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ENFAIT
ENABLING FUTURE ARRAYS IN TIDAL

Final Project and European ESEAs

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 745862.

EnFAIT

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Contents

Abbreviations

ADCP	Acoustic Doppler Current Profilers
AI	Artificial Intelligence
AIS	Automatic Identification System
BAP	Biodiversity Action Plan
CC	Community Councils
CCT	Coastal Character Types
CfD	Contracts for Difference
EDP	Energy Demonstration Projects
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
EMF	Electromagnetic Fields
EnFAIT	Enabling Future Arrays in Tidal
ERCoP	Emergency Response Co-operation Plan
ESEA	Environmental and Socio-Economic Appraisal
EU	European Union
EV	Electric Vehicle
FGDs	Focus Group Discussions
FITs	Feed-in Tariffs
GHG	Greenhouse Gas
GVA	Gross Value Added
GW	Gigawatt
HIE	Highlands and Islands Enterprise
HVDC	High Voltage Direct Current
GSP	Grid Supply Point
JNCC	Joint Nature Conservation Committee
KIIs	Key Informant Interviews
kW	Kilowatt
LCoE	levelised cost of electricity
MCT	Marine Current Turbines
MYJH	Mid Yell Junior High
MPA	Marine Protected Areas
MS-LOT	Marine Scotland Licensing Operations Team
MW	Megawatt
NCMPA	Nature Conservation Marine Protected Areas
NYDC	North Yell Development Council
OTEC	Ocean Thermal Energy Conversion
PAHs	polycyclic aromatic hydrocarbons
PBDEs	polybrominated diphenyl ethers
PCBs	polychlorinated biphenyls
PEMP	Project Environmental Monitoring Plan
PMF	Priority Marine Features
RO	Renewable Obligation
SAC	Special Area of Conservation
SBB	Spawning Stock Biomass

SC	Shetland Composites
SEPA	Scottish Environmental Protection Agency
SIC	Shetland Island Council
SNH	Scottish Natural Heritage
SPA	Special Protection Areas
SSE	Southern and Scottish Energy
STA	Shetland Tidal Array
UK	United Kingdom
USA	United States of America
UV	Ultra-violet
WP	Work Package

Executive Summary

A Funding Grant was awarded from the European Union's Horizon 2020 research and innovation programme in January 2017 is to demonstrate a grid-connected tidal energy array at a real-world tidal energy site in Shetland, propelling tidal energy towards competing on a commercial basis with alternative renewable sources of energy generation – Enabling Future Arrays in Tidal (EnFAIT). This was provided in response to the EU's call 'LCE-15-2016: *Scaling up in the ocean energy sector to arrays*', which aims to generate significant learning opportunities in demonstrating cost-effective tidal arrays.

As part of EnFAIT, an Environmental and Socio-Economic Appraisal (ESEA) has been prepared under Work Package 8. The objectives of the ESEA are to:

- assess the potential impact, positive and negative, of the tidal energy array on environmental and socio-economic receptors
- present mitigation actions to address any negative environmental and socio-economic risks and impacts, and review the approach taken to develop the environmental monitoring framework
- assess the potential impact of the array on the tidal energy industry at an EU-level
- capture and disseminate lessons learned for the tidal energy industry on managing environmental and socio-economic impacts, applying the existing policy and regulatory framework, developing local supply chains, and techniques for engaging with local communities.

The Shetland Tidal Array (STA) is in the Bluemull Sound, Shetland, between the islands of Unst and Yell as illustrated in Figure 1.

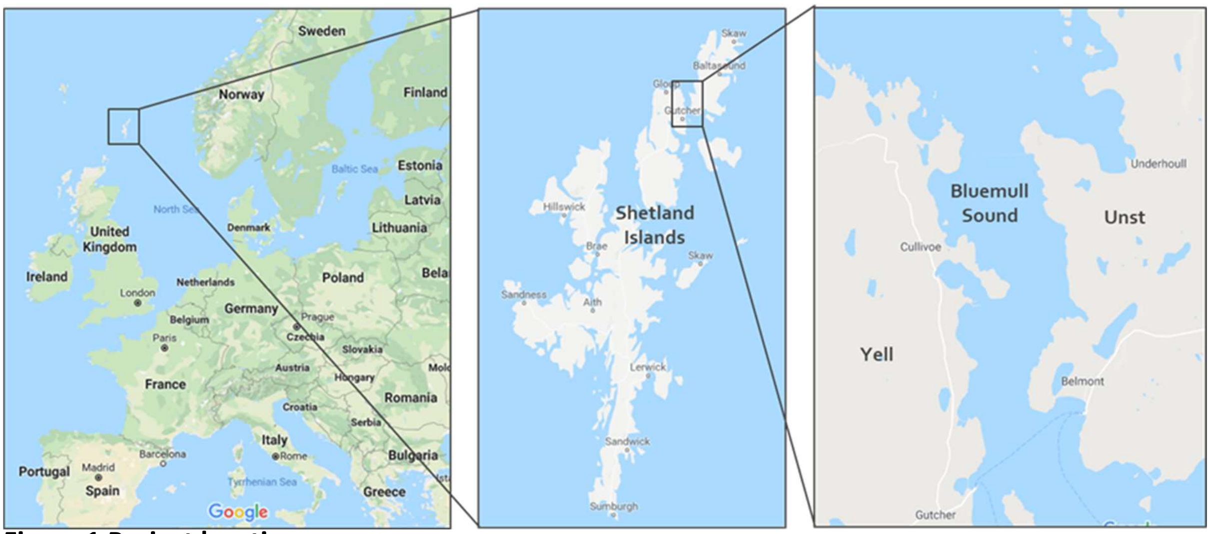


Figure 1 Project location

At the start of the project, the array consisted of three fully submerged turbines, each with a dedicated cable connecting to an onshore transformer station at Cullivoe Pier. Over the course of the project, the three turbines were expanded to six, and wake interactions between the devices were explored. The last three turbines that were added to the array are new generation turbines (M100-D) that have had the gearbox removed, although all turbines remain rated at 100kW. Two of the new devices are connected to an offshore hub from where a single, shared cable takes the combined power to the onshore transformer station. The first three turbines were decommissioned in early 2023, with the array expected to remain in operation until at least 2038.

The turbines comprise a 2-bladed, horizontal axis device installed subsea at a depth of 30-40m. The turbines use gravity base foundations and do not require any piling or drilling into the seafloor. An example of the newer M100-D turbine is illustrated in Figure 2.

Figure 2 The Nova M100-D tidal energy device

As part of onshore infrastructure at Cullivoe Pier, battery storage and Electric Vehicle (EV) charging facilities have been added, providing balanced ‘baseload’ energy to the grid and valuable facilities for the local community.

EnFAIT presents a unique opportunity to gather information from an array of operating turbines and improve the industries’ understanding concerning individual and combined environmental effects of turbines within an array. Environmental survey and monitoring activity has been ongoing in Bluemull Sound, Shetland, since November 2010, according to techniques agreed with environmental regulators. The environmental framework comprised a combination of land-based and sub-surface monitoring to record seabird and marine fauna interactions in the area immediately above and surrounding the tidal array, and beneath the surface of the sea.

During the EnFAIT project, there were no observed collisions between the turbine blades and marine fauna. Most sightings from visual monitoring and/or underwater camera footage comprise fish, very occasional diving seabirds and seals. In 2022, Nova submitted revision 6 of the Project Environmental Monitoring Plan (PEMP) to Marine Scotland and Shetland Island Council, for their consideration. This PEMP was approved in July 2022 and built upon the 12 years of monitoring activity conducted at the site since 2010.

The environmental and socio-economic appraisal started with a review of published information on previous tidal energy projects that were developed within and outside the EU. This aimed to identify details associated with research and development initiatives, existing policy frameworks, challenges in environmental permitting and lessons learned. An environmental and social baseline was subsequently prepared. This examined past and ongoing trends and conditions in Shetland, the North Isles and in Yell. The appraisal methodology involved extensive engagement with a variety of stakeholders including; regulatory authorities; Shetland residents and their elected representatives; Shetland Island Council; and key informants with detailed knowledge of local environmental conditions and tourism activities.

During the initial appraisal process in 2018, a postal questionnaire was sent to all residents on Yell (455 in total) in partnership with SIC who are implementing an energy efficiency improvement programme for residents and businesses on the island. Five questions were added by Nova to the council's questionnaire which aimed to gather resident's perceptions towards tidal energy. The results indicated that there is very strong support towards the development of this type of technology because devices are submerged below water and are not visible; there are no known significant, adverse environmental impacts; and the device uses Shetland's renewable energy resources to generate low-carbon electricity.

Nova and RSK jointly attended a public event on Yell (the Yell Trade Show) during which project partners were able to provide residents with information about the project and listen to local attitudes and opinions. A series of engagement activities were conducted in Shetland, including focus group discussions, key informant interviews and workshops with school children. The overall outcome of the local community engagements was that there is extensive support for the development for this type of technology. There is also an expectation that the project should expand its presence at Cullivoe Pier and establish a visitor's board to provide local people with information on the purpose of the tidal devices which are fully submerged beneath the sea and are largely invisible to local people.

An initial appraisal of the effects of the project was completed in 2018 at a UK level, and at an EU level to appraise the effects of EnFAIT on the development of the wider tidal energy sector. The outcome of the appraisal was re-visited at the end of EnFAIT in 2023. The appraisal categorised the potential environmental and socio-economic effects of the project using a simple methodology, and this is presented in Table 1.

Table 1 Classification of the effects of EnFAIT

Clear and major positive effect (*expected to contribute a positive, environmental and/or socio-economic change that is recognised at a Shetland/UK and/or EU level*)	✓✓
Broadly supportive or minor positive effect (*results in improved environmental knowledge, or positive environmental and/or socio-economic change)*	✓
Neutral effect *(is not expected to have a positive or adverse effect)*	**0**
Minor negative effect *(expected to result in a localised, adverse environmental and/or socio-economic change)*	✗
Major negative effect *(adverse environmental and/or socio-economic change)*	✗✗
Uncertain effect *(based upon the information available the outcome of the effect cannot be determined at this time and could be either positive or adverse)*	**?**

The results of the final appraisal are presented in Table 2.

Table 2 Results of the appraisal for environmental and socio-economic topic areas

	UK level	EU-level
Environmental topic areas		
Marine and coastal biodiversity	✓	✓
Physical environment and water quality	✓	✓
Underwater noise and vibration	✓	✓
Benthos	0	0
Fish	✓	✓
Seabirds	✓	□
Marine mammals	✓	□
Protected sites	0	?
Air quality and global climate	✓	✓
Seascape and visual character	✓✓	✓✓
Marine and coastal archaeology	0	?
Socio-economic topic areas		
Demographics	✓	✓
Standard of living and housing conditions and vulnerable groups	0	✓
Educational change	✓✓	✓✓
Social cohesion	0	✓
Perception of the sea as a tidal energy resource	✓	✓
Recreational and tourism activities	0	0
Employment and business	✓✓	✓✓
Industrial strategy and rural regeneration	✓	✓
Commercial shipping and navigation	0	?
Effects on the regulatory framework	✓	✓

The environmental appraisal identified that there are no adverse effects from the tidal energy array on marine receptors at a project level. There are neutral effects on benthos, and protected sites as there are no identified interactions with these types of receptors. Positive effects included an increase in biodiversity and abundance of common fish species due to the introduction of new hard structures, and the way in which the project has generated a robust data set that demonstrates how tidal energy devices can be installed and operated without disturbing marine mammals or the physical environment. Another positive is that the introduction of battery storage at Cullivoe Pier has meant that power can be released into the grid when the tides slow and the turbines are not generating, while the introduction of an electric vehicle charging point has provided a benefit to the local community. The knowledge gained from EnFAIT will subsequently make the permitting processes for similar tidal devices less complicated in the future, and this is considered a positive effect from the project.

EnFAIT's environmental monitoring framework has been adapted since the start of Nova's activities in the Bluemull Sound and has generated over 12 years of data. During Phase 1 of EnFAIT, the precise questions that are intended to be answered by the monitoring data remained unclear. During Phase 2 of the project, the land-based surveys were focussed to gather specific information on the behaviour of diving birds and marine mammals in the immediate array area. For future tidal energy projects, it is recommended that the strategic objectives of monitoring are clearly defined at the start, so that the data collection activities can be tailored towards these objectives to ensure that the questions posed become answered over time. There is a risk that similar future projects may become 'data rich and information poor' unless key questions and purposes of the data being collected are clearly understood.

The appraisal of socio-economic topic areas found no adverse effects. Positive effects were identified for demographics, as this new type of renewable energy technology and associated activity could encourage people to stay in Shetland and reverse a current trend of out-migration. There have been positive effects on employment and business through the generation of additional knowledge, revenue and capacity among the local companies used to produce key materials and services. EnFAIT is also strategically aligned with the UK's industrial strategy to focus investment outside urban areas as part of a broader aim for rural regeneration. The project has also raised awareness associated with tidal energy technology through interactions with young people in schools.

The appraisal has identified a set of lessons and recommendations. These include the importance of early engagement with regulators who may be uncertain of how to approach the permitting of tidal energy devices, due to perceived gaps in their policy and regulatory framework, and identifying and agreeing clear monitoring objectives with regulators and key stakeholders. The project has also identified opportunities to automate video data processing and analysis, which being explored.

A key benefit of the EnFAIT project starting at a relatively small-scale is that regulators, and other stakeholders such as fishing groups, have become confident in the effects of the technology gradually. The installation of only a small number of tidal energy devices has caused little-to-no disruption to other users of the shoreline and has prevented stakeholders from suddenly being faced with a large-scale development with uncertain and potentially significant adverse effects. Stakeholders would like to see the project scaled up, with the possibility of future arrays widely welcomed.

In summary, EnFAIT continues to have a positive impact on the local economy. No adverse effects on environmental receptors have been identified at project level. Project activities have demonstrated how regulators are able to respond flexibly during the permitting of tidal energy devices, and that there is strong support amongst local communities for this type of renewable energy technology.

1 Introduction

A Funding Grant was awarded from the European Union's (EU) Horizon 2020 research and innovation programme in January 2017 to demonstrate a grid-connected tidal energy array at a real-world tidal energy site, propelling tidal energy towards competing on a commercial basis with alternative renewable sources of energy generation - Enabling Future Arrays in Tidal (EnFAIT). This was in response to the EU's call 'LCE-15-2016: *Scaling up in the ocean energy sector to arrays*', which aims to generate significant learning opportunities in demonstrating cost-effective tidal arrays.

This document presents updated Environmental and Socio-Economic Appraisals (ESEAs) delivered as part of Work Package (WP) 8 for the EnFAIT project. This satisfies deliverable D8.10 of the EnFAIT project and is to be made available for public dissemination.

1.1 Description of the project and associated facilities

The Shetland Tidal Array (STA) is located in Bluemull Sound, Shetland, between the islands of Unst and Yell as illustrated in Figure 1-1.

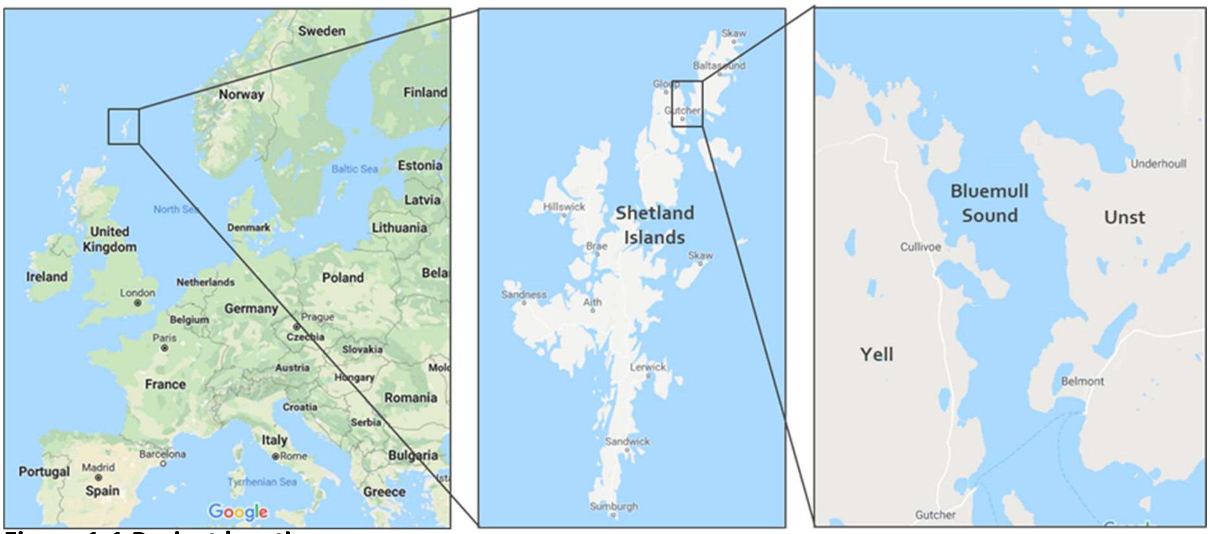


Figure 1-1 Project location

The site is located near the Ness of Cullivoe, a 1km long headland to the north-east of Yell. Figure 1-2 shows the boundary of the STA lease area, issued by Crown Estate Scotland, and within which all of the turbines in the array are installed on the seabed. It also shows the corridor for the export cables which take the power generated from the turbines to an onshore station at Cullivoe Pier.

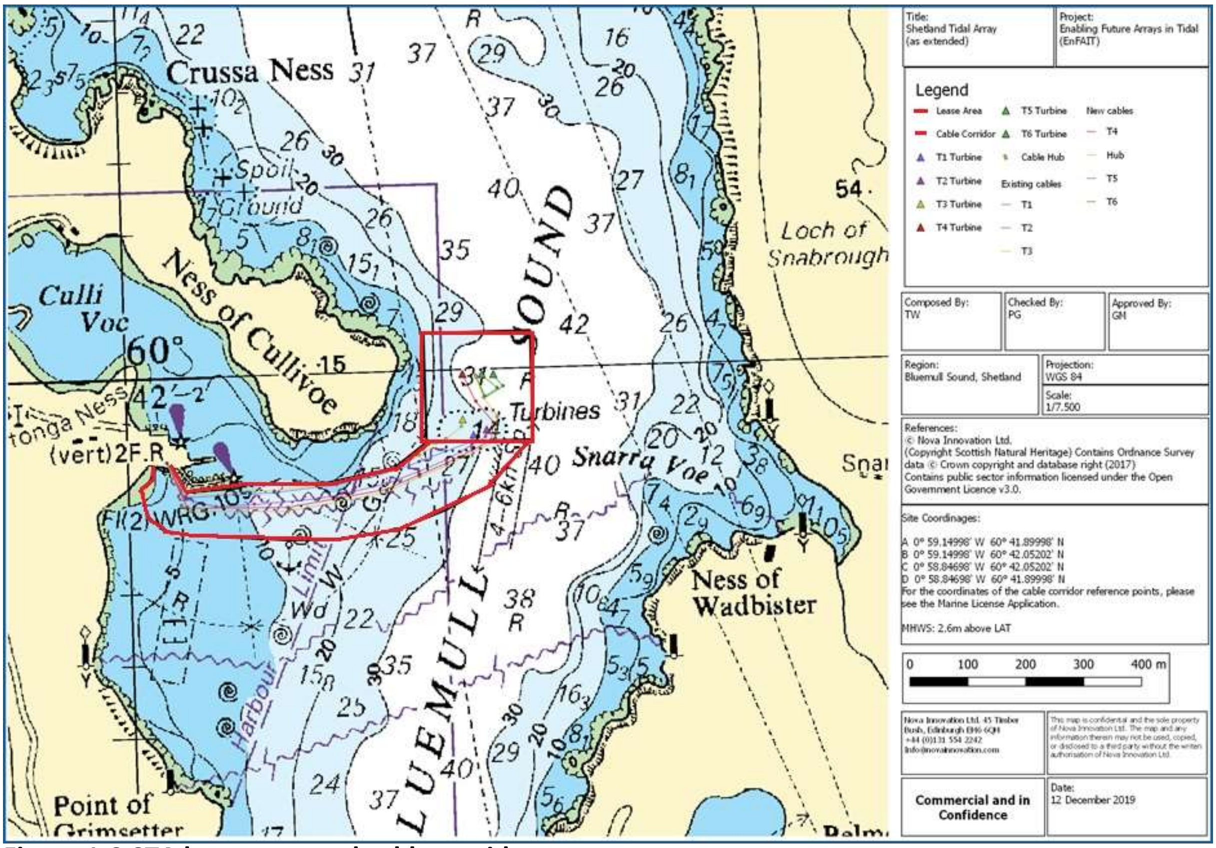


Figure 1-2 STA lease area and cable corridor

Phase 1 of EnFAIT comprised the installation and operation of three conventionally geared 100kW Nova M100 tidal turbines (T1 to T3) in Bluemull Sound. Phase 2 started in summer 2020 and involved the addition of three of Nova's 'next-generation' direct drive 100kW turbines (T4 to T6), which include a number of upgrades, including in the removal of the gearbox with a direct drive generator. In summer 2020 the first of the three direct drive turbines (the Nova M100-D) was installed in Bluemull Sound. In January 2023, the remaining two M100-D turbines were installed, increasing the total number of turbines to six and the installed capacity of the STA to 600kW.

Turbines 1 to 4 in the Shetland Tidal Array each has its own dedicated export cable taking the power generated to shore at Cullivoe. Turbines 5 and 6 are connected to an offshore hub, from where a single, shared export cable takes the combined power from the two turbines to shore at Cullivoe. The offshore hub was installed in January 2023 at the same time as T5 and T6. The individual cables of the array are connected to a transformer station at Cullivoe Pier. Figure 1-3 illustrates the array layout of all six turbines and five export cables.

Phase 2 of EnFAIT includes decommissioning the first three Nova M100 turbines (T1 to T3), to enable learning about real-world decommissioning of multiple turbines. This decommissioning commenced in April 2023, and will be completed during 2023. The remaining turbines in the array (T4 to T6) are expected to remain in Bluemull Sound until the end of their operational life. The turbine design life means that the operation of T4 to T6 has the potential to extend beyond the end date of 1 April 2038 for the Marine Licence currently in place for the STA. An application will be made nearer the time to extend or renew any licences required for the ongoing operation of the STA, according to the regulatory requirements at the time. When the turbines reach the end of their operational life, they will be fully decommissioned, along with all associated infrastructure/equipment.

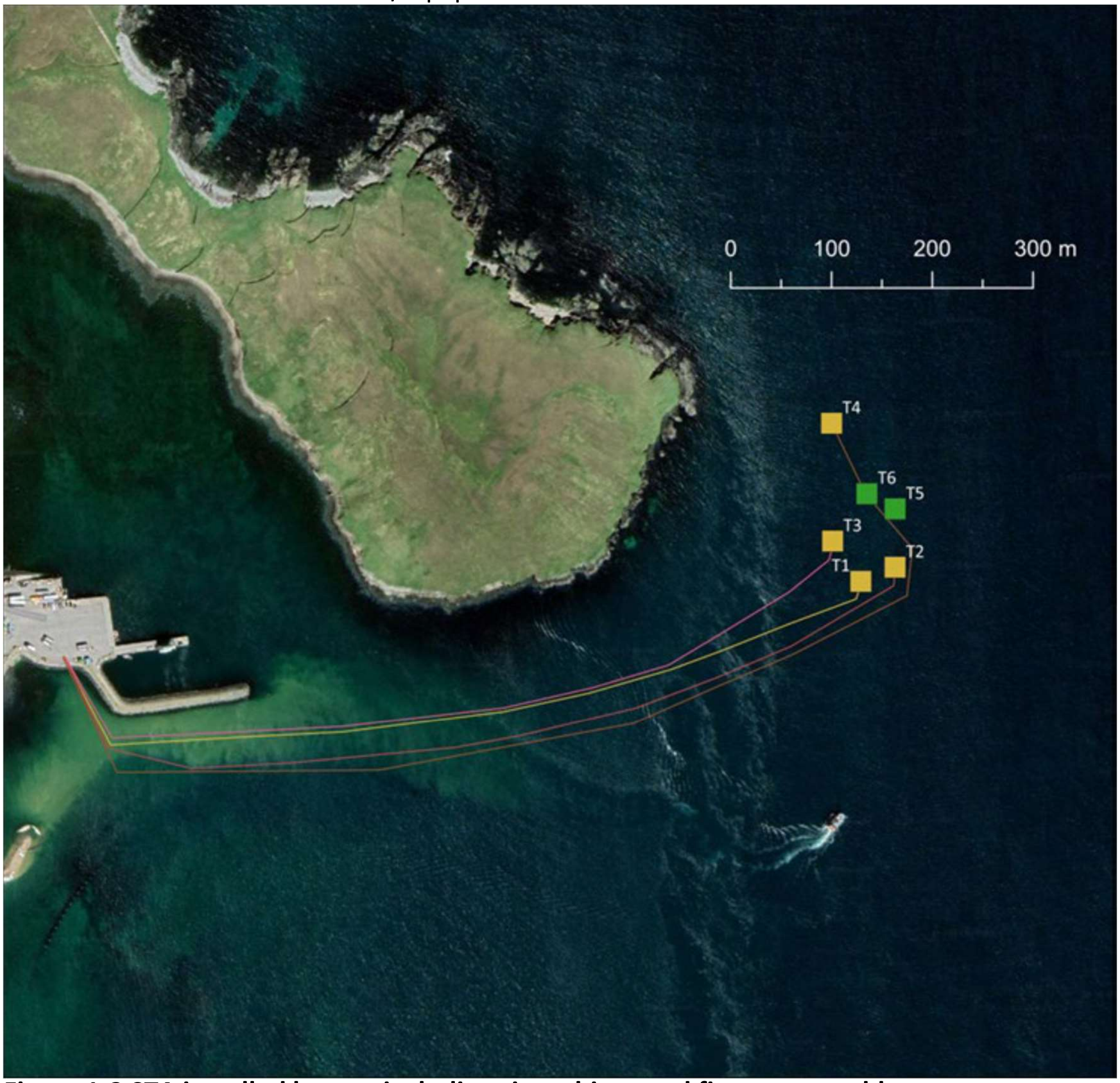


Figure 1-3 STA installed layout, including six turbines and five export cables
Source: Nova Innovation, 2023

Nova's direct drive turbine, the Nova M100-D, comprises a 2-bladed, horizontal axis device installed subsea at a depth of 30-40m. The turbines use gravity base foundations which do not require any piling or drilling into the seafloor. An illustration of the Nova M100-D turbine is shown in Figure 1-4. The minimum depth of water from the sea surface to the top of the turbine (when the blades are in an upright position) is 15m. This depth of water allows the safe passage of vessels so that the array does not present a hazard to navigation.

Each turbine has underwater video monitoring cameras attached to it to enable learning about marine wildlife presence and behaviour around the turbines. Cables provide power and transfer data into a communication module within the turbine nacelle. Each of the three deployed M100-D turbines (T4-T6) has one high-definition camera with a wide-angle lens directed towards the rotor-swept area. The original three M100 turbines (T1-3) each had three cameras with narrower fields of view. Two of the cameras were directed towards the rotor-swept area, while the third was directed towards the seabed. The use of a single camera on T4-T6 was agreed with the regulator (Marine Scotland) and their advisory body on nature conservation (NatureScot). This reduction means that the bandwidth requirements of the fibre optics used to transfer data back to shore are reduced, and the quantity of data generated is less, but still sufficient to enable analysis and reporting on the environmental monitoring. Fibre optics are used to handle the high volume of data.

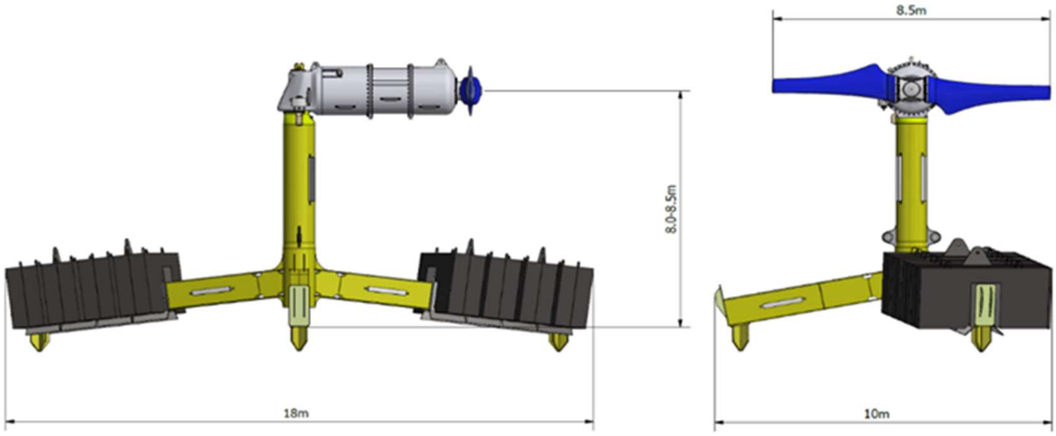


Figure 1-4 The Nova Innovation Nova M100-D Tidal Turbine
Source: Nova Innovation, 2021

Figure 1-5 shows the newer direct-drive turbine on the quayside in Bluemull Sound prior to installation in the STA.

Figure 1-5 Photo of Nova Innovation's M100-D turbine quayside before deployment in Bluemull Sound, Shetland
Source: Nova Innovation, 2020

A photo of a tidal energy device as it was retrieved after a period of 14 months in the sea is provided in Figure 1-6. The photo shows marine growth on the nacelle and turbine blades, which builds up over time.

Figure 1-6 Photo of the tidal energy device after being deployed for 14 months
Source: Nova Innovation, 2018

Cullivoe Pier is used by Nova as a central connection point which contains the transformer and control systems for each tidal energy device, office space and a maintenance workshop. Bluemull Sound was chosen as an appropriate location for a tidal stream energy project for the following reasons:

- The tidal energy resource is particularly high within the Bluemull Sound, just off the Ness of Cullivoe.
- Water depth, which ranges from 30m to 40m is deep enough to ensure that the tidal energy devices do not interfere with vessel navigation.
- The proximity to a nearby energy consumer (an ice factory installed on Cullivoe Pier used by local fishermen) means that energy generated by the tidal energy devices can be used locally.
- A grid connection to the Shetland grid owned and operated by Southern and Scottish Energy (SSE) was available for the export of energy generated.
- Space and infrastructure: there was adequate space available at Cullivoe Pier and hardstanding concreted areas to lay heavy machinery down during the deployment and retrieval of the turbines.

In addition to the onshore station at Cullivoe Pier, battery storage and Electric Vehicle (EV) charging facilities have also been added. The battery storage enables the natural ebb and flow of energy generated by the turbines with the changing tides to be balanced so that ‘baseload’ energy can feed into the Shetland grid. Storing some of the energy in the batteries when the tide is running and the turbines are generating power means that this can be released into the grid when the tides slow and the turbines are not generating. The addition of an EV charging point at Cullivoe provides an important facility for the local community and means that their vehicles can be charged by the ‘power of the tides’.

Cullivoe Pier is owned and maintained by Shetland Islands Council Ports and Harbours Authority. The pier is a shared space, and all pier users pay for their use of the facility. A variety of companies use the hardstanding area; this includes those involved in coastal mussel aquaculture, salmon farming, the offloading of sea products from fishing vessels, and a company involved in the manufacture of salmon farm cages. Nova also uses the hardstanding at Cullivoe for the deployment and retrieval of the tidal turbine nacelles.

The range of companies using the pier and making payments to SIC, contributes to the financial sustainability of the pier. The cost of the infrastructure is shared between different users and as such, it is not overly expensive for any individual business.

Nova is headquartered in Edinburgh, where it has also developed a world-leading turbine manufacturing facility in an upgraded 1970s warehouse. This facility was completed in 2017 and is still in use by Nova for turbine fabrication and maintenance.

Nova's supply chain for operation of the Shetland Tidal Array (based on expenditure over the first 18 months of the EnFAIT project) is 100% from within the EU; 84% from Scotland; and 60% from the Highlands and Islands region. For manufacturing and deploying the initial 3 turbines the project supply chain featured 100% European Union (EU) content and 80% Scottish content, with 25% of supply chain expenditure in the Shetland Islands. By mid-2019, Nova's supply chain had expanded from suppliers in four EU countries to twenty EU countries; with 100% from within the EU, 69% from Scotland and 38% from the Highlands and Islands region (ORECatapult, 2019).

Nova attributes the high local benefit from this project to the relatively small size of the M100 turbine, which allows it to use local companies for vessels, construction, transport and lifting services (Nova Innovation, 2017). Shetland Composites (SC), a local company that used the Nova order to expand its production facility, supplied the blades thus demonstrating the local benefits of marine energy (Shetland Composites, 2015).

1.1.1 Phase 1 decommissioning

Decommissioning of the Phase 1 turbines (T1 to T3) required a separate Marine Licence and European Protected Species licence from Marine Scotland[1], along with approval from the Secretary of State for the Department for Business, Energy and Industrial Strategy[2] for the decommissioning programme, under Section 106 of the Energy Act 2004. This was a legacy requirement for Phase 1, which was originally consented when the United Kingdom (UK) Government had responsibility for decommissioning under the Energy Act (that responsibility has since passed to the Scottish Government).

The EnFAIT Final Decommissioning Plan (EnFAIT-EU-0060) contains further details on the decommissioning of the STA. Nova also produced a number of documents to support their decommissioning licence applications, including

1. Decommissioning Emergency Response Co-operation Plan (ERCoP). This included a Navigational Risk Assessment and assessment of effects on other marine others.
2. Decommissioning Environmental and Protected Species Risk Assessment. This included an assessment of the likely effects on MPAs (including Natura sites) and Priority Marine

[1] Available on Marine Scotland's website https://marine.gov.scot/ml/shetland-tidal-array.

[2] now Department for Energy Security and Net Zero

Features (PMF). On the basis of the information in this assessment, Marine Scotland Licensing Operations Team (MS-LOT) determined that an Appropriate Assessment was not required.

3. Decommissioning Environmental Monitoring and Mitigation Plan. This set out all the measures by which impacts on other marine users and the marine environment would be avoided.

A Decommissioning Method Statement was also produced to describe the procedures and methods to fully decommission the three geared M100 turbines in a safe and responsible manner. Decommissioning commenced in April 2023 and involved the complete removal of each of the three M100 turbines (T1, T2 and T3) and export cables. The nacelle (including blades), substructure and cable of each turbine was removed in turn and taken to shore for recycling or responsible disposal. Weather caused some delays to the decommissioning in April, with all infrastructure successfully and safely removed except for the substructure of T1. A decision was taken to leave this in situ on the seabed in its original installed position, rather than attempt to remove it in poor weather conditions. It will be safely removed during routine maintenance on T4-T6 during 2023.

1.2 Environmental monitoring framework

1.2.1 Overview

Environmental monitoring undertaken to date around tidal stream energy projects has generally focused on the environmental effects of single devices. EnFAIT presents a unique opportunity to gather information from an array of operating turbines and improve understanding about the individual and combined environmental effects of turbines within an array. This will provide a valuable evidence base on which future commercial, consenting and policy decisions for the tidal energy sector can draw.

Environmental survey and monitoring activity has been ongoing in Bluemull Sound, Shetland since November 2010, according to methodologies agreed between Nova and the regulatory bodies. Discussions about environmental monitoring were ongoing and methodologies were subject to amendment or refinement throughout the course of the EnFAIT project, as data was analysed and monitoring objectives were refined. In 2022, Nova submitted revision 6 of the Project Environmental Monitoring Plan (PEMP)[3] to Marine Scotland and Shetland Island Council, for their consideration. This PEMP was approved in July 2022 and built upon the 12 years of monitoring activity conducted at the site since 2010.

Initial environmental surveys were carried out to gather information in support of consent applications for turbine deployments in Bluemull Sound. The focus then shifted to monitoring the effects of the deployed turbines on marine mammals and diving birds, using underwater cameras and land-based vantage point surveys. Underwater cameras were also used to monitor biofouling on turbines and substructures and to inform micro-siting of cables and turbines during deployment to avoid sensitive seabed habitats and species.

The environmental monitoring for EnFAIT focussed on improving understanding of the risk of collisions between marine wildlife and the turbines in the array. This has been identified by industry, regulators and

[3] Nova Innovation (2022). Shetland Tidal Array Project Environmental Monitoring Plan (PEMP) Version 6.0 (EnFAIT-0362). Available to download at: https://marine.gov.scot/ml/shetland-tidal-array

other stakeholders as a key issue in need of priority research, to reduce uncertainty and de-risk consenting for tidal energy[4]. A critical review of the vantage point surveys and underwater video methodologies as well as a review of the key results from environmental monitoring of Phase 1, and environmental monitoring activity at other tidal stream projects, ensured that the environmental monitoring programme for Phase 2 remained fit for purpose and cost effective. Discussions with regulatory bodies and their consultees ensured environmental monitoring during Phase 2 also met the requirements of project licence conditions.

Opportunities to gather further data from the operational array and information to help investigate (for example) the effects of changes in water flow and energy removal of tidal arrays were also explored. For full details of the monitoring programme for the EnFAIT project, refer to deliverable D8.7 which summaries the outcomes from environmental monitoring in year 5 of the project[5].

1.2.2 Land-based vantage point surveys

Monthly land-based vantage point surveys have been carried out continuously since 2010 to determine the presence and activity of birds and marine mammals within the turbine array location and wider area in Bluemull Sound. Surveys are conducted from an elevated observation point at the south-eastern tip of the Ness of Cullivoe, from where the surveyor is well placed to undertake observations across the entire survey area.

