Impacts of Climate Change on Transport and Infrastructure relevant to the coastal and marine environment around the UK and Ireland

Brooks, A.J.[1], Brooke, J.[2], De Dominicis, M, [3], and Roberts, H.[1]

[1]*ABPmer, Quayside Suite, Medina Chambers, Town Quay, Southampton, SO14 2AQ, UK*

[2]*Environmental Consultant Ltd, Deeping St. James, Peterborough, PE6 8ND, UK*

[3]*National Oceanography Centre (UK), Joseph Proudman Building, Liverpool, L3 5DA, UK*

Citation: Brooks, A.J, Brooke, J, De Dominicis, M, and Roberts, H. (2026) Impacts of Climate Change on Transport and Infrastructure relevant to the coastal and marine environment around the UK and Ireland. *MCCIP Science Review 2026*, 26pp.

doi: 10.14465/2026.reu15.tra

Published online: 06 2026

KEY FACTS

What is already happening?

- Increasing construction activity at sea means a greater proportion of our critical infrastructure, particularly offshore renewable energy, is exposed to the effects of climate change on the marine environment.
- Sea levels are rising around the UK at an accelerating rate, increasing flood and erosion risk to critical coastal assets (e.g. energy, transport and water).
- Higher sea levels and more severe storms are increasing the risk to operations which are sensitive to weather-related disruption. These include disruption to ports and shipping through flooding, high winds and waves, heatwaves, cold snaps and fog, and disruption to operation and maintenance of marine infrastructure from weather downtime.

What could happen in the future?

- Sea level is likely to continue to rise at an accelerated rate with an associated increase in flood and coastal erosion risks to coastal infrastructure including ports.
- Increased frequency and severity of storms is anticipated to result in increased disruption to shipping affecting port operations, and greater costs for operation and maintenance of marine structures
- Changes in seabed stresses, sediment transport and siltation due to changes in storm events in-combination with sea-level rise could impact channel maintenance requirements and/or navigational safety
- An increased need for forecasting and early warning systems to manage marine risks to, for example, ferry services and operation and maintenance of marine infrastructure.
- The trans-Arctic shipping route, currently only navigable during summers with limited ice sheet extent, could be navigable four to eight months of the year by 2100.

- Increasing seawater temperatures, particularly in semi-enclosed shallow coastal areas such as estuaries, are expected to affect the design and licensing of cooling and wastewater discharge systems.

SUPPORTING EVIDENCE

Overview

A growing proportion of the UK's infrastructure, particularly for energy generation, is situated in the sea and coastal zone. This infrastructure contributes to a significant proportion of GDP; offshore oil and gas – £20Bn (OEUK, 2023); offshore wind – £6Bn (ONS, 2021); aquaculture – £0.8Bn (Salmon Scotland, 2022); £116Bn generated by through-port trade (Maritime UK 2022). It supports significant direct and indirect employment around the UK, with marine industries supporting approximately 580,000 to one million jobs within the UK (SUDG, 2024). This paper discusses the present and future climate risks to marine transport and infrastructure. It is an update to the previous MCCIP Report Card by Coyle *et al*. (2023). It is informed by, and should be read in conjunction with MCCIP papers on storms and waves (Bricheno *et al*., 2025), coastal geomorphology (Masselink *et al*. 2020), sea level rise (Horsburgh *et al*., 2020), sea temperature (Cornes *et al*., 2025) and ocean circulation (McCarthy *et al*., 2025). Information on the impacts on coastal flooding can be found in Haigh *et al*. (2025).

What is already happening?

Sea-level rise

Sea levels around the UK are rising, with around 19.5cm of sea-level rise recorded along UK coastlines since the 1900s (Kendon *et al*., 2025). There is observational evidence that the rate of sea-level rise is accelerating with two-thirds of the sea level rise observed since the beginning of the last century found occurring in the past 32 years (1993–2024) (Kendon *et al*., 2025). Over this 32-year period, UK sea level has risen by 13.4 cm, slightly higher than the global estimate of 10.6 cm (Thompson *et al*. 2024).

Sea-level rise is not occurring uniformly around the UK but varies regionally, primarily due to differences in isostatic adjustment (vertical land movement following the last deglaciation) (Palmer *et al*., 2018; Kendon *et al*., 2025). For example, tide gauge measurements in Wick (northern Scotland) have recorded increases of 2.9 ± 0.6 mm/year between 1991 to 2020, while Newlyn (south-west England) has measured a rise of 4.2 ± 0.8 mm/year for the same period (Kendon *et al*., 2022).

Winds, storms and waves

While sea-level rise is a primary concern, extreme water level events, which are usually caused by a combination of storm surges, wave conditions and local tides, can have highly damaging impacts and pose an increasing risk to UK coastlines as the underlying mean sea level continues to increase (Palmer *et al*., 2018; Haigh *et al*., 2025). Additionally, high winds, storms and large waves are key hazards to offshore infrastructure.

Over the last 30 years in the south of the UK, significant wave height (approximately equal to the average of the highest one-third of wave heights) has increased, whilst it has decreased in the north (Bricheno *et al*., 2025). These trends are generally attributed to variability in large-scale atmospheric set-up rather than locally generated waves around the UK (Castelle *et al*., 2017; Hochet *et al*., 2021; Bricheno *et al*., 2025). Notwithstanding this significant variability (Earl *et al*., 2013), HadUK-Grid observations of peak windspeeds around the UK show a broadly downward trend compared to the 1980s and 1990s, with mean windspeed also showing a downward trend since the 1960s (Kendon *et al*., 2022). However, any trends must be treated with caution due to the large day-to-day and year-to-year variability (Zeng *et al*., 2019; Wohland *et al*., 2021). Additionally other studies which use alternate observation datasets (e.g. ERA-interim, Murphy *et al*., 2018; ERA5, Laurila *et al*., 2021) find there is no consistent trend in daily mean windspeeds over the UK (Pirret *et al*., 2023). Elsewhere changes in wave conditions can have implications for shipping to and from UK ports with sea ice loss leading to increased wave heights in the Arctic (data between 1992 and 2014) (Collins *et al*., 2019; Fox-Kemper *et al*., 2021).

Extra-tropical cyclones, also called ‘mid-latitude depressions’, are the prevailing weather systems for the UK and can produce storm surges (Horsburgh *et al*., 2020). The North Atlantic storm track brings these storms and associated extreme waves originating over the Atlantic to the UK region. A northward shift in the North Atlantic storm track and mid-latitude depressions is evident over the past 50 years (Gulev *et al*., 2021; Seneviratne *et al*., 2021; Bricheno *et al*., 2025). There is very strong evidence that storminess has increased in the North Atlantic since the 1970s, into at least the 1990s (IPCC, 2013), potentially increasing the occurrence and severity of these systems in the UK. However, the degree of natural variability in these systems means confidence in this trend is comparatively low. In fact, when looking at the observations since the mid-20th century, there is no trend in observed windstorms over the UK (Pirret *et al*., 2023).

A study by Calafat *et al*. (2022) indicates a pattern of increasing storm surge magnitudes along UK coastlines north of 52°N and a decreasing pattern along UK coastlines south of 52°N from 1960 to 2018. These authors challenge the scientific consensus that observed increases in extreme water levels around the UK are primarily driven by changes in mean sea level (Haigh *et al*., 2025). Instead, the study by Calafat *et al*. (2022) finds that trends in surge extremes in Europe since 1960 were comparable to the rate of sea-level rise and that the current coastal planning practice of assuming stationary surge extremes might be inadequate (Calafat *et al*., 2022).

Coastal geomorphology

Coastal geomorphology is a product of the governing oceanographic, sedimentological and geological processes that are present at a given time/location. As these processes exhibit daily, seasonal, annual, and decadal variability, deriving a trend attributable to climate change is challenging. However, a large proportion of the coastline of the UK and Ireland is currently suffering from erosion (17% in the UK; 20% in Ireland). Twenty eight percent of the coastline of England and Wales is experiencing erosion greater than 10 cm per year (Masselink *et al*., 2020).

In locations where the shoreline cannot retreat due to hard coastal infrastructure, coastal habitats are unable to naturally roll back landwards with sea-level rise, resulting in the loss of these habitats (coastal squeeze). The loss of buffer coastal habitats, such as dune systems, saltmarsh and machair (saltmarsh-like habitat found in Scotland), represents degradation of natural inundation and erosion prevention mechanisms, which further increases the risk of erosion and inundation of the coastline and the built environment.

Sea surface temperature

Increases in global air temperatures lead to increases in sea-surface temperature in most global ocean basins (Collins *et al*., 2019), with sea surface temperature (SST) around the UK generally showing a significant warming trend of around 0.3°C per decade over the last 40 years (Cornes *et al*., 2025). Regional variations exist in this trend with surface warming being greatest across the southern North Sea and least in waters off the north-west of the UK (Cornes *et al*., 2025).

Mean ocean-surface warming is also correlated to longer and more frequent extreme warming events, called marine heatwaves (Oliver *et al*., 2018). In the North East Atlantic region, these marine heatwaves can spread across millions of square kilometres of sea area, persist for weeks to months, and occur at the subsurface (Fox-Kemper *et al*., 2021). One recent example of a marine heatwave occurred in June 2023 (Berthou *et al*., 2024). This event was identified as a category 4 marine heatwave with sea-surface temperatures 5°C higher than the 1985–1993 average (European Space Agency, 2023). A significant marine heatwave was also observed throughout much of 2025, with sea surface temperatures in the Celtic Sea, English Channel, and Southern North Sea registering anomalies of 1.5°C to 3°C above the 1982-2012 average (Met Office, 2025, 2026).

Observed impacts of climate change on transport and infrastructure

Climate change has had a wide-ranging impact on marine and coastal industry, and this is set to become increasingly acute as the influence of climate change increases.

