CATAPULT
Offshore Renewable Energy

The Economic Opportunity for Robotics in Offshore Wind and Key Energy Markets

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REPORT

Author: Gavin Smart, ORE Catapult

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ABOUT THE AUTHOR

Gavin Smart joined ORE Catapult in April 2014 and holds the post of Head of Analysis & Insights. Gavin is responsible for developing and maintaining ORE Catapult's financial and economic modelling, which feeds directly into the organisation's commercial strategy.

Gavin spent three years as Senior Investment Analyst for a major European utility and offshore wind developer, developing models and analysis tools for UK and European offshore wind and marine projects. Prior to this, he worked as a Valuation & Business Modelling consultant in the Middle East for one of the "Big Four" accounting firms, engaged in projects covering a variety of industries.

Contact: gavin.smart@ore.catapult .org.uk

BACKGROUND

Robotics and autonomous systems (henceforth, we'll shorten to 'RAS') are set to become a critical component in the safety, cost reduction and efficiency of offshore wind farm operations. They will play a key role in the safe and cost-effective operation of increased numbers of offshore wind turbines, operating in deeper waters and more challenging conditions further from shore.

The potential for robotics is huge, with applications across the offshore wind value chain, including site survey and consenting, installation, operations and maintenance and decommissioning. This presents significant opportunities to technology developers, SMEs and innovators; not just to serve the rapidly growing UK market but also to export innovation to offshore wind markets around the world.

Indeed, we believe that adoption of robotics and autonomous systems by the wind sector will be vital to achieving the renewables expansion needed for Net Zero.

There are three compelling reasons why:

1. To achieve our net zero targets, the UK's offshore wind capacity will need to increase more than sevenfold by 2050. That means pushing operations into ever-deeper, more remote and more treacherous waters with narrower weather windows for safe human access**.**

2. Robotics can take on the routine maintenance tasks such as scouring the surfaces of thousands of blades for critical cracking and erosion (there are 30,000 currently at UK wind farms - onshore and offshore) or checking the approximately 10 million bolts at these farms for loss of tension and integrity. Ultimately, this will mean better pre-emptive maintenance and control over these essential net-zero assets.

3. Finally, with better pre-emptive maintenance, we can extend the lifetime of components and turbines at sea, helping the industry progress to a circular, zero-waste economy.

The market opportunity for offshore wind is a compelling one: a high growth industry that is set to grow at least seven-fold by mid-century, requiring a transformation in its operations and maintenance as assets push into deeper, more remote and tempestuous waters. Many of the technologies being designed for this market are adaptations of existing technologies for similar environments in the oil and gas, shipping and nuclear industries. While offshore wind is now becoming the catalyst for robotics innovations of its own, many of which will have applications well beyond wind.

Offshore wind is our natural starting point for this analysis of the economic opportunity the growing demand for robotics represents, but we have also chosen onshore wind, nuclear and offshore oil and gas as 'spin-off sectors' that many of the same technologies will also find natural homes in. All these areas represent growing markets, except for oil and gas, where we expect a decline to set in during the mid-2040s in line with the global energy transition.

Robotics do of course have far wider application beyond energy industries, but the wind, oil and gas and nuclear industries have been used as representing a meaningful subset of the overall potential market, covering industries which have clear applications for these technologies.

ORE Catapult's Role

ORE Catapult will play a key role in delivering the UK's largest clean growth opportunity, through our mission to accelerate the creation and growth of UK companies in the offshore renewable energy sector. We will use our unique facilities and research and engineering capabilities to bring together industry and academia and drive innovation in renewable energy. In this case, we work with developers of robotic, artificial intelligence and autonomous systems under our Smart O&M programmes that aim to spearhead a digital revolution in the offshore wind sector.

In our latest interactive brochure, you can find out more about ORE Catapult's expanding facilities for robotics and autonomous systems across the UK, our technology innovation and supply chain programmes, collaborative research projects and partnerships with industry and academia.

Read more about ORE Catapult's RAS facilities, services, research and technology innovation projects.