Figure 1-7 shows the initial survey area (delineated by green lines) and the observation (vantage) point on the Ness of Cullivoe (yellow star). The survey area is subdivided into four areas A, B, C and D (indicated by purple subdivisions), marked out using transit sticks from the observation point and markers on the Unst shore. Figure 2.7 also indicates the location of the turbines (black dot) and the cable route back to shore (red line). The yellow line illustrates the trajectory of the marking point for the survey boundary.

[4] ORJIP Ocean Energy (2017). The Forward Look; an Ocean Energy Environmental Research Strategy for the UK. http://www.orjip.org.uk/sites/default/files/ORJIP%20Ocean%20Energy%20Forward%20Look%203%20FINAL.pdf
[5] EnFAIT-EU-0067 (2022). EnFAIT Deliverable D8.7: Y5 Environmental Monitoring Report, pp 21.

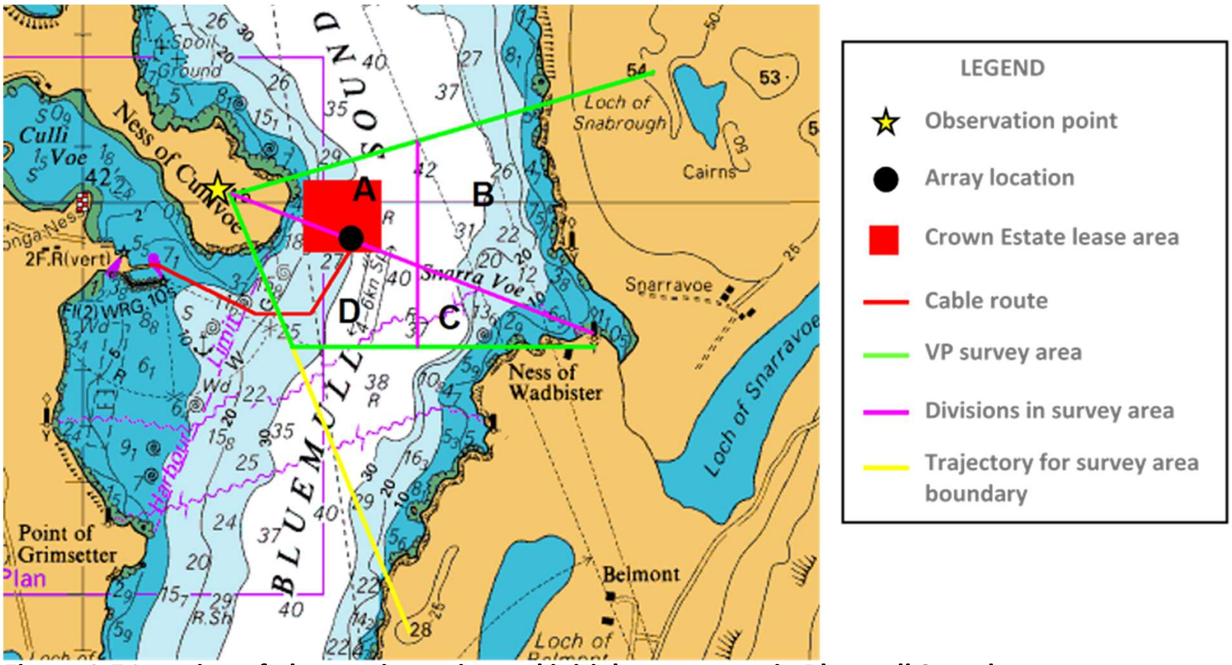


Figure 1-7 Location of observation point and initial survey area in Bluemull Sound
The survey area is subdivided into four areas A, B, C and D. The location of turbines, cable route and Crown Estate Scotland seabed lease area are also indicated.

The design of vantage point surveys for EnFAIT was modified to focus on gathering more specific information on the behaviour of diving birds and marine mammals in the immediate array area, during Phase 2, in consultation with the relevant regulatory bodies. Please refer to the latest Nova PEMP[3] (EnFAIT-0362) for the revised survey area.

Changes to the survey sub-division enabled better coverage of key annual stages in breeding cycles of diving birds and cetaceans and seal moulting and breeding periods. Surveys are divided into 4-month survey periods, as follows:

- April to July (breeding season (birds), common seal pupping, grey seal moulting, harbour porpoise birth period)
- August to mid-September (post-breeding/moult (birds, common seal), harbour porpoise breeding season, gannet fledging)
- Mid-September to October (autumn; start of grey seal pupping)
- November to March (winter; grey seal pupping)

Phase 2 surveys were structured to ensure systematic and consistent coverage across increasing flood, maximum flood, decreasing flood, increasing ebb, maximum ebb and decreasing ebb in each of the 4 survey periods. Within each survey period, two complete tidal cycles are surveyed, with each cycle divided into six 2-hour periods. During each survey, the surveyor scans the sea surface of the array location and surrounding area using binoculars. Birds that are diving or ‘loafing’ on the surface of the water are identified and counted. Those transiting the area (i.e., flying) are not recorded. All marine mammals observed during scans are identified and recorded. Any general behaviour (e.g., diving, feeding), direction of travel and other relevant observations are also recorded.

1.2.3 Underwater video

Underwater video has been used throughout the operational phase of the STA to monitor near-field behaviour of marine wildlife around the turbines. In Phase 2 a single camera was used on each of the three turbines in the extended array (T4, T5 and T6), while each of the three turbines in Phase 1 uses three cameras. Each camera on T4 to T6 has a horizontal field of view in water of 90°, sensitivity of 0.1 lux and resolution of 1000 TV lines. For comparison, the cameras installed on T1, T2 and T3 had a horizontal field of view in water of 70^0, sensitivity 0.001 lux and resolution 750 TV lines.

The cameras on T4-T6 are attached to the side of the nacelles, facing the blades. Analysis of the video footage from T1 to T3 demonstrated this camera position provides the most useful information on near field interactions between wildlife and the moving turbine blades. The three turbines in Phase 1 of the array (T1 to T3) continued to utilise the three-camera monitoring system until they were decommissioned in April 2023.

Cameras are triggered by a motion detection system, based on changes in contrast between successive video images. Video is retained from a few seconds before the trigger for a minimum of ten seconds, or until motion is no longer observed, up to a maximum of 15 minutes, at which point the trigger is reset.

1.2.4 Data analysis

Data from vantage point surveys were analysed to determine the presence and spatio-temporal distribution of birds and mammals in the array area and wider Sound. This information was used to establish which species might be at collision risk and whether any ‘risk factors’ can be identified, such as state of the tide or time of year. The changes made to the vantage point survey design for Phase 2 enabled effort to focus on understanding the occupancy patterns and fine-scale movements of diving birds and marine mammals in the sea area in which turbines are installed in the expanded array. This allowed for a better understanding of the likelihood of near-field interactions between marine wildlife and the turbines, across the full tidal cycle. Data from vantage point surveys helped inform the approach to sampling and analysing the extensive underwater video footage gathered, as well as enabling cross-referencing and comparison across the two data sets, to better understand collision risk.

Underwater footage was manually reviewed to determine whether the cause of the trigger event was a fish, diving bird, marine mammal, other fauna (e.g., jellyfish) or (more typically) suspended detritus in the water, or biofouling on the camera lens. Relevant footage was further analysed to establish species identity and any notable behaviour, including any interactions with moving parts of the turbines. Analysis is a very labour-intensive process and to date, the subsea cameras have recorded many tens of thousands of hours of video footage. Around 25% of the full dataset has been analysed.

Systematic analysis of the underwater video footage has been progressed through EnFAIT and was based on a randomised approach whereby some footage is randomly selected for manual review. This is combined with a stratified sampling protocol based on analysing footage across a representative range of tidal states and times of the year, targeting ‘high risk’ times identified by the vantage point data, when marine mammals and birds are in the array area.

Opportunities to automate video data processing and analysis (for example by filtering out of falsely triggered footage) are being explored, with investigations ongoing outside of EnFAIT. See Section 7.2 for further details.

1.2.5 Results to date

Analysis of the monitoring data gathered from Bluemull Sound has been ongoing over the course of EnFAIT project. For results of the environmental monitoring conducted as part of the EnFAIT project, see

- EnFAIT deliverable D8.5, which summaries the outcomes from environmental monitoring in year 1 of the project
- EnFAIT deliverable D8.6, which summaries the outcomes from environmental monitoring in year 3 of the project
- EnFAIT deliverable D8.7, which summaries the outcomes from environmental monitoring in year 5 of the project.

Formal monitoring reports are also submitted to the regulator, Marine Scotland, to meet the requirements of the Shetland Tidal Array project licence conditions. These reports are all available to download online[6].

Vantage point surveys identified thirty-five species of seabird in the STA and wider Bluemull Sound area. Of the bird species recorded, only fifteen are capable of diving to depths which might bring them into contact with the turbines. Of this small subset of 'at risk' species, very few were observed within the array area itself and even fewer displaying behaviour that could place them at risk of collision (i.e., diving and feeding). Most diving bird species were observed infrequently, or in very small numbers, with by far the most abundant and commonly recorded being black guillemot (*Cepphus grylle)* and European shag (*Gulosus aristotelis)*.

Eight species of mammal were recorded in vantage point surveys; harbour or common seal (*Phoca vitulina*), grey seal (*Halichoerus grypus*), harbour porpoise (*Phocoena phocoena*), Risso's dolphin (*Grampus griseus*), minke whale (*Balaenoptera acutorostrata*), killer whale (*Orcinus orca*), humpback whale (*Megaptera novaeangliae*) and otter (*Lutra lutra*). Of these, most were observed only infrequently, or in very small numbers, with by far the most abundant and commonly recorded being harbour porpoise and common seal.

There has been only one observation of a basking shark (*Cetorhinus maximus*) during vantage point surveys since 2010.

The video cameras provide regular sightings of fish, and occasionally of birds and mammals. The following four species have been identified from underwater video footage analysed:

- Harbour or common seal (*Phoca vitulina*)
- European shag (*Gulosus aristotelis*)
- Black guillemot (*Cepphus grille*)
- Saithe (*Pollachius virens*)

Figure 1-8 shows some images from underwater video footage. These images are exceptional since birds and mammals are only very occasionally observed on the subsea cameras. The images illustrate the quality of video available following turbine deployment at the Shetland site, and the capability of this technology to discern animal presence, species and behaviour.

[6] See https://marine.gov.scot/ml/shetland-tidal-array

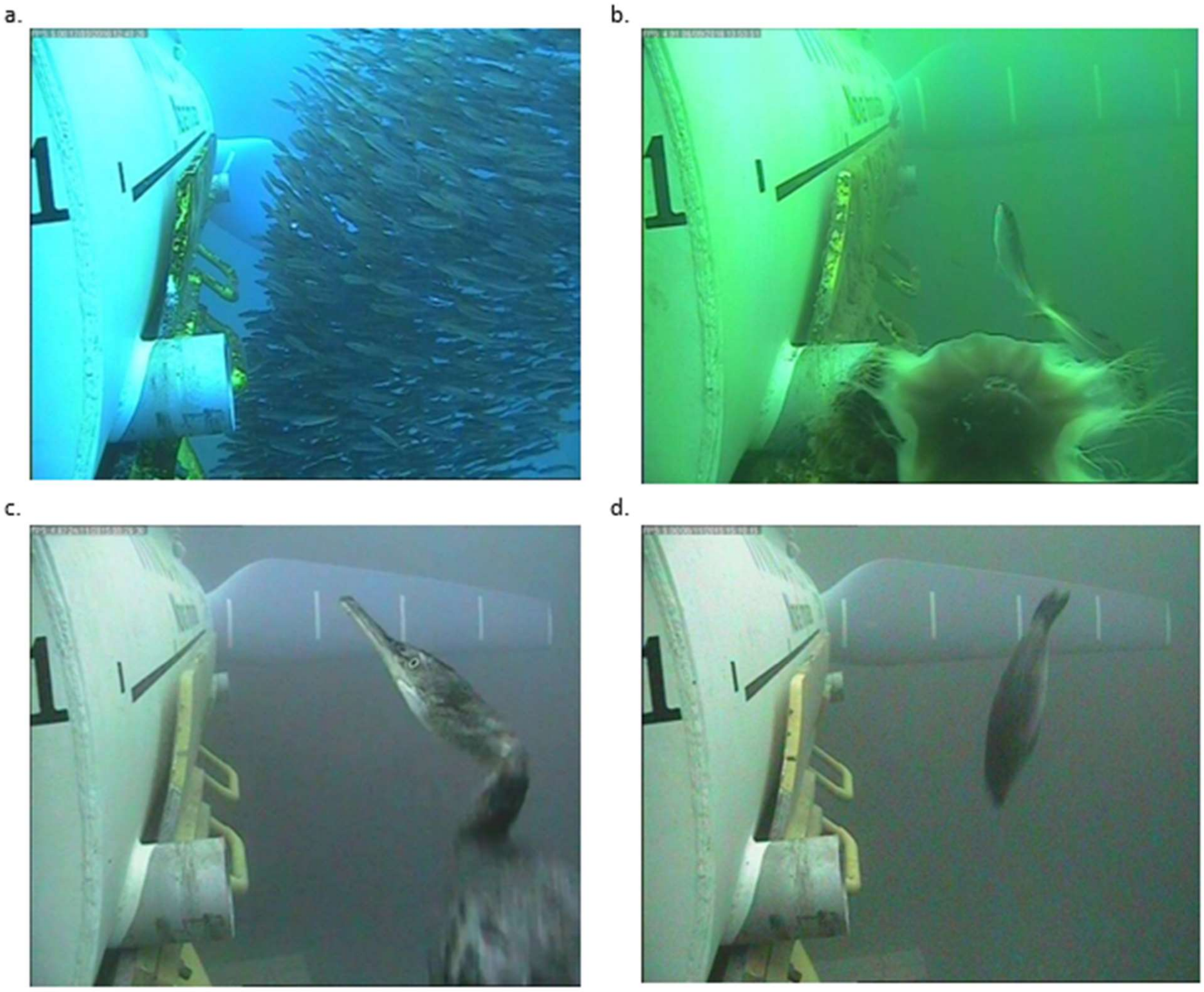


Figure 1-8 Images from underwater video footage, showing a) a school of saithe *Pollachius virens* b) Lion's mane jellyfish *Cyanea capillata* with saithe c) European shag, *Gulosus aristotelis* and d) common seal, *Phoca vitulina*

Turbine blades were stationary during all observations.

Fish are by far the most frequently sighted fauna, the majority of which are saithe. Birds and seals are relatively infrequently observed on the underwater cameras. No cetaceans or basking sharks have been observed in any of the video footage analysed. In footage analysed to date birds and mammals have only been observed when the turbine is not generating, and the blades are therefore not rotating, corresponding to slack water or times of slow current speed. There have been no observed cases of any collisions or near miss events between fauna and the turbine blades.

1.2.6 Ongoing environmental monitoring

Environmental monitoring and data analysis has been ongoing throughout the EnFAIT project and will continue beyond the project. As demonstrated the methodologies have been amended to ensure that the focus is on gathering data of greatest value in understanding the environmental effects of tidal arrays. Going forwards, data is being collected on the presence, abundance, fine-scale movements and behaviour of diving birds and marine mammals in the array area to understand the potential for direct interactions with operating turbines, with the updated objective of understanding specific occupancy patterns and fine-scale movements of diving birds and marine mammals within the area of sea in which the six turbines are located. In addition to refining monitoring focussed on collision risk, this also includes exploring opportunities to gather further data from the operational array and information to help investigate the effects (for example) of changes in water flow and energy removal of tidal arrays.

1.3 Scope of the ESEA Report

The ESEA covers the following:

1. Project-level effects that consider environmental and socio-economic receptors in Shetland and Scotland; and
2. EU-level effects that consider the broader implications on the EU tidal energy sector.

1.4 Objectives and targets

The objectives of the appraisals are to:

- assess the potential impact, positive and negative, of the tidal energy array on environmental and socio-economic receptors
- present mitigation actions to address any negative environmental and socio-economic risks and impacts, and review the approach taken to develop the environmental monitoring framework
- assess the potential impact of the array on the tidal energy industry at an EU-level
- capture and disseminate lessons learned for the tidal energy industry on managing environmental and socio-economic impacts, applying the existing policy and regulatory framework, developing local supply chains, and techniques for engaging with local communities.

The following targets apply to the ESEAs:

- identifying the key environmental and socio-economic considerations that need to be considered during any future scaling up of the development at the project's location
- conducting a detailed review of tidal energy projects in the UK, EU and at selected international sites to identify lessons learned in the application of the regulatory framework to the projects; actions undertaken to develop local supply chains; and local community engagement techniques
- quantifying, to the extent possible, the potential economic impact of the tidal energy array to the Shetland Islands, Scotland, the UK and the EU
- conducting a stakeholder engagement process in an inclusive, informative, participatory and consultative manner that captures the views and opinions of the project from a range of stakeholders.

2 Methodology

This section describes the individual tasks completed during preparation of the ESEA Report:

- WP8 Task 1 – Completion of a literature review of secondary data
- WP8 Task 2 – Collecting information from project partners, project suppliers, regulators and public bodies, the local community, and users of the sea and coastal area
- WP8 Task 3 – Preparing an environmental and socio-economic baseline
- WP8 Task 4 – Undertaking stakeholder engagement activities
- WP8 Task 5 – Completing the appraisal at a project and EU level
- WP8 Task 6 – Preparing the project-level and EU-level appraisal into a single ESEA report
- WP8 Task 7 – Designing a future monitoring, evaluation and reporting framework

The following sections describe each task in more detail.

2.1 WP8 Task 1 – Complete a literature review of secondary data

A literature review of secondary data was completed and gathered information on the following:

- the historical development of the tidal energy industry in the UK and EU, including the historical development of the technology and lessons learned from previous tidal energy arrays
- the marine spatial planning and policy framework in Scotland, the UK and the EU to assess the extent to which they support the future development of tidal energy projects. This involved analysing the framework associated with the management of fisheries, navigation and maritime security, and the way in which maritime and coastal projects obtain environmental permits, licences and consents
- baseline environmental and socio-economic data for the project-level appraisal covering the geography of Shetland

2.2 WP8 Task 2 – Collect information from project partners, project suppliers, regulators and public bodies, the local community and users of the sea and coastal area

2.2.1 Project partners

Key informant interviews (KIIs) with Nova were held to gather information on

- the historical development of the tidal energy technology selected for the project
- the criteria used to select the geographical location for the arrays
- challenges associated with obtaining statutory environmental permits, licences and consents
- the techniques used to record and analyse environmental monitoring data
- Nova’s experience in engaging with the local community
- Nova’s experience in identifying and developing local suppliers.

2.2.2 Project suppliers

In discussion with Nova, a local supplier (Shetland Composites) was visited and interviewed to collect information on the way in the project has impacted his business. This information was used to prepare an example case study that reflects how a tidal energy developer can work in partnership with local suppliers to maximise socio-economic benefits.

2.2.3 National and international regulators

A series of KIIs were held with representatives of the following entities in Shetland during November 2018:

- Shetland Islands Council (SIC) Carbon Management Team
- Elected representatives who are Councillors of SIC
- SIC Ports and Harbours Authority and the SIC Harbour Master

The interviews investigated the extent to which views of acceptability could change if the project were to increase in scale in the future, and public perceptions towards the project more generally.

Introductory letters and template question and answer forms were sent to regulators both inside and outside the EU across the following countries:

- Within the EU: Denmark, France, Germany, Ireland, Italy, The Netherlands, Northern Ireland, Sweden
- Outside of the EU: Canada, India, Indonesia, New Zealand, Norway, South Korea and United States of America (USA).

The aim of contacting international regulators was to gather information about the challenges they face with the permitting of tidal energy projects and investigate how these are overcome, and to understand local community perceptions towards tidal projects and the drivers behind these views.

2.2.4 The local community

IDETA, with support from RSK and Nova, implemented a Local Community Engagement Strategy (WP8 deliverable 8.3). The objectives of the local community engagement strategy were to:

- provide information to stakeholders in Shetland on the EnFAIT Project so that they understand the aims and key activities
- obtain the views and perceptions of people living in Shetland on the EnFAIT Project and assess if these views change during execution of the project
- obtain the views and perceptions of people living in Shetland on the importance of renewable energy sources
- evaluate the effectiveness of local community engagements during the EnFAIT Project so that any lessons learned can be used by other developers of tidal energy projects across the EU in the future.

Engagements with the local community were completed through the following events:

- A questionnaire sent to all households on Yell that was issued by SIC
- Attendance by Nova and RSK at the Yell Trade Fair held on 01 September 2018
- Focus group discussions that were completed in Yell and Lerwick during November 2018

- Focus group discussions and workshops in local schools completed in Lerwick, Brae, Yell and Unst in June 2019.

2.2.5 Environmental and Tourism Advisor

A KII was held during November 2018 with the surveyor from Shetland Ecology Limited who completes Nova's statutory environmental monitoring of bird and sea life within the STA and surrounding area. The surveyor has extensive knowledge of local environmental conditions and acts as a guide during wildlife tours for tourists visiting Shetland.

2.3 WP8 Task 3 – Prepare a project-level environmental and socio-economic baseline

An environmental and socio-economic baseline was prepared using the outcome of and information from the secondary data review, site visits to Shetland, and information collected during focus group discussions and KIIs. The ESEA baseline included descriptions of the environment and socio-economic conditions.

2.4 WP8 Task 4 – Prepare a summary of the outcome of stakeholder engagement activities

The outcome of stakeholder engagement activities was analysed to further explore perceptions towards the tidal energy project and a summary is presented in Chapter 6 of this document.

2.5 WP8 Task 5 – Undertake the appraisal at a project and EU level

After the local community engagement and KII activities had been completed a workshop was held on 14 November 2018 and attended by representatives from IDETA, Nova and RSK to jointly conduct the appraisals.

The project-level and EU-level appraisals are presented using the following topic areas:

- potential environmental effects and how these changed during enlargement and reconfiguration of the STA, and arrays in general, on the following receptors: physical environment and water quality, underwater noise and vibration, marine and coastal biodiversity, benthos, fish, seabirds, marine mammals, protected sites, air quality and global climate, seascape and visual character, and marine and coastal archaeology.
- potential socio-economic effects and how these changed during enlargement and reconfiguration of the STA, and arrays in general, on the following: demographics, standard of living and housing condition, educational change, social cohesion, differentiated impacts on vulnerable groups, perception of the sea for energy, recreational and tourism activities, employment and business, industrial strategy and rural regeneration, structural market conditions for low-carbon energy schemes, offshore public infrastructure, and commercial shipping and navigation.

The EU-level ESEA also includes:

- a review of opportunities and risks associated with developing future tidal energy arrays on socio-economic and environmental receptors

- a summary of lessons learned, including how these could benefit future tidal energy projects as they scale-up from a small number of arrays into large-scale commercial developments

The classification used to describe effects of the project on environmental and socio-economic receptors is summarised below in Table 2.1.

Table 2.1 Classification of effects used for the appraisal

Clear and major positive effect (*expected to contribute a positive, environmental and/or socio-economic change that is recognised at a Shetland/UK and/or EU level*)	✓✓
Broadly supportive or minor positive effect (*results in improved environmental knowledge, or positive environmental and/or socio-economic change)*	✓
Neutral effect *(is not expected to have a positive or adverse effect)*	**0**
Minor negative effect *(expected to result in a localised, adverse environmental and/or socio-economic change)*	×
Major negative effect *(adverse environmental and/or socio-economic change)*	××
Uncertain effect *(based upon the information available the outcome of the effect cannot be determined at this time and could be either positive or adverse)*	**?**

2.6 WP8 Task 6 – Prepare project-level and EU-level ESEA report

The ESEA Report has the following content:

- Chapter 1 – Executive Summary
- Chapter 2 – Introduction
- Chapter 3 – Methodology
- Chapter 4 – Key Findings from the Secondary Data Review
- Chapter 5 – Environmental and Socio-Economic Baseline
- Chapter 6 – Stakeholder Engagement Activities and Outcomes
- Chapter 7 – Project-Level and EU-Level Appraisal
- Chapter 8 – Summary of Lessons Learned and Recommendations
- Chapter 9 - References

2.7 WP8 Task 7 – Design a future monitoring, evaluation and reporting framework

A monitoring, evaluation and reporting framework has been prepared in close liaison with project partners to ensure that data gathered for the ESEA does not overlap with other information already being collected. The framework aims to track changes in environmental and socio-economic conditions during the project using a set of clearly defined key performance indicators.

2.8 WP8 Task 8 – Update the project-level and EU-level appraisals at the end of the project

The initial project-level ESEA and EU-level appraisals have been to capture lessons learned from the operational stage of the arrays. Key conclusions and lessons learned for the tidal energy industry will be identified and described.

3 Key Findings from the Secondary Data Review

3.1 The EU and international market for ocean energy

The international market for ocean energy is growing and it is estimated that by 2050 there will be a global market potential of 350GW (IRENA, 2022), by which time the industry is predicted to be worth €53 billion (OEE, n.d.(a))). Tidal energy development is the most advanced type of ocean energy technology, which also includes wave energy, ocean thermal energy conversion (OTEC) and salinity gradient sources, and it is these that are expected to reach commercial viability in the short to medium term (Uihlein and Magagna, 2015).

Tidal energy has commercial operations in the UK and overseas, while wave energy is considered to be at the prototype stage, with a number of devices being tested in sea conditions (IRENA and OEE, 2023). Initial technological limitations predominantly relate to reliability, performance and survivability of devices. This is particularly true for wave energy, which has benefited less from the transfer of components and knowledge from wind technologies than tidal energy. Tidal technologies have been showing increasing convergence of design and components, which is essential for securing supply chains, increasing standardisation and enabling cost-reduction measures through economies of scale. Owing to this increased design consensus, the presence of an engaged supply chain and extensive testing and operation to prove reliability and survivability, tidal technologies are expected to reach commercial viability before wave technologies (Uihlein and Magagna, 2015). Tidal energy has been using multi-device arrays for the last six years and is currently at pilot farm stage, with full-scale devices demonstrated at sea (IRENA and OEE, 2023).

In 2020, the European Commission set targets of achieving 1GW of ocean energy (and 60GW of offshore wind) by 2030 and 40GW of ocean energy (and 300GW of offshore wind) by 2050 (European Commission, n.d.(a)) Recent cumulative targets for offshore renewable energy aim to achieve 109-112GW by 2030, 215-248GW by 2040, and 281-354GW by 2050 (European Commission, 2023). Although Europe has previously been at the forefront of ocean energy, it is developing globally (Figure 3-1 and Figure 3-2), with international deployment of ocean energy devices, due to increased funding and new policies. In 2022 China added more tidal capacity than Europe, and Israel deployed the country's first grid-connected wave power project (OEE, 2023). The United States Department of Energy's Water Power Technologies Office recently announced $45 million of funding opportunity to advance a comprehensive approach to wave and current energy in the USA (Office of Energy, Efficiency and Renewable Energy, 2023). However, in Europe, both tidal stream and wave energy capacity additions were lower in 2022 than any year since 2010; slow implementation of EU Strategy on Offshore Renewable Energy (EU Offshore Strategy) is a possible cause of that decrease (OEE, 2023).

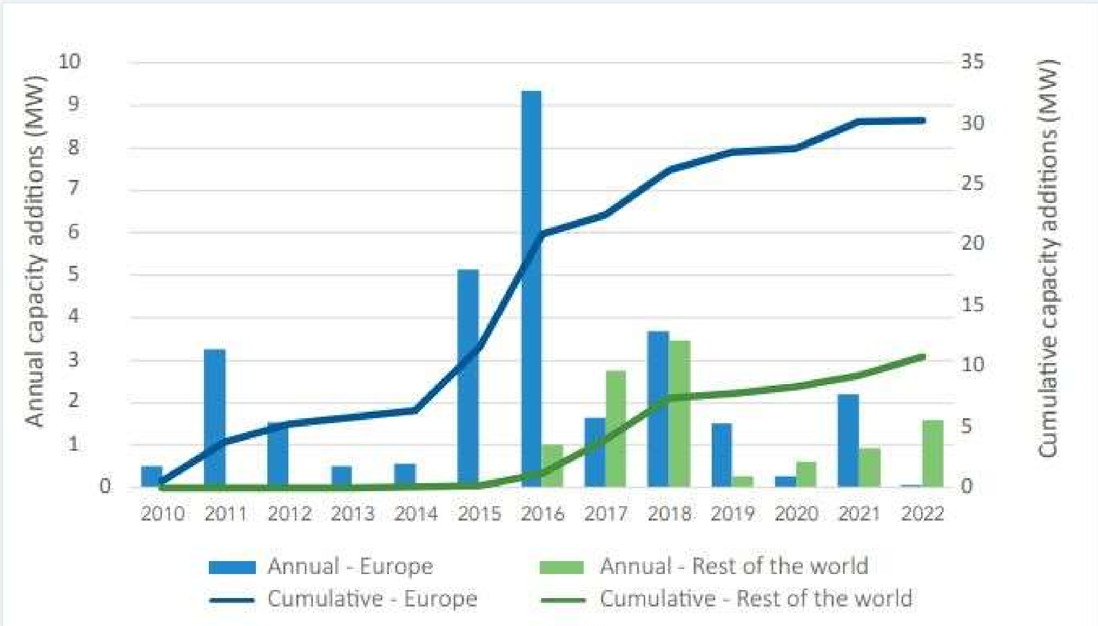


Figure 3-1 Installed global tidal stream energy capacity
Source: OEE 2023

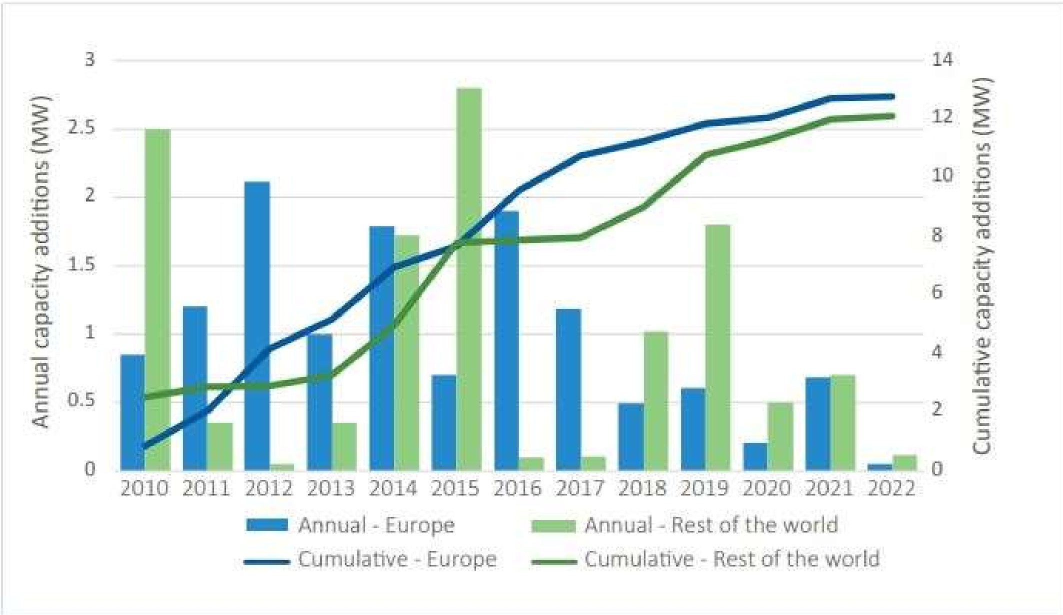


Figure 3-2 Installed global wave energy capacity
Source: OEE 2023

Initial steps have been taken to achieve the targets set by the EU Offshore Strategy, through schemes providing additional funding, such as Horizon Europe and Horizon 2020, and that member states have 'non-binding agreements' which may at some stage include ocean energy in their associated seas (OEE, 2023); these non-binding agreements were recently agreed by Member States (European Commission, 2023). While the technology has continued to evolve from concept to commercialisation, taking these initial steps does not currently appear to be sufficient in making the required progress to achieve the targets (OEE, 2023). Since 2010, current cumulative installations for tidal streams in Europe is at 30.2MW, whilst wave energy is at 12.7MW (OEE, 2023).

Across Europe, there is a need for new economic activities to retain populations and maintain basic services in isolated rural communities. Renewable energy production can foster opportunities for such communities to stimulate and diversify their economic activities (Okkonen and Lehtonen, 2016). By 2050, ocean energy could have numerous socio-economic benefits, such as 400,000 European jobs (OEE, 2020). Recognising the value of the sector, the EU has focused its support on advancing technological development and readiness of ocean energy. Programmes over the past 10 years have provided €375 million in funding for research, development and innovation projects (OEE, n.d.(b)). Recent and current initiatives include Horizon 2020 (of which EnFAIT is a flagship project, with a budget of almost €80 billion (European Commission, n.d.(b)) and the €1 billion Green Deal Call) and the Horizon Europe programme, which will run until 2027 with a budget of €95.5 billion (European Commission, n.d.(c)).

Marine energy was expected to follow the trajectory of other renewables with exponential increases in deployment as technologies become established and costs reduce, resulting in a decrease in the levelised cost of electricity (LCoE) (HIE, 2016). However, the global COVID-19 pandemic resulted in a dip in installations in Europe during 2020, before tidal stream installed capacity returned to pre-pandemic levels in 2021 and wave energy deployments began to rise again (OEE, 2022a). With uncertainties around the supply of energy from non-renewable resources, exacerbated following Russia's invasion of Ukraine, ocean energy could have an important role in providing a secure source of energy. EU funding instruments still need to focus on tackling the challenges of upfront costs associated with commercial deployment of these technologies and encouraging investment into innovative ventures to enable their potential to be reached (EC, 2017). Greatest cost-reductions for ocean energy will be obtained as tidal and wave capacity is increased and large-scale deployments take place; this reduction in the cost of energy will be through economies of scale, the streamlining of supply chains and improvements to devices (IRENA and OEE, 2023). Reduction in the overall cost of ocean energy is required to ensure that it can compete with other, more developed forms of renewable energy technologies (Policy and Government Group, 2022).

3.2 UK wave and tidal energy

The UK is one of the leading nations tackling climate change and is also one of the leaders in research, innovation and development of ocean energy (Policy and Innovation Group, 2022). The marine energy sector presents the UK with a unique opportunity to secure an indigenous, renewable energy source that also delivers significant economic and industrial growth in relatively remote locations. The sector is evolving dynamically with technological progression built upon centuries of shipbuilding and offshore operations including fishing, shipping and oil and gas. There is potential for up to 20% of the UK's energy to be supplied by wave and tidal stream energy, which could contribute to avoidance of 30 million tonnes of annual CO_2 emissions (MEPB, 2015). Renewable energy sources such as ocean energy have potential to contribute to helping the UK government achieve the net zero carbon emissions target by 2050.

The UK marine energy industry has already had a positive impact on the economy by bringing innovation, inward investment and new, skilled jobs into regions experiencing downturns in more traditional sectors such as shipbuilding, fishing, and oil and gas. By 2016, more than £0.5 billion of new, mainly private, investment came into the UK marine energy sector. Despite being comparatively new, the sector supported 1700 jobs with the potential for this to expand to an anticipated >20,000 jobs over the decade from 2016 (HIE, 2016). In 2019, the estimated turnover for the marine engineering and scientific industry for marine renewable energy was £1.7 billion, with turnover growing 14% between 2010 and 2019 (Cebr, 2022). The estimated employment in the marine engineering and scientific industry for the marine renewable energy sector was estimated to be at 7000 jobs in 2019 (Cebr, 2022).

This positive economic benefit is a result of support from the UK government as the marine energy sector has continued to evolve. The UK faces global competition from France, Ireland, Japan, Canada and in more recent years, from the USA and China, as well as other nations looking to capture this economic opportunity and there is a risk that it could lose its technology lead without appropriate policy support and funding. This would be a repetition of how the UK ceded a global lead in wind energy to Denmark, where the Danish government provided early market support mechanisms, enabling small manufactures to become global players. The UK government are currently showing support for tidal energy projects and by the end of September 2022 there were three projects that had received consent, with total capacity of 97MW (Mawhood *et al*., 2022). Additional support has been provided through funding schemes.

The Contracts for Difference (CfD) scheme is considered to have a key role in ensuring the UK remains at the forefront in marine renewable energy. Despite being able to compete for funding in CfD applications since the scheme began, no tidal stream and wave energy technologies (alongside floating offshore wind) were awarded funding in the first three rounds between 2014 and 2019 (Mawhood *et al*., 2022). However, in 2021 the UK Government announced that it would ringfence £20 million per year for tidal stream energy in the fourth round of allocations of the CfD (Mawhood *et al*., 2022). It is hoped that this targeted funding can help to emulate the success of the offshore wind industry developments; to both develop the technology and reduce the costs. Subsequently, in the fourth round of applications during 2021-2022, 41MW of tidal stream energy projects were awarded CFD contracts (Mawhood *et al*., 2022). In March 2023, it was announced that the ringfence for the fifth round of CfD funding would be reduced from £20 million to £10 million for tidal stream energy with the move from bi-annual to annual CFD rounds (UK Marine Energy Council, 2023).

Previous challenges to technological progress included limited access to finance and a shortage of sites with affordable grid connections, which, coupled with uncertainties around UK market visibility in the long term, negatively impacted investor confidence (MEPB, 2015). The limited proof of the effectiveness of technological progress was another issue that had further hindered investment, particularly for wave energy (Uihlein and Magagna, 2015). The combined effects of these issues became apparent in 2014, a challenging year for the UK sector marked by redundancies and restructuring with some wave energy companies entering administration (MEPB, 2015) because of downsizing and withdrawal of interest by investors in technological development (Uihlein and Magagna, 2015).

