Clean Maritime Demonstration Competition

Funded by UK Government

Department for Transport

Innovate UK

Round 2: project overview

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Foreword

Decarbonisation of our transport system is critical to the UK reaching Net Zero. This includes reducing the impact of shipping on the environment.

That is why the Department for Transport (DfT) is supporting the decarbonisation of our maritime sector through its research and development programme called the UK Shipping Office for Reducing Emissions (UK SHORE). Innovate UK and DfT are working together to kickstart R&D into maritime environmental innovation, and will continue to develop learnings, evaluation and proposals to meet long-term growth and decarbonisation goals. The UK SHORE programme is supporting the development and acceleration of clean maritime solutions through the Technology Readiness Level (TRL) pipeline towards market-readiness.

The Clean Maritime Demonstration Competition (CMDC) is part of the UK SHORE programme and provides match-funding for the design and development of clean maritime solutions towards commercialisation. To support the decarbonisation of the UK maritime sector and ports, DfT has awarded £130m in grant funding across five rounds of the CMDC to innovative projects since March 2021.

The second round of the CMDC (CMDC2) awarded £12m to 31 projects to undertake feasibility studies and pre-deployment trials between January 2023 and August 2023. Through UK SHORE, DfT has funded a vast range of projects, and this brochure outlines what each of them have achieved.

Many of these projects have gone on to develop their technology further, including through CMDC3, CMDC4 and the £80m Zero Emission Vessels and Infrastructure (ZEVI) competition. CMDC2 also featured three green corridor feasibility study projects. These pioneering studies have built the foundation for the establishment of green shipping lanes between the UK and its European neighbours, delivering on our commitments in the Clydebank Declaration.

I would like to thank all the organisations involved in CMDC2 for their innovation and dedication to delivering these groundbreaking projects at pace. I look forward to seeing these clean maritime technologies develop further over the coming years, as they help to make our sector sustainable for years to come.

Lola Fadina
Director, Maritime,
Department for Transport

Department for Transport

Introduction

With the development of cutting-edge technologies and innovations, the UK is pioneering the global movement to decarbonise shipping and deliver net zero emissions.

The Department for Transport Clean Maritime Demonstration Competition (CMDC) is a critical driving force for this effort. The projects involved not only have the potential to reduce greenhouse gas emissions, but to boost jobs in coastal communities and drive long-term economic growth for the UK.

Building on the success of the previous round, CMDC Round 2 supported the feasibility studies and pre-deployment trials of 31 clean maritime solutions. The competition was launched in May 2022 and ended in August 2023, with £12 million allocated in funding.

The winning projects focused on one or more of the following themes:

- Prioritised technology, such as the safe onboard storage of hydrogen and ammonia, development of green shipping corridors, and whole-ship energy efficiency designs
- On-vessel low and zero-emission technologies, such as vessel propulsion and auxiliary engines
- Port and shoreside (including offshore solutions), such as shoreside low and zero-carbon fuelling, and charging infrastructure and management

Despite the scope and complexity of these projects, the results are impressive. With the support of the competition, many have moved onto the next phase of real-world demonstration and commercialisation.

"Without Innovate UK, it would have been impossible to get to where we've got to. The funding is fantastic and it's a very visionary programme."

Paul Cairns, CMDC participant and managing director of MJR Controls

Several of the projects from CMDC Round 2 have also progressed to the third and fourth rounds of the CMDC. The third round launched in September 2022 and ends in March 2025; the fourth round launched in July 2023 and also ends in March 2025.

To achieve the goal of reaching net zero by 2050 the next decade will be decisive. Developing green infrastructure and fuels and continuing to decarbonise the sector will help to reinforce the UK maritime industry as one of the strongest and most competitive worldwide.

The Clean Maritime Demonstration Competition is funded by the Department for Transport and delivered by Innovate UK.

Numbers at a glance

number of projects funded under CMDC Rounds 1-4

138

amount of funding for CMDC Rounds 1-4

£128m

% of UK trade by volume moved by sea

95%

£ contributed by ports to the UK economy each year

7.5bn

% of world's total CO2 emissions contributed by the shipping industry

2.5%

Impact

Decarbonising maritime is essential to achieve net zero in the UK by 2050.

Transport is the largest emitting sector in the UK, accounting for 29.1% of greenhouse gas emissions. Urgent action is needed to transition the shipping industry to zero emissions and fight climate change.

Many of the promising solutions needed to decarbonise the maritime sector are now reaching the demonstration stage. From hydrogen-powered vessels to offshore charging systems, these innovations have the potential to accelerate decarbonisation – but we need to increase the pace of deployment to enable significant fleet-wide changes in the 2030s.

Government support is required to drive this effort forward. It unlocks vital investment and new funding routes, but also provides the guidance, network and platform for these projects to succeed.

The Clean Maritime Demonstration Competition shows the impact of this investment, enabling projects to test new technologies in a safe environment, make valuable connections and move a step closer to achieving ambitious net zero goals.

"Government intervention and funding sends such a clear message – it's a vote of confidence. It helps us to build the reputation and credibility that we're worth investing in, and recognises that we have the capability to help decarbonise and reach those targets. It's that confidence that organisations like us need in the early days."

Rachel Edwards, Head of PR and Communications at Artemis Technologies. After participating in CMDC2, the business is getting ready to scale and plans to export their product globally.

Feedback on CMDC2

"Our progress with material testing wouldn't have been possible without this funding. That's the bottom line."

"CMDC taught us that this was the area we have the most potential to do something different."

"CMDC has been a game changer for us. We've trained new people, got new premises, and got that confidence to go ahead."

"We couldn't have done it without CMDC. Innovate UK have been extremely helpful right from the start."

"The CMDC has been the catalyst for pioneering research and development across the maritime sector. The impact of the CMDC programme has been felt across the entire UK"

"It was a big opportunity for us to start projects we wouldn't have otherwise, and to develop our team."

"Without Innovate UK, it would have been impossible to get to where we've got to."

"CMDC has accelerated our ambitious net zero goals. We wouldn't be where we are without the commitment and support from the funding."

Case Studies:

Vessel Projects

Building a clean powertrain for commercial shipping

Lead: Ecomar Propulsion

Partners: O.S. Energy (UK) Limited, University of Exeter

This project sought to deliver a fully integrated one-megawatt electrical propulsion system for use by commercial marine operators. The system is powered by batteries and hydrogen fuel cells, and is aimed at scalable solutions that can be rapidly installed in new and existing vessels.