PURPOSE OF THIS REPORT

The purpose of this research was to stimulate interest in the future market potential of robotics and autonomous systems. The scale of this global opportunity presents a strong argument for the UK to back the development and commercialisation of these technologies and invest in world-class facilities for their developers.

It should also provide inspiration to developers working in a variety of technology areas–from data and digital, robotics and autonomy to artificial intelligence and mission planning. Offshore wind is a sector that is highly welcoming to cross-sector innovation, and this report gives a glimpse into how this sector's opportunity can open doorways into markets beyond.

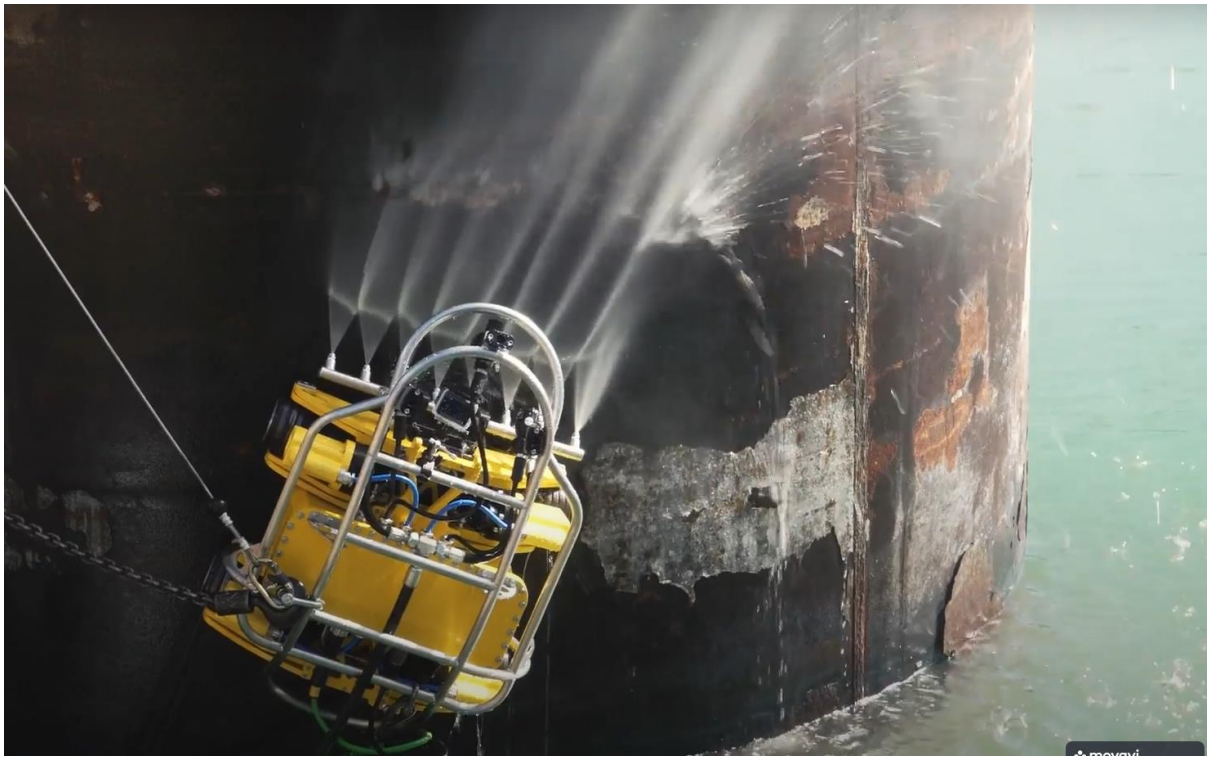


IMAGE 1. Innvotek's Amphibian demonstrates its inspection and cleaning capabilities at ORE Catapult's National Renewable Energy Centre in Blyth, Northumberland. This platform has a variety of applications in the wind, shipping and oil and gas sectors.

