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Acronyms

Acronym	Description
ABP	Associated British Ports
ADCP	Acoustic Doppler Current Profiler
AEP	Annual Energy Production
AFL	Agreement for Lease
AR	Allocation Round
CAPEX	Capital Expenditure
CFD	Computational Fluid Dynamic
CfD	Contract for Difference
DECEX	Decommissioning Expenditure
DEVEX	Development Expenditure
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
EMODnet	European Marine Observation and Data Network
FEED	Front-End Engineering Design
GIS	Geographic Information System
GVA	Gross Value Added
ICT	Information and Communication Technology
IRR	Internal Rate Of Return
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
LCOE	Levelized Cost Of Energy
MCZ	Marine Conservation Zones
MMO	Marine Management Organisation
MoU	Memoranda of Understanding
O&M	Operations and Maintenance
OMP	Orbital Marine Power Ltd
OPEX	Operating Expenditure
ORE Catapult	Offshore Renewable Energy Catapult
PPA	Power Purchase Agreement
PTEC	Perpetuus Tidal Energy Centre
PTEP	Poole Tidal Energy Partnership
ROV	Remotely Operated Vehicle
SAC	Special Areas of Conservation
SAE	SIMEC Atlantis Energy
SPA	Special Protected Area
SSEN	Scottish and Southern Electricity Networks
SSSI	Site of Special Scientific Interest
TIGER	Tidal Stream Industry Energiser Project
TSE	Tidal Stream Energy

Executive Summary

The Isle of Wight, off the South Coast of the UK, is an area of potential for tidal stream energy (TSE). The tidal flows in the wider region are significant, with areas of interest including the flow through the Solent (the channel between the Isle of Wight and the mainland), Portland Bill to the west and, most notably, the Perpetuus Tidal Energy Centre (PTEC) to the south of the Island.

The Isle of Wight has proximity to grid infrastructure and population centres in Hampshire. The current site is a 5km^2 area and aims to be operational by 2027/2028. The initial plan is to deploy about ten tidal turbines, with a capacity of 20MW, that would power 12,000 homes, equivalent to around 20% of the homes on the Isle of Wight or generate Green Hydrogen. Beyond this, there is the potential for higher capacity to be developed on the site, with up to 300MW estimated in some studies.

This work is being supported by the Tidal Stream Industry Energiser (TIGER) Project, a €45.3m Interreg-funded project assisting developments at six sites in the Channel region between the UK and France.

This report aims to assess the potential of the Isle of Wight sites for a commercial TSE array. The report targets prospective project developers, investors, policymakers and suppliers who would benefit from an updated holistic and third-party evaluation. Our study consists of the following aspects:

- *A Literature review*: including descriptions of the site's history, the main stakeholders, regional support and schemes and the flow conditions.
- *A Geographic Information System* (*GIS) analysis*: to assess the size of the commercial farm that could be built, identify potential impacts on other sea users and show the potential barriers and geographical aspects that must be considered.
- *A techno-economic analysis*: to estimate the levelized cost of energy (LCOE) that a representative farm at the site could achieve and the CfD strike price that would be required to encourage project development and private investment. We considered optimistic and pessimistic industry cases and applied learning rates to gain insight into the trajectory of LCOE and appropriate CfD strike prices over time.

From our analysis, we provide the following insights into the site:

- PTEC is a state-of-the-art tidal energy generation project with strong local currents. There do not appear to be any significant conflicts with other sea users as the site and the surrounding area have little to no significant fishing or commercial shipping activity. The exception could be environmental designation areas, as the Island of Wight is primarily surrounded by a Special Protected Area (SPA), with the PTEC site on the periphery of a Special Area of Conservation (SAC). Therefore, the export cable would need to go through the SAC to get to the onshore substation and grid connection point.
- The Yarmouth Harbour site is located in an area used heavily by multiple sea-users, but mainly yachts and other pleasure crafts. This is not necessarily a barrier, as some TSE developers have tested here previously and the channel is large enough to accommodate a small device for testing close to the pier. The Yarmouth Harbour site is largely free from fishing activity.

- The University of Exeter has modelled the tidal flow speeds at PTEC and outside of Yarmouth Harbour using a fully coupled flow-wave model of the English Channel using Delft3D-SWAN, indicating maximum spring tidal currents in excess of 3m/s. The area is known for its uneven bathymetry, resulting in turbulent flows which may make the site less desirable for some tidal technologies. In addition, the PTEC site is situated in a deeper channel, much of it deeper than 50m, while the Yarmouth Harbour site is very shallow, generally not exceeding 20m.
- The techno-economic assessment considers two hypothetical tidal farms example; PTEC Phase 1 (30MW) and PTEC Phase 2 (100MW):
    - PTEC Phase 1: by 2030, our model indicates that an LCOE of £88.3 – 146/MWh could be achieved for a 30MW farm of 2.5MW devices, with a central estimate of £100.6/MWh.
    - PTEC Phase 2: by 2032, our model indicates that an LCOE of £70.5 – 120.9/MWh could be achieved for a 100MW farm of 2.5MW devices, with a central estimate of £83/MWh.
- It should be noted that the analysed farms' capacities are hypothetical and idealised, purely based on the area as indicated by the Geographic Information System (GIS). In reality, the site's challenging physical characteristics, particularly the uneven bathymetry, may limit the capacity of deployment.

To summarise, our analysis shows that the Isle of Wight, specifically the PTEC site, has great potential for a commercial array that could provide meaningful amounts of predictable power into the grid. PTEC is a fully consented 30MW site with 300MW potential and has the potential to be economically competitive. The attraction of the PTEC site is the approved capacity and the vast growth potential of the site. Moreover, PTEC has the potential to generate hundreds of MW of TSE, which would be a significant contribution to the UK's renewable energy mix. Additionally, the existing and further engagement with local councils and government could help build support for TSE projects in the region, attracting investment and supporting the industry's growth. The Yarmouth Harbour has merits as a test site, with reasonable flow speeds and sheltered waters. The proximity to Yarmouth Harbour also enables ease of access to deploying and recovering any device/s. The main issue with this site is that it is a relatively narrow and busy channel with a lot of boating activity, likely requiring more careful stakeholder engagement.

Figure 1 – The PTEC site shoreline [1].

1 Introduction

The Isle of Wight, off the South Coast of the UK, is an area of potential for tidal stream energy (TSE). The tidal flows in the wider region are significant, with areas of interest including the flow through the Solent (the channel between the Isle of Wight and the mainland), Portland Bill to the west and, most notably, the Perpetuus Tidal Energy Centre (PTEC) to the south of the Island.

PTEC is a state-of-the-art tidal energy generation project with strong local currents. The Isle of Wight has proximity to grid infrastructure and population centres in Hampshire. The PTEC project aims to showcase a range of commercial, industry-leading TSE technologies at the site. The current site is a 5km^2 area and aims to be operational by 2027/2028. The initial plan is to deploy about ten tidal turbines, with a capacity of 20MW, about 2.5 km south of St Catherine's Point. This would power 12,000 homes, equivalent to around 20% of the homes on the Isle of Wight or generate Green Hydrogen. Beyond this, there is the potential for higher capacity to be developed on the site, with up to 300MW estimated in some studies.

As well as PTEC, the Solent and Portland Bill are also TSE sites of interest. Within the Solent, close to Yarmouth Harbour, several tidal devices were tested, most notably Sustainable Marine Energy's PLAT-O platform in 2014. More recently, QED Naval is setting up a test site in the area to test their community-scale Subhub platform. Portland Bill has been the subject of several studies, most notably by the University of Southampton [2]. It has been estimated that up to 300MW could be deployed in the vicinity, with interest previously expressed by MCT and SIMEC Atlantis Energy.

This site report describes the wider region, encompassing the Isle of Wight, and assesses the future TSE capacity that could be deployed.

- **Note:** Portland Bill site was initially considered in this study. However, it was later descoped when the site developer informed the Offshore Renewable Energy (ORE) Catapult that the agreement for lease (AFL) with the Crown Estate for the site expired. Work completed for the Portland Bill site can be found in Appendix A. Portland Bill.

1.1 Perpetuus Energy Ltd

Perpetuus Energy Ltd is a private company that owns and will operate the PTEC tidal site. Isle of Wight Council was a co-founder and is a stakeholder in PTEC, having invested £1m into the project since 2013. Perpetuus is Latin for perpetual, representing the continuous and recurring nature of the tidal resource.

PTEC partnered with the European Marine Energy Centre (EMEC), based on the Island of Orkney in Scotland, in October 2020 [2]. This partnership builds on knowledge and activities identified by the TIGER project, with EMEC supplying their experience to help prepare PTEC for device deployments. EMEC has been a success story for Orkney and the marine energy industry. It has been estimated that the organisation has generated £306m in gross value added (GVA) and 4,500 full-time equivalent jobs between 2003 and 2019 [3]. It is thought that PTEC can emulate this success.

PTEC aims to develop the PTEC site into a fully commercial site, incorporating proven tidal turbine technology. It is different to EMEC in this respect as it is not a test site, but the ambition is to showcase different tidal technologies at array scale. PTEC are in discussions with several leading tidal stream developers to make this a reality.

1.2 QED Naval Ltd

QED Naval (referred to as QED) was founded in 2008 and is a partner in the TIGER project. QED's management team has experience working within the naval defence sector, developing state-of-the-art SMART stealth technologies, which has given them valuable experience in maritime sector in the area of product design.

QED is developing the Subhub tidal platform, which is in an early stage of development (TRL 6/7). Subhub is a submersible foundation platform structure for tidal turbines and provides a means of transporting and fixing tidal turbines to the seabed. It supports every stage of a tidal turbine's life, from installation and maintenance to decommissioning.

The main advantages of Subhub are reported on the QED Naval website[1] as follows:

- It has a unique ballasting system which can be self-installed and self-aligned with the flow.
- It requires limited support from commonly available tugs and barges.
- It requires only a single, quick offshore operation to install, making its deployment very low-cost.
- Its hull form design accelerates the flow to extract the most energy from the site, overcoming the tidal shear
- It has a no-noise installation with zero aesthetic impact on the seascape, which, as a result, has a low environmental impact

Overall, QED claims that the Subhub can enhance the tidal site yield by up to 48% and that the platform enables low-cost deployment and maintenance.

[1] https://qednaval.co.uk/technology/#subhub

Figure 2 – Subhub platform being tested at Strangford Lough. Taken from [3].

Figure 2 shows the Subhub platform being tested at Strangford Lough in Northern Ireland. Strangford Lough was selected as a site for testing and commissioning specifically due to its large variety of conditions, making it suitable for testing different design concepts. In addition, the Strangford site has fast-flowing water, a pure rock sea bed and is very close to the shoreline, making it very accessible and an ideal location for testing.

Further tests are ongoing, funded through TIGER, which aims to deploy the device in the Solent, close to Yarmouth Harbour. In June 2021, the Subhub was towed to Pembroke Dock in South Wales to be retrofitted with Tocardo turbines prior to deployment ion the Solent.

In January 2020, QED acquired Tocardo Tidal Power through a joint venture with HydroWing. Tocardo is a Dutch turbine manufacturer with a long track record in the industry. The company was founded in 2008, a spin-off of Dutch company Teamwork Technology which specialises in engineering consultancy for marine renewables. Tocardo has turbine scales that can be used for different types of technology. One example is run-of-river applications, where they supplied five of their T-2 turbine model to the Oosterschelde Tidal Power Plant in 2015. Tocardo took ownership of this plant in 2020 [4]. HydroWing specialises in substructure for tidal, in a similar business model to QED. Their multi-rotor system consists of a frame with 3-5 Tocardo turbines mounted. In addition, HydroWing has been exploring hydrogen production markets with its latest product, the THyPSO [5].

1.3 TIGER activities

The TIGER project is a broad base of partners, including academia, research and industry and is led by the ORE Catapult. The project will enable knowledge sharing and learning by linking PTEC and QED with other TIGER partners, accelerating tidal energy deployment in the region.

Related activities being funded within TIGER include:

- Ensuring all licences, permits and grid connection offers are secured and maintained, keeping the PTEC site ready for future Contract for Difference (CfD) Allocation Round (AR) participation, a vital revenue subsidy for tidal stream power exported to grid.

- Acoustic Doppler Current Profiler (ADCP) deployment at the PTEC site by EMEC and Orbital Marine Power Ltd (OMP).

- Computational Fluid Dynamic (CFD) modelling of the Channel region to inform initial tidal site scoping and planning by TIGER academic partners.

- Technical due diligence of QED's community Subhub and industrial Subhub technology development.

- Deployment of QED's Community-scale Subhub technology in the Solent for testing and proof of concept purposes.

- Detailed design work for the Industrial Scale Subhub technology to potentially be deployed at PTEC.

2 Site history

2.1 PTEC

Work on the PTEC project, formerly known as the Solent Ocean Energy Centre, started in 2010, and the seabed agreement for lease was secured in November 2012. The local planning authority granted the planning application in September 2015 and the Marine Management Organisation (MMO) in April 2016, followed by a grid connection offer for 30MW.

PTEC received full consent in 2016 but was put on hold due to a change in the CfD policy. The government removed a ringfence on marine energy deployment in the AR3, meaning that tidal was unable to compete with the more established and cheaper offshore wind projects bidding in.

In October 2020, the PTEC project was brought out of hibernation. However, there have been several public consultations and planning applications related to the onshore grid infrastructure in 2021, including noise modelling studies of the proposed substation, a consultation with local residents and an arboricultural impact assessment examining the trees in the vicinity of the proposed substation.

No PTEC projects were awarded CfDs in AR4 in 2021, with the 40.8MW awarded projects in Scotland at Meygen and Eday, and in Wales at Morlais. The desire is to be awarded CfD contracts in AR5 and beyond or Private Power Purchase Agreement (PPA) as the cost of tidal energy reduces.

A pivotal sub-lease agreement between PTEC and OMP was signed in 2021, with an initial target deployment of up to 20MW by the end of 2027/2028. OMP is an innovative Scottish engineering company based in Orkney. They have deployed several generations of their technology at EMEC, with the latest, the O2, installed during the summer of 2021. Note that this was signed before OMP's success in AR4, which is expected to be OMP's main priority going forward, however they do still have an interest at the PTEC site.

2.1.1 Grid connection

The export cables will carry out the electricity generated by the tidal turbines to land at Castle Cove. Castle Cove was chosen to minimise the environmental impact. A plan to build an onshore substation near the sea is planned, which, with underground cables, will connect and transfer the power to the substation at Wootton Common and the Isle of Wight's electricity grid. Consent has been granted for both the offshore and onshore developments that are required for the project. In addition, a 20MW grid connection offer has been accepted. An onshore substation will be built at Flowersbrook in Ventnor.

2.2 The Solent

Within the Solent, there have been several tidal stream energy devices tested. For example, Sustainable Marine (formerly Sustainable Marine Energy) did some testing of a 100kW platform, their PLAT-O prototype, in 2014 and 2015, before relocating their headquarters to Edinburgh, Scotland. There were also plans to test the Trident Renewable Energy Systems Aquasail concept in 2015, which aimed to obtain a marine license for scale testing close to Yarmouth Pier. However, the company was officially liquidated in 2020 after a hiatus period.

More recently, and as previously mentioned, QED is developing a demonstration site in the Solent, outside Yarmouth Harbour to test their community-scale Subhub concept.

2.3 Portland Bill

Portland Bill has seen interest from developers in the past. In 2014, MCT agreed an Agreement for Lease with the Crown Estate for a project, with a capacity of 30MW. This agreement expires in July 2024. MCT fell into liquidation and some assets, including this agreement for lease were acquired by SIMEC Atlantis Energy (SAE) in 2015. SAE have confirmed they are no longer actively developing this site and expect to hand back the lease to The Crown Estate. Despite this, the Portland Bill site remains a site of interest for tidal stream energy development.

3 The region

3.1 The Isle of Wight

The Isle of Wight is an English county based approximately eight kilometres south of Southampton and three kilometres off the south coast of England, in the Channel. The population density is about 370 people per square kilometre, with a total population of 142,300. According to the Office for National Statistics (ONS) NOMIS portal, 57,300 people are currently employed.

Some notable features of the population demographics include the following [6]:

- Less working age population compared to the Great Britain average (56% vs 62.5%) and a greater proportion of retired people compared to Great Britain's average (20% vs 13.5%)

- Of the population not working, 33.5% want a job, compared to the Great Britain average of 20.5%.

- There is a lower density of jobs available compared to the Great Britain average (0.8 vs 0.87). This is the ratio of total jobs to the population aged 16-64.

- A higher proportion of part-time workers, 39% vs the Great Britain average of 32%.

- There is a marked migration of young people from the island, who leave for increased career opportunities and higher education, which is counterbalanced by an inflow of older people who move to the island for retirement [7].

TSE projects at the island could help create employment opportunities on the island in both direct jobs (for example, at PTEC and Yarmouth Harbour) and indirect jobs. This would galvanise the local economy. As TSE technology has a low visual and environmental impact, tourism would not be affected as a key industry and source of income for the island. In recent years the island has seen growth in its Information and Communication Technology

(ICT) sector, as well as high-value manufacturing and higher-value services [8]. For the earlier stage tidal projects envisioned for the island, this could present an opportunity to use local content and grow skills.

While the island does have an airport, Sandown Airport is used for hobbyists and does not accept commercial flights. In addition, there is no bridge to the island, so the only way of accessing it is via the 45-minute ferry from Lymington or Portsmouth on the mainland.

One renewable energy company with a significant presence on the island is Vestas, the wind turbine manufacturer. The Isle of Wight is home to Vestas's blade factory, which employs 700 people and has manufactured over 10,000 onshore and offshore wind turbine blades since 2002 [9]. In 2021, it reached the milestone of 1,000 offshore wind turbine blades used across the UK. For example, 99 of the 114 blade sets for the Seagreen wind farm, currently under construction off the east coast of Scotland, are being manufactured on the island, with blade painting and finishing at Vestas's facility in Hampshire [10]. While these blades would not be suitable for tidal turbines, and Vestas has never indicated an interest in the sector, it demonstrates the engineering expertise available on the island and the potential synergies that could be established in the future.

The island is connected to the mainland via three submarine 132 kV interconnectors (two working and one as a back-up for reliability), with a capacity of 90 MW each [11].