Ports and Shipping

Ports are increasingly sensitive to weather hazards and climate-related risks due to their exposed position along coasts and estuaries (Asariotis *et al*., 2024; Jenkins *et al*. 2025). As noted by Dawson *et al*. (2016), rough seas can prevent ships docking, temporarily limiting arrivals of fuel (and other cargoes) to the UK. Flood, storm or heat-related disruptions to road or rail networks affect the distribution of fuels and other cargos to and from ports, whilst port infrastructure is also exposed to coastal erosion and flood risk. Half of the

UK's port capacity is located on the east coast, where the risk of damage from storm surge is greatest (Dawson *et al*., 2016). These UK-wide impacts will increase the risks of potential port closures and downtime with associated revenue losses and increased operational costs.

Ten out of 14 port authorities voluntarily reported to the Climate Change Committee under the UK Climate Change Act 2008 third round of Adaptation Reporting Power (ARP3), including those managed by Dover Harbour Board (Port of Dover, 2021), Mersey Docks and Harbour Company and Port of Sheerness Ltd (Peel Ports, 2021), Port of London Authority (Port of London Authority, PLA 2021) and Associated British Ports (ABP, 2021). The ports of Dover, Mersey, Sheerness, Felixstowe, Harwich and London submitted updated reports under the fourth round (ARP4) as did the Port of Milford Haven. Most reports identified risks from increases in significant wave height, changes in wind speed or direction, and storm surge on top of rises in sea level to disrupt operations and/or damage port infrastructure.

Some ports also highlighted risks to shipping, impacting windows for safe navigation including pilotage, or changes in hydrography affecting dredging requirements. Other issues include possible extreme heat compromising working conditions and impacting older structures. The implications of reduced summer rainfall for safety of operations/navigation in upstream sections on the River Thames were also highlighted (PLA, 2021). London and Dover ports (PLA, 2021, Port of Dover, 2021) highlighted the impacts of increases in the frequency of winter fog conditions, and Liverpool port (Peel Ports, 2021) identified potential impacts on lock gate operations. Most of the ports that prepared ARP3 and/or ARP4 reports identified or alluded to important interdependencies and/or highlighted the increased risk of cascading failures, for example in transport, electricity or water supply (refer to coastal structures below). Some pointed to the wider potential impacts of climate change disruption in global supply chains.

The Companies (Strategic Report) Climate-related Financial Disclosure Regulations 2022 (UK Government, 2022) have now been established mandating that large UK companies (which includes larger ports) publicly disclose their climate-related risks and opportunities aligned with the Task Force on Climate-related Financial Disclosures (TCFD) framework. These regulations require public disclosure of a company's climate-related risk along with targets and key performance indicators for managing that risk. This increased awareness in climate-related risks encourages operators to review and identify the potential impacts of climate change to their operation and to devise and implement appropriate mitigation strategies, increasing preparedness.

Offshore structures and infrastructure

Offshore infrastructure includes assets associated with the oil and gas industry, renewable energy industries, telecommunications and interconnector cables and aquaculture. Pipelines will also soon be installed for carbon storage purposes.

Oil and gas infrastructure may be fixed or floating and include platforms, rigs, pipelines etc., producing or transporting product from the reservoirs to processing terminals on the UK's coastline or moving product between countries. Since 2010, there has been substantial growth of the marine renewable energy sector including wind, tidal stream and wave energy. Much of this growth has focused on the expansion of offshore wind farms and is leading to an exponential increase of offshore infrastructure and the services on which they rely (i.e. survey vessels, cable installation, port infrastructure). Offshore windfarm assets include those with fixed foundations to ~60 m depth and floating offshore wind turbines. Additionally, renewable energy assets (marine and coastal) are now being designed to include hydrogen production and energy storage battery facilities to enable continued energy generation during unfavourable generation conditions (Murray, 2022).

Offshore infrastructure above or below water, whether on fixed foundations, or floating and moored through catenary lines and anchors, is potentially vulnerable to high wind speeds, large wave heights, and strong currents. Due to a changing climate, these assets may be exposed to more extreme weather conditions than originally anticipated. A large number of offshore wind turbines in Europe have required extensive repair over the past few years. Indeed, it has been estimated that extreme weather conditions have caused about 80% of all North Sea offshore turbines to sustain failing grouted connections (Diamond, 2012).

The expansion of offshore wind farms is now moving into deeper waters. In the North Sea, these areas are typically seasonally stratified, with lower tidal velocities and weaker natural tidal mixing. The installation of new offshore wind farms in deeper stratified waters could potentially perturb the natural equilibrium of vertical mixing and stratification through enhancing turbulent mixing in the water column (Carpenter *et al*, 2016). These changes in mixing could alter primary production dynamics, influencing the timing of phytoplankton blooms and cascading energy availability through upper and lower trophic levels. With climate change some areas that are currently mixed may potentially become stratified and hence be impacted by the presence of windfarms. However, wind farms can potentially counteract those changes by increasing the mixing (Dorrell *et al*, 2022). The magnitude of this mixing, additional to natural background processes, has yet to be fully quantified. However, should the combined effects be large enough, it could reduce shelf sea stratification. Therefore, this issue is now a key research area and is attracting considerable attention from regulatory bodies and statutory nature conservation bodies during the project consenting stage, to ensure that offshore wind growth does not have the potential to destabilise and fundamentally change shelf sea systems.

As an island nation, the UK is heavily dependent on the uninterrupted provision of telecommunication, energy and electricity services delivered by subsea cables and pipelines. Protection of the subsea power cable network, in particular, is a key consideration with approximately 80% of all financial losses and insurance claims in the offshore wind industry attributed to electricity transmission cable failures (Arikan and Campbell, 2021). Climate change could lead to increased risk of exposure, scour and failure of these assets.

Significant investment is focusing on more robust and durable high-voltage energy transmission cables, transferring electricity between countries (interconnectors). The UK currently has ten operational international interconnectors providing 10.3 GW of capacity (NCE, 2026). These infrastructure assets play an important role in ensuring national energy security and are key to enabling the UK to reach net zero targets (GB Energy, 2025).

Currently, more than 97% of all intercontinental digital data traffic is carried by subsea telecommunications cables due to the limitations of satellite transmission. Trillions of dollars are traded along this network each day, which also enables internet services by supporting remote working and a host of virtual digital data transfer and storage applications (Bueger *et al*., 2022). As a consequence, the UK relies heavily on over 70 subsea fibre optic cable systems comprising many hundreds of individual cables, that help facilitate national and international communications by internet and telephone traffic (The Crown Estate, 2023). The UK, as an island nation, is thus vulnerable to cascading failures of the global communications network with marine climate related impacts to global communication systems potentially having acute impact to UK connectivity (Clare *et al*., 2022). This was demonstrated by the failure of underwater communications to Orkney and Shetland in 2022 (BBC, 2022). While this event was likely caused by fishing activity, climate-driven hazards, such as extreme weather, pose an increasingly important threat. Telecommunication cables laid in water depths of less than 1500 m are generally buried to protect them from damage by bottom fishing, anchor drops as well as natural processes such as storms and seafloor sediment mobility. Approximately 10% of instances of damage to seafloor cables result from scour abrasion or chaffing, that can occur due to the action of vigorous seafloor currents, particularly where cables cannot be buried and must be surface laid (e.g. where seafloor comprises bedrock) (Kordahi *et al*., 2016). Cable-landing locations (where cables come ashore) are additionally vulnerable to climate-related stressors similar to other coastal infrastructure, such as extreme weather events (Clare *et al*., 2022).

Coastal structures and infrastructure

Within the UK, 35 power stations, 34 electricity substations, 22 clean water facilities and 91 sewage treatment works are currently at significant risk from coastal flooding and erosion (Jaroszweski *et al*., 2021). 511 km of vital coastal rail links are also at risk, including 25 railway stations (Jaroszweski *et al*., 2021). In recent years, high temperatures, strong winds and flooding have had a significant effect on the UK's railways. These adverse conditions are accelerating asset deterioration and increasing the likelihood of critical coping thresholds for railway operators being exceeded, such as on rail temperatures, resulting in buckling, or drainage capacity exceedance, causing flooding (JCNSS, 2022), with coastal stretches of rail at greatest risk from flooding.

The main climate-change related risk to coastal energy infrastructure, particularly power stations, is coastal inundation. All the UK's nuclear reactor plants are currently located at coastal sites. However, the risk of nuclear reactor plants being inundated is judged as low due to the sites having very high standards of protection (Jaroszweski *et al*., 2021). For example, Sizewell C Nuclear power station and access road is being designed to withstand a 1-in-10,000-year storm and 1-in-100,000-year surge events (EDF and CGN, 2021).

Much of the wastewater infrastructure around the UK combines rainfall and sewerage. As a result, intense runoff events commonly exceed the capacity of treatment plants. Increases in the intensity and frequency of intense rainfall events is a significant factor in any increases in combined sewer overflows (discharge of raw sewage) to fluvial systems and/or the marine environment (Ofwat, 2011). Following the legal duties on water companies and government to reduce sewage discharged into waterways - as set out in the Environment Bill 2020 (UK Government, 2020), the Storm Overflows Taskforce was formed. This was aimed at eliminating harm from storm overflows, through a review of options to mitigate untreated discharge and offset increases in storm-related discharges (Gill *et al*., 2021). Scottish Water published an investment route map to mitigate the impact of overflows in 2021, outlining improvements to 108 Scottish assets (Scottish Water, 2021). UK Government has also recently pledged to half sewage pollution from water companies by 2030 (Defra, 2025).

Individual infrastructure assets do not operate in isolation but are interdependent due to reliance on other assets for access, power, fuel and communications. These critical infrastructure networks are often co-located and therefore they experience the same hazards; are managed and used by the same organisations (Dawson *et al*., 2016); or are at risk of failure propagation and cascading risks (Arrighi *et al*., 2021). For example, the rail line between the Port of Immingham and Drax Power Station was damaged by flooding in February 2020 which also threatened the supply of biofuel to the power station (DRAX, 2022).

What could happen in the future?

