The national and global opportunity for

BRITISH-MADE ZERO CARBON VESSELS

to service **offshore wind assets**

Report by Critical Future Ltd

Sponsored by Bibby Marine Services

CRITICAL FUTURE

BIBBY MARINE LIMITED

TABLE OF CONTENTS

The national and global opportunity for British-made zero carbon vessels to service offshore wind assets

EXECUTIVE SUMMARY

This paper presents a unique opportunity for the United Kingdom of Great Britain and Northern Ireland. While the global maritime industry frantically searches for means to reduce greenhouse gas emissions in shipping, the solution lies in wait of UK government activation.

Our original research presented in this report reveals the following:

1. **British-made:** the UK can build zero carbon ships in our own shipyards.
2. **Platform ready:** the technology for zero carbon vessels is available right now, and ready for deployment by key maritime players like Bibby, a 200-year-old British company.
3. **Wind-win:** an excellent use case for such zero carbon vessels is servicing British wind farm assets, creating a virtuous cycle of carbon reduction in renewable energy production and maintenance.
4. **Levelling up:** the best region for this technology would be the North of England, specifically based on our analysis of the North West and specifically Merseyside, where key stakeholders in the private and public sectors are fully supportive.
5. **Meeting sustainability targets:** this project will reduce UK and global greenhouse gas emissions substantially, in line with the UK government's Clean Maritime Plan and carbon reduction commitments.
6. **Government support required:** industry does need support from the UK government to make this happen, with match funding of £55–75 million to produce the world's first zero carbon vessel.
7. **Economic return:** this funding will generate in return £10 for every £1 spent, as demonstrated by our economic modelling.
8. **Global defensible industry:** through this initiative, the UK will be able to create a world-leading high-tech industry which can be exported around the globe, driving economic returns for generations.

Considering the economic, environmental, and social benefits for the UK, this paper calls for government financial investment and regulatory support. It also presents the case for public private partnership in the form of government match funding in a specific proposal from Bibby Marine Services, a company established more than 200 years ago – part of the UK's maritime heritage.

HOW THE UK CAN LEAD THE WORLD IN ZERO CARBON VESSELS

The offshore wind market will unlock great opportunities for the UK in green electricity power generation and clean alternative fuels production.

International shipping accounts for 2–3% of global carbon dioxide (CO2) emissions. The UN's International Maritime Organization has a long-term goal to cut greenhouse gas emissions by 50% from 2008 levels by 2050. To accomplish this, fast-tracking of zero emissions fuels in commercially viable ships is required by 2030, as all these vessels will be part of the ocean fleet in 2050.

Nations around the world have started to explore technology systems and alternative fuels solutions for their ships. There is room for many options to be considered, like electric and hybrid power, hydrogen, ammonia, and other fuel types. However, research and development will prove crucial to these projects. According to Baroness Worthington, there is no 'silver bullet'. Instead, there is a diverse range of 'silver buckshot' solutions, suitable for different segments of the market, which together could take the sector towards zero carbon by 2050.

The UK wishes to lead this transition phase to a green economy and plans to reach zero emission shipping by 2050. Besides being the sixth largest manufacturer in the world by output, the UK is also a world leader in the offshore wind market, with more installed capacity than any other country. Currently, offshore wind powers the equivalent of 4.5 million homes each year and generates over 10% of UK electricity. The offshore wind market will unlock great opportunities for the UK in green electricity power generation and clean alternative fuels production. The UK currently has over 20 gigawatts (GW) of cumulative installed wind energy capacity, with over 10 GW provided from offshore sources. In the coming years, its installed offshore wind energy capacity is likely to rise to over 15 GW, with more than 3,000 turbines by 2030.

*The Merseyside region could become a **global centre of excellence for the offshore wind industry** and play a pivotal role in the creation of essential gains and jobs in the region, boosting the Merseyside economy by around £**740 million per vessel built.***

Investment in the offshore wind market will increase substantially both globally and regionally. In fact, forecasts indicate a global investment of £2.5 trillion in wind energy by 2040. Moreover, there will be an increase in offshore floating opportunities which will prove essential for the whole market. This in turn will mean greater demand for service operation vessels (SOVs), which play a vital role in the functioning of offshore wind farms by safely transferring maintenance crew to offshore turbines.

Both the offshore wind market and new-technology SOVs could offer considerable export opportunities for the UK, helping to establish the country as a global leader in the field. Considering economic value, port freight tonnage, regeneration potential, government research and development (R&D) support, business environment, connectivity quality, wind farm proximity, and rebalancing potential, our analysis shows that the North West (or the North East) would be the best region to lead this work.

The UK is a world leader in the offshore wind market, with more installed capacity than any other country.

Such an investment could revolutionize the shipping industry, facilitate the regeneration of the North West (and other suitable regions), and contribute to the development of the Northern Powerhouse. The Merseyside region could become a global centre of excellence for the offshore wind industry and play a pivotal role in the creation of essential gains and jobs in the region, boosting the Merseyside economy by around £740 million per vessel built. It is also one of the eight locations in England to be designated as special economic zones (freeports). Alternatively, Teesside in the North East is about to be 'reborn as an industrial powerhouse', creating many jobs, after the area was also recently named as one of the eight freeports.

Bibby Marine Services owns and operates bespoke offshore SOVs and walk-to-work vessels to serve offshore wind farms. It belongs to Bibby Marine Limited, one of the five companies of the Bibby Line Group, which is headquartered in Liverpool. Bibby Line Group is a diverse, £800 million global business with a history of over 200 years. It operates in 14 countries, employing around 4,000 people in sectors including retail, financial services, distribution, marine, and infrastructure.

Now more than ever, Bibby Marine Services focuses on environmental issues, incorporating the triple bottom line approach into its strategic planning. Its mission is to develop and construct zero carbon emission vessels in the next 10 years. This is partly to keep up with new regulations, but most importantly to contribute to the transition to a zero carbon economy and prevent climate change that would have disastrous consequences for the planet.

Bibby has already received a grant to explore a range of zero carbon fuel systems through the WaveMaster Zero C Research and Development Project. The project is supported by a grant from MarRI-UK, a collaborative innovation vehicle for UK industry and academia to tackle innovation and technology challenges together. The project is expected to generate essential gains in offshore energy and the SOVs market in general. Bibby will use its fleet of Bibby WaveMaster walk-to-work SOVs to examine five alternative fuel concepts: biofuel (HVO), hydrogen, ammonia, methanol, and battery power.

Given sufficient support, Bibby Marine Services plans to invest in this ambitious target by introducing British-built zero carbon emission vessels within the next decade. If funding can be provided for the initial pilot vessel, there could be a series of vessels.

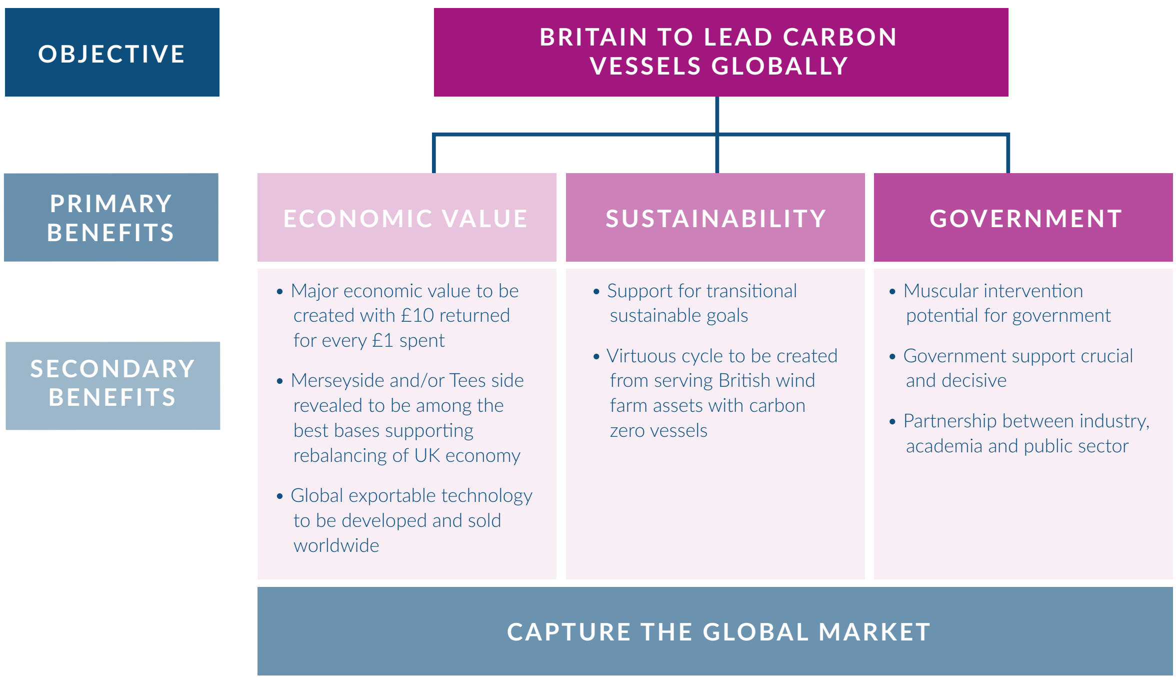
This investment is expected to bring essential economic and social returns for the whole country. Based on an analysis of the multiplier effects using the input-output tables for specific industries, it is estimated that each £1 of investment in zero carbon emission vessels will generate a return of over £10 for the UK economy. This outcome takes into consideration the building of new ships together with the benefits of servicing offshore wind farms. It means that an initial investment of £55–75 million for the first vessel in a potential series would generate £580–790 million per vessel built.

Moreover, more jobs would be created throughout the supply chain. Using the full-time equivalent (FTE) multipliers for the two relevant industries reveals that the gross effect on jobs for the UK economy would be close to 500 for every ship built, assuming an initial employment of 200 people.

There would also be catalytic effects with a long-term effect on economic growth. These include sustainability benefits, skills education, and innovation within the manufacturing location and in its supply chain, as well as the spillover effects of R&D investment, with social returns of 25–66% according to the related literature.

However, this can only be done with sufficient financial and regulatory support and a 'consortium' effort, especially given the intense international competition and the extent of such support provided in other countries, including within the EU.

The race for the transition to a carbon-free economy is well underway. Merseyside or Teesside would be optimal places to bring together all the required resources for the UK to be one of the top players globally in terms of output production. The UK is seeking to take a leading position in the transition to a greener and more sustainable economy and plans to reach zero-emission shipping by 2050. However, to achieve that goal, a series of measures needs to be taken and implemented immediately. In its Clean Maritime Plan, the government sets the pathway for a new era for the UK, but we need effective policy actions within this roadmap.



Note: Main contribution points of investment in zero carbon emission vessels.

Our findings suggest that the UK needs to take immediate action to capitalize on this unique opportunity. The UK should accelerate investments in zero carbon emission projects to catch up with other nations' attempts, which are already in place.

The platform is ready – through zero carbon shipbuilding, the country can invest to reap remarkable rewards. If the initial construction can be funded, Bibby and associated consortium partners can then invest in a series of SOVs. The resulting benefits and gains can be realized only if industry, academia, and government work closely together on a joint strategy to maximize the domestic and international success of British-made vessels serving offshore wind.

A ZERO CARBON EMISSION PLATFORM READY TO CHANGE THE MARITIME SECTOR

The next decade will prove critical for the maritime sector. Efforts around the globe have been focusing on what the optimal decarbonization options are by examining different alternative solutions. In line with international and European initiatives, the UK has set its own goals towards a zero carbon future and aspires to put green ships into operation in its waters by 2030.

A zero carbon platform is ready to be used, with Bibby Marine developing a specific enforceable plan through its R&D project on alternative fuels and technologies. A combination of onboard hydrogen and ammonia technologies (e.g. fuel cells), together with battery technology as backup, make up an ideal hybrid solution for vessels servicing wind farms.

Component 1: fuel cells

Fuel cells are an efficient technology to unlock the use of future alternative fuels. Fuel cells convert fuel into electricity and, although electricity is used for auxiliary purposes in ships, recent trends have shown that electricity can also be used for propulsion (Van Biert et al., 2016). Fuel cells can improve energy conversion efficiency to over 60%, and if waste heat is used, an 80% efficiency can be achieved (O'Hayre et al., 2016). Fuel cells can use either hydrogen or ammonia.

Component 2: hydrogen

Most ongoing pilot projects investigate hydrogen. The International Energy Agency (IEA) shows that the global demand for pure hydrogen for the period 1975–2018 has increased, illustrating that demand for hydrogen is growing. While the cost of producing hydrogen is the greatest challenge, especially for green hydrogen, forecasts indicate that it can become price-competitive compared to blue and grey hydrogen. Production costs for green hydrogen are projected to fall significantly in the next decade due to economies of scale, technological improvements, and renewable deployment. These costs have dropped by 50% since 2015 and could be further reduced by 30% by 2025 thanks to increased scale and standardized manufacturing, among other factors (Mallouppas and Yfantis, 2021). Regarding storage technologies, compressed hydrogen is currently the most accepted and used storage method in the shipping industry.

Component 3: ammonia

Ammonia is also an attractive and competitive solution. Compared to hydrogen, it allows more storage in liquid form without the need to use cryogenic storage. Moreover, the capital cost required to store hydrogen is far more expensive than ammonia, even though the energy density is similar. Nevertheless, both alternative fuels can be used as primary fuels in fuel cells (Europa Seaways and ShipFC projects).

Component 4: battery

Furthermore, evidence shows that battery technology costs for electric vehicles are rapidly falling, suggesting this technology might be a more viable and readily available option for other transport sectors such as shipping. More precisely, lithium-ion (Li-ion) battery technology is the best option and the most mature battery technology for marine application ***(Figure 1)***. Compared to lead-acid batteries, lithium batteries are considered a preferred technology in marine vehicle traction and they:

- perform better and last longer
- weigh less and take up less room
- recharges much faster
- provide a higher percentage of nominal capacity without shortening their life
- maintain voltage through almost all the discharge cycle

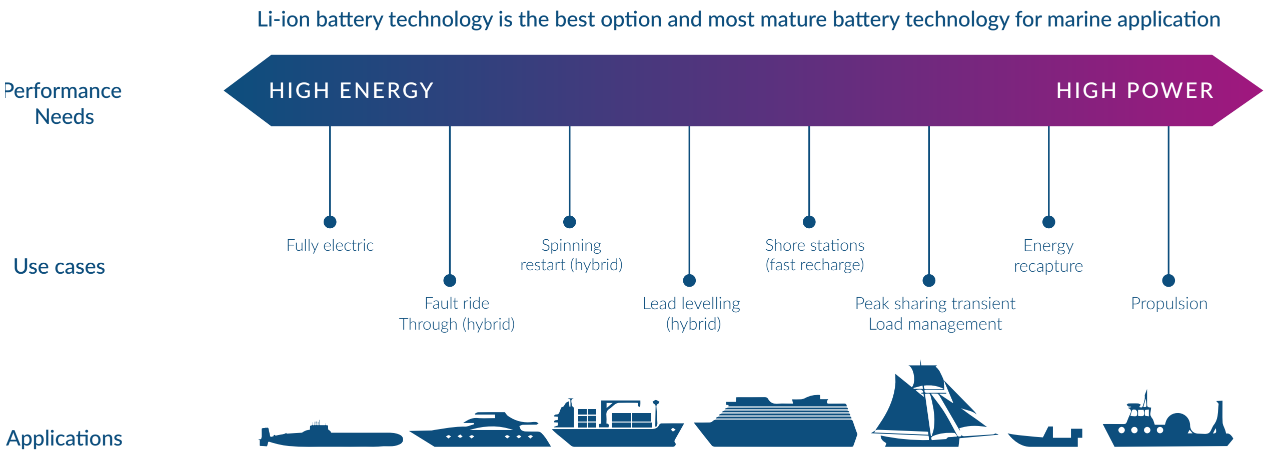


Figure 1: Li-ion battery technology in marine applications.

