

Creating a world
fit for the future



Buoying up ambitions for decarbonisation

The future of the shipping sector



Introduction

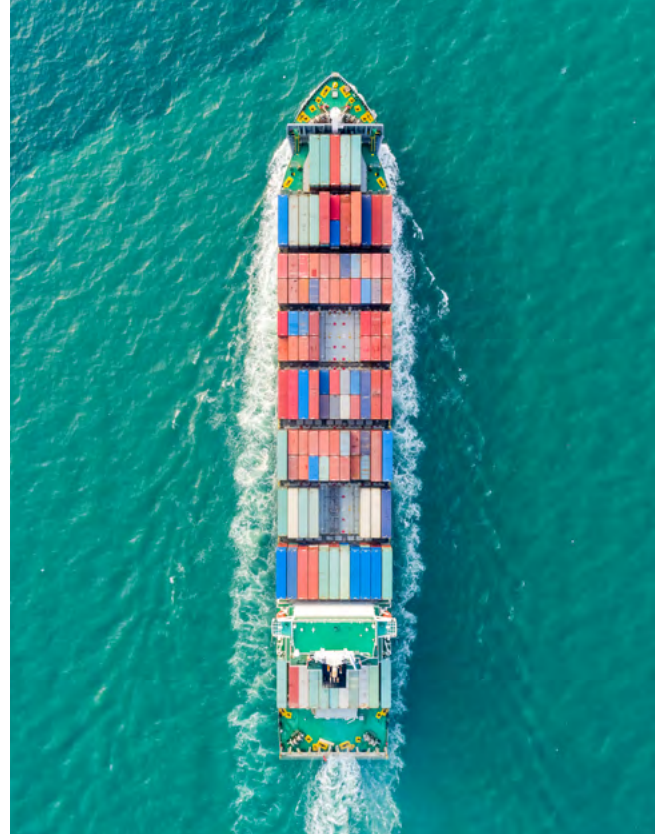
“To reach a port, we must sail – sail, not tie at anchor – sail, not drift.”

The marine sector needs to heed the words of Franklin D Roosevelt as it charts a course to a decarbonised future.

Dropping anchor is not an option as investors and policymakers put pressure on companies to make the changes that will help the sector sail into a greener future.

With so many potential alternatives on the horizon, going with the flow may not be the best plan. It is a time for difficult, and perhaps brave, decisions to be made by industry leaders to navigate towards a net-zero future.

In this white paper, we will examine some of the uncertainties and barriers and show how Ricardo can help steer the sector into calmer waters.



The position of the sector



International shipping emits around 940 million tonnes CO₂ each year – that is more than the whole of Germany – and is responsible for 2.5% of all greenhouse gas emissions globally. As other sectors and countries take action to decarbonise, that percentage will increase.

The cost of fuel can account for anything from 35% to around 53% of the operating cost of ships, putting pressure on finding a cost-effective alternative fuel for the sector. Currently, shipping uses about 350 million tonnes of fuel per year, and future fuels will need to be safely and cost-effectively transported to ports and bunkered across the globe.

With 90% of global trade by weight carried by sea, there is a huge challenge to cut emissions. The road transport sector has its own bridge to cross, but electrifying vehicles is much further progressed than finding alternative fuels for ships.

Several key nations and regions, including the EU, the UK and the USA, have already set their net-zero ambitions and others will follow suit, many with timescales of targeting net zero by the 2040s or 2050. But the current level of ambition for shipping is to cut emissions by 50% by 2050 (albeit phrased as 'at least'), and, according to a recent report from the International Energy Agency (IEA), the sector is expected to fall short of that target.

The challenge facing the sector comes in many forms, not least of which is that shipping is already very efficient when compared with other transport methods, sometimes leading to those in the industry querying the need to act. But the necessity is clear that all sectors have to decarbonise. The solution needs to significantly lower emissions, ultimately to zero, and be cost-effective.

The time for change is here. Vessels have long lifetimes and if action isn't taken now the sector will potentially be locking in future emissions for many years.



Drivers to act

The maritime sector is not immune to the pressures faced by industries across the globe to lower their emissions and make the planet net zero by 2050.