Isle of Wight Council has set a target to reduce carbon emissions by increasing their low-carbon electricity generation, aiming to become self-sufficient in electricity from renewable sources [12]. They also have the ambitious target to achieve net zero by 2030, 20 years earlier than the 2050 UK target, requiring the island to reduce or offset emissions by 12.8% per annum [12]. Recent renewable energy projects being developed on the island include the Riding Sunbeams project, a world first that aims to directly power trains with solar energy, and a project to examine the feasibility of using solar for hydrogen production [13].

The Isle of Wight has a reputation as one of the sunniest places in the UK. As a result, solar is regarded as an attractive renewable energy resource for the island, with about 90MWp of supply. However, the grid infrastructure is noted as being constrained, which is especially a problem for solar, which can overload the grid during peak supply. For example, in 2017, the island required grid upgrades to cope with the increasing levels of renewables, which meant that the solar had to be curtailed [14]. As of 13th April 2023, the winter peak demand and the total renewable capacity of the Isle of Wight were 129MW and 280MW, respectively [15].

Grid improvement for the island is an active area of research at the University of Southampton, for example, as noted in [11]. This could present an opportunity for the tidal stream, supplying electricity at different times of day and providing grid stability.

3.2 Port facilities

The unsuccessful 970MW Navitus Bay offshore wind project signed memoranda of understanding (MoU) with three local ports in 2015: Poole, Portland and Yarmouth. All three were considered for construction and operation and maintenance (O&M) activities, the advantage being their proximity to the wind farm site. As part of this agreement, all three ports were required to keep some areas of the ports free should the project go ahead [16].

3.2.1 Poole

Poole Harbour is one of the world's largest natural harbours, with 10,000 acres of area. In their 2012 Port Master Plan, setting out their strategy for the following 20 years, they noted that a key objective is to bring forward schemes to provide "port infrastructure to support a renewable energy maintenance and support base" [17].

Poole Harbour has been investigated as a potential location for a small tidal scheme to provide heating for local residents by powering a water resource heat pump [18]. The Poole Tidal Energy Partnership (PTEP) was set up in 2011 to examine this, including some students from Bournemouth University. However, the water was deemed too shallow for even a small-scale tidal turbine (1 - 5m). PTEP is a registered company but has appeared dormant for several years.

The port has seven berths and boasts several mobile cranes, which could be suitable for some tidal turbine assembly (lifting capacity of approximately 60 tonnes). Ships of up to 210m can use the port, and the relatively shallow water was increased in 2018 to accommodate vessels with up to 8.7m of draft [19]. This recent expansion, which cost £10m [20], means that the port would, for example, be suitable for floating devices like the OMP O2, which requires a 2m draft when towing [21].

3.2.2 Portland

Portland Harbour, sheltered behind the Isle of Portland, was the largest manmade harbour in the world when it was constructed in 1959 (and reportedly still is today) [22]. It has a land estate of almost 200 hectares and covers a marine area of over 2400 hectares, with a water depth of 11.6m at the deepest berth [23].

Global Marine Services Ltd are based at the port, with subsea cable installation and maintenance expertise. The port also has unrestricted access, with no tidal restrictions [24], so it can be accessed throughout the year. This would make it suitable for an O&M base for an offshore renewable energy project.

Portland Port has a clear desire to be used for offshore renewable energy. This is apparent through its website and a publicly available offshore renewable energy brochure [24]. This differs from many of the larger commercial ports, for example, Southampton and Portsmouth (covered below), which are more focused on shipping.

3.2.3 Yarmouth

Yarmouth Harbour is situated on the Isle of Wight. It is most well known as the ferry port on the Isle of Wight, providing the main link to the mainland. It is most known as a recreational harbour, housing pleasure boats. However, it has supported a number of marine projects in the past. These include Sustainable Marine’s testing in the Solent and Trident Energy in 2013-2016.

As mentioned, the harbour was identified as a potential O&M base location for the Navitus Bay project. This would have created about 100 jobs and provided about £10m a year for the local economy [25].

QED is targeting Yarmouth Harbour as the company plans to deploy their community-scale Subhub for testing as part of the TIGER project. ADCPs were deployed at the site in April 2021, the operations assisted by EMEC [26].

3.2.4 Southampton

The Port of Southampton is a passenger and cargo port in the central part of the south coast of England, 16 km inland and between the confluence of the rivers Test and Ichen. It is the second largest container port in the UK and one of the busiest ports due to its deep water, favourable location and its ability to handle virtually any type of cargo. In addition, the surrounding natural geography of Southampton Water has a unique double high tide, prolonging the period of high water, which increases its accessibility for very large vessels [27].

Southampton Port is owned by Associated British Ports (ABP), which owns 20 other ports across the UK. It was used for some construction activities for the Rampion offshore wind farm; for example, the 2000-tonne offshore substation was shipped to the port before installation the following week [28]. It is, however, mostly regarded as a port for shipping and logistics. Its deep water and extensive facilities, for example, a $54m investment into a 120-metre crane rail extension, means that it can service the world's largest vessels with the world's largest cranes [29].

3.2.5 Portsmouth

Portsmouth Port is a major UK port responsible for handling millions of customers and vital cargo across the globe. The port is accessible from the motorway and major shipping lanes, making it an ideal location for ferries, cruises and freight.

The port is one of the leading in the UK on sustainability issues. In 2019 it stated its aim of becoming the UK's first net zero emissions port with plans to become energy self-sufficient by 2030 [30]. This includes installing solar and small-scale wind systems, a hydrogen electrolyser, and forcing contractors on-site to use low-emissions vehicles. In 2021, Portsmouth Council supported the plans for providing shore power, using battery storage, to power small cruise ships [31].

In 2018 cargo operator MMD Shipping Services, based in Portsmouth, secured a 10-year deal with MHI Vestas (now Vestas) to transport wind turbine blades from their Isle of Wight factory to their facility on the mainland [32].

As with Southampton, Portsmouth Port has had limited involvement with offshore renewable projects due to South England's lack of offshore wind farms.

3.3 Other renewables

3.3.1 Rampion offshore wind farm

Rampion offshore wind farm is operated by RWE, the majority shareholder with a 50.1% share. It is also owned by the Canadian energy company Enbridge which has a 24.9% share, and Offshore Wind Co. (led by Macquarie), with a 25% share[2]. The nameplate capacity of the offshore wind farm is 400 MW, consisting of 116 wind turbines on monopile foundations. The 16 km offshore export cable transfers the power to an onshore substation.

A proposed expansion of the Rampion offshore wind farm, Rampion 2, is under development. The proposed farm is located close to the existing Rampion wind farm and 30km east of the Isle of Wight. An environmental impact assessment is being undertaken to ensure any potential significant environmental effects from the proposed project's construction, operation or decommissioning are appropriately understood. RWE plan for the wind farm to be operational by the end of the decade [33].

4 Viable farm locations

For this analysis, we used Geographic Information System (GIS) datasets and analysis methods to indicate the areas available within the region for future commercial farms. This also includes considerations of potential exclusions that could impact project viability. The motivation is to give context beyond TIGER when future sites are being examined for next-generation technology.

[2] https://www.rampionoffshore.com/about/owners/

4.1 Methodology

4.1.1 Tidal flow speed data

For the GIS study, we chose an analysis area encompassing the two TSE sites of interest:

1. PTEC
2. Yarmouth Harbour

The University of Exeter, a TIGER project partner, provided tidal flow time-series data. They produced a fully coupled flow-wave model of the English Channel using Delft3D-SWAN. The model was constructed on an unstructured mesh with a variable resolution. The grid is formed of rectangular and triangular cells with variable resolutions ranging from 2km up to as fine as 20m in the areas of greatest interest, including tidal energy sites at PTEC and Alderney Race. The model produced 30 years of hindcast data from 1990-2020, including flow velocities, water level variation and wave parameters.

The model was validated using several in-situ measurements collected from various sources. ADCP measurements, tidal gauges and wave buoys were all used in the validation. A complete description of the modelling work undertaken with TIGER can be found in deliverable T1.7.2 [34].

4.1.2 Data from technology providers

Several technology providers were contacted, to understand the deployment constraints that affect their specific devices. They were asked about their current generation of technology as well as the trends that they anticipated for future device generations. This covered the following aspects:

A. Device properties

1. Device rating
2. Rotor diameter (nominal and minimum/maximum envisioned)
3. Rated flow speed
4. Cut-in and cut-out flow speeds
5. Clearance above and below device
6. Design water depth range (min and max)

B. Farm properties

1. Farm size (at given date)
2. Design turbine spacing
3. Approximate farm energy density
4. Foundation properties:
5. Preferred foundation type

6. Corresponding design conditions (seabed gradient, seabed type, installation vessel required)

C. Transmission system properties

1. Maximum distance to shore (to prevent high transmission losses)
2. Devices per subsea hub
3. Grid requirement (based on farm size, kVA)

Devices included small (<500kW) and utility-scale (2MW+) fixed devices and utility-scale floating devices.

We used this data to assign appropriate technologies for the two sites of interest.

4.1.3 Environmental constraints

We devised a list of various environmental constraints to investigate across the wider region. The aim was to indicate which factors could cause problems for larger commercial TSE projects.

Hard constraints we considered were:

- Areas close to shipwrecks (<250m)
- Oil and gas platforms, boreholes and exploration zones
- Offshore wind farms and other marine renewables (operational and in development)
- Dredge spoil dumping sites
- Site agreements for mineral/aggregate extraction
- Dumped munitions
- MMO designated shipping lanes

We also mapped soft constraints. Development in these areas could be possible but would require more detailed site assessment and evaluation. These included:

- Vessel traffic
- Fishing activity
- Marine protected areas: Site of Special Scientific Interest (SSSI), Special Protected Areas (SPA), Special Areas of Conservation (SAC)
- Seabed sediment type
- Location of grid

Main data sources included:

- Admiralty data portal (bathymetry data)

- Crown Estate data portal (wind farm lease areas)
- European Marine Observation and Data Network (EMODnet) data portal (human activities, e.g. dredge spoil dumping, dumped munitions)
- Scottish and Southern Electricity Networks (SSEN) Distribution (transmission and distribution grid lines)

4.2 Tidal stream energy scoping maps

This section presents maps to describe the resource, site conditions and constraints across the wider Isle of Wight region. Generally, the maps are focused on Portland and PTEC, as these are the most promising commercial-scale sites.

4.2.1 Flow speed

Figure 3 (top) shows the peak spring tidal current across the region, a proxy for the energy available in the flow. Peak tidal currents above 3 m/s indicate economically viable sites, and large areas where tidal currents speed exceed 2.5 m/s across the map.

While low flow speed is unsuitable for current commercially available technology, it could become feasible for low flow technologies in the future (for instance, kites or devices utilising bigger rotors).

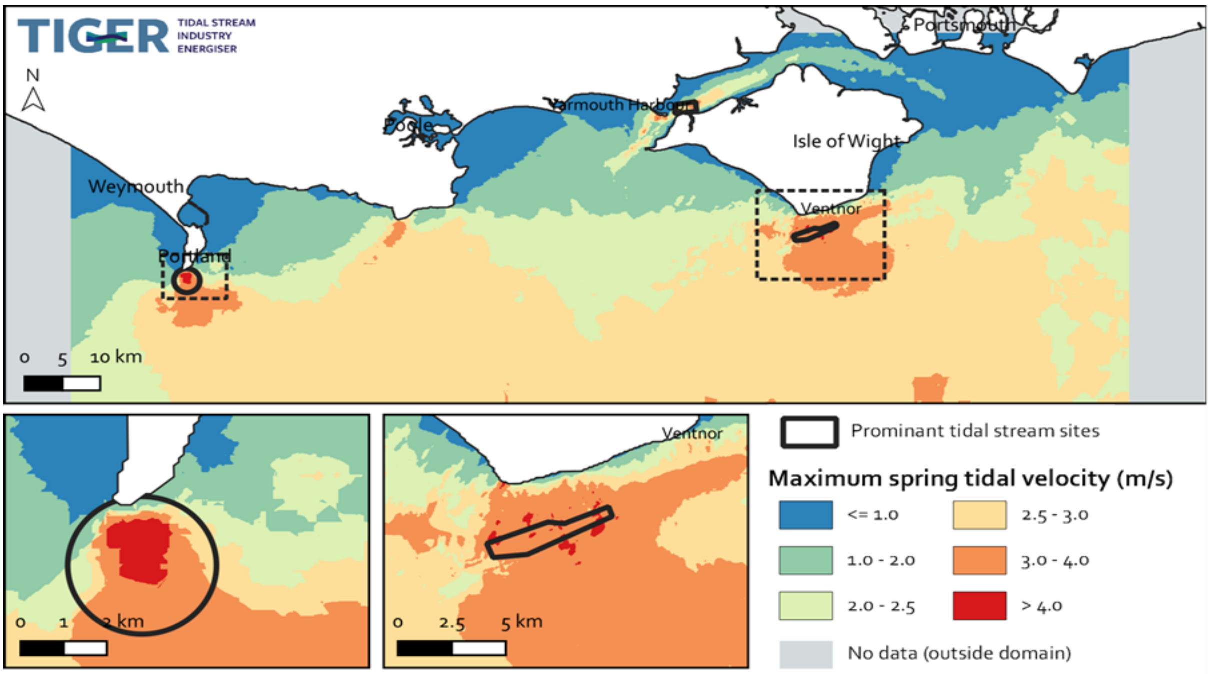
Around the coastline, there are several hotspots, the most notably off the south coasts of Portland and the Isle of Wight. There are also faster flow speeds in the Solent to the northwest of the Isle of Wight, close to Yarmouth Harbour, although this is a much smaller area of seabed.

4.2.2 Bathymetry

Figure 3 (bottom) shows the bathymetry across the region. The water is generally shallow, consistent with high energy TSE locations.

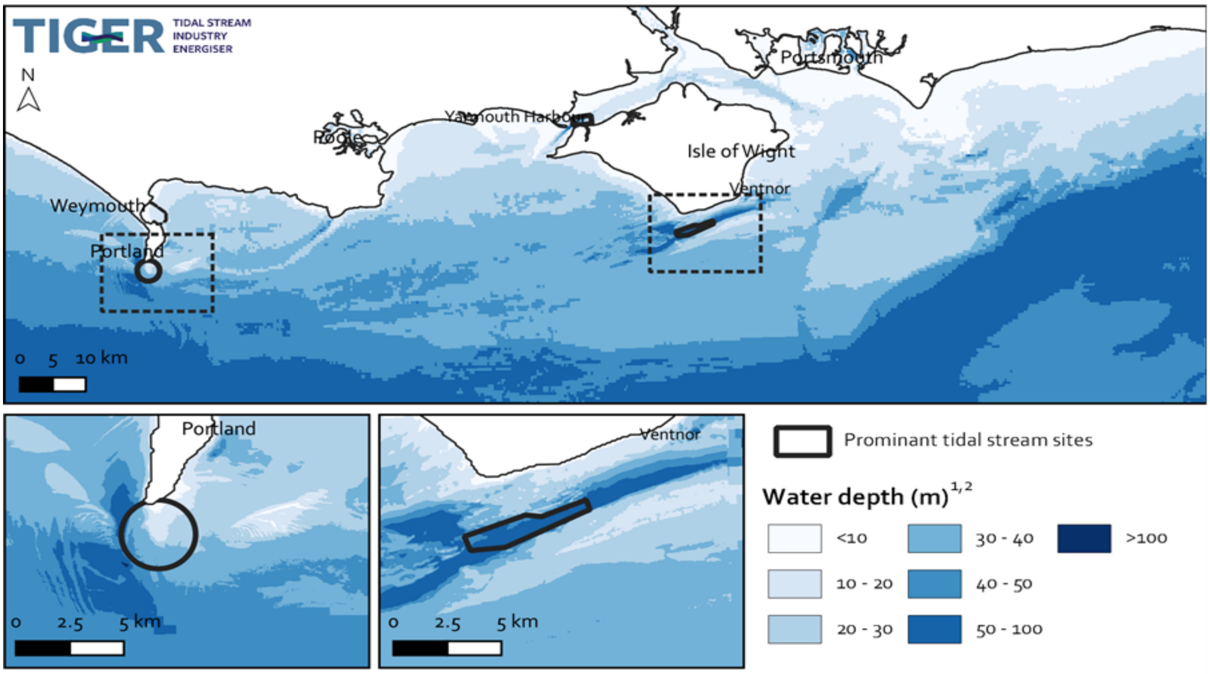
The PTEC site is situated in a deeper channel, much of it below 50m and reaching 70m LAT in some places. This makes it suitable for next-generation larger rotor devices (24m+ rotor diameter, horizontal axis). However, the seabed is relatively uneven, so it would potentially be more suited to piled foundations for seabed mounted devices, although this decision would require more detailed site knowledge and Front-End Engineering Design (FEED).

The Yarmouth Harbour site is very shallow, generally not exceeding 20m. This means that it is only suitable for testing smaller-scale devices.



Data provided by TIGER Partner, the University of Exeter, generated using Delft 3D hydrodynamic model. 2D mesh interpolated into a raster using tools within GIS software (QGIS).

Maximum spring tidal velocities data was supplied by University of Exeter who generated it using Delft 3D.



1: GEBCO Compilation Group (2020) GEBCO 2020 Grid (doi:10.5285/a29c5465-b138-234d e053-6c86abc040b9)
2: Contains United Kingdom Hydrographic Office data © Crown copyright and database right

Figure 3 – Maximum spring tidal velocities (top) and bathymetry (bottom) across the Isle of Wight region.

4.2.3 Vessel density

Figure 4 (top) shows vessel traffic density across the region. The Solent, between the Isle of Wight and the mainland, is a busy shipping area, with large vessels travelling to Southampton and Portsmouth harbours. These vessels route around the Island's east side, meaning that any project would not be viable.

The Yarmouth Harbour site is within a bustling area of seabed, mainly yachts and other pleasure crafts. Although this is not necessarily a problem, as some TSE developers have tested here previously (see Section 3.2.3), the channel is large enough to accommodate a small device for testing close to the pier.

The commercial-grade site at PTEC is relatively quiet by comparison. North of Portland Bill, there is commercial activity in the water surrounding Portland Harbour but little in the vicinity of the site. Therefore, we believe that both fixed bottom and floating devices could be suitable with appropriate signage and exclusion zones marked on the relevant charts.