The zero carbon platform of hydrogen/ammonia fuel cells with battery backup seems effective for short-sea shipping. More precisely, hybrid marine engines are attractive because they can be fueled by diesel, LNG, or hydrogen, and use a fuel cell, batteries, or an electric motor (Newman, 2017). Hybridization can offer 10–40% fuel savings (DNV GL, 2016). Hybrid propulsion also allows design flexibility in order to satisfy the financial and environmental considerations of the operator (Royal Academy of Engineering, 2013). Although this option currently seems more applicable to short-sea distances and small ships, it can definitely extend to larger vessels and revolutionize the whole maritime industry.

Component 5: infrastructure

In terms of infrastructure, availability is already in place or being developed. This includes:

- the Northwest Energy and Hydrogen Cluster development of a hydrogen pipeline linking the cities of Liverpool and Manchester
- the HyNet hydrogen/carbon capture utilization and storage (CCUS) project
- the Gigastack project for industrial-scale, low-cost renewable hydrogen production through the electrolysis process.

Furthermore, port cities are perfectly positioned to help catalyze a reduction in shipping emissions[1].

The zero carbon platform is ready: Figure 2 presents a high-level overview, and much more detail is available from Bibby. In line with recently launched strategy to make the UK a scientific superpower, the government needs to promptly increase investment in zero emission vessels to catch up with global competition and gain a competitive edge in the international arena of green transition.

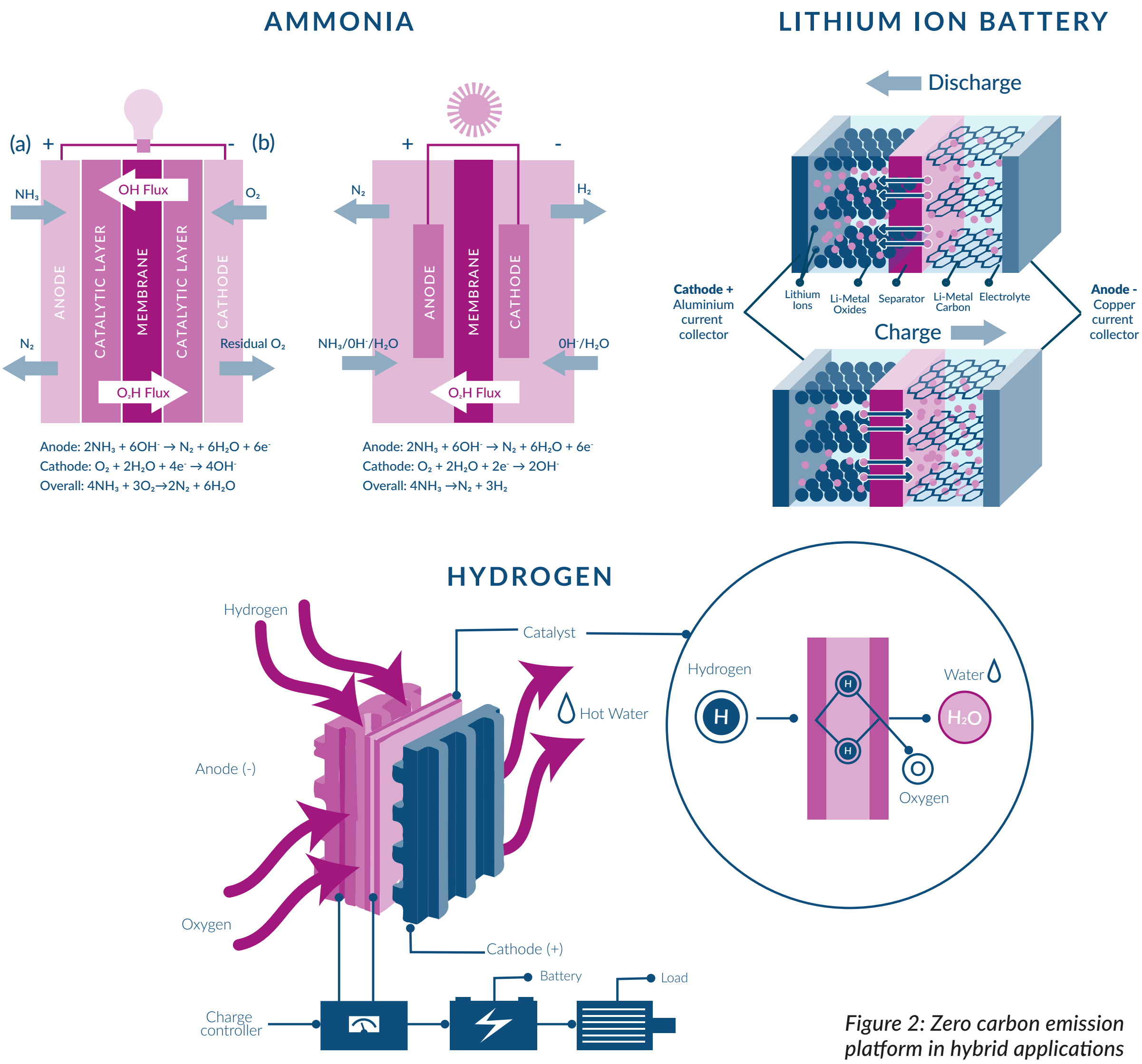
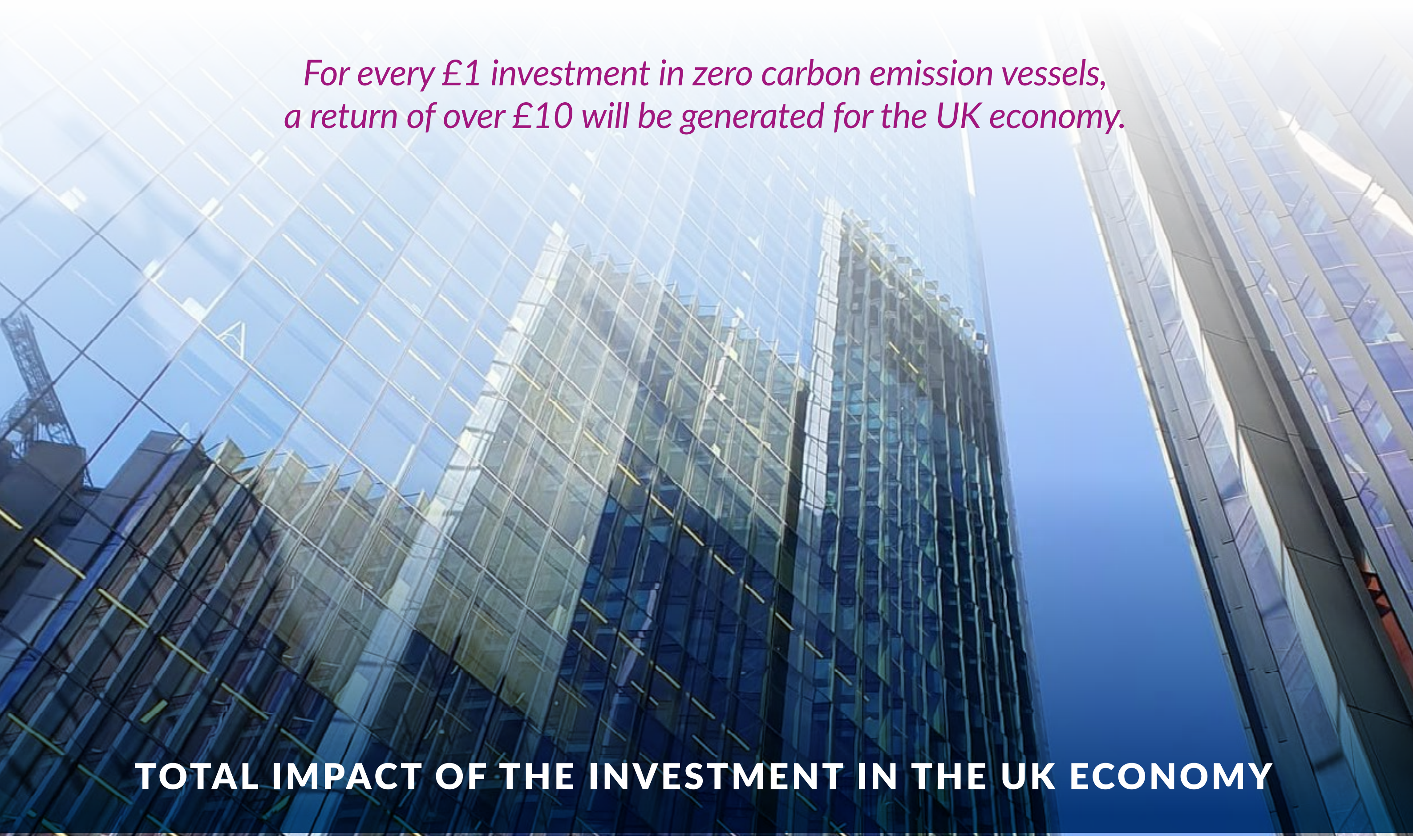


Figure 2: Zero carbon emission platform in hybrid applications

1. A port can provide clean renewable energy to ships in port – as well as to the city and surrounding industrial clusters – and support vessels on the approach to the port.



For every £1 investment in zero carbon emission vessels, a return of over £10 will be generated for the UK economy.

TOTAL IMPACT OF THE INVESTMENT IN THE UK ECONOMY

Original research by Critical Future for this report has found that for every £1 spent on this initiative, over £10 will be returned to the UK economy. The model is explained below.

The latest data (2018) from the input-output and use tables of the Office for National Statistics indicate that an investment in zero carbon emission vessels will generate returns more than four times the initial investment amount. This type of investment is foremost considered an investment in 'ships and boats'.

This result is known as the Type II variant. It contains the direct and indirect effect (Type I variant), as well as the induced effect of the multiplier.

Type I captures the impact of the £1 increase in total demand – which is equivalent to an increase in total output – plus indirect effects in the industry's upstream supply chain.

For instance:

- If there is an increase in final use for a particular industry output, we can assume that there will be an increase in the output of that industry, as producers react to meet the increased use. This is the direct effect.
- As these producers increase their output, there will also be an increase in use for their suppliers, and so on down the supply chain. This is the indirect effect (Scottish Government, 2020).
- Adding the induced effect, we account also for the employment effects resulting from employees who spend their wages in the wider economy, generating more GDP and jobs *(Figure 4).*

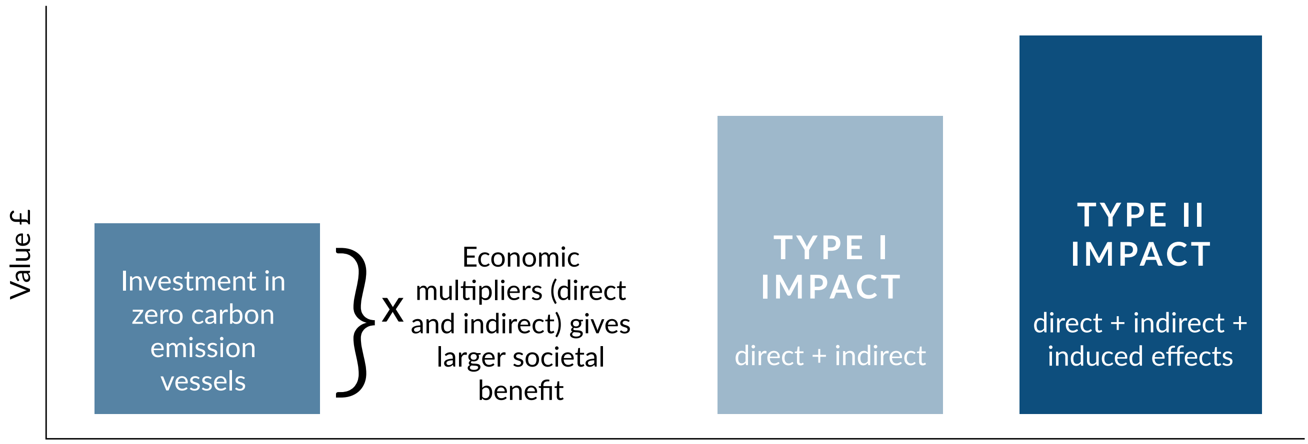


Figure 3: Graph showing the multiplying effect of an investment in zero carbon emission vessels through the direct, indirect, and induced effects.

Therefore, in our model we use the concept of multiplier ***(Figure 3)***. This is a measure of how pounds injected into the economy are respent, leading to additional economic activity.

The central multiplier is the output multiplier for the industry. This tells us the amount of output (generally reported in £ million) that is generated throughout the economy (across all industries) per £1 million of final consumption demand for the related industry's output. For example, for any increase in demand for manufactured products, there will be an increase in that industry's output. In turn, this will cause additional changes and increases in demand for intermediate inputs from other sectors, and so on.

This pattern reveals an interplay and interdependence between sectors. So, we use the input-output model, which provides a detailed analysis of the flow of products and resources within a given economy and its sectors.

Such models can be used to estimate economic multipliers for specific industries. First, we consider the Bibby project as an investment in the 'ships and boats' industry. Then we proxy the wind farm servicing by examining the 'rest of repair and installation' sector as well.

We find that the total multiplier of an investment in 'ships and boats' is 4.84. In other words, for every (z) amount of £ invested in the industry, {(z) × 4.84} total gains will be generated.

This includes:

- the 1.91 Type I multiplier ***(Figure 5)***
- the 2.93 employment effects contained in the induced impact of the Type II variant.

However, the gains are even broader if we consider the services provided by vessels in the wind farm industry. In this case, we report a total multiplier of 5.75 ***(Figure 6)***, which means that the contribution in this sector is even greater.

Besides output-accelerating effects from such investment, job creation effects could bring potential gains for the whole supply chain. Employment effects show the direct plus indirect employment change

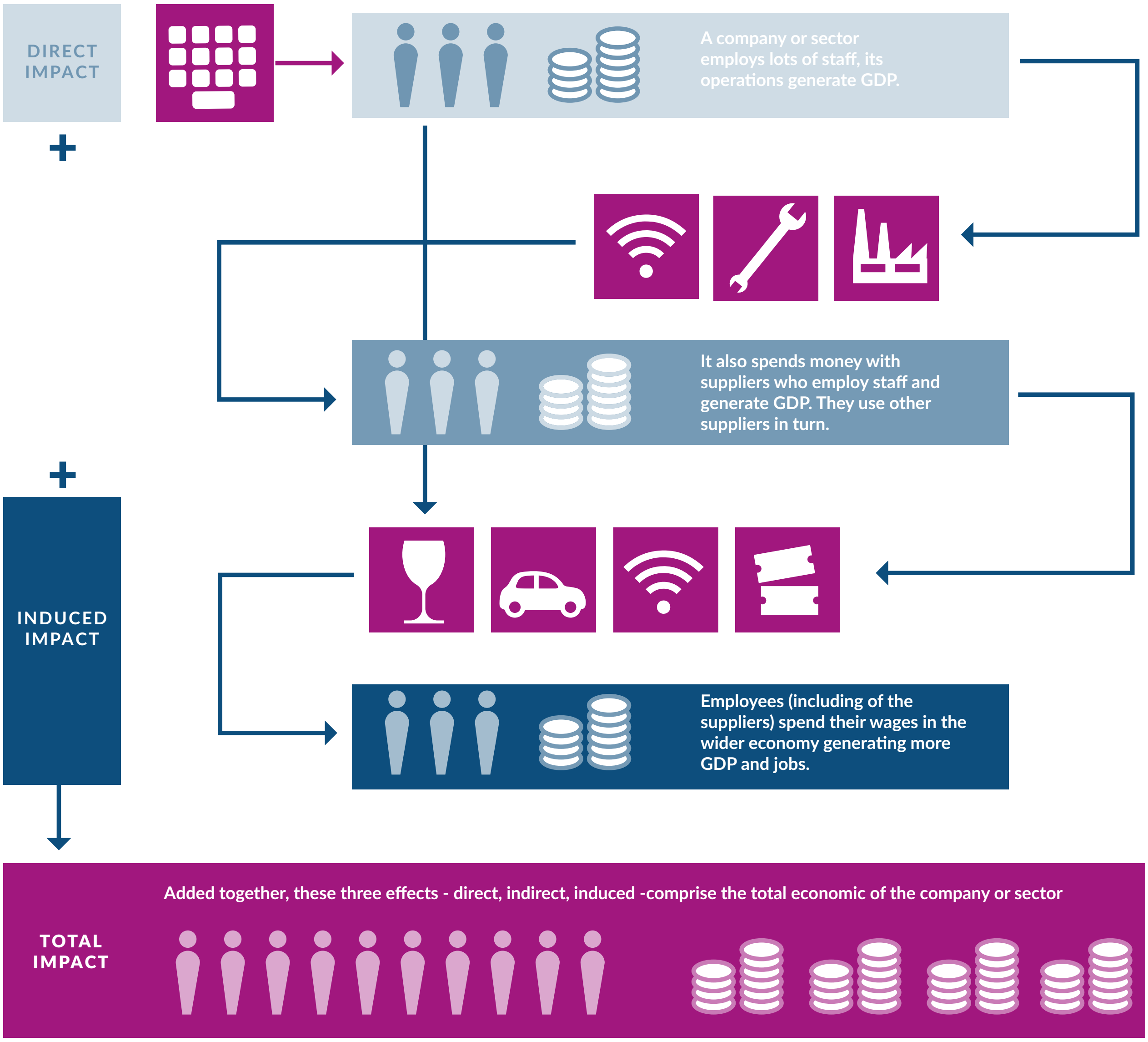


Figure 4: Infographic showing that the total impact of an investment is the outcome of the direct, indirect, and induced effects. The direct and indirect impact gives the Type I variant of the multiplier. The induced impact is provided in the Type II variant. Source: Oxford Economics, 2018.

to the direct output change due to a unit increase in final use (the Type I multiplier in our case).