Those pressures are coming from different quarters, whether it is financiers looking to protect their capital or the supply chain's desire for decarbonised goods – after all, for net-zero products to be exported around the world, shipping also has to become net zero.

The drivers to act are coming from various levels:

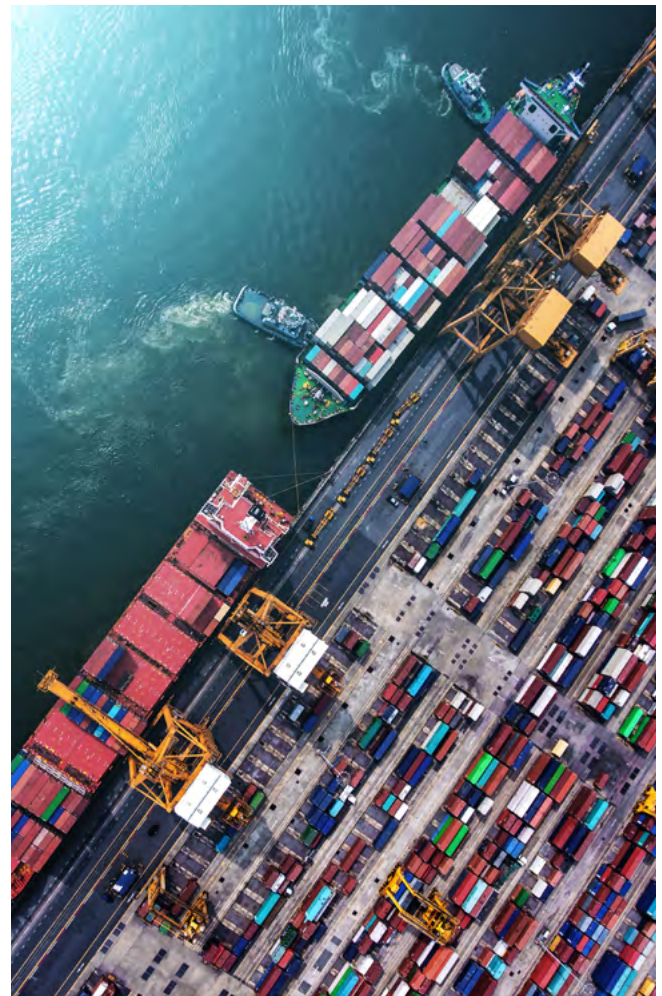
- At a global level, the International Maritime Organization's (IMO) initial ambition, set out in 2018, targeted at least a 50% reduction in international shipping emissions by 2050 compared to 2008 levels (and a 70% carbon intensity improvement by 2050). These figures are likely to be tightened when the IMO-revised strategy is published in 2023.
- At a regional level, the EU has recently included several elements related to decarbonising the maritime sector in its July 2021 policy package 'Fit For 55'. This included at its core a proposal to extend the EU's emissions trading system to include the maritime sector, as well as proposals for alternative fuel infrastructure, upper limits on the greenhouse gas content of fuels and EU-wide minimum rates of taxation on marine fuels. While the final details on these measures will be negotiated in the coming dialogue between the European Commission, Council and Parliament, it's clear that there is ambition for change to reduce GHG emissions and air pollutant emissions, and this could have financial implications beyond the EU's maritime borders. These measures are expected to lead to increased uptake of low- and zero-emission fuels and vessel efficiency improvements, with benefits of reduction of greenhouse gases and air pollutants that outweigh the additional compliance costs that the sector would face.
- At a national level, the UK is an example of individual countries planning to decarbonise shipping, with its aim for a net-zero maritime sector by 2050 at the latest. This is to be implemented with policies including extending the Renewable Transport Fuel Obligation (RTFO) to support renewable fuels of non-biological origin used in shipping, and consulting on a phase-out date for the sale of new non-zero emission domestic vessels.
- In the USA, the Biden administration is pushing for 100% decarbonisation of shipping by the middle of the century.

Through the policies and implementation measures being enacted, there is increasing funding from governments and institutions to move from "desk studies" to demonstrators, on to implementation at scale. Early movers will gain advantage by accessing this financial support, which will not be available to those who delay.