A number of these challenges, such as grid connection, remain, highlighted through the constraints of the grid and cable routing that resulted in the scaling-down of Nova's Enlli Tidal Energy Project off the Llŷn Peninsula, Wales in 2023. Technological concerns over wave energy remain, with the ability of a device to survive in extreme conditions and their efficiency highlighted as two of the challenges (UK Research and Innovation, 2021). The reduced ringfence funding for tidal stream energy from the CfD scheme is also likely to present challenges to the sector, which requires continued financial support at this nascent stage to advance developments. This may lead to fewer projects and increased costs of project delivery (UK Marine Energy Council, 2023). It has been suggested that current barriers to attracting finance relate to uncertainties associated with the technology, the cost of finance and the overall investment needs that occur during the demonstration and pre-commercial phases (ETIP Ocean, 2019; IRENA and OEE, 2023).

The UK is a leader in tidal technology development and demonstration with several full-scale prototypes and array projects continuing to be developed and tested. Devolution in Scotland and Wales has allowed regional authorities to produce innovative strategies and support for marine renewable energy beyond the scope of UK-wide policy.

Tidal energy in Wales

As of 2022, cumulative investment into the marine renewable sector in Wales amounted to £159.6 million, an increase of £13.7 million on the previous year (Marine Energy Wales, 2022). Since 2015, the majority of spending and investment has been for tidal stream (£70.575 million). Other marine energy sectors which have received spending and investment to date include wave and floating platform technologies (£25.563 million) and tidal range (£6.418 million) (Marine Energy Wales, 2022). With regards to the 2022 spending and investment, tidal stream received the second largest proportion of money, £3.8 million, after research, which received £4.6 million. Prior to 2022 there had been record levels of growth year on year, however 2022 saw a slight slowdown, which is possibly attributed to the knock-on effects of COVID-19, resulting in delays and interruptions to work (Marine Energy Wales, 2022).

There are currently 422 full-time employees in the marine energy sector in Wales, an increase from 188 full-time employees in the previous year (Marine Energy Wales, 2022). Jobs include technology and project developers; in particular, growth has been observed in the supply chain, where more companies are becoming involved in the sector.

Much of the investment for marine energy in Wales has been in Anglesey due to the tidal stream activity, whilst Pembrokeshire accounts for the greatest employment associated with the sectors as a result of the established supply chain cluster around Milford Haven (Marine Energy Wales, 2022).

In regard to the marine energy consenting strategy in Wales, a number of topic-specific information notes were published in July 2022, which were co-produced by the Welsh Consenting Strategic Advisory Group's Science and Evidence subgroup[7]. These notes were established to provide a starting point for applicants, to highlight possible consenting challenges and provide initial support for marine licence applications. A number of topics are included, which assist applicants in locating appropriate data sources and evidence to help determine the significance of any potential impacts from the proposed development.

Marine Current Turbines' (MCT) proposed 10MW Anglesey Skerries project was one of the first tidal array projects to go through the consenting process in Wales. It was located less than 1km off the north coast of Anglesey between the Skerries islands and Carmel Head (Project Management Support Services, 2006). Consent was never awarded before the project was dropped by MCT and then Atlantis, who acquired it in their takeover of MCT. Despite this, Anglesey has been of increasing importance for tidal energy development following the announcement of Minesto's commercial scale project in Holyhead Deep and also the 'Morlais' West Anglesey Tidal Demonstration Zone.

The West Anglesey Tidal Demonstration Zone, or 'Morlais' project, is located approximately 1km from the west coast of Holy Island at its nearest point (Royal Haskoning DHV, 2015). Menter Môn is the third-party manager for the West Anglesey Tidal Demonstration Zone. Menter Môn is a third-sector company spanning the private, voluntary and community sectors and was established in 1995 to deliver EU rural development programmes. Its key objective is to facilitate economic regeneration on Anglesey (Menter Môn, 2017). During earlier phases of the project, Morlais attracted £300,000 of funding from the Nuclear Decommissioning Authority and the Welsh Government, and a further £142,000 from Menter Môn, Isle of Anglesey County Council and Ynni'r Fro investment (Morlais, 2017). The project has since received £31

[7] Marine renewable energy: environmental information notes. Available online: https://www.gov.wales/marine-renewable-energy-environmental-information-notes

million of funding from the EU's regional funding programme and a further £1.2 million investment from The Crown Estate to support environmental monitoring and mitigation (Welsh Government, 2022).

The Morlais Project, which covers a 35km^2 area of seabed and has potential to generate up to 240MW of electricity, submitted applications for consent in 2019. It received consent in December 2021 (Morlais, n.d.) and is now in the construction phase. EnFAIT partner Nova is a berth holder at the Morlais site, shared with French tidal energy developer Sabella.

To the north west of the Morlais Project is the site of the Minesto Holyhead Deep project, located west of Anglesey, 8km from the port of Holyhead (Minesto, n.d.). The long-term plan for Minesto at Holyhead Deep is to expand the site to a commercial tidal energy array, which will have an installed capacity of 80MW, with the site being developed in phases from development to a full-industrial array. Minesto also have a hub of engineering and operational activities at Holyhead, which has been operational since 2020 (Minesto, n.d.).

Scottish Tidal Energy

Remote, small communities, such as those in the Scottish islands, can greatly benefit from projects that capture their significant and abundant resources such as marine energy (Okkonen and Lehtonen, 2016). The majority of UK tidal and wave resource is in Scottish waters with >50% of the available UK tidal resource in the Pentland Firth between mainland Scotland and Orkney (Johnson *et al*., 2013). Within the regional economies of Orkney, Shetland and the Outer Hebrides, much revenue comes from activities within the islands, e.g., public sector services, tourism, agriculture, aquaculture and renewable energy. However, a strong dependency on supply and export with the mainland remains and, despite tourism and marine renewable energy being growth sectors, there is heavy reliance on diesel for energy generation, particularly in the Shetland Islands (Okkonen and Lehtonen, 2016).

Since 2000, the UK government has had funding and schemes in place to promote community renewable energy, emphasising the community benefits in the form of economic regeneration and achieving low-carbon economies alongside social cohesion and acceptance (Okkonen and Lehtonen, 2016). Scottish marine renewable policies and financial incentives acknowledge the need for increased employment, income and regional economic gains in rural areas where declining traditional industries require diversification. In addition to policy support is the need for community action on renewables to sustain and direct local activity and engagement; there is scope for such action to connect EU and regional renewable policies through bottom-up, place-based approaches (Okkonen and Lehtonen, 2016).

The Scottish Government has committed to continuing to support the development of the wave and tidal energy sectors, recognising the economic and climate opportunities of the sector (Scottish Government, 2022). Scotland is considered to be at the forefront of tidal stream energy, with the world's first offshore tidal array (Nova's Shetland Tidal Array) deployed in 2016/17, and the world's largest tidal stream generating station (Meygen) built in 2018 with funding from the UK Government and support from the Renewables Obligation mechanism (UK Government, 2021). Furthermore, in 2021, Scotland had the largest tidal stream deployment in the world: 50% of the world's installed tidal stream capacity was in Scottish waters (UK Government, 2021). The consenting process in Scotland is also considered to have benefits, allowing faster processing than other nations, due to MS-LOT providing a 'one-stop shop' for projects seeking consent.

The EnFAIT project in Bluemull Sound is part of the Scottish suite of tidal energy projects, with the first phase comprising three 100kW Nova M100 turbines, with power exported to an onshore station at

Cullivoe Pier. A further 100kW Nova M100-D (direct drive) turbine was deployed at the site in 2020, and an additional two M100-D turbines in January 2023, bringing the total capacity to 600kW.

The MeyGen project, currently the largest planned tidal stream project in the world, began the first phase of the multi-turbine tidal array project in the Pentland Firth in Scotland using technology developed by Atlantis Resources and Andritz Hydro Hammerfest in 2015/2016 (Dreyer *et al*., 2017). Phase 1A of the project entered the operations phase (25 years) in April 2018 and by March 2023 had generated 51GWh (SAE Renewables, 2023). Marine Current Turbines (acquired by Atlantis Resources in 2015) conducted extensive testing and monitoring, particularly for marine mammals, such as common seals, over the seven-year deployment of its SeaGen tidal turbine in Strangford Lough, Northern Ireland (Dreyer *et al*., 2017). Phase two of the Meygen development (28MW) was awarded a CfD in Allocation Round 4 with a target commissioning date of 2027, whilst the 52MW phase 3 is consented and under development. (SAE Renewable, 2023). The overall site has a capacity of 398MW (SAE Renewables, 2023).

The European Marine Energy Centre (EMEC) is located in Orkney, which has both full and small-scale testing capacity available to wave and tidal developers (Dreyer *et al.,* 2017). In 2016-18 a 2MW floating tidal device designed and operated by Scottish firm Scotrenewables (now Orbital Marine Power) generated more than 3GWh of electricity at the EMEC site (Orbital Marine, 2018). EMEC has enabled deployment of 35 marine energy devices from 22 wave and tidal clients from 11 countries, helping to develop products, reduce risk, cut costs and improve efficiency (EMEC, 2023). As well as contributing to the wider advances in ocean energy, the centre has resulted in positive benefits for Orkney. Between 2005-2023, over £30 million (50%) of EMEC spend has been in Orkney and between 2017-2023 there was an increase in the number of people directly employed (increasing from 44 to 84 people) (EMEC, 2023). The EMEC Fall of Warness test site is also the location of the 2.2MW O2 Orbital Marine Power device, which was built under the Horizon 2020 FLOATEC project, and received further investment in 2022 from Scottish National Investment Bank and individual investors from Abundance Investment (Orbital Marine, 2022).

With regards to wave energy, the Archimedes Waveswing deployed in Orkney was one of only three European wave energy deployments in 2023 (OEE, 2023), and received funding from Wave Energy Scotland.

3.3 Challenges and barriers

Initial challenges and barriers to ocean energy (technological, political and market) were identified through the Strategic Initiative for Ocean Energy (SI Ocean), which consulted and engaged with industry representatives and stakeholders to identify gaps in knowledge and the technology needs of the sector. It went on to prioritise these sectoral needs as activities divided between responsibilities of government, industry and research as follows, while emphasising the need for significant cross-industry efforts to be made (MacGillivray *et al*., 2013). Needs were identified at a government, industry and research-level and comprised the following:

- Government: At European, member state and regional levels, there is a need to identify suitable mechanisms to support the development of devices and subcomponents, demonstrate their reliability and transfer and disseminate knowledge.
- Industry: Industry and supply chain leadership is needed to outline and develop solutions for the design and maintenance of devices, perform data collection, provide foundations and moorings, and assess offshore grid design and optimisation.
- Research: There is a need for fundamental research to underpin and develop state-of-the-art knowledge that would benefit novel system concepts, including resource analysis tools, techno-

economic analysis tools, environmental monitoring and assessment, knowledge transfer and dissemination, and array interaction analysis.

Throughout Europe, marine energy resources are often strongest in areas where grid connection, infrastructure and port access are weakest. However, this issue has already been faced by more mature renewable technologies and solutions should be transferred (Badcock-Broe *et al*., 2014).

The lack of suitable grid connections was identified as a standout barrier by some developers. Further constraints come from environmental uncertainties, which can result in extensive, stringent ecological monitoring requirements; administrative bottlenecks in consenting due to a lack of uniform approaches at EU levels and lack of experience at many regional levels; and social impacts associated with poor engagement of communities (Uihlein and Magagna, 2015).

Also previously identified was a need to streamline consenting processes and formulate protocols for environmental monitoring through strategic initiatives, coordinated research and data sharing to spread the consenting challenges across projects and developers. Three key areas for improvement across the EU were identified to improve the process: improving environmental planning; simplifying consenting and environmental processes; and promoting best practice. Across member states, there is a responsibility for shaping the regulatory framework particularly within environmental and spatial planning directives. For example, Marine Scotland and the Marine Management Organisation both provided 'one-stop shops' from which they coordinate with other regulators and stakeholders (Badcock-Broe *et al*., 2014).

Following the European Commission's Communication on Blue Energy in January 2014, the Ocean Energy Forum was established to draw together industry and public authorities to identify remaining challenges and actions needed in the form of the Ocean Energy Strategic Roadmap, which was finalised in November 2016 (EC, 2017). Four main actions were identified as having collective potential to reduce red tape for ocean technologies:

1. A European phase-gate scheme is required to validate sub-systems and early prototypes in less mature technologies that are aligned with funding resources.
2. A public-private investment support fund should be established to finance start-up capital needs.
3. An insurance and guarantee fund should help cover the risk associated with deploying a new technology.
4. Studies, research and actions on environmental consenting should help de-risk consenting procedures and allow the use of best practice and experience between member state authorities.

Currently, although the sector has continued making progress and furthered developments and deployments in recent years, a number of the challenges and barriers outlined above remain. These include technological aspects, policy issues and requirements surrounding funding needed to maintain progress. Steps are being taken to address the issues outlined and progress will continue as the sector evolves. Current concerns are that technology remains expensive and is considered to have high risk factors, with private investors unlikely to invest without market visibility and targets being clearly set by governments (IRENA and OEE, 2023). The ability to demonstrate such market visibility is an important requirement in attracting interest from private investors.

Ocean energy technology developers have noted difficulty in accessing funding opportunities, resulting in little funding being awarded from current schemes. A lack of relevant calls and disadvantageous selection criteria design are considered to be the predominant reasons for schemes such as Horizon Europe, Innovfin Energy Demonstration Projects (EDP) and the Innovation Fund currently providing little support to ocean energy projects (OEE, 2022b).

The Innovfin EDP scheme from the European Investment Bank provides loans to innovation projects, including renewable energy technologies. Challenges and barriers associated with developers in ocean energy obtaining loans through this scheme are highlighted by:

- developers being requested to show the success of the technology, which includes visibility on sales and high bankability as a prerequisite to provide loans for demonstration projects (IRENA and OEE, 2023; OEE, 2022b). This can be difficult for innovative technologies
- to date, only one ocean energy project has currently been granted a loan (IRENA and OEE, 2023).

The European Innovation Fund is another available programme that can provide funding to projects capable of demonstrating innovative low-carbon technologies. Challenges and barriers associated with developers in ocean energy obtaining funding through the programme include:

- the complexity of the programme providing potential difficulties for small and medium enterprises to submit successful bids
- the design of the scheme targets larger projects, with a relatively low weight given to innovation (IRENA and OEE, 2023). This can make it difficult for newer, more innovative technology to receive funding
- the number of renewable energy applications in the second large-scale call dropped considerably in comparison to the first call, seen as an indication that companies were not putting the required resources into the application, due to a lack of confidence from the renewable sector towards the fund (OEE, 2022b).

This lack of accessibility for ocean energy projects has subsequently been recognised and changes have been implemented to improve the accessibility and innovative range of the scheme, including calls better suited to mid-size ocean energy projects (IRENA and OEE, 2023).

The lack of current market visibility is another challenge and barrier to the ocean energy sector, with regards to attracting private investment. Potential methods to help increase private investment and provide signals of the future market include:

- having an effective policy framework in place, which supports the sector, would help to improve this market visibility and subsequently increase interest from private investment (IRENA and OEE, 2023). The urgency of the need to create such policies to maintain interest from private investment is highlighted as reported private investment in ocean energy in Europe in 2022 was less than that of 2021 (OEE, 2023).
- having national deployment targets alongside earmarked revenue support; these targets directly publicise the size of the market, reduce capital costs of projects (by reducing perceived market risks) and increase access to finance (IRENA and OEE, 2023). Providing clear indications of the positive outlook for the sector and minimising any perceived risks is likely to increase the likelihood of interest from private investment, allowing the sector to advance and develop at a greater pace.

Constraints and bottlenecks in the offshore renewable energy sector are also barriers to the speed at which the sector can progress, both in relation to the technology, the ability for the supply chain to cope and adapt with demands, and the consenting process (Soukissan *et al.,* 2023). At the consenting stage, some bottlenecks will require significant funding in order to resolve. The bottlenecks include

- time taken to acquire permissions

- time for multiple consent applications
- lack of clarity and guidance around the process
- multiple and disproportionate environmental impact assessment requirements
- degree of environmental monitoring and documents required to support the application
- lack of flexibility to change technology specifications following granted consent (Soukissan *et al.,* 2023).

Further issues may arise when the consenting process is tailored for fixed offshore wind, making it difficult to apply the process to other forms of offshore renewable energy (Soukissan *et al.,* 2023). The need for a streamlined consenting process, as previously identified, remains.

A more streamlined consenting process is also a current, key demand from the wind industry (ETC, 2023), and it is suggested that it should be put in place for each of the respective ocean energy sectors. Due to the innovative nature of the developments in ocean energy, there can be limited experience with the appropriate regulatory authorities in providing consent (IRENA and OEE, 2023). Trying to utilise processes put in place for other offshore industries can be difficult to apply to innovative ocean energy technologies, given the differing environmental impacts and scales of projects. By developing a streamlined consenting process for specific sectors, the costs of the consenting process would be reduced and the speed at which developments can progress increased (IRENA and OEE, 2023). Furthermore, establishing a single point of contact within the regulatory authorities for developers, who can assist with any requirements, is also considered to be a help through the consenting process (ETC, 2023). Scotland provides a good example, where MS-LOT are the single point of contact for developers throughout the consenting stages and can process both onshore and offshore works, which reduces administration; the consenting process in Scotland therefore requires less time than in other countries (ETIP Ocean, 2021; IRENA and OEE, 2023).

Research is continuing to help address challenges and barriers relating to environmental concerns associated with ocean energy projects. Understanding these interactions will have increased importance as projects move from small-scale demonstrations to full-scale commercial arrays. Continuing to build data from the interactions between ocean energy devices and the marine environment is required to help establish actual and perceived risks. A collation of the current knowledge surrounding the environmental effects of marine renewable energy has been outlined in the 'OES-Environmental 2020 State of the Science Report' (Copping and Hemery, 2020). It acknowledges that challenges may remain for the consenting of commercial developments, due to the risks to the environment, habitats and animals. At present, findings in relation to collision risk have shown no collisions between the devices and diving seabirds or marine mammals, and although fish are often present in close proximity to turbines, no obvious harm has occurred, implying that collisions are considered to be very rare (Copping and Hemery, 2020). Further research and understanding of interactions between animals, environmental conditions and ocean energy devices is required, particularly in order to understand interactions that may occur once the scaling-up increases.

3.4 Lessons learnt from outside the EU

In the USA in 2007, Verdant Power piloted an array of small turbines as part of the Roosevelt Island Tidal Energy project in the East River, New York. The US Ocean Renewable Power Company led the Maine Tidal Energy Project which featured a single grid-connected turbine in Cobscook Bay (Dreyer *et al*., 2017). The Fundy Ocean Research Center for Energy in Canada began initial test deployments of tidal energy devices in 2016 (Dreyer et al., 2017).

In many countries, policy makers have become increasingly concerned with public acceptance of renewable energy policy as associated technologies are increasingly deployed in response to climate change issues (Devine-Wright, 2011). There is an opportunity in the USA, which currently remains at the research and development stage, to learn about attitudes to the development of tidal energy before projects move to commercialisation. This also provides scope to consider environmental, economic and social concerns as the technology develops. Such research can guide public policy creation in relation to the allocation of funding for marine energy innovation. In turn, long-term policy support and investment helps to attract the private investment needed to drive the sector forwards (Dreyer *et al*., 2017).

A study to measure public views towards tidal energy in Washington State in 2017 found views are positive overall, as indicated by high levels of both acceptability and support. These increased levels of acceptability and support were found to be associated with higher levels of perceived benefits and climate change beliefs, whereas these decreased with greater perceived risks associated with tidal energy (Dreyer *et al*., 2017).

The perceived risks and benefits of tidal energy affect the level of public acceptability and support for tidal energy policies and projects. The 2017 study also applied social science research to development lifecycle phases of tidal technology to consider how support for tidal energy varies along the innovation chain. The study outputs can be used to inform the development strategy for tidal energy in Washington State, as they show the public is most likely to support grants for laboratory-based research and development, and scaling of tidal technology with a grid-connected pilot phase over other phases of the innovation chain (Dreyer *et al*., 2017).

More broadly, this study of development pathways for renewable energy technologies demonstrates a need to incorporate environmental psychology perspectives and methods to provide insights to reducing investor uncertainty and maximise public support for the advancement of new energy technologies. Such research can provide valuable insight for public policy makers particularly in relation to funding by providing a better, evidence-based understanding of public support of technology along the innovation chain (Dreyer *et al*., 2017).

At a time when nations were pledging financial and political support for renewables in response to the Paris Agreement, it was important that funding aligns with societal preferences to attain market acceleration objectives. A separate Washington State study found that state residents are willing to pay well above public spending for tidal energy research and development initiatives. This discrepancy has been attributed to the concept that individuals consider non-market benefits of such investments, e.g., reducing carbon emissions and harvesting local energy sources that provide for both current and future generations (Polis *et al*., 2017).

Recent research on the 'socio-technical assessment of marine renewable energy potential in coastal communities' (Kazimierczuk *et al.,* 2023), aimed to assess how social perceptions and the technical potential of tidal energy could be integrated to help improve alignment between community values and energy development. Interviews with community representatives of two coastal communities (Sitka, Alaska and the San Juan Islands in Washington State) were carried out to establish how energy development objectives are shaped by community values, resource relations, and institutional relations. The findings suggested that the deployment potential was greater when there was alignment of strategic development and community-level visioning with community priorities. It was also found that an important priority to resolving issues which surrounded values-based conflicts, and energy and economic development was the opportunity for engagement between citizen-led coalitions and various civic organisations (utilities companies and City Government). Furthermore, bottom-up participation in development decisions tended to give rise to greater trust than top-down directives aimed at singular values such as economic growth, or just regulatory compliance (Kazimierczuk *et al.,* 2023). These findings could be applied during the planning phases of developments in other regions of the world.

The EU's competitors are setting aside considerable funds to drive the advancement of their marine renewable technologies forwards. For example, China previously announced, in a five-year plan to accelerate the development and use of ocean energy, that $363 billion will be invested in renewable energy by 2020. The plan looked to bring tidal, wave, OTEC and salinity gradient sources into the country's energy mix. Plans involved wave and tidal demonstration projects, including a new £200 million marine laboratory campus with a vision to create a Chinese version of EMEC with inputs to the feasibility study from EMEC (EMEC, 2017). China has since seen the rewards of commitments to investing in ocean energy; in 2022 the country was ahead in tidal stream global capacity additions for the second time in three years and also has the world's second largest tidal farm at 3.3MW capacity in a project supported by the Chinese Government (OEE, 2023). The advances can be attributed to the increased funding that has been received and highlights the importance of continued funding in order to progress the technology; over the last five-year period, investment in the Chinese sector has been triple that of the EU (OEE, 2023). Other market incentives utilised in China have included the temporary feed-in tariff for the Hangzhou LHD Lin Dong Ocean Energy Technology Co., Ltd. (LHD) project, which is the first current energy project to implement a temporary on-grid tariff policy (Na Ni, 2023). Other countries which use a feed-in tariff are Canada and Israel; in Israel feed-in tariffs (alongside both public and private support) enabled the country to deploy its first grid-connected wave power project in 2022 (OEE, 2023).

New policy developments in areas outside of the EU, such as the USA, Canada and China have been noted as being factors in the progress made by these nations in 2022 (OEE, 2022). China released the '14th Five-Year Plan for a Modern Energy System' in 2022, under which they will continue to implement tidal current energy demonstration projects and promote the application of megawatt tidal current energy power generating units, whilst also exploring and promoting the construction of wave energy demonstration projects and promoting the application of various forms of wave energy generation devices (IEA-OES, 2023).

Other lessons learnt from outside the EU in relation to the licencing and permitting process include the benefits that can be achieved for the industry by amending the appropriate renewable energy Acts, an example being revisions to the 'Marine Renewable Energy Act' in Nova Scotia in 2022. Changes were made in order to 'provide greater clarity regarding the Act's licensing system to address industry concerns, improve and clarify the administration of the Act's Demonstration Permit Program, and respond to lessons learned through the ongoing administration of the legislation and address other administrative changes' (IAE-OES, 2023). One noted amendment was a change to the licence framework which now allows projects to be sited closer together, whilst also being able to share common infrastructure (e.g., anchors and moorings); reducing the amount of deployed infrastructure will reduce project costs and support project investment decisions and planning, which will lead to the deployment of projects (IAE-OES, 2023).

3.5 Diversification of existing sectors

As the ocean energy sector advances, there is acknowledgement of the need to increase the number of industry personnel with the skills and knowledge required to develop and deploy the emerging technology (IRENA and OEE, 2023). Options for increasing the professionals in the sector include reskilling those involved in non-renewables (fossil fuel industries) into the renewable energy sector and work alongside those in academia and education by aligning elements of the curricula with jobs in the sector (IRENA and OEE, 2023). By providing those already in other marine sectors with additional skills applicable to the marine renewable industry and introducing those in education to relevant knowledge and understanding of the industry, this gives opportunities to expand the likely future workforce capacity that will be required as the ocean energy sector continues to develop.

The supply chain for tidal energy offers significant scope for diversification of existing sectors, such as commercial fishing, where reductions in employment have been significant. A range of required services have been identified that could potentially be provided by fishing vessels, including physical surveys, environmental surveys, metocean surveys, and construction and maintenance support. In addition to the diversification opportunity this offers the fishing community, it also has potential to benefit developers through cost reductions for vessels, as deployment is currently very costly (MarineSpace, 2015). Nova explored the use of local fisherman in Wales to provide survey services (vessels), for which an angling charter vessel was used and demonstrated the opportunity for diversification between the sectors.

Following the trail blazed in Orkney and Shetland, marine service companies are transferring their commercial fisheries skills, knowledge and experience of working in harsh remote locations into the marine renewable energy sector. Based upon current vessel requirements and value of services for the Morlais Demonstration Zone, the economic value to be generated was estimated to be £3.5 million over 10 years if the project is developed as planned. Of this figure, approximately £400,000 would be over three years of the development phase, approximately £1.4 million during construction, and annual operation approximately £300,000 for 25 years. Additionally, services to other projects in the area were calculated to amount to a further £2.9 million over 10 years. Standards and competencies for vessels and crews have been identified and specified for this supply sector and the potential for collaboration between individual vessel operators to develop a one-stop shop for developers (MarineSpace, 2015). Another industry which may benefit from diversification opportunities with the marine renewables sector are boat builders, which can be used in the manufacturing elements of devices or infrastructure construction requirements; in Shetland a former boatbuilder is manufacturing the blades for tidal devices used by Nova.

Dafydd Gruffydd from Menter Môn said, "*One of our objectives is to ensure that the local supply chain is fully aware of developments and able to respond to the opportunity. The study identified work to the value of £3.5 million which could be delivered by fishermen utilising their skills, marine experience and vessels at their disposal*" (Tidal Energy Today, 2015).

The potential for collaboration within ocean energy sectors in Scotland has also been assessed, with the conclusion being that wave and floating wind energy could benefit from sharing infrastructure, services and supply chain, in an effort to continue developments to produce commercially viable and cost competitive wave energy (Wave Energy Scotland, 2023). Within the scenarios assessed, all were shown to reduce the costs of energy by significant amounts for wind and wave energy; cost reductions could be close to 40% for wave energy convertor developers (Wave Energy Scotland, 2023). The benefits suggest that sharing infrastructure with floating wind could provide an effective pathway for the progression of the wave energy industry (Wave Energy Scotland, 2023).

There is also potential for integration of ocean energy alongside the aquaculture industry through the supply of renewable energy, such as tidal and wave energy. However, positions for co-location need to ensure that conditions are suitable for aquaculture operations, whilst still ensuring there is sufficient wave or tidal capacity to produce the energy (Freeman *et al.,* 2022).

Other collaborations between sectors to help advance technology come through the research from universities alongside technology companies, to provide collaborative inputs to the emerging technologies; for example, ORE Catapult and four Welsh Universities are collaborating at the Marine Energy Engineering Centre of Excellence (MEECE, n.d.). Combining knowledge from a number of universities and companies involved with developing innovative technologies can help to advance the developments in ocean energy.

4 Environmental and Socio-Economic Baseline

4.1 Environmental baseline

4.1.1 Physical Characteristics of the Marine Environment

Bathymetry

Around Shetland the seabed slopes steeply, reaching depths greater than 50m within 1km of the coastline and, in some areas, it is 100m deep at less than 1.5km from shore (and locally 140m) (Slater and Shucksmith, 2021). Depths are roughly 100–120m at 10km from the shore (Doody, 1997). The depth of the numerous channels between islands varies considerably (Howson, 1998).

The Bluemull Sound is a tidal channel between the islands of Yell and Unst, with a maximum depth of 50m. The bathymetry of the Bluemull Sound is shown in Figure 4-1.

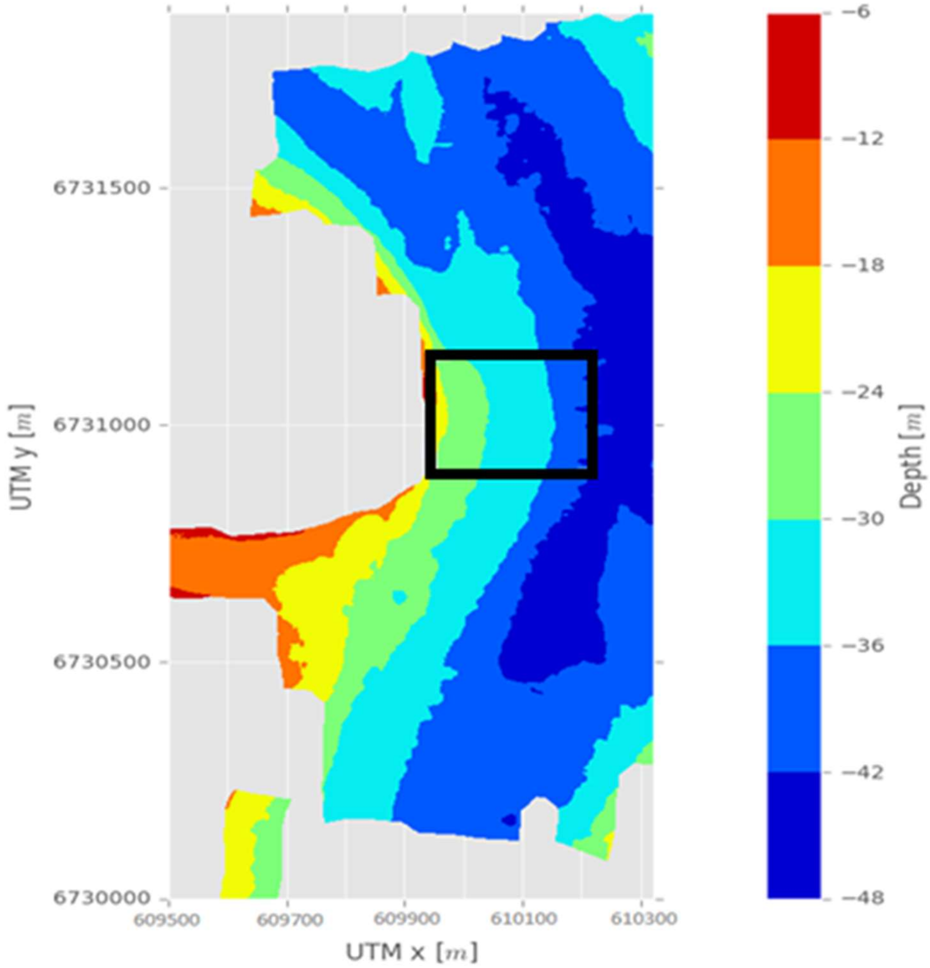


Figure 4-1 Bluemull Sound bathymetry
The lease area in which the array is situated is depicted in black.
Source: Medina-Lopez, 2018

Currents and waves

Around Shetland tidal currents can be strong; they are intensified tidal streams with speeds as high as 3.5–4.5m/s in areas such as Bluemull Sound and Yell Sound (Baxter *et al.*, 2011; Slater and Shucksmith, 2021). Tidal streams were modelled for SIC in 2011, with the overall maximum velocity generally low around Shetland (0–0.6m/s). However, stronger currents were present around Sumburgh Head, Muckle Flugga and through the Yell and Bluemull Sounds (Halliday, 2011). Modelling completed for EnFAIT shows that surface current speeds can reach a maximum of 3m/s in Bluemull Sound (Figure 4-2).

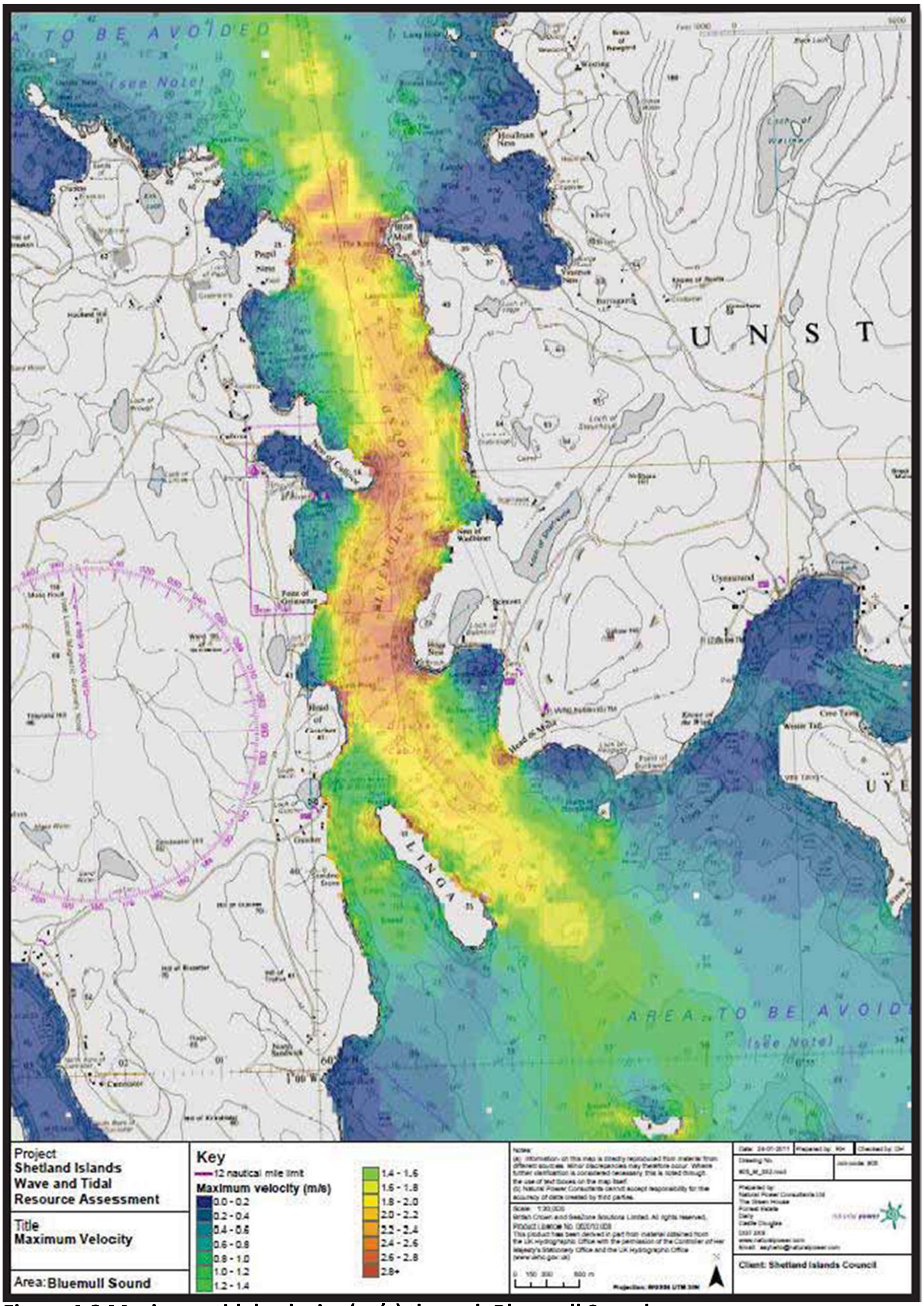


Figure 4-2 Maximum tidal velocity (m/s) through Bluemull Sound
Source: Halliday, 2011

With the wind direction predominantly from the south-west, Shetland is particularly exposed to the weather systems of the North Atlantic. The extended areas of open ocean to the west allow a powerful wave climate to develop, with large regular waves (swell) and wind-driven seas (Baxter *et al.*, 2011; Halliday, 2011). The highest wind speeds and strongest gusts in Britain have been recorded in Shetland and there are gales for 58 days of the year, on average (Slater and Shucksmith, 2021). Temperatures are relatively stable, ranging from 1-16°C (Slater and Shucksmith, 2021).

Broadly, Shetland has western and eastern facing wave climates, with larger waves on the exposed western coast. Modelled mean annual wave height close to shore on exposed coasts is 0.6–1.2m, while in voes and sounds it is only 0.2–0.8m. Bluemull Sound was modelled within the western facing wave climate, although it is well sheltered from wave action and has a mean annual wave height of 0.2–0.6m (Halliday, 2011).

4.1.2 Marine and Coastal Biodiversity

<u>Seabed and shoreline ecology</u>

In Bluemull Sound, the intertidal zone between high and low tides comprises predominantly rocky shores, with communities of brown seaweed (e.g., channel wrack, spiral wrack, bladder wrack, serrated wrack and egg wrack) with some small sandy beaches. There are also a few saltmarshes along the Yell coast (Wilding *et al.*, 2005, Shucksmith, 2017).

