeing significant numbers of boats with batteries.

3. **Offshore supply ships (64 operational, 5 under construction, 69 total)**
This sector bucks the trend somewhat in that these vessels are often much larger, however their operations to off-shore facilities (such as oil platforms or wind farms) are generally much shorter in comparison to long-range shipping activities. Electrified vessels in this category are more likely to be a form of hybrid technology due to the more energy intensive requirements of the operations.

Mirroring the road transport sector, Norway is leading the way for electric maritime with 38% of the world's electrified ships. The rest of Europe is the second largest market, although this is dominated by the Nordic region.

For the latest data on electrified vessels, refer to the Maritime Battery Forum's Ship Register (hosted by DNV-GL's Alternative Fuel Insight platform on behalf of MBF).

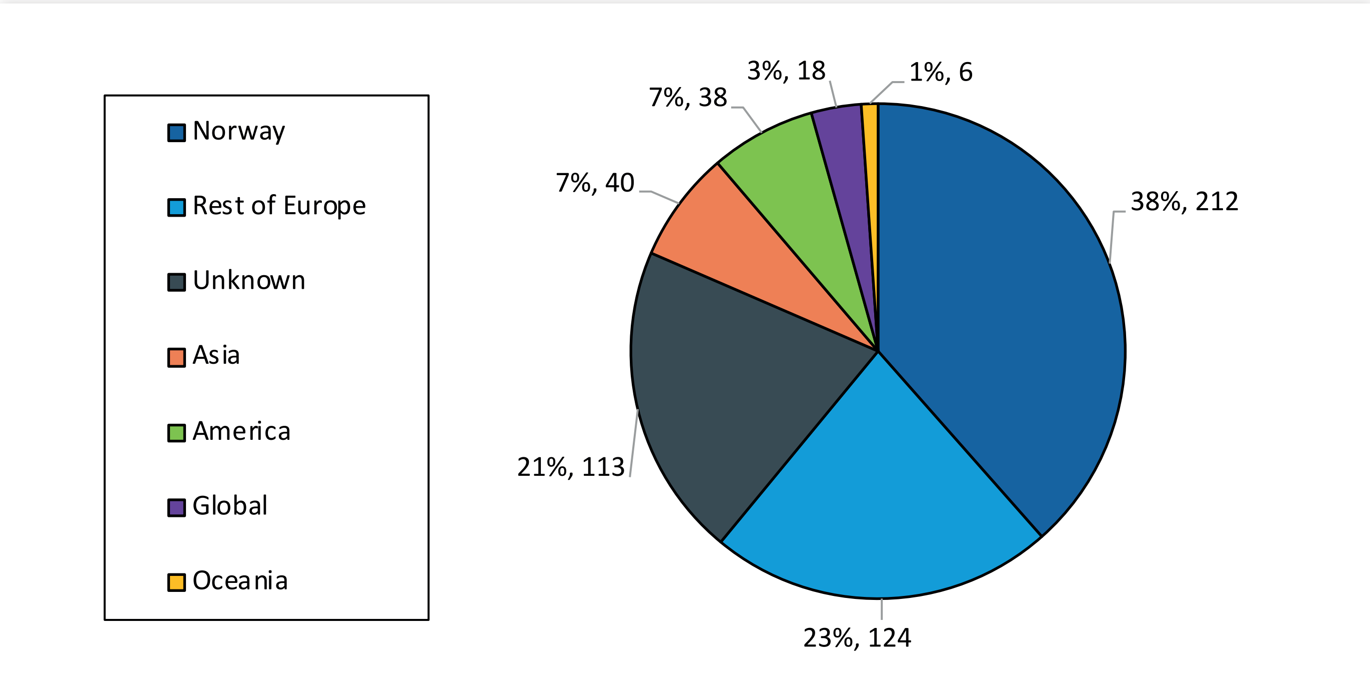

Figure 9: Electric Maritime Market by Area of Operation [12]