Winds, storms and waves

In the North Atlantic, towards the end of the century, under higher-emission scenarios, an overall reduction in mean significant wave height is projected, although heights of the most extreme wave are projected to increase (Bricheno and Wolf, 2018; Palmer *et al*., 2018; Morim *et al*., 2019; Bricheno *et al*., 2025). The UK Climate Projections 2018 (UKCP18) show UK daily mean surface wind speeds are projected to slightly increase in winter and slightly decrease in summer (Murphy *et al*., 2018), however there are large uncertainties associated with this as the projected changes are small compared to interannual variability and other projections. For instance, the Coupled Model Intercomparison Project (CMIP) 5 shows even less of a trend in winter daily mean surface wind speeds (Pirret *et al*., 2023). Meanwhile, climate projections from CMIP5, CMIP6 and UKCP18 suggest that the frequency of winter windstorms over the UK is projected to increase (2061-2080 compared to 1981-2000) under a high emissions scenario (RCP8.5) although the projected increase in storminess differs between the models (Zappa *et al*., 2013; Priestley and Catto, 2022; Pirret *et al*., 2023). As future winters are projected to be increasingly dominated by cyclonic weather systems, western coasts of the UK are anticipated to be preferentially impacted by a higher incidence of strong winds and waves (Slingo *et al*., 2021). Additionally, the Atlantic Meridional Overturning Circulation (AMOC) plays an important role in the regulation of Northern Europe weather systems: this is projected to weaken over the 21st century (Fox-Kemper *et al*., 2021; McCarthy *et al*., 2025) which may cause an increase in winter storminess in the UK (Jackson *et al*., 2015; Bellomo *et al*., 2023).

Sea-level rise

Sea-level rise is already occurring and is accelerating, with projections indicating that even with large reductions in greenhouse gas emissions, continued sea-level rise will occur beyond 2100 (Palmer *et al*., 2018; Palmer *et al*., 2020; Fox-Kemper *et al*., 2021). For example, under the high emissions scenario RCP8.5 London is projected to experience between 0.53 m and 1.15 m increase in sea level by 2100, relative to a 1981-2000 average sea-level baseline (Palmer *et al*., 2018).

Plausible projections of 'high-end' sea level rise are available which consider processes such as ice sheet instability that could lead to mean sea level rise above the projected likely range. For the UK, a high-end sea level rise scenario (termed 'H++') of 0.93 to 1.90 m by 2095 was provided in 2009 as part of the UK Climate Projections 2009 ('UKCP09') analysis (Lowe *et al*., 2009). However, there is significant uncertainty around high-end projections, with others arguing that a figure of (up to) 1.6 m by 2100 is more plausible (e.g. van de Wal *et al*., 2022). To help manage this uncertainty, a new framework to explore high-end sea-level rise for the UK has been put forward by Weeks *et al*. (2025). This framework reflects advances in understanding of ice sheet instability processes since the existing H++ scenario was developed for UKCP09.

Coastal morphology

Changes to coastal morphology associated with climate change are anticipated to continue with increases in sea levels causing accelerated rollback or squeeze of coastal habitats. As sea-level rise continues, potential erosion rates are anticipated to increase and have a progressively disruptive impact on coastal assets (Rennie *et al*., 2021). For example, without further intervention the erosion of vulnerable coastlines in Scotland could increase from 46% of the present-day 'soft coast' extents to 84% in 2100 under a high emission scenario, with a total of £1.3 bn of Scottish assets potentially at risk (Rennie *et al*., 2021). Changes in wave climate, storm severity and water levels are anticipated to stimulate change in coastal and inshore morphology at a local scale. The impact of coastal erosion is expected to remain highly variable along the UK coastline and dependent on the governing physical conditions locally and the coastal defences or management strategies in place.

Sea-surface temperature

Sea-surface temperatures have risen over the past few decades and under various climate-change scenarios sea-surface temperatures are projected to continue to rise. The UK's National Oceanography Centre (NOC) outlines that temperatures have risen by 0.3°C per decade since 1980 and predict future rises of 3.11°C by 2100. The warming is expected to be greatest across the North Sea in both surface and bottom temperatures, which is a continuation of the spatial pattern of trend observed in recent decades (Cornes *et al*., 2025). Additionally, the frequency, duration, spatial extent and intensity of marine heatwaves are very likely to increase under all emission scenarios (Collins *et al*., 2019).

Climate models project that the AMOC will likely weaken by the end of the century although there is significant uncertainty with regards to the magnitude of weakening. However, weakening of the AMOC would reduce the northward movement of warm water, meaning northwest European waters would potentially experience less warming than if the AMOC didn't weaken (Met Office, 2024).

Implications for industry

For all marine and coastal industries, climate change is likely to result in a harsher environment with increased exposure to hazards. This will make infrastructure more vulnerable to damage, increase health and safety risks to operatives, and increase periods of weather downtime. This will in turn increase the costs associated with the design, operation, maintenance and decommissioning of infrastructure.

National and global policies for both the reduction in greenhouse gas emissions and enhancement of energy security means there will be increasing amounts and types of marine infrastructure. The Great British Energy Strategic Plan identifies floating offshore wind as having a critical role to play in the UK's progress towards net zero (GB Energy, 2025); however, the expansion of offshore wind into deeper, more exposed locations, will also mean that there is potentially greater exposure to climate related marine risk.

There is also a global drive for industrial decarbonisation resulting in emerging marine industries. Examples include carbon capture and storage (Viking, 2023), offshore hydrogen production, e-fuel (renewable synthetic fuels) or other fuel generation (DNV, 2023), and underwater datacentres (Microsoft, 2023). The risks associated with the design, operation and decommissioning associated with this decarbonisation infrastructure in a changing climate will become more evident with increasing application.

This broadening of application along with the increasing severity of climate change impacts, means that the risks and financial costs associated with successful operation in marine and offshore industry sectors are expected to increase. This diversification is anticipated to provide opportunities for new and novel offshore infrastructure and marine monitoring technologies with recent innovations such as using fibre optic cables as seafloor sensors (Marra *et al*., 2022), allowing increased data collection of ocean conditions.

In addition to adapting to the impacts from climate change, it is also important to mitigate them. The International Maritime Organisation's (IMO) has identified greenhouse gas (GHG) emissions targets (40% reduction by 2040 and 70% by 2050), as articulated through its strategy on the reduction of greenhouse gas emissions from ships (IMO, 2023). This is aimed at building international capacity for the implementation of greenhouse gas reduction strategies which includes transition to biofuels, hydrogen, electric and hybrid propulsion, combined with efficiencies in planning and optimising of shipping logistics. However, member states of the IMO have yet to reach a consensus on the implementation of the framework and a decision won't now be made until autumn 2026 at the earliest.

Financial institutions (including banks and investment funds) are becoming more aware of climate-related risks, and assets holders within the marine and offshore industry are seeking to better understand and mitigate such risks. The insurance sector is also taking steps to address the challenges associated with increasingly frequent climate change-related damage and disruption, and climate-related contractual and liability-related issues are similarly attracting growing attention. Such initiatives will have implications for the ports sector (PIANC, 2024) and other marine industries.

Ports and shipping
The analysis in BPA (2021) and Coyle *et al*. (2023) highlights specific future risks to UK port assets and operations. Additionally, the Environmental Defence Fund (2022), Izaguirre *et al*. (2021) and PIANC (2020, 2022) highlight the potential for climate change to lead to significant adverse impacts on port assets and operations around the world. While there will be differences associated with the specific location (exposure) and characteristics of individual ports many of the risks identified in these papers will be relevant to UK ports. These include:

- Increased risk of coastal flooding, especially related to sea-level rise (Haigh *et al*., 2025).
- More-intense rainfall putting greater pressure on drainage systems; causing pluvial flooding of coastal infrastructure.
- Extreme heat and cold adversely affecting port operations and some infrastructure, for example lock or bridge mechanisms may be impacted by extreme heat (Brooke *et al*., 2024); extreme heat/humidity or extreme cold can impact on stored commodities, either directly or indirectly due to power failure.
- Seabed stresses and associated sediment transport, siltation, and scour changes due to changes in storm events in-combination with sea-level rise, as well as with altered rainfall patterns, impacting channel maintenance dredging requirements and navigational safety (Rulent *et al*., 2026; ABP, 2021).
- Changes in storminess and storm tracks/wind speeds/wave heights affecting berthing, pilotage and cargo handling including crane operations (ABP, 2021).

- Increase in winter fog days in the south-east of the UK, potentially impacting pilotage activities and safety generally, especially in areas used by both recreational and commercial vessels (PLA, 2015).
- Warmer air and water temperatures increasing rates of vegetation growth, desiccation, etc. and facilitating establishment of invasive alien species that can adversely impact on assets and equipment by fouling/smothering or burrowing etc.
- Climate change-induced changes in salinity/acidity affecting species at the edge of their range with implications for recreation and tourism related industry such as fishing or wildlife watching, Barange *et al*. (2018).
- Implications of increased acidity for corrosion rates of steel structures (Brooke *et al*., 2024).
- Weather-related disruption to inland distribution networks (road, rail, waterborne) resulting in knock-on effects on port operations (Arrighi *et al*., 2021).
- Long-term intentions of third-parties responsible for critical infrastructure assets within the port hinterland (e.g. commitment to maintenance of flood defences or erosion protection).
- Increased water demand and summer water shortages potentially affecting locking activities, including on inland waterways.
- Increased summer cooling demands as storage units and workspaces overheat.
- Power outages caused by damage to the distribution network.
- Climate-related disruption in global supply chains can impact on ports. Currently 95% of all goods entering and leaving Britain are moved by sea (Department for Transport, 2022). Disruption at ports has the potential to compromise global supply chains and maritime trade, with local-global geo-political and economic/financial consequences (IPCC, 2022).
- Disruption associated with extreme weather may damage goods directly, (flood damage to goods in storage), cause delays in the shipping of perishable goods (foodstuffs and medicines), through spoiling. This prospective loss represents increased financial risk associated with shipping as well as ports, for relevant industries (PIANC, 2024)..