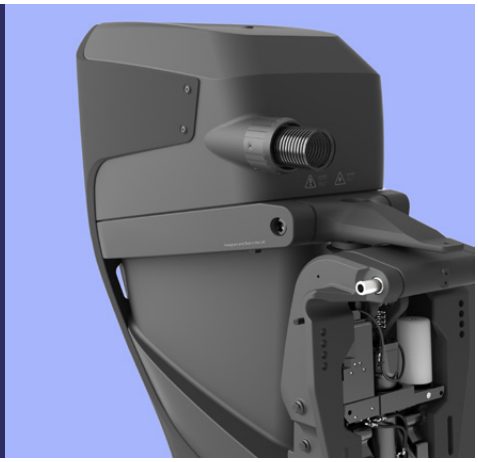
The project aimed to discover new control strategies which can be incorporated into a sophisticated new electronics package and to deliver a new prime mover and energy system which is lighter, more energy dense and easy to install.

It has led to innovations in use of transverse flux and axial flux technologies, and enabled Ecomar to expand their capabilities beyond just propulsion technologies and investigate a full hydrogen-powered system.

> CMDC has been a game changer for us. We've trained new people, got new premises, and got that confidence to go ahead."
>
> Eugene Bari, Founder and CEO of Ecomar Propulsion

The next steps

Ecomar Propulsion will use the new system for further validation and development of advanced electronics. A type-approved product based on the axial flux design will be prepared for installation, and put into production if approved.



Designing a hydrogen-powered uncrewed surface vessel

Lead: SEA-KIT International

Partners: Bramble Energy

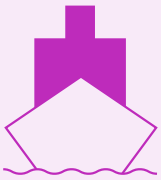
The objective of this project was to build on work completed in CMDC1, which proved that hydrogen could be used to power uncrewed surface vessels, by using novel printed circuit board fuel cell (PCBFC) technology.

This project focused on meeting regulatory requirements, as well as specific operational capabilities to ensure it would fit wider market demand. A key achievement was an Approval in Principle from classification society Lloyd's Register, for both the fuel cell system and uncrewed surface vessel.

Overall, the project was successful with all objectives fulfilled. The team made the effective decision to engage Lloyd's Register early, which enabled them to fully understand its rulesets and align project deliverables to fit.

The UK has set a target of reducing greenhouse gas emissions from shipping by **at least 50% by 2050.**

(Source: https://gtr.ukri.org/projects?ref=10040059)



The next steps

SEA-KIT have since secured Zero Emission Vessels and Infrastructure (ZEVI) funding. This will enable them to progress with the build of the uncrewed surface vessel design, and move through the next operational stages to prepare for commercial readiness.

Designing a prototype of a liquid hydrogen powertrain

Lead: ACUA Ocean

Partners: Krensen, Trident Marine Electrical Ltd

ACUA Ocean successfully developed and tested a non-commercial low voltage concept powertrain system in CMDC1 Strand 2.

Since then, multiple companies have shown interest in procuring a hydrogen powertrain system.

This project focused on designing and manufacturing a prototype of a liquid hydrogen powertrain solution that could be used across recreational and commercial vessels. The study involved the live testing of hydrogen and electrical systems working in conjunction with automated safety mechanisms, as well as a market assessment of the commercial opportunities available.

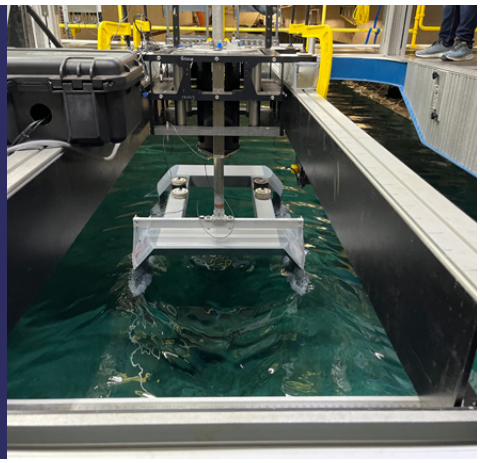
The powertrain was successfully assembled and tested as part of the project, with the Factory Acceptance Test proving electrical fast-charge of a 63kWh battery pack from shore using a combined charging system connector up to 20kW.

The global recreational boat sector was valued at **$29bn in 2022.**

(Source: https://gtr.ukri.org/projects?ref=10040008)

The next steps

The powertrain system will be retrofitted into ACUA Ocean's H-USV design, which is being prototyped as part of CMDC 3. The prototype will progress the technology up to TRL8, with the aim of achieving MCA certification to operate and full design approval from classification society Lloyd's Register.



Designing hydrogen fuel cell systems for electric foiling vessels

Lead: Artemis Technologies

Partners: University of Ulster, Lloyd's Register EMEA, Energia Hydrogen Limited

Currently, compact high-power density marinised fuel cell systems are not available for small to midsize commercial vessels. There are significant barriers to entry, such as complications with safe hydrogen storage.

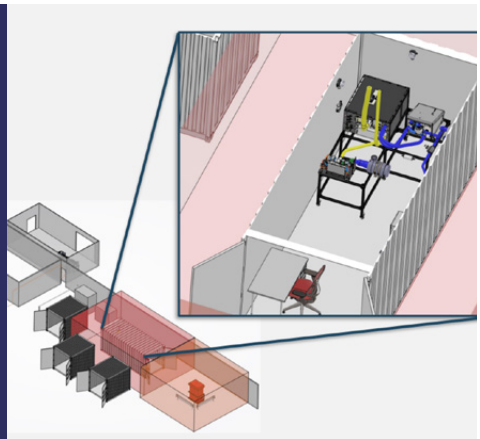
The project aimed to determine if it was technically and economically viable to incorporate a hydrogen fuel cell range into Artemis Technologies' eFoiler vessels. This included designing and building a bench test version of the proposed hydrogen fuel cell range extender, which allowed the team to perform tests in a controlled environment and simulate real-world duty cycles.

After successful execution of the project, the hydrogen fuel cell range extender solution has been deemed viable.

> CMDC provides a safe space to try out these types of technologies and test the water, literally. It gives us that sandbox and the opportunity to learn fast."
>
> Rachel Edwards, Head of PR and Communications at Artemis Technologies

The next steps

A real-world demonstration of a hydrogen fuel cell range extender fitted to an eFoiler vessel, which will prove the capability of the range extender and validate the bench testing carried out in the project.