In the table below, we present the FTE multipliers for the two industries relevant to our study, based on up-to-date data from the Office for National Statistics. If we assume that Bibby's investment generates 200 FTE jobs initially (a very likely scenario), then by applying the below multipliers:

- 362 direct and indirect FTE jobs would be created for the 'ships and boats' industry (200 × 1.81).
- Considering also the 'rest of repair and installation' sector, the investment will generate 332 jobs (200 × 1.66).
- The net effect on the jobs supported throughout the supply chain for the UK economy would then be an additional 294 jobs (162 from 'ships and boats' + 132 from 'rest of repair and installation').
- The final effect on job creation could be even larger if we also account for the induced effect and add the Type II variant to our calculations.

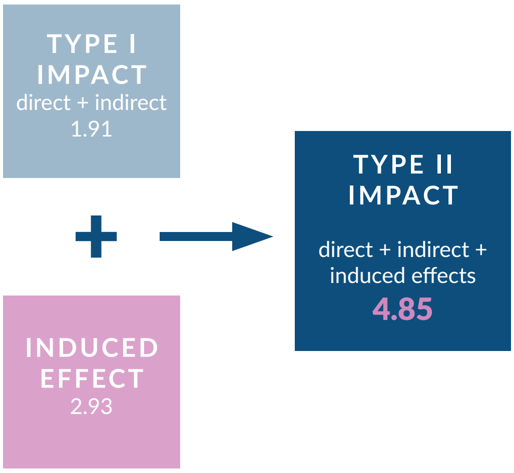


Figure 5: Total effect of an investment in zero carbon emission vessels as an investment in the 'ships and boats' industry.

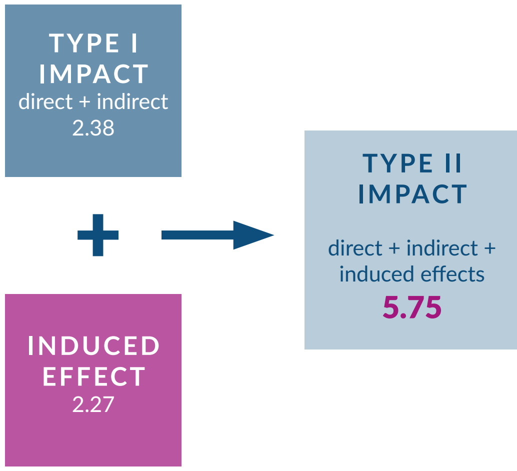


Figure 6: Total effect of an investment in zero carbon emission vessels as an investment in the 'rest of repair and installation' industry.

Besides output-accelerating effects from such investment, job creation effects could bring potential gains for the whole supply chain. Employment effects show the direct plus indirect employment change to the direct output change due to a unit increase in final use (the Type I multiplier in our case).

In the table below, we present the FTE multipliers for the two industries relevant to our study, based on up-to-date data from the Office for National Statistics. If we assume that Bibby's investment generates 200 FTE jobs initially (a very likely scenario), then by applying the below multipliers:

- 362 direct and indirect FTE jobs would be created for the 'ships and boats' industry (200 × 1.81).
- Considering also the 'rest of repair and installation' sector, the investment will generate 332 jobs (200 × 1.66).
- The net effect on the jobs supported throughout the supply chain for the UK economy would then be an additional 294 jobs (162 from 'ships and boats' + 132 from 'rest of repair and installation').
- The final effect on job creation could be even larger if we also account for the induced effect and add the Type II variant to our calculations.

Industry	FTE multiplier
Building of ships and boats	1.81
Rest of repair and installation services	1.66

Note: Type I UK employment multipliers, reference year 2015.
Source: Office for National Statistics, 2019 update.

WIDER ACCELERATING EFFECTS OF AN INVESTMENT IN ZERO CARBON EMISSION VESSELS

In addition to the direct, indirect, and induced effects of this investment, there are also catalytic effects, which have a long-term effect on economic growth.

These effects include:

- sustainability issues
- skills education
- innovation within the manufacturing location and its supply chain
- the spillover effects of R&D investment.

These contributions would accelerate the gains for the UK economy calculated above.

Sustainability benefits and protection of the environment are some of the first effects, due to carbon emission savings. Based on the estimations from the SWIFTH2 project for a daily distance route of up to 100 kilometres, these emission savings could be translated into 676 tonnes of carbon dioxide – equivalent to 147 cars off the road each year.

The technology that will be developed is going to revolutionize the whole shipping industry. But there will also be cluster effects providing essential knowledge spillovers into the rest of the shipping sector and other national industries. Spillovers from R&D are critically important for companies like Bibby Marine that serve the wind farm market, which is important for the UK economy in the production and transmission of electricity power. Such spillovers promote economic growth via productivity improvements in the use of capital and labour. According to Oxford Economics (2013), these knowledge spillovers can occur via:

- the transfer of technology, processes, and know-how through the diffusion of manufacturing standards from one firm to another, either in its supply chain or across industries
- formal or informal diffusion of knowledge within a supply chain through firms' participation in new high-technology development programmes, through supplier development activities, or through the simple migration of staff
- participation in collaborative research programmes permitting access to intellectual capital, such as through links with universities and other research institutes
- other transfers of knowledge through interlocking supply chains across industries, through either knowledge-sharing or imitation of products or technologies.

In the UK, Bibby Marine Services contributes to increased productivity and living standards across the wider community and the development of a knowledge economy. These factors support sustainable economic growth.

Catalytic effects may include:

- spillover effects of R&D spending in the region
- skills education and innovation within the region
- the wider contribution to skills education and innovation in the UK.

R&D increases productivity in a variety of ways: by improving the quality of goods, by reducing the costs of producing existing goods, and by increasing the range of goods or intermediate inputs available. Furthermore, R&D carried out in one firm can have positive spillovers to other firms or industries, as the benefits accrue to competitors, other firms, suppliers, and customers (Oxford Economics, 2013).

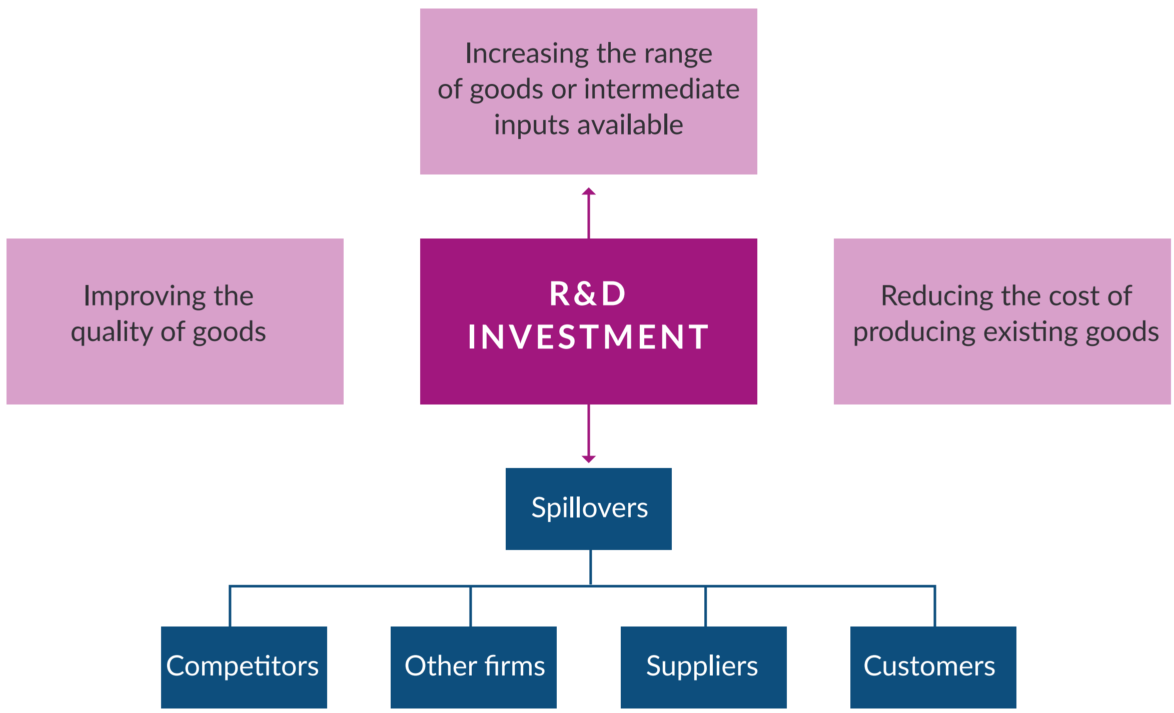


Figure 7: Productivity increases due to R&D expenditure.
Source: Oxford Economics, 2013.

R&D investment generates private and social returns. Typically, social returns to R&D are much greater than private (own firm) returns. The social benefits generated by R&D expenditure are usually measured by the sum of the producer and consumer surpluses.

Some studies have tried to measure these social returns using regression analysis across industries.

Sveikauskas (2007) found that private returns to R&D are between 10% and 26%, while social returns range between 25% and 66%. On the other hand, R&D causes increases in productivity, which can be measured by estimating the impact of R&D on total factor productivity (TFP) – an indication of the economy's long-term technological advancement.

Another study found that the long-term elasticity of TFP with respect to business R&D is 0.14, meaning that for every per cent increase in R&D, TFP increases by 0.14% (Duverger and van Pottelsberghe de la Potterie, 2011).

Based on the above economic model of input-output tables, for £1 investment in zero carbon emission vessels, a return of over £10 will be generated for the UK economy. Therefore, an initial investment falling in the range of £55–£75 million will generate approximately £580–£790 million in total output terms.

However, as discussed above, there will also be essential social gains from the R&D investment, which could be estimated at between £13.75 million and £49.5 million. These output and social gains are then distributed as shown in Figure 8: £266.2–£363 million will be generated from 'ships and boats', £316.25–£431.25 million will come from 'rest of repair and installation', and the rest will constitute the accelerator effects resulting from the green investment in R&D and the knowledge spillovers down the supply chain and across industries (e.g. £13.75–£49.5 million).

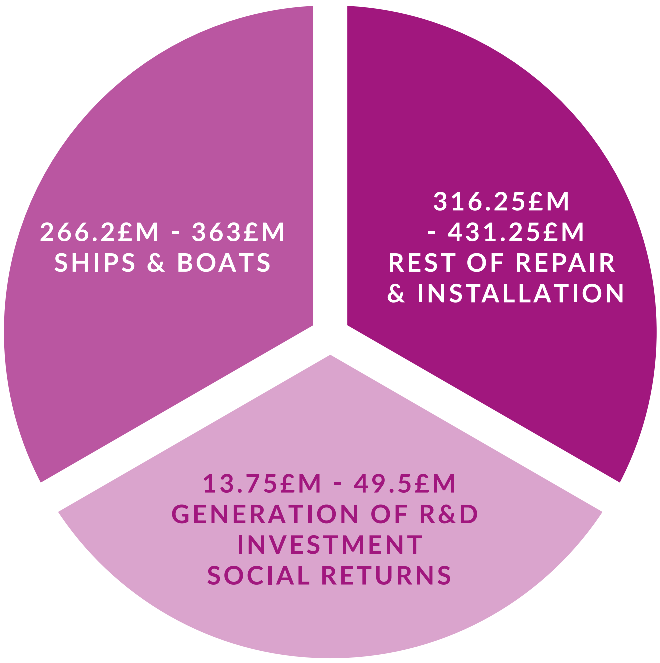


Figure 8: Decomposition of the sources of total gains from an investment in zero carbon emission vessels.

THE INVESTMENT IN GREEN SHIPS IS PROVED A VIABLE COMMERCIAL PLAN

The offshore wind market will be the key that unlocks great opportunities for the UK in terms of both green electricity power generation and clean alternative fuel production. Data shows that offshore wind capacity has increased substantially over the years ***(Figure 9)***, and the UK ranked first in capacity terms for offshore and nearshore wind turbines both in operation and under construction as of October 2019 ***(Figure 10)***.

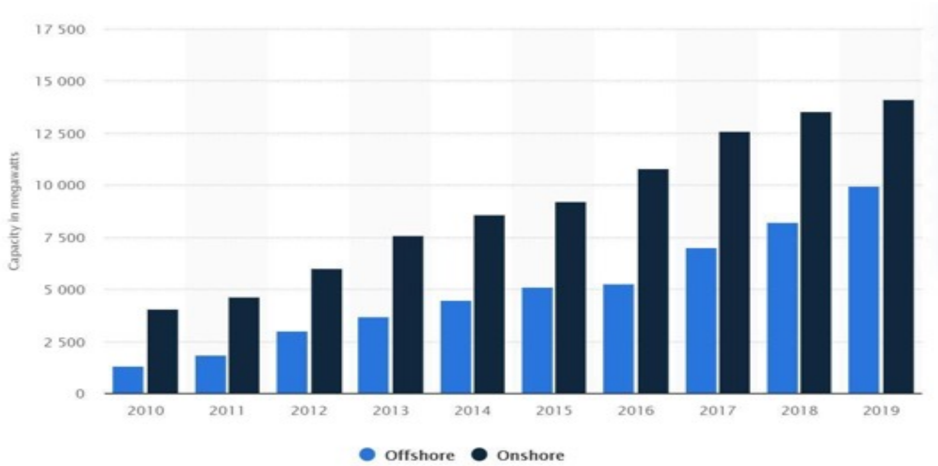


Figure 9: Offshore and onshore wind capacity in the UK, 2010–19.
Source: Statista.