Very few ports are expected to remain unaffected by changing climate, so those that are currently wholly or partly unprepared will need to act to ensure resilience of both new and existing infrastructure and operations. For new infrastructure, this will mean designing to withstand or otherwise accommodate both slow onset changes and more-frequent extreme events, paying attention to the resilience of linked systems including road and rail transport, energy and supply chains (Pery *et al*., 2021). For existing ports, this may mean retrofitting or replacing infrastructure and/or improving operational resilience. For some facing existential threats, it may involve transformational change such as relocation. Most importantly climate risks need to be mainstreamed into corporate strategies and into organisations' risk registers so that both threats and opportunities can be identified, and appropriate responses developed (PIANC, 2022). These include non-structural initiatives such as contingency plans and early warning systems alongside structural retrofitting or operational change.

Much of the work required to support increased attention to preparedness focuses on better understanding risk. As indicated by Jaroszweski *et al*. (2021), comprehensive data on the scale of risk from coastal erosion and flood risk for transport infrastructure, including ports, is among the key data required. The same is the case for changes in waves, wind speed and storminess; extreme heat and humidity; and fog. However, evidence-based risk and vulnerability assessment relies on a combination of data (including time-series data) and relevant projections, which are typically more uncertain for select marine parameters such as wind, waves, fog, and sediment transport, than for air temperature, precipitation or sea level. The ability to understand and reliably accommodate uncertainty, for example through sensitivity testing, is therefore vital (PIANC, 2022).

Ferries and vital transport infrastructure are at a unique risk to increased climate change with a high proportion of UK ferry routes only partially sheltered from significant wave conditions. The Scottish Western Isles (Coll *et al*., 2013) and Scilly Isles are particularly vulnerable. Presently, isolated island and coastal communities are heavily reliant on these 'lifeline' routes for commodities and employment but also schooling and healthcare. This uncertainty hinders commercial investment with conditions on Islay – for example – already becoming more challenging for whisky exporters (Roberts and Maslin, 2021) due to weather downtime for ferry operations.

Smaller harbours and marinas may also experience effects from climate change associated with increased periods of adverse weather conditions and potential reduction in periods and volumes of recreational boating and tourism.

Warming seas are projected to cause a poleward shift in marine ecosystems, modifying existing opportunities for commercial fisheries (and port income). Modelling has predicted a global reduction in fishery catch potential from 2000 levels by 12.1% by 2050 under a high-emission (RCP8.5) scenario (Barange *et al*., 2018). However, the direct impact of this to UK waters, fishing, and dependent industry remains uncertain (Berry and Brown, 2021).

Climate change will bring opportunities as well as risks. The projected increase in the marine renewable energy sector will increase the demand for port services with the need for construction and operation and maintenance bases to support offshore wind farms. Ports will also play a vital role in supporting new industry and technologies including hydrogen and ammonia production and carbon capture and storage. Some UK ports may benefit from the increase in trans-Arctic shipping route traffic with predictions of significant transit windows of up to 200 days per year through the North-West Passage and Northern Sea Route simulated by Mudryk *et al*. (2021). Others may benefit from changes in global trade associated with climate-driven changes in population, agriculture or manufacturing (Hanson and Nicholls, 2020). More locally, some ports and harbours may gain, while others lose due to the migration of commercial fish stocks or other types of marine wildlife.

Offshore structures and industry

The urgency to mitigate the effects of climate change necessitates an unprecedented global deployment of offshore renewable energy technologies, mostly consisting of offshore wind but also tidal stream, tidal range, wave energy, and floating solar photovoltaic (Ouro *et al*, 2024). The UK government has a major commitment to offshore wind, aiming for 43-50 GW by 2030 as part of its 'Clean Power 2030 Action Plan' (UK Government, 2024). While the UK Government does not yet have specific policy targets for tidal stream capacity, the UK is currently a global leader in developing this technology and has potential for large amounts of energy to be produced by it (Coles *et al*, 2021). Studies have shown the practical UK tidal stream resource to be around 11 GW (Coles *et al*, 2021). This spans a wide range of locations around the UK coast, although the UK resource is concentrated at only a few large sites, mainly in Scotland (MeyGen, Pentland Firth; EMEC Fall of Warness, Orkney) and Wales (Morlais, North Wales), with a pipeline of tidal stream projects ready and due to be commissioned between 2026 and 2029 (Supergen ORE Hub, 2024). Eight tidal range projects are also currently being considered along the west coast of the UK, from Cumbria to Somerset, giving a potential for over 20 GW installed capacity (BHA, 2026). Global deployment of wave energy is currently low, but it could follow a similar growth path to offshore wind. The UK is currently a leader in developing wave energy technologies and has significant resource that can be exploited in the future (Jins and Greaves, 2021).

The power generated by offshore wind depends very strongly on wind speed and subsequently, change in the characteristic wind distribution due to climate change could lead to variable energy yields (Doddy Clarke *et al*., 2022; Warder *et al*. 2024; Abdelaziz *et al*. 2025). It is noted that future projections of wind climate are variable and highly uncertain (Palmer *et al*., 2018, with changes in offshore wind yield likely occurring both spatially (i.e. regionally) and temporally (i.e. seasonally). Extreme weather periods, such as heatwaves, cold snaps and droughts could lead to demand-driven overstress of energy infrastructure especially offshore and coastal locations, thus threatening national energy security (Clare *et al*., 2022). During the winter of 2022–23 long periods of high pressure/low wind were encountered with energy generators having to turn to emergency coal-fired power stations to avoid interruption to the energy supply (Climate Change Committee, 2023; BBC, 2023).

The spatial distribution of future UK offshore wind farms will also influence potential power generation output, characteristics, and variability. Current installation is heavily concentrated in a few areas, particularly off the east coast of England and in the eastern Irish Sea. A wider geographic spread of offshore development can potentially result in an improved and less-variable UK-aggregated power generation profile: it would be less impacted by periods of low generation ('wind droughts') and extreme wind power ramping events, without negatively impacting mean or peak generation outputs (Giddings *et al*, 2024).

A recent poleward shift in North Atlantic storm tracks has been observed, together with an increase in storm intensity (Bricheno *et al*. 2025). To better understand the risk from extreme weather on current and future renewable generation and demand, the Met Office, in collaboration with the National Infrastructure Commission and the Climate Change Committee, developed the Adverse Weather Scenarios for Future Electricity Systems dataset (National Infrastructure Commission, 2022). It comprises adverse weather scenarios, based on physically plausible weather conditions, representing a range of possible extreme events. It can be used to stress test proposed future highly renewable energy dependent electricity systems to inform resilience planning.

The risk to offshore infrastructure from storms and high waves is assessed as medium magnitude from the 2050s onwards, according to the UK's Third Climate Change Risk Assessment (CCRA3) (Jaroszweski *et al*., 2021). The current risk is considered low magnitude. This change is in part due to increasing offshore renewable energy infrastructure linked to the UK and devolved administration Net Zero targets. There is also some evidence that changes to wave height, wind speed and sea level rise could exacerbate the risks to offshore infrastructure in future.

Climate-change induced variability in the oceanographic climate may modify the risk profile of many marine assets on the UK’s continental shelf, heightening risk of damage to, and failure of, these assets (Clare *et al*., 2022). Wilkie and Galasso (2020) found increased risk of structural failure of offshore floating wind components under climate-change scenarios. Floating wind turbine designs must account for these changing conditions, such as designing mooring systems that can withstand climate-related stresses.

Increased storminess and regional sea level rise can have an impact on the seafloor and its sediments. This could lead to more frequent periodic disturbance of an otherwise increasingly immobile seabed, resulting in (for instance) cable exposure and enhanced scour around marine structures. Rulent *et al*. (2026) has mapped where the seabed composition is more likely to change in the future, pointing towards the importance of seasonal variability and hotspots where future changes in seabed mobility will need to be taken in consideration. While sea-level rise brings a small but predictable and consistent change in seabed stresses, future storminess is expected to bring rare but large seabed stresses. These storms will be able to locally increase the seabed stress of up to an order of magnitude in some regions and need to be taken into consideration when planning operational structures. An increased number and strength of winter storms will lead to larger areas of seabed, and coarser sediments becoming mobilised (Rulent *et al*., 2026).

These changes and increased variability may result in the need for additional scour protection on the seabed (rock armour). Adapting to these increased risks is anticipated to increase operation and maintenance costs, requiring more-frequent structural checks, increased engineering costs associated with construction, maintenance and repair and additional spend associated with added redundancy.

Many aspects of the deployment, operation and maintenance, and decommissioning of offshore structures depend on 'weather windows' for at-sea working to be conducted safely. Current weather window patterns are projected to alter under a changing climate, bringing both risks and (potentially) opportunities. The increased potential for weather downtime affects all marine industries including renewable energy generation, oil and gas, aggregate extraction, and other industries. The potential for impact will be dependent upon a range of factors including location, nature of operations and type of vessels involved. This has led to increasing uptake of metocean forecasting capability in offshore industries as an attempt to better define weather windows and mitigate this impact (Acton, 2021).

Coastal structures and infrastructure
The impact of climate change on coastal flooding is presented in MCCIP paper 'Impacts of climate change on coastal flooding around the UK and Ireland' (Haigh *et al*., 2025). Here we focus on the key potential impacts to UK coastal structures and infrastructure.

Projected sea-level rise is anticipated to exacerbate existing pressures on coastal infrastructure and defences and challenge the existing management of coastal resilience. Hooper and Chapman (2012) suggest that the threat of flooding from sea-level rise combined with pluvial flooding from extreme precipitation events is expected to further expose coastal road and rail transport links and infrastructure to an even higher level of risk. Sayers *et al*. (2020) found that by 2100 and under a 4°C global warming scenario, the length of rail track at risk from coastal flooding could increase by 400% in England, 50% in Northern Ireland, and 75% in Scotland. Similarly, in England, the coastal flood risk to sewage works and electricity substations could increase by 200% and 55%, respectively, by the 2080s. Additionally, Brand *et al*., (2018) outline that without intervention, 80 out of the 1200 known landfill sites in low-lying coastal areas in England are projected to become exposed to erosion within the next 40 years.