METHODOLOGY AND MARKET BREAKDOWNS

The analysis has been conducted slightly differently for different industries depending on the information available. Detailed analysis was conducted of the key operations and maintenance (O&M) tasks and costs identified and costed in ORE Catapult's in-house O&M cost model.

Offshore Wind

The cost of each task for a sample 1GW project was split into:

- Labour
- Equipment and consumables
- Vessels

For each task, an assessment was made of:

1. The applicability and timescales for RAS to impact or replace the task [Scale: 5-10 years; >10 years; or N/A)]

2. The cost reduction impact of RAS on labour and vessels (equipment and consumables assumed to be unaffected) [Scale: Low 5%; Medium 20%; and High 50%]

3. The portion of the revised cost attributable to RAS [Scale: Low 2%; Medium 10%; and High 20%]

The portion of revised cost attributable to RAS (Step 3) across all tasks was aggregated to form an estimate of the O&M spend on RAS for the sample 1GW project.

The market value of RAS in offshore wind O&M at 2030, 2040 and 2050 was estimated as the spend per 1GW multiplied by the number of UK offshore wind GW's in operation by each year and based on the timescales for application (Step 1).

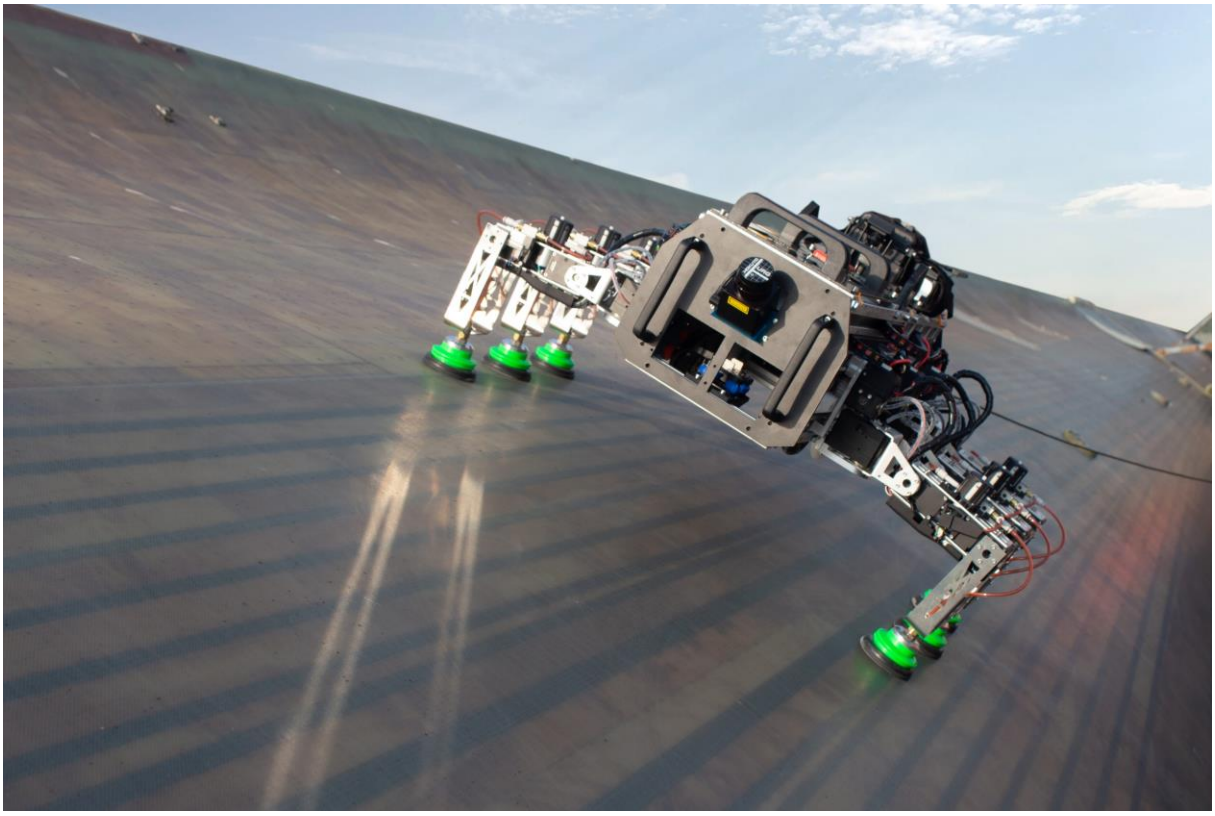


IMAGE 2. BladeBUG's inspect-and-repair robot can crawl wind farm blades and is now being extended to bolt inspections on turbine structures using an ultrasonic solution created by EchoBolt. Both technologies were supported by ORE Catapult and have trialled at the Levenmouth Demonstration Turbine.

The market penetration in each of 2030, 2040 and 2050 of RAS in the total UK offshore wind O&M market was estimated as RAS market value divided by total estimated market value. The resulting estimates for market penetration in offshore wind O&M are:

2030 3.8%

2040 4.5%

2050 4.5%

The same levels of market penetration were applied to estimates of the offshore wind O&M markets in the rest of Europe and Rest of World (RoW) to derive estimates of export market potential.

Table 1: Offshore wind - key inputs and estimates

Metric	Unit	2030	2040	2050
Installed capacity - UK	GW	35	60	100
Installed capacity - rest of Europe	GW	67	147	263
Installed capacity - RoW	GW	111	253	380
Installed capacity - Global	GW	213	460	743
Total O&M market - UK	£m	1,474	2,526	4,210