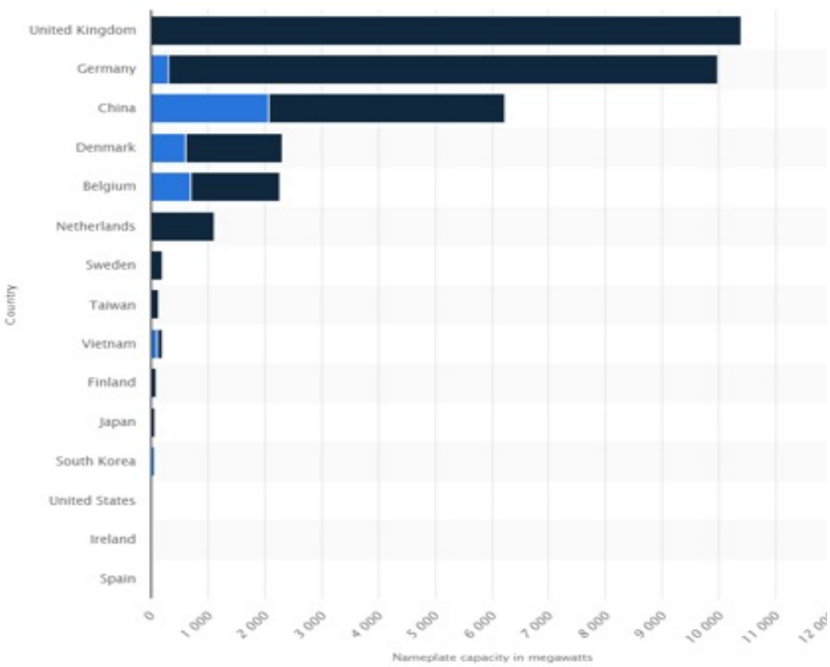


Figure 10: Capacity of offshore and nearshore wind turbines in operation and under construction, October 2019, by country.
Source: Statista.

The UK currently has over 20 GW of cumulative installed wind energy capacity, with over 10 GW provided from offshore sources. This is predicted to increase greatly in the coming years, reaching an installed offshore wind energy capacity of over 15 GW with more than 3,000 turbines in 2030 ***(Figure 11)***. The government has set an ambition to deliver up to 40 GW of offshore wind capacity by 2030. In addition, the Climate Change Committee says that the UK will need a target of 75 GW of offshore wind to meet its legally binding target of net zero greenhouse gas emissions by 2050 (The Crown Estate).

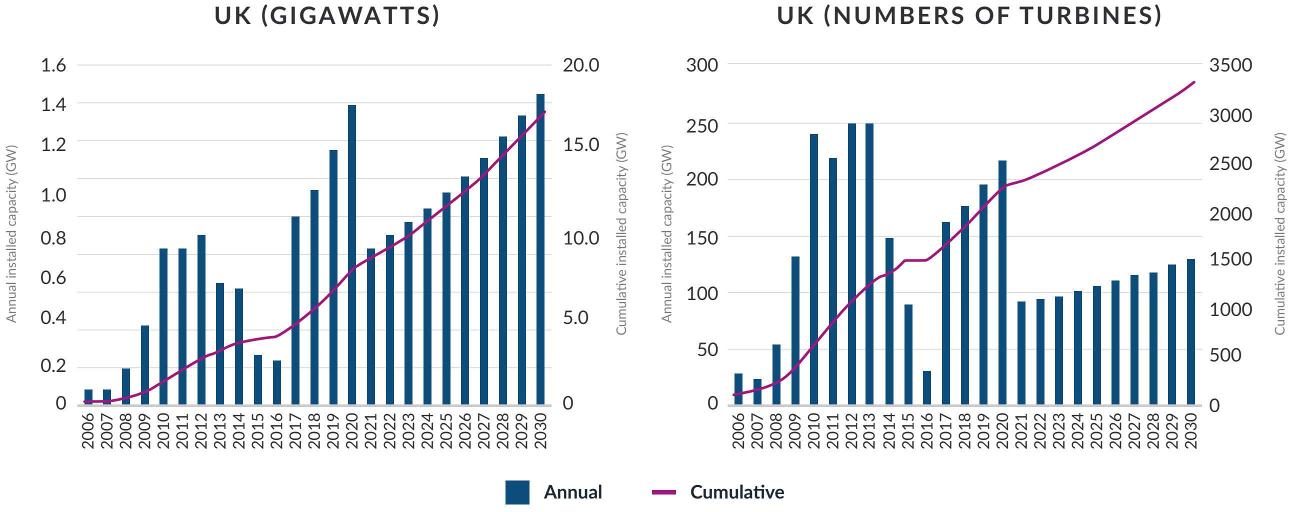


Figure 11: UK offshore wind market size by GW and by number of turbines.
Source: Catapult, 2000.

The offshore wind market will prove critical in the future. It currently provides 10% of the UK's electrical energy, and this will rise to 35% by 2030. It also provides approximately 11,000 long-term quality jobs around the UK and is projecting 27,000 by 2030. The cost of electricity from upcoming offshore wind projects has fallen by 50% within two years and is now considered the most cost-effective low-carbon pathway for large-scale generation in the UK.

Because of this, investments will increase substantially both globally and regionally. In fact, forecasts indicate a £2.5 trillion global investment in wind energy by 2040 (Offshore Wind Industry Council, 2019).

Moreover, there will be an increase in offshore floating opportunities which will play an important role for the whole market. The government commitment to deploy around 75 GW by 2050 necessitates the geographical spread of projects around the country beyond nearshore areas. This means that floating wind technology will be key to unlocking potential deep-water sites around the UK. Evidence indicates that the total (domestic and export) market for UK-provided offshore wind could exceed £10.5 billion in 2050 in a high scenario. If this happens, offshore wind projects will be among the largest infrastructure projects in the UK.

All the above provide strong evidence that there will also be an increase in demand for SOVs in the years to come. SOVs play a vital role in the functioning of offshore wind farms by safely transferring maintenance crew to offshore turbines. Many crew transfer vessel companies already have contracts in place to service offshore wind farms.

However, all ships – both new and existing – have to satisfy the goals set by major global and regional initiatives for the transition to a green economy. Bibby's investment will bring essential gains that will overcome any initial costs in terms of economic and environmental returns. The UK leads the offshore wind market, and it can absolutely drive the sustainability pathway. Evidence reveals an upcoming increase in offshore wind energy capacity and turbines installation, which will reasonably lead to a rising demand for sustainable SOVs. Both the offshore wind market and new-technology SOVs can offer great export opportunities for the

WHICH UK REGION SHOULD DEVELOP THE BRITISH-MADE ZERO CARBON VESSELS?

We have established that zero carbon vessels will return major gains to the UK and, combined with serving wind farms, deliver double impact. So where should these British-made zero carbon ships be built? Which region will contribute and benefit the most?

The UK is divided into 12 regions ***(Figure 12)***. We compare the economic and business opportunities in these areas, concluding that the North West would be an ideal base. The North East is an alternative option, as it is comparable in terms of future facilities and infrastructure and the government's Northern Powerhouse policy.

Following a comprehensive analysis of the regions, Critical Future has developed a prioritization matrix offering a quantitative score for the attractiveness of this project. The criteria in this prioritization matrix include:

- port freight tonnage
- economic value
- regeneration potential
- government support with R&D
- business environment
- connectivity quality
- wind farms
- rebalancing potential.

According to data from Statista, Liverpool was among the top three sea ports by freight in the first half of 2020. The 2019 tonnage data also shows a leading position for Liverpool. Liverpool follows after London in the South East, and Grimsby and Immingham on the East Coast, in tonnage for all cargo for both inward and outward directions ***(Figures 13 and 14)***. The Tees and Hartlepool port follows after Liverpool, with a similar amount of port sea freight.

Figure 12: UK regions. Source: UK.

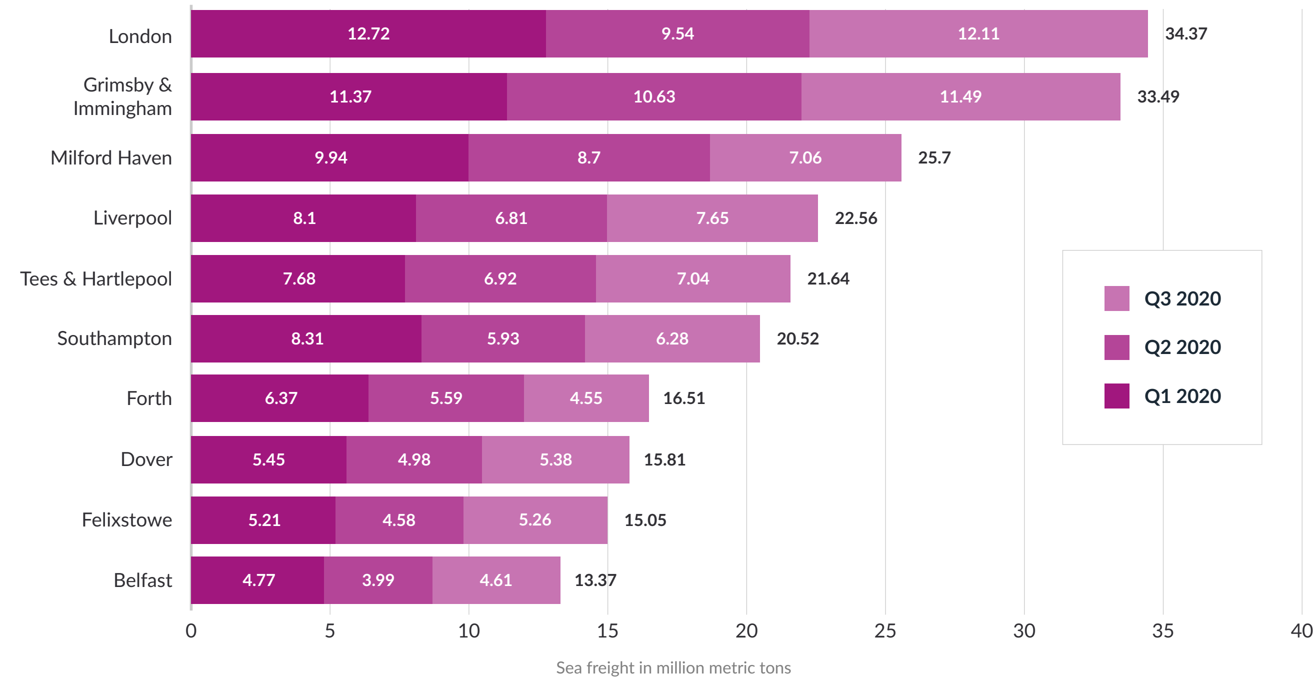
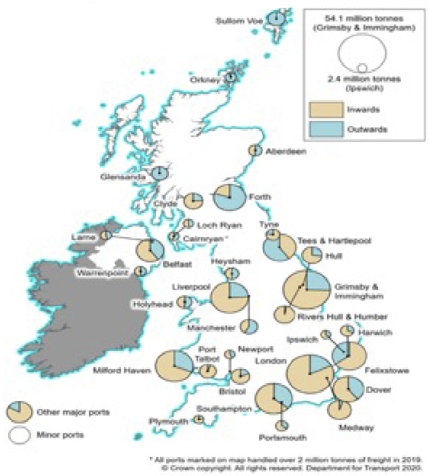


Figure 13: Sea ports freight (in million metric tons) in the UK between first and third quarter of 2020. Source: Statista.

UK PORTS BY DIRECTION



TONNAGE (THOUSANDS) - ALL CARGO, BOTH DIRECTIONS (2019)

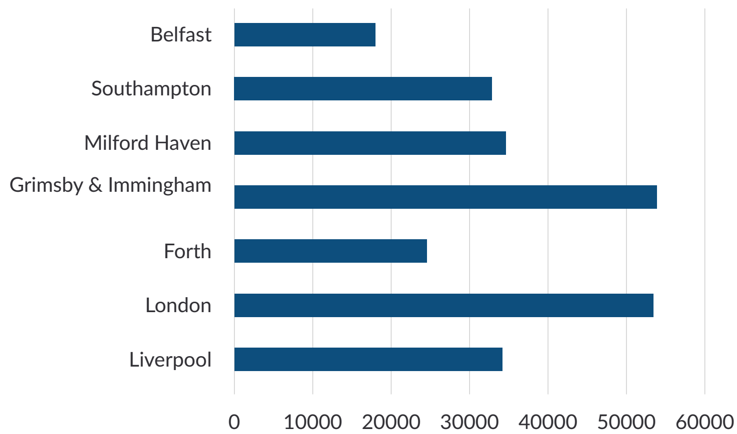


Figure 14: UK ports by direction, 2019; UK ports tonnage, all cargo (both directions), 2019. Source: Office for National Statistics.

UK Research and Innovation centre (UKRI) strongly supports R&D spending in all regions. Among its targets is the acceleration of R&D expenditure to 2.4% of GDP by 2027 and 3% in the longer term.

To reach that goal, UKRI is raising the intensity of R&D in all regions of the UK, to ensure the whole country benefits from increased public and private investment. Figure 15 shows R&D activity in 2017–18. It indicates significant concentrations of funding, skilled people, and more mature ecosystems in some of the more prosperous parts of the UK – most notably in London and the East of England.

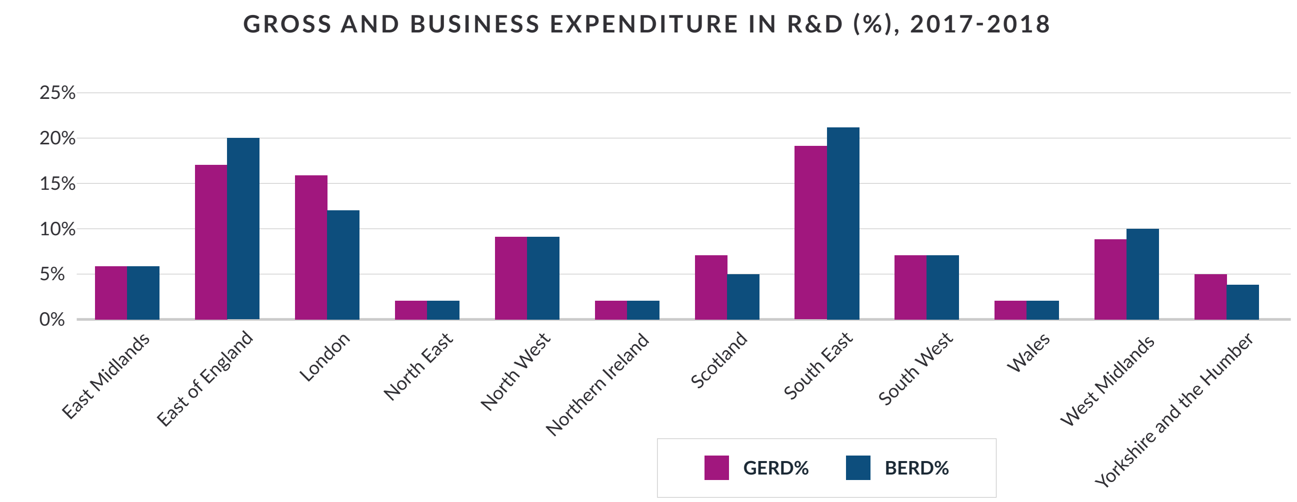


Figure 15: Gross and business expenditure in R&D (%), 2017–18.
Source: UKRI.

The whole UKRI project will be part of a wider government programme to understand the evidence on regional R&D activity and the opportunities for further investment across the country (UKRI)[2]. Looking at ***Figure 15***, the North West region comes right after the East Coast in R&D activity (excluding London and the South East). It is worth noting, though, that according to UKRI data[3], the North West receives a relatively low amount of innovative funding ***(Figure 16).***

Region	Innovative UK total allocation 2017–18 FY (£m)
East Midlands	65
East of England	114
London	214
North East	32
North West	55
Northern Ireland	9
Scotland	44
South East	184
South West	134
Wales	20
West Midlands	235
Yorkshire and the Humber	47

Figure 16: *Innovative UK total allocation by region, 2017–18, £ million.*
Source: *UKRI.*

2. To promote equal growth opportunities for each region, a £4.8 billion fund was created to level up every corner of the UK. The Levelling Up Fund, announced in early 2021, will be extended to the whole of the UK to help boost growth in Scotland, Wales, and Northern Ireland.
3. Innovate UK funding is focused on supporting UK business innovation, including in collaboration with research organizations. According to UKRI, the regional distribution of Innovate UK allocations is closely linked to the economic composition of each part of the country. The data shows large year-on-year fluctuations in funding allocations, driven in part by occasional large grants for centres such as the Catapult network.