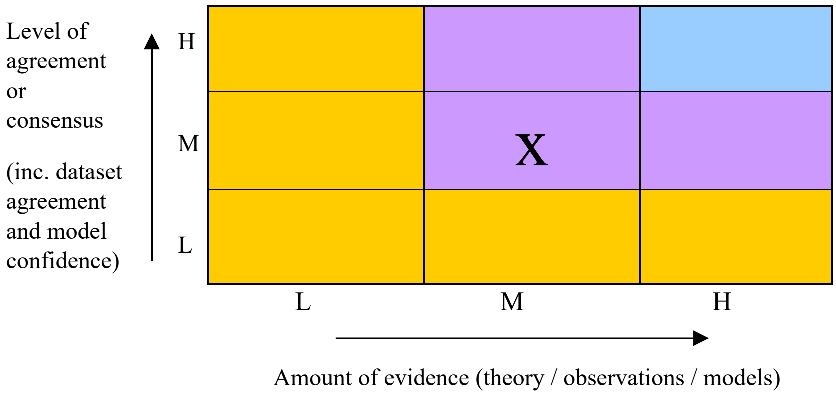
In order to minimise the costs of treating wastewater, sewage treatment plants serving coastal populations have typically been constructed at low elevations near the coast. This facilitates the conveyance of wastewater flows to the plant by gravity and minimises the number of pumping stations required. In addition, coastal locations allow for efficient discharge of treated effluent to adjacent coastal water bodies, although increases in sea levels may require a transition from gravity to pumped discharge systems. During prolonged warm periods, wastewater treating plants may incur higher energy requirements and there may also be changes to the performance of biological systems, oxidation ponds and sludge management, resulting in changes to effluent discharge characteristics and odour increase (Hughes *et al*., 2021). Additionally, extreme rainfall and runoff events are projected to increase, putting the UK's combined wastewater treatment and storm overflow systems under increased pressure. This increases the risk of wastewater overflows and pollution events (Gill *et al*., 2021) which affect water quality through bacterial pollution and increased nitrogen and ammonia, as well as depletion of dissolved oxygen in riverine and coastal waters as a result of eutrophication. Clear links have been identified between reduced water quality and the (unfavourable) condition of Marine Protected Areas (MPAs) (e.g. NRW, 2025): when MPAs are in unfavourable condition there is a greater bar for consent for new development of infrastructure in their vicinity. Accordingly, a climate-related reduction in water quality could theoretically impede development in some areas. The risk of reduced water quality caused by wastewater discharge into coastal receiving waters can be mitigated by upgrading of infrastructure (including smarter designs and improved stormwater storage) and sustainable water management techniques.

Cooling of most coastal power plants in the UK, and specifically nuclear reactor power plants, is achieved through direct cooling by running seawater via inlets through the plant and discharging it at a slightly higher temperature. Warming sea-surface temperatures may reduce the power efficiency of thermal power plants by reducing the temperature differential of cooling water, lowering the ratio of electricity produced to the amount of fuel used in the processing (Linnerud *et al*., 2011), increasing costs and lowering yield. Environmental regulations also impose limits on the temperature of the returned water (typically 30°C) as well as on the temperature differential between inlet and discharge. Therefore, increasing water temperature may also require power stations to change their cooling methods to comply with their environmental permits, as occurred in Finland, Sweden and Germany in 2018 (Hersher, 2018). If the inlet water approaches the limit set for discharge, or the cooling waters are unable to effectively cool reactors, the plant will be unable to run at full power. This may become a more frequent consideration in the future when extreme prolonged heatwave conditions are combined with rising sea-surface temperatures. This may lead to an uptake in alternative cooling methods, such as at Barking Reach Power Station, on the tidal section of the River Thames. When active, this station ran for much of the year on direct cooling but is required under its consents to switch to tower cooling during the summer months when the river temperature exceeds 21.5°C (Turnpenny *et al*., 2010).

New industries are moving into offshore areas. For example, Norway and Scotland are some of the first countries to approve licences for open-ocean finfish aquaculture in increasingly exposed locations (Morro *et al*., 2022). Future increases in sea-surface temperature could increase productivity, but warmer conditions may also increase the frequency and magnitude of welfare risks to farmed species (e.g. harmful algal blooms, Amoebic gill disease and jellyfish: Morro *et al*., 2022) and also introduce greater pressures from invasive species due to changing marine habitat extents. Potential increases in storminess are anticipated to expose offshore-aquaculture setups to pen failures and escapes, increasing maintenance costs and presenting escalated risk to endemic populations (Føre and Thorvaldsen, 2021). However, the role of climate change in future operation in this emerging industry sector remains uncertain and highly dependent on the sector’s ability to adapt to environmental challenges (Barange *et al.*, 2018). Climate change also presents opportunities for increased productivity as it facilitates the northward migration of species, potentially opening new cultivation opportunities (Surminski, 2021).

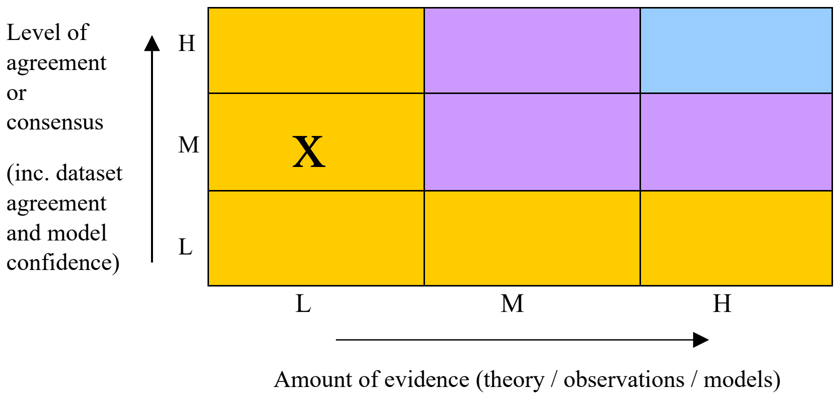
CONFIDENCE ASSESSMENT

What is already happening?



Access to data and information remains difficult. Industry (consultancy and private companies) have difficulty accessing contemporary academic literature. Additionally, much of the progress in understanding of climate associated risk to infrastructure is undertaken within companies and is considered commercially sensitive and not published. As a result, the exchange, review and dissemination of emerging understanding between the scientific community and industry is poor, with the primary source of collaboration between those two groups being restricted to discrete research funding projects and word of mouth.

What could happen in the future?



Confidence with regards to assessments of potential future impacts to coastal and marine transport and infrastructure is intrinsically linked to the robustness of future climate change projections. For sea-level rise, projections have relatively high levels of confidence irrespective of emission scenario and there is a recognition of reductions in sea-ice extents and sea-surface temperatures. Conversely, confidence in the projected future patterns of some impacts (including changes to storms and waves) is much lower, with significant spatial variability and conflicting model simulations. Accordingly, there remains uncertainty as to exactly how coastal and marine transport and infrastructure may be impacted in future. Notwithstanding this, with significantly more of our energy infrastructure in the marine environment, including offshore windfarms, tide and wave power generators, electricity transmission infrastructure as well as telecommunications cables, the risk of climate-related damage is expected to increase.

The overall confidence assessment has not changed from the previous paper, and we conclude that the amount of evidence remains low on the future impacts of climate change on marine and coastal transport and infrastructure.

KEY CHALLENGES AND EMERGING ISSUES

Top challenges

1. The accelerated expansion of the marine renewable energy sector means an increasingly significant proportion of nationally critical infrastructure is being built in the marine environment. This infrastructure is also being deployed in deeper and more-exposed offshore locations, along with an increasing network of associated transmission cables and interconnectors. The risk of damage to our energy network from climate change related storm events is therefore increasing.
2. As the lifespan of the marine infrastructure is extended, there is a need for improved data and models on changes to weather parameters, most notably wind and wave regimes, to adapt designs to a changing climate.
3. There is also a need to better understand and share the information on how climate change affects infrastructure performance, deterioration, and threshold failure.

Top emerging issues

1. The growth in marine renewable energy is significantly increasing demand for port area needed for the construction, operation, and maintenance of offshore windfarms. The ongoing expansion of the marine renewable energy sector and the advancement of decarbonisation technologies are expected to further increase the need for port facilities and infrastructure.
2. There is a call from industry to understand the interdependencies and cascading risks to nationally critical infrastructure, and to the UK Government to provide the mechanisms for these to be investigated

and mitigated (The Joint Committee on the National Security Strategy, 2022).

3. Companies are now required to report climate risks under The Companies (Strategic Report) (Climate-related Financial Disclosure) Regulations 2022. There is increasing recognition of the growing financial risk of inaction on climate change resilience from the finance, insurance and contractual/liability sectors: understanding climate-associated financial risk is therefore becoming increasingly business-critical.
4. Warming seawater temperatures may have a significant impact on the operation of marine cooling and outfall systems as well as present challenges for marine aquaculture and fisheries activities. The impact of increasing temperatures on the viability of sea farming operations however remains poorly understood.

REFERENCES

Abdelaziz, S., Sparrow, S. N., Hua, W., & Wallom, D. C. H. (2025). Assessing the long-term effects of climate change on offshore wind operations in the UK. *Energy*, 332, Article 137062. https://doi.org/10.1016/j.energy.2025.137062

Asariotis, R., Monioudi, I. N., Mohos Naray, V., Velegrakis, A. F., Vousdoukas, M. I., Mentaschi, L., & Feyen, L. (2024). Climate change and seaports: Hazards, impacts and policies and legislation for adaptation. *Anthropocene Coasts*, 7(1), 14. https://doi.org/10.1007/s44218-024-00047-9

ABP (2021). *Climate Change Adaptation Report: 2021 Update*. Associated British Ports, London.