Total O&M market - rest of Europe	£m	2,821	6,189	11,073
Total O&M market - RoW	£m	4,674	10,652	16,000
Total O&M market - Global	£m	8,968	19,368	31,284
RAS penetration	%	3.8%	4.5%	4.5%
O&M RAS market - UK	£m	56	113	189
O&M RAS market - rest of Europe	£m	107	277	496
O&M RAS market - RoW	£m	178	477	716
Offshore Wind O&M RAS market	£m	341	867	1,401

Onshore Wind

The same process applied to offshore wind was carried out for onshore wind, with key differences being:

- Vessel costs excluded to arrive at high-level estimates of onshore wind O&M costs
- Applicability of RAS reduced or excluded for many tasks as not being as relevant as offshore (for example, RAS assumed to have similar applicability for blade maintenance activities, but much lower or zero applicability for other turbine and balance of plant activities)

The resulting estimates for market penetration in onshore wind O&M are:

2030 2.3%

2040 2.4%

2050 2.4%

Key figures are shown in Table 2. Note that the onshore wind O&M cost base is lower than for offshore wind, meaning that the penetration %s are only slightly lower than for offshore wind.

Table 2: Onshore wind - key inputs and estimates

Metric	Unit	2030	2040	2050
Installed capacity - UK	GW	21	29	39
Installed capacity - rest of Europe	GW	229	307	415
Installed capacity - RoW	GW	977	1,452	2,162
Installed capacity - Global	GW	1,227	1,788	2,616
Total O&M market - UK	£m	718	991	1,333
Total O&M market - rest of Europe	£m	7,825	10,491	14,181
Total O&M market - RoW	£m	33,385	49,617	73,878
Total O&M market - Global	£m	41,928	61,098	89,392
RAS penetration	%	2.3%	2.4%	2.4%
O&M RAS market - UK	£m	17	24	32
O&M RAS market - rest of Europe	£m	182	249	337
O&M RAS market - RoW	£m	778	1,179	1,756
Onshore Wind O&M RAS market	**£m**	**977**	**1,452**	**2,124**

Nuclear Energy

A higher--level approach was taken for nuclear energy. Estimates of O&M cost per MW were taken from the 2016 *Electricity Generation Cost Report* from the Department for Business, Energy and Industrial Strategy (nuclear was not updated in 2020 report) and applied to estimates of future nuclear capacity in the UK, rest of Europe and RoW from the International Atomic Energy Agency (*Electricity and Nuclear Power Estimates for the Period up to 2050*) to make an estimate of the value of the nuclear energy O&M market.