Given the lead times involved and the longevity of vessels, there is a real risk of stranded assets from taking a "business as usual" approach. Vessel financiers may soon demand "decarbonisation ready" on newbuilds and consider the cost of future retrofits when assessing the value of the existing fleet to avoid this – a key driver for the funding of new or refurbished vessels.

And it is important not to forget that shipping does not stand alone: with so many ports across the globe being in cities that have their own air quality targets and facing local drivers to act. Decisions made for vessels now will have a far-reaching impact and could result in multiple environmental benefits.

Put quite simply, there is no escaping this growing pressure to take action now.



Uncertainties and barriers

Making changes is far from straightforward, though. While the public may still be suffering range anxiety on electric cars, a large container ship travelling from China to Europe would need about a million Tesla batteries to complete the journey. Compared to shipping, car manufacturers have it relatively easy, which is why electric cars are already a frequent sight on our roads and almost all ships still use fossil fuels.

For the shipping sector, the barriers and the uncertainties are far-reaching. Due to the wide variety of vessel types, the future fleet may use one of a number of low or zero-carbon fuels, and ports need to have not only the bunkering barges, fuel storage and fuel suppliers to supply them, but also the knowledge to do so safely. The zero-carbon transition for shipping is much more complex than the switch to electric passenger cars.

Among the many other factors affecting how – and when – companies will introduce changes are:

Technology and fuel

There is a large choice of future fuels that could become viable for decarbonising shipping. From hydrogen, ammonia and methanol to biogas, synthetic fuels and even electricity for the shortest of journeys, the choice is potentially bewildering. And for every potential fuel, there are opinions, both helpful and not, on which one (if any) should be chosen.

To add to this complexity, there is a risk that there will no longer be a one size fits all scenario, as different fuels may suit different classes of vessel and operating patterns. International cargo ships with long trans-oceanic voyages may need a different solution from passenger vessels doing short Channel hops. These challenges and uncertainties span the entire value chain, from vessel charterers and operators to legislators, ports, bunkering suppliers and fuels manufacturers.

Faced with this, it is unsurprising that decision makers are unable to invest in the technology for fear they will end up backing what could turn out to be an expensive wrong decision.

The future means leaving the safe harbour that has existed for years in the sector. The current technologies, including choice of fuel, are reliable and durable, as well as being easy to handle and cheap. What lies beyond appears to be expensive, although costs are expected to fall, and some aspects of the new technologies are not yet fully demonstrated at scale (but are imminent and expected to be at this stage in a few years).

Shipping companies will also need to consider which ports offer the fuel type they choose, while the ports will also need to make a decision on what fuels and refuelling capacity to provide.

Liquid fossil fuels are very energy dense. Some of the potential fuels do not have the range to match existing fuels, which for some vessel types could entail a trade-off between bunkering frequency and cargo capacity. However, for many vessel and fuel combinations, there may be few compromises when switching to a clean fuel. Decision makers will need to understand the best options for their fleets or their fuel and port customers.

The technology and fuel challenges include:

- Fossil LNG is seen by several organisations as a transition or interim fuel. However, there are concerns regarding upstream and bunkering methane leakage as well as methane slip during combustion. There are fears that if LNG is taken up as an interim fuel, that this will divert investment away from truly sustainable zero-carbon options. It is unlikely that businesses will want to pay to retrofit vessels and upgrade infrastructure twice – once to methane, then a second time to ammonia, for example.
- While the shipping industry is a highly cost-effective way to transport people and goods, much of this low price is reliant on the cost of fuel. It is highly likely that future fuels will be more expensive, but how much more expensive is the key question: estimates of the costs vary widely as many of the underpinning technologies are only now beginning to scale up. This cost uncertainty makes it difficult to plan investments in vessels and infrastructure.
- Most marine powertrains and associated onboard systems provide many years of reliable service. Buyers of low-carbon replacements will need reassurance that this dependability can be matched. Early adopters may need to be prepared for teething troubles. Will powertrain manufacturers be able to provide assurance for the lifetime/reliability of new engines running on different fuels?
- Large methanol engines are already available, and large ammonia engines are coming to market imminently, but marine MW scale fuel cells are not readily available. Some shipyards are starting to build vessels “ready” for zero-carbon fuels, but the choice and scale needed for the transition to cleaner fuels is not available.
- In order to meet IMO decarbonisation glidepaths, operators could choose to use other emerging technologies, such as onboard carbon capture, wind assistance or hybridisation, rather than cleaner fuels. Decision makers will need guidance as to whether it would deliver a better return to invest in these technologies or the new fuels. Or indeed whether to use them in combination to offset increased fuel cost.