In permanently submerged (subtidal) areas, the strong tidal streams present in Bluemull Sound result in a variety of tide-swept algal communities (Irving, 1997; Howson, 1998). The central channel, closest to the turbine array, is dominated by rocky outcrops, and a kelp forest is present to depths of around 20m (Wilding *et al.*, 2005). The kelp communities support a variety of biodiversity including red seaweeds, sponges, sea squirts, anemones, sea stars and molluscs (Shucksmith, 2017).

The northern end of Sound has steeply sloping bedrock with particularly strong tidal currents and surges, with fields of a type of soft coral (dead man's fingers) and associated organisms including sponges, sea squirts and sea anemones (Howson, 1998; Wilding *et al*., 2005). Pebbles and cobbles covered with a sea-fir (hydroid *Sertularia argentea*), are present in deeper water, while a tide-swept cobble and bedrock slope is present in the southern entrance to the Sound, supporting horse mussel beds, dead man's fingers and brittlestars. Horse mussel and brittlestars are also present on the mixed sediment found in areas with weaker tides (Irving, 1997; Howson, 1998; Wilding *et al.*, 2005). In the eastern approaches to the Sound, the seabed is mixed sediments, and includes the largest bed of maerl (a calcareous algae) in Shetland (Irving, 1997; Wilding *et al.*, 2005).

Shellfish of commercial importance are likely to be present in the edges of the Bluemull Sound, including edible (brown) crab, velvet swimming crab, and lobster. Across Shetland, creeling grounds are important although not that prevalent in the Bluemull Sound area (Shucksmith, 2017; SIMSP, 2015). King scallops (*Pecten maximus*) are found on sandy/gravelly substrates and may also be present (Shucksmith, 2017). The stocks of crabs and lobster are thought to be stable or increasing based on landings per creel (Shucksmith, 2017). With regards to the commercial shellfish species landed in Shetland in 2021, by weight, this comprised of scallops (60%), edible crabs (19%), lobsters (1%), velvet crabs (6%) and whelks (14%) (Napier, 2022a).

Fish

Sharks, skates and rays

There have been 30 species of sharks, skates and rays (elasmobranchs) recorded in Scottish waters, 25 of which occur in coastal waters. Three of the seven species listed as priority marine features for Scotland are found within the Shetland region: basking shark, common skate and spiny dogfish (Shucksmith, 2017). There is insufficient data to assess population trends and distribution of these three species around Shetland (Shucksmith, 2017).

There are recorded sightings of basking sharks in the Bluemull Sound, mainly to the south of the Sound (SIMSP, 2015). Lesser-spotted dogfish, common skate, and various ray species (cuckoo, spotted, thornback) were caught each year between 2011 and 2014 during inshore fish surveys of Shetland waters (Napier, 2011, 2012, 2013, 2014) and so are likely to also be present in the Bluemull Sound.

Bony fish

Bony (teleost) fish include several of commercial importance. Key species which make up the bulk of Shetland catches include pelagic species such as mackerel and herring and demersal fish species including haddock, cod, whiting, saithe, monkfish and megrim (Shetland Island Marine Planning Partnership, 2021).

During underwater video surveys recorded at STA at Bluemull Sound, conducted by Nova, saithe (*Pollachius virens*), was the most abundant species observed (Nova Innovation, 2022a; Nova Innovation 2022b).

In 2021, pelagic fish such as mackerel and herring accounted for 61% of the total weight landed in Shetland, whilst whitefish such as cod, haddock, monks and flatfish accounted for 34% (Napier, 2022a). Other fish pelagic species which were landed in Shetland included blue whiting. The top ten species of whitefish which were landed in Shetland during 2021 were monkfish, cod, haddock, megrim, whiting, hake, saithe, ling, plaice and lemon sole (Napier, 2022a).

Trends in fish stocks in Scotland from 2022 suggest that 'the general overall picture continues to be one of relatively high abundances, following increases over the last two decades, and of relatively low levels of exploitation following decreases over the same time period' (Napier, 2022b). The spawning stock biomass (SBB) of cod increased by 22% in 2022, the SBB of haddock has increased five-fold in the three years since 2019 and the SBB of North Sea whiting has doubled in size between 2017-2022 (Napier, 2022b). In general, the SBB of most whitefish stocks have increased since mid-2000s, despite some stocks being lower than they have been in the past (Napier, 2022b).

Commercially important demersal species which have been observed throughout Shetland inshore fish surveys between 2011-2022 (Fraser *et al.,* 2022) include:

- Haddock (*Melanogrammus aeglefinus*)
- Plaice (*Pleuronectes platessa*)
- Whiting (*Merlangius merlangus*)
- Cod (*Gadus morhua*)
- Monkfish (*Lophius spp*.)
- Squid (*Loligo spp.)*
- Lemon sole (*Microstomus kitt*)
- Thornback ray (*Raja clavata*)
- Cuckoo ray (*Raja naevus*)

* Spotted ray (*Raja montagui*)
* Saithe (*Pollachius virens*)
* Megrim (*Lepidorhombus whiffiagonis*)
* Witch (*Glyptocephalus cynoglossus*)
* Ling (*Molva molva*)
* Turbot (*Scophthalamus maximus*)
* Hake (*Merluccius merluccius*)

Haddock was shown to be the main component of catches in 2022, whilst cod and whiting were shown to have relatively low abundance compared to previous years (except for cod in shallow areas) (Fraser *et al*., 2022).

Two species of anadromous fish (those that migrate up rivers from the sea to spawn) are also found around the Shetland coast: with brown/sea trout present in lochs and burns, and Atlantic salmon (*Salmo salar*) also present, although as Shetland does not have large rivers very few salmon enter the burns to spawn. Some Atlantic salmon are thought to be present in the Burns and Loch of Gutcher (*c.*3km from the turbine array), and the Burn and Loch of Snarravoe (*c.*1.2km distant), however. There is also insufficient data to assess population trends for either species, although sea trout numbers are considered lower than historic levels (Shucksmith, 2017).

Marine mammals

Whales, dolphins and porpoises (cetaceans)

Cetacean species are protected under Annex IV of the EU Habitats Directive and most are also UK Biodiversity Action Plan (BAP) Priority species.

The waters around Shetland are diverse in terms of cetaceans, with 15 species observed in the coastal and offshore waters (Shucksmith, 2017). The species include harbour porpoise (*Phocoena phocoena*), common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), striped dolphin (*Stenella coeruleoalba*), white-beaked dolphin (*Lagenorhynchus albirostris*), white-sided dolphin (*Lagenorhynchus acutus*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), killer whale (*Orcinus orca*), minke whale (*Balaenoptera acutorostrata*), pilot whale (*Globicephala melas*), pygmy sperm whale (*Kogia breviceps*), sperm whale (*Physeter macrocephalus*), sei whale (*Balaenoptera borealis*) and beluga whale (*Delphinapterus leucas*) (Shucksmith, 2017).

Surveys of Bluemull Sound have been conducted on Nova's behalf since the EnFAIT project's inception. Surveys of the area between May 2017 and April 2018 recorded harbour porpoises throughout the year, while minke whales were seen between November 2017 and January 2018 (Nova Innovation, 2018). During subsequent surveys in Bluemull Sound between March 2020 and March 2022, three species of cetacean were recorded, harbour porpoise, killer whale and minke whale (Nova Innovation, 2022c). Harbour porpoise were the most common species observed. Other species may be present as the Bluemull Sound is thought to be an important foraging area (Shucksmith, 2017).

The known seasonality and observed group sizes around Shetland are shown in Table 4.1, for the species commonly recorded in Bluemull Sound.

Table 4.1 Peak sighting months and group sizes around Shetland for five cetacean species most commonly reported in Bluemull Sound

Common Name	Peak sightings	Group Size
Harbour porpoise	July to October	1–3
Risso's dolphin	April to November	5 –20
Killer whale	June and July	1–15
Minke whale	July to September	1–15
Humpback whale	June and July	1–2

Sources: Bolt *et al*. 2009; Deecke *et al*. 2011; Sea Watch Foundation 2012

Seals

Shetland is nationally important for two species of seal, the common seal and the grey seal, and is home to 15% and 2.5% of the UK populations respectively (Shetland Island Council, 2017a). Both species breed on Shetland and are protected under Annex II and IV of the EU Habitats Directive, while the common seal is a BAP Priority species.

There are protected haul-out sites for both species of seal around Shetland (Figure 4-3). Two of the protected haul-out sites are in the area surrounding Bluemull Sound: one on the northwest coast of Unst (c.2.5km from turbine array), and one on the northwest tip of Fetlar (c.8.5km). In total, Shetland has 47 protected seal haul-outs around the coast, with two Special Areas of Conservation (SAC) (Mousa and Yell) for common seals (Slater and Shucksmith, 2021).

During Nova's surveys of Bluemull Sound between March 2020 and March 2022, both grey seal and common seal were observed, with common seal being the most common species in the surveys. Both species were observed during the period of August to March (Nova Innovation, 2022c).

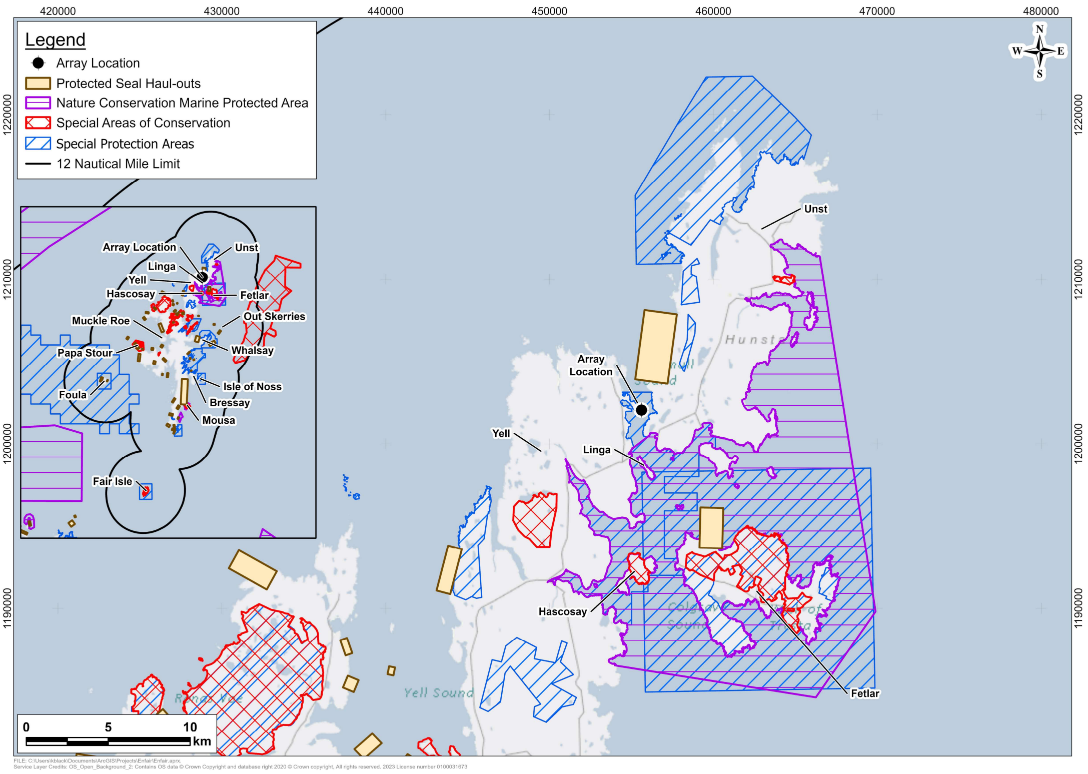


Figure 4-3 Protected areas around Shetland

During August 2019 counts, 293 common seals were recorded at south-east Yell and north-east mainland, whilst 69 grey seals were also recorded (Morris *et al.,* 2021). Common seals are the most commonly sighted seal in Bluemull Sound, although grey seals are seen regularly as the southern end of the Sound is identified as an area of high foraging effort for both species (Shucksmith, 2017).

Populations of both seal species are considered to be either stable or declining in Shetland (SIC, 2021).

There are records of vagrant Arctic species with the most common visitor the bearded seal. Within the Bluemull Sound, a ringed seal was recorded at Cullivoe in 2001 (Shetland Sea Mammal Group).

<u>*Otters*</u>

Despite their near-threatened status, Shetland has a population of European otter accounting for around 14% of the UK otter population, meaning that the population in Shetland is of national and international importance (Slater and Shucksmith, 2021). Otters are sighted year-round and are seen most regularly along the Yell Sound coast, and along the Bluemull Sound coast, into Colgrave Sound around the island of Hascosay (SIMSP, 2015). They are generally seen singly or in small groups, usually of a mother and one or two cubs. They have a habitat preference for low, rocky coastlines, which has shallow water (Slater and Shucksmith, 2021).

Otters are protected under Annex II and IV of the EU Habitats Directive and are a BAP Priority species. Their typical dive depth is approximately 3m (Nolet *et al*., 1993).

<u>*Birds*</u>

Wild birds in Shetland are protected under the EU Birds Directive and the Wildlife and Countryside Act 1981.

Shetland has multiple internationally important colonies of breeding seabirds with 23 species known to breed in Shetland (Shetland Heritage, 2013; Shucksmith, 2017). It is considered that there are one million breeding seabirds in Shetland and 21 of the 24 native British seabirds can be found (Slater and Shucksmith 2021). Internationally important wintering populations also occur, including eider ducks, red-throated divers, long-tailed ducks, and red-breasted merganser (Shucksmith, 2017). Internationally important breeding populations of waders and/or waterbirds are included in the qualifying features for the Fetlar Special Protection Area (SPA) (*c.*4 km from the turbine array at its closest point), including colonies of red-necked phalarope, dunlin and whimbrel (JNCC, 2001).

Bluemull Sound supports colonies of breeding birds along its coastlines. The largest breeding colonies present are of Northern fulmars. Smaller colonies of cliff breeding birds (black guillemot, kittiwake, manx shearwater, puffin, razorbill and common guillemot, European shags and cormorants, and Arctic and common terns are also present along the coast.

Colonies of breeding Arctic and great skua are found across most of Yell and Unst, with some along the Bluemull Sound coast. In the southern Bluemull Sound area colonies of breeding gulls (black-headed, common, great and lesser black-backed and herring) and European storm petrels are also present (SISMP, 2015).

The Bluemull Sound area is also an important foraging area for breeding red-throated divers. The islands of Yell, Unst and Fetlar supported 194 pairs in 2006, and they forage in shallow coastal waters, including

Bluemull Sound, within 9km of their nesting sites (Philip, 2016). As a result, the area, which includes the turbine array, is a SPA: Bluemull and Colgrove Sounds (Figure 5.3). The SPA covers an area of 46.7km^2, and is designated because of the red-throated diver (an Annex 1 species) population which is of European importance (Marine Scotland, 2020a). The waters of the SPA are considered to provide feeding grounds for over 170 breeding pairs of the species, accounting for 14% of the British population (Marine Scotland, 2020a).

During Nova's surveys of Bluemull Sound between March 2020 and March 2020, species of diving birds recorded included long-tailed duck, common guillemot, razorbill, black guillemot, Atlantic puffin, red-throated diver, great northern diver, northern gannet, great cormorant and European shag (Nova Innovation, 2022c). Species which were observed throughout the year included black guillemot, northern gannet and European shag.

Several important wintering species are present in Bluemull Sound. Large flocks of long-tailed duck and red-throated diver have been recorded in the southern section of the Bluemull Sound, while small flocks of Slavonian grebe have been recorded in the northern part of Bluemull Sound (SIMSP, 2015). Eider ducks are present in the Bluemull Sound area during the moulting season and during winter, where they were attracted to salmon cages (Heubeck and Mellor, 2013; Shucksmith, 2017).

Black guillemots and shags were the most frequently observed birds during a non-breeding season survey in January 2012 (Robbins *et al.*, 2013, 2014) and during Nova's monitoring of Bluemull Sound between March 2020 and March 2022, with black guillemots the most abundant species (Nova Innovation, 2022c).

The Shetland-wide census of moulting common eiders in 2019 recorded a count of 3639 birds, showing a continued decline in the trend for the population since 1997 and a 20.9% decrease since 2015 (SOTEAG, 2019). Eiders were observed during a winter boat survey at Hascosay, Bluemull and Colgrave Sounds and south Unst (SOTEAG, 2019).

Population estimates are not available for Bluemull Sound itself, but seabird populations have declined throughout Shetland since the Seabird 2000 census, except for gannets and black guillemots (Shuckmith, 2017). In Shetland there are currently an estimated:

- 3,639 eider ducks (SOTEAG, 2019)
- 400 pairs of red-throated diver, 40% of the UK population (SIC, 2017a)
- 39,000 pairs of gannets, 12% of the UK population (SIC, 2017a)
- 16,000 adult black guillemots, 41% of its UK population (SIC, 2017a)
- 80,800 attendant adult common guillemots (Shucksmith, 2017)
- 50,000 pairs of puffins, 10% of the UK population (SIC, 2017a)
- 6,000 pairs of shags, 21% of the UK population (SIC, 2017a).

Winter counts of seaduck and diving seabirds along the Hascosay, Bluemull and Colgrave Sounds and the south Unst for the 20019/2020 survey were as follows (SOTEAG, 2019):

- 1273 common eider
- 668 long-tailed duck
- 2 common scoter
- 4 velvet scoter
- 11 red-breasted merganser
- 11 red-throated diver

- 16 great northern diver
- 1 white-billed diver
- 227 cormorant
- 1260 shag
- 10 common guillemot
- 421 black guillemot

Protected Sites

Areas designated for nature conservation around Shetland are shown in Figure 4-3. 14 of the 15 SPAs in Shetland are designated for seabirds (the other is for terrestrial birds only). There are 13 SACs, seven of which have a marine element (Shetland Islands Marine Planning Partnership, 2021).

Three protected areas are located within or near to Bluemull Sound:

- the Fetlar to Haroldswick Nature Conservation Marine Protected Area (NCMPA) was designated in part due to the importance of the area for foraging black guillemots, and the presence of maerl and horse mussel beds (SNH, 2017)
- the Fetlar SPA supports a variety of breeding and wintering birds included on Annex I of the EU Birds Directive, as well as hosting a seabird assemblage of international importance (JNCC, 2001)
- Bluemull Sound and Colgrave SPA is designated for red-throated divers (Marine Scotland, 2020a).

4.1.3 Water Quality

In a review of long-term monitoring of Shetland seas, Dawson *et al.* (2011) noted an overall temperature increase of approximately 1.5°C in winter and of approximately 0.5°C in summer between 1900 and 2009. Long-term data shows that the warmest average sea temperature is present during August (average 13.1°C) and it is coldest during March (average 8.2°C) (SeaTemperature, 2023). In the last 30 years, sea temperature has risen by 0.22°C per decade (Marine Scotland, 2021).

The mean annual salinity at the sea surface is just over 35ppt in the sea surrounding Shetland (Baxter *et al.*, 2011). The water is classified as well-mixed oceanic water in winter and weakly stratified oceanic water in the summer (Connor *et al.*, 2006). The salinity in Scottish offshore waters has been shown to have a decreasing trend since 2014. Although also observed in coastal areas, this is not to such a high extent, due to the greater year-to-year variability as a result of freshwater run off (Marine Scotland, 2020b).

The Scottish North Sea has lower concentrations of suspended sediment than the southern North Sea. The modelled turbidity for the waters around Shetland is *c.*5mg/l (Baxter *et al.*, 2011).

Under the EU Water Framework Directive and according to the Scottish Environmental Protection Agency (SEPA) waterbody classification, the coastal waters around Shetland were classified as good in 2020 (Marine Scotland, 2023). In general, water contaminant concentrations are low, with an improving trend and few concerns about quality (Shucksmith, 2017).

4.1.4 Sediment Quality

Concentrations of contaminants in sediment are low, with metal concentrations in Shetland lower than elsewhere in Scotland (Shucksmith, 2017).

Hazardous substances, which included polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs) and heavy metals such as mercury, cadmium and lead, have been assessed in sediment and biota at biographic regions, which included the Northern North Sea (east Shetland) and Scottish Continental Shelf (west Shetland) biogeographic regions. The concentrations were shown to be generally above background concentrations, but below levels where there could be potential adverse effects; these concentrations were also typical of the Scottish Continental Shelf and the Northern North Sea (Marine Scotland, 2021). Furthermore, no increasing trends were found.

4.1.5 Underwater noise

Underwater noise is a combination of noise from natural, including waves, weather and animals and anthropogenic sources. Anthropogenic noise has the potential to impact marine species through the masking of acoustic cues, physical trauma, habitat displacement or behavioural changes.

In Shetland and at Cullivoe Pier anthropogenic noise sources include shipping, fishing, occasional dredging, marine recreation and acoustic deterrents (particularly for aquaculture). There is currently insufficient data to assess trends of underwater noise around Shetland, and it is unknown whether it is at a level that will impact marine life.

Within Bluemull Sound vessels are the most common source of underwater noise. There is small scale fishing through the Sound and the harbour at Cullivoe is used for landing catch (NAFC Marine Centre, 2016a), as well as the docking of small recreational vessels (SIC, 2018a). A ferry runs daily between Gutcher on Yell, Belmont on Unst and Harmars Ness on Fetlar (SIC, 2018b). Vessels used to service the aquaculture developments are also commonly present as there are four finfish sites and one shellfish site in the southern half of the Sound with a shore base at Cullivoe. Due to the presence of aquaculture in Bluemull Sound, there is also the potential for acoustic deterrents in the area (NAFC Marine Centre, 2016a). Cullivoe harbour is a busy fishing port; in 2021 it was ranked 19th in the UK for the value of fish and shellfish landed and was in the top 15 ports for whitefish landings (Napier, 2021).

4.1.6 Seascape

The seascape of Shetland has been formed over millions of years, creating a diverse and unique environment that is an intrinsic part of island life. There are 2 seascape character types which have been mapped at a regional level – low, rocky island coasts and remote high cliffs – while at a local level, 12 coastal character types (CCT) have been identified. These include developed and undeveloped voes and firths, developed and undeveloped island sounds, bays, islands, exposed coast and harbours (NAFC Marine Centre, 2016a; Shuckmith, 2017).

The Shetland coastline has been divided into 43 coastal character areas and the Bluemull Sound is one of them. The coastal character types (CCT) of the Bluemull Sound are shown in Figure 5.4. The dominant CCT of Bluemull Sound is 'exposed coast- low rocky shore' (Slater and Shucksmith, 2021). The entire Sound is a Developed Island Sound, with various piers along both coasts and numerous aquaculture developments. Cullivoe has a small marina and pier infrastructure, and a mussel site at the mouth of the voe. Linga was inhabited at one time, while the Holm of Heogland is a tidal island connected to Unst at low tide with evidence of a settlement on the island (NAFC Marine Centre, 2016a).

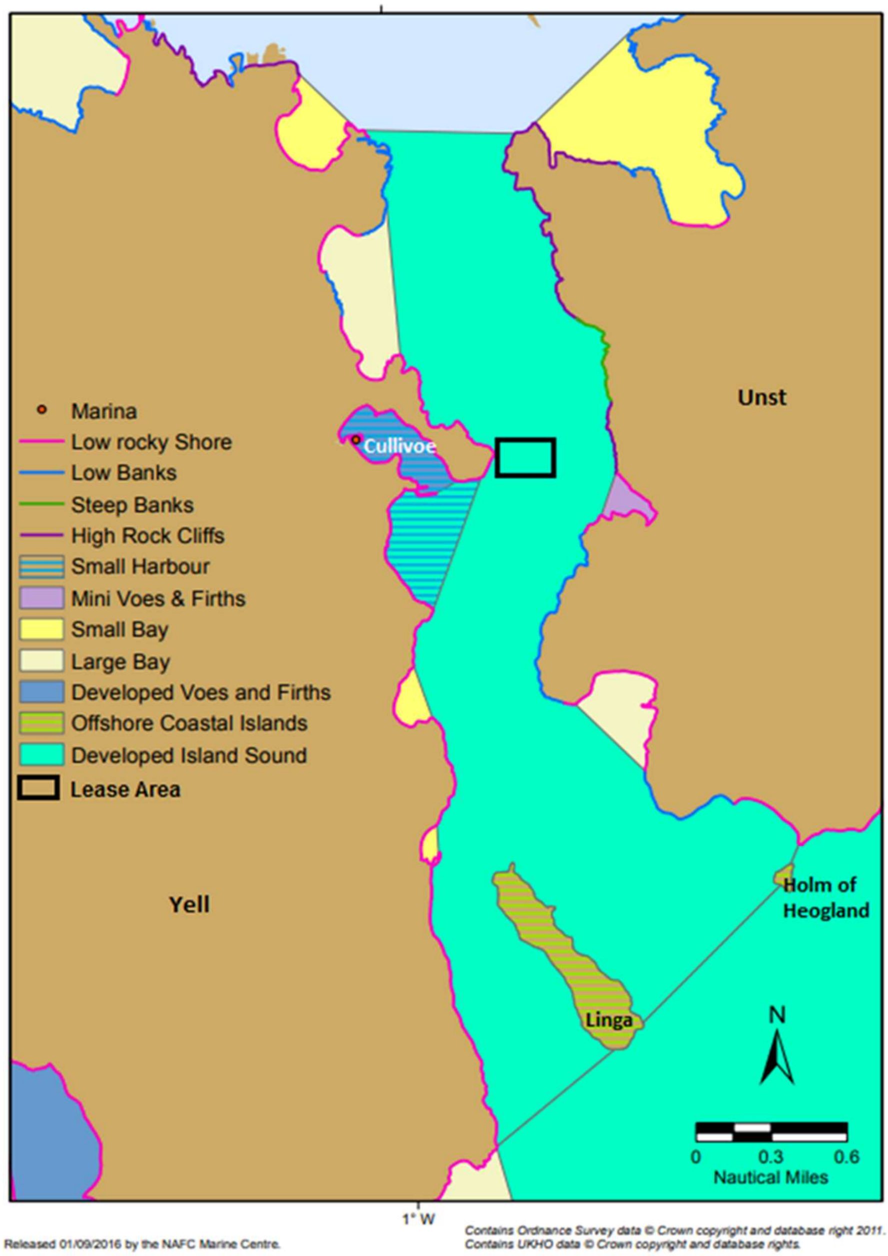


Figure 4-4 The coastal character types of Bluemull Sound coastal character area
Source: Adapted from NAFC Marine Centre, 2016a

4.1.7 Marine Archaeology

Around Shetland there are around 1490 shipwrecks but only a small number are known in detail (Shetland Islands Marine Planning Partnership, 2021). The wrecks of two 17th century ships, the Dutch East Indiaman *Kennemerland* and the Danish warship *Wrangels Palais*, are encompassed in the Out Skerries Historic Marine Protected Area (MPA) (Historic Environment Scotland, 2015). Furthermore, there are 14 wrecks for which the surrounding seabed is leased by SIC, as a method of protecting the resource (Shetland Islands Marine Planning Partnership, 2021). There is also high potential for new submerged sites or deposits of archaeological interest, as there are areas of drowned terrestrial sites and cultural landscapes (SIMSP, 2015; Shuckmith, 2017). The locations of submerged archaeology within the Shetland Island Marine region, are shown in Figure 4-5.

There are fifteen known wreck sites within the Bluemull Sound itself, although locations are only tentative (PastMap, 2018). Around Cullivoe there are two wrecks, both just north of the Ness of Cullivoe approximately one kilometre from the turbine array (PastMap, 2018; SIMSP, 2015); the 17th century Dutch East Indiaman *Lastdrager* (Canmore, 2018a,b) and the 19th century ship *Harmonia* (Canmore, 2018c). There were also two 19th century wrecks in Snarra Voe, on the opposite side of the Sound to Cullivoe (PastMap, 2018; SIMSP, 2015); the ketch *Equestrian* (Canmore, 2018d) and the barque *Fanny M Carrill* (Canmore, 2018e).

Although there are numerous wreck sites, Bluemull Sound is not considered to be an area of submerged archaeological potential (SIMSP, 2015).

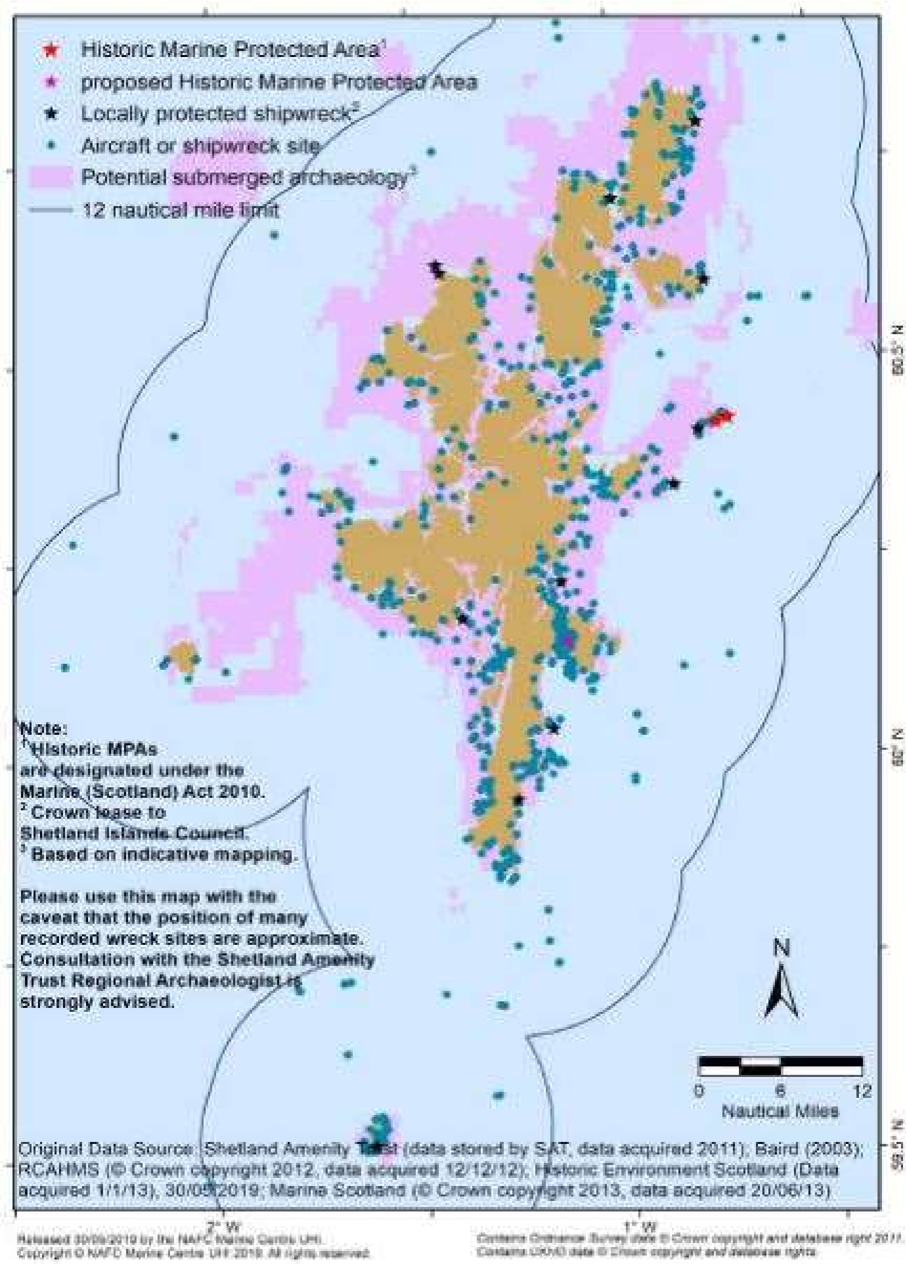


Figure 4-5 The locations of submerged archaeology within the Shetland Island Marine region
Source: Shetland Islands Marine Planning Partnership, 2021

4.2 Socio-economic baseline

4.2.1 Governance and administration

Shetland is a North Atlantic archipelago that is the most northerly part of the British isles and a sub-national jurisdiction of Scotland (Grydehøj, 2013). Shetland is served by a devolved Scottish government, headed by the Scottish First Minister who is formally nominated by the Scottish parliament and appointed by Her Majesty the Queen.

While Scotland is part of the United Kingdom of Great Britain and Northern Ireland, a significant amount of legislative power has been devolved to the Scottish Government (Scottish Government, 2015). The Scottish Government runs the country in relation to matters that are devolved from the UK Government in Westminster, such as health, justice, rural affairs, equal opportunities, local government, transport and taxation (Scottish Government, 2018a). Other matters, including energy policy, foreign policy and defence, are dealt with centrally by the UK government. Consequently, the responsibility associated with the provision of energy across Shetland lies with Westminster.

The administrative structure of Scotland is outlined in Figure 4-6.

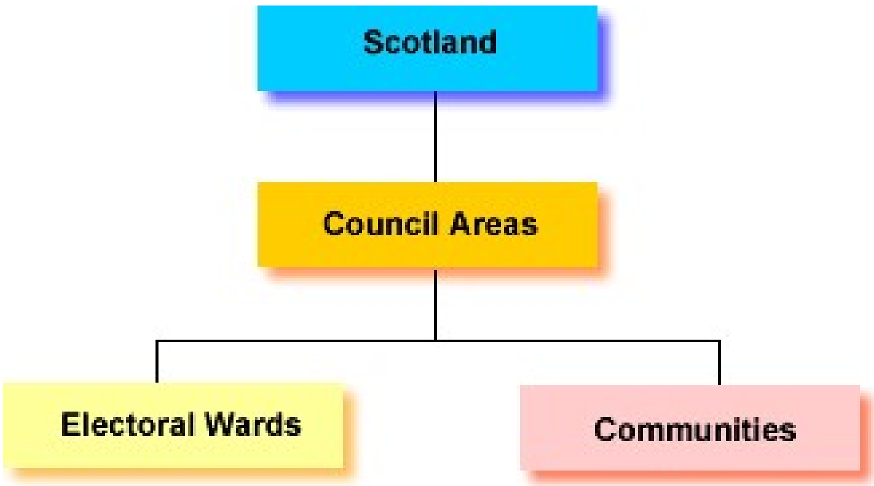


Figure 4-6 Administrative Structure in Scotland
Source: ONS, 2018

Local Government

Local authority areas (or council areas) play an important role in the devolved government of Scotland. Local authorities are autonomous bodies, independent of central government control that are responsible for delivering essential public services in areas such as education, social care, housing and planning, environmental protection and waste management (Scottish Government, 2018b).

There are thirty-two local authority areas in Scotland, each representing a particular geographical region (Campbell and Burrowes, 2016). Scotland's three island communities of Orkney, Shetland and Comhairle nan Eilean Siar are the least populated local authority areas (ibid.).

SIC is the local authority for Shetland and has full control over all developments around the Isles (Tallack, 2007). SIC is made up of 22 elected councillors serving on seven electoral wards (see Figure 4-7). Six out of the seven electoral wards in Shetland are represented by three councillors, while Lerwick South ward has four councillors. Shetland councillors act as policy makers and carry out strategic and corporate functions. They bring local people's views into the council's decision-making process, deal with individual casework on behalf of constituents and assist in resolving community concerns or grievances.

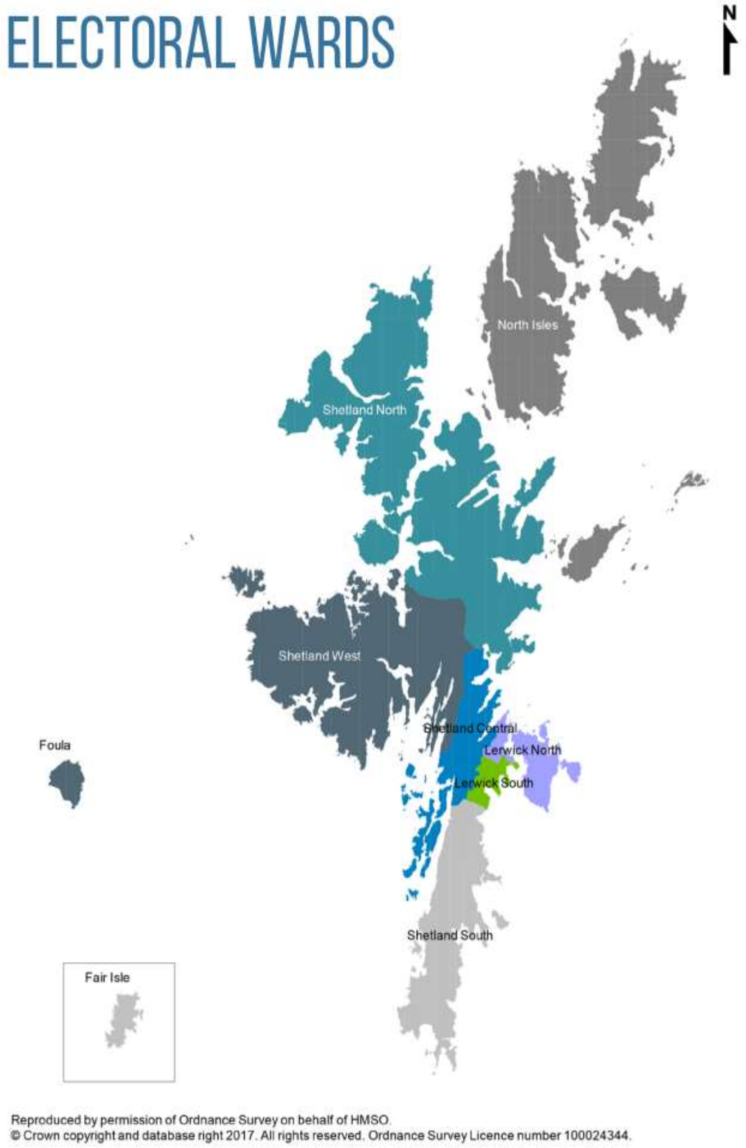


Figure 4-7 Electoral Wards in Shetland

Source: Local Government Boundary Commission for Scotland, 2017

SIC is primarily funded through a block grant from the Scottish Government, which amounts to around 85% of its net revenue expenditure. Additional funding comes from council tax on residential property, charges for local government services (such as car parking fees and income from social care services) and rent from council housing (Scottish Government, 2018c). The main administrative centre of Shetland and the location of the SIC headquarters is the town of Lerwick on Mainland.