Given the complex and hazardous nature of nuclear O&M tasks, the market penetration %s estimated for offshore wind were applied to obtain estimates of RAS market value in 2030, 2040 and 2050.

The table to the right summarises the key inputs and estimates.

Table 3: Nuclear energy - key inputs and estimates

Metric	Unit	2030	2040	2050
Installed capacity - UK	GW	5	8	11
Installed capacity - rest of Europe	GW	143	134	121
Installed capacity - RoW	GW	274	344	407
Installed capacity - Global	GW	422	486	539
Total O&M market - UK	£m	365	583	802
Total O&M market - rest of Europe	£m	10,425	9,769	8,821
Total O&M market - RoW	£m	19,975	25,041	29,670
Total O&M market - Global	£m	30,764	35,393	39,293
RAS penetration	%	3.8%	4.5%	4.5%
O&M RAS market - UK	£m	14	26	36
O&M RAS market - rest of Europe	£m	396	437	395
O&M RAS market - RoW	£m	760	1,121	1,329
Nuclear Energy O&M RAS market	**£m**	**1,170**	**1,585**	**1,759**

Offshore Oil and Gas

A higher--level approach was taken for offshore oil & gas. Estimates of OPEX ($15 per barrel) were applied to annual production for UK, rest of Europe and RoW. In line with work undertaken with the Net Zero Technology Centre in 2020 looking at the North Sea, offshore oil & gas production is assumed to decline 25% from 2030 to 2040 and by a further 25% from 2040 to 2050.

Given the similarities in working conditions between offshore wind and offshore oil & gas, the market penetration %'s estimated for offshore wind were applied to obtain estimates of RAS market value in 2030, 2040 and 2050. The level of penetration in oil & gas may be greater, given that most installations are manned (while wind turbines are unmanned), so our estimates may be conservative.

Table 4: Offshore oil & gas - key inputs and estimates

Metric	Unit	2030	2040	2050
Annual production - UK	mbbl*	617	463	347
Annual production - rest of Europe	mbbl	2,008	1,506	1,129

Annual production - RoW	mbbl	8,326	6,244	4,683
Annual production - Global	mbbl	10,950	8,213	6,159
Total O&M market - UK	£m	7,000	5,250	3,938
Total O&M market - rest of Europe	£m	22,781	17,086	12,814
Total O&M market - RoW	£m	100,000	75,000	56,250
Total O&M market - Global	£m	129,781	97,336	73,002
RAS penetration	%	3.8%	4.5%	4.5%
O&M RAS market - UK	£m	266	235	176
O&M RAS market - rest of Europe	£m	866	765	574
O&M RAS market - RoW	£m	3,802	3,358	2,519
Offshore Oil & Gas O&M RAS market	£m	4,935	4,358	3,269