The novel engine using ammonia as zero-carbon fuel

Lead: Osprey Research

Partners: Lapwing Technology LTD, Stuart Group Limited

Electric engines are growing in popularity, but a limited number of vessels can be 100% electric. An alternative, zero-carbon solution is needed for marine and other off-highway applications.

The solution is likely to be a combustion engine that uses hydrogen as fuel, but the volume and form that hydrogen would need to take doesn't currently exist.

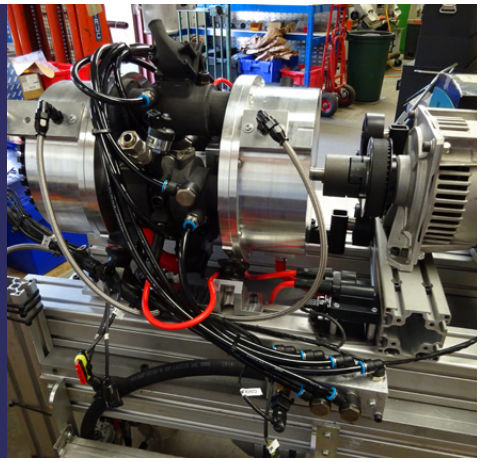
This project explored the feasibility of ammonia as a zero-carbon fuel, which unusually contains more hydrogen than hydrogen itself. In addition to testing how to burn ammonia, CMDC Round Two enabled Osprey to explore a radical new engine type that would be more compatible with the way that ammonia burns. The engine would feature low-friction elements to increase its efficiency, as well as features that would reflect the low flame speed of ammonia.

The project successfully demonstrated the potential of this new engine type for burning ammonia, and has attracted interest in the creation of a bigger engine.

> Running out of battery on the M1 is just embarrassing. Running out of battery in the middle of the North Sea is fatal."
>
> Andrew Barnes, Director at Osprey Engines

The next steps

Now embarking on a CMDC Round 4 project, Osprey Research hopes to develop a demonstrator engine that runs on ammonia, and work with a customer to install it into a vessel.



An innovative solution to decarbonise CTV operations

Lead: Artemis Technologies

Partners: Tidal Transit Limited, Offshore Renewable Energy Catapult, Lloyd's Register EMEA

There are over 370 high-speed crew transfer vessels (CTVs) operating in UK and European waters today, which emit around 1,278 tonnes of carbon dioxide equivalent each year.

These emissions are set to increase significantly, with an estimated 1,687 CTVs required by 2050 to service European market growth.

Artemis Technologies is developing an electric propulsion system called the 'Artemis-eFoiler'. It integrates a high-power density electric drivetrain into an autonomously controlled hydrofoil. As an eFoiler vessel accelerates, the hydrofoils lift the hull out of the water, reducing drag and improving speed and efficiency.

In CMDC Round 1, the project partners determined that an eFoiler-CTV was not only technically feasible but offered major environmental and performance benefits. In Round 2, the aim was to bring together partners from across the whole supply chain to accelerate the detailed design and engineering of a 24m eFoiler-CTV.

> One of the things that I liked about CMDC was that the journey from feasibility to detailed design and demonstration was really, really well thought out."
>
> Katrina Thompson, Programme Director at Artemis Technologies

The next steps

After a successful project, the next key milestone for Artemis Technologies is to get the eFoiler 24 ferry on the water. A technology demonstration is planned to run from Bangor to Belfast and Northern Ireland.

Developing an ultra-efficient, zero-emission electric powerboat

Lead: Optima Projects

Partners: RAD Propulsion, Fawley Waterside and Red Funnel

Electric boats have a wide range of applications in both the leisure and commercial markets.

Optima has developed an ultra-efficient hull that significantly reduces energy consumption. It allows boats to achieve a greater range under battery power, whilst still providing a top speed of 20 knots or more.

This project enabled Optima to take their hull concept and integrate it with a clean, steerable electric drive design, both of which had been produced in CMDC1. These would be tested against regulatory compliance standards to take them closer to commercial realisation. The team also planned to develop designs for a 12m leisure/commercial variant of the vessel.

The project successfully got Optima's design on the water, moving the vessel and its supporting electric propulsion systems considerably closer to commercial realisation.

> Our progress with material testing wouldn't have been possible without this funding. That's the bottom line."
>
> Chloe Kendall, Director and Co-Founder of Optima Electric Yachts

The next steps

The Optima e10 boat with the newly fitted RAD40 drive system will undertake endurance trials to verify its long-range capabilities. The team hopes to be taking pre-orders for vessels by the end of 2024, having already received expressions of interest.

De-risking the supply of high-efficiency hydrogen engines

Lead: Carnot Engines

Partners: Carisbrooke Shipping Ltd, University of Strathclyde, Innovate UK, University of Southampton

Mitigating and solving man-made climate change has fast become a social necessity.

This feasibility study focused on de-risking the next steps in supplying a high-efficiency hydrogen engine to the marine sector. The study also explored the design for a novel, thermally insulated combustion engine, including the fuel system and design consideration for the use of hydrogen as a fuel.

The project made impressive strides forward, showing how the technology could be applied to the marine sector and where there's potential for commercialisation from a design and regulatory perspective.

A shift to a hydrogen economy is underway with the UK Government committing to a **£240 million** investment in a Net Zero Hydrogen Fund.

(Source: https://gtr.ukri.org/projects?ref=10041177)

The next steps

The team is already working on a CMDC Round 3 project to demonstrate the technology in a deck-mounted containerised auxiliary power plant. It will also be the first test of using hydrogen in the engine as a fuel and achieving compliance (for a 40-day trial) of the technology in a marine application.

Identifying sub-24m vessel green fuels of the future

Lead: MAHLE Powertrain

Partners: Clean Air Power GT Limited, University of Nottingham, RNLI, Royal National Lifeboat Institution

This project sought to establish options for the RNLI to decarbonise its fleet of rescue vessels. Data analysis and simulations were used to understand which zero emission technologies are suitable for the RNLI and, by extension, the wider sub-24-metre category.

The project also aimed to research the benefits of MAHLE Jet Ignition in reducing emissions and increasing efficiency of hydrogen-based internal combustion engines.