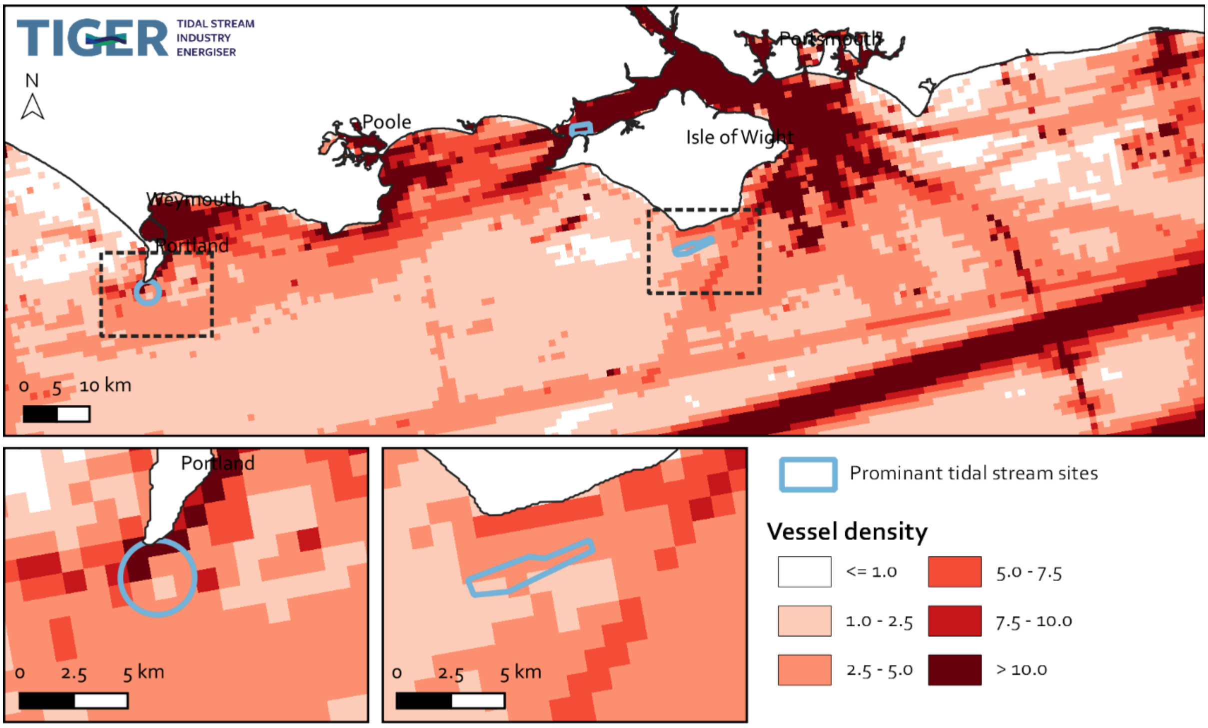
4.2.4 Environmental protection areas

Figure 4 (bottom) shows the designated environmental areas across the area. These include SAC, SPA for protected birds and Marine Conservation Zones (MCZ).

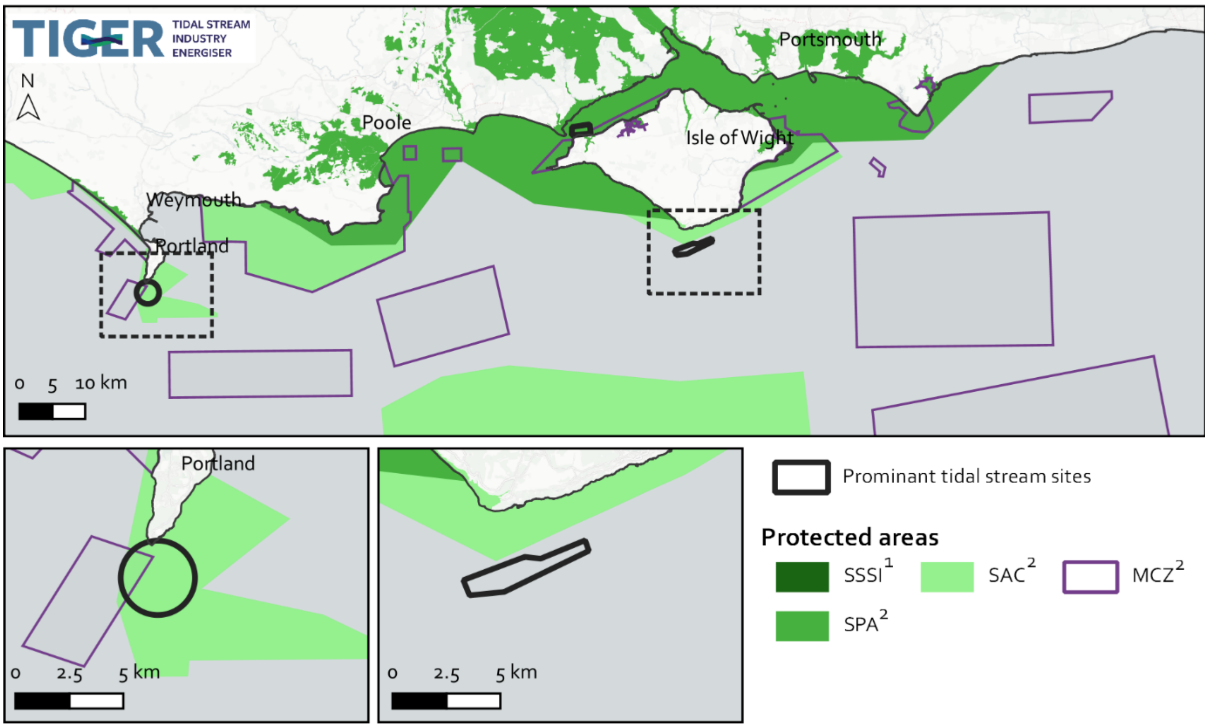
The Island is primarily surrounded by a SPA, with the PTEC site just on the periphery of a SAC. Therefore, the export cable would need to go through the SAC to get to land.

TSE projects have historically been granted marine licenses and consents in such areas (e.g. the Ramsey Sound site in Pembrokeshire); however, care needs to be taken. Ultimately the presence of SPAs and SACs is likely to increase the timescales associated with consenting to a project and may mean more environmental monitoring is required adding to the development costs of any project. However, SPAs are less of a concern for TSE projects compared to wind farms, as the submerged rotors can only affect diving birds.

Guidance has been published by Natural England and the Joint Nature Conservation Committee (JNCC) regarding Offshore Wind Leasing Round 4 areas and the potential impact of cabling on SPA and MCZ areas [2]. Any potential tidal stream project would also need to consider such factors.



Data obtained from the European Marine Observation and Data Network (EMODnet). The maps are based on AIS data yearly purchased from Collecte Localisation Satellites (CLS) and ORBCOMM.



1: Contains Natural Resource Wales data © copyright and database right [2018].
2: Contains Joint Nature Conservation Committee data © copyright and database right [2020].

Figure 4 – Vessel density (top) and designated environmental protected areas (bottom) across the Isle of Wight region.

4.2.5 Fishing activity

Figure 5 (top) shows the fishing activity across the region. Two datasets are overlaid: from the Global Fishing Watch data portal (block colours) and the MMO (hatched squares).

The PTEC and Yarmouth Harbour sites are largely free from fishing activity. However, engagement with local fisheries is advisable for this site.

4.2.6 Seabed sediment

Figure 5 (bottom) shows the seabed sediment classification across the region. This is a FOLK-5 classification, categorising the seabed into five broad categories, and is based on survey data that has been interpolated over larger areas.

The data indicate that both the Yarmouth Harbour and PTEC sites are on coarse-grained sediment. This would be suitable for both gravity base and piled foundations. A recent report published by EMEC noted that the seabed is “generally rock with some superficial course sediment”. Tidal sites tend to be rocky as the strong currents sweep sediment away. This can make the sites less preferred for piled foundations, as piling into bedrock is more laborious and costly.

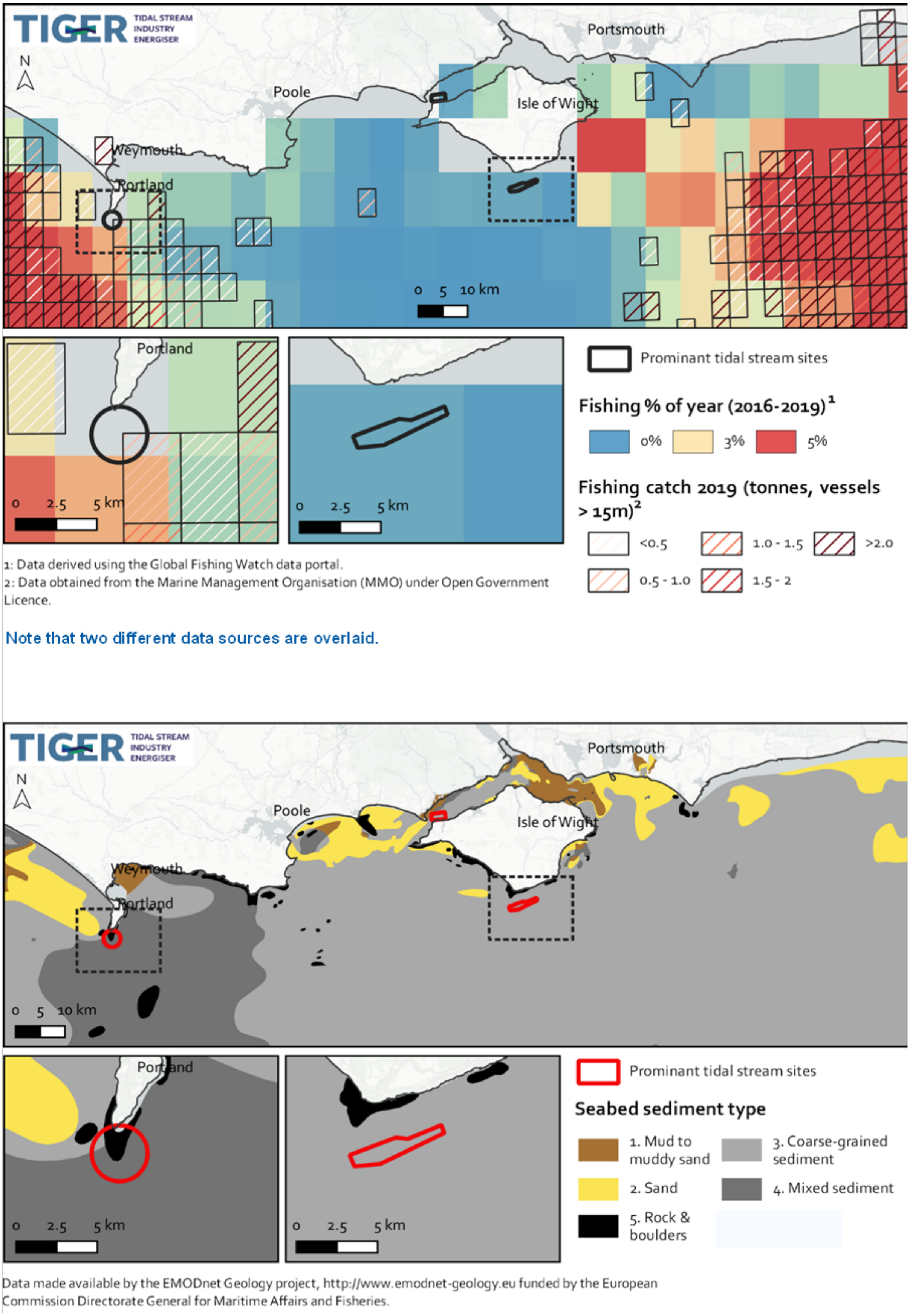


Figure 5 – Commercial fishing activity (top) and FOLK-5 seabed sediment classification (bottom) in the Isle of Wight region.

4.2.7 Extreme wave height

Figure 6 shows the extreme wave heights in the region, a 50-year return period. This dataset was provided by ABPmer, who generated it using their SEASTATES North West European Shelf Wave Hindcast Model. The estimates are considered realistic, with similar patterns of variance compared to other data sources, however are not locally validated and are treated as indicative estimates. Data is interpolated to a 3km^2 grid. The SEASTATES model is primarily a deep-water model and, as a result, does not adequately represent model shallow water effects (e.g. shoaling, refraction, wave breaking).

Considering these caveats, the map indicates that 1 in 50 year extreme waves are less than 9m in the analysis area. Therefore, tidal turbines would have to be designed with this in mind to ensure survivability.

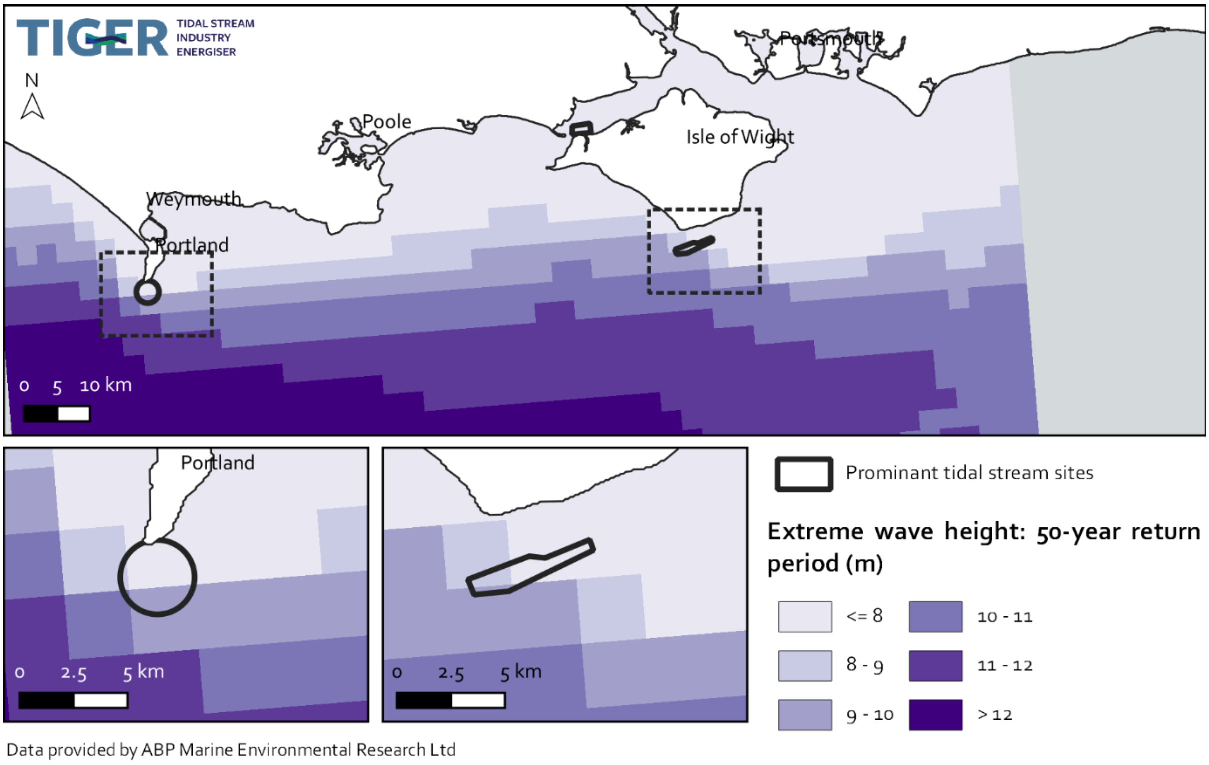


Figure 6 – Extreme significant wave height (50-year return period) across the region.

4.2.8 Hard constraints

Figure 7 shows hard constraints, namely areas of seabed that other sea users use. Not all of these would prohibit TSE deployment, but these layers indicate areas that it would be more difficult to develop and would need engagement with more stakeholders.

The PTEC site is free from exclusions, except for some isolated shipwrecks that could be easily avoided given the large size of these locations. The PTEC site is within about 3km of a high-density navigation route at its eastern edge. Still, the site has all of the necessary consents, and this would only need to be considered if the site was to expand significantly eastwards.

The Yarmouth Harbour site coincides with a high-density navigation route as classified by the MMO. However, the shallow water reinforces the belief that this site is only suitable as a test site for a smaller rotor device. Generally, projects should allow clearance of 10-15m below LAT so that vessels can pass above safely (e.g. as described in [35]).

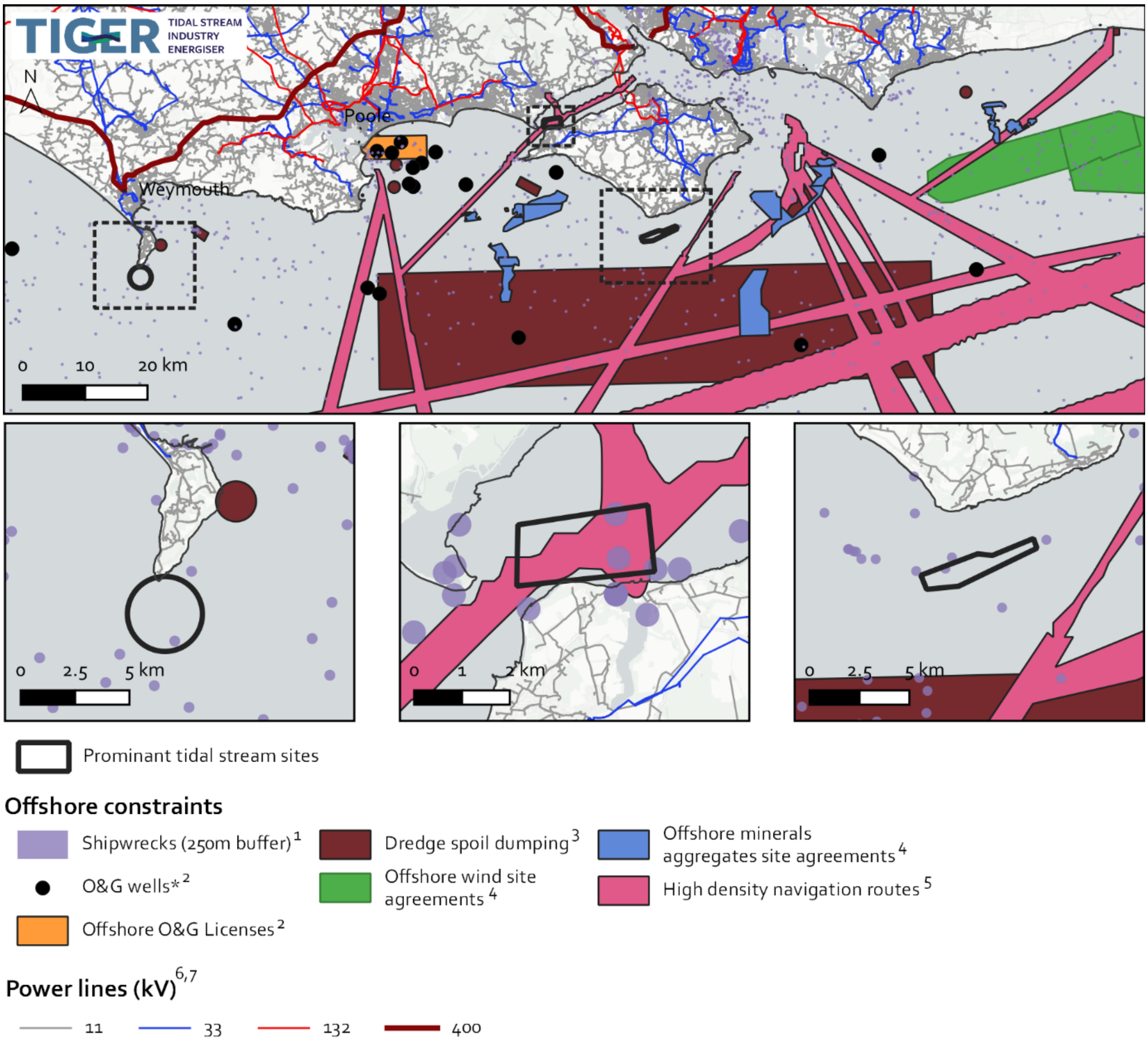
Across the region, there are also areas of mineral/aggregate extraction, dredge spoils dumping and past oil and gas exploration activity. These areas are not close to the promising TSE locations.