Next, we present data on economic value for each region. Figures 36 and 37 show each region's contribution to total UK GDP and the annual growth in real GDP (%) with 2018 data. The contribution of the North West is substantial, coming right after the South East and London ***(Figure 17).*** It is also valuable to look at the dynamic contribution of each region, which is provided by the annual growth rate ***(Figure 18).*** Again, the North West shows great potential as it follows London and the East of England. The North East also presents signs of dynamic convergence, although it comes after Yorkshire, the East Midlands, and Wales.

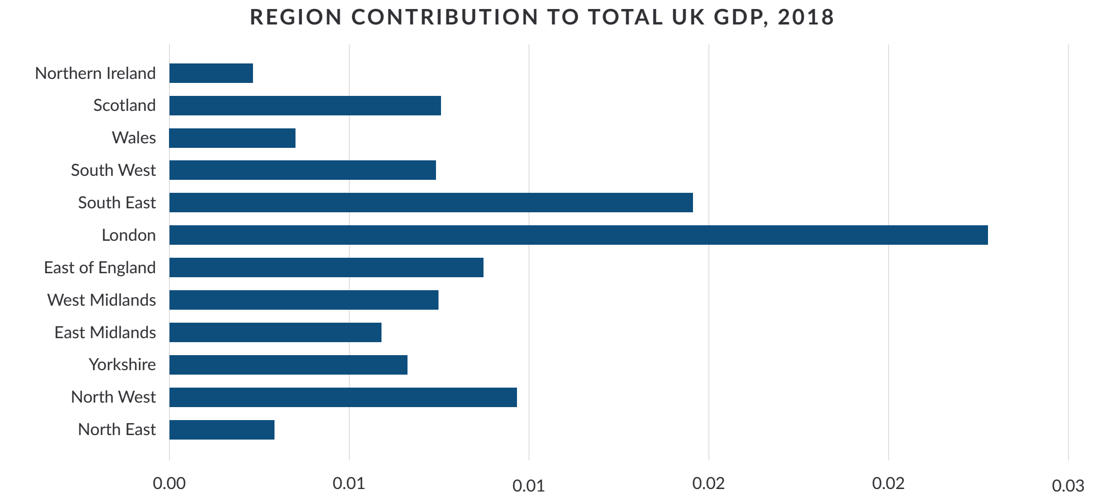


Figure 17: *Region's contribution to total UK GDP, 2018.*
Source: *Office for National Statistics, own calculations.*

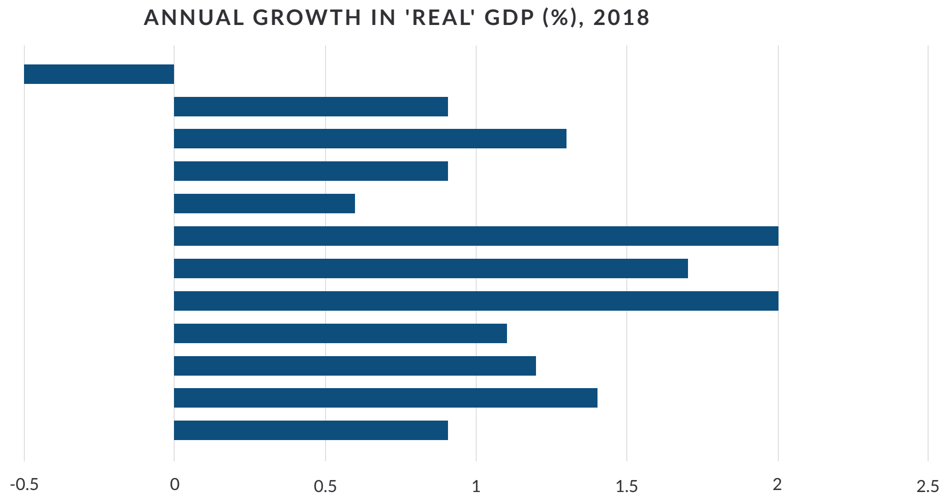


Figure 18: Annual growth in real GDP (%), 2018.
Source: Office for National Statistics.

In terms of wind capacity, the North West has the largest offshore wind capacity after the East. However, Figure 19 indicates that the North West, Wales, and Northern Ireland have the largest operational capacity. Moreover, the East of England and the North East show a dynamic potential as they plan for a capacity of 6,500 megawatts (MW) and 4,860 MW respectively.

	CAPACITY (MW)			
	Operational	Under construction	Planned	Consented
East of England	1.176	1.050	6.500	-
North East	64	40	4.860	-
North West / Wales / Northern Ireland	2.070	660	-	-
Scotland	221	688	3.450	3,259,6
South England	1.295	400	340	-
Yorkshire and the Humber	893	580	3.600	3.464

Figure 19: Offshore wind capacity by region.
Source: RenewableUK, 2017.

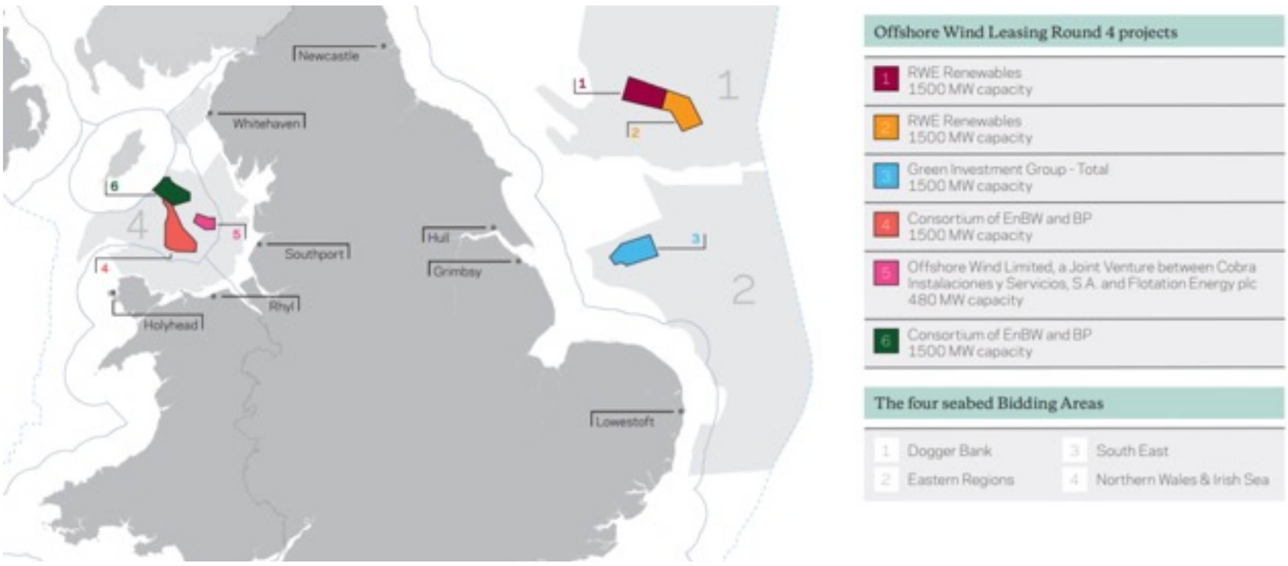


Figure 20: Offshore Wind Leasing Round 4 projects.
Source: The Crown Estate.

The Liverpool City Region is the most efficient port location to service the UK and Ireland. It is well connected by the national motorway network, rail, and water to fabrication, assembly, and operation and maintenance facilities at Cammell Laird, the Port of Liverpool, and along the River Mersey and Manchester Ship Canal.

Moreover, the Liverpool City Region has developed expertise in the movement of goods with companies such as Stobart Group and Bibby Distribution (Offshore Wind Energy Hub, Liverpool City Region). Finally, Cammell Laird, which is based in Liverpool, is among the biggest companies in the shipbuilding industry in the UK (based on market share).

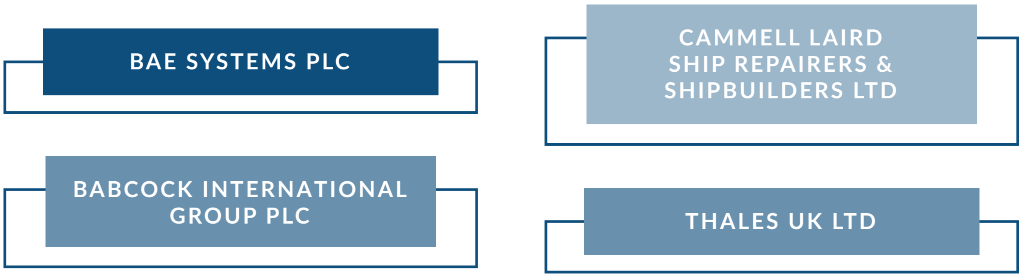


Figure 21: Top four shipbuilding companies in the UK.
Source: IBISWorld.

Based on the above evidence, we present the cluster/prioritization matrix ***(Figure 22)***, which clearly shows that the North West would be an ideal base. Alternatively, Teesside of the North East has been 'reborn as an industrial powerhouse' and will create many jobs, after the area was named as one of the eight low-tax freeports.

In addition, the US conglomerate General Electric (GE) has confirmed the building of an offshore wind blade manufacturing facility. The factory is expected to open in 2023 to supply the Dogger Bank offshore wind project 130 kilometres off the Yorkshire Coast (Financial Times, 2021). Moreover, Equinor and SSE Renewables – two of the companies behind Dogger Bank, which is the world's biggest offshore wind farm – plan to create a new base at the Port of Tyne.

It seems that there is a rebalancing potential for the North East as it enters the government's green agenda. Government funding to build green energy facilities at Teesside and Immingham will result in 6,000 new jobs. The GE investment, together with the region's new freeport status and the £20 million state funding for the creation of the Teesworks Offshore Manufacturing Centre, make the region a dynamic centre of excellence.

Cluster/ Region	Economic Value	Port Freight Tonnage	Regeneration Potential	Government Priority/ Support/R&D	Business environment	Connectivity quality	Wind farms	Rebalancing potential	Score
North West	8	7	10	9	10	10	10	9	73
South West	6	8	8	8	8	8	9	6	61
North East	9	6	6	10	9	8	9	5	62
London	10	10	6	10	9	9	8	5	68
East	8	7	6	10	8	8	9	4	60
East Midlands	4	9	7	8	7	7	10	6	58
Yorkshire and the Humber	5	9	7	6	8	8	10	6	59
North East	4	8	10	6	9	9	9	10	65
North Ireland	2	4	9	5	8	8	7	8	51
Scotland	6	5	9	7	8	8	7	8	58

Figure 22: Cluster/region prioritization matrix.
Key: Green: high score (≥65); orange: medium score (55–65); red: low score (≤55).

THE LIVERPOOL CITY REGION IS INVESTING STRONGLY IN THE TRANSITION TO A CARBON-FREE ECONOMY, GENERATING A VITAL ECOSYSTEM

The investment in zero carbon emission ships could offer the potential to regenerate Liverpool and contribute to the Northern Powerhouse ***(Figure 26).***

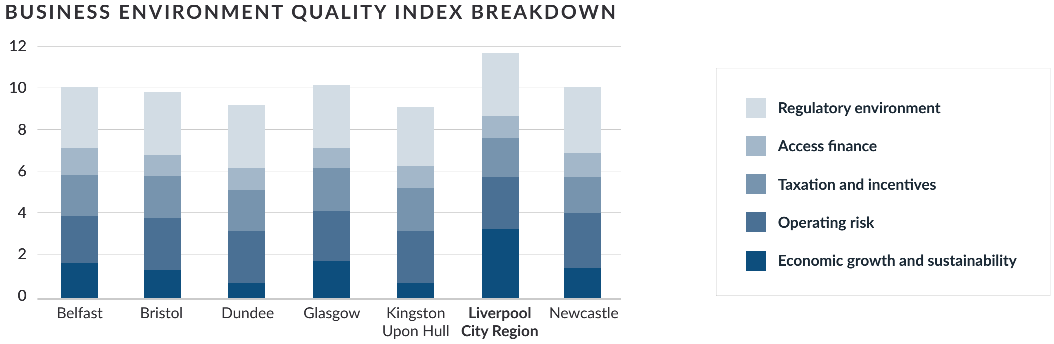
Evidence shows that the Liverpool City Region can become a global centre of excellence for the offshore wind industry. According to the Offshore Wind Energy Hub of the Liverpool City Region, the major investment by RWE at Cammell Laird helps position the Liverpool area as a key location to service Round 3 developments over the next 10 years.

The wind energy resources of the Atlantic, Irish, and Scottish waters are yet to be realized. The Liverpool City Region is also ideally situated as a base to service the potential Round 3.5 and Round 4 West Coast UK developments over the next 20 years. This will provide a long-term West Coast UK market for developers, manufacturers, and suppliers that invest in facilities in the Liverpool City Region and a long-term return on this investment, in the UK's West Coast Offshore Wind Energy Hub (Offshore Wind Energy Hub).

Moreover, Liverpool has excellent UK and European connectivity by road, rail, air, and water ***(Figure 24).*** It provides access to:

- West Coast UK offshore wind farms
- East Coast UK offshore wind hubs and offshore developments
- UK-based fabrication sites
- UK-based operation and maintenance support bases
- Northern European base harbours
- Southern European steel manufacturers and forges
- intercontinental deep-sea suppliers
- London by rail in two hours, with hourly services
- over 70 European destinations by direct air service from Liverpool John Lennon Airport.

In fact, Liverpool is the top-ranking region for business environment and connectivity quality indices ***(Figure 23).***



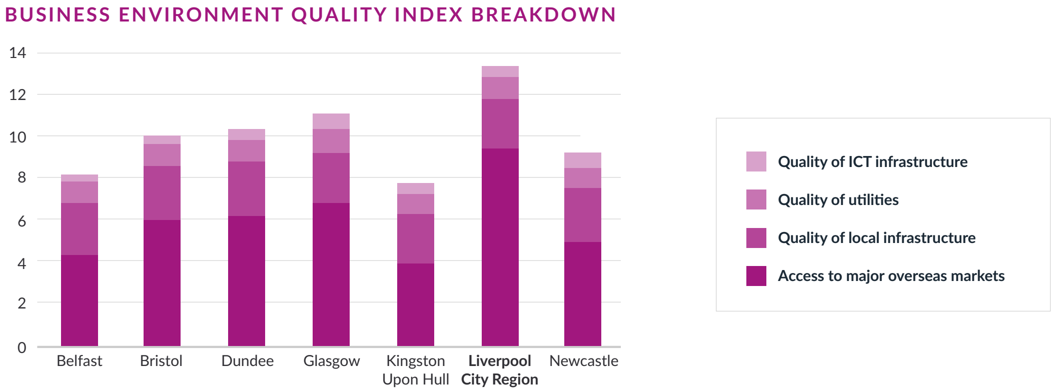


Figure 23: Business environment and connectivity quality indices.Source: Offshore Wind Energy Hub, Liverpool City Region.

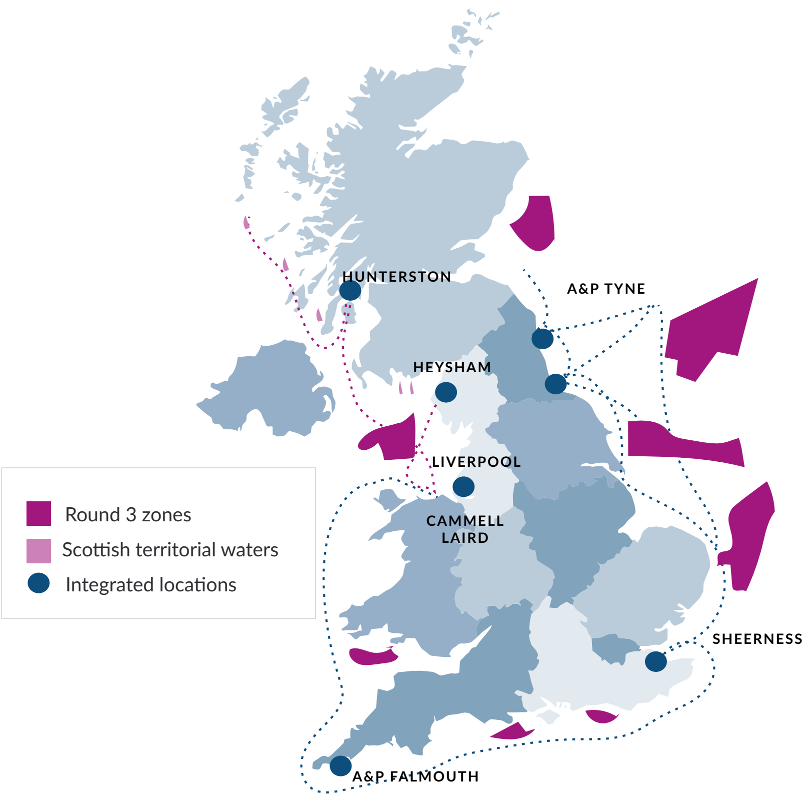


Figure 24: UK-wide assets and connectivity.
Source: Offshore Wind Energy Hub, Liverpool City Region.