Acton, C. (2021). The impacts of climate change on the windows of offshore operations. *Proceedings of the ASME 2021 40th International Conference on Ocean, Offshore and Arctic Engineering. Volume 9: Ocean Renewable Energy*. Available at: asmedigitalcollection.asme.org/OMAE/proceedings-abstract/OMAE2021/85192/1121610

Arikan, Y. and Campbell, M. (2021). Maximising power cable reliability for offshore wind. Available at: acteon.com/blog/maximising-power-cable-reliability-for-offshore-wind/

Arrighi, C., Pregnolato, M. and Castelli F. (2021). Indirect flood impacts and cascade risk across interdependent linear infrastructures. *Natural Hazards Earth System Sciences*, **21**, 1955–1969. doi.org/10.5194/nhess-21-1955-2021

Barange, M., Bahri, T., Beveridge, M.C., Cochrane, K.L., Funge-Smith, S. and Poulain, F. (2018). *Impacts of Climate Change on Fisheries and Aquaculture: synthesis of current knowledge, adaptation and mitigation options, FAO Fisheries and Aquaculture Technical Paper No. 627,* FAO, Rome, pp.611-628.

BBC (2022). Damaged cable leaves Shetland cut off from mainland. Available at: www.bbc.co.uk/news/uk-scotland-north-east-orkney-shetland-63326102

BBC (2023). Emergency coal power plants used for first time as UK sees cold snap. Available at: www.bbc.co.uk/news/business-64879044

Bellomo, K., Meccia, V.L., D'Agostino, R. Fabian, F. Larson, S.M, vonHardenberg, J., *et al.* (2023). Impacts of a weakened AMOC on precipitation over the Euro-Atlantic region in the EC-Earth3 climate model. *Climate Dynamics,* **61**, 3397–3416. doi.org/10.1007/s00382-023-06754-2

Berry, P. and Brown, I. (2021). National environment and assets. In *The Third UK Climate Change Risk Assessment Technical Report* (eds Betts, R.A., Haward, A.B. and Pearson, K.V.). Prepared for the Climate Change Committee, London.

Berthou, S., Renshaw, R., Smyth, T. *et al*. Exceptional atmospheric conditions in June 2023 generated a northwest European marine heatwave which contributed to breaking land temperature records. *Commun Earth Environ* 5, 287 (2024). doi.org/10.1038/s43247-024-01413-8

British Hydropower Association (BHA). (2026). Tidal Range. Available at: https://british-hydro.org/tidal-range-hydropower/.

BPA (2021). Climate change and ports impacts and adaptation strategies. Available at: www.britishports.org.uk/content/uploads/2021/03/bpa_hr_wallingford_climate_change_adaptation.pdf

Brand, J.H., Spencer, K.L., O'Shea, F.T. and Lindsay, J.E. (2018). Potential pollution risks of historic landfills on low-lying coasts and estuaries. *Wiley Interdisciplinary Reviews: Water*, **5**(1), e1264.

Bricheno, L.M. and Wolf, J. (2018). Future wave conditions of Europe, in response to high-end climate change scenarios. *Journal of Geophysical Research: Oceans*, **123**(12), 8762–8791. doi.org/10.1029/2018JC013866

Bricheno, L.M., Woolf, D., Valiente, N.G., Makrygianni, N., Chowdhury, P., and Timmermans, B. (2025). Climate change impacts on storms and waves relevant to the UK and Ireland. *MCCIP Science Review*, 24pp.

Brooke J, Giovando J, Dahl T, Joyner B and Herbert L. (2024). Port and inland waterway design and operation in the face of climate change uncertainty. Proceedings of the Institution of Civil Engineers – Civil Engineering. https://doi.org/10.1680/jcien.23.00134

Bueger, C., Liebetrau, T. and Franken, J. (2022). Security threats to undersea communications cables and infrastructure – consequences for the EU. Policy Department for External Relations Directorate General for External Policies of the Union. PE 702.557. Available at: https://www.europarl.europa.eu/RegData/etudes/IDAN/2022/702557/EXPO_IDA(2022)702557_EN.pdf

Calafat, F.M., Wahl, T., Tadesse, M.G. and Sparrow, S.N. (2022). Trends in Europe storm surge extremes match the rate of sea-level rise. *Nature,* **603** (7903), 841–845. doi.org/10.1038/s41586-022-04426-5

Carpenter, J. R., Merckelbach, L., Callies, U., Clark, S., Gaslikova, L., and Baschek, B. (2016). Potential impacts of offshore wind farms on north sea stratification. PLoS ONE 11, e0160830. doi: 10.1371/journal.pone.0160830

Castelle, B., Dodet, G., Masselink, G. and Scott, T. (2017). A new climate index controlling winter wave activity along the Atlantic coast of Europe: The West Europe Pressure Anomaly. *Geophysical Research Letters*, **44**(3), 1384–1392. doi: 10.1002/2016GL072379

Clare, M. A., Yeo, I. A., Bricheno, L., Aksenov, Y., Brown, J., Haigh, I. D. *et al.* (2022). Climate change hotspots and implications for the global subsea telecommunications network. *Earth-Science Reviews*, 104296.

Climate Change Committee, (CCC) (2023). Progress in reducing UK emissions 2023 Report to Parliament Climate Change Committee June 2023. Available at: www.theccc.org.uk/wp-content/uploads/2023/06/Progress-in-reducing-UK-emissions-2023-Report-to-Parliament-1.pdf

Coles, D., Angeloudis, A., Greaves, D., Hastie, G., Lewis, M., Mackie, L., McNaughton, J., Miles, J., Neill, S., Piggott, M. *et al*. (2021). A review of the UK and British Channel Islands practical tidal stream energy resource*, Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 477, p. 20210469. doi: 10.1098/rspa.2021.0469

Coll, J., Woolf, D. K., Gibb, S.W. and Challenor, P.G. (2013). Sensitivity of ferry services to the Western Isles of Scotland to changes in wave and wind climate. *Journal of Applied Meteorology and Climatology*, **52**(5), 1069-1084.

Collins M.M. Sutherland, L. Bouwer, S.M. Cheong, T. Frölicher, H. Jacot Des Combes, M. *et al.*, (2019). Extremes, Abrupt Changes and Managing Risks. In *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (eds Pörtner, H.-O., D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama, and N. Weyer), pp. 589-655. www.ipcc.ch/srocc/chapter/ chapter-6.

Cornes, R.C., Artioli, Y., Hermanson, L., Hunter, W.R., Jacobs, Z. L., Kent, E.C., Oltmanns, M., Rabe, B., Renshaw, R., Tinker, J. and Wilson, R.J. (2025). Climate change impacts on sea temperature around the UK and Ireland. *MCCIP Science Review*, 24pp.

Dawson, R.J., Thompson, D., Johns, D., Gosling, S., Chapman, L., Darch, G., Watson, G., Powrie, W., Bell, S., Paulson, K., Hughes, P. and Wood, R. (2016). *UK Climate Change Risk Assessment Evidence Report: Chapter 4, Infrastructure*. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.

Department for Environment, Food & Rural Affairs (Defra). (2025). Reed: Government to cut sewage pollution in half by 2030. Available at: https://www.gov.uk/government/news/reed-government-to-cut-sewage-pollution-in-half-by-2030

Department for Transport (2022). Port freight statistics: background quality report. Available at: www.gov.uk/government/statistics/port-freight-annual-statistics-2021/port-freight-statistics-background-quality-report

Diamond, K. (2012) Extreme weather impacts on offshore wind turbines: Lessons learned. *Natural Resources and Environment*, DHI, 2020, Arcadis Ost 1 Offshore wind farm, Met Ocean Study for Detailed Design. Rev 4.

Digre, H. (2020) Hybrid feed barges are becoming the new standard. ScaleAQ Available at: scaleaq.com/news/2020/12/hybrid-feed-barges-are-becoming-the-new-standard/

DNV (2023). Energy Transition. Are offshore energy islands the future of hydrogen and e-fuel production? Available at: www.dnv.com/energy-transition/offshore-energy-islands.html

Doddy Clarke, E., Sweeney, C., McDermott, F., Griffin, S., Correia, J. M., Nolan, P. and Cooke, L. (2022). Climate change impacts on wind energy generation in Ireland. *Wind Energy*, **25**(2), 300-312.

DRAX (2022). Keeping the lights on: Network rail reopens a vital British freight line after major repair-operation. Available at: www.drax.com/press_release/keeping-the-lights-on-network-rail-reopens-a-vital-british-freight-line-after-major-repair-operation/

Earl, N., Dorling, S., Hewston, R. and Von Glasow, R. (2013). 1980–2010 variability in UK surface wind climate. *Journal of Climate*, **26**(4), 1172-1191.

EDF and CGN (2021). Sizewell C project: Sizewell C Coastal Defences Design Report V2.0. Available at: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010012/EN010012-007645-Sizewell%20C%20Project%20-%20Other-%20Sizewell%20C%20Coastal%20Defences%20Design%20Report%20-%20Revision%202.0.pdf

Environmental Defence Fund (2022). Act now or pay later. The impact of climate change on Shipping. Available at: https://www.edf.org/sites/default/files/press-releases/RTI-EDF%20Act%20Now%20or%20Pay%20Later%20Climate%20Impact%20Shipping.pdf

European Space Agency (2023). UK suffers marine heatwave. Available at: www.esa.int/ESA_Multimedia/Images/2023/06/UK_suffers_marine_heatwave

Føre, H. M. and Thorvaldsen, T. (2021). Causal analysis of escape of Atlantic salmon and rainbow trout from Norwegian fish farms during 2010–2018. *Aquaculture*, **532**, 736002.

Fox-Kemper, B., Hewitt, H.T., Xiao, C., Aðalgeirsdóttir, G., Drijfhout, S.S., Edwards, T.L. *et al.* (2021). Ocean, Cryosphere and Sea Level Change. In *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (eds Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. *et al.*) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1211–1362. doi:10.1017/9781009157896.011

GB Energy (2025). Great British Energy Strategic Plan. Available at: https://www.gbe.gov.uk/

Giddings, J., Bloomfield, H., James, R., & Blair, M. (2024). The impact of future UK offshore wind farm distribution and climate change on generation performance and variability. *Environmental Research Letters*, 19(6), 064022.