4.2.9 Grid

Figure 7 also shows the electricity lines. Transmission lines (400kV) were sourced from National Grid. Distribution grid data (11-132kV) was provided by Scottish and Southern Electricity Networks (SSEN) Distribution. Unlike other UK TSE sites, where sites are more remote and grid connections are less established, the Isle of Wight region is well connected.

Yarmouth Harbour and PTEC are both closer to a 33kV grid connection. Depending on specific turbine siting, Yarmouth Harbour is within 1km of an 11kV line on the Isle of Wight and has the option to route to the mainland if the Island network proves to be too constrained. A grid connection is not necessary for a single turbine, as being developed by QED (an early TRL test project).

The 33kV connection would be necessary for an early-stage PTEC array, and there would likely be a need to route to the 132kV or 400kV transmission network on the mainland if a larger project is realised. While the island is served with 132kV links, other renewable projects will require grid connection. In addition, as pointed out in a scoping report by EMEC [36], cables would have to route through the SAC, requiring additional environmental impact assessments (EIA).



* All decommissioned/abandoned in exploration phase

1: Contains public sector information, licensed under the Open Government Licence v3.0, from the UK Hydrographic Office
2: Data from the Oil and Gas Authority (OGA)
3: Data obtained from the European Marine Observation and Data Network (EMODnet)
4: Contains data provided by The Crown Estate that is protected by copyright and database rights
5: Data published by the MMO. High density navigation routes minus harbour authority areas. See policy notes for details (S-PS-3)
6: Distribution network data (11, 33, 132kV) from Scottish and Southern Electricity Networks (SSEN) Distribution
7: Transmission network data (400kV) from National Grid

Figure 7 – Offshore constraints and sea use across the region.

4.2.10 Final areas identified

Figure 8 indicates the areas available for commercial sites, showing the hard constraints (grey), unsuitable water depth areas (blue) and suitable flow speeds (orange/red) on a single map. The individual hard constraint layers are transparent; the darker the shape of the grey, the more constraints that are present. The water depth exclusion considers locations shallower than 25m. Given current market-leading device concepts and target markets, these are deemed not commercially viable.

Specific areas of interest for commercial projects have been identified with the dashed line. TIGER project partners informed the 3.5 m/s cut-off (red areas), which is arbitrary in nature but indicates the area that would be of interest for next-generation TSE projects.

As identified by the MMO, the Yarmouth Harbour site is constrained by shallow waters and the aforementioned high vessel traffic. Despite this, there is still the potential for a smaller test project, as this would have a low footprint, as has been proven with previous testing by Sustainable Marine.

Shallower waters slightly constrain the PTEC site; however, there is a significant unconstrained area of 10 km^2.

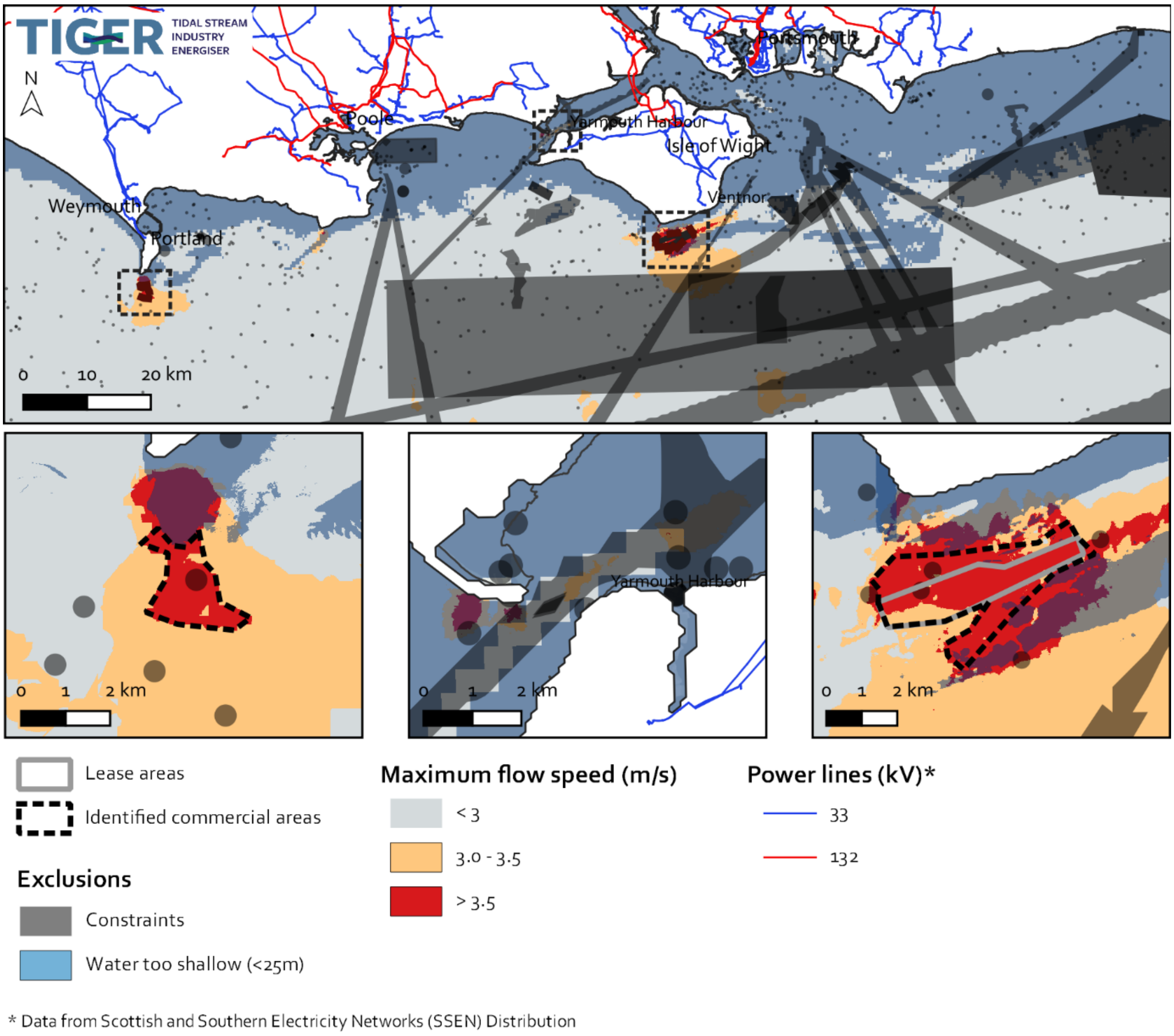


Figure 8 – Areas identified as suitable for commercial scale TSE projects (dashed line). Maximum spring tidal velocity (red/orange), water depth exclusion (blue) and constraints (grey) are also shown. The darker the area the more constraints are applicable.

4.3 Site summary

Table 1 shows the main characteristics of the two Isle of Wight TSE sites of interest. Of the two, PTEC is of the most commercial interest. This is because it has the most energetic flows and gets deep enough in places to accommodate next-generation large rotor devices (>24m rotor diameter). The site also has full consent for up to 30MW, with the site owner estimating up to 300MW [37]. Judging by the GIS constraints, the only significant environmental barriers we envision are the distance to the 132kV grid for a larger project and the need to route cables through a SAC.

Yarmouth Harbour has merits as a test site, with reasonable flow speeds and sheltered waters. The proximity to Yarmouth Harbour also enables ease of access to deploying and recovering any device/s. The main issue with this site is that it is a relatively narrow and busy channel with a lot of boating activity, likely requiring more careful stakeholder engagement. While the depth does exceed 50m in localised areas, much is shallow.

Table 1 – Tidal stream sites of interest in the vicinity of the Isle of Wight.

Site name	PTEC	Yarmouth Harbour
Owner/developer	Perpetuus Energy Ltd	QED Naval
Status	Fully consented, seeking CFD or private offtake	In development
Current lease area (km^2)	5.1	N/A
Consented/estimated capacity (MW)	Up to 30MW (consented)	<1MW
Site area identified in GIS (km^2) (max spring tidal velocity >3.5m/s)	10	N/A
Maximum spring tide flow velocity (m/s)	4.5	3.5
Water depth range (m)	25 - 70	10 - 55
Potential ports	Yarmouth Poole Portland	Yarmouth
Potential cable landing	Castle Cove (Ventnor)	Yarmouth Harbour
Key environmental considerations	Nearby SAC/SPA for cable routing Potential uneven bathymetry Access to grid for large projects	Within a busy vessel channel Shallow water limits potential turbine locations (need to allow clearance above) Interactions with recreational maritime activities

5 Techno-economic assessment

In this section, the economic potential of the PTEC site is investigated. This includes commentary on the capacity available, the levelized cost of energy (LCOE), and the revenue support that would be required to enable further developments beyond the lifetime of the TIGER project.

5.1 Methodology

The techno-economic assessment consisted of the following steps:

1. Define representative commissioning dates, technologies and farm sizes for TSE projects at PTEC.
2. Devise annual energy production (AEP) estimates based on the above.
3. Feed AEP and turbine specification into a techno-economic model to calculate LCOE.
4. Identify appropriate CfDs for the sites based on relevant deployment timescales and project internal rate of return (IRR).

5.1.1 Modelled farms

For this study, we decided to build on existing recent knowledge. In late 2021, EMEC conducted a detailed study on behalf of PTEC to assess the PTEC and Portland Bill sites [36]. This included analysis of the resource (using MIKE 21), potential array layouts, local sensitivities and environmental factors and potential cable landing and grid connection points. This study was delivered in October 2021.

From the report, EMEC shared the following observations:

- For PTEC, they note that 100MW should be deployable at PTEC without incurring significant wake or blockage effects. The north and south of the PTEC lease reads are shallower and thus better suited for ~1MW turbines, while larger multi MW fixed or floating devices could be deployed in the deeper waters.

The report does not estimate AEP; they assume a gross AEP of 40% for the economic calculations and state the need to quantify AEP as future work. We aimed to build on the EMEC study by including a more detailed analysis of LCOE and required CfD.

Based on the information available, we decided to model two distinct farms:

- *“PTEC Phase 1”:* A 30MW array at PTEC (as currently consented). We decided to assume a floating technology, as the current PTEC lease area is deep and encompasses a prominent seabed trench (see Figure 3 (bottom)). This also reflects the agreement between Orbital Marine Power and PTEC, as stated publicly in 2021 [38].

- *“PTEC Phase 2”:* An additional 100MW at PTEC. This represents a second project phase. While EMEC advocates a mixture of technologies at the site, we decided to keep with a floating technology. This is because the learning and past experience from the first floating array would give such a project developer an edge in building out capacity at the site.

These are summarised in Table 2.

Table 2 – Device and farm assumptions used for the techno-economic analysis.

Property	Unit	PTEC "Phase 1"	PTEC "Phase 2"
Site	-	PTEC	PTEC
Commissioning year	-	2030	2032
Farm size	MW	30	100
Foundation type	-	Floating	Floating
Representative device rated power	MW	2	2.5
Representative device rotor diameter	m	20	24
Number of devices	units	15	40

5.1.2 Techno-economic analysis

Approach

We devised representative costs for the projects and technologies using data from TIGER project partners and calculated LCOE using standard industry assumptions at an appropriate commissioning date. We projected costs into the future by applying anticipated industry-wide learning rates, as witnessed in other energy technologies (e.g. solar, offshore wind).

We calculated appropriate CfD strike prices for the farms by analysing the lifetime revenue and costs and benchmarking the strike price to a project IRR. Then, we back-calculated the CfD revenue support required to achieve different levels of project IRR (excluding tax and debt financing) to determine an appropriate strike price.

We calculated LCOE and IRR metrics for three scenarios: Baseline, Optimistic and Pessimistic, modelled with different input assumptions, to indicate the uncertainty and potential range of values that could be expected.

Modelling assumptions: costs

To model the future cases, we first derived the present-day case (assumed 2022). Data sources included bills of materials from TIGER partners, data from ORE Catapult cost models and wider industry knowledge. A market forecast was created considering the likely buildout based on current sites with consented capacity. This aligns with projections from organisations like the MEC and European Commission[3].

Turbine capital expenditure (CAPEX) was primarily sourced from TIGER partners and adjusted to represent the device ratings being considered. Foundation costs were devised by assuming appropriate material masses and costs (i.e. "cost per tonne") and comparing them with offshore wind costs. Transmission costs were obtained from the EMEC study for PTEC and checked against ORE Catapult datasets used for offshore wind. Development (DEVEX), insurance, contingency and decommissioning (DECEX) costs were modelled as

[3] The MEC want the UK government to adopt a target of 1GW of marine energy (wave and tidal) by 2035. The European Commission have a deployment target of 100MW of wave and tidal by 2025 and 1GW by 2030

https://www.oceanenergy-europe.eu/wp-content/uploads/2022/06/Last-Stop-to-2025.pdf percentages of the total CAPEX, in line with estimates from both the TSE and offshore wind industries.

Installation, planned O&M and unplanned O&M were sourced from TIGER partners and checked using a purpose-built model. This model was created in Microsoft Excel. It uses a frequency-based approach, calculating the costs of marine operations by calculating the timescales of the operations and multiplying by the charter rate of a suitable vessel. The model also includes costs of vessel mobilisation and demobilisation, spare parts and considers the distance vessels need to travel to and within the farm. For the unplanned O&M, the model assumes a fixed number of interventions per year. The model can choose whether to mobilise a vessel each time or to keep a permanent vessel on a long-term charter, selecting the cheapest option.

For the 30MW PTEC project, we assumed that it could be connected to local 33kV networks on the Isle of Wight. The 100MW PTEC Phase 2 farm is deemed too large to connect to the island's network due to network constraints (as mentioned in earlier sections). In this case, we assume strings of devices are connected to an intermediate collector station at St Catherine's Point and then connected via a 132kV connection to Fawley on the mainland. This is achieved via a ~50km subsea cable which makes landfall at Lepe, in the Solent.

Vessel costs were obtained from ORE Catapult models and cross-checked with TIGER partners. We assumed that a multicat with diver/ remotely operated vehicle (ROV) support could be used for inspection and minor on-site repair.

Reductions in CAPEX and operating expenditure (OPEX) were modelled by applying learning rate-based reductions to the various cost items. These were set between 8 and 17%, depending on the cost category, reflecting the longer-term learning rate as has been seen historically for other renewables [39]. Learning reduction was not applied to transmission charges.

Modelling assumptions: AEP

As pointed out above, EMEC did not calculate AEP in their study of PTEC, instead stating a 40% capacity factor "as a proxy value for simple techno-economic calculations". This 40%, stated as not including maintenance periods, is in line with present-day projects. For example, the MeyGen project quoted a 40% gross capacity factor (34% net) in 2020 [40]. This capacity factor is also assumed in other studies; for example, Coles et al. calculated a 40% capacity factor at PTEC for an array consisting of 1.3MW, 24m rotor diameter turbines [41].

Given time constraints on this project, it was not possible to derive capacity factors for the farms analytically (for example, using flow models like TELEMAC or THETIS). Instead, we applied representative values. This is something that can be improved on in future studies. We applied a "learning rate" of negative 1% to simulate both technological and operational efficiencies that would improve yield and reduce downtime in the future.

5.2 Results: PTEC Phase 1 (30MW)

Figure 9 shows the LCOE as calculated for the three scenarios. In all three cases, most of the LCOE is in the device CAPEX, as one would expect, considering that it is a floating device.

The optimistic scenario, at £88/MWh, is largely driven by the higher capacity factor assumed (net capacity factor of 38%) as well as slight reductions assumed in transmission and installation. The pessimistic scenario assumes a lower net capacity factor of 31.5%

(assuming both a lower gross capacity factor and slightly higher losses) as well as a more expensive device cost and foundation. As our data for these components was limited for a one-off device, we wanted to examine the case of higher costs.

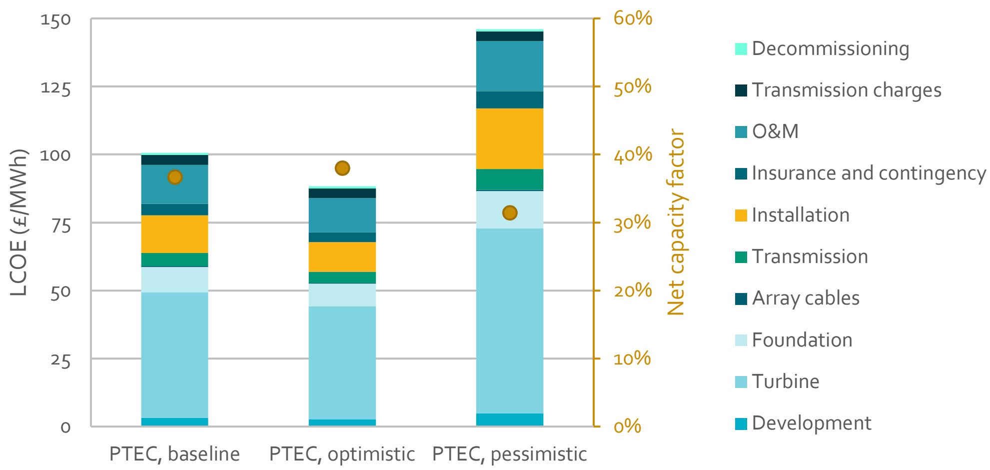


Figure 9 – LCOE breakdown for the three scenarios devised for the PTEC Phase 1 case. Net AEP is shown on the secondary Y axis.