The study established the usage patterns of the RNLI fleet to identify which green fuels would provide sufficient range. This data and advanced simulations highlighted the importance of methanol and ammonia in decarbonising this category, as the results showed engines run on pure hydrogen have too limited a range for use in rescue operations.

> CMDC taught us that this was the area we have the most potential to do something different"
>
> Jonathan Hall, Chief Engineer for Research and Advanced Engineering at MAHLE Powertrain

The next steps

MAHLE Powertrain will collaborate with connections made through CMDC to develop these combustion techniques further, working towards a complete ammonia-fuelled system for marine vessels. Demonstrations to interested end-user customers are in the pipeline.

Testing the feasibility of a 100% electric foiling pilot vessel

Lead: Artemis Technologies Ltd

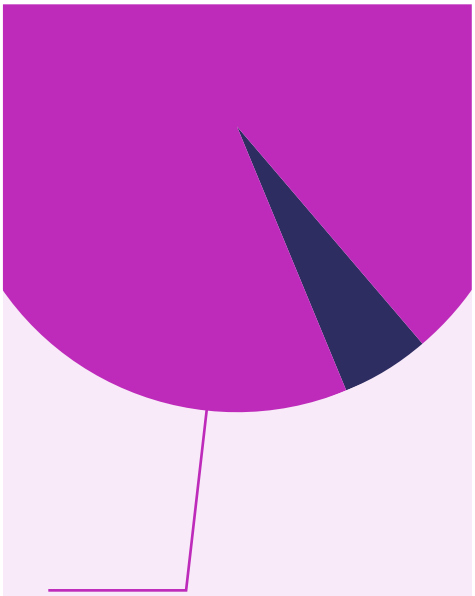
Partners: Belfast Harbour Commissioners

The UK is heavily dependent on sea trade. Maritime pilots play a key role in keeping essential ships moving safely, while experienced pilotage is also vital for preventing damage to national infrastructure and the environment.

As the need for maritime pilots expands, the effort to decarbonise pilot vessels is also accelerating.

This project aimed to test whether a 100% electric foiling pilot vessel (the 'eFoiler-Pilot') was a technically and economically viable solution for pilotage. By collecting data and conducting research into pilot vessel design, requirements and specification, the team could develop a concept design and analyse its performance against real-world duty cycles.

The project was successful and the eFoiler-Pilot concept has been deemed capable of performing pilotage applications in this port.



95%

of UK trade by volume is moved by sea

(source: https://gtr.ukri.org/projects?ref=10041953)

The next steps

A real-world demonstration of a purpose-built eFoiler-Pilot performing pilotage operations in an active port. This will address primary barriers to adoption and validate the simulations and modelling of this study.

Creating a hydrogen-fuelled hovercraft propulsion system

Lead: Blue Bear Systems Research

Partners: GreenJets Limited, Aquatera Limited, Nyobolt Limited, Bamble Energy Limited, The European Marine Energy Centre Limited, Griffon Hoverwork Limited

ZEHPHyr1, Zero Emission Hydrogen Powered Hovercraft, is an 8-month feasibility study seeking to de-risk the main barriers to zero-emission hovercraft operations.

In addition to operational factors, these barriers include the existing technical limitations of hydrogen-based propulsion systems, and the lack of hydrogen infrastructure availability, such as methods to produce, store and distribute the fuel.

The central innovation in this project is replacing the existing diesel engines of today's hovercraft with a zero-emission hydrogen propulsion system to overcome some of these barriers.

There is currently no liquid hydrogen production in the UK, presenting a huge economic and logistical challenge for clean fuel adoption.

(Source: https://gtr.ukri.org/projects?ref=10040672)

The next steps

The next stage of development will see the novel propulsion system demonstrated on 12-seat and 80-seat hovercraft. The project is also expected to enable the commercialisation of spillover products, such as MW class fuel cells for use in other marine vessels, and electric thrusters with applications in other industries like aerospace.

Seakeeping, cost and GHG efficiency of <24m SWATH design for ROV deployment

Lead: ACUA Ocean

Partners: University of Southampton

Offshore wind farm subsea inspections are critical to infrastructure. Subsea inspections require launch and recovery of remote operated vehicles (ROVs), of which current models are inefficient and responsible for significant diesel consumption.

This project undertook testing of the smaller, more efficient, hydrogen-powered ACUA Ocean SWATH vessel design and concluded that it was capable of conducting the same operations, in significantly higher seastates.

This proved the feasibility of deploying the vessel for use in offshore inspections, and actually demonstrated that the vessel can expand the operational capacity of maintenance fleets.

> The CMDC has been the catalyst for pioneering research and development across the maritime sector. The impact of the CMDC programme has been felt across the entire UK”
>
> Michael Tinmouth, Co-founder and COO of ACUA Ocean

The next steps

ACUA Ocean are now hoping to capitalise on the progress made and advance to a detailed design of the launch and recovery system under a prospective CMDC 4 application. ACUA Ocean are seeking additional design and R&D funding in order to bring the solution to market with significant commercial interest in place for demonstrations in Q3 2025.

Converting inland marine engines to run on hydrogen

Lead: E.P. Barrus

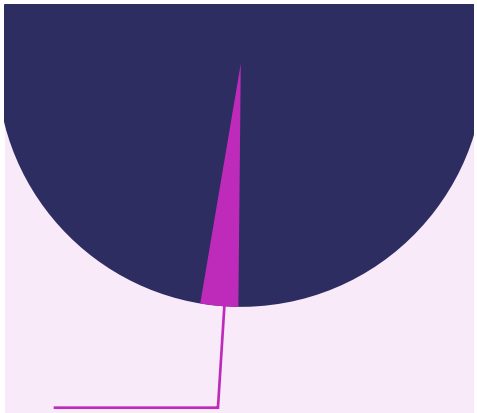
Partners: Brunel University London, Borgwarner Technologies Ltd, General Engine Management Systems Ltd, Innovate UK

Hydrogen is one of the most promising fuels for decarbonising the marine sector. Its combustion produces zero carbon emissions, and it has the potential for domestic off-grid production.

The quickest and most economical way to switch to hydrogen as a marine fuel would be to convert existing diesel engines to run on hydrogen. This project aimed to examine a cost-effective way of conducting these modifications.

The study first established a base level understanding of hydrogen combustion, by running tests on single-cylinder engines and extrapolating the test data to multi-cylinder platforms.

The results were promising, with only minimal adjustments to the original design of vessel engines needed.