SIC is headed by a leader who is elected by other SIC members. In addition to the council leader, SIC members elect a civic head. The civil head in Shetland is the Convener, who represents the islands at civic and ceremonial events at home and further afield. The Convener chairs SIC meetings, facilitates debate, and where possible, enables the council to reach a consensus view (The Scottish Parliament, 2018).

There are also 18 community councils (CC) in Shetland. CCs are voluntary bodies established within a statutory framework. They represent the most local tier of elected representation and play an important role in local democracy by representing local views which can influence decisions on planning and the provision of local services (SIC, 2018d). Many CCs receive council area funding for running costs only and rely on voluntary work and fund-raising. CCs can, however, obtain grants for specific scheme (ONS, 2018a).

4.2.2 Demographics

Shetland is an island archipelago made up of more than 100 islands and islets, 16 of which are inhabited. The islands are situated approximately 160km from mainland Scotland, 280km south-east of the Faroe Islands and 320km west of Norway (NAFC, 2017a). There are four main islands of Shetland: Mainland (899km^2), Yell (212km^2), Unst (120km^2) and Feltar (38km^2) (Shetland, 2018a).

In 2021, the total population of Shetland was 22,940 (NRS, 2022), which is approximately 0.4% of Scotland's total (SIC, 2017a). Around 80% of the islands' total population resides on Mainland, mostly living in the capital Lerwick (McHattie *et al.*, 2018). Between 2001-2021, the population of Shetland increased by 5% while Scotland's overall population rose by 8%. Nevertheless, Shetland had the second lowest population out of all 32 council areas in Scotland and is projected to continue to have the second lowest population as its population size slowly decreases over the next five years (NRS, 2022).

In 2021, there were slightly fewer women (49%) than men (51%) living in Shetland. This is in contrast to the gender ratio of Scotland's overall population, where there are more women (51%) than men (49%) (NRS 2022). As Figure 4-8 indicates, only one out of the six age groups of Shetland's population has more women than men; the 75 and over age group.

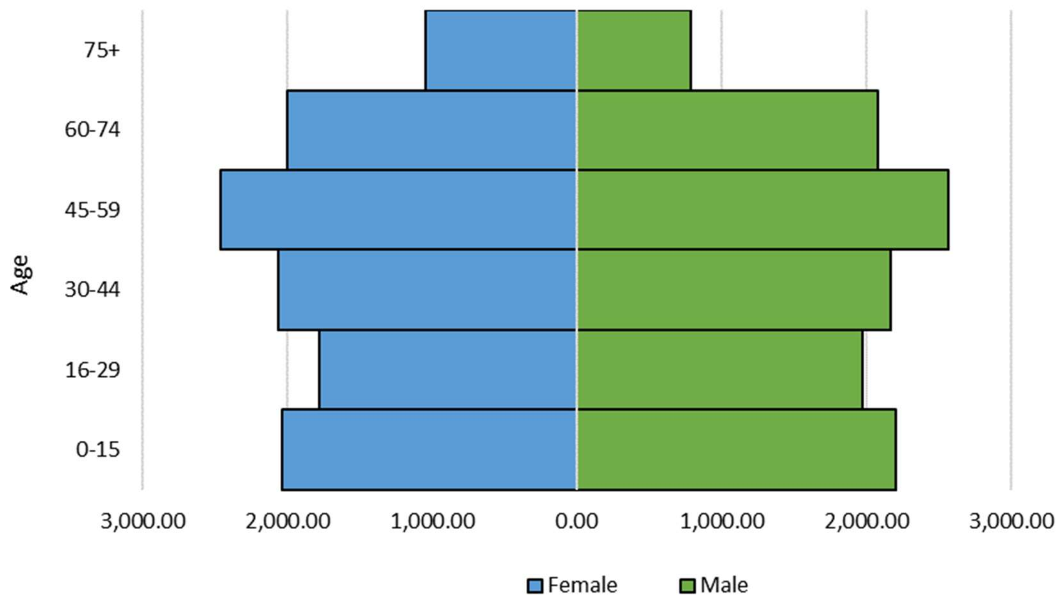


Figure 4-8 Age Profile of Shetland in 2021 by Gender
Source: NRS, 2022

Figure 4-8 illustrates that the largest proportion of the population in 2021 were aged 45 to 64. An estimated 23% of the population in Shetland were aged 25 to 44 years. This is smaller than in Scotland where the figure is 26%. Persons aged 65 or over constitute 21% of the population in Shetland; this is larger than in Scotland where the figure is 19% (NRS 2022). Shetland's aging population means that the islands are beginning to suffer from a demographic imbalance. To redress the impact of the aging population, Shetland needs to attract upwards of 1400 working aged people by 2028 (Shetland News, 2017).

Migration

Shetland is well used to migration flows. Historically, large numbers of workers have been required to undertake various oil and gas related projects and to develop the extensive reserves of oil and gas in the West Shetland basin (HIE, 2015). In more recent years, Shetland has relied on workers from EU countries to support the hotel and hospitality, healthcare and seafood sectors (Politico, 2017; ShetNews, 2020). For example, Shetland's largest salmon farming company relies on EU nationals to make up over 20% of its workforce (COSLA, 2017).

Out-migration is currently greater than in-migration. Between 2015 and 2021, Shetland recorded an average net outflow of about 78 people per year. An average of 627 people per year entered while an average of 660 people per year left. The total net of migrants in Shetland between 2020-2021 was higher for men (64) than for women (59). The age group with the highest out-migration was 15 to 19 years old (-35). In contrast, the age group with the highest in-migration was 20 to 24 years old (NRS, 2022). Out-migration remains a key concern for many in Shetland, with the recent exodus of EU nationals in particular cited as a challenge for the islands' economy.

Within the islands, Shetland has experienced a steady migration of people from remote and rural communities towards its main centres of population (HIE, 2018a) which is negatively impacting rural areas. More affordable housing is needed for Shetland to attract new people to the islands and to grow the local workforce (Marter, 2018), particularly in the North Isles which offer relatively fewer housing and employment opportunities for young people (Cope, 2018).

North Isles

The North Isles of Yell, Unst and Fetlar have a combined population of 1659 (SIC, 2017a). There are some differences between the age profiles in the Unst and Yell population, but the actual numbers are small (Kerr *et al*., 2017).

Yell is the largest of Shetland's North Isles at 83 square miles (133km). It is 17 miles long (27km), 7 miles (11km) wide and has three main settlements, Burravoe in the south, Mid Yell in the centre and Cullivoe in the north (SIC, 2007). Mid Yell lies along a voe, an inlet from the sea, and has a sheltered harbour which has led to its growth as the main settlement of the island.

The residents of Yell and Unst have access to job opportunities and local services. However, forecasts suggest that these population will decline in the years ahead, due to the higher proportion of older people and a slightly smaller population of working age (Kerr *et al*., 2017).

4.2.3 Economy and livelihoods

Economic activity in Shetland is very strong, with high employment and a productive business base (SIC, 2017b). The latest Shetland Regional Accounts recorded local economic output at well over £1 billion. The economic activity rate[8] is over 88%, and the out-of-work benefit claimant count is less than 0.7% (SIC,

[8] The economic activity rate is the number of 16-64-year-old people in work.

2017b). An estimated 76% of the local population was employed in 2022, which is close to the national average of 77% employed in Scotland overall. Only 2% of the total population in Shetland was unemployed (ONS, 2022). However, it is common for unemployed people in Shetland to migrate to mainland Scotland in search of work, and this must be taken into account when considering the islands' low unemployment rate. The average household income in Shetland was £33,934 in 2015, which was lower than the Aberdeenshire (£38,612), the Scottish (£34,619) and the UK average (£36,400), but higher than Highlands (£32,721) and Orkney (£29,808) (HIE, 2015). The lower wages in Shetland are also combined with the higher living costs of the islands. The cost of living in the islands were between 10%-40% higher than on the UK mainland in 2015. According to the Shetland Islands Council, the cost of living has since increased to a total of 20%-60% higher than the UK average (SIC, 2022). The islands also enjoy the fifth highest Gross Value Added (GVA) per head of all Scottish local authorities, behind only Aberdeenshire and the country's three main cities (SIC, 2017b). The main sources of revenue in Shetland are fishing and aquaculture, the petroleum industry (crude oil and natural gas production), agriculture, the creative industries and tourism.

Fishing and Aquaculture

Shetland is surrounded by some of the richest fishing grounds in the world (SIC, 2017b), and the marine and coastal environment is central to the sustainability of the Islands' economy. Fishing is Shetland's biggest industry; the sector supports a diverse range of employment opportunities including fish catching, fish processing, marine engineering, marine transport, oil support services and tourism (SIC and NAFC, 2015).

The aquaculture sector has also become a major industry in Shetland and represents one of Shetland's largest employers, with almost 500 full-time employees working in salmon and shellfish production alone (HIE, 2017). At the time of writing, Shetland produces around one quarter of Scotland's salmon as well as 81% of its mussels (Shetland, 2023). Shetland's aquaculture industry attracted over £17.8 million in capital investment in 2014, paid out £12.9 million in salaries and fostered a local industry spend (on all services required to support production) of roughly £30 million (FFE, 2018).

Collectively, Shetland's fishing and aquaculture industries contribute approximately £320 million per year to the local economy (more than oil, agriculture, knitwear and tourism combined) (Shetland, 2023). The industries directly employ more than 1000 local people, and indirectly support many more jobs and businesses. The total value of Shetland's maritime sector is about £650 million, almost two-thirds of the total value of the economy (NAFC, 2017b) This outpaces the more recently established oil industry several times over (Miller, 2018).

North Isles

Although most fishing in Shetland occurs around mainland, with Lerwick Harbour being one of Britain's main centres for the landing, selling, processing and shipment of seafood, fishing and aquaculture also represents an important livelihood strategy in the North Isles.

Cullivoe harbour in North Yell is the closest designated landing port to the rich fishing grounds to the north of Shetland. The port has recently upgraded its pier facilities and has seen increased whitefish landings in recent years and salmon farming (SIC, 2018c). Cullivoe harbour has a number of charter fishing boats that cater for both tourists and locals. In 2003, the North Yell Development Council (NYDC) opened the Cullivoe Harbour Industrial Estate which provides a key facility for local businesses.

Aquaculture predominantly takes place across the voes and sounds throughout Shetland; it is another cornerstone of the local economy on the island of Yell, and there are a growing number of businesses in the sector. Cooke Aquaculture operates a salmon processing facility in Mid Yell that can process all the salmon the company produces in Shetland (FFE, 2016). The processing facility is the largest employer on the island (Shetland Visitor, 2018).

Petroleum

Oil and gas was first discovered in the East Shetland Basin in the early 1970s (SOTEAG, 2018) and has occupied a principal role in the islands' economy ever since. The oil and gas industry has added around two thousand jobs to the islands' workforce as well as over £100 million to the economy each year (SDS, 2016). Newer oil developments to the west of Shetland have also been connected to the oil terminal at Sullom Voe, which is currently one of the largest terminals in Europe (European Commission, 2013).

Taxes from oil have increased public-sector spending on social welfare, art, sport, environmental measures and financial development. Similarly, the islands' oil revenues have funded the Shetland Charitable Trust, which in turn funds a wide variety of local programmes. The balance of the fund in 2012 was £217 million, approximately £9,500 per head (European Commission, 2013).

Farming

Farming has been a primary part of life for as long as people have inhabited Shetland, with livestock being the dominant enterprise (SAOS, 2017). The islands are considered to have poor arable land in comparison to the nearby Orkney islands (Linklater, 1990), meaning that income and food have always been supplemented by fishing. However, the land is extremely amenable to grazing sheep and the islands boast a large population of sheep, which are used primarily for meat and wool. There is also a long tradition of peat harvesting which is cut during days of favourable weather in May and June, and then dried so that it can be used for winter fuel in stoves and fireplaces.

North isles

Yell is the least cultivated of Shetland's inhabited islands and its settlements tend to lie around the coastal fringe (Undiscovered Scotland, 2018). However, in the north of the island, crofting[9] and sheep farming are common livelihoods. Yell also hosts an increasing number of food production enterprises, which aim to address poor food quality on the island. In recent years, residents and community groups have begun to grow food in "covered allotments"; super-strong polytunnels that are often built with recycled plastic salmon pipes aim to protect produce from winds that frequently exceed 100mph in winter (Financial Times, 2017

4.2.4 Education and health

Education

Shetland's education system covers the entire population between the ages of three and 18. The provision of education is the sole responsibility of SIC who must, by law, provide an efficient and suitable education for all school-aged children. The provision of education includes all aspects of education from the maintenance of school buildings to the delivery of the curriculum.

Schools in Shetland

There is a total of 31 Local Authority schools in Shetland (see Figure 4-9) comprising:

[9] Crofting is a form of small-scale agriculture land leasing arrangement, unique to Scotland and an integral part of life in the Highlands and Islands. A "crofter" is a person who occupies and works the landholding area, known as a croft, paying rent to the landlord of the croft.

- 22 primary schools
- 4 junior high schools (schools with nursery, primary and secondary departments)
- 1 high school
- 1 high school with a nursery and primary department
- 1 school with a nursery, primary and secondary department

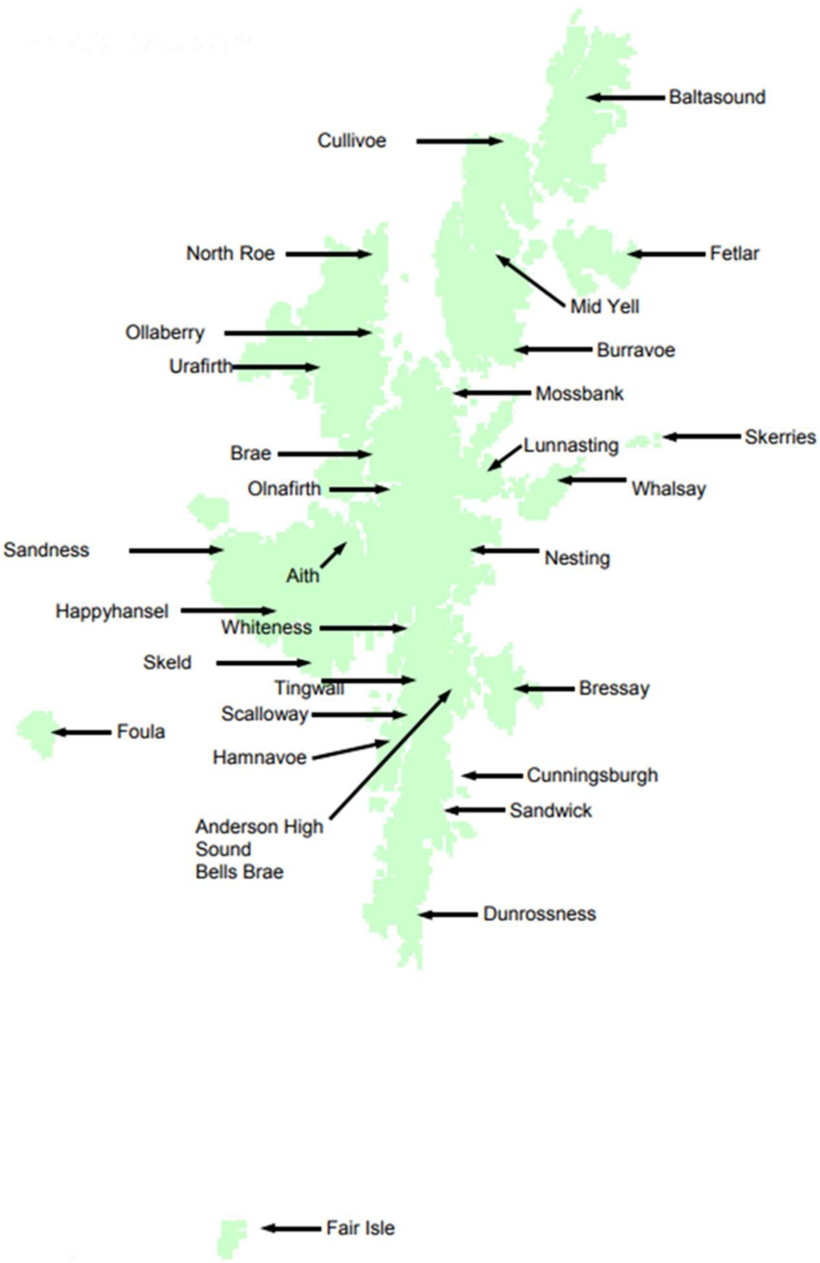


Figure 4-9 Location of Schools in Shetland
Source: *SIC, 2018e*

North Isles

There are three schools and a nursery on the island of Yell. Burravoe Primary School serves the south end of the island from West Yell to Gossabrough and had 13 pupils in 2016. Cullivoe Primary School at the north end of the island had 29 pupils (CPS, 2018). Mid Yell Junior High (MYJH) school provides education for children from nursery to S4. MYJH presently has 73 pupils at primary and secondary level, and there are a further 21 children in the Nursery class (ibid.).

There are schools on two of the other North Isles; Fetlar Primary School on Fetlar has three pupils, while Baltasound Junior High on Unst has 68 pupils (BPS, 2018).

Health

Shetland is well provisioned for the health and social needs of its community. Around 585 staff work in the healthcare sector and 22,045 of the Islands 23,080 residents are registered with a GP (SIC, 2017b). Local hospital and community services are mainly provided from the Gilbert Bain Hospital on Mainland with a further 10 health centres (GP practices) serving communities around the islands.

Shetland has an aging population, which is leading to an increased need for care centres and facilities for elderly people. The islands are also experiencing an increase in the number of people with dementia; 5% of people over 65 (approximately 200 in Shetland) and 20% of those over 80 years of age (NHS and SIC, 2016) currently live with the condition. The islands currently have eight elderly care homes.

When the pandemic struck in 2020, Shetland was initially one of the worst hit areas of the United Kingdom by head of population. Since their first outbreak, the region has had a total of 7,836 covid-19 cases (NHS Scotland, 2023). In April 2021, Shetland had the highest rate of second doses across Scotland. An estimated 44% of the adult population had received both doses of the vaccine, with another 69% of adults having received at least one jab (Shetland Times, 2021).

North Isles

Medical cover for the Yell area is provided by the Yell Health Centre, which has one full-time GP and one Nurse. Elderly care in Yell is provided by Isleshavn, a centre which offers long term residential care, short term or respite care, intensive community support at home and day services to any adult who has undergone an assessment. Unst Health Centre on Unst has 2 doctors and a nurse. Unst's care home is Nordalea, a residential resource centre which provides long term residential care, short term or respite care for adults in the area. Both elderly care centres in the North Isles are run by SIC and have 17 beds and 16 day-support places between them (Kerr *et al.*, 2017).

Residents in the North Isles tend to record lower levels of overall health than other areas of Shetland. Based on GP practice records for 2015, Yell and Unst have the highest rate of hypertension (high blood pressure) of all GP practices in Shetland (Kerr *et al.,* 2017). Yell has had a consistently higher rate of obesity compared to the rest of Shetland since 2006, and Unst has also had a higher rate, although slightly less than Yell (ibid.). High rates of obesity are closely tied to the high rates of diabetes in Yell and Unst. Yell also has consistently higher rates of coronary heart disease than other practices in Shetland (Kerr *et al*., 2017).

4.2.5 Transport and sea navigation

Air, sea and road infrastructure within Shetland is managed and maintained by SIC. ZetTrans is a transport partnership that sits within the council and is the functional provider of all public bus services, and inter-island air and ferry services (ZetTrans, 2018).

Sumburgh airport is the main airport serving Shetland and is located on the southern tip of the mainland, approximately 25 miles south of Lerwick (HIA 2018). The NorthLink ferry is the main service connecting mainland Scotland and Shetland, and provides services between Lerwick, Aberdeen and Kirkwall, operated under public subsidy.

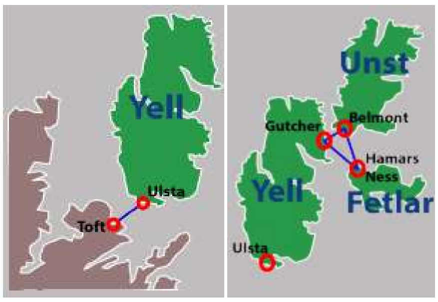
An inter-island ferry service also transports people and goods from Shetland Mainland to the North Isles and other inhabited islands. Inter-island ferries are operated by SIC and make as many as 6000 journeys in a single month, carrying over 88,000 passengers (NorthLink, 2018). Services are fast and frequent; Ferries from Toft (Mainland) to Ulsta (Yell), and from Gutcher (Yell) to Belmont (Unst) run every 15 minutes, seven days a week (SIC 2018b). The price of an adult return fare on ferries from Mainland to Yell, and from Yell to Unst, is £5.50. The price of a return fare for elderly people and under 19s is £1.00 (SIC, 2018b).

Car ownership in Shetland is one of the highest in the UK, but Shetland is also served by a good bus network. The main service centre is Lerwick and it is possible to commute to the town by bus multiple times a day, six days a week from most parts of Shetland, including the Northern Isles.

In addition to Shetland's air, sea and road infrastructure, a launch site and ground station is being developed on the Lamba Ness peninsula in Unst. Known as the SaxaVord Spaceport, this site will be designed to support satellite operations and allow small rockets to deliver payloads. The SaxaVord Spaceport is planning for their first launch to take place in 2023 (SaxaVord, 2023).

North Isles Transport

The ferry from Mainland to Yell operates from Toft, a very small settlement in the north of Mainland, to Ulsta (see Figure 5.9). The larger settlements on Yell, such as Mid Yell and Cullivoe tend to be located in the east and north of the island, meaning that an onward car or public transport connection is typically required from Ulsta. Further, the only main road in Yell runs directly from the ferry terminal at Ulsta at the southern tip of the island to Gutcher in the north, all remaining routes are single track (Yell Community Council, 2018). This contributes to very high levels of household car ownership in Yell (SIC, 2016b). Ferries within the North Isles operate from Gutcher in Yell to Belmont in Unst and Hamarsness in Fetlar (see Figure 4-10).



Route	Crossing Time	Distance (miles)
Toft to Ulsta	20 Mins	2.8
Gutcher to Belmont	10 Mins	1.1
Gutcher to Hamarsness	30 Mins	3.7
Belmont to Hamarsness	30 Mins	4.4

Figure 4-10 NorthLink inter-island ferry routes within the North Isles, crossing times and distances
Source: ZetTrans*, 2018*

A recurring theme for the supply Shetland's transport provision is the relatively high cost of providing transport services. Main issues include: high capital investment required for vessels, ferry terminals and airports; high operating costs due the dispersed population; total travel time, and severe sea and weather conditions (SIC, 2016a).

Bluemull Sound is an active channel for shipping and Cullivoe Pier is busy year-round with traffic associated with the operation of nearby aquaculture fish farms. The level of activity near the site is illustrated in Figure 4-11, which shows surveys of Automatic Identification System (AIS) tracks from vessels in the Bluemull Sound from two, 2-week periods in July 2014 and February 2015. On a typical day, 10 or more AIS-enabled vessels pass within 1km of the array site, with a similar level of activity observed for smaller, non-AIS enabled vessels. The AIS enabled vessels are of a similar size to, or larger than, the multicat vessels used for array operations.

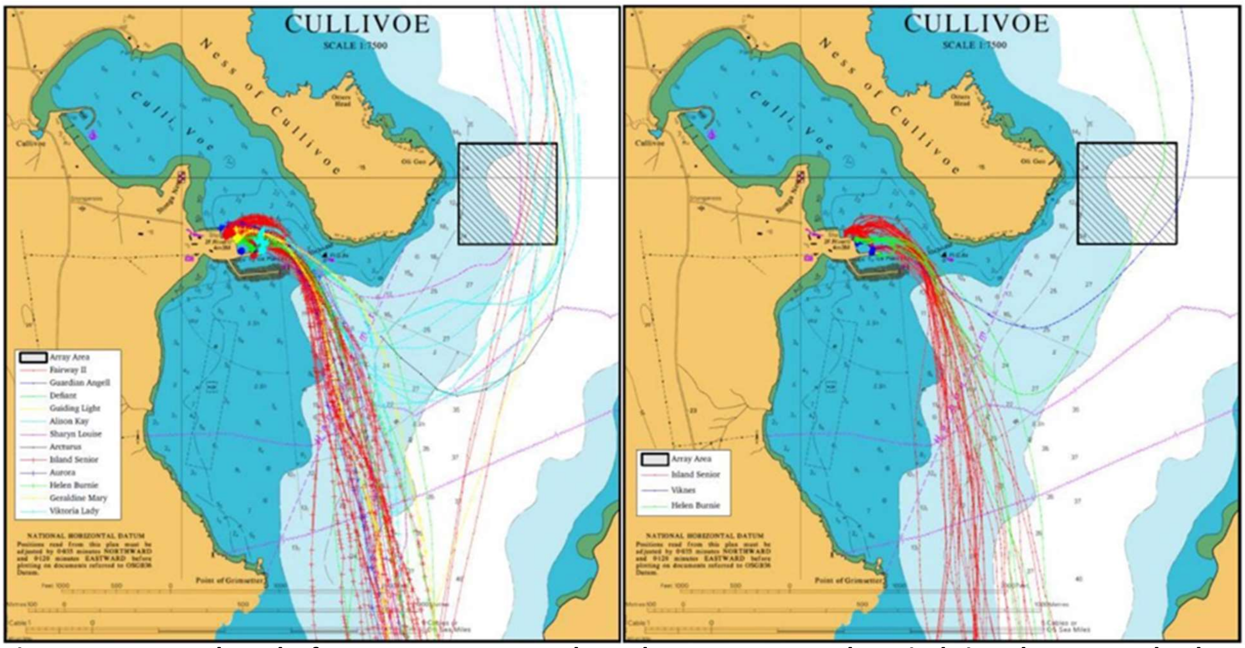


Figure 4-11 Vessel tracks from AIS surveys conducted over two 2-week periods in July 2014 and Feb 2015

Source: Nova Innovation, 2018

4.2.6 Landscape and tourism

The main impetus of Shetland's tourism is the landscape and scenery, and the pristine wilderness that is afforded by the island's sparse population (Miller, 2018). In addition to the remote wilderness, Shetland's weather is considerably milder than its other northern counterparts. While occupying the northern latitudes along with Norway and Iceland, the temperature range of the islands stays between 0 degrees Celsius and 15 degrees Celsius with extremes being only as low as -8 degrees (Miller, 2018).

A survey commissioned by SIC and VisitScotland found that there was a total of 73,262 visits to the isles in 2017, contributing around £23.2 million to the local economy. This represents an increase from 64,655 visits in 2013 (Progressive, 2018). However, the population of holiday or recreational based tourism has been declining over the last 15 years, with the numbers of this kind of visitor falling by 11% (Scotinform, 2014).

The number of work or business-based visitors is increasing; in 2017, 35% of all visitors to Shetland were visiting for professional purposes (Progressive, 2018). Although business tourists typically spend more per trip than recreational tourists, they are less likely to travel to the other islands or even leave the islands' capital, Lerwick (Scotinform, 2014).

With the largest population of all the island's towns and most of the island's businesses and services, Lerwick holds the majority of the island's capital. Lerwick also receives most of SIC funding. In 2017, almost all visitors to Shetland visited Lerwick during their trip, and the majority also visited South Mainland. Around half of all visitors mentioned visiting Central Mainland, North Mainland and Westland; while around a third mentioned visiting the North Isles of Unst and Yell (Progressive, 2018).

The North Isles lend the most potential for experiencing wilderness. They also contain a dense concentration of nature reserves and historic sites. There are several nationally important nature reserves such as the RSPB's Lumbister, the Yell Sound islands and the island of Hascosay (Shetland, 2018b). While there exists the basis for a tourist-based industry on the northern islands, their small populations mean that they rely on a sparse tourist population. Of those tourists who did visit the North Isles in 2017, the most popular attraction was Hermaness Nature Reserve. Just under half also visited the Unst Heritage Centre (Progressive 2018).

4.2.7 Use of the coastal environment and the sea

Shetland is surrounded by productive seas and lies at the heart of rich fishing grounds. The sea has had a strong influence on the islands' economy, culture and heritage (NAFC, 2017c).

Fishing is the biggest industry in Shetland and comprises pelagic fish (e.g., mackerel, herring and blue whiting), whitefish (e.g., cod, haddock, whiting, monkfish and flatfish) and shellfish (e.g., lobsters, crabs and scallops). Pelagic fish live near the surface of the sea or in mid-water and account for the most valuable portion of Shetland's annual catch. Almost 50,000 tonnes of pelagic fish, worth about £41 million were landed in Shetland in 2016. Pelagic fish accounted for approximately two-thirds of the fish landed in Shetland in 2016 (NAFC, 2016b).

Whitefish live on or close to the bottom of the sea. The waters around Shetland contain a wide range of demersal fish, with at least 55 different species caught by local vessels over the past decade (Shetland Fishermen, 2018). Almost 19,000 tonnes of whitefish, worth £33 million were landed in Shetland in 2016 and whitefish accounted for one-quarter of the landings in 2016 (NAFC, 2016b).

Shellfish are found nearer to the shores. Approximately 3,000 tonnes of shellfish, worth almost £5 million were landed in 2016. The weight and value of shellfish landings were substantially higher than in 2015, largely the result of a development of a queen scallop fishery south-west of Shetland during the year by a small fleet of fishing boats. Shellfish continues to account for the smallest proportion of landings in Shetland (NAFC, 2016b).

Most fishing in Shetland occurs around Mainland, with Lerwick Harbour being one of Britain's main centres for the landing, selling, processing and shipment of seafood. Figure 4-12 shows the total weights and values of fish and shellfish landed in Shetland in 2016 by place of landing.

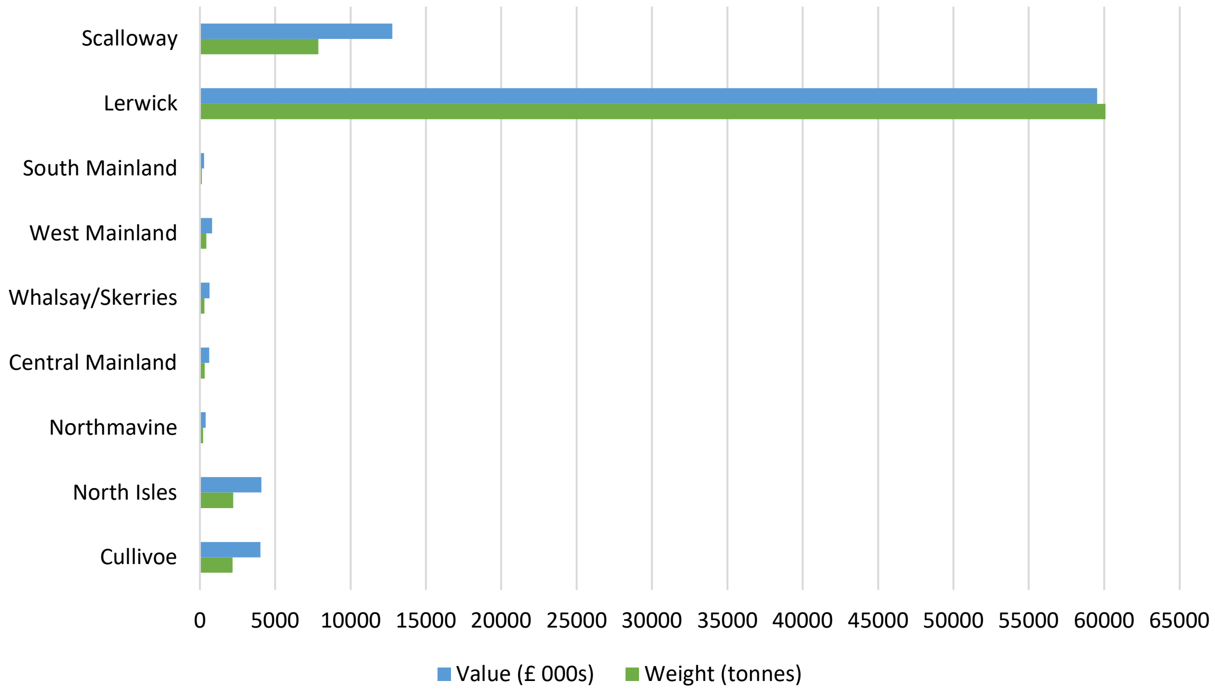


Figure 4-12 Total Weights and Values of Fish and Shellfish Landed in Shetland (by all boats) in 2016 by place of landing
Source: NAFC 2016*b*

North Isles

Figure 4-12 indicates that the North Isles (consisting of Yell, Unst and Fetlar) are the third most productive fishing grounds (after Lerwick and Scalloway) with 2,215 tonnes of fish landed in 2016. Most of the fish caught in the North Isles was landed at Cullivoe which was ranked 25th in the UK for the weight of fish (whitefish and pelagic) and shellfish landed in 2016. The harbour landed one tenth of all whitefish landed in Shetland in 2016 and was ranked 13th in the UK for whitefish landings (NAFC, 2016b). After Lerwick and Scalloway, it is also one of the principal landing places for shellfish. Cullivoe is the closest designated landing port to the rich fishing grounds to the north of Shetland. The port has seen increased whitefish landings in recent years, as well as activity in the renewables sector and salmon farming (SIC, 2018c).

4.2.8 Energy supply and demand

Historically, peat or imported coal or oil was used for heating in Shetland. In recent decades there has been a move away from these traditional sources and households instead rely on electricity.

Current sources

At the time of writing, energy in Shetland is being generated by:

- Lerwick Power Station (LPS): a 67MW diesel-fired station commissioned in 1953. The power station runs mainly on medium and heavy fuel oil. LPS is the islands' primary source of electricity (SSEPD, 2014).
- The Sullom Voe Terminal Power Station, which was originally developed to meet the oil terminal's full electricity needs but later connected to the wider island's network to allow export under a commercial arrangement (SSEPD, 2014). SVT has an installed capacity of 100MW but power levels

vary; it currently exports up to 22MW to the Shetland system and the availability of the SVT in the long term is uncertain (SSEPD, 2014).

- Burradale Wind Farm; a 3.68MW wind farm owned by Shetland Aerogenerators. Burradale was originally commissioned in 2000 and consists of five turbines. Burradale is one of the most productive wind farms in the world (SSEPD, 2018).
- The 4.5MW Garth wind farm, commissioned in North Yell in 2017.
- Several small-scale community-based wind farms and generators.
- Solar energy at a very localised level.

There are five community built and community-owned onshore wind turbines near Cullivoe on Yell. The Garth Windfarm project was set up entirely by members of the community and Northern Yell Development Council (NYDC), who have legal ownership on behalf of the community. The turbines, a substation and electrical connections to the local grid were built in quick succession in early 2017. The windfarm can produce 4.5MW of power and displaces power made by fossil fuels at LPS, reducing Shetland's carbon emissions by up to 12,000 tonnes of CO_2 every year (Tridos Bank, 2017). The windfarm will also generate around £1 million profit per year over the next 20 years creating a substantial long-term income for the island of Yell that will support the local community (Dalby, 2017).

Future plans

Until now, Shetland has not been connected to the national electricity network, and therefore has relied on local sources of generation to meet its own energy needs. At the time of writing, the process to connect Shetland to the UK grid via a 257 km subsea cable and onshore infrastructure is underway. The project is known as the Shetland High Voltage Direct Current (HVDC) link. The first phase of cable was laid in 2022. The project is expected to be completed in 2024. Once Shetland is connected to mainland UK, the distribution and transmission networks will need to be connected at a new substation, known as a Grid Supply Point (GSP). SSE is working to develop and construct the new GSP on land close to the existing LPS.

Work is also underway to develop a large windfarm, the 'Viking Energy Project' which is owned and operated by Viking Energy Windfarm (and its main shareholder, SSE renewables). The Viking project will consist of 103 wind turbines set around the central mainland of Shetland. This wind farm will be powered by turbines running in 4.3MW power mode (ShetNews, 2023). All the turbines are expected to be installed in 2023, with the wind farm anticipated to begin operations by Q4 2024 (Power Technology, 2023). The Viking project has attracted diverse views and opinions and has been met with resistance by some Shetlanders. Key concerns relate to visual impacts on the landscape, and the limited positive impacts for local residents from the community benefit fund.

Challenges

The isolated nature of Shetland's energy infrastructure results in energy supply costs that are significantly higher than in the rest of Great Britain (DECC, 2015). Shetland's maritime climate also means that the islands have a higher-than-average requirement for heating; high wind speeds are common and weather conditions can change rapidly throughout the year (SSEPD, 2014). In 2009, average consumption of electricity per household was more than twice the Scottish average at 10,348kWh (SSEPD, 2014). Further, Shetland contains some 'hard to treat' low thermal efficiency properties, and the population earns less than 75% of the UK average per household income. These factors combined lead to a disproportionate level of fuel poverty in the Islands (DECC, 2015) (see also Section4.2.11).

Despite producing large amounts of the UK's energy in oil, gas and renewable energy, remote parts of Scotland face strong fuel poverty. The Shetland Islands Council made an estimate in 2022 that some 96% of its residents could find themselves in fuel poverty over the next year. They warned that local communities must earn a salary of £104,000 to avoid fuel poverty, which is greatly surpasses the average local salary (SIC, 2022).