Decisions need to be made based on evidence, not speculation and Ricardo has the insight to help.

What Ricardo can do

Ricardo can draw on its engineering expertise, test facilities and modelling capability to provide evidence for decision makers. We frequently collate, sift and interpret evidence on technologies and fuels for private and public sector clients.

Time

The recent IPCC report has made it clear that the time to act to prevent the worst effects of climate change is now. Delaying until the perfect, low cost, low impact technology is available is no longer an option for any industry, let alone high visibility industries such as aviation and shipping. This is the reason for policies with international reach such as the EU's Fit For 55 package, which aims to reduce CO₂ levels by 55% by 2030. These policies will impact shipping, and those who do not act will face financial penalties.

While the current IMO decarbonisation strategy does not send a strong signal for the significant changes needed, the revision in 2023 will undoubtedly see stronger decarbonisation ambitions.

The safety and operational requirements for many of the potential future fuels are in development. This makes vessel and infrastructure design challenging. However, the existing low flashpoint fuels regulations, together with interactions with the classification societies, should provide sufficient guidance to allow designs to proceed. Indeed, Lloyds Register has approved in principle five ammonia-fuelled ships in the past three years (though this is a tiny fraction of the ships delivered over that period).

What Ricardo can do

Ricardo can assemble the roadmaps for your decarbonisation pathways, drawing on the substantive experience developing strategy for our clients.



Eco-system/interconnections

The sector risks finding itself in a chicken and egg situation – a decision must be made about which fuel to adopt, but that could be dependent on the bunkering facilities. However, if port authorities are waiting to see which way the shipping companies will go before committing themselves, there is no progress.

Studies have shown that the majority of investment will be required for fuel production and bunkering infrastructure. But until commitments are made to go down a particular route, few are willing to take the risk. Governments can, in some instances, unlock this situation by providing funding for infrastructure as proof of concept. But for larger scale adoption, it will have to fall to industry to make the leap, perhaps with some government incentives. One such possibility could be for agreements between vessel operators and specific ports they operate from for a long-term clean fuel purchase agreement. Or newly renewables-rich countries may seek to exploit their new energy source by making favourable agreements with operators or charterers.

What Ricardo can do

With our vast experience of techno-economic modelling and input to policymaking, Ricardo is ideally placed to help all the players in the marine industry make robust decisions about investment, strategy and policy to enable a de-risked transition to cleaner fuels.

Economics

Today, with cheap fuels and no legislative penalties for inefficiency, there is no significant financial incentive for major change. However, the introduction of the IMO's carbon intensity index (CII) will force improvements (or scrappage) on the worst performing vessels while the EU's Fit for 55 package is due to mandate improvements at a fleet level. With the complex ownership of financiers and charterers, there is no one organisation that is responsible for decarbonisation.

End-user pressure could bring about change as more organisations, especially those which are consumer-facing, are looking to be net zero. This will not be possible if they continue to ship items without improvements in the sector. The global manufacturing trade is underpinned by shipping and if positive moves are not made towards reducing global warming impacts, the whole "manufacture globally, sell globally" paradigm is at risk.

The current situation cannot be retained in the long-term and it is no longer a question of 'if' the sector changes, but 'when'.

What Ricardo can do

Our team of economists undertake economic modelling and quantitative analysis, using a range of techniques and software packages to provide analyses on cost-benefit and cost-effectiveness.

What Ricardo has done

Technology and fuel

Orkney Islands

Ricardo is working with a consortium led by EMEC Hydrogen on an ambitious seven-month project demonstrating technologies to enable maritime decarbonisation in Orkney.