2.5%

The marine sector contributes to 940 million tonnes of CO2 per year, equating to roughly **2.5%** of global greenhouse gases.

(Source: https://gtr.ukri.org/projects?ref=10040621)

The next steps

Currently, the modifications would only be suitable for fixed-load applications such as generators. Further testing is now needed to prove that the load required for a typical inland vessel's engine falls within the same bracket.

Developing eco-friendly small vessels using efficient design and clean fuel

Lead: O.S. Energy (UK) Ltd

Partners: Newcastle Marine Services Ltd, University of Strathclyde, Chartwell Marine Ltd, Cedar Marine Limited, Solis Marine Engineering Limited, University of Exeter, Harland and Wolff (Appledore) Limited, Ecomar Propulsion Ltd

Developing environmentally friendly vessels means making current models as energy efficient as possible, and compatible with clean and effective alternative fuels.

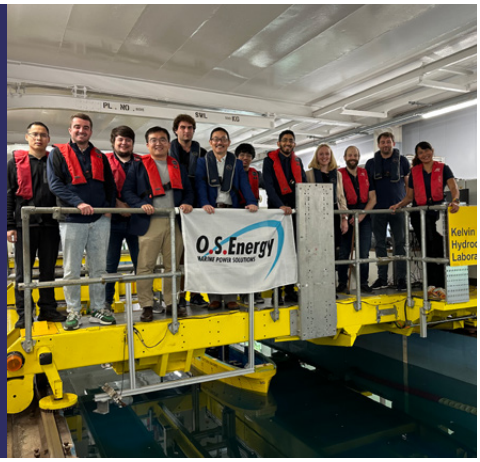
This project aimed to design an energy-efficient offshore support and research vessel (OSRV) that can run on cleaner fuel. This involved two initiatives: to improve the design of the existing fleet for greater energy efficiency, and to replace the marine diesel currently used with an alternative fuel – with the ultimate goal of designing and manufacturing new vessels which operate using these advancements.

The project sought to solve the current challenge of finding alternative fuels with enough energy per unit of storage to power not just small OSRVs, but large container and cruise ships, too. There is an opportunity for fuel developers to test their concepts on these OSRVs before scaling up to larger engines.

> I'm full of good words about CMDC. It was a big opportunity for us to start projects we wouldn't have otherwise, and to develop our team."
>
> Martin Nuernberg, Director at O.S. Energy

The next steps

Enabled by CMDC funding, energy-efficient propeller models are now in testing and retrofit, while investigation is underway for a hydrogen storage system to use green electricity.



Converting existing vessels to sustainable power

Lead: R3Energise Ltd

Partners: Chartwell Marine Ltd, Newcastle Marine Services Ltd

Building new vessels is carbon-intensive and costly, so the ability to re-energise existing vessels will provide a cleaner and more economically viable path to decarbonisation.

This project sought to demonstrate the feasibility of the first re-energised crew transfer vessel (CTV) for UK offshore renewable energy farms.

With the funding, the consortium developed a model to assess the technology options available and what would be required to re-fit an existing vessel with zero-emission technology. It was able to select and engineer effective equipment to completely decarbonise existing CTVs, preventing them from being scrapped.

Decarbonising the marine sector will rely on **converting existing tonnage to sustainable power.**

(Source: https://gtr.ukri.org/projects?ref=10042373)

The next steps

Apply the lessons learned to bring to market the product of re-energising existing tonnage.

Pioneering wind propulsion to cut fuel use and emissions

Lead: GT Wings Limited

Partners: The Manufacturing Technology Centre Limited

The goal of this project was a full technical and economic feasibility study into AirWing, a wind propulsion system providing auxiliary power to a range of vessels.

The project encompassed an assessment of the global greenhouse gas reduction potential of AirWing, and a plan to demonstrate the technology on a vessel. Work was also undertaken to determine how AirWing would be manufactured and commercialised.

GT Wings credited CMDC with giving the company its opportunity to prove the concept, then raise funding to grow the team. AirWing will be the first of its kind in exploring how modular manufacturing can be a route to on-shoring higher proportions of shipbuilding.

> We couldn't have done it without CMDC. Innovate UK have been extremely helpful right from the start"
>
> George Thompson, CEO and Founder of GT Wings

The next steps

Demonstration of AirWing20™ (AW20) on a 125-metre Carisbrooke Shipping (UK) Vectis 11k vessel. The results will predict the potential fuel reduction and greenhouse gas emission abatement achieved by implementing AirWing. GT Wings will then hold a demonstration event in November 2024 for interested parties to see AirWing in action.

Designing a fuel cell and powertrain system for CTVs

Lead: Auriga Energy Ltd

Partners: Compound Semiconductor Applications Catapult Limited, Deregallera Ltd

This project aimed to define a design for a fuel cell and powertrain system to power a crew transfer vessel (CTV). The system should replace legacy combustion engine power units in CTVs to deliver zero-emissions operations.

Enabled by novel motor, drives, and power electronics, the modular fuel cell system will deliver more than three megawatts of power. This fuel cell module will be further developed with the integration of Deregallera's parallel "multi motor/inverter" system powertrain.

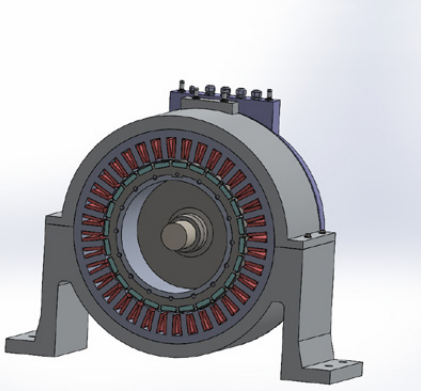
The project successfully defined a modular marinised engine system.

Delivering zero-emission power to CTVs could save up to **938 million kg of CO2eq per year.**

(Source: https://gtr.ukri.org/projects?ref=10042336)

The next steps

A follow-up study will define how fuel cells and diesel hybrid systems can be safely installed in CTVs to de-risk the deployment of this technology. The partners will seek the required onboard hydrogen storage technology and the finance to facilitate the future full power system.



Investigating cracked ammonia as a clean power source

Lead: Ocean Infinity Innovations

Partners: Sunborne Systems Ltd, Cummins Ltd, Innovate UK

Ammonia is a natural zero-carbon energy source which naturally eliminates carbon and sulphur emissions at point of use and overcomes the limitations of hydrogen.