The type of fuel used to heat residential houses in Shetland varies and is illustrated in Figure 4-13.

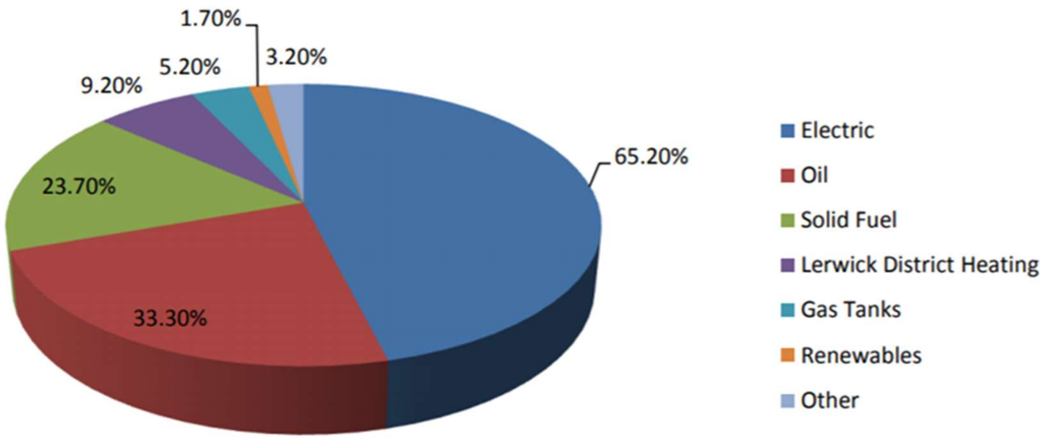


Figure 4-13 Type of fuel used to heat residential houses
Source: SIC, 2013

Figure 5.12 illustrates the main types of heating used in homes in Shetland, according to a survey commissioned by SIC CAB (2013). Electric heating is the most common kind of heating (65.2%), followed by oil heating (33.3%) and solid fuel heating (23.7%). Other heat sources used by residents include gas tanks, renewables and the Lerwick District Heating scheme. Many residents in Shetland use a combination of the sources listed above to heat their homes.

4.2.9 Telecommunications

The Scottish government has recently invested over £600million in funding for digital infrastructure, promising that all Scottish premises would be able to access broadband with a download speed of at least 30Mbps by 2021 (HIE, 2018b).

Shetland is currently in the process of rolling out a fibre optic broadband network across the islands as part of the Government's Digital Scotland Superfast Broadband project (HIE, 2018b). In the past four years, a massive fibre network has been created in the region, through a new backbone of fibre on land and marine subsea cables (HIE, 2018b). While less than 4% of residents in Shetland had access to fibre broadband in 2013, by early 2018 75% of homes and businesses were able to access superfast download speeds of 24Mps or above (HIE, 2018b). However, many of the homes connected to the network are in larger population centres on Mainland, with most residents in Yell and Unst too far from access points and thus less likely to be able to access fibre optic broadband.

4.2.10 Community wellbeing and identity

Shetland consistently scores highly in surveys ranking the quality of life of rural areas in Scotland, either coming top overall, or second behind Orkney. The islands score highly relative to the average for Scotland on several indicators such as health, happiness, community cohesion, life expectancy, employment, school results and low levels of crime.

The prevalence and incidence of mental health problems and mental illness in Shetland is lower than the Scottish average. The percentage of people prescribed medication for anxiety, depression or psychosis in 2014/15 was 14%, while the Scottish average was 17%. The suicide rate in 2009–2013 was 24 per 100,000 people, which was similar to the Scottish rate (Millard *et al.*, 2016).

The crime rate for recorded drug crimes and the crude rate for referrals to the children's reporter for violence-related offences were all lower than Scotland's overall rate. The rate for prisoner population, at 94 per 100,000 people, was significantly lower than the Scottish rate of 171 (Millard *et al.*, 2016).

Shetland is a socially cohesive community with a thriving voluntary base. There are over 600 community organisations, voluntary groups and social enterprises in Shetland, and roughly one third of the adult population gives time to volunteer in the community every year (Scottish Rural Network, 2018). The North Isles have a very high level of community cohesion, with a particularly active third sector (SIC, 2016b).

Table 4.2 presents the Office of National Statistics' estimated levels of personal wellbeing in Shetland. Each of the elements is measured in 'marks out of 10'; for example, people surveyed in 2015/16 felt that their levels of satisfaction with life averaged 8.03 on a scale of 1 to 10. They felt that their anxiety levels measured, on average, 2.56 out of 10, demonstrating high levels of overall wellbeing in Shetland (NHS Shetland, 2017). Average levels of personal wellbeing were higher in Shetland than in Scotland as a whole.

Table 4.2 ONS estimated levels of wellbeing in Shetland

Average (mean) ratings										
	2011/12		2012/13		2013/14		2014/15		2015/16	
	Shetland	Scotland	Shetland	Scotland	Shetland	Scotland	Shetland	Scotland	Shetland	Scotland
Satisfaction	8.12	7.51	0	+0.01	-0.30	+0.05	+0.10	+0.08	+0.11	+0.02
Worthwhile	8.29	7.68	-0.17	+0.02	-0.06	+0.04	+0.07	+0.10	+0.01	-0.02
Happy	8.03	7.31	-0.2	-0.02	-0.01	+0.05	-0.06	+0.08	-0.14	-0.03
Anxiety	2.33	3.06	+0.03	-0.13	-0.14	-0.04	+0.10	-0.06	+0.24	+0.02

Source: NHS Shetland, 2017; ONS, 2018b

Alcohol consumption, however, remains a concern in Shetland, and causes a significant amount of harm to individuals, families and the community. 1 in 3 men (35%) and nearly 1 in 5 (18%) women in Shetland are drinking at hazardous or harmful levels. There were 155 alcohol related hospital stays in Shetland in 2016. The annual cost of alcohol harm to Shetland (in terms of health, social care, crime and productive capacity) was £395 per person (NHS Shetland, 2017).

Yell has an average rate of mental health prevalence compared to the rest of Shetland (Kerr *et al.*, 2017). The rates of new diagnoses of depression in Yell and Unst are within the expected range (ibid). According to the Scottish Index of Multiple Deprivation (SIMD)[10], Unst and Fetlar both have very low levels of crime, but the rates are slightly higher in Yell.

Identity in Shetland is a complicated and contested question. Shetland has unique historical and cultural links with Scandinavia (Malm, 2013); the islands were integrated into the Norwegian state in about 875 and the remained under Scandinavian rule until the mid-13th Century (ibid.). Though Shetland passed over to Scotland in 1469 (McHattie *et al*., 2018), the Scandinavian connections remain strong, culturally as well as linguistically (Malm, 2013).

Shetland is fiercely independent in spirit and many Shetlanders today view themselves not as Scottish, but as a separate cultural identity with a distinct heritage and tradition (McHattie *et al*., 2017), which stems from a continuous dialogue with neighbouring cultures across the whole north Atlantic region and beyond.

The Old Norse[11] language is in practically every place name in Shetland; Lerwick utilises Old Norse to anchor the significance of its place name: Lerwick or "Leirvik", meaning "Muddy Bay" (Shetland Heritage, 2018). The strength of Shetland's "Scandinavian sympathies" are physically and visibly expressed through the well-preserved archaeological sites, the Island's flag[12] and the winter festival of Up-Helly-Aa which serves as a vivid reminders of the islands' Viking past (Visit Scotland, 2018). The Island's motto, which appears on the SIC coat of arms is "*með lögum skal land byggja*". This Icelandic phrase means "*by law shall the land be built up*".

Although English is the medium of written communication, Shetlandic is still a living spoken dialect with a distinctive Scandinavian lilt. Many Shetlanders write in local dialect on social media (De Luca, 2017).

4.2.11 Vulnerable and disadvantaged groups

Shetland faces specific issues around geographical remoteness, declining populations, ability to access fuel, transport, digital connections and services.

Living costs in Shetland, and especially in more remote parts of the islands, are significantly higher than in many other parts of the country (SIC, 2016b). In 2016, a minimum acceptable standard of living in remote rural Scotland typically required between a tenth and a third more household spending than in urban parts of the UK (IPSOS, 2016). This contributes to what has been called "hidden" incidences of poverty and deprivation in many rural island communities, that are sometimes masked by national data (NHS Shetland, 2018). The most prevalent household income bracket in Shetland is £10-20K, which is below the UK average of £23,474 (Scottish Parliament 2017). Average incomes are slightly lower in the North Isles than in other parts of Shetland.

Owing to the relatively low household income of many Shetlanders and the relatively high cost of living in Shetland, 43% of all households are estimated to be living in fuel poverty[13] (2015). The proportion of

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[10] SIMD is the Scottish Governments official tool to identify areas of multiple deprivation in Scotland.

[11] Norse is the old Germanic (Norwegian) language used in Shetland

[12] The Shetland Island's flag uses the colours of the flag of Scotland, but in the form of the Nordic cross in order to symbolise Shetland's historical and cultural ties with the Nordic region. The colours and device are the inverse of that of the flag of Finland.

[13] Fuel poverty is where a household has to spend more than 10% of its income on heating costs.

pensioners estimated to be living in fuel poverty in Shetland is 68% (ibid.) These figures are higher than the Scottish average of 39.1% (Scottish Government, 2014) and similar to Orkney, where the rate is 63% (the highest in the United Kingdom) (OIC, 2016). In England, the incidence of fuel poverty is 11.1%, in Wales it is 23%, Northern Ireland is 22% and across the UK the incidence is estimated to be 15%.

Over 13% of households in Shetland are estimated to be living in extreme fuel poverty[14] (SIC, 2015). However, fuel poverty levels in Shetland are likely to be considerably higher than these figures suggest as no detailed surveys have taken place since 2013. It is thought that over 60% of all households in Shetland could currently be living in Fuel Poverty (SIC, 2015).

Shetland's high rates of fuel poverty can be attributed in part to the climate, strong winds, and wind-chill. A combination of these factors means households need to have heating on for a higher proportion of the year than elsewhere in the UK (SIC, 2015). It is estimated that Shetland households need to use twice the national average amount of energy per home (SSEPD, 2014). There is also a higher energy tariff levied in the Highlands and Islands and a lack of cheaper alternative heating sources, such as mains gas. Additionally, many houses in Shetland, particularly in the North Isles, are in poor physical condition and this exacerbates the costs and overall challenge of keeping homes warm. In response to this challenge, SIC are currently implementing an energy efficiency scheme to residents and businesses in Shetland, providing them with energy inspections and grants to improve energy efficiency (such as window and loft insulation) within properties.

[14] Extreme fuel poverty is where a household has to spend more than 20% of its income on heating costs.

5 Stakeholder Engagement Activities and Outcomes

This section provides a summary of the findings from stakeholder engagement activities that have been completed during preparation of the ESEA Report.

5.1 Engagement with the local community

The local community were engaged through the following activities:

- Through a postal questionnaire that was sent by SIC to all residents on Yell during August 2018;
- During a trade fair called the 'Yell Show' held at East Yell Public Hall on 01 September 2018;
- During a series of focus group discussions completed during November 2018, June 2019 and June 2023;
- Through workshops with students in schools based in Yell, Unst and Lerwick during November 2018, June 2019 and June 2023;
- Through a series of key informant interviews completed during June 2023.

5.1.1 SIC postal questionnaire

During August 2018 SIC sent out 455 questionnaires to all households on Yell which included four questions inserted by Nova. The questionnaire asked residents to provide responses to the following four questions and measured attitudes and opinions on a Likert scale[15]. A total of 105 questionnaires were returned, with only two households not competing the four questions raised by Nova, reflecting a response rate of 23%.

A summary of the responses received for the questions inserted by Nova is provided in Figure **5-1**.

Question 1. In general, to what extent do you support the development of the following energy technologies in Shetland?

a) Offshore wind energy
b) Onshore wind energy
c) Tidal energy
d) Biomass
e) Solar energy

Figure 5.1 shows the extent of support for each type of energy technology.

[15] The Likert scale is a commonly used survey technique designed to uncover different degrees of opinion. Respondents are asked to select a rating on a scale (e.g. 1 to 5) that ranges from one extreme to another, such as "strongly agree" to "strongly disagree".

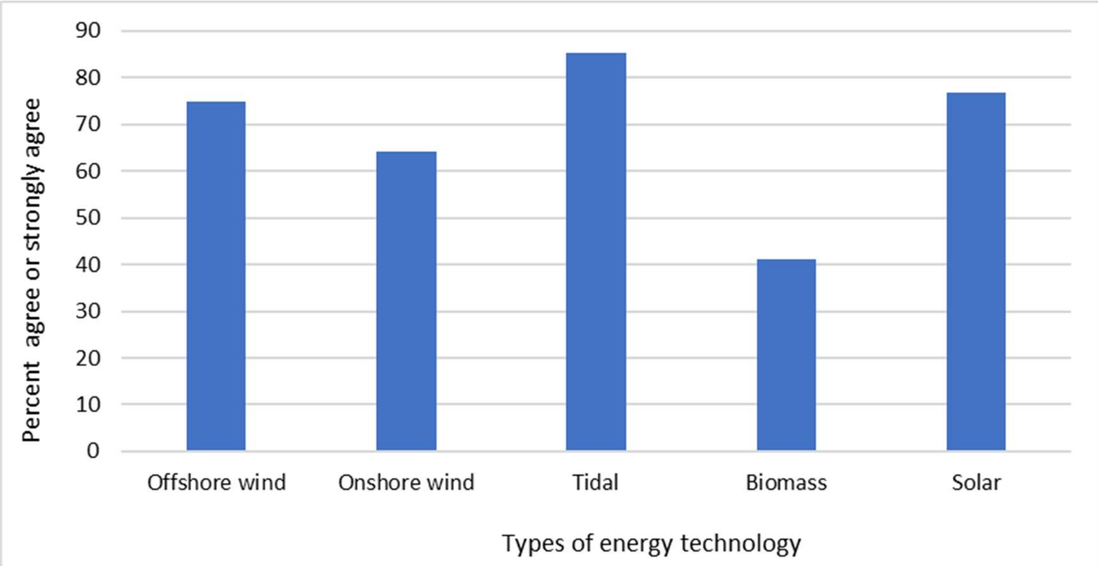

Figure 5-1 Percentage of respondents who either 'agreed' or 'strongly agreed' with the development of each type of energy technology

The responses from Question 1 indicate that tidal energy has the greatest level of support with 85% of respondents indicating that they 'agreed' or 'strongly agreed' with the development of this type of technology.

Question 2. Are you aware of the renewable tidal energy demonstrator project that is currently active in Bluemull Sound, near Cullivoe, led by Nova Innovation?

The results from Question 2 indicate that 87% of respondents were aware of the demonstrator project.

Question 3. At present, most of our electricity comes from diesel generators at Lerwick Power Station. Scottish and Southern Electricity (SSE) currently plan to continue operating the power station until at least 2025. Please indicate to what extent you agree with each statement below:

a) I am supportive of the tidal energy project being implemented in Yell
b) I am content with the existing, main source of electricity
c) Shetland should make use of its natural resources (e.g. wind, tide, sun) to generate energy locally
d) Shetland should not be using fossil fuels, which contribute to climate change, to generate its electricity
e) Electricity in Shetland is unreasonably expensive

Figure 5-2 presents the responses from Question 3. The data has been converted into percentages and shading has been applied to group the range of values, with the most frequent responses shaded in dark green.

Question 3	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
3a – Support the tidal energy project	1	3	10	25	61
3b – Content with main source of electricity	11	26	45	16	2
3c – Shetland should use its natural resources	2	0	8	26	64
3d – Shetland should not use fossil fuels	5	3	35	30	27
3e – Electricity in Shetland is expensive	1	3	26	30	40

Figure 5-2 Responses to Question 3

Figure 5-2 indicates that 86% of respondents to Question 3 were supportive[16] of the tidal energy project. Only 18% of respondents 'agreed' or 'strongly agreed' that they were content with the existing main source of electricity. A total of 90% 'agreed' or 'strongly agreed' that Shetland should make use of its natural resources to generate electricity locally and move away from the use of fossil fuels. A total of 70% of respondents indicated that electricity in Shetland is expensive.

Question 4. In the future, Shetland may be able to use its strong tidal currents by further developing tidal energy projects at one, or more, locations along the coastline. This would give more source options for the provision of our local electricity supply and reduce carbon emissions. Please indicate to what extent you agree or disagree with each statement below:

a) I would support development if it worked in harmony with the environment, and with other users of the sea
b) I would support this development if it does not increase the cost of electricity
c) I would support the use of different electricity charges to encourage the use of cleaner forms of generation
d) I would support this development if it contributed to growth of the local economy (supply chain, investment, jobs and skills)
e) This type of development would contribute to Shetland's energy security
f) I would be interested to participate in this type of development (professionally via supply chain, financial support, or in other ways)

The responses to Question 4 are illustrated in Figure 5-3 and expressed as percentages using the responses received.

[16] Respondents are considered 'supportive' if their response to the statement is "agree" or "strongly agree".

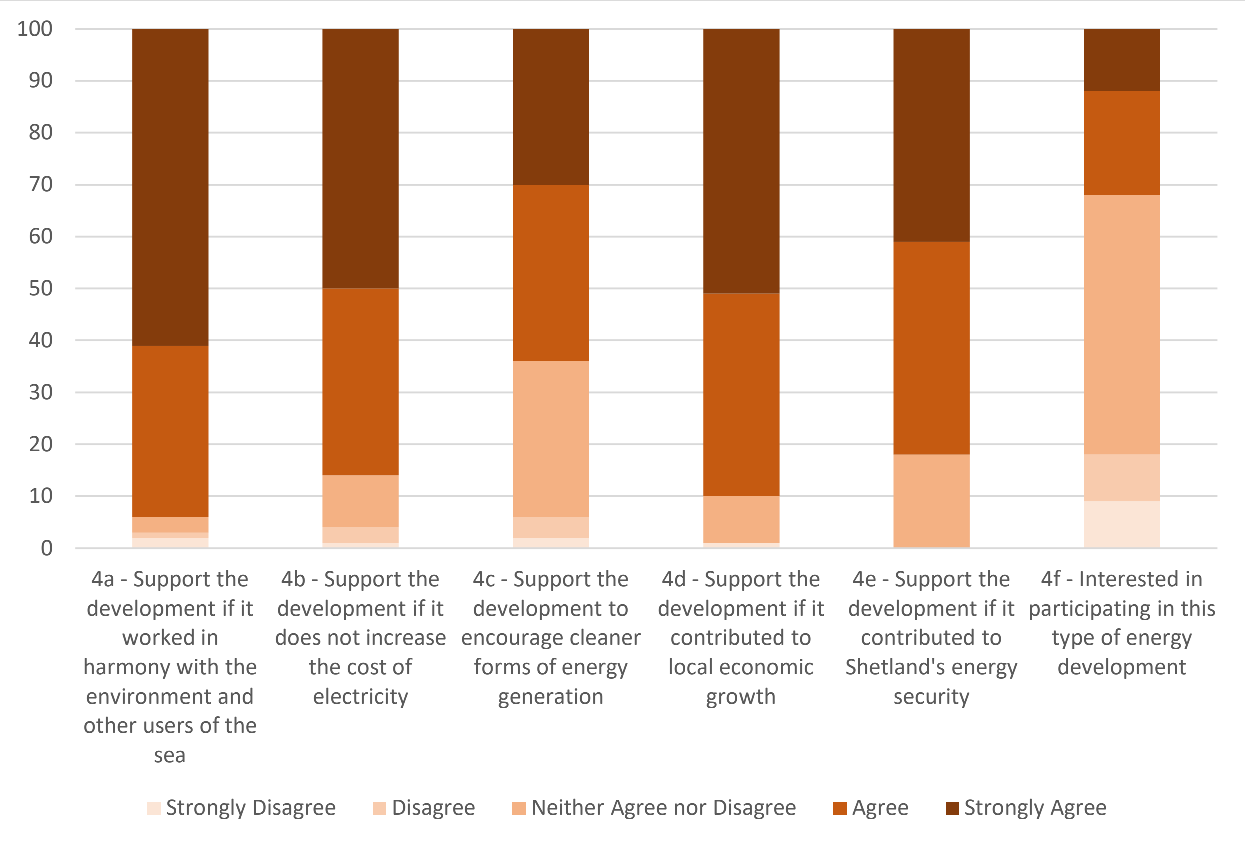

Figure 5-3 Responses to Question 4

Figure 5.3 indicates that the majority of respondent to Question 4 support tidal energy development if it worked in harmony with the environment and with other users of the sea, did not increase the cost of electricity, and contributed towards Shetland's energy security and local economic growth.

5.1.2 Attendance at the Yell Show

The 2018 Yell Show was attended by approximately 500 people from a wide age range who live in Yell or elsewhere in Shetland. The Yell Show is mainly an agricultural event showcasing livestock (sheep, cattle, Shetland ponies, poultry) alongside farming machinery that is available to hire or purchase from local companies.

Within the building used for the Yell Show a variety of community-based competitions were ongoing, including baking and photography. A variety of organisations active in Yell were also present, such as the Royal National Lifeboat Institution, SIC and local charities. Nova and RSK jointly attended the event with a stand as this provided a valuable opportunity to meet local people, provide information on the tidal energy project, introduce the EnFAIT project and discuss the tidal energy devices with local people.

The stand used was branded with Nova's logo and brochures on Nova's activities and EnFAIT were available for local people to read through and take home with them. A 1:70 scale model of a tidal energy turbine was used to attract people to the stand, along with two laptops showing the EnFAIT video and a 20-second video of underwater footage from a device with rotating blades on a continuous loop. The video of the turbines moving underwater attracted people to walk towards the stand and discuss the project with Nova/RSK. In total approximately 50 visitors visited the stand during the event and local people were asked to complete a feedback form after learning about the project.

A total of 22 feedback forms were filled in to gain an understanding of local people's awareness of the project, perceptions of tidal energy, and communication preferences for receiving future updates on progress. In general, people viewed tidal energy as 'favourable'; 68% were 'very supportive' and the remainder 32% were 'supportive', particularly when compared with wind power which had less support due to the perceived landscape and visual impact.

Almost all visitors attending the stand (95%) were aware of the tidal energy project being implemented in the Bluemull Sound, many of whom had heard about the project through word-of-mouth. There was a lack of understanding of the progress achieved to date with over half of visitors not realising that the devices were already deployed underwater and were actively generating energy. 32% of people were aware that the project will be expanded from three turbines to six as part of the EnFAIT project. Upon learning more about the project there was a general desire to receive future information updates with the preferred method used being the local newspaper, social media and from local radio.

5.1.3 Focus group discussions

Phase 1 (2018 and 2019)

During the first round of community engagement (Phase 1), community focus group discussions (FGDs) were held at Cullivoe Community Hall in Yell and at Islesburgh Community Centre in Lerwick. These FGDs took place in November 2018. The aim of the FGDs was to investigate local perceptions towards the project and this type of renewable energy technology, explore ongoing socio-economic change in Yell and Shetland, and how to spread the awareness of the project amongst the local community. People were invited to attend by Nova and between eight to ten people were present at each session.

The discussion started with a short introduction to the representatives present from Nova/IDETA/RSK and a video available on the EnFAIT website was played to introduce the project. After a short pause for questions, the discussions commenced with the RSK facilitator asking questions to the group (Figure 6.4) to start a discussion.

Figure 5-4 Community focus group discussion at Cullivoe Community Hall

All FDGs were supportive of the development and were very interested to learn more about the project. Key points raised during the community focus group discussions included the following:

1. The project could assist in broadening young people's knowledge on renewable energy technologies and encourage them to study engineering and practical vocational skills. It was

noted that schools usually focus on university enrolment where many young people study media courses, rather than encouraging people to seek apprenticeships and vocational studies.

2. The project could encourage young people to stay in Shetland which may prevent the continuing out-migration of young people. It was noted that many students travel to the mainland for further education and decide not to return as they become overqualified and there are few specialised jobs in Shetland.
3. Shetland should market itself as a centre for renewable energy potential due to planned onshore wind energy developments and given the tidal energy resource available. The creation of a 'green' energy island could also encourage more tourists to travel to Shetland.
4. There was concern about the potential for marine fauna (such as fish and otters) to be harmed by the rotating turbines. Nova subsequently explained that the otter species typically dives to a maximum depth of 3m, and an environmental monitoring framework had been established which uses underwater video cameras. To date, there have been no collisions observed between the blades and marine wildlife which includes diving seabirds.
5. The project is not well known by many local people, with some even questioning whether the turbines are installed below the sea surface, as they are not visible. It was suggested that Nova install a sign and provide more information to local people.
6. There was a general desire for Nova to establish a maintenance workshop on Yell which could employ more local people. There is potential for a light industrial facility to be constructed close to Cullivoe Pier, extending the existing facility; this could be used by Nova for turbine maintenance, as well as by other local companies.
7. Whilst the generation of renewable energy is a positive outcome from the project, it is not expected to result in lower electricity prices to household consumers and businesses. This is due to the way in which electricity supply is managed across the UK through supply contracts with energy companies.
8. The fact that the tidal energy device structure and turbines are not visible is important for the public acceptability of this type of technology, particularly when compared with onshore wind which has significant local opposition due to its visibility. A further advantage is the absence of an onshore footprint; the project will neither damage peatlands nor change drainage networks as a result of the installation of access roads, typically required by onshore wind power projects.
9. There is a high level of expectation associated with Nova's ability to generate local employment opportunities in Yell and elsewhere in Shetland because of the project. It was noted that Nova have several specialised employment positions in Edinburgh but none in Yell, with currently a single permanent employee based in Shetland. However, it was also acknowledged that Nova have made extensive use of both local companies and Shetland-wide services to provide hotel accommodation and transport and vessels to deploy/retrieve the tidal energy turbines. Additionally, it was recognised that Nova have employed a Shetlander who (at the time) lived in Edinburgh and works as an offshore operations engineer (he has since returned with his family to live in Shetland).
10. It was recommended that a visitor resource should be established at Cullivoe Pier to attract tourists to travel to this location and learn more about tidal energy technology. The resource could include, for example, a large notice board, live video feeds from the underwater cameras, and information about the energy level being generated and supplied to the grid.

Phase 2 (2023)

During the second round of community engagement (June 2023), community discussions were held with stakeholders. These discussions took place through open house drop-in sessions at Cullivoe Community Hall in Yell and Islesburgh Community Centre in Lerwick.

The aims of the discussions were to: obtain the input of stakeholders in terms of both the impact of the project on their lives and livelihoods, and on their perceptions of the project and tidal energy more generally; understand how these perceptions may have changed over the duration of the EnFAIT project and provide opportunities for stakeholders to express their opinions, concerns, and recommendations.
The main aim was to provide stakeholders with an update on project progress and investigate if there were any changing local perceptions towards the project, tidal technology and also towards renewable energy in general.

The discussions started with introductions to the representatives present from Nova and RSK, followed by a video of the EnFAIT project . The RSK facilitator asked the following questions to the attendees:

1. How important is the marine and coastal environment to the a) sense of identity and b) livelihoods of people in Shetland?
2. In your opinion, what are the key challenges related to energy in Shetland (and in Yell)?
3. At this time, how supportive are you of the tidal energy project based at Cullivoe pier?
4. In your opinion, how might views / perceptions change if the project were to increase in scale in the future?

Following the discussions, time was set aside for a dedicated question and answer session.

Attendees were also asked to fill out a four-question survey, which is discussed in Section 5.1.4.

All focus group discussion attendees were in support of the EnFAIT project. Key points raised during the discussions included the following:

- Tidal energy is regarded as more reliable than wind energy. It also creates little to no visual impact, which makes it extremely favourable amongst the local community. Tidal energy was noted by one attendee as “just another means of using the sea”, meaning harvesting the tides for energy is no different than harvesting the waters for fish.
- Energy companies on the islands need to decide which energy projects get to give what amount of power to the local grid. It was acknowledged that there will be times when the tidal array will not be allowed to provide power to the local grid, and thus will not be able to be used at full capacity (without co-located storage capacity).
- Viking is producing far more energy than locally needed to be exported to the national grid, creating tensions amongst the local communities as to why Shetland needs to supply the energy for the rest of the region. There is a general consensus that the local communities are not seeing enough direct benefits from the Viking wind farm profits, which has resulted in increased negative perceptions towards large-scale renewable energy projects in general. There is also the rising fear that Shetland is becoming too industrialised as an island.
- Unlike the Viking wind farms however, the NYDC wind farms have received full support by the local communities because the communities can clearly see the project’s profits return directly to the community. It was highlighted that community development is critical to the continued support from the locals.
- Locals are aware that there are currently a handful of proposed energy projects that may develop on the islands. It was recognised that this potential increase in energy projects could result in an increase in the cost of labour, as demand continues to expand while the scale and availability of local labour remains limited.

- Attendees were interested in understanding if the EnFAIT project had any upcoming plans for expansion. An expansion in tidal energy would be welcomed over the development of more wind farms on the islands.

5.1.4 Key Informant Interviews

Various key informant interviews (KIIs) took place throughout Yell and Lerwick during the second round of community engagement (June 2023), with the purpose of gathering perceptions and opinions from identified stakeholders who have first-hand knowledge about the community. Six one-on-one interviews took place, with a total of eleven interviewees. KIIs were held with:

- Shetland Islands Council – Ports and Harbours Authority;
- Shetland Islands Council – Transport, Infrastructure and Environment Committee;
- Shetland islands Council – Future Energy;
- RS Henderson Haulage Company;
- Distribution Network Operator, Scottish & Southern Electricity Networks', Lerwick Power Station;
- Shetland Environmental Ltd, tourist guide and environmental surveys.

Questions asked during the KIIs included:

1. What is the role of your organisation and what are your activities (in general and/or for the EnFAIT project)?
2. Do you have any perceptions of impacts from the tidal energy project on the physical/socio-economic environment?
3. At this time, how supportive are you of the energy project?
4. Have any other (external) stakeholders raised any concerns about potential impacts?
5. How has people's interest/ awareness of the project and renewable energy in general changed in Shetland over the past few years?
6. In your opinion, how might views of acceptability change if the project were to increase in scale in the future?
7. What are the key challenges for electricity supply and demand in Shetland?
8. Any other questions?

Similar to the FGDs, the KIIs started with a short introduction to the representatives present from Nova and RSK, followed by the same EnFAIT project video. After a short pause for questions, the discussions commenced with the RSK facilitator asking questions to the attendees. Attendees were also asked to fill out a four-question survey, which is discussed in Section 5.1.5.

All key informant interviewees were in support of the EnFAIT project. Key points raised during the discussions included the following:

- There are no negative perceptions felt towards the EnFAIT project. Many interviewees showed great interest in the tidal array and preferred an expansion of the tidal technology over more wind farms.
- Shetland continues to tackle fuel poverty as energy costs continue to increase. Harsh climate and poorly insulated infrastructure simultaneously result in an inefficient use of energy and a high demand for it. Recent events, such as Brexit and the pandemic, have likewise escalated fuel poverty struggles.

- The continuing rise in energy costs has created increasing frustration amongst the locals about how renewable energy is being developed and implemented on the islands. Several community members mentioned feeling like their communities are disproportionately bearing the burdens and costs to host large renewable energy projects.
- There is concern about harnessing Shetland's resources for the benefits of other regions of the UK. The community generally does not want their energy resources to primarily serve others before their own communities.
- Locals do not believe they are seeing enough direct benefits from the Viking wind farm profits, causing tensions and a lack of support by the communities. Interviewees have also repeatedly voiced their concerns with the visual impact of the large-scale wind turbines on the islands.
- Community members are appreciative of the electric vehicle charging station located in Yell that is powered by the tidal array. It has been regarded as a clear example of the direct community benefits locals receive from the project.
- Nova is employing Shetland Composites to additionally manufacture the blades for other Nova tidal energy projects internationally. This includes projects developed by Nova in France and Canada.
- Awareness of the EnFAIT project happening on Yell is high. However, few are aware of the project's progress or outcomes. This is partly due to the fact that the tidal turbines are largely out of sight, and therefore cause no visual impact.
- Some stakeholders commented that the project could be doing more to inform the general public of the project's ongoings and benefits, such as through advertisement, PR and media, and continued engagement.
- Local Shetland skills, knowledge and expertise has been highlighted as key to facilitating success of this project. Shetland has a great deal of local engineering knowledge in particular due to the islands' thriving oil and gas industry.
- Brexit has greatly affected the work labour in Shetland over the past few years, with the out-migration of EU nationals leaving vacancies in several industries. This has especially taken a hit on the local hospitality industry.
- Vacancies are common in the public sector due to recruiting from a relatively small pool of prospective employees. Public sector institutions are struggling to compete with large companies in the private sector that can offer more competitive salaries.
- The greater the scale, the greater potential for collision impact. If the tidal array was to expand, it will be important that that marine life has a clear route through the tidal turbines. The turbines will need to be placed in a pattern that complements the movement of local marine life. The movement patterns of local marine life will need to be identified.
- No clashes have been reported by any users of the pier at Cullivoe. Stakeholders agree that there has been good cooperation and collaboration by all parties, with minimal interference to existing activities and operations.
- If the scale of the tidal array was to increase in the future, consultation with fishermen and other stakeholders will be required to ensure that there remains no interference with fishing or navigation. Project planning should take into account existing infrastructure and activities at potential future sites.

5.1.5 Survey questionnaire

All community members engaged in the June 2023 FDGs and KIIs were asked to complete a four-question survey aimed at understanding the level of support and interest stakeholders had, and could continue to have in the EnFAIT project. A total of 14 surveys were submitted, reflecting a 100% response rate.

A summary of the responses received for the questions is provided in Figure 5-5, Figure 5-6 and Figure 5-7. Community members were asked to answer to what extent they support or agree with the following topics and sentences, rating them between a number of 1-5; with number 1 meaning "strongly disagree" and number 5 meaning "strongly agree".

Question 1. In general, to what extent do you support the development of the following energy technologies in Shetland? *Please indicate to what extent you agree with each statement in the table below.*

a) I support offshore wind energy
b) I support onshore wind energy
c) I support tidal energy
d) I support biomass
e) I support solar energy

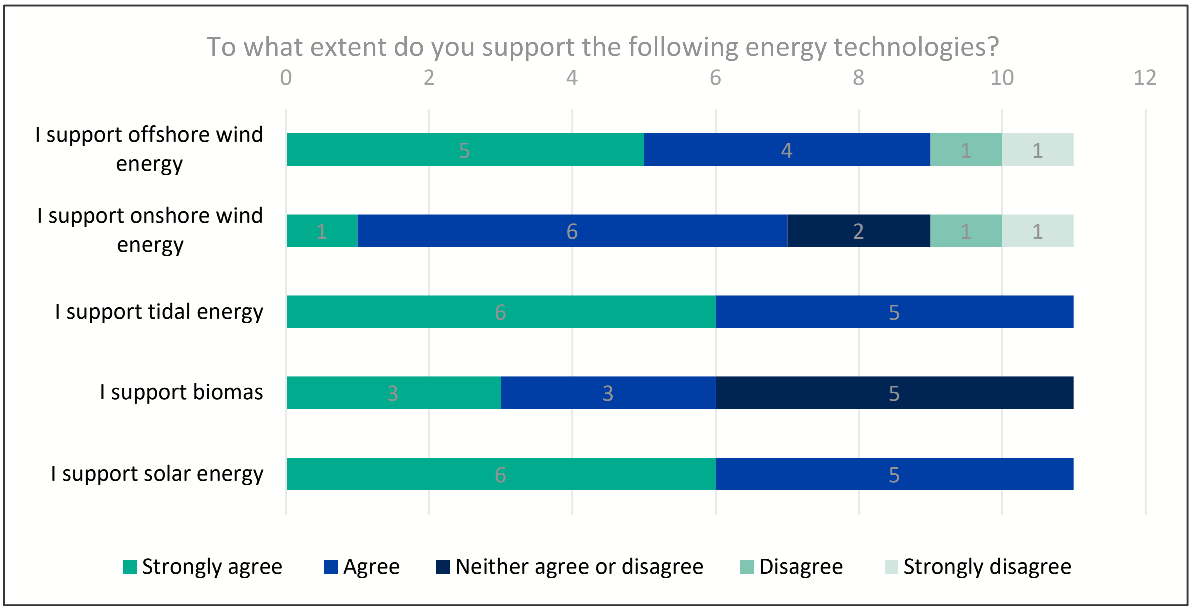

Figure 5-5 Q1 responses

Question 2. The majority of Shetland's electricity comes from diesel generators at Lerwick Power Station operated by Scottish Southern Electricity Network (SSEN). The station is currently near the end of its scheduled full duty operational life. *Please indicate to what extent you agree with each statement below.*

a) I am supportive of the tidal energy project being implemented in Yell
b) I am content with the existing, main source of electricity
c) Shetland should make use of its natural resources (e.g., wind, tide, sun) to generate energy locally
d) Shetland should not be using fossil fuels to generate its electricity.
e) Electricity in Shetland is too expensive

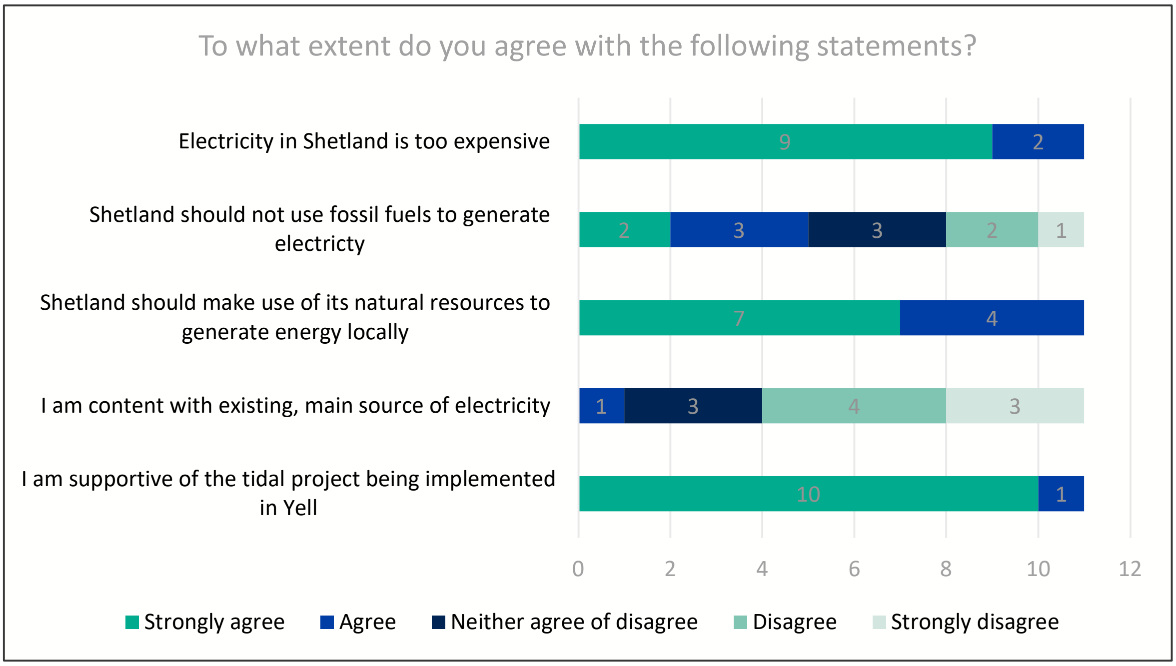

Figure 5-6 Q2 responses

Question 3. In the future, Shetland may be able to use its strong tidal currents by further developing tidal energy projects at one, or more, locations along the coastline. This would give more source options for the provision of local electricity supply and also reduce carbon emissions. *Please indicate to what extent you agree or disagree with each statement below.*

a) I would support this development if it worked in harmony with the environment, and with other users of the sea.
b) I would support this development if it does not increase the cost of electricity.
c) I would support the use of different electricity charges to encourage the use of cleaner forms of generation.
d) I would support this development if it contributed to growth of the local economy (supply chain, investment, jobs and skills).
e) This type of development would contribute to Shetland's energy security.
f) I would be interested to participate in this type of development (professionally via supply chain, financial support, or in other ways).