*mbbl = 1,000 barrels

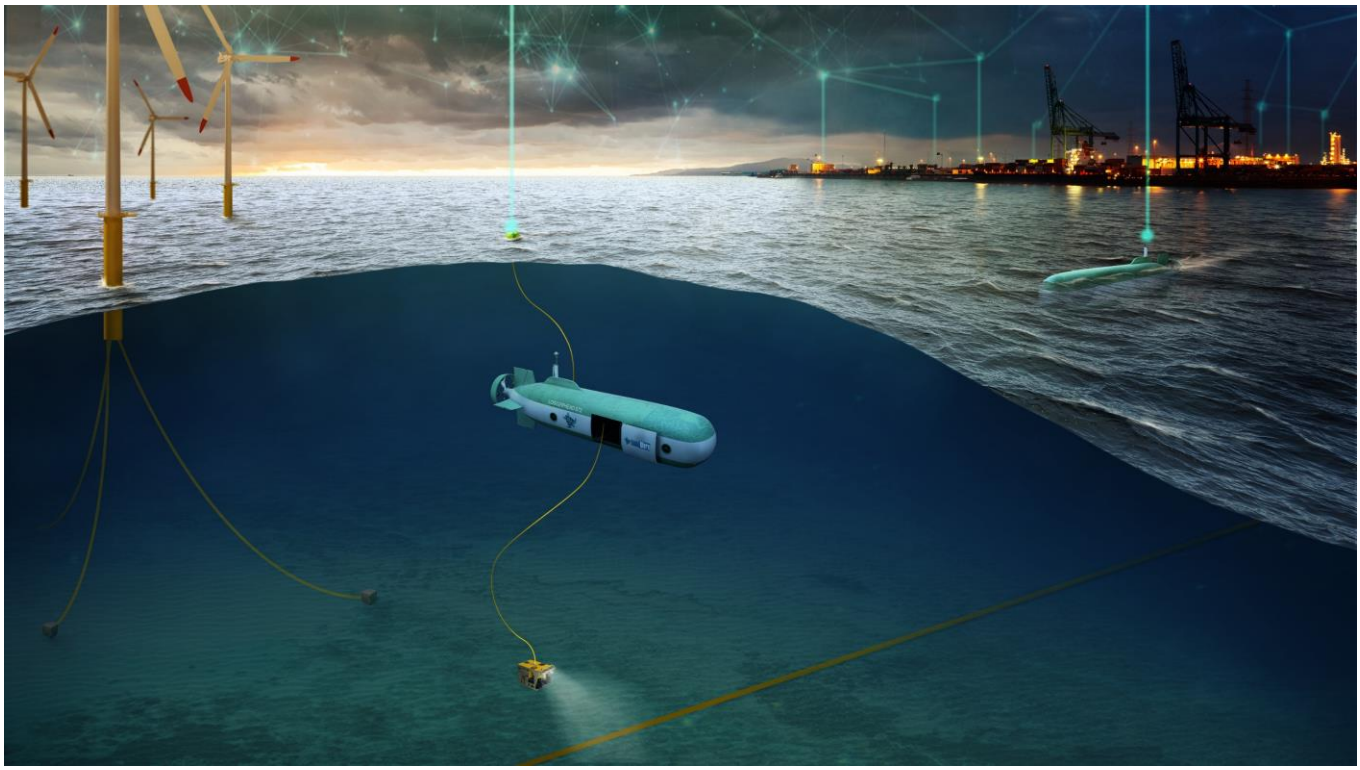


IMAGE 3. Aberdeen's Honuworx is developing a subsea robotic system concept, known as Loggerhead, which will utilise an uncrewed submersible robotic vessel as a mobile power and communication hub for ROVs and AUVs

SUMMARY OF RESULTS

We estimate that the market for O&M RAS in these industries will grow from £350m (UK) and **£7.2bn (global) in 2030** to £400m (UK) and **£8.1bn (global) by 2040** and £430m (UK) and **£8.4bn (global) by 2050.**