Figure 10 shows the project IRR achieved as a function of the CfD strike price. We estimate that a 10% IRR could be achieved for a strike price of £143/MWh, although this does not include debt or tax. A commissioning date of 2030 lines up with AR6, assuming annual CfD auctions are maintained. AR4 saw four projects awarded CfDs at £178.30/MWh, implying that a decrease of 17% in strike price over two years is required. Please note the AR4 CfD price of £178.30 is at 2012 prices which is equivalent to £220.56 at 2023 prices.

For the optimistic scenario, the strike price falls to £132/MWh for a 10% IRR. Conversely, for the pessimistic, the strike price rises to £190/MWh.

Note that these results are particularly sensitive to the capacity factor assumed. PTEC is a lower flow site compared to other UK sites (e.g. MeyGen) and needs a comprehensive analysis considering the specific flow conditions and turbine properties (rotor diameter and rated power) to improve on this estimate. The analysis is also sensitive to the market forecast (floating technology global deployments estimated at ~110MW by 2030), which drives the learning rate based on cost reduction forecasts. This can be improved over time as the project pipeline grows and the next generation of arrays are installed (AR4).

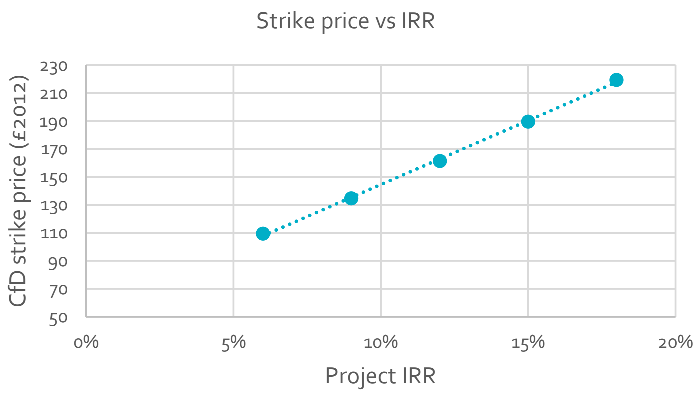


Figure 10 – CfD strike price vs project IRR for the PTEC Phase 1 baseline scenario.

5.3 Results: PTEC Phase 2 (100MW)

Figure 11 shows the LCOE breakdown for the three scenarios. The baseline LCOE is 17% lower than the Phase 1, 30MW case. Most costs are assumed to be lower due to the increased learning for the later commissioning date and the better economies of scale for the larger farm. However, the significantly higher transmission cost counters these savings, as the farm is connected to the mainland via a 132kV connection to Fawley. In reality, this cost could be spread over multiple projects and potentially shared by multiple project developers to provide a connection for other local projects. We also assumed a slightly higher wake loss for the larger farm (8% vs 5% for the 30MW farm).

The optimistic scenario, at £70.5/MWh, is largely driven by the higher capacity factor assumed (net capacity factor of 38%) as well as slight reductions assumed in transmission and installation. On the other hand, the pessimistic scenario assumes a lower net capacity factor of 30.7% (assuming both a lower gross capacity factor and slightly higher losses) as well as a more expensive device cost and foundation. As our data for these components was limited for a one-off device, we wanted to examine the case of higher costs.

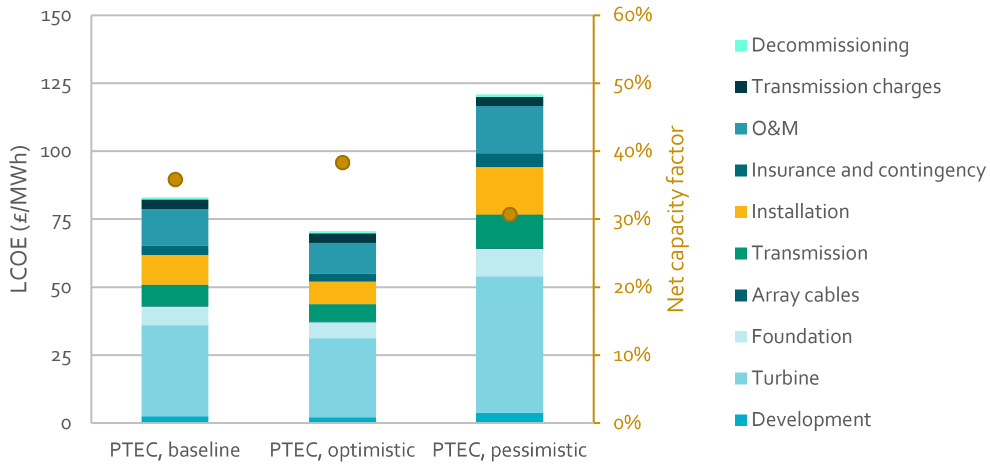


Figure 11 – LCOE breakdown for the three scenarios devised for the PTEC Phase 2 case. Net AEP is shown on the secondary Y axis.

Figure 12 shows the project IRR achieved as a function of the CfD strike price. We estimate that a 10% IRR could be achieved for a strike price of £128/MWh, although this does not include debt or tax. For the optimistic scenario, the strike price falls to £115/MWh for a 10% IRR. Conversely, for the pessimistic, the strike price rises to £170/MWh.

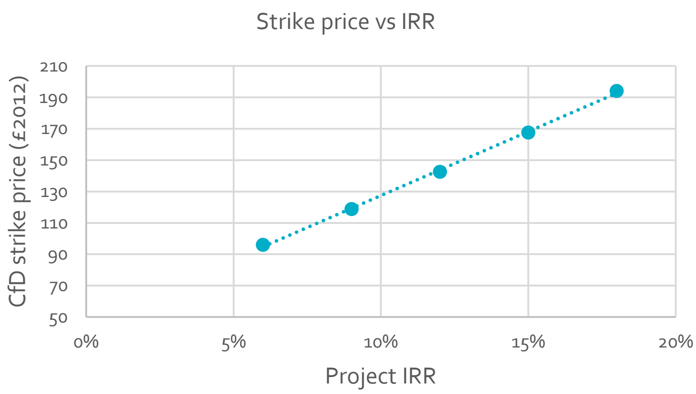


Figure 12 – CfD strike price vs project IRR for the PTEC Phase 2 baseline scenario.

6 Summary and recommendations

This study analysed the TSE potential in the Isle of Wight, England region. We have examined a number of different issues, including past track record, ports of interest, geospatial analysis of the available area and techno-economic viability. In this section, we summarise the study and provide recommendations of areas to focus on to ensure that the regional benefits of TSE are captured.

6.1 Summary

Socio-economic viability

The Isle of Wight is a location that could benefit from the potential jobs and employment that a TSE site could bring. As a renewable energy technology, the TSE site could provide an opportunity for the local community to be involved in a new industry and benefit from the associated employment opportunities. The TSE site would also have the advantage of being close to several local ports, such as Yarmouth, Poole, and Portland, providing logistical support for the project.

Moreover, the Isle of Wight Council supports renewable energy and has set more ambitious net-zero targets than the central government. The Isle of Wight Council has set a target of reaching net-zero emissions by 2030, which is more ambitious than the UK government's target of achieving net-zero emissions by 2050 [42]. This supportive stance towards renewables could create an environment conducive to developing a TSE site on the island.

However, it should be noted that while there may be some local suppliers of interest, such as the Vestas factory, they may not be able to meet the current industry scale. As a result, additional suppliers may need to be sourced outside the Isle of Wight to support the TSE site's development and operation. Nonetheless, the potential benefits of job creation, utilisation of local ports, and a supportive local government suggest that the Isle of Wight could be a promising location for a TSE site.

Environmental viability

The presence of SACs, SPAs, and MCZs near tidal energy sites could pose challenges to developing these projects. One potential issue is the impact on cable routes. Protected areas may restrict the placement of cables, limiting the possible routes for transmitting electricity generated by the TSE site. Additionally, certain technologies may be more suitable for use in protected areas than others. For example, some technologies may impact the environment more than others, making them unsuitable for use in protected areas.

However, the planned TSE project, PTEC, has obtained full consent, suggesting that these potential issues have already been considered. Nonetheless, there may be concerns about the potential for future site expansion encroaching on SACs. Developing TSE projects while minimising their impact on protected areas is possible. This can be achieved through careful planning, site selection, and technology choices. Furthermore, the potential benefits of tidal energy, such as its ability to generate renewable energy and reduce greenhouse gas emissions, make it a promising technology for the future.

Geospatial viability

Several factors could impact the development of tidal energy projects in the area. One positive aspect is that the area's flow speeds are adequate. Furthermore, the PTEC project has minor constraints and low interactions with other sea users. This is an important consideration as interactions with other users, such as shipping or fishing, can create conflicts that could hinder the project's development. It is, therefore, paramount to note that any interactions with sea users must be carefully managed and mitigated to ensure that the project is developed sustainably.

From a geospatial perspective, the deployment of 100MW+ projects in the area appears to be feasible. However, it is important to note that factors such as wake interactions and blockage effects could impact the efficiency of the technology. These factors have not been examined in this report and must be carefully considered during the planning and development stages.

The PTEC site has a good range of depth, allowing for greater flexibility in the types of technology deployed in the area. However, the uneven seabed in some areas could limit the ability to use piled foundations. Therefore, it would be necessary to carefully evaluate the seabed conditions in the area to determine the most suitable foundation type for the project.

Yarmouth Harbour has the potential to be a suitable test site for tidal energy technology. However, testing in the Solent could be more challenging due to the increased activity in the area. It may be easier to test the technology at other sites, such as the EMEC.

Finally, all the sites in the area have appropriate local connections to the grid, with a capacity of 33kV. However, for larger projects exceeding 50MW, the grid connections could be more challenging. Particularly for the PTEC project, which will need to route the energy to the mainland, careful planning and management would be necessary to ensure that the grid connections are adequately developed.

Techno-economic viability

The LCOE and CfD strike prices in the area are competitive with some of the best sites in the UK. However, it is important to note that these assessments are high-level and indicative, and a more detailed analysis would be needed to evaluate the economic viability of the projects fully. The CfD strike price levels in the area are not significantly below the levels seen in the AR4 of the UK's CfD scheme. This suggests that the planned PTEC tidal energy project should remain attractive for the next few CfD rounds, assuming the strike price does not drop dramatically.

However, more work needs to be done to quantify the area's AEP and capacity factor for tidal energy projects. This is an important consideration because it would help to more accurately assess the potential energy output of specific projects in the area. This information is vital for evaluating a project's economic viability and making investment decisions.

The transmission link for larger tidal energy projects in the Isle of Wight area could be a potential issue, and it would be essential to consider how this could be funded. Connecting a large project to the grid can be a significant cost, and the feasibility of a project may depend on the availability of funding for this aspect of the development. The cost of connecting a tidal energy project to the grid is affected by several factors, including the distance from the project site to the nearest grid connection point, the capacity of the grid infrastructure, and the availability of land to lay cables. Transmission links can be prohibitively expensive in some cases, particularly if the project is located in a remote or isolated area.

Overall summary

PTEC is a fully consented 30MW site with 300MW potential, situated to the south of the Isle of Wight. The site is well placed to provide green energy for the grid or Green Hydrogen in the Solent region. PTEC site has the potential to be economically competitive, with a calculated CfD strike price that is not significantly below the AR4 figure. The company also has access to further opportunities to develop the potentially large-capacity TSE sites along the South Coast. Although PTEC is currently England's most advanced and ready-to-use site, its full potential has been restricted due to the lack of government revenue support in establishing an appropriate infrastructure. However, the attraction of the PTEC site is the approved capacity and the vast potential of the site. PTEC is therefore actively pursuing a significant investment with an energy company to overcome the commercial disadvantages through a long-term PPA, which takes account of the predictability and local convenience of tidal energy.

Moreover, PTEC has the potential to generate tens or even hundreds of MW, which would be a significant contribution to the UK's renewable energy mix. However, to attract tidal energy developers to these sites, it will be important to make the site more attractive to developers. This could involve a range of measures, including improving the accessibility of the site, providing support and incentives for developers, and streamlining the regulatory approval process. Additionally, further engagement with local councils and government could help build support for TSE projects in the region, attracting investment and supporting the industry's growth.

6.2 Recommendations

From this study, we recommend the following future steps:

- **Establish grid viability:** further research into grid connection options for larger 100MW+ farms, especially at PTEC, is required. The research should account for the cost and funding sources of the grid infrastructure. Larger scale projects are necessary to reach economic levels, and so electricity distribution companies need to be brought into the discussion to ensure that there is sufficient grid capacity for future projects. Additionally, integrating other renewable energy technologies, such as solar, on the island should be considered.
- **Further investigation into environmental areas:** investigate the implications that SPA, SAC and MPZ areas might have from a planning and cost perspective. For instance, when planning a subsea cable lay, it is important to consider any marine protected areas along the proposed route and ensure that the cable installation and maintenance activities do not harm the protected species and habitats and minimise the impact on the marine ecosystem. This may involve adjusting the cable route, modifying installation and maintenance activities, and obtaining necessary permits and approvals from relevant authorities. Moreover, complying with regulations related to marine protected areas may increase the overall cost of the subsea cable lay. Additional equipment, personnel, and permits may be required, and delays and other expenses may be associated with modifying the cable route or installation procedures. However, failure to comply with these regulations can result in fines, legal action, and environmental damage, which can be much more costly in the long run.
- **Further analysis of AEP and capacity factor:** using a tidal flow model such as TELEMAC or THETIS, carry out a detailed analysis of AEP and capacity factors and extend the work of the University of Exeter to include turbine drag and wake effects. AEP will have a significant impact on project viability and LCOE.
- **Collaborate with PTEC to identify funding streams:** PTEC is in a unique position with a fully consented 30MW site with 300MW potential. However, whilst PTEC is England's most advanced, commercially ready site, full exploitation has been inhibited by the

absence of government revenue support to develop the required infrastructure. This has put PTEC at a commercial disadvantage against the Welsh and Scottish sites, which have received grants of around £31m for each site (MeyGen £40m and Morlais £31m) and are therefore better able to compete for the government CfD contracts.

- **Improve LCOE analysis:** In order to enhance the economic analysis, it is necessary to collect high-quality data from technology providers, which can lead to a more comprehensive evaluation of cash flow, taking into account factors such as financing arrangements, tax, and depreciation. In addition, consulting with financial institutions and the investment community regarding the necessary improvements to make the site more attractive.
- **Bring the local community on side:** the region is a popular tourist destination, and a tidal farm would offer improvements to local employment, diversifying the local economy. We recommend engaging with the community early on to understand their opinions and encourage support. A community ownership model, whereby the community has a stake in a tidal project and can benefit financially, could be a way to increase support and awareness.

7 References

[1] Perpetuus Tidal Energy Centre, “The Story So Far,” [Online]. Available: https://perpetuustidal.com/the-story-so-far/. [Accessed 04 11 2021].

[2] L. S. Blunden and A. S. Bahaj, “Initial evaluation of tidal stream energy resources at Portland Bill,” *Renewable Energy,* vol. 31, no. 2, pp. 121-132, 2006.

[3] Offshore-Energy.Biz, “Watch: Subhub Tidal Platform Deployment,” 21 2 2019. [Online]. Available: https://www.offshore-energy.biz/watch-subhub-tidal-platform-deployment/. [Accessed 03 11 2021].

[4] A. van Unen, “Tocardo Acquires the Largest Tidal Array in the World,” Tocardo, 12 10 2020. [Online]. Available: https://www.tocardo.com/tocardo-acquires-1-25mw-oosterschelde-tidal-power-plant-the-largest-tidal-array-in-the-world/. [Accessed 03 11 2021].

[5] Hydrowing, “Tidal Hydrogen Production Storage and Offtake,” 06 05 2020. [Online]. Available: https://hydrowing.tech/news/05/2020/tidal-hydrogen-production-storage-and-offtake/. [Accessed 03 11 2021].

[6] NOMIS, “Labour Market Profile - Isle Of Wight,” [Online]. Available: https://www.nomisweb.co.uk/reports/lmp/la/1946157281/printable.aspx. [Accessed 03 11 2021].

[7] Isle of Wight Council, “Isle of Wight Joint Strategic Needs Assessment,” Isle of Wight Council Public Health Information Team, 2015.

[8] Economic & Business Intelligence Service (EBIS), “Isle of Wight Economic Profile 2019,” Isle of Wight Council, 2019.

[9] L. Little, “Vestas produces 1,000th offshore wind blade on Isle of Wight,” Isle of Wight County Press, 27 04 2021. [Online]. Available: https://www.countypress.co.uk/news/19261158.vestas-produces-1-000th-offshore-wind-blade-isle-wight/. [Accessed 04 11 2021].

[10] A. Durakovic, “Vestas to Produce 99 Seagreen Blade Sets in UK,” Offshore Wind.biz, 2 6 2021. [Online]. Available: https://www.offshorewind.biz/2021/06/02/vestas-to-produce-99-seagreen-blade-sets-in-uk/. [Accessed 4 11 2021].

[11] E. Ridett, “Realising the Isle of Wight’s aspiration for renewable energy power generation and local consumption,” University of Southampton, [Online]. Available: https://energy.soton.ac.uk/realising-the-isle-of-wights-aspiration-for-renewable-energy-power-generation-and-local-consumption/. [Accessed 03 11 2021].

[12] Isle of Wight Council, “Climate and Environment Strategy 2021-2030,” 2020.

[13] Bex Pearce, “World first project powering railways with renewable energy being developed on the Isle of Wight,” On The Wight , 01 06 2020. [Online]. Available:

https://onthewight.com/world-first-project-powering-railways-with-renewable-energy-being-developed-on-the-isle-of-wight/. [Accessed 03 11 2021].