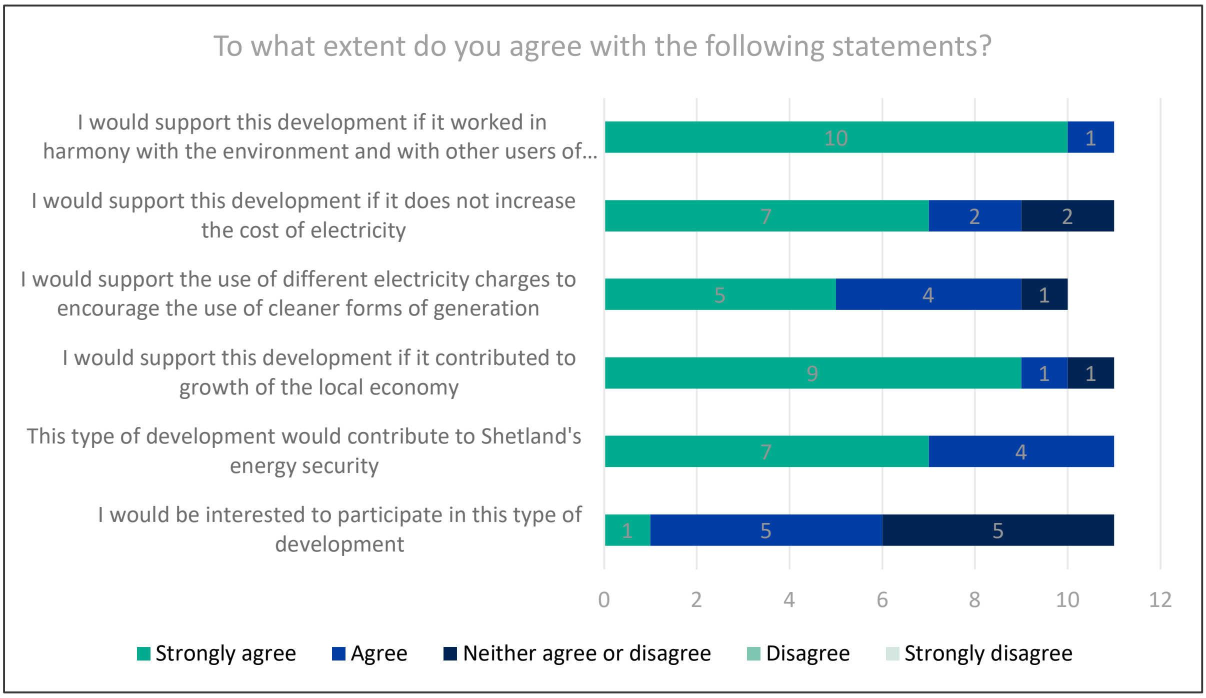

Figure 5-7 Q3 responses

5.1.6 Workshops with students in schools

During November 2018 various workshops were held with school children in Shetland. One workshop was conducted at Mid Yell Junior High School with 25 students aged 11-12 years, and two workshops were held at Anderson High School (with 25 students in each session) aged 14-17 and 16-17. All three workshops were jointly facilitated by Nova, IDETA and RSK.

The aim of the workshops was to provide information about the EnFAIT project, investigate student's awareness of different types of renewable energy technologies, understand their perceptions towards Shetland's environmental and socio-economic resources, and to investigate interactions between different types of resources. The resource of the sea was offered as an example. The sea is used for vessel navigation which allows the transport of tourists (and their cars) by ferry. Tourists travel across the islands to see the landscape, seascape, and the pristine wilderness that is afforded by the Shetland's sparse population. Tourism generates local employment and income to business owners, which subsequently contributes to maintaining a standard of living for Shetland's residents.

At the start of the workshop, the EnFAIT project was introduced using the promotional video and the model tidal turbine. There was a strong emphasis on the engineering and scientific aspects of the project to maximise the learning opportunity for the students.

After the introduction was completed, various questions were raised by participants and responded to by Nova or RSK. These included: how the tidal energy devices impact life on the seabed; why Bluemull Sound was chosen as the location for the project; whether EnFAIT will be affected by Great Britain leaving the EU in March 2019; the potential for interference to occur between users of Cullivoe Pier; and the efficiency of the technology to generate energy.

After the questions had been addressed, students were split up into small groups and asked to complete a participatory mapping exercise. Students were provided with a large piece of paper and coloured pens. The students were initially asked to list the different types of renewable energy technologies with which they were familiar, and to rank these numerically in order of importance. Students were then asked to draw an image of Shetland as a circle. The aim of using a circle to represent Shetland was to ensure that the map was conceptual and avoid students spending time on preparing an accurate geographical outline of the archipelago. Students were asked to draw, using symbols where possible, images representing the different types of environmental and socio-economic resources available in Shetland. They were guided to consider the area inside the circle as representing land-based resources, the edge of the circle as the coastal environment, and the outer area representing the sea and offshore resources. The students were asked to prepare their map within 20 minutes and work collaboratively, discussing as a group the different types of resources present in Shetland.

As the students worked, representatives from Nova/IDEATA/RSK walked around each group to introduce links between environmental and socio-economic resources to enable students to better understand the interactions.

Students were able to list the main types of renewable energy resources with relative ease; however, biomass was often left out. The most important types of renewable resource identified by students in the workshop were wind and tidal energy.

Figure 5-8 shows examples of students working in their groups. Figure 5-9 provides examples of the participatory maps prepared by participants and a summary of the different types of resources identified.

Figure 5-8 Students undertaking the resource mapping exercise

Examples of resources:

- Soil for the cultivation of crops
- Offshore and onshore wind energy
- Tidal energy
- Sea providing navigation to ferries and fishing boats
- Sea providing fish and other types of sea products such as mussels and areas for aquaculture
- Marine fauna which attracts tourists
- Coastal setting which attracts people to visit Shetland
- Music and cultural events such as Up Helly Aa which is a traditional Viking fire festival
- Offshore oil and gas
- Peatlands
- Land used as fodder by sheep which sustains the livelihoods of sheep farmers
- Land and houses used for people to live in and to attend community events
- The coastline and cliffs provide habitats for nesting birds and attract tourists which benefits people working in them
- Cultural identity and a sense of belonging

Figure 5-9 Examples of student's participatory maps, November 2018

An additional session was held with students in Cullivoe Primary School in June 2023. The session consisted of nine students in P1-P7 (aged 5-11) and was jointly facilitated by Nova and RSK.

The session began with a short introduction by the teacher to the representatives present from Nova and RSK. This was followed by an introduction to the EnFAIT project and conversation with the students about their involvement in the naming of the wind turbines. Many of the students had visited the tidal energy site before and played a role in naming of one of the turbines: Hali Hope. The teacher played a video of the students performing a song that they had written about the turbine.

Afterwards, students took part in a participatory mapping activity. Students were split into three small groups: each group was provided with a large piece of paper and coloured markers. The students were initially asked to draw an image of a map of Yell, differentiating the land, the shoreline and the sea. They were then asked to help to identify types of resources available to them in Yell, both on land, around the shoreline and in the sea. They were encouraged to draw all of the different types of resources on their maps. The aim of the activity was to encourage the students to consider the different types of natural and human resources that they use and rely on in their communities, with the idea of urging them to consider renewable energy, in addition to different types of ecosystem services. Students came up with a range of interesting land-based, shoreline and offshore resources ranging from fruits and vegetables grown in polytunnels, to mussels, crabs and lobsters, to whales, in addition to energy sources such as sun, wind, tides and waves.

The students worked together in their groups for 30 minutes and then presented their maps to each other. Figure 5-10 provides examples of the participatory maps prepared by the students.

Figure 5-10 Examples of student's participatory maps, June 2023

5.2 Project suppliers

Since bird and mammal surveys started in Bluemull Sound in November 2010, Nova has used a local company, Shetland Ecology Limited to deliver these.

A Key Informant Interview (KII) was held with the Managing Director of Shetland Composites who manufactures the tidal energy turbine blades at a plastics workshop in Lerwick. The aim of the interview was to understand the impact Nova has had on a local supplier's business and workforce. The interview commenced after a short introduction and an explanation of the purpose of the interview.

SC has been working with Nova since the company was founded in 2010. The company manufactured a set of three blades that were attached to the first tidal energy device installed in the Bluemull Sound during 2014. SC have also manufactured the blades for the three M100 turbines (T1-T3) and then the three M100-D turbines (T4-T6). Collaboration with Nova has had a significant positive impact upon SC's business operations. The additional revenue generated, combined with increased technical knowledge gained from developing and manufacturing the blades has enabled SC to grow, expanding both its premises and workforce.

In January 2017, SC moved into an upgraded workshop which was partly funded by Highlands and Islands Enterprise (HIE). The upgraded facility has a new heated area which allows SC to operate on the premises all year-round, including during the winter months. Involvement in the EnFAIT project has also supported, along with other awarded contracts, SC to expand its workforce from three to six employees, increasing the capabilities and technical expertise of the company. They manufactured the blades for the C1 turbine, Nova's Canadian turbine which is an M100-D model. A selection of photos from SC's warehouse is illustrated in Figure 5-11 **Shetland Composites owner, warehouse and other types of tidal energy components**
and Figure 5-12.

Figure 5-11 Shetland Composites owner, warehouse and other types of tidal energy components

Figure 5-12 Shetland Composites manufacture of the turbine blades

6 Appraisal at a Project-Level and EU-Level

The purpose of this section is to present the results of the project-level and EU-level appraisal and assign a score in accordance with the classification in Table 6.1. The appraisal is presented as a series of tables using short bullet points.

Table 6.1 Classification of effects used for the appraisal

Clear and major positive effect (*expected to contribute a positive, environmental and/or socio-economic change that is recognised at a Shetland/UK and/or EU level*)	✓✓
Broadly supportive or minor positive effect (*results in improved environmental knowledge, or positive environmental and/or socio-economic change)*	✓
Neutral effect *(is not expected to have a positive or adverse effect)*	**0**
Minor negative effect *(expected to result in a localised, adverse environmental and/or socio-economic change)*	×
Major negative effect *(adverse environmental and/or socio-economic change)*	××
Uncertain effect *(based upon the information available the outcome of the effect cannot be determined at this time and could be either positive or adverse)*	**?**

6.1 Environmental appraisal topic areas

Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
• **Marine and Coastal Biodiversity – Dec 2018**EnFAIT has carried out a rigorous assessment of the environmental effects of the project to support license applications, working closely with experts at SNH. This process identified collision risk as the primary area of uncertainty and this has remained the focus of the environmental monitoring framework. • Underwater video footage has been collected to establish whether the tidal array represents a collision risk to fish, mammals or seabirds. Over 4,000 hours of video footage have been analysed and no collisions with turbines have been identified. • Seabed cables will not pose a collision risk as they are laid directly on the seabed. There is a remote possibility of collisions taking place between marine fauna and turbine cables at a different project location with different, surface-mounted tidal technology if the cables were installed so that they rise vertically from the seabed to the surface. • The introduction of hard, submerged, surfaces could generate an 'artificial reef' effect that increases marine biodiversity and attracts fish. This has been regularly observed at offshore wind farms and their monopole structures. The Bluemull Sound already provides a hard substrate as fine material has been removed by strong currents. Consequently, the tidal energy devices are not introducing hard substrates. No increase in biodiversity, or the frequency of fish, is expected. • Marine species are known to be particularly sensitive to changes in electromagnetic fields (EMF). The tidal array introduces a small change to EMF fields which is not expected to interfere with migratory fauna or species who use the seabed, and this does not require further investigation. *Summary: to date the project has not affected marine and coastal biodiversity within the Bluemull Sound.*	**Marine and Coastal Biodiversity – June 2023** • EnFAIT carried out a rigorous assessment of the environmental effects of the project to support license applications, working closely with experts at NatureScot. While collision risk was considered the primary area of uncertainty, data surrounding collision risk continues to build, with potential conditions being put into licences and permits to reduce collision risk. Collision risk remains a focus of environmental monitoring frameworks. • Underwater video footage has continued to be collected to establish whether the tidal array represents a collision risk to fish, mammals or seabirds. Throughout EnFAIT no collisions with turbines have been identified. • Seabed cables have not posed a collision risk as they were laid directly on the seabed. There is currently no evidence to suggest that there has been any collision between marine fauna and turbine cables, even if the cables were installed so that they rise vertically from the seabed to the surface, from any projects. • The introduction of hard, submerged, surfaces generated an 'artificial reef' that increases marine biodiversity and attracts fish. This has been regularly observed at offshore wind farms and their monopole structures. The turbines within Bluemull Sound created an artificial reef for species such as saithe, that were found aggregating around the turbines. An increase in biodiversity and fish frequency was recorded around the turbines. Structures of various marine renewable energy devices and infrastructure are known to create artificial reefs; infrastructure such as cable laying routes have capacity to change narrow areas of seabed over considerable distances. *Summary: to date the project has a minor positive effect on marine and coastal biodiversity within Bluemull Sound. This positive effect on biodiversity would be anticipated to also be observed during other tidal energy project deployments in the EU. The degree of change in biodiversity will likely de dependant on the species present and the structures installed.*	0	0	✓	✓

Physical Environment and Water Quality – Dec 2018 • The three turbines currently installed in the Bluemull Sound occupy approximately 0.25% of the channel cross section by area. • The amount of hydrodynamic energy removed from the tidal stream has been estimated to be less than 0.3% of the average energy in the flow. • There is no evidence from the environmental monitoring framework that indicates the tidal array is significantly changing hydrodynamic conditions. • Marine wildlife and their habitats, such as high energy circalittoral rock, are highly dependent on high energy flows have not been identified in Bluemull Sound. However, there is a possibility that at other locations across the EU marine wildlife could be affected by modifications to hydrodynamics and this would need to be assessed using the specific environmental conditions present. • Acoustic Doppler Current Profilers (ADCPs) deployed as part of the EnFAIT project will be used to record changes in energy flows before/after the tidal array. • Scour erosion has been recorded by the environmental monitoring framework (video footage). The erosion is highly localised, minor in depth and has not affected the stability of the device on the seabed. The seabed is dominated by stone pavement as fine material is naturally removed by the high energy flows. • Changes to water quality are not expected to occur from the tidal array. Whilst there is a small risk of an oil or grease leak from the turbine in the event of a major failure, this has not occurred to date and these types of hazardous substances are effectively contained, doubly sealed within the turbine enclosure. • The extent of marine growth (often referred to as fouling) on the turbine blades and nacelle is an issue that needs to be addressed. Nova is currently investigating the use of different types of anti-fouling coatings to reduce the build-up of material in the future as marine fouling could reduce turbine output and interfere with operations and maintenance. • Seabed cables connecting the tidal array to the equipment located on Cullivoe Pier have not been affected by the build-up of marine growth. However, in other locations there is a potential for marine growth to appear and this should be investigated based upon the specific environmental conditions present. *Summary: to date the project has resulted in a significant improvement to our environmental knowledge in relation to how marine tidal energy devices interact with the environment.*	**Physical Environment and Water Quality – June 2023** • When all six turbines were installed in the Bluemull Sound, they occupied approximately 0.5% of the channel cross section by area. • There is no evidence from the environmental monitoring framework that indicates the tidal array is significantly changing hydrodynamic conditions. Due to the dynamic nature of tidal array project locations, it may be possible to generalise findings between sites, although local conditions must also be considered. • Study results at the benthic boundary layer at the EMEC site showed the change in flow velocity and turbulence intensity in the wake of a bottom-mounted foundation for a tidal turbine; flow velocity decreased by 31% and turbulence intensity increased 10-15% (Fraser *et al.,* 2017; Copping and Hemery, 2020). This shows potential for tidal hydrodynamic conditions to change in the presence of marine renewable energy structures. • Much of the evidence for changes to physical processes comes from modelling studies, which suggest the risk of any change oceanographic systems from marine renewable energy devices in small numbers is low. • ADCPs were deployed around the STA as part of the EnFAIT project and the results will be detailed in OREC's (Ocean Renewable Energy Coalition) Array Interaction Model Final Report, which will be available to the public upon release. • Scour erosion has been recorded by the environmental monitoring equipment (video footage). The erosion is highly localised, minor in depth and has not affected the stability of the device on the seabed. The seabed is dominated by stone pavement as fine material is naturally removed by the high energy flows. Furthermore, upon decommissioning of Phase 1 T1-T3, initial assessments suggest no damage to habitat or seabed. Scour erosion may be observed at other EU locations, where the nature of tidal energy sites will be subject to high energy flows which will remove fine material. • The extent of marine growth (often referred to as fouling) on the turbine blades and nacelle is an issue that needs to be addressed. Nova investigated the use of different types of anti-fouling coatings to reduce the build-up of material in the future as marine fouling could reduce turbine output and interfere with operations and maintenance (particularly on T4). The Phase 2 turbines were installed with an ultra-violet (UV) light directed at the cameras, which suggested UV light prevented biofouling on cameras. Biofouling by filter-feeding organisms has been acknowledged to potentially alter hydrodynamics and phytoplankton processes at offshore wind farm devices, however the scale of this biofouling for marine renewable energy devices is not anticipated to be as high, due to the these providing less habitat opportunity within the water column, than wind structures (devices do not span the whole of the water column). Marine growth on structures increases the surface area of the devices, with potential to alter the tidal flow.	✓	✓	✓	✓

Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
	Summary: the project has resulted in a significant improvement to our environmental knowledge in relation to how marine tidal energy devices interact with the environment. Key findings from the EnFAIT project have shown the potential to reduce biofouling, particularly on cameras. Work at other locations has shown the potential for changing hydrodynamic conditions at the benthic boundary layer in the wake of marine renewable energy structures on the seabed. Given the nature of tidal project sites, it may be possible to apply findings regarding physical characteristics, to other locations.				
Underwater Noise and Vibration – Dec 2018 • Tidal array deployment does not generate significant levels of underwater noise or vibration as the base structure is placed directly on the seabed. Subsea piling or drilling is not required. • Operation of the turbine blades are not expected to generate significant levels of underwater noise and vibration above background noise from the tidal flow, vessel traffic and busy nearby harbour. However, this has not been measured to date and no quantitative information is available. • The location of the tidal array, adjacent to Cullivoe Pier, is frequented by fishing and other types of vessels passing through the Bluemull Sound. Marine fauna and diving seabirds will therefore be used to high levels of background noise and vibration. • During 2019 the feasibility of deploying acoustic hydrophones to record the noise profile generated by the tidal turbines and array will be explored. Ambient background noise levels at different locations within the Bluemull Sound, outside of the tidal array may also be measured. Whilst not raised as an environmental issue of concern by the regulatory bodies during the consenting process for the project, the data generated will provide valuable evidence for consenting of projects at other sites where underwater noise may be more of a concern and will be useful during any future enlargement of the array in Bluemull. • Data collected by the hydrophones will be used to compare the noise footprint of the tidal array with the known hearing range for a variety of marine mammals to investigate further potential effects associated with underwater noise and vibration. *Summary: At a project-level and EU level the effect on underwater noise and vibration is unknown as there is no quantitative data available.*	**Underwater Noise and Vibration – June 2023** • During February 2023, a hydrophone was used to determine the underwater noise level at the STA. Initial results[17] suggest that noise produced from both direct-drive and geared turbines in the array is unlikely to result in injury to marine mammals. Disturbance may be possible, particularly at close range, which could be beneficial for reducing collision risk with operational turbines due to evasion techniques employed by marine mammals. Disturbance is unlikely to occur over a wide area. *Summary: At a project-level and EU level the effect on underwater noise and vibration is minor positive, given that no adverse impacts are anticipated, and the noise present could prevent collisions. . The noise levels could be applied to project devices and species at EU level.*	?	?	✓	✓

[17] See Appendix 1 for a brief overview of the underwater acoustic characterisation of turbines at the STA.

Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
Benthos – Dec 2018 • There are no sensitive benthic habitats or benthos near the Bluemull Sound, or within the tidal array. • The physical footprint of the tidal energy structure occupies a very small area on the seabed and any impacts associated with crushing benthic species will be highly localised. • The location on the seabed of each tidal energy structure is surveyed for obstacles and marine benthic habitats using underwater cameras before installation. • At other locations across the EU, sensitive benthic habitats may be present and the placement of the structure on the seabed could result in loss of benthic habitats. This should be investigated based upon the specific environmental conditions present within the deployment area using underwater cameras. *Summary: The project has no significant impacts to benthos.*	**Benthos – June 2023** • There are known horse mussel beds found within the Fetlar to Haroldswick Marine Protected Area (MPA). These beds are sensitive and protected, however as any impacts on benthic species will be highly localised it is unlikely the STA will impact these beds. The location on the seabed of each tidal energy structure was surveyed for obstacles and marine benthic habitats using underwater cameras before installation. • Upon decommissioning of the T1-T3 turbines, the seabed was surveyed and no damage to the seabed or habitats was observed during initial assessments. • At other locations across the EU, sensitive benthic habitats may be present and the placement of the structure on the seabed could result in loss of benthic habitats. This should be investigated based upon the specific environmental conditions present within the deployment area using underwater cameras. *Summary: The project has no significant impacts to benthos as long as all cables and devices are sited to avoid any in suitable tidal areas.* *The limited change to benthic habitats and seabed upon the removal of devices, suggests a neutral effect resulted from the presence of devices at the project and suggests similar for other EU projects.*	0	?	0	0

Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
Fish – Dec 2018 • The type and distribution of different fish species present in the Bluemull Sound and surrounding region is well understood as the area is known for its fishing resources. • Using the results of the environmental monitoring framework, there is no evidence to indicate that the tidal array is resulting in injury/mortality to fish species. No collisions have been recorded to date. • There is a potential that the turbine and nacelle structure is acting as an aggregating device, like a buoy or float. Underwater video footage indicates fish occasionally congregate close to the structures. • The reason fish are moving close to the devices is not known. They may be behaving in a naturally inquisitive manner, saving energy by swimming in the wake of the turbine, or trying to feed off marine growth attached to the structures. *Summary: At a project level the effect on fish is neutral. However, the effect on fish at an EU-level is unknown as fish communities vary significantly along the coastlines and the potential for effects should be investigated based upon the specific environmental conditions present.*	**Fish – June 2023** • Using the results of the environmental monitoring framework, there is no evidence to indicate that the tidal array is resulting in injury/mortality to fish species. No collisions have been recorded and any close interactions between fish and turbines is continued to be considered rare. • The turbine and nacelle structure acts as an aggregating device, with underwater video footage indicating fish congregate close to the structures. • Significantly fewer fish were observed from the video footage whilst the turbine was in operation meaning the collision risk is significantly lower. • During the 2020-2022 monitoring period, fish were observed sheltering from the main tidal flow whilst the turbine was operational, on a very small number of occasions and were not in proximity to the rotating blades. Fish were most frequently observed on the decreasing ebb and flow tides. • Other projects have observed fish passing, investigating or feeding the nacelle, and shoaling around the device within the camera's field of view at speeds below 0.8m/s, suggesting tidal turbines act as fish aggregating devices (Hutchison *et al*., 2020). *Summary: At a project level the effect on fish is minor positive effect, due to the aggregating nature of devices. The effect on fish at an EU-level is negligible as although fish communities vary significantly along the coastlines and the potential for effects should be investigated based upon the specific environmental conditions present, any collisions between fish and turbines are considered to be rare, with aggregation effects potentially considered positive for fish populations.*	0	?	✓	✓

Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
Seabirds – Dec 2018 • A variety of seabird species are frequently observed within the Bluemull Sound and recorded by the environmental monitoring framework. • Except for a few species, most seabirds present are not able to dive to the depth of the top of the turbine blade which is at least 15m below the water surface. • Seabird monitoring results indicate that they have not been disturbed by the tidal array. For example, underwater footage has recorded very few instances of birds near the turbines and has not recorded any collisions between a turbine blade and a diving seabird. • The use of underwater cameras is an effective way to collect data on seabird activity. The results are currently being combined with monitoring data gathered from observation on the sea surface across the tidal array and surrounding area. A joint analysis will subsequently be undertaken on the surface monitoring data and underwater video. • Seabirds do not generally dive into the Bluemull Sound where the tide is at its fastest; diving activity in the Sound is concentrated at slack tide. However, it is possible that the turbine and nacelle structure are attracting fish which in turn could attract diving seabirds. • Further environmental monitoring and analysis is needed to confirm the impact of the tidal array on seabirds, although to date there are no adverse impacts and this is a positive, 'learning' effect of the project. *Summary: At a project level there are no identified adverse effects on seabirds recorded to date. The effect on seabirds at an EU-level is unknown as seabirds, and their diving depth, varies significantly along the coastlines and between species. The potential for effects should be investigated based upon the specific environmental conditions present.*	**Seabirds – June 2023** • Black guillemot and European shag remain the only bird species observed underwater around the turbines. • The habitat use by birds observed at Bluemull Sound varied by tidal state; European shag and black guillemot were most common at flood tides, whilst Atlantic puffin were more abundant during ebb tides during 2020-2022 land-based monitoring. • Occurrences of seabirds in the underwater footage was rare, with only one European shag being observed in the 2020-20222 footage, which occurred when the turbine was not in operation. • There have been no collisions between seabirds and the turbines. • The continued monitoring has enabled further data collation to understand the interactions and collision risks between seabirds and turbine devices. • The Bluemull and Colegrave Sounds SPA is designated for red-throated divers; although observed in land-based surveys in Bluemull Sound during 2020-2022, no interactions were observed between the species and devices in the underwater footage. • Further environmental monitoring and analysis is needed to confirm the impact of the tidal array on seabirds, although there have been no reported adverse impacts and this is a positive, 'learning' effect of the project. This data can be used to apply to other locations. • Potential short-term displacement of seabirds at any site within the EU-level during construction, maintenance and decommissioning activities, however using Bluemull as an example, populations will return quickly and therefore, long term effects on seabird populations are not expected. *Summary: At a project level there are no identified adverse effects on seabirds recorded. The effect on seabirds at an EU-level is likely to be a relatively minor negative at worst; while seabirds may be displaced during the installation and decommission phases of the project the birds are likely to return quickly, with no long-term effects. The potential for effects should be investigated for any proposed development based upon the specific project design details and the environmental conditions present.*	✓	?	✓	✗

Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
Marine Mammals – Dec 2018 • A variety of marine mammals have been observed within the Bluemull Sound and include otters, seals, whales and dolphins. • Otters are frequently observed adjacent to Cullivoe Pier who are attracted by the presence of fishing vessels who occasionally release catch to the sea. However, otters prefer to forage in shallow water close to shore and have not been observed close to the array. • The presence of marine mammals is recorded on an ongoing basis by underwater cameras and through observation on the sea surface across the tidal array and surrounding area. Common seals have been occasionally observed on underwater cameras; no other mammals have been observed subsea. • Analysis of underwater camera footage has not recorded any collisions with turbines. There is currently no evidence to date that indicates tidal array is disturbing any of the marine mammals identified and this is a positive 'learning' effect. • Environmental monitoring data will continue to be collected from the underwater cameras and combined with the results of the visual monitoring on the sea surface. *Summary: At a project level, there are no identified adverse effects on marine mammals and the project has improved our understanding as to how marine mammals interact with the tidal array. The effect at an EU-level is unknown due to the variation in the type and abundance of marine mammals around coasts. The potential for effects should be investigated based upon the specific environmental conditions present.*	**Marine Mammals – June 2023** • Land-based surveys during 2020-2022 monitoring at Bluemull Sound recorded a number of marine mammal species. • No marine mammals were observed in the underwater video footage between 2020 and 2022, indicating no interactions with the turbines. • Continued data collection and analysis can be used to increase knowledge and potentially apply to other locations. • Passive acoustic monitoring results from the MeyGen project collected two years of data until Phase 1 of the project was decommissioned in October 2019; results suggested porpoises were more likely to be present in winter and at night. Porpoises were also less likely to be present when the turbines were operational (Gillespie and Johnson, n.d.). • Seals were shown to avoid the turbines during operation, but used the site when turbines were not operating, and movement behaviour suggested that pre-installation foraging sites were not significantly obstructed (Gillespie and Johnson, n.d.). *Summary: At a project level, there have not been any identified adverse effects on marine mammals to date and the project has improved our understanding as to how marine mammals interact with the tidal array. Based on results from Bluemull, the effect at an EU-level is likely to be minor negative at worst bearing in mind variations in the type and abundance of marine mammals throughout EU waters as well as the animals' ability to exhibit evasive techniques. To date, there have been no collisions with turbines recorded. The potential for effects should be investigated for any proposed development based upon the specific project design details and the environmental conditions present.*	✓	?	✓	✗

Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
Protected Sites – Dec 2018 • The tidal array is located a significant distance from the nearest protected sites or seabird colony, which is the Fetlar to Haroldswick Nature Conservation Marine Protected Area, the boundary of which is 2km to the South. It includes protected species such as Black guillemots, Horse mussel beds and pearl beds. There is also a protected seal haul-out site 2.5km to the North. • However, it is possible that highly mobile species such as seabirds and some types of marine mammals (seals, whales, dolphins) observed in the Bluemull Sound may have originated from a protected site. • In the absence of any identified adverse impacts on seabirds, fish or marine mammals the potential for the tidal array to be impacting the status of a protected site or colony is very low. *Summary: At a project level there are no identified effects on protected sites or colonies. The effect at an EU-level is unknown and the potential for effects should be investigated based upon the seabird and marine mammal species present in the deployment area, and the proximity to protected sites and colonies.*	**Protected Sites – June 2023** • The Bluemull and Colegrave Sounds SPA is located to the south of the tidal array. Red-throated divers are the protected bird species for which this SPA is designated. Only a small number of red-throated diver were observed during land-based surveys at Bluemull Sound during 2020-2022, and none were observed in the underwater footage, suggesting interactions with the turbines rare highly unlikely and therefore any impact on the conservation objectives of the site are negligible *Summary: At a project level there are no identified effects on protected sites or species. The effect at an EU-level is unknown and the potential for effects should be investigated based upon the protected habitats and/or species present in any proposed array deployment area.*	0	?	0	?

<table>
<tr><th rowspan="2">Initial Appraisal</th><th rowspan="2">Updated Appraisal</th><th colspan="2">Initial Report</th><th colspan="2">Updated Report</th></tr>
<tr><th>Project-Level</th><th>EU-Level</th><th>Project-Level</th><th>EU-Level</th></tr>
<tr><td>Air Quality and Global Climate – Dec 2018
The installation and deployment of the tidal energy devices, which use cranes attached to vessels, results in a highly localised and temporary, deterioration in air quality from the use of combustion vessels. A small quantity of greenhouse gas (GHG) is also generated.
Energy generated by the tidal array is supplied to SSEN and feeds into the Shetland grid. This contribution results in Lerwick Power Station using slightly less diesel fuel than they would otherwise have consumed. Whilst the amount of energy supplied to the grid is a small percentage of the total energy supplied by Lerwick Power Station, operation of the turbines has reduced Shetland’s GHG footprint and the volume of air emissions generated.
Summary: At a project-level the tidal energy array is contributing towards an improvement in air pollution and reducing the total volume of GHG generated through the substitution of diesel, albeit on a very small scale. At an EU-level the project continues to demonstrate the potential for tidal energy to comprise an important component of the broader renewable energy mix, also a positive effect.</td><td>Air Quality and Global Climate – June 2023
The removal for maintenance and re-deployment of the tidal energy devices, which use cranes attached to vessels, results in a highly localised and temporary, deterioration in air quality from the use of combustion vessels. A small quantity of GHG is also generated.
Energy generated by the tidal array feeds into the Shetland grid. Whilst the amount of energy supplied to the grid is a small percentage of the total energy supplied by Lerwick Power Station, the EnFAIT project has illustrated that operation of the turbines has reduced Shetland’s GHG footprint and the volume of air emissions generated.
The addition of the battery storage system on Cullivoe Pier allows the energy captured during periods of peak generation can be used to supply a constant source of electricity to the Shetland grid, even when tides slow and the turbines are not generating. This further reduces Shetland’s illustrated that operation of the turbines has reduced Shetland’s GHG footprint and the volume of air emissions generated.
The addition of an EV charging point at Cullivoe enables charging from tidal energy, and provide an important facility for the local community, reducing air emissions from vehicles.
Other projects within the EU are also starting to develop battery storage, such as the Orbital project at EMEC, which increases the reliance of electricity supply to the grid and reduces reliance on fossil fuels.
Summary: At a project-level the tidal energy array is contributing towards an improvement in air pollution and reducing the total volume of GHG generated through the substitution of diesel, particularly in proximity to Cullivoe. At an EU-level the project continues to demonstrate the potential for tidal energy to comprise an important component of the broader renewable energy mix, also a positive effect, and other projects are starting to deploy batteries to maintain a continuous electricity supply to the grid.</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
</table>

Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
Seascape and Visual Character – Dec 2018 • Results from the SIC questionnaire completed in August 2018 indicated that the public acceptability of renewable energy technology in Shetland is strongly linked to their visibility. • Interactions with local people at the Yell Trade Show and from community focus group discussions reinforce this finding. • The turbines in the Bluemull Sound have no influence on seascape or visual character as the array is fully submerged and not visible. All onshore equipment is located at Cullivoe Pier, next to existing light industrial facilities. • A key advantage of tidal energy technology is that it can be visually unobtrusive. • The seascape and visual character of Shetland is core to the identity of islanders. This is seen as an important resource that supports the tourism sector and a range of associated business activities. *Summary: At a project-level the public acceptability of the tidal array, close to an area with sensitive seascape and visual character, has been demonstrated. At an EU-level, it is likely that submerged tidal arrays will have high level of public acceptability and this is a key advantage of this type of technology.*	**Seascape and Visual Character – June 2023** • As the turbines in the Bluemull Sound have no influence on seascape or visual character As the array is fully submerged and not visible., there is no influence on seascape and visual character by the turbines in Bluemull Sound, while the onshore equipment at Cullivoe Pier blends into the existing light industrial facilities. • A key advantage of tidal energy technology is that it is largely visually unobtrusive. Interactions with local people from community focus group discussions suggested that this was considered favourably, particularly in the context of other recent large-scale wind energy projects in Shetland that have significantly altered the visual landscape. • The visibility of a project remains a concern of stakeholders throughout the EU, although when it is demonstrated that devices or arrays are not surface piercing, as with EnFAIT, the acceptability of a project increases. *Summary: At a project-level the public acceptability of the tidal array, close to an area with sensitive seascape and visual character, has been demonstrated, particularly in the context of onshore wind farms. At an EU-level, it is also considered likely that submerged tidal arrays have high level of public acceptability and this is a key advantage of this type of technology.*	✓✓	✓✓	✓✓	✓✓
Marine and Coastal Archaeology – Dec 2018 • Whilst there are a variety of shipwrecks located throughout the Bluemull Sound, none are close to the tidal array. • Installation of the tidal energy devices do not require marine piling. • The technology is suitable for deployment within areas where there are marine and coastal archaeological resources. *Summary: At a project-level there is no effect on marine and coastal archaeology. At an EU-level, the effect on marine and coastal archaeology is unknown and the issue would need to be considered on a project-specific basis. Due to the absence of marine piling and cable burial, the technology is potentially suitable for use within areas sensitive to marine and coastal archaeology.*	**Marine and Coastal Archaeology – June 2023** • Removal and redeployment of tidal turbines during maintenance has had no discernible impact on any of the shipwrecks located in Bluemull Sound. • Additional analysis of impacts on cultural heritage, which includes archaeology and architecture is required in France, when assessing factors for Marine Renewable Energy (Copping and Hemery, 2020). *Summary: At a project-level there is no effect on marine and coastal archaeology. At an EU-level, the effect on marine and coastal archaeology is unknown and the issue would need to be considered on a project-specific basis. Due to the absence of marine piling and cable burial, the technology is potentially suitable for use within areas sensitive to marine and coastal archaeology.*	0	?	0	?