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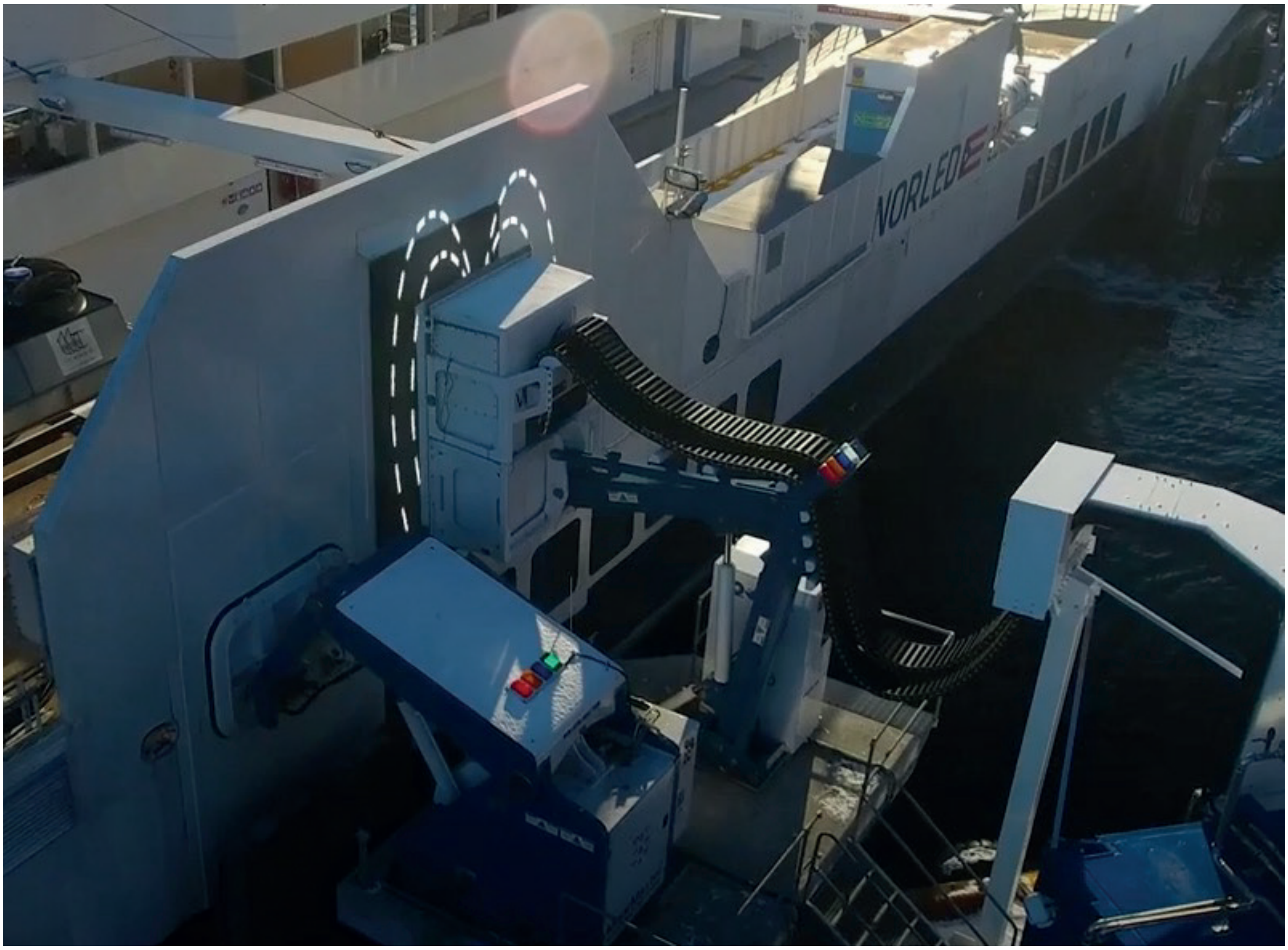
2.4 Charging Infrastructure

Clearly, for a plug-in hybrid or pure-electric ship to become a possibility, shore-side charging infrastructure is required. There are lessons that can be learnt from the automotive industry which, whilst still in the early-adopters phase, is more mature than the maritime industry. Whilst the automotive experience is relevant, there are additional requirements that are unique to electric ships that need to be considered if the technology is to be successful.

This paper has provided a background to the electric maritime industry. In the following document in the series, the current state of the maritime charging infrastructure will be explored in order to:

- Understand the key requirements that are placed on these charging systems; and
- Provide a single source of key information and make recommendations for the many stakeholders who will hold an interest in the technology. Stakeholders will include boat operators; chargepoint manufacturers and operators; local authorities; port and marina operators and policy makers.