[14] D. Toogood, “DIFFICULT TIMES FOR SOLAR ENERGY ON THE ISLE OF WIGHT,” Island Echo, 2 06 2017. [Online]. Available: https://www.islandecho.co.uk/difficult-times-solar-energy-isle-wight/. [Accessed 03 11 2021].

[15] Scottish & Southern Electricity Networks (SSEN), “Isle of Wight ANM,” [Online]. Available: https://www.ssen.co.uk/our-services/active-network-management/iow-anm/. [Accessed 13 April 2023].

[16] Offshorewind.biz, “Navitus Bay Signs MoU with Three Local Ports,” 01 04 2014. [Online]. Available: https://www.offshorewind.biz/2014/04/01/navitus-bay-signs-mou-with-three-local-ports/. [Accessed 05 11 2021].

[17] Port of Poole, “POOLE HARBOUR COMMISSIONERS DRAFT MASTER PLAN - VERSION TWO,” 2012.

[18] T. Ginige, F. Ball and J. Butters, “Harnessing marine renewable energy from Poole Harbour: a case study,” *Int. J. Liability and Scientific Enquiry,* vol. 6, pp. 1-26, 2013.

[19] Poole Harbour Commissioners, “PORT FACILITIES,” [Online]. Available: https://www.phc.co.uk/commercial/port-facilities/. [Accessed 05 11 2021].

[20] “Poole Harbour to open £10m port expansion in January,” BBC, 27 10 2017. [Online]. Available: https://www.bbc.co.uk/news/uk-england-dorset-41778882. [Accessed 05 11 2021].

[21] A. Scott, “'Don't judge it on its nameplate: this 2MW turbine could be key to tidal power's lift-off',” Recharge, 10 05 2021. [Online]. Available: https://www.rechargenews.com/energy-transition/dont-judge-it-on-its-nameplate-this-2mw-turbine-could-be-key-to-tidal-powers-lift-off/2-1-1008293. [Accessed 05 11 2021].

[22] Portland Port, “History,” [Online]. Available: https://www.portland-port.co.uk/history. [Accessed 08 11 2021].

[23] Portland Port, “Port Capabilities,” [Online]. Available: https://www.portland-port.co.uk/port-capabilities. [Accessed 08 11 2021].

[24] Portland Port, “Offshore renewable energy brochure,” 2021.

[25] BBC, “Navitus Bay: 'worth £10m' to Yarmouth harbour,” 09 09 2014. [Online]. Available: https://www.bbc.co.uk/news/uk-england-29123629. [Accessed 08 11 2021].

[26] TIGER, “EMEC and QED Naval deploy flow measurement equipment at Yarmouth Harbour,” 9 04 2021. [Online]. Available: https://interregtiger.com/emec-and-qed-naval-deploy-flow-measurement-equipment-at-yarmouth-harbour/. [Accessed 8 11 2021].

[27] Marine Management Organisation, “Seascape Assessment for the South Marine Plan Areas,” 2013.

[28] M. Hawkins, The Argus, 23 04 2017. [Online]. Available: https://www.theargus.co.uk/news/15240393.powerful-addition-to-offshore-wind-farm/. [Accessed 04 11 2021].

[29] D. Slade, "Biggest cranes in the world to travel length of DP World terminal in Southampton," Southern Daily Echo, 22 07 2021. [Online]. Available: https://www.dailyecho.co.uk/news/19462164.biggest-cranes-world-travel-length-dp-world-terminal-southampton/. [Accessed 04 11 2021].

[30] Business Hampshire, "Portsmouth sets ambition to become the UK's first zero emission port," 20 12 2019. [Online]. Available: https://businesshampshire.co.uk/portsmouth-port-ambition-zero-emission/. [Accessed 05 11 2021].

[31] F. Bahtić, "Portsmouth International Port to become shore power ready as part of net zero drive," Offshore Energy.biz, 13 10 2021. [Online]. Available: https://www.offshore-energy.biz/portsmouth-international-port-to-become-shore-power-ready-as-part-of-net-zero-drive/. [Accessed 05 11 2021].

[32] "MAJOR DEAL WITH OFFSHORE WIND COMPANY MARKS CHANGE OF DIRECTION FOR MMD SHIPPING SERVICES," Portsmouth International Port, 2018 04 18. [Online]. Available: https://www.portsmouth-port.co.uk/news/major-deal-with-offshore-wind-company-marks-change-of-direction-for-mmd-shi. [Accessed 05 11 2021].

[33] K. Nye, "Rampion 2 wind farm extension opens informal consultation," RWE Renewables GmbH, 18 01 2020. [Online]. Available: https://www.rwe.com/en/press/rwe-renewables/2021-01-18-rampion-2-wind-farm-extension-opens-informal-consultation. [Accessed 18 01 2023].

[34] Tidal STream Industry Energiser (TIGER) Project, "Deliverable T1.7.2: Consolidated report on site and turbine modelling," TIGER, 2022.

[35] Nova Innovation Ltd, "Marine Scotland License Application," Nova Innovation Ltd, 2018.

[36] European Marine Energy Centre (EMEC), "PTEC 2 Feasibility Study," EMEC, 2021.

[37] R. Stevens, "The Perpetuus Tidal Energy Centre Ltd submission to the EAC inquiry into the role of tidal Energy in the UK's low carbon energy mix," Environmental Audit Committee, London, 2020.

[38] Renewables Now, "Orbital plans 15 MW of tidal turbine installs at PTEC by 2025," 20 05 2021. [Online]. Available: https://renewablesnow.com/news/orbital-plans-15-mw-of-tidal-turbine-installs-at-ptec-by-2025-741765/. [Accessed 02 11 2021].

[39] D. Coles et al., "A review of the UK and British Channel Islands practical tidal stream energy resource," *Proc. R. Soc. A,* vol. 477, no. 20210469, 2021.

[40] Black & Veatch, "Lessons Learnt from MeyGen Phase 1A: Final Summary Report," DEPARTMENT FOR BUSINESS ENERGY & INDUSTRIAL STRATEGY (BEIS), 2020.

[41] D. Coles et al., “Impacts of tidal stream power on energy system security: An Isle of Wight case study,” *Applied Energy,* vol. 334, p. 120686, 2023.

[42] On the Wight, “Isle of Wight council set out strategy for Island to become CO2 net zero in nine years,” 2021. [Online]. Available: https://onthewight.com/isle-of-wight-council-set-out-strategy-for-island-to-become-co2-net-zero-in-nine-years/#:~:text=To%20meet%20the%20target%20of,12.8%20per%20cent%20per%20year..

[43] West Dorset District Council and Weymouth & Portland Borough Council , “Joint Local Plan Review for West Dorset, Weymouth and Portland,” 2017.

[44] Wind Power Monthly, “UK's PowerGen unveils south coast plans for offshore wind plant at Portland harbour,” 1 1 2003. [Online]. Available: https://www.windpowermonthly.com/article/958842/uks-powergen-unveils-south-coast-plans-offshore-wind-plant-portland-harbour. [Accessed 4 11 2021].

[45] B. Randall-Smith, “Lib Dems hope to bring back dead Navitus Bay wind farm,” 4COffshore, 27 10 2020. [Online]. Available: https://www.4coffshore.com/news/lib-dems-hope-to-bring-back-dead-navitus-bay-wind-farm-nid19368.html. [Accessed 04 11 2021].

[46] Dorset Council, “Renewable energy action plan,” [Online]. Available: https://www.dorsetcouncil.gov.uk/-/renewable-energy-action-plan. [Accessed 1104 2021].

[47] T. Adcock and S. Draper, “ON THE TIDAL STREAM RESOURCE OF TWO HEADLAND SITES IN THE ENGLISH CHANNEL: PORTLAND BILL AND ISLE OF WIGHT,” in *Proceedings of the ASME 2014 33rd International Conference on Ocean, Offshore and Arctic Engineering*, San Francisco, 2014.

[48] TIDAL ENERGY Limited, “DeltaStream Demonstration: Ramsey Sound, Pembrokeshire,” 2008.

[49] PMSS on behalf of the Welsh Development Agency, “Wales Marine Energy Site Selection,” 2006.

[50] E.ON, “E.ON and Lunar Energy announce proposal to build one of the world’s largest tidal stream power stations off the Welsh coast,” 25 October 2007. [Online]. Available: https://www.eonenergy.com/about-eon/media-centre/eon-and-lunar-energy-announce-proposal-to-build-one-of-the-worlds-largest-tidal-stream-power-stations-off-the-welsh-coast/. [Accessed 6 July 2021].

[51] Regeneris Consulting, “The Economic Impact of the Development of Marine Energy in Wales,” 2013.

[52] BBC, “Failed Ramsey Sound tidal energy scheme 'faulty for months',” 12 December 2016. [Online]. Available: https://www.bbc.co.uk/news/uk-wales-politics-38236014. [Accessed 6 July 2021].

[53] Tidal Energy Ltd., “DeltaStream Demonstrator Project: Non-technical summary,” 2009.

[54] Tidal Energy Ltd., “DeltaStream Demonstration: Scoping report,” 2008.

[55] Marine Energy Wales, “Marine Energy Test Area secures Marine Licence,” 25 January 2021. [Online]. Available: https://www.meta.wales/news/marine-energy-test-area-secures-marine-license/. [Accessed 7th July 2021].

[56] A. Ajdin, “EMEC strengthens alliance with META,” Offshore Energy, 6 May 2020. [Online]. Available: https://www.offshore-energy.biz/emec-strengthens-alliance-with-meta/. [Accessed 7 July 2021].

[57] A. Garanovic, “META tidal stream resources up for assessment,” Offshore Energy, 15 jUNE 2021. [Online]. Available: https://www.offshore-energy.biz/meta-tidal-stream-resources-up-for-assessment/. [Accessed 7 July 2021].

[58] Marine Energy Wales, “WEST ANGLESEY TIDAL DEMONSTRATION ZONE,” [Online]. Available: https://www.marineenergywales.co.uk/marine-energy-in-wales/demonstration-zones/anglesey-demonstration-zone/. [Accessed 8 July 2021].

[59] Morlais Energy, “Partners,” [Online]. Available: https://www.morlaisenergy.com/partners/. [Accessed 8 July 2021].

[60] Cadw, “Pan-Wales heritage interpretation plan: Wales – the first industrial nation,” 2011.

[61] T. M. a. L. Kitson, “The End of Coal Mining in South Wales: Lessons learned from industrial transformation,” International Institute for Sustainable Development, 2017.

[62] The National Lottery Community Fund, “The Welsh Government Coastal Communities Fund,” The National Lottery Community Fund, [Online]. Available: https://www.tnlcommunityfund.org.uk/funding/programmes/coastal-communities-fund. [Accessed 8 July 2021].

[63] Welsh Government, “Small Scale Coastal Infrastructure Scheme,” Welsh Government, 2021.

[64] Energy Wales Marine Energy Task and Finish Group, “Marine Energy Plan for Wales - Unlocking the Energy in Our Seas,” 2015.

[65] Marine Energy Wales, “State of the Sector 2020: Economic Benefit for Wales,” Marine Energy Wales, 2020.

[66] Welsh Assembly Government, “Marine Renewable Energy Strategic Framework: Approach to Sustainable Development,” 2011.

[67] Welsh Government, *Kery Facts: SMARTCymru,* 2017.

[68] Business Wales, “SMART Cymru supports Bombora to develop mWave, a membrane driven wave energy generator.,” [Online]. Available: https://businesswales.gov.wales/expertisewales/product/bombora-wave-power-europe-limited/smart-cymru-supports-bombora-develop-mwave-membrane. [Accessed 8 July 2021].

[69] Swansea-Based Company Raises GBP 1 Mln for Wave Device Development, "OffshoreWIND.biz," 8 July 2014. [Online]. Available: https://www.offshorewind.biz/2014/07/08/swansea-based-company-raises-gbp-1-mln-for-wave-device-development/. [Accessed 8 July 2021].

[70] Bloomberg, "Welsh Government Awards €14.9 Million of EU Funding to Leading Marine Energy Developer Minesto," 31 May 2019. [Online]. Available: https://www.bloomberg.com/press-releases/2019-05-31/welsh-government-awards-14-9-million-of-eu-funding-to-leading-marine-energy-developer-minesto. [Accessed 8 July 2021].

[71] Minesto, "Deep Green Holyhead Deep Project Phase 1 (0.5MW): Non-technical Summary," 2016.

[72] Welsh Government, "Summary statistics for South West Wales region," 2020.

[73] PACEC, "Economic Profile of Pembrokeshire: Final Report from PACEC," Pembrokeshire County Council, 2015.

[74] E. Bell, "The recovery of seabird populations on Ramsey Island, Pembrokeshire, Wales, following the 1999/2000 rat eradication," in *Island invasives: scaling up to meet the challenge*, Gland, Switzerland, IUCN, 2019, pp. 539-544.

[75] PEMBROKESHIRE COAST NATIONAL PARK, "Supplementary Planning Guidance: Seascape Character Assessment: Ramsey Island coastal waters: S," 2013.

[76] Minesto, "Holyhead Deep – the world's first low-flow tidal stream project," [Online]. Available: https://minesto.com/projects/holyhead-deep. [Accessed 8 July 2021].

[77] Tidal Energy Ltd., "Tidal Stream Energy Demonstration Array St David's Head, Pembrokeshire: Environmental Scoping Report," 2012.

[78] Port of Milford Haven, "Oil & Gas," [Online]. Available: https://www.mhpa.co.uk/oil-and-gas/. [Accessed 9 July 2021].

[79] Carbon Trust, "Future Potential for Offshore Wind in Wales," Welksh Government, 2018.

[80] Port of Milford Haven, "PEMBROKE PORT DEVELOPMENTS," [Online]. Available: https://www.mhpa.co.uk/pembroke-port-developments/. [Accessed 9 July 2021].

[81] Pembroke Port, "PORT SUBMITS PLANNING APPLICATION TO PREPARE SITE FOR MAJOR £60M MARINE RENEWABLE ENERGY DEVELOPMENT," 18 December 2020. [Online]. Available: https://www.pembrokeport.com/news/port-submits-planning-application-to-prepare-site-for-major-60m-marine-renewable-energy-development/. [Accessed 9 July 2021].

[82] Cardiff University, "An analysis of economic activity dependent on the Milford Haven Waterway," Milford Haven Port Authority, 2012.

[83] Offshore Renewable Energy Catapult, “Benefits of floating offshore wind to Wales and the South West,” 2020.

[84] European Marine Energy Centre (EMEC), “HYDROGEN R&D FACILITIES,” [Online]. Available: http://www.emec.org.uk/facilities/hydrogen/. [Accessed 12 July 2021].

[85] R. Flynn, “EMEC’s Hydrogen Journey,” 2019.

[86] M. Dolman, W. Nock and S. King, “Hydrogen development in Wales,” Element Energy, Cambridge, 2020.

[87] Wave Hub Ltd., “Pembrokeshire Demonstration Zone: Advancing Offshore Renewable Energy,” Wave Hub Ltd,.

[88] RWE, “RWE launches its Pembroke Net Zero Centre to help drive decarbonisation in South Wales,” 26 May 2021. [Online]. Available: https://www.rwe.com/en/press/rwe-generation/2021-05-26-rwe-launches-its-pembroke-net-zero-centre. [Accessed 13 July 2021].

[89] M. Harrold, P. Ouro and T. O'Doherty, “Performance assessment of a tidal turbine using two flow references,” *Renewable Energy,* vol. 153, pp. 624-633, 2020.

[90] Business Live, “Stena Line cancels Fishguard-Rosslare sailings for a week,” 12 February 2021. [Online]. Available: https://www.business-live.co.uk/ports-logistics/stena-line-cancels-fishguard-rosslare-19825963. [Accessed 13 July 2021].

[91] M. Harrold and P. Ouro, “Rotor loading characteristics of a full-scale tidal turbine,” *Energies,* vol. 12, p. 1035, 2019.

[92] M. Togneri and I. Masters, “Micrositing variability and mean flow scaling for marine turbulence in the Ramsay Sound,” *J. Ocean Eng. Mar. Energy,* vol. 2, pp. 35-46, 2016.

[93] P. Evans, S. Armstrong, C. Wilson, I. Fairley, C. Wooldridge and I. Masters, “Characterisation of a highly energetic tidal energy site with specific reference to hydrodynamics and bathymetry,” in *EWTEC*, Aalborg, 2013.

[94] P. A. Gillibrand, R. A. Walters and J. McIlvenny, “Numerical simulations of the effects of a tidal turbine array on near-bed velocity and local bed shear stress,” *Energies,* vol. 9, p. 852, 2016.

[95] University of Strathclyde, “Methodology for a Decision Support Tool for a Tidal Stream Device,” 2014. [Online]. Available: http://www.esru.strath.ac.uk/EandE/Web_sites/13-14/Tidal/site.html. [Accessed 15 July 2021].

[96] D. Haverson, J. Bacon, H. C. Smith, V. Venugopal and Q. Xiao, “Modelling the hydrodynamic and morphological impacts of a tidal stream development in Ramsey Sound,” *Renewable Energy,* vol. 126, pp. 876-887, 2018.

[97] S. L. Ward, M. R. Hashema and S. P. Neill, “Characterising the tidal energy resource of Pembrokeshire,” in *4th Oxford Tidal Energy Workshop*, Oxford, 2015.

[98] ABPmer, “Sustainable management of marine natural resources - Mapping natutral resources,” Welsh Government, 2020.

[99] PEMBROKESHIRE COAST NATIONAL PARK, “Pembrokeshire Coast National Park Seascape Character Assessment: St David's Head,” 2019.

[100] Cambrian Offshore South West Ltd, “Ramsey Sound site description,” Not published, 2020.

[101] IRENA, “FUTURE OF WIND: Deployment, investment, technology, grid integration and socio-economic aspects,” International Renewable Energy Agency, Abu Dhabi, 2019.

[102] A. Iyer, S. Couch, G. Harrison and A. Wallace, “Variability and phasing of tidal current energy around the United Kingdom,” *Renewable Energy,* vol. 51, pp. 343-357, 2013.

[103] SEENEOH, “Tidal site development guidelines: Site Selection Methodology (deliverable WP T1.1.3),” TIGER project, 2021.

[104] The Offshore renewable Energy Catapult, “Floating offshore wind constraint mapping in the Celtic Sea,” 2020.