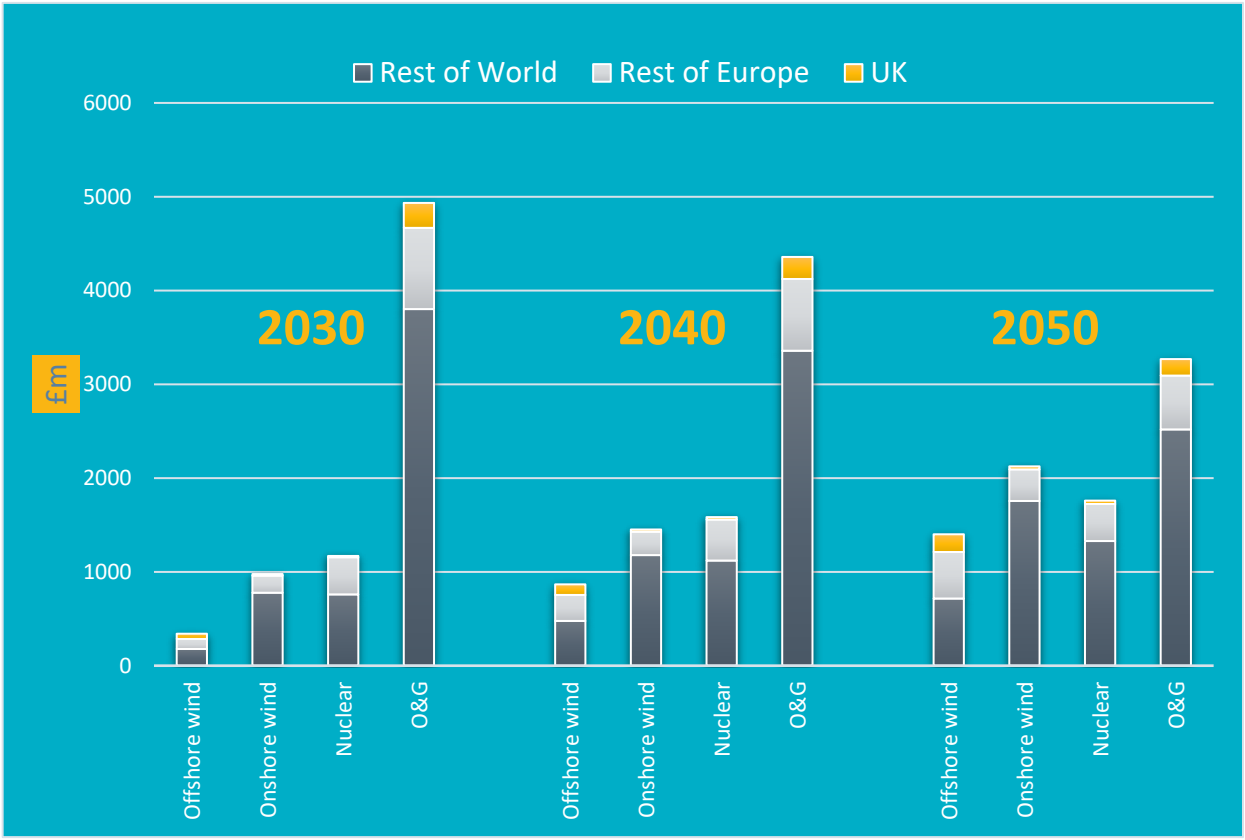
The export potential is significant, with the rest of Europe accounting for roughly 20% of the global market and RoW accounting for roughly 75% across the forecast period. From a UK perspective, offshore wind and offshore oil & gas are by the far the largest domestic markets in the industries analysed here.

Overall, the largest market potential may well be in offshore oil & gas, given the size of the operating base. However, the size of the market is expected to decline over time from £4.7bn in 2030 to £3.1bn in 2050 but continues to represent a significant domestic and export opportunity

Offshore wind O&M RAS will be a significant market in its own right but is forecast to be a relatively small share of the overall O&M RAS market. Offshore wind will grow from 5% of the market in 2030 to 11% in 2040 and 17% in 2050.

With offshore wind going through a period of unprecedented growth and with operators continually seeking innovative ways to maximise performance and minimise time spent by personnel offshore, innovators can see offshore wind as the ideal route into a growing market with broad application across multiple industries.