3 The Opportunity for the City of Plymouth

The net-zero electrification of the maritime sector is underway. The first electric- passenger and car-ferry, The Ampere, launched in 2015 in Norway, which has 38% of the world's ships with batteries. This is perhaps unsurprising, given that Norway is also the world leader in Electric Vehicle sales - 64.5% of new passenger car sales were BEV in 2021 [13] [14]. This status was achieved as a result of multiple factors, perhaps most important of which is strong government incentives. In addition, Norway has a sizeable maritime industry, an energy system based upon renewable hydro-electric generation, and the world's second longest coastline by country.

The UK can list similar credentials; with 51 major ports including Plymouth providing the backbone to an island nation's maritime industry that is one of the world's largest. UK maritime supports 957,000 jobs and £37.4bn Gross Value Added contribution to the economy [15]. Plymouth, known as Britain's Ocean City, is not only a city with a rich maritime history, but is still a successful modern-day port. Plymouth's varied operations include international and local ferry services, freight shipping, cruise operations, military operations, private boating, and fishing. In addition, Plymouth hosts many companies and institutions involved with marine services, manufacturing, and research.

The E-Voyager

Plymouth is leading the way in the UK. The e-Voyager, designed and developed by Plymouth Boat Trips and Voyager Marine in partnership with University of Plymouth, University of Exeter, Teinbridge Propeller and EV Parts, became the UK's first electric sea-going ferry last year. A retro-fitted fully-electric vessel, the e-Voyager is planned to enter service with Plymouth Boat Trips as a passenger ferry. The e-Voyager will service local ferry operations in Plymouth's coastal waters and the Tamar estuary.

Analysis conducted by The University of Plymouth estimates that 5,500 vessels in the UK could be replaced or retrofitted with a pure-electric propulsion system.

The e-Voyager project was one of 10 funded by Maritime Research and Innovation UK's (MarRI-UK) £1.4 million Clean Maritime call, an initiative backed financially by the DfT. MarRI-UK is a new innovation institution with partners from academia and industry set up maritime technology challenges. Plymouth Boat Trips will use the learnings from the e-Voyager project as it progresses to electric conversions of larger vessels in fleet.

Figure 10: The e-Voyager - the UK's first sea-going electric ferry

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Figure 11 and Table 1 give details on Plymouth's five local ferry routes which are invaluable for the local community and leisure industry. However, all these routes currently are served by diesel powered vessels. There is an immediate opportunity for Plymouth City to exploit the experience gained from the e-Voyager to electrify its local ferry network.

The e-Voyager partnership is installing charging infrastructure that will support its zero emission operations. However, to electrify the remaining vessels in the local network, and lead the way for other ships in the city to do the same, a more comprehensive charging infrastructure network will be required. The requirements and case studies provided in the next paper in this series should be used to guide the deployment of this network and lead by example in the UK.