However, ammonia is not straightforward to use as a fuel: its long ignition time and slow flame speed make it challenging to burn in internal combustion engines, and doing so still emits CO2. A truly zero-carbon solution is to partially crack the ammonia into a blend of ammonia and hydrogen.

This project sought to conduct a feasibility study of a one-megawatt internal combustion engine for marine vessels, fuelled by partially cracked ammonia.

The study included all aspects of the technology, from cracking and combustion through to integrating the fuel into the vessel, to identify system requirements and create a design.

The project was successful, even demonstrating better-than-expected results in engine performance, which laid the foundation for future demonstration projects.

Nearly **20 megatonnes of ammonia** is routinely handled in ports around the world every year.

(Source: https://gtr.ukri.org/projects?ref=10043416)

The next steps

Develop a roadmap to complete the development cycle by delivering a land-based engine demonstration, then a full sea-going demonstration unit.

Minimising the structural weight of marine vessels

Lead: Malin Marine Consultants

Partners: BAE Systems Surface Ships Limited, Altair Engineering Limited, Lloyd's Register EMEA, University of Strathclyde

To reach net zero, there will be two key starting points for maritime transport: reducing ship weight and power demand, and improving the underlying efficiency of vessels.

This feasibility study focused on using topology optimised designs, automation and metallic large-scale additive manufacturing to enable the light-weighting of marine vessels. The 'MarilLight' project aimed to use this transformative process to reduce the structural weight of standard steel-hulled ships by 25%, as well as reducing emissions, manufacturing lead time and production time.

The project was successful, showing that a 24-78% reduction in the weight of ships' structural components could be achieved through topology optimisation, with no performance impact. The total weight of a steel ship could be reduced by 5-16% through the widespread application of these structures, and manufacturing emissions could be reduced by 37%.

The shipping industry contributes at least **2.5% of the world's total CO2 emissions**

(Source: https://gtr.ukri.org/projects?ref=10039936)

The next steps

Develop a full-size demonstrator part of a non-critical component of a vessel, achieving part certification, and then installing it onboard an operational vessel. This will help to determine how the demonstrator part performs compared to a conventionally manufactured component.

Case Studies:

Infrastructure Projects

Testing a sustainable offshore charging system

Lead: MJR Controls

Partners: Damen Services (United Kingdom) Limited, Blackfish Engineering Design Limited, Bibby Marine Services Limited, Offshore Renewable Energy Catapult, Clean Offshore Limited

The shift towards electric and hybrid marine vessels is being hampered by the lack of safe, practical and cost-effective infrastructure for offshore charging.

Offshore charging poses a number of challenges. Bad weather can cause a vessel to move around violently, with movements particularly aggressive in a small boat. Users need to not only be able to connect to charging while moving, but disconnect the boat in an emergency, where normal connectors will fall into the sea and be destroyed.

Building on knowledge gained in CMDC Round 1, this project aimed to design and develop an offshore charging system for service operation vessels. In particular, it looked at how vessels could reliably connect to offshore generation infrastructure in terms of connector designs, electrical and mechanical integration, and the connector handling system required.

Round Two testing showed better results than expected in many areas, and enabled the team to identify areas for improvement ahead of offshore trials.

> Without Innovate UK, it would have been impossible to get to where we've got to. The funding is fantastic and it's a very visionary programme."
>
> Paul Cairns, Managing Director of MJR Controls

The next steps

Complete offshore trials, then commercialise the system and sell it as a product to the offshore wind market. The business is already talking to offshore wind farm owners, operators and developers about how it could be integrated into new wind farms.

Developing an energy-efficient proposition to decarbonise ports

Lead: H2GO Power

Partners: Waterwhelm

Ports are a significant part of the UK economy, but their total electricity demand is rising fast. Demand is expected to hit around 250 GWh in 2050 – up from just 20 GWh in 2016.

This project looked at the feasibility of a system that employs desalination and water treatment solutions, as well as hydrogen technologies to support the decarbonisation of ports. The proposed system uses a circular design to exploit available energy and material streams, and achieve a more cost-efficient solution.

The project was assisted by one of the UK's largest port operators and its feasibility was also assessed by H2GO's AI-enhanced software platform, in order to optimise hydrogen systems in terms of cost and environmental footprint.

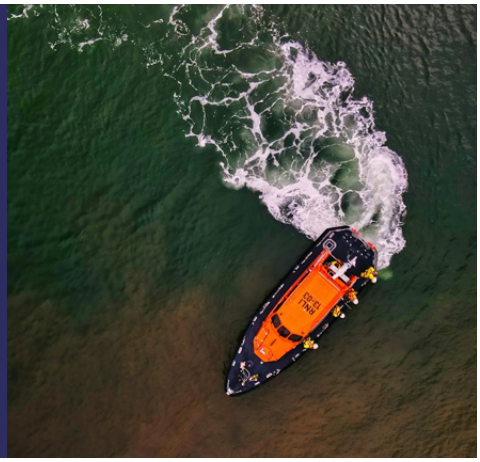
The team effectively worked towards the set objectives and the project's positive outcomes have proved the system's feasibility as a mechanism for decarbonising port facilities.

Ports contribute **£7.5 billion** to the UK economy each year

(Source https://gtr.ukri.org/projects?ref=10041604)

The next steps

Scheduling and proceeding with a full-scale demonstration of the system at a port facility.



A world-first exploration into virtual bunkering for electric vessels

Lead: Aqua superPower

Partners: Indra Renewable Technologies, Cenex and University of Plymouth

New charging infrastructure is required at harbours to support the transition to electrically powered recreational and commercial craft.

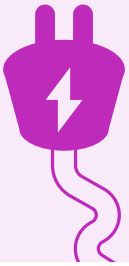
One of the biggest barriers to widescale adoption of electric boats is the lack of sufficient and affordable power at harbours and marinas. Other barriers include high upfront costs and potential battery degradation when leisure crafts aren't frequently used.

This project assessed the feasibility of utilising electric vessel batteries through bi-directional charging infrastructure. It set out to evaluate technical considerations for enabling the bi-directional movement of energy, the most suitable scenarios for deployment and the potential for carbon reduction, as well as economic opportunities and value for stakeholders.

After a thorough vessel-to-grid evaluation, the project concluded that the technology could provide significant opportunities for the UK – both environmentally and economically – with high export potential. There is also the opportunity to improve battery health and reduce costs for vessel owners, which will enable the transition to electric.