Figure 25: Bibby's location between Liverpool Maritime Academy and the National Oceanography Centre. Source: Offshore Wind Energy Hub, Liverpool City Region.

Bibby is headquartered in Liverpool and can easily gain access to a range of port and harbour facilities. It is ideally suited to base port installation, manufacture and operation, and maintenance support.

The Liverpool City Region is one of very few UK locations capable of linking East and West Coast UK operations into an efficient, integrated solution for ports, landholdings, marine fabrication, and supply chain. Bibby's investment will add new potential to the area by generating economic returns together with knowledge spillovers and social returns for the whole region. It will invest in science and innovation, reinforcing the Northern Powerhouse, which aims to reposition the British economy away from London and the South East. This will contribute to the agglomeration economies, saving costs as firms are located near each other and operate in clusters.

Liverpool will also play a pivotal role in the creation of essential gains and jobs in the region, as it is going to bid for one of the 10 new freeport zones around the UK[4]. After Brexit, the government wants to level up the country by ensuring that towns, cities, and regions can benefit from the opportunities that leaving the EU brings (UK Government, 2020). It will create freeports to achieve this[5]. These innovative hubs will boost global trade, attract inward investment, and increase prosperity in the area by generating employment opportunities and valued-added benefits.

A freeport plan could boost the Merseyside economy by £739 million a year. Chris Shirling-Rooke, Chief Executive of Mersey Maritime, highlighted its importance, saying: 'Until 2012, the Port of Liverpool was the largest freeport in the UK and I hope local partners will be first in the line to bid to become one of the 10 new freeports.'

4. A freeport can be considered as an area that is inside the UK geographically, but legally outside the UK customs territory. This means that goods can be imported, manufactured, or re-exported inside the free-trade zone without incurring domestic customs duties or taxes. These are only paid on goods entering the domestic economy. Free-trade zones often also support economic activity through financial incentives like R&D tax credits, regulatory flexibility, and tax reductions (Sunak, 2016).
5. As of March 2021, the eight initial locations designated as special economic zones in the UK are: East Midlands Airport, Felixstowe and Harwich, Humber, Liverpool City Region, Plymouth, Solent, Thames, and Teesside (Financial Times, 2021).

Figure 26: The Northern Powerhouse.
Source: mcginley.co.uk.

The main advantage of freeports is that they encourage imports by lowering duties and paperwork costs. In addition, manufacturers inside the freeport can benefit from cheaper imported inputs compared to those outside the area (Institute for Government, 2020). All the above, together with the huge investments in green alternative fuels, indicate the transformation of the Liverpool City Region into a vital ecosystem for the UK.

Furthermore, all the latest developments and projects in the Liverpool City Region point to hydrogen exploitation. Recent reports have highlighted that converting the UK's gas grid to hydrogen could play a pivotal role in meeting the emissions reduction target. In fact, it is widely accepted that this option is the 'least regrets', lowest cost decarbonization option for the UK's energy consumption.

A recent study by Mouli-Castillo et al. (2021) shows that geological hydrogen storage capacity exceeds the UK's heating seasonal storage needs. The study focuses on maintaining the existing gas distribution network. It finds that, to balance the significant annual cyclicity in energy demand for heating, hydrogen could be stored in gas fields offshore and transported via offshore pipelines to the existing gas terminals and into the gas network. Only a few offshore gas fields are required to store enough energy as hydrogen to balance the entire seasonal demand for UK domestic heating.

Gas network operators and the government are currently working to demonstrate the technical feasibility, costs, and relative safety of converting the gas network to either 100% hydrogen or a methane/hydrogen blend. The gas distribution networks have plenty of unused capacity – more than would be required to meet the additional energy transportation requirements to displace petrol and diesel (Liverpool-Manchester Hydrogen Hub, 2017).

The North West Energy and Hydrogen Cluster covers the traditional industrial powerhouses of the Liverpool and Manchester City regions, as well as Cheshire and Warrington. It plans to create the UK's first carbon industrial cluster by 2030 by investing in the development of a North West Hydrogen Hub base at Protos. The Protos development is ideally situated to provide access both to shipping and to all hydrogen chain components. In addition, the Manchester–Liverpool corridor will have a significant role in solving the UK's energy trilemma, as they are already working on the development of a hydrogen pipeline linking the cities of Liverpool and Manchester. This will facilitate the development of refuelling points in the region **(***Figure 27***)**.

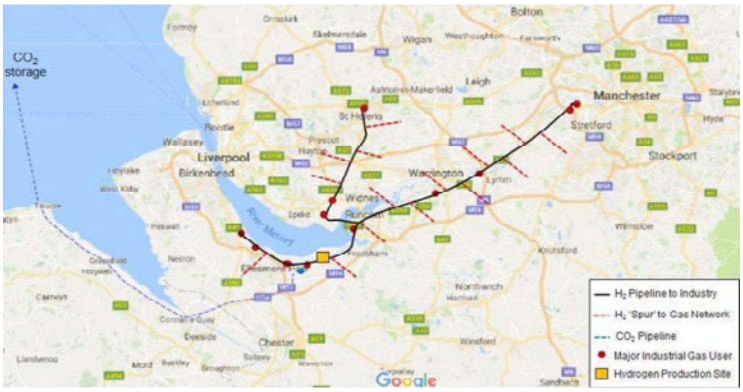


Figure 27: Cadent's proposed hydrogen pipeline.
Source: Liverpool-Manchester Hydrogen Hub, 2017

The Cluster is also home to HyNet, one of the country's leading hydrogen/CCUS projects. HyNet brings an integrated approach to low-carbon hydrogen production using CCUS and distribution of hydrogen for transport, industry, and domestic heating (North West Business Leadership Team, 2019). According to recent evidence, Indian energy company Essar plans to build the UK's biggest low-carbon hydrogen production hub to help the country's transition to a more environmentally sustainable economy. This £750 million investment will be made jointly with Progressive Energy as part of its HyNet scheme: a greater project that aims to supply low-carbon hydrogen to industrial sites and homes in North West England. The plan predicts the building of two plants by Essar next to its Stanlow refinery on the Mersey Estuary. Natural gas and fuel gases from the refinery will be converted into low-carbon hydrogen, with carbon dioxide captured and stored in depleted undersea gas fields 60 kilometres offshore in Liverpool Bay. The refinery will then be converted to burn hydrogen instead of natural gas.

HyNet is already making trials for hydrogen power with Pilkington at Port Sunlight on the Mersey. If the trial is successful, Cadent, which owns the local gas infrastructure, will build the supply pipelines that will feed households and potentially ships and trains across the North West.

Major projects are taking place on the East Coast, too. An interesting UK project for industrial-scale, low-cost renewable hydrogen production through the electrolysis process is the Gigastack project, which is located in the Humber region. It is being undertaken by a consortium led by ITM Power, an electrolyser systems manufacturer based in Sheffield. The other partners are wind power producer Ørsted, oil refining company Phillips 66, and low-carbon energy consultant Element Energy. The design of a 5 MW electrolyser stack was developed and an initial feasibility study was completed as part of phase one of the project in September 2019. It is now in phase two, which will conduct a front-end engineering design (FEED) study for the deployment of a 100 MW electrolyser system at the Humber Refinery in North Lincolnshire, operated by Phillips 66.

Gigastack received £7.5 million funding from the Department for Business, Energy and Industrial Strategy (BEIS)[6], in February 2020. It is one of the five demonstration-phase projects related to bulk hydrogen production and supply in the UK[7]. The FEED will incorporate staged installations of electrolyser module systems using ITM Power's new generation polymer electrolyte membrane (PEM) electrolyser stack technology. The power required for the electrolysis process will be sourced from Ørsted's 1.4 GW Hornsea Two offshore wind farm, and the hydrogen generated at the electrolyser facility will be used for carbon-free refining processes at the Humber Refinery.

6. he BEIS innovation fund includes a £90 million ($115 million) package in support of the UK's 2050 net zero greenhouse gas emission target.
7.The other projects that received BEIS funding are: i) Dolphyn, led by Environmental Resources Management Limited (ERM) with a contract value of £3.12 million; ii) Acorn Hydrogen Project, led by Pale Blue Dot Energy (PBDE) with a contract value of £2.7 million; and iii) Bulk Hydrogen Production by Sorbent Enhanced Steam Reforming (HyPER) project, led by Cranfield University with a contract value of £7.44 million.

BIBBY MARINE COULD BOOST THE MERSEYSIDE ECONOMY AND HELP TO STRENGTHEN LIVERPOOL AS A MAJOR INDUSTRIAL AREA IN THE UK

The race for the transition to a carbon-free economy has started and it is expected to bring economic, social, and ecological gains. The UK is well positioned in the global arena. However, to lead the trail it needs to accelerate R&D investment expenditure together with other structural reforms like freeports and funding opportunities.

The Liverpool City Region can bring together all the required resources to keep the UK in a world-leading position in terms of output production.

Bibby Marine, a company with more than 200 years of history, is headquartered in Liverpool and is a valuable member of the Mersey Maritime Cluster.

Bibby WaveMaster 1

BIBBY MARINE LIMITED

Bibby Line Group, the oldest independent deep-sea shipping line in the world[8]

Bibby Marine Limited is one of the five companies belonging to the Bibby Line Group, which is headquartered in Liverpool. Bibby Line Group is a diverse, £800 million global business. It operates in 14 countries and employs around 4,000 people in sectors including retail, financial services, distribution, marine, and infrastructure. With a history going back to 1807, when it was founded by the first John Bibby, it is considered the oldest independently owned deep-sea shipping line in the world.

Among many milestones in its history, in 1970 Bibby Line was awarded the highest honour that can be bestowed on a UK company – The Queen's Award to Industry. In 1976 and 1982 it won The Queen's Awards for Export Achievement, and in 2001 the Queen's Award for Enterprise. In 1982, Bibby Line began to diversify its maritime business to include interests such as Coastels and jackup platforms. The whole process resulted in the creation of Bibby Marine Limited, the holding company for Bibby Marine Services and Bibby Maritime.

8. https://bibbylinegroup.co.uk/ and https://bibbylinegroup.co.uk/companies/bibby-marine/

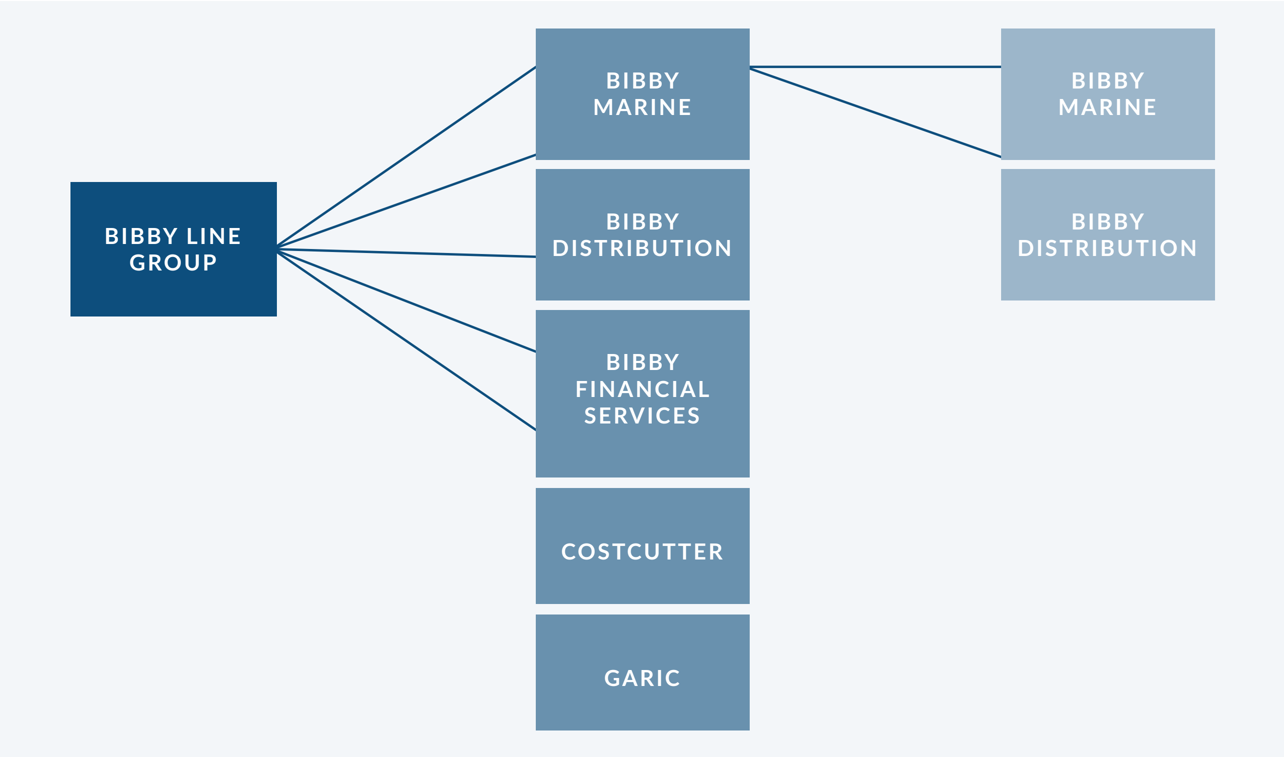


Figure 28: Chart showing Bibby Line Group's composition today.
Source: Bibby Line Group.

Bibby Marine Services owns and operates bespoke offshore SOVs and walk-to-work vessels, while Bibby Maritime is occupied with floating accommodation for many projects across the world in different industries.

Of the greatest accomplishments of Bibby Marine Services was the award-winning Bibby WaveMaster 1, which was launched in 2017 to serve the marine needs of offshore wind farm operators. WaveMaster 1 maximized working time, comfort, and safety for up to 30 days at a time. Her success was remarkable, so Bibby Marine Services secured a built-to-tender sister vessel, the Bibby WaveMaster Horizon. Both SOVs contribute significantly to the offshore wind market, providing unique walk-to-work technology that allows crews to access turbines directly.

Addressing the major challenges of the offshore wind industry, both Bibby SOVs projects drive innovation by offering high-quality services for staff and crew. It isn't practical to transport maintenance crews to and from the offshore wind parks every day because of working conditions and their distance from the shore. What's more, competition between the offshore wind industry and the offshore oil and gas industries means there is a need for innovative practices. Bibby Marine Services stands out with two solutions – WaveMaster 1 and WaveMaster Horizon.

WaveMaster 1 is equipped with a motion-compensated transfer gangway to allow maintenance personnel to walk between the vessel and an offshore structure. This offers safety and support in the harsh working conditions of the wind parks. Its development has been driven mainly by functional requirements, based on feedback from potential end users, offering storage facilities and accommodation enabling staff and crew to stay out at sea for up to one month. WaveMaster Horizon was built for the same purposes, incorporating appropriate modifications.

Figure 29: Bibby WaveMaster Horizon.
Source: Bibby Marine Limited.