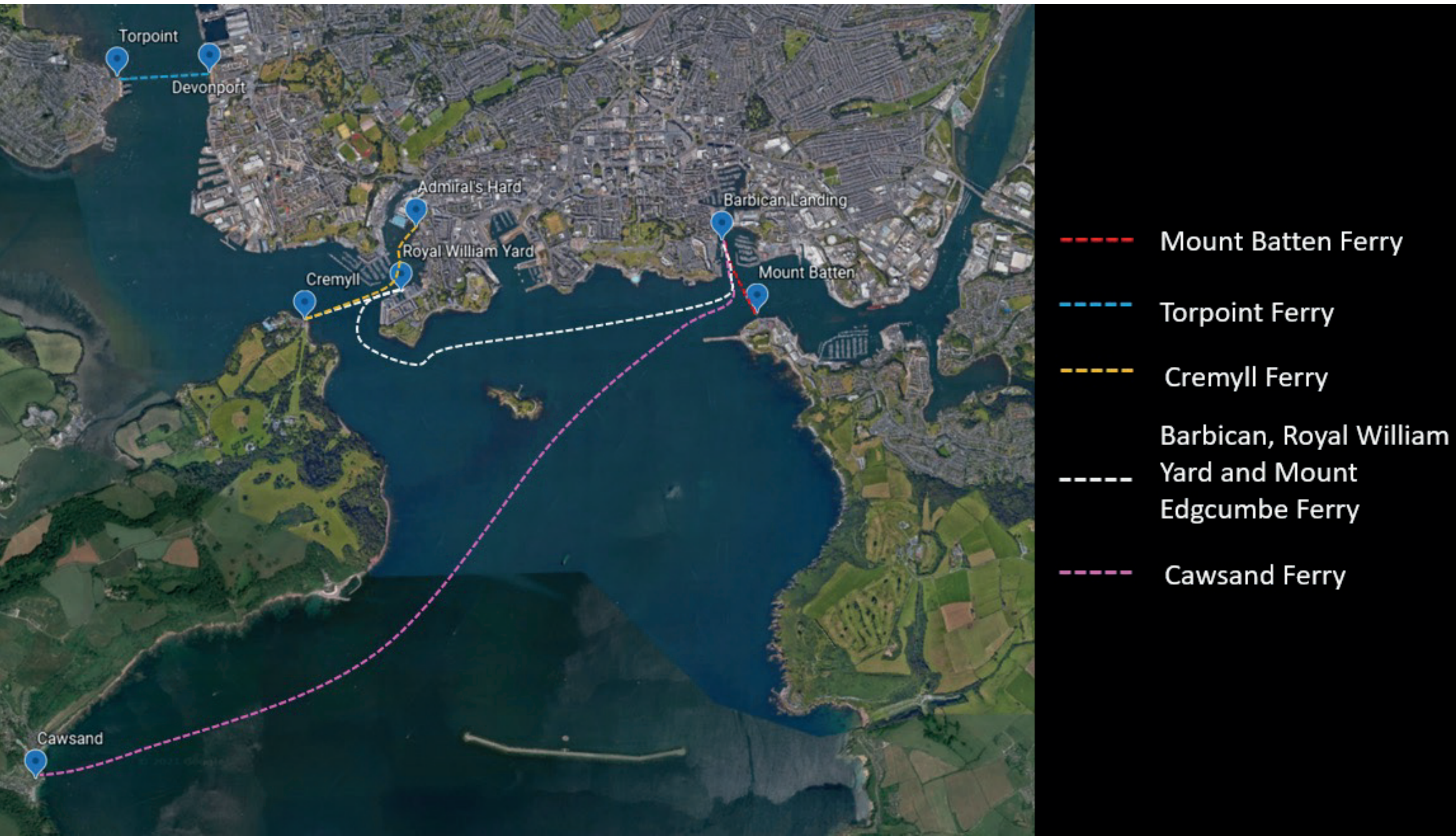

Figure 11: Plymouth Local Ferry Routes

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	ROUTE	PURPOSE	VESSEL(S)	TIMETABLE	OPERATOR(S)
Mount Batten Ferry	Barbican Landing (Plymouth) to Mount Batten, approximately 500 m in 5 minutes	Pedestrians, bicycles	3 vessels – one 120 passenger; two 12 passenger	Every 30 minutes	Universal Marine Ltd
Torpoint Ferry	Devonport (Plymouth) to Torpoint (Cornwall), up to 650 m in 6 minutes	Car, pedestrians, bicycles	3 x diesel-electric, 73 m length car ferries with max capacity of 73 cars	24-hour service, up to 10 minute frequency at peak times	Tamar Bridge & Torpoint Ferry Joint Committee (Plymouth City Council & Cornwall County Council)
Cremyll Ferry	Admiral's Hard (Plymouth) to Cremyll (Cornwall), approximately 1100 m in 8 minutes	Pedestrians, bicycles, packages	Unknown	Approximately every 30 minutes, first and last ferries vary with season	Plymouth Boat Trips
Barbican, Royal William Yard & Mount Edgcumbe Ferry	Barbican Landing (Plymouth) to beach, approximately TBC	Pedestrians	Unknown	Summer service – daily every 90 minutes	Plymouth Boat Trips
Cawsand Ferry	Barbican Landing (Plymouth) to Mount Edgcumbe via Royal William Yard, approximately TBC	Pedestrians	Unknown	Summer service – daily every 90 minutes	Plymouth Boat Trips

Table 1: Plymouth Local Ferry Routes

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5 About the Author

Cenex was established as the UK's first Centre of Excellence for Low Carbon and Fuel Cell technologies in 2005.

Today, Cenex focuses on low emission transport & associated energy infrastructure and operates as an independent, not-for-profit research technology organisation (RTO) and consultancy, specialising in the project delivery, innovation support and market development.

We also organise Cenex-LCV, the UK's premier low carbon vehicle event, to showcase the latest technology and innovation in the industry.

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