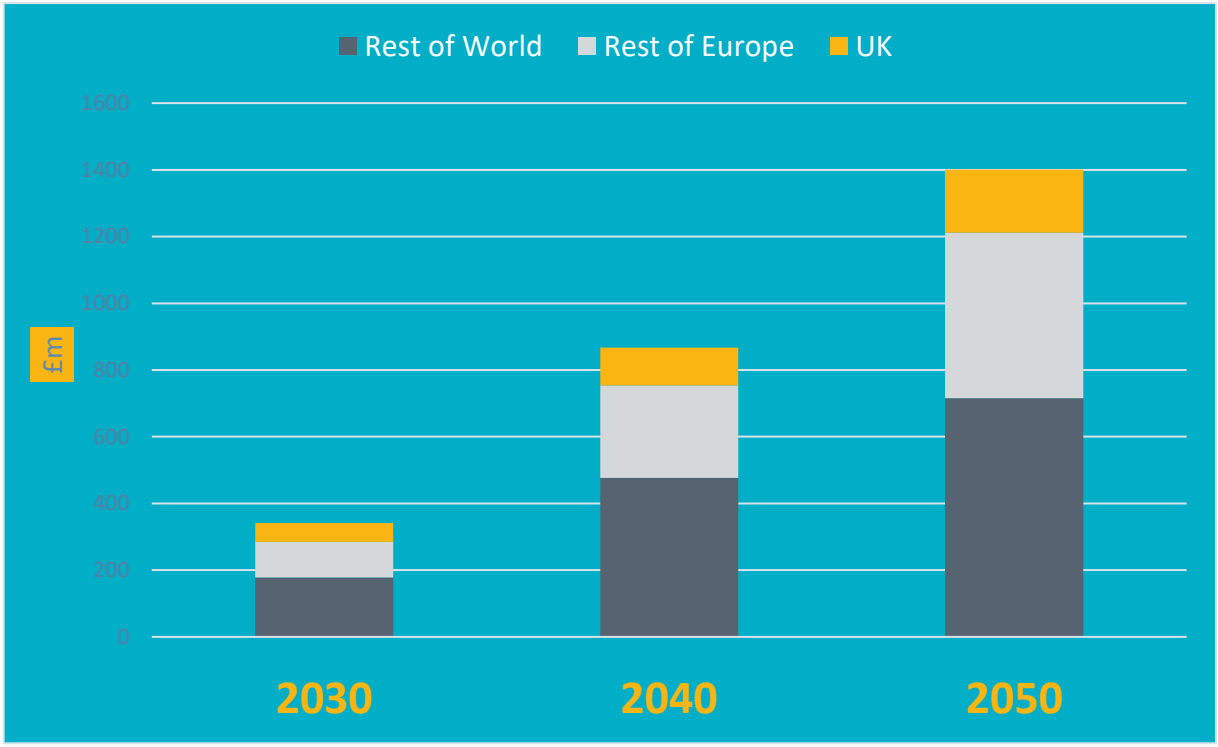
Figure 1. Potential RAS market sizes by industry and geography



Offshore Wind RAS Market

We estimate that the UK offshore wind O&M market for RAS will double in size from £55m in 2030 to £110m in 2040, with a further 70% growth to £190m by 2050. Our estimates show the global export market for RAS in offshore wind O&M growing by 160% from £285m in 2030 to £750m in 2040 and by a further 60% by 2050 to £1.2bn

Figure 2. Potential offshore wind RAS market sizes by geography



CATAPULT
Offshore Renewable Energy

GLASGOW

ORE Catapult
Inovo
121 George Street
Glasgow
G1 1RD

+44 (0)333 004 1400

BLYTH

National Renewable
Energy Centre
Offshore House
Albert Street, Blyth
Northumberland
NE24 1LZ

+44 (0)1670 359555

LEVENMOUTH

Fife Renewables Innovation
Centre (FRIC)
Ajax Way
Leven
KY8 3RS

+44 (0)1670 357649

GRIMSBY

O&M Centre of Excellence
ORE Catapult, Port Office
Cleethorpe Road
Grimsby
DN31 3LL

+44 (0)333 004 1400

ABERDEEN

Subsea UK
30 Abercrombie Court
Prospect Road, Westhill
Aberdeenshire
AB32 6FE

07436 389067

CORNWALL

Hayle Marine Renewables
Business Park
North Quay
Hayle, Cornwall
TR27 4DD

+44 (0)1872 322 119

PEMBROKESHIRE

Marine Energy Engineering
Centre of Excellence (MEECE)
Bridge Innovation Centre
Pembrokeshire Science
& Technology Park
Pembroke Dock, Wales
SA72 6UN

+44 (0)333 004 1400

CHINA

11th Floor
Lan Se Zhi Gu No. 15
Ke Ji Avenue,
Hi-Tech Zone
Yantai City
Shandong Province
China

+44 (0)333 004 1400

LOWESTOFT

OrbisEnergy
Wilde Street
Lowestoft
Suffolk
NR32 1XH

01502 563368