[105] M. Glarou, M. Zrust and J. C. Svendsen, “Using Artificial-Reef Knowledge to Enhance the Ecological Function of Offshore Wind Turbine Foundations: Implications for Fish Abundance and Diversity,” *J. Mar. Sci. Eng.,* vol. 8, p. 332, 2020.

[106] NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY, “WORLD PORT INDEX: TWENTY-SEVENTH EDITION,” THE UNITED STATES GOVERNMENT, Springfield, Virginia, 2009.

[107] Marine Scotland, “ectoral marine plan for offshore wind energy: social and economic impact assessment scoping report,” Scottish Government, 2018.

[108] T. Karna, S. C. Kramer, L. Mitchell, D. A. Ham, M. D. Piggott and A. M. Baptista, “Thetis coastal ocean model: discontinuous Galerkin discretization for the three-dimensional hydrostatic equations,” *Geoscientific Model Development,* vol. 11, p. 4359–4382, 2018.

[109] F. Rathgeber, D. A. Ham, L. Mitchell, M. Lange, F. Luporini, A. T. McRae, G. T. Bercea, G. R. Markall and P. H. Kelly, “Firedrake: Automating the finite element method by composing abstractions,” *ACM Transactions on Mathematical Software,* vol. 43, 2016.

[110] A. Avdis, A. S. Candy, J. Hill, S. C. Kramer and M. D. Piggott, “Efficient unstructured mesh generation for marine renewable energy applications,” *Renewable Energy,* vol. 116, p. 842–856, 2018.

[111] Bangor University, “UKHO Tide Gauge Data Network,” 2017.

[112] Seazone Solutions Ltd, “Edina Digimpa Service. Hydrospatial one. Gridded bathymetry,” 2014.

[113] L.Mackie, P.S.Evans, M.J.Harrold, T.O’Doherty, M.D.Piggott and A.Angeloudis, “Modelling an energetic tidal strait: investigating implications of common numerical configuration choices,” Applied Ocean Research, 2021.

[114] Pembrokeshire Coast National Park, “Seascape Character Area Descriptio: St Brides Bay,” 2013.

[115] Dogger Bank Offshore Windfarm, “Dogger Bank Offshore Wind Farm: Decommisioning Programme,” 2020.

[116] ICF Incorporated, L.L.C., “Comparison of environmental effects from different offshore wind turbine foundation,” U.S. Department of the Interior Bureau of Ocean Energy Management (BOEM), Fairfax, VA, USA, 2021.

[117] SIMEC Atlantis, “PORTLAND BILL,” [Online]. Available: https://simecatlantis.com/projects/portland-bill/. [Accessed 03 11 2021].

[118] D. S. Coles, M. Lucas, D. White and J. Miles, “Cost modelling and design optimisation of tidal stream turbines,” in *European Wave and Tidal Energy Conference (EWTEC)*, Plymouth, UK, 2021.

Appendix A. Portland Bill

Portland Bill

Portland Bill has seen interest from developers in the past. Portland Bill has historically been given less focus by SAE. In 2022 Proteus Marine Renewables acquired a majority stake in the Advanced Tidal Engineering and Services division from SAE. It is unclear if this has changed the ownership of the Portland Bill lease. Proteus are focussed on delivering the Neptyde project in the Raz Blanchard, as majority shareholder of Normandie Hydroliennes, and so it is likely to remain a secondary site of interest regardless of the controlling interest.

The Isle of Portland

Unlike the Isle of Wight, the Isle of Portland is connected to the mainland via a road bridge from Weymouth on the south coast. The island has a population of about 13,000, with a further 52,000 in Weymouth. Because of its proximity and easy access to Weymouth, the island has less autonomy than the Isle of Wight, for example the local Borough council representing both areas. Portland Bill is the name of a well-known lighthouse on the south coast of the Isle of Portland.

The Joint Local Plan Review, jointly published by West Dorset District Council and Weymouth & Portland Borough Council in 2017 notes that the GVA in Weymouth and Portland "remains significantly below the South West and national averages". It also notes that the tourism sector is dominant, with higher proportions of businesses in hospitality, entertainment and recreational sectors [43].

The island is serviced by an 18MW grid connection. There has been talk of commercial scale renewable projects in the area, including a small scale wind farm within the breakwaters at Portland Harbour [44] and the 970MW Navitus Bay offshore wind farm 10km south. Neither of these were developed, with Navitus Bay refused planning permission in 2015, although there has been talk of reviving the development more recently [45]. The main reason why this farm was rejected was due to the visual impact, the relatively close to shore wind turbines risking damaging tourism. It was opposed by all local councils except the Isle of Wight. As tidal stream is much less visible than offshore wind, particularly bottom-fixed devices, this would be less of an issue for the technology and could present an opportunity.

Dorset Council have a net zero target of 2040, ten years earlier than the UK's national target. In their action plan they note that renewable energy has a significant role to play, with one their objectives to "Increase renewable energy generation in Dorset" [46]. Within this are included several notable actions, including undertaking detailed resource mapping, lobbying central government to overcome major hurdles and working with renewable energy developers to secure new generation.

Vessel density

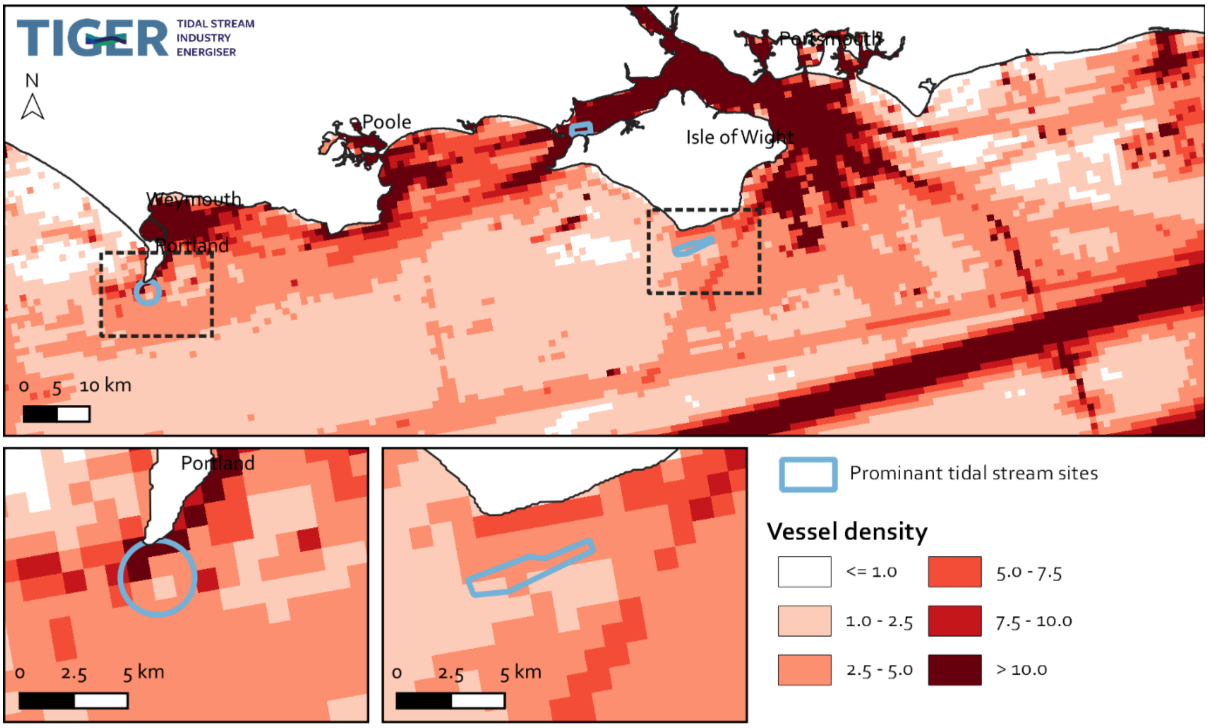
Figure 13 (top) shows the density of vessel traffic across the region. The Solent, between the Isle of Wight and the mainland, is a busy shipping area, with large vessels travelling to Southampton and Portsmouth harbours. These vessels route around the east side of the Island, meaning that any project were would not be viable.

The commercial grade site at Portland Bill is relatively quiet by comparison. North of Portland Bill there is commercial activity in the water surrounding Portland Harbour but little in the vicinity of the site. We believe that both fixed bottom and floating devices could be suitable with appropriate signage and exclusion zones marked on the relevant charts.

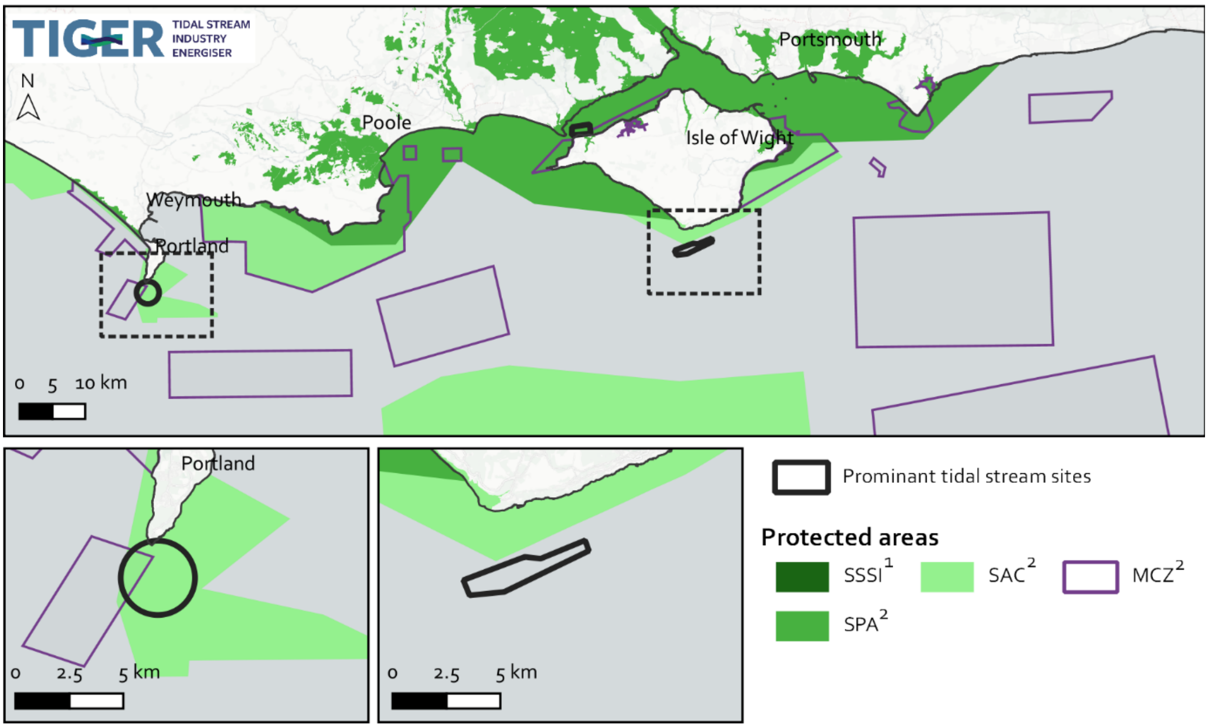
Environmental protection areas

Figure 13 (bottom) shows the designated environmental areas across the area. These include SAC, SPA for protected birds and Marine Conservation Zones (MCZ).

The Island is largely surrounded by a SPA, with the PTEC site just on the periphery of a SAC. The export cable would need to go through the SAC to get to land. The Portland site is within a SAC and encroaches slightly onto a MCZ.



Data obtained from the European Marine Observation and Data Network (EMODnet). The maps are based on AIS data yearly purchased from Collecte Localisation Satellites (CLS) and ORBCOMM.



1: Contains Natural Resource Wales data © copyright and database right [2018].
2: Contains Joint Nature Conservation Committee data © copyright and database right [2020].

Figure 13 – Vessel density (top) and designated environmental protected areas (bottom) across the Portland Bill region.

Fishing activity

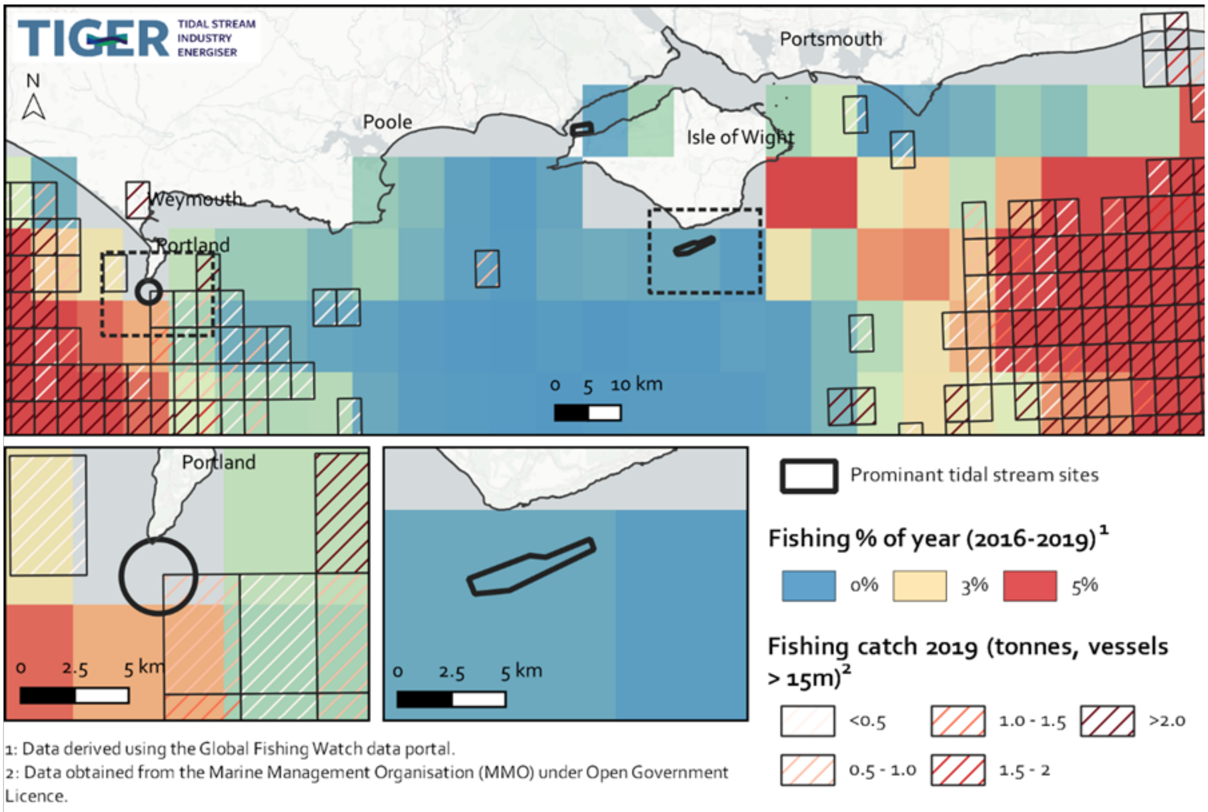
Figure 14 (top) shows the fishing activity across the region. Two datasets are overlaid: from the Global Fishing Watch data portal (block colours) and from the MMO (hatched squares).

The Portland site is on the edge of very heavy fishing activity towards the south west of the Channel. Engagement with local fisheries would be more important for this site.

Seabed sediment

Figure 14 (bottom) shows the seabed sediment classification across the region. This is a FOLK-5 classification, categorising the seabed into five broad categories, and is based on survey data that has been interpolated over larger areas.

Such rocky seabed is apparent at the Portland Bill site. This could make piling difficult, and would require further investigation to determine the optimal found type, based on the technology of interest.



Note that two different data sources are overlaid.

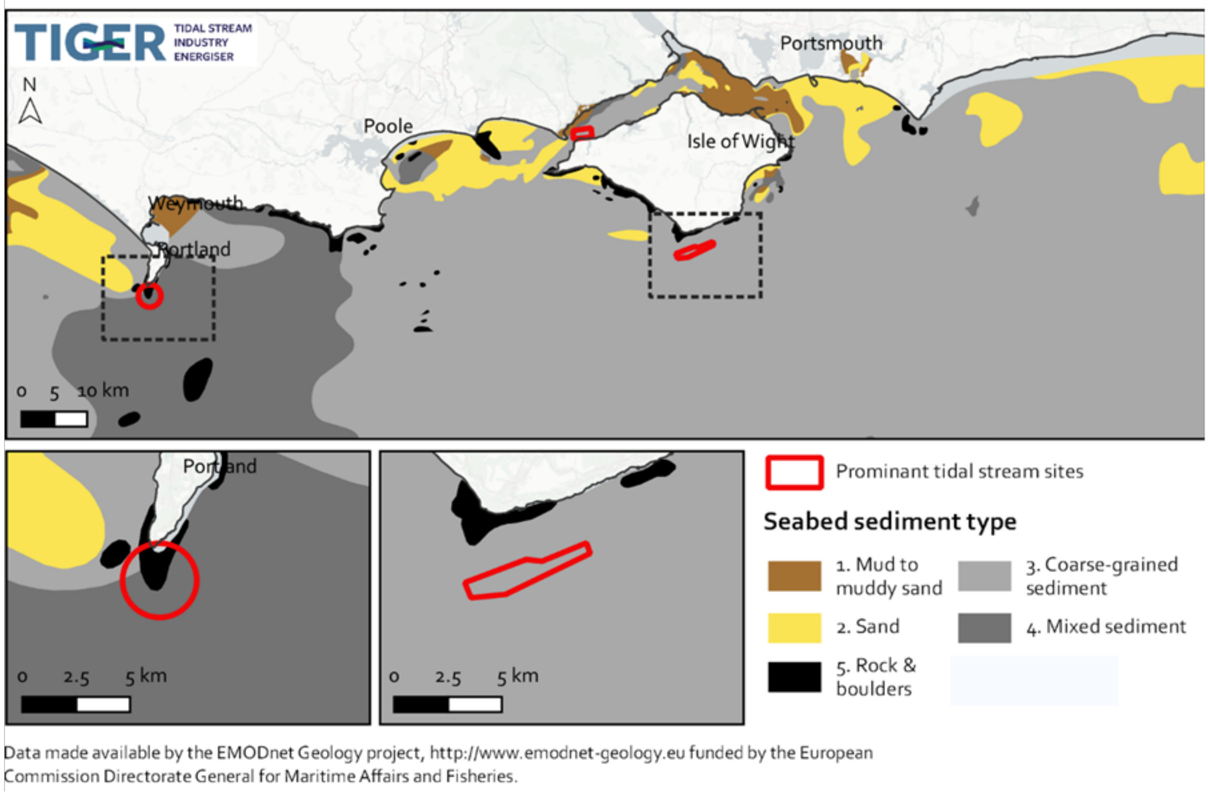


Figure 14 – Commercial fishing activity (top) and FOLK-5 seabed sediment classification (bottom) in the Portland Bill region.