Gill, E., Horton, B., Gilbert, J., Riisnaes, S. and Partridge, E. (2021). Storm Overflow Evidence Project. Final Report v3. Available at: assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1030980/storm-overflows-evidence-project.pdf

Gulev, S.K., P.W. Thorne, J., Ahn, F.J., Dentener, C.M., Domingues, S., Gerland, D. *et al.* (2021). Changing State of the Climate System. In *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (eds Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger *et al.*) Cambridge University Press, Cambridge, United Kingdom and New York, pp. 287–422. doi:10.1017/9781009157896.004

Haigh, I.D., Brown, J., Dornbusch, U., Lyddon, C., McCarthy, G.D., Nicholls, R.J., Palmer, M.D., Payo, A. Penning-Roswell, E., Sayers, P., Schmidt, D.N., and Valiente, N.G. (2025). Climate change impacts on coastal flooding, relevant to the coastal and marine environment around the UK and Ireland. *MCCIP Science Review*, 24pp

Hanson, S.E. and Nicholls, R.J. (2020). Demand for ports to 2050: Climate policy, growing trade and the impacts of sea-level rise. *Earth's Future*, 8, e2020EF001543. doi.org/10.1029/2020EF001543

Hersher, R. (2018). Hot Weather Spells Trouble For Nuclear Power Plants In Europe. NPR. Available at: www.npr.org/2018/07/27/632988813/hot-weather-spells-trouble-for-nuclear-power-plants

Hochet, A., Dodet, G., Ardhuin, F., Hemer, M. and Young, I. (2021) Sea State Decadal Variability in the North Atlantic: A Review. *Climate*, **9**(12), 173.

Hogarth, P., Hughes, C. W., Williams, S. D. P. and Wilson, C. (2020). Improved and extended tide gauge records for the British Isles leading to more consistent estimates of sea level rise and acceleration since 1958. *Progress in Oceanography*, 184. doi.org/10.1016/J.POCEAN.2020.102333

Hooper, E. and Chapman, L. (2012). Chapter 5 The Impacts of Climate Change on National Road and Rail Networks. *Transport and Sustainability*, **2**, 105-136.

Horsburgh, K., Rennie, A. and Palmer, M. (2020). Impacts of climate change on sea-level rise relevant to the coastal and marine environment around the UK. *MCCIP Science Review*, 2020, 116–131. doi: 10.14465/2020.arc06.slr

Hughes, J., Cowper-Heays, K., Olesson, E., Bell, R. and Stroombergen, A. (2021). Impacts and implications of climate change on wastewater systems: A New Zealand perspective. *Climate Risk Management*, **31**, 100262.

IMO (2023). Initial IMO GHG Strategy. Available at: www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx

IPCC (2013). *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (eds Stocker, T.F. D. *et al.*), Cambridge University Press.

IPCC (2022) *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (eds H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama), Cambridge University Press.

Izaguirre, C., Losada, I., Camus, P., Vigh, J. and Stenek, V. (2021). Climate change risk to global port operations, *Nature Climate Change*, **11**(1), 14-20.

Jackson, L.C., Kahana, R., Graham, T., Ringer, M.A., Woollings T., Mecking, J. V. and Wood, R.A. (2015). Global and European climate impacts of a slowdown of the AMOC in a high resolution GCM. *Climate Dynamics*, **45**(11), 3299-3316. doi:10.1007/s00382-015-2540-2

Jaroszweski, D., Wood, R. and Chapman, L. (2021). Infrastructure. In *The Third UK Climate Change Risk Assessment Technical Report* (eds Betts, R.A., Haward, A.B., Pearson, K.V.), Climate Change Committee, London.

Jenkins, K., Nicholls, R. J., & Sayers, P.(2025). Climate change adaptation in the port industry: Evaluating evidence of implemented adaptation using a national adaptation inventory. *Earth's Future*, 13,e2024EF005841.

Jin, S. and Greaves, D. (2021). Wave energy in the UK: Status review and future perspectives, *Renewable and Sustainable Energy Reviews*, 143, p. 110932. doi: 10.1016/j.rser.2021.110932.

Joint Committee on the National Security Strategy, JCNSS (2022). Readiness for storms ahead? Critical national infrastructure in an age of climate change. First Report of Session 2022-23 HC132 HL74. Parliamentary Copyright House of Commons 2022.

Kendon, M., Doherty, A., Hollis, D., Carlisle, E., Packman, S., Jevrejeva, S., Matthews, A., Williams, J., Garforth, J. and Sparks, T. (2025). State of the UK Climate in 2024. *International Journal of Climatology,* **45**, Article S1. https://doi.org/10.1002/joc.70010

Kendon, M., McCarthy, M., Jevrejeva, S., Matthews, A., Sparks, T., Garforth, J. and Kennedy, J. (2022). State of the UK Climate 2021. *International Journal of Climatology*, **42**(S1), 1– 80.

Kordahi, M., Stix, R. and Rapp, R. (2016). Global trends in submarine cable system faults, Submarine Cable Environment Group., SubOptic 2016.

Linnerud, K., Mideksa, T.K. and Eskeland, G.S. (2011). The impact of climate change on nuclear power supply. *The Energy Journal*, **32**(1).

Laurila T.K., Sinclair V.A., and Gregow H., (2021): Climatology, variability, and trends in near-surface wind speeds over the North Atlantic and Europe during 1979–2018 based on ERA5. International Journal of Climatology 41: 2253– 2278. https://doi.org/10.1002/joc.6957

Lowe, J.A., Howard, T., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., Ridley, J., Dye, S. and Bradley, S. (2009). UK Climate Projections science report: Marine and coastal projections. Met Office Hadley Centre, Exeter, UK. ISBN 978-1-906360-03-0

Maritime UK. (2022). State of the Maritime Nation 2022. Maritime UK. Available at: https://www.maritimeuk.org/state-of-the-maritime-nation/

Marra, G., Fairweather, D.M. Kamalov, V. Gaynor, P. Cantono, M. Mulholland, S. *et al*. (2022) Optical interferometry–based array of seafloor environmental sensors using a transoceanic submarine cable.Science376,874-879

Masselink, G., Russell, P., Rennie, A., Brooks, S. and Spencer, T. (2020). Impacts of climate change on coastal geomorphology and coastal erosion relevant to the coastal and marine environment around the UK. *MCCIP Science Review*, 2020, 158-189.

McCarthy, G. D., Graham, J.A., Hermanson, L., Hodge, K. R., Moat, B. I., Moffa-Sanchez, P., Petit, T., Robson, J. (2025). Climate change impacts on ocean circulation relevant to the UK and Ireland. MCCIP Science Review, 35pp. doi: 10.14465/2025.reu05.cir

Met Office (2026). 2025 is double-record breaker: UK's warmest and sunniest year on record. Available at: https://www.metoffice.gov.uk/about-us/news-and-media/media-centre/weather-and-climate-news/2026/2025-is-double-record-breaker-uks-warmest-and-sunniest-year-on-record

Met Office (2025). Waters surrounding UK experiencing significant marine heatwave. Available at: https://www.metoffice.gov.uk/blog/2025/waters-surrounding-uk-experiencing-marine-heatwave

Met Office (2024). The Atlantic Meridional Overturning Circulation in a changing climate. Avaialble at: https://www.metoffice.gov.uk/blog/2024/the-atlantic-meridional-overturning-circulation-in-a-changing-climate#:~:text=She%20continued:%20%E2%80%9COne%20unlikely%20possibility,industries%20and%20renewable%20energy%20production.

Microsoft (2023) Project Natick. Available at: natick.research.microsoft.com/

Morim, J., Hemer, M., Wang, X. L., Cartwright, N., Trenham, C., Semedo, A. *et al.* (2019). Robustness and uncertainties in global multivariate wind-wave climate projections. *Nature Climate Change*. **9**(9), 711–718. doi.org/10.1038/s41558-019-0542-5

Morro, B., Davidson, K., Adams, T.P., Falconer, L., Holloway, M., Dale, A. *et al.* (2022). Offshore aquaculture of finfish: Big expectations at sea. *Reviews in Aquaculture*, **14**(2), 791-815.

Mudryk, L.R., Dawson, J., Howell, S.E., Derksen, C., Zagon, T.A. and Brady, M. (2021). Impact of 1, 2 and 4 C of global warming on ship navigation in the Canadian Arctic. *Nature Climate Change*, **11**(8), 673-679.

Murphy J.M., Harris, G.R., Sexton, D.M., Kendon, E.J. Brett, P.E., Clark, R.T. *et al*., (2018): UKCP18 Land Projections: Science Report. Available at: https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Land-report.pdf

Murray, C. (2022). Shell, Eneco building green hydrogen and battery storage system for wind farm off Dutch coast. Energy Shortage News. Available at: www.energy-storage.news/shell-eneco-building-green-hydrogen-and-battery-storage-system-for-wind-farm-off-dutch-coast/

National Infrastructure Commission (2022). Adverse weather scenarios and future electricity generation: project overview. Available at: nic.org.uk/studies-reports/national-infrastructure-assessment-old/adverse-weather-scenarios-for-future-electricity-systems-overview/

Natural resources Wales (NRW) (2025). Further action needed to protect Wales's marine protected areas. Available at: https://naturalresources.wales/about-us/news-and-blogs/news/2025-news-releases/further-action-needed-to-protect-wales-s-marine-protected-areas/?lang=en

NCE (2026). How Britain plans to increase its fleet of international subsea interconnectors. Available at: https://www.newcivilengineer.com/latest/how-britain-plans-to-increase-its-fleet-of-international-subsea-interconnectors-25-03-2026/.