Access to sufficient, affordable power at harbours and marinas is a **significant barrier to the adoption of electric boats.**

(Source: https://gtr.ukri.org/projects?ref=10042157)



The next steps

Deploy demonstration projects to prove technological solutions, optimise carbon reduction and test scenarios that are unique to the maritime sector. While there are currently no vessel-to-grid projects globally, learnings can be taken from vehicle-to-grid projects in the automotive sector.

Creating floating fuel depots to support increased marine traffic

Lead: Apollo Offshore Engineering

Partners: EMEC and Aquatera

The next few years will see a significant increase in marine traffic associated with offshore wind development. At the same time, maritime technology will introduce measures to decarbonise with clean fuels and vessel electrification.

This project explored the technical and economic possibilities of floating fuel depots to facilitate fleet fuel supply, while optimising transit distances, reducing emissions and easing pressure on port facilities.

To demonstrate the project's potential, a network of strategic locations for floating fuel depots were considered to support the North Sea Scotwind development. The project also aimed to identify optimum locations for boats to refuel, by focusing on future fuel types such as hydrogen, e-methanol and ammonia.

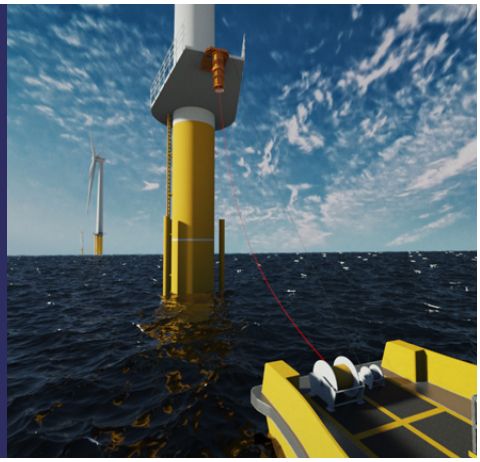
Planned project outputs included a concept design for a modular floating fuel depot system, which considered offshore generation, the storage of fuels for the maritime sector, and how existing infrastructure could be repurposed.

A system of Floating Fuel Depots (FFDs) is proposed as a means of facilitating the **supply of clean fuels to vessels.**

(Source: https://gtr.ukri.org/projects?ref=10042072)

The next steps

At the end of the project, Apollo, EMEC and Aquatera look forward to sharing the outcomes and deliverables industry wide. The team hope to support the rapid expansion in offshore wind (ScotWind and INTOG), support sustainable decommissioning of North Sea oil and gas assets as well as life extension projects, as well as freight and tourism vessels.



Decarbonising port activity to reach net zero by 2040

Lead: Aberdeen Harbour Board

Partners: Energy Systems Catapult Limited, Connected Places Catapult

The Port of Aberdeen plays an important role in international trade and helps to enable local, regional and national supply chains.

This project aimed to accelerate the Port of Aberdeen's transition to net zero by 2040. The study focused on understanding future power demands, as well as the potential low-carbon energy supply sources and technologies that could be used to power the port.

Once this research was complete, the team planned to develop an implementation roadmap which would outline plans to decarbonise port operations and improve conditions for both port users and the wider Aberdeen City region.

The project captured significant information in support of port user activity, future energy demands and low-carbon supply sources. A roadmap was successfully developed that outlines different decarbonisation options.

> CMDC has accelerated our ambitious net zero goals. We wouldn't be where we are without the commitment and support from the funding."
>
> Marlene Mitchell, Commercial Manager at Port of Aberdeen

The next steps

Plan short and medium-term activities for the port. The project's findings indicate that shore power is a key near-term solution, but this requires significant infrastructure investment and will need further analysis before it's delivered. Medium-term options will focus on alternative future fuels to deliver a comprehensive solution for port users.

Building a zero-emission, multi-fuel station for small crafts

Lead: Unitrove Innovation

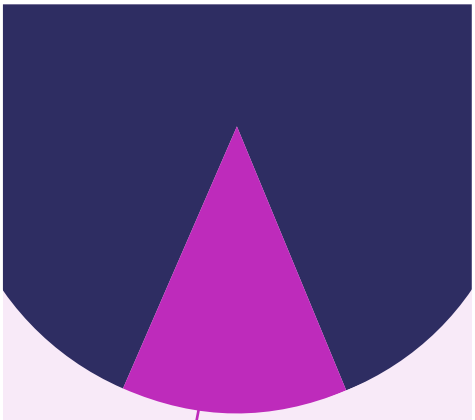
Partners: University of Strathclyde, Aqua Ocean, ZEM tech

Decarbonising small crafts requires the safe storage of hydrogen and ammonia, the continuous availability of zero-carbon fuel for bunkering, and vessel owners being willing to convert to zero-carbon fuels.

This project aimed to identify and remove the barriers to a zero-carbon future by designing and developing a commercially viable, zero-emission, multi-fuel station. This fuel station would be able to deliver liquid hydrogen, compressed gaseous hydrogen and electricity to vessels in a safe and cost-effective way.

Unitrove Innovation also hoped to facilitate the commercialisation of liquid hydrogen, and take into consideration the human element of training and upskilling requirements.

The project's techno-economic study was successfully completed, and the team were able to develop a photorealistic video animation of the station in operation.



13%

Waterborne transport accounts for **13%** of greenhouse gas emissions from the EU transport sector.

(Source: https://gtr.ukri.org/projects?ref=10042449)

The next steps

Building a zero-emission, multi-fuel station as part of a live demonstration to fuel a liquid hydrogen vessel, a compressed gaseous hydrogen vessel and a battery electric vessel.

Case Studies:

Combined Vessel & Infrastructure Projects

Exploring the possibility of hydrogen-fuelled CTVs

Lead: SSE Renewables Developments

Partners: Simpson Oils Ltd, The European Marine Energy Centre Ltd, Innovate UK, Wick Harbour Authority

This project launched a feasibility study to develop a low-emissions, hydrogen-fuelled crew transfer vessel (CTV) operating from Wick, Caithness to serve the Beatrice offshore wind farm.

The goals were to develop a CTV that met the requirements of the wind farm, and identify the infrastructure that would be needed to safely transport, store and use the hydrogen to power the CTV. The study planned for a demonstration of the hydrogen-powered CTV and onshore refuelling infrastructure to prove the feasibility of low emissions vessels.