Bibby Marine Limited develops and maintains high standards of corporate social responsibility, investing both in giving back to society and in the protection of the environment. The company is socially accountable, supporting local and national projects with its Giving Something Back programme. It also participates in the Apprenticeship Levy programme, investing in the continued professional development of its employees and stressing the importance of effective leadership as integral to both individual and company-wide success. Integrating effective leadership skills and education into every company's system of operations improves motivation, augments performance and allows for growth and lasting success. Finally, Bibby participates in the UK tonnage tax programme which was introduced in 2000. Tonnage tax is a core part of the government's approach to boosting the UK fleet and increasing the number and training of seafarers.

CAN THE UK LEAD THE WORLD IN BUILDING ZERO CARBON VESSELS?

Insights from expert interviews[9]

We have found strong support for this initiative in our interviews with leading figures in the maritime and renewable energy fields, in both the public and private sectors.

Sir Michael Bibby envisages a sustainable future for the company. He said: 'It is not all about making profit; we need to create something good for the long-term future.' He believes that now is the right time to ask for government support for this investment, which will add value and expertise in the UK. Besides, it is a technology that the UK can absolutely export in the form of a final product or consultancy services.

Chris Shirling-Rooke, Chief Executive of the Mersey Maritime Cluster, foresees a 'Global Britain' with Liverpool an important centre of excellence. He said: 'The UK can lead the world. It has everything needed – shipyards, companies, technology, and a high skill base. Hence, the building of green ships is something that has to be British. We have all the resources.'

Rupert Hare, Chief Executive of Houlder Ltd, agrees that the UK has the capabilities to build these vessels. He said: 'We have all the facilities and we have done it before – we can absolutely do it again.'

Cammell Laird is among the top five shipbuilding companies in the UK and it is headquartered in Liverpool. David McGinley, Chief Executive of Cammell Laird, foresees great opportunities and regeneration potential in the region if these 'green' ideas are brought about. He said: 'Bringing zero

9. We would like to thank the following people for their valuable insight into this study: Sir Michael Bibby, CEO of Bibby Line Group; Tom Chant, CEO of Society of Maritime Industries; Tristan Chapman, Senior Vice President of Clean Energy at Lloyd's Register; Tony Graham, former COO of Cammell Laird; Rupert Hare, CEO of Houlder Ltd; Charles Haskell, Maritime Decarbonisation Hub Program Manager, and Katharine Palmer, Global Head of Sustainability for LR's Marine and Offshore business at Lloyd's Register; David McGinley, CEO of Cammell Laird; Mark Lawther, Head of Sales at Harland & Wolff; Rob Osborne, Support and Innovation Engineer at Bibby Marine Services; Chris Shirling-Rooke, CEO of Mersey Maritime Cluster; Seena Shah, Head of Marketing and Communications at Harland & Wolff; Robert Speht, experienced consultant in offshore wind; John Strang, Marine Sector Manager, Department of International Trade; Len Taylor, Northern Power House Sector Specialist Offshore Wind and Renewables.

“The UK can lead the world. It has everything needed – shipyards, companies, technology, and a high skill base.”

Chris Shirling-Rooke, Chief Executive of the Mersey Maritime Cluster

carbon emission vessels in Britain the next 10 years is absolutely a doable project and Cammell Laird is a good place to build these ships.’

Based in Belfast, Harland & Wolff Group is another major shipbuilding company that supports this investment. Seena Shah, Head of Marketing and Communications at H&W, believes that Brexit gives good options to achieve net zero. She said: ‘We need to create the environment and every pound spent in the UK can bring even greater gains.’

Moreover, Liverpool is leading major projects on hydrogen exploitation, trying to make onshore infrastructure available in the next few years. Sir Michael Bibby believes that a hybrid solution would be best for Bibby’s ships. Also, Rupert Hare suggests that Bibby needs to consider future requirements and avoid any costly retrofitting by investing in hybrid solutions.

Tony Graham, former Chief Operating Officer at Cammel Laird, foresees huge potential in Liverpool: ‘There are wind farms, and we can produce low-cost hydrogen. The city wants to become hydrogen-friendly and it already invests in hydrogen fuel cells on buses.’ He also mentioned that one of the crucial issues for both shipyards and shipowners is de-risking factors.

Robert Speht, an experienced consultant in offshore wind, strongly believes that it is technically feasible to bring zero emission vessels in the next decade. Regarding the optimal technology for Bibby’s ships, he said: ‘Battery electric is not a stand-alone option, but a fuel cell powered with hydrogen could be a solution.’

Nevertheless, Tristan Chapman, Senior Vice President of Clean Energy at Lloyd’s Register, believes that hydrogen is not the full answer. Chris Shirling-Rooke provided the same feedback. Moreover, Rupert Hare forecasts an increase in demand for electricity.

One certain conclusion is that decarbonizing shipping has to be a coordinated attempt, and partnerships need to be brought about in order to request government support. As Chris Shirling-Rooke said: ‘It is definitely a consortium project accelerating good ideas.’

Although many companies may enter a period of uncertainty on which is the best solution, policymakers have to secure funds to accelerate investments and make the UK a global leader.

Moreover, Len Taylor, Northern Powerhouse sector specialist, highlights the fact that this coordinated attempt needs to focus on all parts of the supply chain. ‘We have to make green all the components involved till the final stage of bringing the ship in sea,’ he said.

Bibby Marine and many companies in the Liverpool City Region work towards this target and contribute to the creation of a highly integrated ecosystem of high skills and technology know-how that will generate economic and social returns for the whole region.

RECOMMENDATIONS FOR POLICYMAKERS

Through its Clean Maritime Plan, the government sets out the path to a new era for the UK. But what are some of the critical initial steps in this roadmap?

We have developed a clear 10-step plan for policymakers.

1. Collaborate with industry, academia, and government to develop policies that meet the needs of all stakeholders and draw on their collective intelligence.
2. Issue calls addressed to all UK regions to gather data and evidence for the specific domestic needs of each area. This way, authorities will be able to suggest and offer targeted solutions.
3. Support major English ports and speed up the freeports bidding process.
4. Fund by accelerating MarRI-UK support and other funding towards the clean maritime sector. Allocate funds in less prosperous areas and maritime clusters. The British banking sector and the government should work in partnership to secure funds for developing and manufacturing zero emission shipping technology.
5. Rebalance the policy agenda towards the Northern Powerhouse enhancement.
6. Capitalize on the UK competitive edge in alternative fuels like hydrogen and ammonia and speed up the R&D and facilities construction phase.
7. Review the existing legislative framework on greenhouse gas emissions regulations and establish new rules regarding the appropriate use and the relevant requirements and specifications of alternative fuels.
8. Reconsider the licensing regime in the post-Brexit landscape to support investments and key UK industries.
9. Prioritize zero carbon emission vessels that service the wind farm industry – an essential sector for the UK. The government should set the domestic market as a priority to achieve carbon-neutral by 2030. This is why funding should be allocated initially towards domestic short-distance green ships.
10. The timing is opportune, but international competitive threats are growing. The UK must act now, capitalizing on the post-Brexit landscape, to drive growth in key British industries and support triple bottom line impacts.

9. We would like to thank the following people for their valuable insight into this study: Sir Michael Bibby, CEO of Bibby Line Group; Tom Chant, CEO of Society of Maritime Industries; Tristan Chapman, Senior Vice President of Clean Energy at Lloyd's Register; Tony Graham, former COO of Cammell Laird; Rupert Hare, CEO of Houlder Ltd; Charles Haskell, Maritime Decarbonisation Hub Program Manager, and Katharine Palmer, Global Head of Sustainability for LR's Marine and Offshore business at Lloyd's Register; David McGinley, CEO of Cammell Laird; Mark Lawther, Head of Sales at Harland & Wolff; Rob Osborne, Support and Innovation Engineer at Bibby Marine Services; Chris Shirling-Rooke, CEO of Mersey Maritime Cluster; Seena Shah, Head of Marketing and Communications at Harland & Wolff; Robert Speht, experienced consultant in offshore wind; John Strang, Marine Sector Manager, Department of International Trade; Len Taylor, Northern Power House Sector Specialist Offshore Wind and Renewables.

The importance of acting now in building British zero carbon assets

By 2025, the government expects all vessels operating in UK waters to maximize the use of energy efficiency options. All new vessels ordered for use in UK waters are being designed with zero emission propulsion capability.

However, the country can rely on its own resources to build these new sustainable ships. Attempts from around the world are taking place and the UK needs to stand at the forefront. The country can service its wind farms by building its own green vessels. But this needs to be done promptly.

Edda Wind, the offshore wind segment of the Østensjø Group in Norway, has signed long-term time charter agreements with MHI Vestas and Ocean Breeze Energy for two of the four offshore wind vessels ordered from Spanish yards. Edda Wind has signed a construction contract for two commissioning service operation vessels (CSOVs) at Astilleros Gondan and a construction contract for two SOVs at Astilleros Balenciaga in northern Spain. The second SOV and the second CSOV will both be delivered in the fourth quarter of 2022. However, the charter agreement with MHI Vestas for a new-build SOV will start in the second quarter of 2022, while the charter agreement with Ocean Breeze will start in the first quarter of 2021. The CSOVs are 88.3 metres and the SOVs 82.4 metres long. The vessels will be delivered with a hybrid propulsion system that can reduce greenhouse gas emissions. Later on, they will also have the potential for a zero emission hydrogen technology installation. Moreover, there is another vessel under construction. The Wind of Hope is being built at Cemre Shipyard in Turkey for vessel owners Louis Dreyfus Armateurs. It is expected to operate at the Hornsea Two wind farm in early 2021. This is also an example of a hybrid electric vessel with a ship length of 84 metres.

These facts indicate an immediate acceleration in SOV building, which means some of the first zero carbon emission vessels will be entering service in the next two years. If the UK government wishes to compete in international markets and gain a competitive edge, achieving its net zero emissions targets at the same time, it will have to take immediate action and support the construction of British zero carbon assets to serve the wind farm industry. The UK could stand to achieve significant success domestically and globally by investing more than its competitors.

On the other hand, increases in investments in the offshore wind industry show that in the years to come, the already substantial economic impact of offshore wind is going to be remarkable.

These benefits and potential gains can be realized only if industry, academia, and government work closely together on a joint strategy to maximize the domestic and international success of British-made vessels serving offshore wind. The government can kick-start this process by funding the initial construction of a minimum carbon offshore vessel (SOV) in conjunction with Bibby Marine.

Close collaboration between government, industry, and academia to ensure the promising future for the country in the shipping industry.

Accelerate MaRI-U funding towards clean maritime sector and speed up the process of freeports.

Government should work in partnership with the British banking sector to secure funds towards zero emission technology.

Government should issue calls addressed to all UK regions to gather data and evidence for the domestic specific needs for each area. Offer targeted solutions and allocate funds in less prosperous areas and maritime clusters.

Government should maximise the huge potential of the UK's electricity energy generation from offshore wind farms.

Re-consideration of the licensing regime to support investments.

Give priority to zero carbon emission vessels that service the wind farm industry – an essential sector for the UK.

A priority for the domestic market in order to achieve carbon neutrality by 2030.

Figure 30: *Top five policy recommendations for the government to enhance offshore wind industry.*

CONCLUSIONS & RECOMMENDATIONS:
a once-in-a-lifetime opportunity for the United Kingdom of Great Britain

The UK has a unique opportunity to lead the world with British-made zero carbon vessels serving wind farm assets. This will provide collateral benefits:

1. Reinvigorating British shipbuilding: once the envy of the world, it has since suffered relative decline but has the skills, assets, and capabilities to drive this world-changing technological opportunity.

2. Meeting sustainability targets: driving down carbon footprints in maritime, initially in the UK but later globally, supporting one of the major emitters of greenhouse gases, the global maritime industry, to become carbon-neutral. A phenomenal British-made gain for sustainability.

3. Economic value: delivering £10 in return for every £1 spent, in quantifiable gains demonstrated by the modelling in this report.

4. Rebalancing the UK: supporting the levelling up agenda with jobs, technology, and wealth creation in the North of England, including Merseyside, where the local authority is fully in support of this initiative.

5. Win-win with wind: creating a virtuous circle with renewable wind energy, a field where the UK is a global leader, through zero carbon vessels to service wind assets, removing the diesel red line currently cutting through UK wind maintenance.

6. Building a globally defensible UK industry: Developing leading-edge technology in zero carbon vessels, in demand globally, which the UK can export driving wealth and gains for generations to come.

No other opportunity quite combines as powerfully the UK's unique maritime heritage with our technological capabilities, manufacturing base, renewable energy assets, sustainability goals, and levelling up agenda.

We call on policymakers for support with this time-limited unique opportunity for the United Kingdom of Great Britain and Northern Ireland:

Professor Christopher Halliburton, ESCP Business School

Dr Artemis Stratopoulou, Athens University & Economics and Business

Sir Michael Bibby, Bibby

Merseyside maritime authority

Other experts interviewed

Adam Riccoboni, CEO, Critical Future

Other signatories

REFERENCES

Andersson, K., Brynolf, S., Hansson, J., Grahn, M. (2020), 'Criteria and decision support for a sustainable choice of alternative marine fuels', Sustainability 12(9): 3623. Available at: https://doi.org/10.3390/su12093623

Artemis Technologies (2020), 'Belfast Maritime Consortium headed by Artemis Technologies joins Maritime UK'. Available at: https://www.artemistechnologies.co.uk/

Aqua Consultants (2017), Liverpool-Manchester Hydrogen Hub – Energy to Fuel the Northern Power House: A Study for Peel Environmental.

Backwell, B., Medic, N. (2016), Offshore Wind Energy: Powering the UK since 2000, 2nd edition, Haynes.

Balcombe, P., Brierley, J., Lewis, C., Skatvedt, L., Speirs, J., Hawkes, A., Staffell, I. (2019), 'How to decarbonise international shipping: options for fuels, technologies and policies', Energy Conversion and Management, 182: 72–88. Available at: https://doi.org/10.1016/j.enconman.2018.12.080

Bibby Line Group. Available at: https://bibbylinegroup.co.uk/

Bibby Marine Limited. Available at: https://bibbylinegroup.co.uk/companies/bibby-marine/

Bounds, A. (2021), 'Hydrogen project aims to drive UK transition to a low-carbon economy', Financial Times. Available at: on.ft.com/39ySPsr

BSLBATT, 'Marine Applications'. Available at: https://www.lithium-battery-factory.com/marine-lithium-batteries/

Cebr (2012), 'Economic impact of offshore wind'. Available at: https://cebr.com/reports/economic-impact-of-offshore-wind/

Cadent (2017), The Liverpool-Manchester Hydrogen Cluster: A Low Cost, Deliverable Project. Available at: http://www.h2fcsupergen.com/wp-content/uploads/2015/08/Cadent_Liverpool-Manchester-Project-Summary-report.pdf

Catapult Offshore Renewable Energy (2000), An Innovator's Guide to the Offshore Wind Market. Available at: https://ore.catapult.org.uk/?orecatapultreports=an-innovators-guide-to-the-offshore-wind-market

D'Hernoncourt, J., Cordier, M., Hadley, D. (2011), Input-Output Multipliers: Specification Sheet and Supporting Material, Spicosa Project Report, Université Libre de Bruxelles, CEESE, Brussels. Available at: http://www.coastal-saf.eu/output-step/pdf/Specification%20sheet%20I_O_final.pdf

Department for Business, Energy & Industrial Strategy (2020), UK Research and Development Roadmap.

Available at: https://www.gov.uk/government/publications/uk-research-and-development-roadmap

Department for Transport (2019), Clean Maritime Plan. Available at: https://www.gov.uk/government/publications/clean-maritime-plan-maritime-2050-environment-route-map

DNV GL, Alternative Fuels and Technologies for Greener Shipping: Summary of an Assessment of Selected Alternative Fuels and Technologies. Available at: https://hydrogeneurope.eu/sites/default/files/2018-04/DNV_GL_Executive-Summary-Alt-Fuels_guidance_paper_2018-04_web.pdf

DNV GL (2016), Handbook for Maritime and Offshore Battery Systems: Guidance Paper.