OEUK (2023) Economic Report 2023: Business Environment and Economics, OEUK reports. Available at: https://oeuk.org.uk/product/economic-report-2023/

Ofwat (2011). Future Impacts on Sewer Systems in England and Wales: Summary of a Hydraulic Modelling Exercise Reviewing the Impact of Climate Change, Population and Growth in Impermeable Areas up to Around 2040. Available at: www.ofwat.gov.uk/wp-content/uploads/2015/11/rpt_com201106mottmacsewer.pdf

Oliver, E.C. Donat, M.G. Burrows, M.T. Moore, P.J. Smale, D.A. Alexander, L.V. *et al*., (2018). Longer and more frequent marine heatwaves over the past century. *Nature Communications*, **9**(1), 1324. doi:10.1038/s41467-018-03732-9

ONS (2021). Wind Energy in the UK: June 2021. Available at: www.ons.gov.uk/economy/environmentalaccounts/articles/windenergyintheuk/june2021

Ouro, P., Fernandez, R., Armstrong, A., Brooks, B., Burton, R. R., Folkard, A., & Watson, F. M. (2024). Environmental impacts from large-scale offshore renewable-energy deployment. *Environmental Research Letters*, 19(6), 063001.

Palmer, M., Howard, T., Tinker, J., Lowe, J., Bricheno, L., Calvert, D., Edwards, T., Gregory, J., Harris, G., Krijnen, J., Pickering, M., Roberts C. and Wolf J. (2018). UK Climate Projections Science Report: UKCP18 Marine report. Met Office Hadley Centre: Exeter.

Palmer, M.D., Gregory, J.M., Bagge, M., Calvert, D., Hagedoorn, J.M., Howard, T., Klemann, V., Lowe, J.A., Roberts, C.D., Slangen, A.B., and Spada, G. (2020). Exploring the Drivers of Global and Local Sea-Level Change Over the 21st Century and Beyond, *Earth's Future*, **8**(3), e2019EF001413. doi.org/10.1029/2019EF001413

Peel Ports (2021). Climate Change Adaptation Report for Port of Sheerness Ltd and Mersey Docks and Harbour Company Ltd. Available at www.peelports.com/media/ldsif0sl/port-of-sheerness-mersey-docks-and-harbour-company-climate-change-adaptation-report-2021.pdf

Pery, M., Navarrete, R., Muradăs, P., Puig, M., Lambrecht, N., Valencia A.M. and Castillo. P. (2021). Climate risk and ports: a practical guide on strengthening resilience, Inter-American Development Bank.

PIANC (2020). *Climate Change Adaptation Planning for Ports and Inland Waterways*, PIANC WG 178, EnviCom.

PIANC (2022). *Managing Climate Change Uncertainties in Selecting, Designing and Evaluating Options for Resilient Navigation Infrastructure*, PIANC PTGCC Technical Note 1, EnviCom.

PIANC (2024). *Climate Change Costs to Ports and Waterways: Scoping the Business Case Assessment for Investment in Adaptation*. PTGCC Technical Note 2, PIANC, EnviCom.

Pirret J.S.R., Fung F., Locatelli T. and Manning C., (2023). UK Climate Projections Factsheet: Storms. Met Office, Exeter. Available at: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-factsheet-storms.pdf

PLA (2021) Climate Change Adaptation Report Third Round Update From Port of London Authority. Available at: www.pla.co.uk//assets/adaptingtoclimatechangesubmissionfinal.pdf

Pontee, N. (2013). Defining coastal squeeze: A discussion. *Ocean and Coastal Management*, **84**, 204-207.

Port of Dover (2021). Climate Change Adaption report 2021. Available at: www.doverport.co.uk/administrator/tinymce/source/Climate%20Change%20Adaptation%20Reporting.pdf

Priestley, M. D. K. and Catto, J. L. (2022): Future changes in the extratropical storm tracks and cyclone intensity, wind speed, and structure, Weather and Climate Dynamics, 3, 337–360, https://doi.org/10.5194/wcd-3-337-2022

Rennie, A.F., Hansom, J.D., Hurst, M.D., Muir, F.M.E, Naylor, L.A., Dunkley, R.A. and MacDonell, C.J (2021). *Dynamic Coast: The National Overview* (2021), CRW2017_08. Scotland's Centre of Expertise for Waters (CREW). Available at: crew.ac.uk/publications .

Roberts, C. and Maslin, M. (2021). How might climate change impact Scotch Whisky production in the next 50-100 years? University College London. Available at: fosm.de/wp-content/uploads/2021/10/How-might-climate-change-impact-Scotch-whisky-production-in-the-next-50-100-years_v2.pdf

Rulent, J., Bricheno, L., McCarron, C. *et al*. Climate change affects future sea-bed mobility via storms and sea level rise. Commun Earth Environ 7, 496 (2026). https://doi.org/10.1038/s43247-026-03500-4Salmon Scotland (2022). Annual survey shows record level of Scottish salmon. Available at: www.salmonscotland.co.uk/news/press-release/annual-survey-shows-record-level-of-scottish-salmon

Sayers, P.B., Horritt, M., Carr, S., Kay, A., Mauz, J., Lamb, R. and Penning-Rowsell, E. (2020) Third UK Climate Change Risk Assessment (CCRA3): Future flood risk. Research undertaken by Sayers and Partners for the Committee on Climate Change, Committee on Climate Change, London.

Scottish Water (2021). Improving Urban Waters - Route Map. Available at: www.scottishwater.co.uk/About-Us/What-We-Do/Urban-Waters-Routemap

Seneviratne, S.I., Zhang, X., Adnan, M., Badi, W., Dereczynski, C., Di Luca, A. *et al.* (2021). Weather and Climate Extreme Events in a Changing Climate. In *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (eds. Masson-Delmotte, V., P. Zhai, A.Pirani, S.L. Connors, C. Péan, S. Berger *et al.*). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1513–1766. doi:10.1017/9781009157896.013

Slingo, J. (2021). Latest scientific evidence for observed and projected climate change. In *The Third UK Climate Change Risk Assessment Technical Report* (eds Betts, R.A., Haward, A.B. and Pearson, K.V.) Prepared for the Climate Change Committee, London.

https://policyexchange.org.uk/wp-content/uploads/2017/11/Undersea-Cables.pdf

Seabed User & Developer Group (SUDG) (2025). Socio-economic benefits of UK marine industries. Available at: https://www.sudg.org.uk/post/the-socio-economic-benefits-of-marine-industries

Supergen ORE Hub, 2024, ORE Outlook 2040 UK Offshore Renewable Energy in 2040: Building a Sustainable and Competitive ORE Sector on a Pathway to Net Zero by 2050. https://supergen-ore.net/uploads/resources/Final-version-Supergen-ORE-Hub-2040-ORE-Outlook-report.pdf

Surminski, S. (2021). Business and industry. In *The Third UK Climate Change Risk Assessment Technical Report* (eds Betts, R.A., Haward, A.B. and Pearson, K.V.). Prepared for the Climate Change Committee, London.

The Crown Estate (2023). Cables and Pipelines. Available at: https://www.thecrownestate.co.uk/en-gb/what-we-do/on-the-seabed/cables-and-pipelines/

Thompson, P. R., M. J. Widlansky, E. Leuliette, *et al*. (2024). "Global Oceans-Sea-Level Variability and Change [in: State of the Climate in 2023]. *Bulletin of the American Meteorological Society* 105, **8**: S183. https:// doi. org/ 10. 1175/ BAMS-D- 24- 0100. 1.

Turnpenny, A.W.H., Coughlan, J., Ng, B., Crews, P., Bamber, R.N. and Rowles, P. (2010). Cooling Water Options for the New Generation of Nuclear Power Stations in the UK. Environment Agency (UK). Report SC070015/SR3.

UK Government (2020). Environment Bill 2020: Policy Paper. Available at: https://www.gov.uk/government/publications/environment-bill-2020

UK Government (2022) The Companies (Strategic Report) (Climate-related Financial Disclosure) Regulations 2022. Available at: https://www.legislation.gov.uk/uksi/2022/31/contents/made

UK Government. (2024). Clean Power 2030 Action Plan. Available at: https://www.gov.uk/government/publications/clean-power-2030-action-plan

UK Government. (2025). Energy trends: UK renewables www.gov.uk/government/statistics/energy-trends-section-6-renewables)

van de Wal, R. S. W., Nicholls, R. J., Behar, D., McInnes, K., Stammer, D., Lowe, J. A., *et al*. (2022). A high-end estimate of sea level rise for practitioners. Earth's Future, 10, e2022EF002751. https://doi.org/10.1029/2022EF002751

Viking, C. C. S. (2023). Capturing CO2. Securing the future. Available at: www.vikingccs.co.uk

Warder, Simon C. & Piggott, Matthew D., 2025. The future of offshore wind power production: Wake and climate impacts. *Applied Energy*, 380(C).

Weeks, J. H., Allison, L. C., Beverton, A., Lowe, J. A., Orr, H. G., Roberts, H., & Palmer, M. D. (2025). A new framework to explore high-end sea level rise for the UK: Updating H++. *Earth's Future*, 13, e2025EF006086. https://doi.org/10.1029/ 2025EF006086

Wilkie, D. and Galasso, C. (2020). Impact of climate-change scenarios on offshore wind turbine structural performance. *Renewable and Sustainable Energy Reviews*, **134,** 110323.

Wohland, J., Folini, D., and Pickering, B. (2021). Wind speed stilling and its recovery due to internal climate variability, Earth Syst. Dynam., 12, 1239–1251, https://doi.org/10.5194/esd-12-1239-2021

Zappa, G., Shaffrey, L. C., Hodges, K. I., Sansom, P. G. and Stephenson, D. B. (2013): A Multimodel Assessment of Future Projections of North Atlantic and European Extratropical Cyclones in the CMIP5 Climate Models, Journal of Climate, 26(16), 5846-5862. https://doi.org/10.1175/JCLI-D-12-00573.1

Zeng, Z., Ziegler, A.D., Searchinger, T., Yang, L. Chen, A. Ju, K *et al*. (2019). A reversal in global terrestrial stilling and its implications for wind energy production. Nat. Clim. Chang. 9, 979–985. https://doi.org/10.1038/s41558-019-0622-6