The project has identified the capabilities of hydrogen-powered CTVs, and the parameters required for the safe and efficient operation of the onshore refuelling systems.

CTVs currently contribute significantly to the estimated **284 kilotonnes of CO_2 emissions generated every year by operations and maintenance emissions.**

(Source: https://gtr.ukri.org/projects?ref=10040568)

The next steps

To take the information gathered from the study and move towards real-world implementation of hydrogen-fuelled CTVs on an operational wind farm. This will have to address the main obstacles, including an immature market for hydrogen CTVs and the limited availability of green hydrogen.

Developing a sustainable power source for unloading operations

Lead: Independent Control Systems Ltd

Partners: Cemex UK Operations Ltd, University of Warwick

The existing supply-on-demand model of supplying berthed ships with power is not optimised for cargo vessels.

The goal of this project was a feasibility study around establishing a store-and-release energy solution to be situated on shore, and connecting this power supply to ships which require fluctuating amounts of electricity during cargo operations.

The solution would deliver pre-stored power to vessels while unloading cargo. This avoids the need to burn more of the ship's fuel to keep the power on, without incurring peak electricity prices. Doing so would benefit smaller vessels in particular, which may otherwise struggle to decarbonise because of space constraints.

An effective system to connect vessels to shore and a working software model were developed.

The UK's current maritime electrical supply is **unsuitable for commercial cargo ships.**

(Source: https://gtr.ukri.org/projects?ref=10040066)

The next steps

Independent Control Systems will now submit a bid to produce a demonstrator at the Learmouth site in Southampton, to assess if the system is viable in practice.

An ambitious blueprint for a green shipping corridor

Lead: Port of Tyne Authority

Partners: Newcastle University, EDF Energy R&D, Lloyd's Register, ARUP, the North East LEP and the Connected Places Catapult

Achieving zero emissions in maritime transportation requires change on a huge scale.

Green shipping corridors can spur early adoption of fuels and technologies, which can create a knock-on effect on shipping emissions on other routes. These shipping corridors provide a pathway to full decarbonisation, helping to deliver low and zero emissions across the maritime sector.

This innovative project aimed to assess the feasibility of a green shipping corridor from the UK's north-east shore, with the vision of joining up with the Europe Green Corridors Network and accelerating uptake through diffusion. It included analysing green shipping technology requirements for both vessel and landside infrastructure, and producing a roadmap for implementation.

All deliverables were successfully completed before the end of the project and its findings will inform the next stages of corridor development.

The Clydebank Declaration pledged **six green shipping corridors by 2025**

(taken from https://gtr.ukri.org/projects?ref=10041636)

The next steps

After identifying gaps in the supply of renewable methanol to the Port of Tyne and bunkering infrastructure at the port, a demonstration of methanol bunkering will be a key next step.

Establishing a green corridor from the UK's busiest ferry port

Lead: Dover Harbour Board

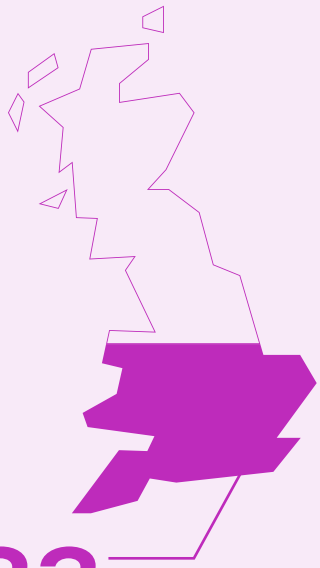
Partners: DFDS, Irish Ferries, Ikigai Capital, JG Maritime Solutions, SSE and ABB

The Port of Dover operates up to 120 ferry movements per day and handles around £144 billion of UK trade, making it the busiest port in the UK.

The aim of this project was to examine the feasibility of a green corridor between the Port of Dover and the Ports of Calais and Dunkirk, supporting the Port of Dover's ambition to be carbon net-zero by 2025.

This included assessing the emissions of potential future fuels for both ferries and port infrastructure, such as synthetic fuels, ammonia, hydrogen (combustion and fuel cell), liquified natural gas and electrification. The project also aimed to identify relevant regulations and policy measures needed to deliver a green corridor, and produce a business plan and roadmap.

This project had a large consortium of partners representing all parts of the green corridor, with the inclusion of ferry operators and expertise from the marine and net zero industries. Despite this, all tasks were completed on schedule.



33%

The Port of Dover is responsible for **33%** of all UK-EU trade.

(Source: https://gtr.ukri.org/projects?ref=10038742)

The next steps

Complete a feasibility study to agree and design the technical connection between all six stakeholders, optimise the ferry schedule, and look at renewable energy generation and storage options to provide sufficient power for future vessels. This will then pave the way for a demonstrator project.

Feasibility of the first hydrogen-powered North Sea crossing

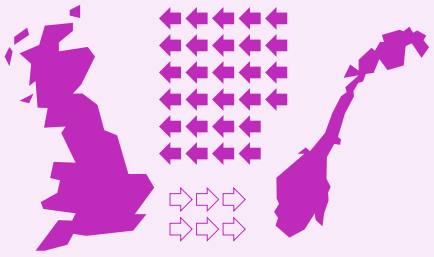
Lead: ACUA Ocean

Partners: Aberdeen Harbour Board

This project sought to assess the feasibility of a North Sea green shipping corridor, and to produce a demonstration plan for the first hydrogen-powered crossing in 2025.

The study was completed successfully, and established safety and operational factors for using hydrogen fuel in port environments. It also examined how commercially and environmentally viable a green shipping corridor would be between the Ports of Aberdeen and Stavanger.

This work has accelerated understanding of the short-sea shipping sector. Moving away from large crewed vessels to smaller, remotely operated vessels that are available 24/7 and can operate all year round provides an exciting capability opportunity for offshore energy and renewables customers.



UK exports to Norway amounted to **£6.8bn** in the first quarter of 2021, while total UK imports from Norway amounted to **£28.6bn.**

(taken from https://gtr.ukri.org/projects?ref=10039998)

The next steps

The feasibility study highlighted that hydrogen was not an economically viable or suitable emission reduction solution for the Aberdeen to Norway trade flow. However, significant opportunities were identified for ACUA Ocean H-USV technology to provide logistics and supply support from the Port of Aberdeen to offshore energy platforms in the North Sea.

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