DNV GL (2019), Comparison of Alternative Marine Fuels, Report no. 2019-0567, Rev.3, Document no. 11C8I1KZ-1. Available at: https://safety4sea.com/wp-content/uploads/2019/09/SEA-LNG-DNV-GL-Comparison-of-Alternative-Marine-Fuels-2019_09.pdf

Duverger, C., Van Pottelsberghe de la Potterie, B. (2011), 'Determinants of productivity growth: Science and technology policies and the contribution of R&D', EIB Papers, 16(1): 53–60.

Ecuity, Engie, STFC, Siemens (2020), Ammonia to Green Hydrogen Project: Feasibility Study. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/880826/HS420_-_Ecuity_-_Ammonia_to_Green_Hydrogen.pdf

E4tech, UMAS, Frontier Economics (2019), Reducing the Maritime Sector's Contribution to Climate Change and Air Pollution – Economic Opportunities from Low and Zero Emission Shipping: A Report for the Department for Transport. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/815666/economic-opportunities-low-zero-emission-shipping.pdf

Fuel Cells and Hydrogen Joint Undertaking (FCH), 'Major project to convert offshore vessel to run on ammonia-powered fuel cell'. Available at: https://www.fch.europa.eu/press-releases/major-project-convert-offshore-vessel-run-ammonia-powered-fuel-cell

Future Inc., Renewable Energy (2020), 'The fuel that could transform shipping', Future Inc. Available at: https://www.bbc.com/future/article/20201127-how-hydrogen-fuel-could-decarbonise-shipping

Halim, R. A., Kirstein, L., Merk, O., Martinez, L. M. (2018), 'Decarbonization pathways for international maritime transport: a model-based policy impact assessment', Sustainability 10(7): 2243. Available at: https://doi.org/10.3390/su10072243

Hansson, J., Brynolf, S., Fridell, E., Lehtveer, M. (2020), 'The potential role of ammonia as marine fuel – based on energy systems modeling and multi-criteria decision analysis', Sustainability 12(8): 3265. Available at: https://doi.org/10.3390/su12083265

Hansson, J., Månsson, S., Brynolf, S., Grahn, M. (2019), 'Alternative marine fuels: prospects based on multi-criteria decision analysis involving Swedish stakeholders', Biomass and Bioenergy, 126: 159–173.

Hughes, D. W. (2018), A Primer in Economic Multipliers and Impact Analysis Using Input-Output Models. Institute of Agriculture, The University of Tennessee. Available at: https://extension.tennessee.edu/publications/Documents/W644.pdf

IEA (2019), 'Global demand for pure hydrogen, 1975–2018'. Available at: https://www.iea.org/data-and-statistics/charts/global-demand-for-pure-hydrogen-1975-2018

Institute for Government (2020), 'Trade: freeports and free zones'. Available at: https://www.instituteforgovernment.org.uk/explainers/trade-freeports-free-zones

International Chamber of Shipping (2020), Catalysing the Fourth Propulsion Revolution: The Urgent Need to Accelerate R&D to Deliver Zero carbon Shipping by 2050. Available at: https://safety4sea.com/wp-content/uploads/2020/11/catalysing-the-fourth-propulsion-revolution.pdf

International Maritime Organization, 'Reducing greenhouse gas emissions from ships', Available at: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx

International Renewable Energy Agency (2018), Hydrogen from Renewable Power: Technology Outlook for the Energy Transition. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Sep/IRENA_Hydrogen_from_renewable_power_2018.pdf

International Renewable Energy Agency (2020a), 'Making green hydrogen a cost-competitive climate solution'. Available at: https://www.irena.org/newsroom/pressreleases/2020/Dec/Making-Green-Hydrogen-a-Cost-Competitive-Climate-Solution

International Renewable Energy Agency (2020b), Green Hydrogen: A Guide to Policy Making. Available at: https://www.irena.org/publications/2020/Nov/Green-hydrogen

International Transport Forum, Decarbonising Maritime Transport: The Case of Sweden, OECD. Available at: https://www.itf-oecd.org/sites/default/files/docs/decarbonising-maritime-transport-sweden.pdf

International Transport Forum (2018), Decarbonising Maritime Transport. Pathways to Zero-Carbon Shipping by 2035. Available at: https://www.itf-oecd.org/sites/default/files/docs/decarbonising-maritime-transport.pdf

Isbell, P., Edes, B. (2021), 'Port cities are key to reducing maritime carbon emissions'. Available at: https://www.brinknews.com/port-cities-are-key-to-reducing-maritime-carbon-emissions/

Leontief, W. (1970): 'Environmental repercussions and the economic structure: an input-output approach', The Review of Economic Statistics, 52(3): 262–277.

Liverpool City Region Local Enterprise Partnership, Cammell Laird, Peel Ports, Liverpool City Region Offshore Wind Energy Hub. Available at: https://www.liverpoollep.org/wp-content/uploads/2015/06/wpid-offshore-wind-energy-hub-04-2012.pdf

Lloyd's Register (2019a), 'Making shipping a zero-carbon industry: How do we turn ambition into reality?' Available at: https://www.lr.org/en/latest-news/making-shipping-zero-carbon/

Lloyd's Register (2019b), 'Fuel production cost estimates and assumptions', Zero-Emission Vessels: Transition Pathways.

Louis Dreyfus Armateurs (2020), 'Launching of Wind of Hope in Turkey'. Available at: https://www.lda.fr/en/launching-of-wind-of-hope-in-turkey/

Mallouppas, G., Yfantis, E. A. (2021), 'Decarbonization in shipping industry: A review of research, technology development, and innovation proposals', Journal of Marine Science and Engineering 9(4):415. Available at: https://doi.org/10.3390/jmse9040415

MAN Energy Solutions, Batteries on Board Ocean-Going Vessels. Available at: https://www.man-es.com/

docs/default-source/marine/tools/batteries-on-board-ocean-going-vessels.pdf

Maritime UK. Available at: https://www.maritimeuk.org/

Maritime UK (2018), A comparison of hydrogen and ammonia for future long distance shipping fuels. Available at https://www.maritimeuk.org/media centre/publications/annual-review-2018/

McDonough, T. (2020), 'Freeport plan could boost Mersey economy by £739m a year', LBN Liverpool Business News. Available at: https://lbndaily.co.uk/freeport-plan-boost-mersey-economy-739m-year/

McKinlay, C., Hudson, D. A., Turnock, S. R. (2020), 'A comparison of hydrogen and ammonia for future long distance shipping fuels', LNG/LPG and Alternative Fuel Ships, Royal Institute of Naval Architects.

Mohd Adli, N., Zhang, H., Mukherjee, S., Wu, G. (2018), 'Review—ammonia oxidation electrocatalysis for hydrogen generation and fuel cells', Journal of The Electrochemical Society 165(15): J3130-J3147.

Mouli-Castillo, J., Heinemann, N., Edlmann, K. (2021), 'Mapping geological hydrogen storage capacity and regional heating demands: an applied UK case study', Applied Energy 283.

Newman, N. (2017), 'Hybrid ships take to the high seas', E&T Magazine. Available at: https://eandt.theiet.org/content/articles/2019/01/hybrid-ships-take-to-the-high-seas/

North West Business Leadership Team (2019), The North West Energy and Hydrogen Cluster: Delivering the Decarbonisation of the North West Industrial Sector. Available at: https://nwblt.com/wp-content/uploads/2019/06/The-North-West-Energy-and-Hydrogen-Cluster-Prospectus.pdf

NYU Stern Center for Sustainable Business, Return on Sustainability Investment Model (ROCI). Available at: https://www.stern.nyu.edu/experience-stern/about/departments-centers-initiatives/centers-of-research/center-sustainable-business/research/return-sustainability-investment-rosi

OffshoreWind.biz (2020), 'Bibby WaveMasters chart zero-emissions course'. Available at: https://www.offshorewind.biz/2020/05/22/bibby-wavemasters-chart-zero-emissions-course/

Office for National Statistics, UK (2017), Input-output Analytical Tables: Methods and Application to UK National Accounts.

Office for National Statistics (2020), Input-output supply and use tables.

Office for National Statistics (2019), Type I UK employment multipliers and effects, reference year 2015.

Office for National Statistics (2019), Port freight annual statistics.

Office for National Statistics (2018), Regional economic activity by gross domestic product, UK.

O'Hayre, R., Cha, S.-W., Colella, W., Prinz, F.B. (2016), Fuel Cell Fundamentals, 3rd ed.

Østensjø Rederi, 'Edda Wind secures long-term contracts for two offshore wind vessels'. Available at: https://ostensjo.no/edda-wind-secures-long-term-contracts-for-two-offshore-wind-vessels/

Oxford Economics (2018), The True Impact of UK Manufacturing, The Manufacturing Technologies Association.

Oxford Economics and Prometeia (2013), The Contribution of Finmeccanica to the UK: Technology, Growth, Investment.

Payne, S., Thomas, N. (2021), 'Eight bidders gain freeport approval in move to boost English regions', Financial Times.

Point and Sandwick Trust (2019), Scottish Western Isles Ferry Transport using Hydrogen (SWIFTH2): Feasibility Report. Available at: http://www.pointandsandwick.co.uk/wp-content/uploads/2019/07/Scottish-Western-Isles-Ferry-Transport-using-Hydrogen-Feasibility-Report.pdf

Radowitz, B. (2021), 'Ørsted and Siemens Gamesa eye "fully marinised" offshore wind to hydrogen', Recharge. Available at: https://www.rechargenews.com/wind/Ørsted-and-siemens-gamesa-eye-fully-marinised-offshore-wind-to-hydrogen/2-1-941167

RenewableUK, 'Wind energy'. Available at: https://www.renewableuk.com/page/WindEnergy

RenewableUK (2017), Offshore Wind: Regenerating Regions – Investment and Innovation in the UK, Offshore Wind Week 2017.

RenewableUK (2019), Floating Wind: The UK Industry Ambition. Available at: https://www.scottishrenewables.com/assets/000/000/475/floating_wind_the_uk_industry_ambition_-_october_2019_original.pdf?1579693018

Reuters (2019), 'Shipping sector sets course for zero carbon vessels, fuel by 2030'. Available at: https://www.reuters.com/article/us-climate-change-un-shipping-idUSKBN1W81B8

Robinson, A., Didey, A. (2020), Small Business Research Initiative (SBRI) Ph 1 on SMAHRT (Smart Modular Ammonia to Hydrogen Refuelling Terminals), Neoptera Aero 2020.

Royal Academy of Engineering (2013), Future Ship Powering Options: Exploring Alternative Methods of Ship Propulsion, Royal Academy of Engineering: London, UK.

Safety4sea (2020), 'Shipping decarbonization: What does the future hold'. Available at: https://safety4sea.com/cm-shipping-decarbonization-what-does-the-future-hold/

Scottish Government (2020), 'Information on the Supply, Use and analytical Input-Output Tables produced by the Scottish Government', Supply, Use and Input-Output Tables.

Smith, M. (2020), 'Switching to lithium batteries on your boat', Power and Motor Yacht. Available online at https://www.powerandmotoryacht.com/maintenance/switching-to-lithium-batteries-on-your-boat

Smyth, J. (2020), 'Australia backs desert project to export green hydrogen to Asia', Financial Times. Available at: https://www.ft.com/content/73505b3c-acd8-4bd5-b91a-fddfa2f331fb

Søgaard K., Bingham C. (2020), 'Mapping of zero emission pilots and demonstration projects'. Available at: https://www.globalmaritimeforum.org/news/mapping-of-zero-emission-pilots-and-demonstration-projects/

Statista, 'Leading sea ports by freight handled in the UK between 1st and 3rd quarter 2020'. Available at: https://www.statista.com/statistics/1001996/leading-sea-ports-for-freight-traffic-uk/

Sunak, R. (2016), The Free Ports Opportunity: How Brexit Could Boost Trade, Manufacturing, and the North, Centre for Policy Studies.

Sveikauskas, L. (2007), R&D and Productivity Growth: A Review of the Literature, Bureau of Labor Statistics Working Paper 408.

‘SWIFTH2 project for hydrogen powered ferries in Scotland’ (2019), Fuel Cells Bulletin, 2019(10): 6.

The Crown Estate (2020), ‘Offshore Wind Leasing Round 4: Delivering a low carbon future’, Available at: https://www.thecrownestate.co.uk/en-gb/what-we-do/on-the-seabed/offshore-wind-leasing-round-4/

The Manufacturers’ Organization UK, ‘UK manufacturing: the facts 2019/20’. Available at: https://www.makeuk.org/insights/publications/uk-manufacturing-the-facts-2019-20

The Maritime Executive (2020), ‘Plan for large green ammonia production plant for shipping industry’. Available at: https://www.maritime-executive.com/article/plan-for-large-green-ammonia-production-plant-for-shipping-industry

Thomas, N., Pickard J., Foster, P. (2021), ‘Teesside jobs boost as GE confirms plans for UK wind turbine plant’, Financial Times. Available at: https://www.ft.com/content/e303c1bc-4a07-4f33-b001-bac872de3cd0

Turner, K. (2015), Preliminary Study on Developing Economic Multipliers for CO2-EOR Activity, Scottish Carbon Capture & Storage.

UK Government (2021), ‘Fund extended to help level-up every corner of United Kingdom’. Available at: https://www.gov.uk/government/news/fund-extended-to-help-level-up-every-corner-of-united-kingdom

UK Government (2020), ‘Hydrogen Supply Competition Phase 2 successful projects’. Available at: https://www.gov.uk/government/publications/hydrogen-supply-competition/hydrogen-supply-programme-successful-projects-phase-2

UK Government (2020), ‘Freeports consultation: boosting trade, jobs and investment across the UK’. Available at: https://www.gov.uk/government/consultations/freeports-consultation/freeports-consultation

UK Research and Innovation, ‘Regional distribution of funding’. Available at: https://www.ukri.org/about-us/what-we-do/funding-data/regional-distribution-of-funding/

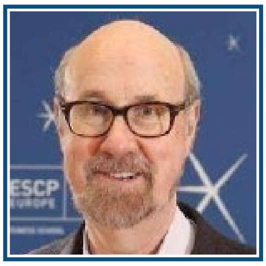
Van Biert, L., Godjevac, M., Visser, K., Aravind, P.V. (2016), ‘A review of fuel cell systems for maritime applications’, Journal of Power Sources, 327: 345–364.

Whitmarsh, M. (2019), The UK Offshore Wind Industry – Supply Chain Review, Offshore Wind Industry Council. Available at: https://www.renewableuk.com/resource/resmgr/publications/supply_chain_review_31.01.20.pdf

World Bank (2019), Gross Domestic Product ranking table. Available at: https://datacatalog.worldbank.org/dataset/gdp-ranking

World Economic Forum (2020), ‘A new report outlines the shipping industry’s plans for decarbonization.’ Available at: https://www.weforum.org/agenda/2020/07/shipping-industry-plans-to-decarbonize/

World Economic Forum (2019), ‘An expert explains: how the shipping industry can go carbon-free.’ Available at: https://www.weforum.org/agenda/2019/09/an-expert-explains-how-the-shipping-industry-can-go-carbon-free/



Professor Halliburton is full Chair, full Professor at ESCP Business School. He has degrees from the universities of Durham and London School of Economics (LSE) and has lectured at London Business School. Advisor to leading companies and government.

Dr. Artemis Stratopoulou, is a researcher in economics at the Athens University of Economics & Business. Dr. Stratopoulou holds a PhD and MSc in Economics and is a senior consultant at Critical Future advising leading companies.

Adam Riccoboni is the CEO of Critical Future, author of “The AI Age”, Lectures in AI at ESCP, Speaker for All Party Parliamentary Group on Artificial Intelligence, Advisory Board of OrbitMI, Advisory Board of the AI Institute of SKEMA Business School, award winning entrepreneur and active strategy & AI consultant.

CRITICAL FUTURE

Critical Future is a strategy, technology & sustainability consultancy trusted by many of the world’s biggest brands. Critical Future’s White Paper’s inform the government, media and business communities on important technology & business issues of the day.

www.criticalfutureglobal.com

CRITICAL FUTURE