The £2.2 million HIMET (Hydrogen in an Integrated Maritime Energy Transition) project is exploring solutions for decarbonising ferries as well as shore-side activities in ports. It is one of 55 projects selected for funding under the Department for Transport's flagship Clean Maritime Demonstration Competition, delivered in partnership with Innovate UK.

For the project, Ricardo is designing and developing the combustion system and the engine hardware to convert an existing natural gas engine to 100% hydrogen operation. The engine is being updated and tested in the new hydrogen engine test facility in the Ricardo Shoreham test centre.

For this multi-cylinder development, Ricardo is leveraging its existing world-renowned knowledge of engine development, and expertise it is gaining from testing a hydrogen single cylinder research engine. The replacement of a marine diesel engine with a hydrogen version is a promising pathway to provide new and retrofitted vessels with zero carbon emission propulsion.

For on board auxiliary power generation, Ricardo is also developing a bespoke Balance of Plant (BOP) for the multiple fuel cell stacks. This will enable scalability of the fuel cell system while ensuring high system efficiency within packaging volume constraints that is a known challenge when scaling up fuel cells. Ricardo is using the thermal and energy management optimisation research activities conducted on fuel cell systems in recent years and the broad supply chain knowledge acquired as an independent and supplier-agnostic engineering consultancy.

Multi-MW proton exchange membrane (PEM) fuel cell for cruise ships

Ricardo is helping a world-leading cruise line operator to decarbonise its future vessel fleet. The project will deliver a multi-MW hydrogen fuel cell system to enable zero carbon emissions in port operations and navigation in coastal and specific areas.

Ricardo's team will define the overall system architecture, individual component specifications and packaging, engage with suppliers of fuel cell stacks and Balance Of Plant (BOP) components for integration into the vessel. The fuel cell system is designed around the customer's needs for packaging and will benefit from the Ricardo design approach for multi-stack fuel cells to ensure high efficiency at the MW scale size required.

The customer needed a flexible approach to meet the project targets and off-the-shelf products in the market did not meet their expectations. Being supplier and technology agnostic, Ricardo was able to respond to the customer's needs for challenging packaging and efficiency and to propose a solution that is fit for purpose.

Ricardo is a one-stop-shop for hydrogen fuel cell support, from providing concept definition, detailed design and analyses, prototype builds, through to validation and in-house testing using the Shoreham hydrogen facility.



Roadmap to decarbonisation

A high-speed engine manufacturer wanted to determine what its future power generation products range should be in the 0.5 to 3.0 MW power band. With a focus on marine propulsion and power generation, it was important for the client to understand:

- The global and regional climate ambitions to 2050, including market and competitor responses
- The pros and cons, market and technology readiness of fuel cells versus low and zero-carbon fuelled internal combustion engines
- The market, technology readiness and prospects of hydrogen and other low/zero carbon fuels from both fossil and renewable sources compared to diesel

Ricardo provided a thorough analysis of the market drivers, carbon policies, carbon pricing, and competitors (both direct and indirect) across different regions and sectors. Scenarios were developed for a range of plausible hydrogen uptake and climate policy directions from today to 2050. Suitable products were considered across the different sectors in each scenario using total cost of ownership (TCO), lifecycle energy cost and lifecycle greenhouse gas modelling to quantify the products.

At the end of the project, the client was provided with analysis and valuable insight for each sector in each scenario, product and fuel roadmaps to 2050 with sales split forecast, competitors' expected strategies and product direction, and detailed models of the CO₂ lifecycle and its cost.



Time

International Maritime Organization (IMO)

Ricardo was contracted by the IMO to perform a study on well-to-wake methods for marine fuels.

The team has identified all significant methods, legislation and regulations pertaining to well to tank, tank to wake/wheels and well to wake/wheels. Ricardo performed a review of the impact categories covered by each of the above, identifying differences in approach, and also identified the most suitable methods or regulations to perform detailed case studies.

During the project, Ricardo proposed a number of fuel combinations that could be used as case studies to identify differences or weaknesses in the methods and regulations, which were then selected by IMO members.