Hard constraints

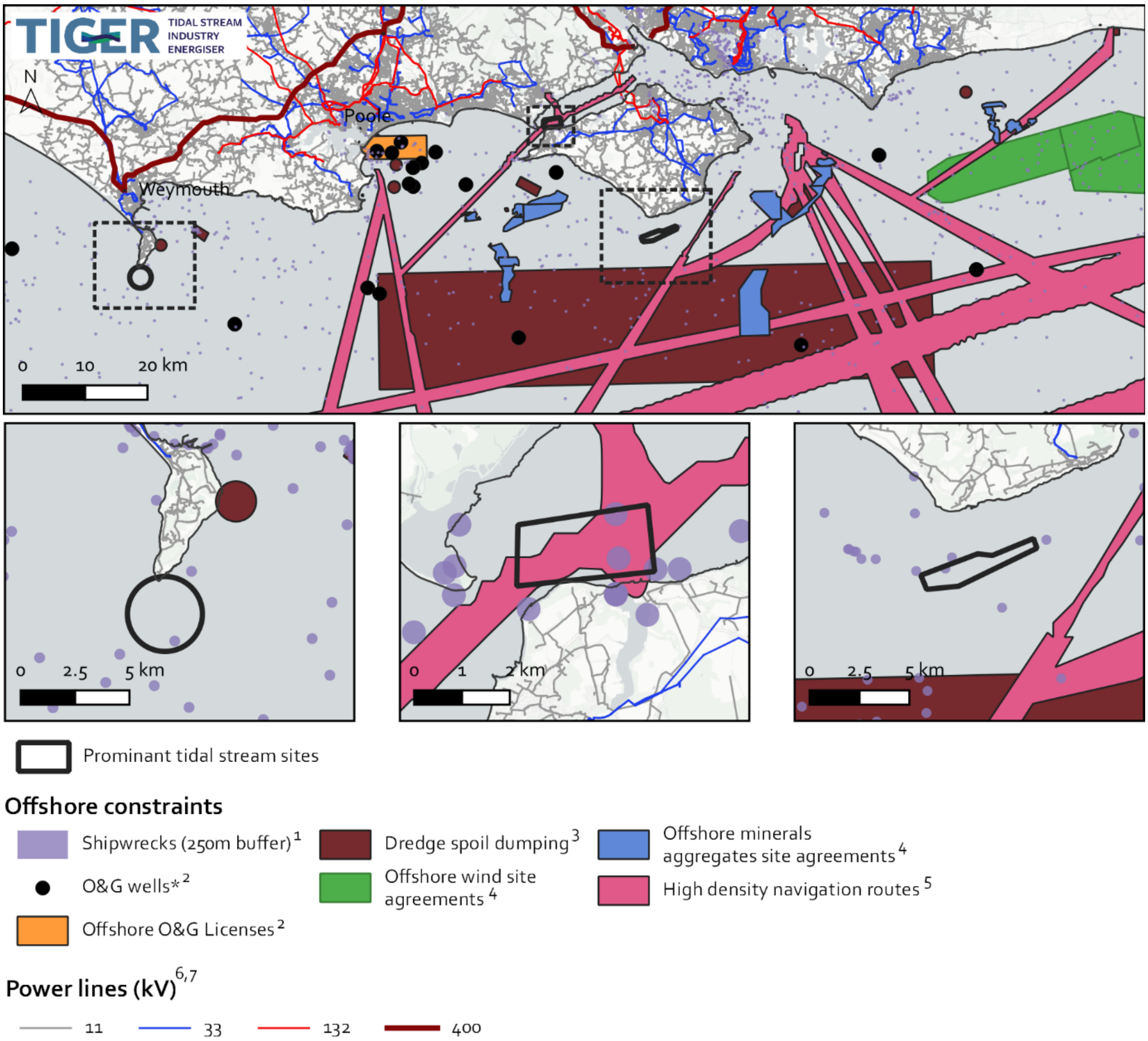
Figure 15 shows hard constraints, namely areas of seabed that are used by other sea users. Not all of these would prohibit TSE deployment, but the presence of these layers indicates areas that would be more difficult to develop and would need engagement with more stakeholders.

The Portland Bill site is free from exclusions, save for some isolated shipwrecks with could be easily avoided given the large size of these locations.

Grid

Figure 15 also shows the electricity lines. Transmission lines (400kV) were sourced from National Grid. Distribution grid data (11-132kV) was provided by Scottish and Southern Electricity Networks (SSEN) Distribution. Unlike other UK TSE sites, where sites are more remote and grid connections are less established, the Isle of Wight region is well connected.

The Isle of Portland is linked to the mainland via a road bridge and a 33kV grid connection feeds the island from the north. The 400kV transmission network connects into a substation at Chickerell which steps down to 33kV; this would be the obvious point for a grid connection, particularly for a larger project. To link to this directly would require ~11km cable to shore and then a ~4km cable to the substation (straight line distances, in reality will depend on topology and land usage onshore). Such a cable would need to route through the SAC surrounding the Island and navigate the Chesil shingle barrier beach (see Figure 4 (bottom)).



* All decommissioned/abandoned in exploration phase

1: Contains public sector information, licensed under the Open Government Licence v3.0, from the UK Hydrographic Office
2: Data from the Oil and Gas Authority (OGA)
3: Data obtained from the European Marine Observation and Data Network (EMODnet)
4: Contains data provided by The Crown Estate that is protected by copyright and database rights
5: Data published by the MMO. High density navigation routes minus harbour authority areas. See policy notes for details (S-PS-3)
6: Distribution network data (11, 33, 132kV) from Scottish and Southern Electricity Networks (SSEN) Distribution
7: Transmission network data (400kV) from National Grid

Figure 15 – Offshore constraints and sea use across the region (Portland Bill).

Final areas identified

Figure 16 indicates the areas available for commercial sites, showing the hard constraints (grey), unsuitable water depth areas (blue) and suitable flow speeds (orange/red) on a single map. The individual hard constraint layers are transparent, the darker the shape of grey the more constraints that are present. The water depth exclusion considers locations shallower than 25m. These are deemed not commercially viable given current market leading device concepts and target markets.

Specific areas of interest for commercial projects have been identified with the dashed line. The 3.5 m/s cut-off (red areas) was informed by TIGER project partners and is arbitrary in nature, but gives an indication as to the area that would be of interest for next generation TSE projects.

The Portland Bill site is constrained to the north, where the water is shallow. Considering flow speeds above 3.5 m/s, an area of 2.2 km2 has been indicated as most interesting for a next generation commercial project.

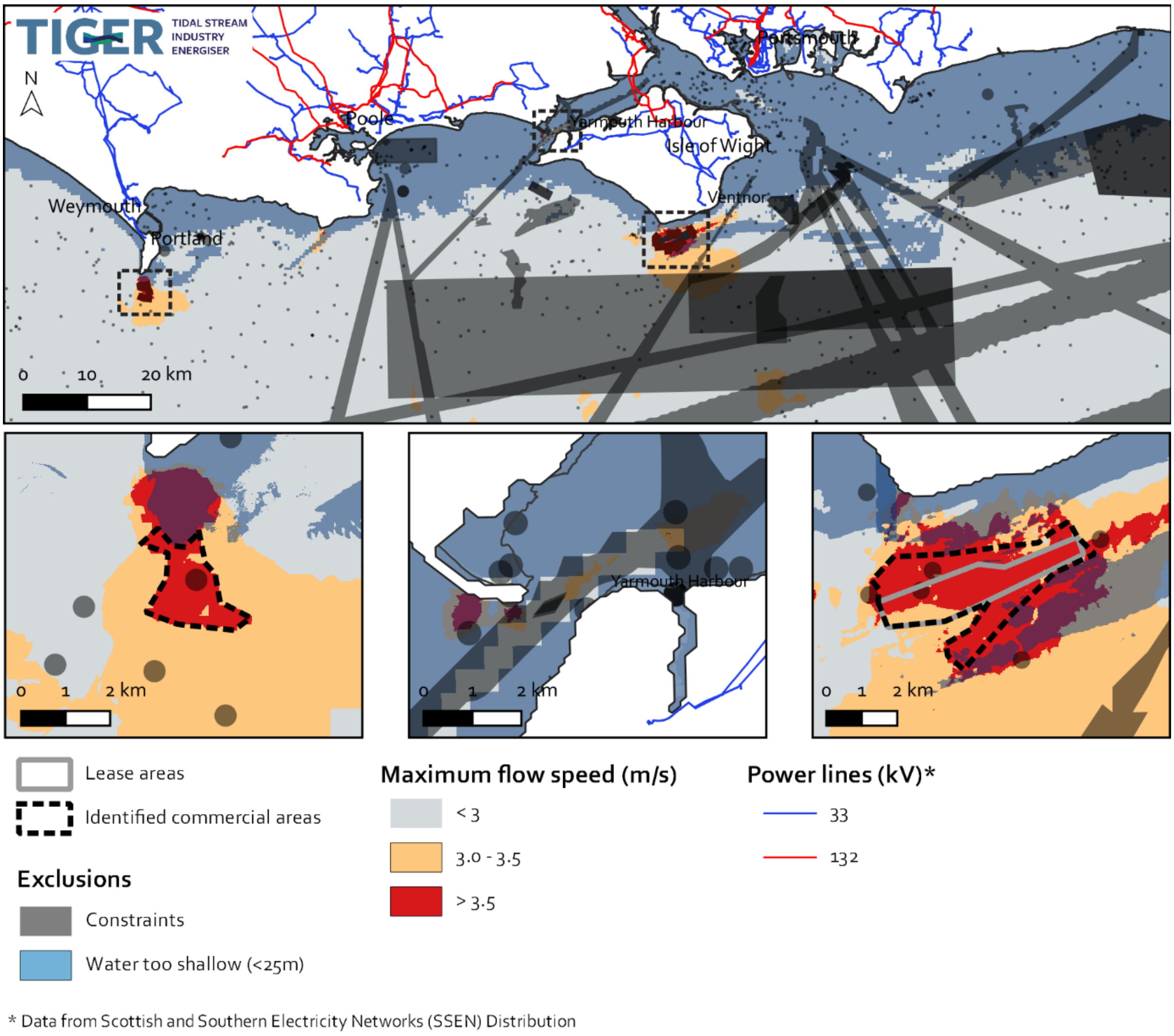


Figure 16 – Areas identified as suitable for commercial scale TSE projects (dashed line). Maximum spring tidal velocity (red/orange), water depth exclusion (blue) and constraints (grey) are also shown. The darker the area the more constraints are applicable.

Site summary

Table 3 shows the main characteristics of the Portland Bill TSE site of interest. Portland Bill is an interesting site, with high flow speeds. This site is more constrained than PTEC, especially regarding the water depth, which limit the area available and size of turbines that could be deployed.

Table 3 – Portland Bill site summary.

Site name	Portland Bill
Owner/developer	SIMEC Atlantis Energy
Status	AFL expired in 2019
Current lease area (km^2)	~1.0
Consented/estimated capacity (MW)	Up to 30MW (estimated)
Site area identified in GIS (km^2) (max spring tidal velocity >3.5m/s)	2.2
Maximum spring tide flow velocity (m/s)	3.6
Water depth range (m)	30 – 45
Potential ports	Portland Poole Yarmouth
Potential cable landing	Isle of Portland Weymouth (mainland)
Key environmental considerations	Shallow waters Proximity to higher vessel traffic areas and fishing activity Within a MCZ and SAC

Techno-economic assessment

In this section the economic potential of the Portland Bill site is investigated. This includes commentary on the capacity available, LCOE, and the revenue support that would be required to enable further developments beyond the lifetime of the TIGER project.

Modelled farms

For this study we decided to build on existing, recent knowledge. In late 2021, EMEC conducted a detailed study, on behalf of PTEC, to assess the PTEC and Portland Bill sites [36]. This included analysis of the resource (using MIKE 21), potential array layouts, local sensitivities and environmental factors and potential cable landing and grid connection points. This study was delivered in October 2021.

From the report EMEC shared the following observations:

- Portland Bill would be suited to 1-2MW turbines. It could accommodate 300MW of capacity, but this would require more detailed analysis of blockage and wake effects. They stated that *"At a minimum 100 MW should be deployable without any major impact to overall flow regimes or device yields, if positioned appropriately"*.

  They also included an indicative, hypothetical farm layout consisting of 2MW turbines, using a combination of multi-rotor tri-frames (2MW total) and single rotor 2MW turbines. These could be piled or gravity base.

The report does not contain an estimation of AEP; they assume a gross AEP of 40% for the purposes of the economic calculations and state the need to quantify AEP as future work. We aim to build on the EMEC study by including more detailed analysis of LCOE and required CfD.

Based on the information available we decided to model the below farm:

- "*Portland Bill Phase 1*": A 30MW array at Portland Bill. This matches the SAE agreement for lease at the site. We decided to assume a fixed bottom technology, given SAE's close links with technology provider Proteus and the shallow water which would make floating foundations less viable. We assumed a delayed commissioning date, compared to PTEC Phase 1, as this site does not have full consents.

These are summarised in Table 4.

Table 4 – Device and farm assumptions used for the techno-economic analysis for the Portland Bill site.

Property	Unit	Portland Bill "Phase 1"
Site	-	Portland Bill
Commissioning year	-	2032
Farm size	MW	30
Foundation type	-	Fixed bottom
Representative device rated power	MW	1.5
Representative device rotor diameter	m	18
Number of devices	units	20

Modelling assumptions: costs

For the 30MW Portland Bill project, we assumed that it could be connected to local 33kV networks at Chickerell.

Results: Portland Bill Phase 1 (30MW)

Figure 17 shows the LCOE breakdown for the Portland Bill 30MW farm scenarios.

Clear differences can be seen in the breakdown compared to the PTEC 30MW Phase 1 scenario (Figure 9). The main reason is due to the different technology assumed, fixed-bottom vs floating, which results in a lower turbine CAPEX but a higher OPEX. As we also assume a slightly later commissioning date, 2032 vs 2030 for PTEC Phase 1, there is more time for learning driven LCOE reduction. This results in a marginally lower LCOE for the

Portland Bill project (£98.8/MWh vs £100.6/MW). The range between optimistic and pessimistic scenarios is also narrower (£46.5/MWh difference vs £57.7/MWh) because we had access to better cost data for the fixed bottom device (both quantity and quality of data).

Note that a lower AEP was assumed at the Portland Bill site (33.2% net capacity factor in the baseline case). This decision was taken to reflect the lower flow speeds seen by the fixed-bottom device, as it is lower in the water column, and because the site is considered a lower quality site than PTEC generally (for example, with less promising flow conditions [47], lower area available and less suitable bathymetry which limits the rotor diameters possible).

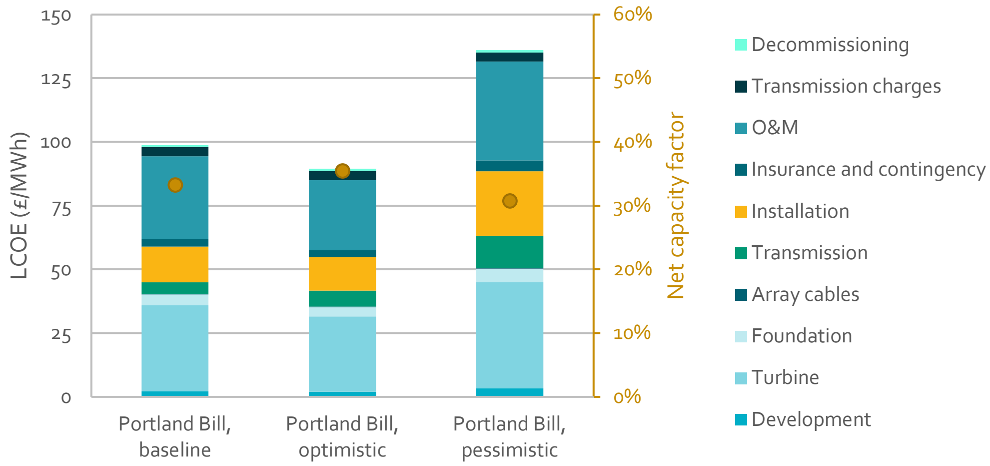


Figure 17 – LCOE breakdown for the three scenarios devised for the Portland Bill case. Net AEP is shown on the secondary Y axis.

Figure 18 shows the project IRR achieved as a function of the CfD strike price. We estimate that a 10% IRR could be achieved for a strike price of £137/MWh, although note that this does not include debt or tax. For the optimistic scenario, the strike price falls to £131/MWh for a 10% IRR. Conversely, for the pessimistic, the strike price rises to £178/MWh.

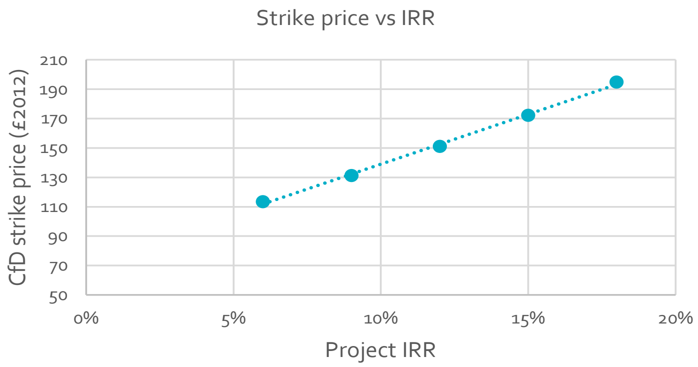


Figure 18– CfD strike price vs project IRR for the Portland Bill baseline scenario.

Summary and recommendations

The summary and recommendations in Section 6 apply to the study area in the Isle of Wight, including the Portland Bill site. More specifically to the Portland Bill TSE site of interest:

- Portland Bill site is more constrained than PTEC, especially regarding the water depth, which limits the area available and size of turbines that could be deployed to sub 20m rotor diameter fixed-bottom devices.

- Portland Bill site viability will depend on the status of the SAE lease area.