The methods or regulations were applied to the fuels, allowing Ricardo to perform detailed examination of the methods, highlighting where the end results differ because of the method used for each fuel. Based on the results, Ricardo has suggested a WTW approach that the IMO could use when setting regulations for future marine fuels.

The findings were due to be published by the IMO at ISWG–GHG 10.

Eco-system/interconnections

Shetland Islands

Ricardo is a key member of a £500,000 project to support the transition to zero-carbon fuels for the Shetland Islands' maritime industry that has received support from the UK Government's Clean Maritime Demonstration Competition (CMDC).

The NEPTUNE project, funded by the Department for Transport and delivered in partnership with Innovate UK, is developing a desk-based decision modelling and support system (DEMOSS) tool that will help to analyse, scope and develop plans for supporting the transition.

It is being led by the University of Strathclyde in partnership with Ricardo, Babcock International and Shetland Islands Council and aligns with the archipelago's 2030 net-zero target.

For the project, Ricardo is developing a 'digital twin' of representative marine vessels and the port energy infrastructure within the island energy system to facilitate testing of different scenarios, energy flows and emissions impacts for vessels from 'well to wake'. This 'digital twin' will help analyse, scope and develop plans supporting the island maritime eco-system's transition to zero emission.

The NEPTUNE Project aligns with project ORION, set up in April 2020, which aims to help turn Shetland into an international clean energy hub under ambitious plans that will see major oil and gas fields become net zero by 2030.

Ricardo's vision for the future

THE MARINE SECTOR

- A vibrant marine sector, respected for contributing to global decarbonisation
- New opportunities for shipping energy from newly renewable rich areas to consumers
- There will be some changes to marine operation and costs, but it will still be the backbone of global trade
- Decarbonisation may be a driver for sustainable practices across marine, with opportunities for increased value of trained seafarers and good environmental practices
- Legislative requirements may lead to more scrutiny: monitoring of compliance in deep water

FLEETS

- Decommissioning of high-carbon fleet may accelerate – will require tracking of good practice
- Digitalisation of operating practices to minimise fuel use and waiting time, plus the potential of V2X (Vehicle to Everything) communication
- To meet decarbonisation goals, the sector will need massive investment, which is an opportunity for finance companies and insurers

PORTS

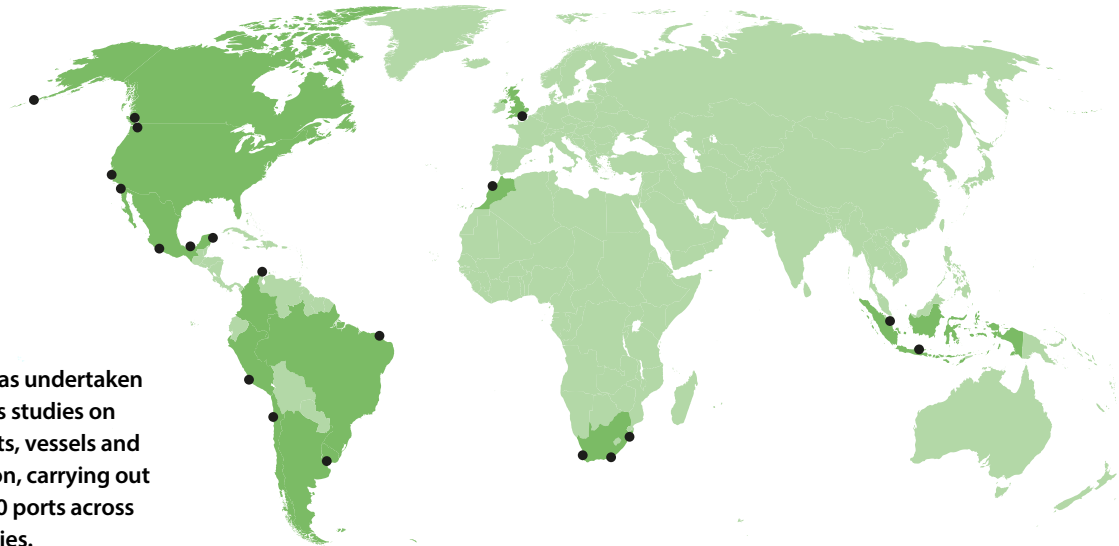
- Ports can be hubs for low-carbon transport, heating and innovation
- Not all ports will have all fuels
- Ports may specialise in one fuel and partner with a neighbour for others

WORKING TOGETHER

- Partnerships between operators and ports/bunkering to stimulate growth of sector
- Collaboration through routes/ports/fuels and low carbon corridors
- Massive opportunities for shipbuilders and the supply chain as the fleet is renewed and refitted

Why Ricardo?

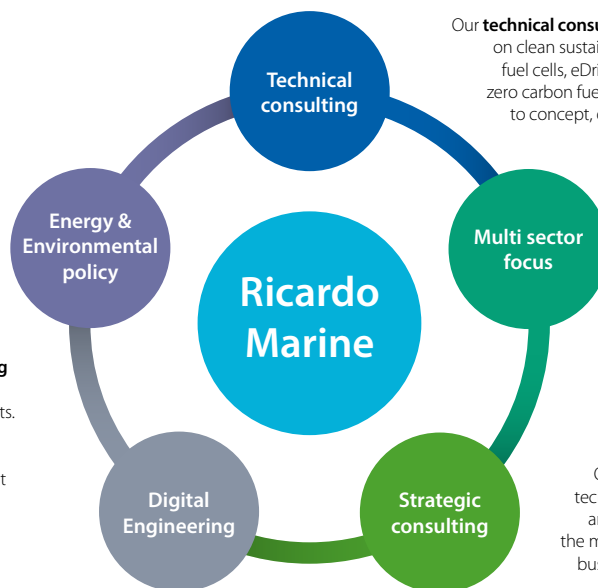
- We are independent and can cut through political or business bias to identify best, or most likely, solutions for operators, bunker suppliers, legislators, ports, and fuels manufacturers.
- We are experts in the full gamut of: propulsion, policy, fuels, emissions and environment.
- We can apply insights from work on policies for legislators such as the IMO and EU, as well as strategic studies such as those for EDF and OC, to help businesses start implementing marine decarbonisation at the lowest possible risk.
- We have partners in business, academia, NGOs and legislators giving us a broad understanding.
- We have carried out numerous studies on fuels, ports, vessels and production, carrying out work in 20 ports across 13 countries.
- In-depth understanding of energy infrastructure, from ports to hydrogen generation.
- We are the experts in modelling, simulation and testing, as illustrated in our work with Shetland and others.
- We have already provided strategic advice on which technology to develop to ensure asset and company viability into 2050s.



Ricardo has undertaken numerous studies on fuels, ports, vessels and production, carrying out work in 20 ports across 13 countries.

Our **energy & environment** business supports governments and authorities on environmental and emission policies and infrastructure. This provides us with unique insight on infrastructure and policy development which is key for the understanding and planning of solutions to decarbonise the marine sector.

Our software business provides the unique digital backbone to enable **digital engineering** to cover the full development cycle, leveraging data to optimise our current and future products. Our marine customers benefit from innovative software, the development of virtual products and validation tools to reduce the development time and costs especially for alternative propulsion systems.



Our **technical consulting** business delivers turnkey engineering projects on clean sustainable propulsion and power generation: battery and fuel cells, eDrives and clean ICE using conventional and alternative zero carbon fuels including hydrogen and ammonia. From feasibility to concept, detailed design, analysis, prototype build, testing and production support – we can help.

By operating in the **whole spectrum of the transport sector**, from automotive to off-highway, motorcycle, power generation, marine, rail up to aerospace, we bring innovative solutions and experience validated on other areas, reducing the technology and financial risks.

Our **strategic consulting** business supports firms on technology and market evolution, and help in acquiring and retaining a sustainable competitive advantage on the market. With a deep understanding of the market and businesses we can deliver the best technical product to our marine customers.

Find out more

Hydrogen and renewable energy will play a critical role in enabling the marine industry to meet its targets of significantly reducing carbon emissions and limiting its impact on climate change. Ricardo's alternative fuel and renewable energy experts have been supporting the industry, operators and ports with understanding the policies and technologies needed to support achievement of mandatory emission requirements.

To find out more, visit <https://ricardo.com/hydrogen#marine>





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