6.2 Socio-economic appraisal topic areas

Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
Demographics – Dec 2018 • The continuing out-migration of young and qualified people from Shetland to the Scottish mainland and other parts of the UK is of concern to stakeholders. • The development of new technology has the potential to reduce out-migration through the provision of skilled local jobs. The direct employment impact has been limited to date, as the majority of Nova's workforce are based in their Edinburgh office and warehouse, rather than in Shetland. However, future expansion of this and other tidal sites in Shetland will lead to increased opportunities for skilled local employment for building and servicing tidal energy projects. • The project has stimulated economic growth and skilled employment amongst local businesses through the expansion of the supply chain. For example, revenue from the array has helped Shetland Composites to expand its premises and workforce. To date, over 50% of project spend has gone to companies in Shetland or Orkney and over 30 local companies have been involved in the project. The capital spend on Shetland-based companies through the supply chain is expected to encourage people to stay in Shetland. *Summary: At a project-level, the effects on demographics are positive as the development of new technology and increased capital spend will encourage people to stay in Shetland. At an EU-Level the effects on demographics are also positive as the technology is particularly suited to rural and remote areas that may be experiencing a similar demographic trend of out-migration.*	**Demographics – June 2023** • Out-migration of (predominantly) young and qualified people from Shetland to the Scottish mainland and other parts of the UK is still a concern for stakeholders. • Out-migration of EU nationals has occurred over the past few years and is a key concern for many Shetlanders. The exodus of EU workers has left vacancies in several industries that cannot be filled locally, which places pressure on businesses, particularly in the hospitality sector. • Vacancies are commonplace in the public sector, which is recruiting from a relatively small pool of prospective employees. Public sector institutions struggle to compete with large companies in the private sector that can offer workers more competitive salaries. • If scaled up, these types of projects can stimulate economic growth and provide opportunities. In areas like Shetland which are becoming increasingly attractive to companies developing innovative projects, competition for a limited pool of highly skilled workers is a factor that should be considered. *Summary: At a project-level, the effects on demographics are positive as the development of new technology and increased capital spend will encourage people to stay in Shetland. At an EU-Level the effects on demographics are also positive as the technology is particularly suited to rural and remote areas that may be experiencing a similar demographic trend of out-migration.*	✓	✓	✓	✓
Standard of living, housing condition and vulnerable groups – Dec 2018 • Local people refer to the 'Shetland price factor' as goods and services are transported to the archipelago from the Scottish mainland. Transport involves using a ferry from the Scottish mainland to Sumburgh, and then road transport and ferries between islands to reach their destination. Costs gradually increase the further away the consumer is from the source of the product.	**Standard of living, housing condition and vulnerable groups – June 2023** • The 'Shetland price factor' coupled with the islands' harsh climate remains a challenge for residents. • Standards of living have decreased for almost all Shetlanders over the past five years. The cost-of-living crisis is having a damaging impact on many households. The average household bill in Shetland in October 2022 was £5578 - more than double the UK average of £2500,	0	✓	0	✓

Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
• This price factor contributes to the high cost of living in Shetland compared with mainland Scotland and other parts of the UK. • Shetland has an average fuel poverty rate of 43%. Fuel poverty is higher amongst those living in the North Isles, and among elderly people over the age of 60; 68% of whom are estimated to be living in fuel poverty. • Shetland has a cold climate and experiences high wind speeds, resulting in homes requiring heating throughout most of the year. High wind speeds contribute to the wind chill effect and exploits cracks and gaps in houses, reducing indoor temperatures and lowering energy efficiency. • Outside of Lerwick, electricity or oil is used as the heating fuel. There is a district heating scheme in Lerwick linked to an energy from waste plant; there is no public gas distribution system on Shetland. • If the energy generated by the tidal array were to be provided at a cheaper price to households, then this could increase standards of living and housing conditions as people would have more money available for other items, apart from heating. This would also contribute towards a reduction in fuel poverty. However, due to the way in which the UK energy market is regulated it is not possible to use public infrastructure (SSE's cabling network) to provide households with cheaper energy. • The provision of low-carbon energy is aligned with SIC's strategy to improve the energy efficiency of residential properties and businesses. The aim is to increase energy generation from renewable energy sources whilst improving the way in which energy is consumed. SIC's grants are currently being used to insulate homes and increase the quality of windows which improves housing condition. However, this initiative lies outside the scope of the EnFAIT Project. • Building on the results of the community engagement activities completed during preparation of the Initial ESEA Report, Nova is considering additional ways that the project can be used to more directly support vulnerable groups. *Summary: At a project-level, there will be no noticeable effects on the current standard of living or housing conditions. At an EU-level, tidal arrays have the potential to generate positive effects to the standard of living and housing conditions if the cost of energy to the household or business consumer decreases, although this does depend on extent to which tidal energy is cheaper.*	according to evidence submitted to the House of Commons Scottish Affairs Committee by SIC. • In 2022, SIC estimated that fuel poverty would reach 96% by April 2023, with almost all households spending 10% of their income on energy costs • The Shetland foodbank handed out 536 parcels from April to September 2022, a rise of 57% on the same period in 2021 (ShetNews, 2022) • Cost-of-living pressures, persistent fuel poverty and perceived unfairness in the type and levels of support offered by the UK government have left Islanders feeling more isolated than ever. *Summary: At a project-level, there will be no noticeable effects on the current standard of living or housing conditions. At an EU-level, tidal arrays have the potential to generate positive effects to the standard of living and housing conditions if the cost of energy to the household or business consumer decreases, although this does depend on extent to which tidal energy is cheaper. More UK government support is needed for host communities.*				

Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
Educational change – Dec 2018 • Stakeholder engagement found that young people in Shetland who choose to enter into further education studies are increasingly focusing on creative media and similar types of courses, rather than vocational and practical courses that Shetland needs, such as mechanics and engineering. • Shetland presently relies on people from the mainland to provide a range of technical services. For example, SIC recently purchased a fleet of electric cars which local garages were initially (the issue has since been rectified) unable to service or fit replacement parts due to a lack of knowledge of this type of new technology. • The project has raised awareness about renewable energy technology amongst young people in schools. Raising awareness of a new technology contributes to the development of society and is a positive effect arising from the project. • The development of new technology in Shetland could inspire more young people to study mechanical and electrical engineering, environmental sciences, and practical courses, which will benefit the local economy and could stimulate further technological investment. *Summary: At a project and an EU-level, the effects are positive as knowledge of the project's technology could inspire young people to follow engineering and science-based courses*.	**Educational change – June 2023** • Stakeholder engagement found children and young people were showing renewed interest in vocational and practical career opportunities, particularly science and engineering. • EnFAIT (and other renewable energy projects on the islands) have continued to raise awareness among young people about different types of renewable energy technology. Raising awareness of the project, and renewable energy in general, can allow for future community support and interest in renewable energy initiatives. • Out-migration of families from the most rural areas in Shetland renders small local schools vulnerable. The number of students enrolled at primary schools on Yell is decreasing. For example, Cullivoe Primary School will only have seven students in total for the next academic year. Schools like Cullivoe are being forced to reconsider whether they can continue to serve the community, or if they must dissolve and merge with (an)other school(s). • The EnFAIT project worked to involve PhD students in aspects of its environmental monitoring, exposing them to a unique and innovative tidal energy project. *Summary: At a project and an EU-level, the effects are positive as knowledge of the project's technology could inspire young people to follow engineering and science-based courses*.	✓	✓	✓✓	✓✓

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<tr><th rowspan="2">Initial Appraisal</th><th rowspan="2">Updated Appraisal</th><th colspan="2">Initial Report</th><th colspan="2">Updated Report</th></tr>
<tr><th>Project-Level</th><th>EU-Level</th><th>Project-Level</th><th>EU-Level</th></tr>
<tr><td>Social Cohesion – Dec 2018
The project has the potential to enhance Shetland's already very strong local identity and increase social cohesion as they are host to a world-first, demonstrator tidal energy project.
However, interactions with local people during preparation of the Initial ESEA Report indicate that locals are not generally motivated by the 'world-first' factor, and instead understandably focus on more immediate concerns such as the high cost of living and electricity in Shetland and economic development.
If the scale of the tidal array were to expand in the future and contribute a significant quantity of renewable energy and economic development to Shetland, then this perception could change.
Summary: At a project-level the effects of the tidal array on social cohesion are neutral. Effects at an EU-level are unknown though they could be positive in other locations, particularly if the tidal array were to contribute a significant quantity of renewable energy or economic impact.</td><td>Social Cohesion – June 2023
As the cost-of-living crisis worsens, frustration amongst local residents about how renewable energy is being developed and operated on the islands is increasing. Many local people feel they are bearing a disproportionate burden and "paying the price" to host large renewable energy projects which will benefit others (corporations, and customers on the mainland) far more than themselves. Several community members raised concern about the harnessing of Shetland's resources for the benefits of other regions of the UK.
Shetlanders do not want their islands to become a renewable energy farms primarily serving others ahead of their own communities. Many are discouraged by the lack of direct benefits they are seeing from the current large-scale renewable energy projects.
Negative perceptions are not felt towards the EnFAIT project, which is widely supported. It was acknowledged that if the tidal array was to expand significantly (and begin to export energy internationally) perceptions of the project may change.
Local residents are very aware of renewable energy initiatives, including the presence of the STA. Despite general knowledge of the project, few know more detail relating to progress or outcomes. Much of this is due to the 'hidden' nature of the turbines, which have no obvious visual impact. However, some stakeholders commented that the project could have done more to inform stakeholders, e.g., through advertisement, PR and media, and continued engagement. An increased focus on the project progress and its local benefits can ensure the continued positive social cohesion and support that currently exists for the tidal arrays.
Summary: At a project-level the effects of the tidal array on social cohesion are neutral. Effects at an EU-level are unknown though they could be positive in other locations, particularly if the tidal arrays were to contribute a significant quantity of renewable energy or economic impact.</td><td>0</td><td>✓</td><td>0</td><td>✓</td></tr>
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<tr><td>Perception of the sea as a tidal energy resource – Dec 2018
The project has raised awareness associated with the potential for the sea to provide energy through tidal arrays.
Based upon local stakeholder perceptions gathered during preparation of the Initial ESEA Report, the coastal and marine environment is increasingly seen as a reliable source of renewable energy, in addition to a resource for fishing and vessel navigation.
Knowledge of the project is being disseminated throughout the EU, through the EnFAIT website, regular press releases, presentations and other communication tools. This is raising awareness across Europe about the potential for tidal energy to contribute towards future low-carbon energy generation.
Summary: At a project and EU-level, the tidal array is enabling people to view the sea as a source of tidal energy and this change in perception is a minor positive effect.</td><td>Perception of the sea as a tidal energy resource – June 2023
All interviewed stakeholders are supportive of utilising the tide as an energy source; and especially as an alternative to more wind farms. Unlike the wind farms, the tidal array is out of sight. Additionally, the EnFAIT project has proven to not have caused any negative impact on local livelihoods or the marine environment.
Tidal energy has proven to be more reliable and predictable than other sources of renewable energy. Community members are aware of these benefits. The community would ideally like a diverse renewable energy landscape, with a greater role for tidal technology in the future.
The project has raised awareness locally of the potential for tidal energy to contribute to the Shetland energy mix. Stakeholders would like to see the project scaled up; the possibility of future arrays was widely welcomed.
Summary: At a project and EU-level, the tidal array is enabling people to view the sea as a source of tidal energy and this change in perception is a minor positive effect.</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Recreational and Tourism Activities – Dec 2028
As the tidal array is submerged, there is no visual or landscape impact from the turbines.
In the future if visitor resources were to be established at Cullivoe Pier, tourists would be able to learn about this new type of technology and understand how the tidal array is being operated.
A large proportion of Shetland’s visitors are nature tourists, motivated to travel to Shetland by a combination of natural scenic beauty, coastal wildlife and the rugged landscape. These types of visitors are likely to be interested in new types of renewable energy technology. Based on the feedback from the ESEA Survey, Nova is considering options for developing visitor resources at the site.
Summary: At a project and EU-level, the tidal array is not having any effect on recreational and tourism activities. The future construction of a visitor resource would attract people to visit the site and learn about this new type of renewable energy technology.</td><td>Recreational and Tourism Activities – June 2023
There has reportedly been an increase in ecotourism over the years, particularly as tourists have returned following the COVID-19 pandemic. However, this is not directly due to the EnFAIT project.
Though the majority of tourists are not aware of the project taking place, they are interested once they learn about it. There is a particular focus on the different types of renewable energy – and the pros and cons of each - among nature and wildlife tourists. Interest has increased since the beginning of early works and construction for the Viking energy project.
Summary: At a project and EU-level, the tidal array is not having any effect on recreational and tourism activities. The future construction of a visitor resource would attract people to visit the site and learn about this new type of renewable energy technology. New energy projects that have greater visual impact than the tidal arrays are providing a renewed focus on types of renewable energy technology.</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
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Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
Employment and Business – Dec 2018 • In the first 18 months of the EnFAIT project, Nova's supply chain has been 100% from within the EU, 84% from Scotland and 60% from the Highlands and Islands region. • Businesses that have been involved in the supply chain have significantly benefitted from the project. For example, Fred Gibson of Shetland Composites (who manufacture the turbine blades) has been able to continue his business operations, and the additional business revenue has contributed to his decision to expand the workforce and construct a new warehouse facility. His role as a supplier has also increased his technical knowledge of turbine blade manufacture which has already led to new exports and will benefit his business in the future both with Nova, and other clients. • If energy generated from the tidal array is provided to other users of Cullivoe Pier through a "private wire", micro-grid network at cheaper rates than grid electricity, this will benefit other pier users through reduced expenditure on energy. Nova is considering options for supplying local consumers with electricity from the tidal array. *Summary: at a project and EU-level, the tidal array has a positive effect on* employment and business.	**Employment and Business – June 2023** • The project has continued to involve local engineering firms and manufacturing companies in its supply chain and has facilitated new business opportunities. Shetland Composites manufactured the blades for the STA and has since expanded its operations, making the blades for other tidal energy projects internationally. This includes projects developed by Nova in France and Canada. • Shetland's specialist skills, knowledge and resources have been highlighted as key to facilitating success of the project. This includes local engineering knowledge from the islands' O&G industry. • Retention of young and qualified local people, as well as in- migration of new people, will be needed if technical projects are to continue advancing and expanding in Shetland. This includes the expansion of the EnFAIT project. • While an expansion of the EnFAIT project is supported by the local community, stakeholders raised concerns about increased collision risk, if the size of the array were to increase significantly. *Summary: at a project and EU-level, the tidal array has a positive effect on employment and business.*	✓✓	✓✓	✓✓	✓✓
Industrial Strategy and Rural Regeneration – Dec 2018 • Nova has recently completed the fabrication of their new workshop in Edinburgh. • This is an example of how the project has resulted in regeneration where an old warehouse built in the 1970s is stripped down and upgraded to support Nova's future activities, as the company moves away from a research and development model into a business growth and operational and maintenance phase. The new workshop provides improved facilities, more space and is designed to support multiple turbine maintenance activities simultaneously. • In addition, supplier Shetland Composites has expanded their business and headcount in Shetland; just one of over 30 local suppliers benefiting from the project. • The project is a good example of pan-European cooperation, where European companies are at the leading edge of the development of new, low-carbon technologies.	**Industrial Strategy and Rural Regeneration – June 2023** • The project remains a good example of pan-European cooperation, where European companies are at the leading edge of the development of new, low-carbon technologies. • If the commerciality of the tidal array is demonstrated by EnFAIT and the tidal array scales up, then Nova would create a maintenance hub in Shetland and the project could contribute towards rebalancing the UK economy, where economic activity is boosted in the outer reaches of the UK, rather than being solely focused on London and Edinburgh. • Development of new investment areas outside of major cities could create 'hotspots' of economic growth to occur, particularly in remote areas such as Shetland. *Summary: at a project and EU-level, the tidal array has a minor positive effect on UK industrial strategy and rural regeneration.*	✓	✓	✓	✓

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<tr><td>If the commerciality of the tidal array is demonstrated by EnFAIT and the tidal array scales up, then Nova would create a maintenance hub in Shetland and the project could contribute towards rebalancing the UK economy, where economic activity is boosted in the outer reaches of the UK, rather than being solely focused on London and Edinburgh.
Development of new investment areas outside of major cities could create ‘hotspots’ of economic growth to occur, particularly in remote areas such as Shetland.
Summary: at a project and EU-level, the tidal array has a minor positive effect on UK industrial strategy and rural regeneration. The effects would be greater if the commerciality of the technology is demonstrated and the tidal array is scaled-up in the future.</td><td>The effects would be greater if the commerciality of the technology is demonstrated and the tidal array is scaled-up in the future.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Commercial Shipping and Navigation – Dec 2018
The depth of the turbine blades is sufficiently below the sea surface to allow the safe passage of vessels.
There is a potential for subsea cables to cross areas used for lobster pots and the collection of other types of crustaceans, or for anchorage. However, this is not a problem when stakeholders are adequately consulted to ensure that cables are appropriately located, such as in the Bluemull Sound.
If the scale of the tidal array at Cullivoe were to increase in the future, consultation with fishermen and other stakeholders will be required to ensure that there remains no interference with fishing or navigation.
Summary: At a project-level there are no effect on commercial shipping and navigation. Potential effects would need to be considered on a case-by-case basis at an EU-Level.</td><td>Commercial Shipping and Navigation – June 2023
No grievances have been reported by any users of the pier at Cullivoe. Stakeholders agree that there has been good cooperation and collaboration by all parties, with minimal interference to existing activities and operations.
If the scale of the tidal array at Cullivoe were to increase in the future, consultation with fishermen and other stakeholders will be required to ensure that there remains no interference with fishing or navigation. Project planning should take into account existing infrastructure and activities at potential future sites.
Summary: At a project-level there are no effect on commercial shipping and navigation. Potential effects would need to be considered on a case-by-case basis at an EU-Level.</td><td>0</td><td>?</td><td>0</td><td>?</td></tr>
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Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
Effects on the Regulatory Framework – Dec 2018 • Small-scale energy suppliers face market barriers to entry in the UK. For example, existing regulations fail to fully recognise the potential benefits of distributed, small-scale generation, such as: reduced network losses; improved local grid balancing services; and increased resilience of remote networks. • Recent UK policy developments include: the removal of feed-in tariffs (FITs) for small scale renewable generators; the closure of the Renewable Obligation (RO); the focus of the remaining CfD support mechanism on very large-scale projects; and the denial of Seed Enterprise Investment Scheme (SEIS) tax relief to companies that generate electricity. This has created a "perfect storm", leading to the collapse of the UK small-scale, low carbon energy market. • Consequently, small-scale project developers are forced to either: cede the UK market to large-scale competitors and move overseas, cease all activities (as many have done), or focus on the "behind the meter" market, selling directly to consumers to offset their electricity consumption. There is currently no route to market for new low carbon energy generating technologies in the UK, which has had a chilling, adverse effect on investment. • Energy policy in Scotland is not a devolved function and remains seated in Westminster, which has a variety of priorities, including: delivering Brexit; driving down energy bills; and developing large-scale energy projects. Ongoing large energy projects typically use imported energy generating technologies such as nuclear (the 3,200 MW Hinkley Point C project which is based upon French technology) and GW generation-scale offshore wind that utilises turbines imported from Denmark and Germany. • Tidal stream energy is a predictable source of low-carbon energy that does not require large capital investment, or a long-time frame from the start of construction until the point of energy generation. Nova recently deployed batteries at the Shetland array to create the world's first baseload tidal power plant; supplying controllable, flexible renewable energy to the Shetland grid. • However, developers of small-scale renewable energy projects face a significant challenge in addressing the current regulatory and market conditions in the UK.	**Effects on the Regulatory Framework – June 2023** • With existing regulatory regimes focussing on wind energy, the expansion of large-scale wind farms that produce more energy than is needed locally creates barriers to small scale distribution, which may possibly exclude the ability for balanced grid services provided by predictable but small-scale tidal project. • The focus of the CfD system is still for larger projects, with a key challenge in convincing the UK government to reinstate revenue support for emerging energy technologies. • Energy policy is now a devolved function and the Scottish Government is committed to supporting the development of the wave and tidal energy sectors. The largest tidal stream deployment in the world has been deployed in Scottish waters, which contained 50% of the world's installed tidal stream capacity in 2021. • The devolution of energy policy to Marine Scotland on behalf of the Scottish Ministers has enabled the creation of a "one-stop shop" in MS-LOT, which allows of a 'single-point of contact' during the permitting process, which has proved extremely effective. Marine Scotland were able to liaise with stakeholders and ensure clear and evidence-based regulations and policies were developed and applied consistently. • At an EU-level, the need for a streamlined consenting process remains, with regulatory frameworks still tailored for fixed offshore wind. Countries within the European market could benefit from the streamlined consenting approach taken in Scotland, where the single point of contact decreases the time period for the consenting process, which is widely regarded as a successful approach • The EnFAIT project has provided an example for regulatory bodies to learn about the way in which the regulatory framework can be applied to small-scale tidal energy projects before the sector scales up. • EnFAIT has also developed a body of environmental monitoring evidence that should be shared and used as transferable knowledge between projects to effectively accelerate and de-risk consenting. Transfer of existing	✓✓	✓✓	✓	✓

Initial Appraisal	Updated Appraisal	Initial Report		Updated Report	
		Project-Level	EU-Level	Project-Level	EU-Level
• A key challenge is convincing the UK government to reinstate revenue support for emerging energy technologies. This used to be offered by the FIT and RO schemes, which spurred a wave of innovation and investment in the UK energy generation sector. Within the CfD framework, the focus is on reducing the cost of energy to consumers, with a push for renewable energy to be deployed at the lowest possible cost. The CfD scheme favours established renewable energy technologies imported from overseas, such as offshore wind, rather than smaller-scale, emerging, home-grown technologies that which be the export opportunities of the future but need to be fostered to grow. *Summary: The tidal array has highlighted the need for existing UK government policy to be adjusted so that structural market conditions in the UK favour the future development of innovative, small-scale, low-carbon energy technologies. At an EU-level, the tidal array has demonstrated the value of project investments such as EnFAIT that sow the seeds of the low carbon technologies of the future, and that would not have taken place without EU support.*	knowledge and evidence will also help ensure that monitoring of future tidal projects, if required, is realistic, effective, targeted on key issues and generates high quality data. • Within the EU ocean energy technology developers ae struggling to access funding opportunities, with a lack of relevant calls and disadvantageous selection criteria design within schemes such as Horizon Europe, Innovfin Energy Demonstration Projects and innovation fund. • Policies supportive of ocean renewable energy will provide reassurance to private investors, giving an element of market visibility, which would help further increase that rate at which the technology is progressing. Continuing to build evidence that reduces the perceived risks to investors will help encourage private investment. *Summary: The need remains for existing UK government policy to be adjusted so that structural market conditions in the UK favour the future development of innovative, small-scale, low-carbon energy technologies. At an EU-level, the development of tidal energy has stalled with funding required to both develop the EU consenting regimes and limited opportunities for low carbon technologies of the future. The value of investing in innovative, small-scale, low-carbon energy technologies is recognised but developers are struggling to entice investors.*				

7 Summary of Lessons Learned and Recommendations

During work to update the ESEA report, further lessons learned have been identified through group discussion with Project Partners and engagement with local community stakeholders and marine environmental regulators. Learning has also grown as the EnFAIT project has moved through its phases. This section presents lessons learned and recommendations, with the aim of benefitting environmental regulators and tidal energy developers who are involved in similar projects in the future.

7.1 Interactions with the regulatory framework

During the permitting process of tidal energy devices, early engagement with regulatory stakeholders is essential to build trust and to determine, in a transparent and collaborative manner, the ways in which regulators should respond where gaps in policy are perceived to exist. For example, during the early stages of consenting for the STA in Bluemull Sound, there was a lack of clarity about the consenting process and evidence base for tidal energy, as the wide range of stakeholders grappled with this new and emerging sector.

The creation of Marine Scotland to act as a 'single-point of contact' during the permitting process proved extremely effective. Marine Scotland were able to liaise with stakeholders and ensure clear and evidence-based regulations and policies were developed and applied consistently. Marine Scotland's policy during the initial permitting of the tidal array was to 'survey, deploy and monitor'. This decision was assisted by the fact that the development was small in scale, allowing a proportionate approach to be adopted to the potential risks involved. Furthermore, the small scale of the project meant that a full Environmental Impact Assessment (EIA) was not required by Marine Scotland. This enabled the project to proceed quickly with a robust environmental monitoring framework in place. The approach also reflects the way in which environmental regulators can respond dynamically to changes in technology and knowledge and use proportionality to support the development of small-scale energy projects.

Under the guidance of Marine Scotland, Scottish Natural Heritage (SNH)[18] completed a collision risk modelling study on behalf of Nova. The study was undertaken using SNH's own methods and specialists (SNH, 2016). This collaboration benefitted both Nova and SNH as there was confidence in the results associated with the types of physical interactions that could occur between the turbines and marine fauna. Due to the small-scale nature of the project, several the potential impacts that had initially been considered were quickly discounted. This enabled both the regulator and Nova to design their monitoring framework around the remaining uncertain risk: collisions with marine fauna by the turbine blades.

The EnFAIT project has provided an opportunity for regulatory bodies and Nova to learn about the way in which the regulatory framework can be applied to small-scale tidal energy projects before the sector scales up. A robust set of environmental monitoring data has been generated on observed environmental interactions with project components and this is expected to de-risk permitting of similar projects in the future.

The project's 'start small' approach enabled stakeholders such as fishermen to become familiar and comfortable with the new technology at a gradual pace. This provides evidence of the way in which EnFAIT

[18] Rebranded NatureScot effective August 2020

is a pathfinder project, demonstrating that way in which different users of the sea and shoreline area can act in harmony with each other.

The Scottish Government believes that community benefits are an opportunity to share the positive effects of renewable energy and has created guidance relating to "community benefits" from offshore renewable projects, often in the form of payments from projects to local community funds. However, the guidance recognises that the tidal energy industry is in its infancy and is not yet at the stage where such community benefits should be considered.

Sharing learning and experience from environmental monitoring of STA is critical in facilitating the development of best practice for cost-effective environmental monitoring of tidal energy projects and the sustainable development of the sector and for improving access to information on tidal energy for the general public. The precautionary approach taken to consenting early tidal energy projects based on theoretical risk was proportionate and rational when empirical evidence from monitoring operational turbines was lacking. As knowledge improves, such as through the STA environmental monitoring programme, it is critical that this evidence is used effectively to accelerate and de-risk consenting. This includes ensuring that pre-application surveys and monitoring to support consent applications are only required by regulators if they are essential to assess the potential for significant environmental effects. It should be reasonable and proportionate to expect some potential effects to be assessed based on transferring knowledge from existing projects without the need for additional survey or monitoring. Transfer of existing knowledge and evidence should also help ensure that monitoring of future tidal projects, if required, is realistic, effective, targeted on key issues and generates high quality data.

The expansion and reconfiguration of the STA provided a unique opportunity to gather data on the environmental effects of a multi-device array of turbines to improve the evidence base available to de-risk consenting of other projects. It also provides an opportunity to contribute to the development of best practice in environmental monitoring of tidal stream turbines and arrays.

The inclusion of decommissioning within the EnFAIT project lifespan has meant that valuable lessons have also been learnt about this phase of a project. With the decommissioning of tidal energy still in its infancy, it is important not to overlook the need for separate licences for decommissioning, since this activity is not covered by licences to construct and operate the project. All the same legal requirements for socio-environmental assessments apply to these new applications, though parallels can be drawn from original project assessments to support the new applications, given that decommissioning is effectively construction in reverse.

7.2 Environmental lessons

Monitoring throughout the EnFAIT project has made a major contribution to improving knowledge on the environmental effects of tidal turbines and arrays and the development of practical, efficient and cost-effective monitoring solutions.

Underwater cameras were used to gather environmental monitoring data; this was an effective way of understanding interactions between the tidal array and marine mammals, fish and seabirds. This was helped by the water clarity within the Bluemull Sound which lends itself to the use of cameras. At other locations, where turbidity is higher, the clarity of water may not be sufficient for underwater cameras to be used. In these locations, non-visual (e.g., acoustic) solutions might be required to assess interactions with marine fauna.

Marine growth on the surface of the cameras reduces the quality of video information as the lens becomes obscured, typically after several months of deployment. NatureScot's Research Report: "Review of underwater video data collected around operating tidal stream turbines" (Hutchison *et al.*, 2020) offered three recommendations in relation to biofouling management:

- Place cameras facing into the current
- Develop a cleaning schedule utilising maintenance windows to manage biofouling effects
- Investigate the effectiveness of new technologies for biofouling management such as
    - Test wipers on cameras to periodically remove biofouling
    - Test coating camera lenses in translucent anti-fouling paint
    - Test placing ultraviolet (UV) LEDs adjacent to cameras to reduce biofouling through the use of UV radiation."

Nova has trialled a variation of the last recommendation to keep the video lenses clean automatically so that the quality of the footage gathered does not decline after deployment of the device. Nova mounted a UV light on to the nacelle of the T4 turbine, prior to installation in October 2020, with the light directed onto the camera lens. The results of the trial showed that the rate of biofouling was lower on this camera lens, than the cameras on the other three turbines. This suggests that the UV light prevented mussel larvae from settling and colonising the camera, preventing the quality of video footage from degrading (Nova Innovation, 2022b).

The collection of underwater video footage, combined with data from land-based observations, has generated a valuable dataset which has been analysed by Nova to understand interactions between the tidal array and marine fauna and how top predator use of the sound may be linked to hydrodynamic conditions. Recommendations on review and analysis of video footage by a human reviewer are made in the NatureScot's Research Report (Hutchison *et al.*, 2020). This includes conducting data analysis as soon as possible to allow the storage of only "useful footage" and ensuring data reviewers are familiarised with camera layout and device schematics before analysis, and that they have a trial period of 5 example clips per reviewer. However, visually interpreting the video footage to check for collisions and other types of events is a time-consuming process, as recognised by the Hutchison *et al.* (2020) recommendation to "ensure data reviewers have regular breaks to ensure visual acuity and concentration is maintained". Nova, in conjunction with CGG, investigated developing a quick, automatic and cost-effective method of interpreting underwater video footage. Section 7.2.1 below describes the potential for machine learning to aid in distinguishing between background "noise" events, and those which require further investigation with the human eye.

7.2.1 Feasibility study: Use of machine learning to streamline Shetland Tidal Array subsea monitoring data analysis and reporting

<u>Introduction</u>

Nova's environmental monitoring programme for the STA, which uses subsea video cameras attached to the turbines, is recognised as one of the world's best datasets on the environmental effects of tidal turbines. Water clarity at the array site in Bluemull Sound means that underwater cameras are a cost-effective and reliable way to monitor nearfield interactions between marine wildlife and the turbines. The camera footage provides valuable information on the presence and behaviour of fish, diving birds and marine mammals around the turbines to understand the frequency and nature of any interactions.

The turbine-mounted cameras generate large volumes of data. For example, from March 2020 to March 2022 approximately 28,000 hours of video footage were collected (Nova Innovation, 2022b). The footage is currently manually processed and analysed. This is a time-consuming process which limits how much of the full dataset can be examined, and the large volume of data also has significant associated bandwidth, processing and storage requirements. The manual analysis of video footage to date indicates that nearfield interactions between marine wildlife and operational turbines are extremely rare events.

Nova recently partnered with CGG, a global technology and High Performance Computing leader, on a feasibility study to explore the development of software and Artificial Intelligence (AI) tools to assist with automatic processing and analysis of video monitoring data. An overview of the feasibility study, the results and next steps are summarised below.

<u>Objectives and methods</u>

The overall aim of the CGG/Nova feasibility study was to explore 'proof of concept' intelligent extraction of underwater footage to reduce the manual processing of Nova's video footage and automated 'event detection'. To achieve this, the study's objectives were to:

- Develop code/algorithms to automatically filter underwater video acquired from Nova's tidal stream turbines in Bluemull Sound, Shetland, to remove 'unwanted footage' and extract only video that contains marine mammals, diving birds or fish ('targets'). Unwanted footage includes video files in which any movement is due to moving turbine blades or biofouling on the turbines.
- Test the effectiveness and accuracy of code/algorithms on further subsets of video data from Nova's turbine monitoring in Bluemull Sound.

The feasibility study involved a series of workflows to develop object detection through advanced image analysis, machine learning image recognition, object classification and automated production of statistics, such as quantification of data storage reduction and number of detections, summarised within a report. Blind tests were undertaken on a subset of videos to quantify and iteratively improve the accuracy of the results.

<u>Results</u>

The final iteration of the feasibility study machine learning workflow delivered an accuracy of 80% for the identification of marine mobile species (marine mammals, diving birds and fish) in video footage. This rose to 95% accuracy when marine mammals, diving birds or fish were classified simply as 'target' or 'non-target' without taxonomic differentiation. The entire workflow, illustrated in the figure below can be run from video inception to production of an automated results report for approximately 20 hours of footage (or 200 videos) in approximately 30 minutes. When using a manual approach, it takes approximately 320 person-hours of analysis for 1600 hours of video. By comparison, this automated workflow, an example of which is shown in **Figure 7-1**, could analyse 1600 hours of video in 40 hours resulting in an 87.5% reduction in interpretation time.

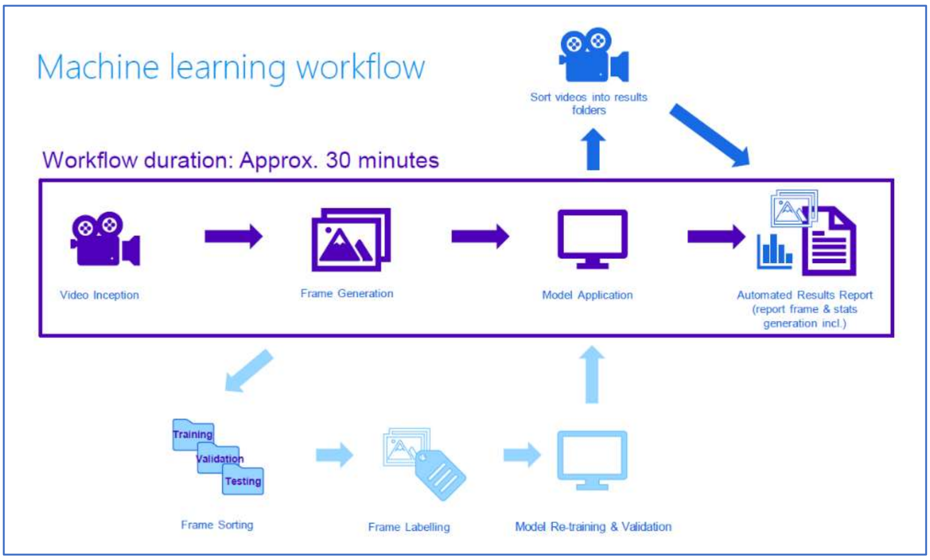

Figure 7-1 Machine learning workflow

Discussion and next steps

This feasibility study successfully demonstrated that machine learning can potentially play a major role in identifying interactions between marine wildlife and tidal turbines. Automated image analysis has been demonstrated to vastly reduce the time required to extract usable data from Nova's subsea video monitoring data compared to manual processing. Automated processing provides a subset of the full dataset for more focused manual scrutiny and analysis, while reducing the overall size of dataset requiring storage. This will facilitate analysis of a much greater proportion of Nova's full dataset and address the growing challenges of data storage requirements. The generation of automated reports and statistical analysis for video analysed can be used to provide outputs for marine regulators to meet monitoring reporting conditions of project licences.

The accuracy of the initial code and runtime speed of the workflow developed in this feasibility study could be further improved through expanding the training dataset of images to include additional species and water conditions. In addition to further refinement using Nova's video data from the Shetland Tidal Array. Similar footage acquired from Nova's environmental monitoring at its other tidal energy sites, including Petit Passage in the Bay of Fundy, Canada, could also be utilised.

7.2.2 Best practice in cost-effective monitoring

The environmental monitoring carried out during the EnFAIT project has made significant contributions to developing efficient and cost-effective techniques and practical solutions to some of the key challenges in monitoring tidal stream energy projects.

Identification of clear monitoring objectives

There is a risk that a project falls into a situation where it is 'data rich and information-poor' ("drip") if the strategic questions behind the collection of environmental data are not sufficiently defined. This has been observed in monitoring programmes for many marine renewable energy projects, which gather large amounts of data but fail to address key evidence gaps or improve understanding on environmental effects (MMO, 2014).

Clear objectives for the STA environmental monitoring programme were defined and agreed with the regulators and key stakeholders for the project, allowing for the design of a focused and efficient monitoring programme. Analyses for data were also defined in advance of monitoring activity so there was a clear pathway from data collection through to analysis and reporting.

Integrating ecological and engineering specialists

The development of methods and instruments to measure mobile species occupancy and behaviour in such high energy environments and around marine energy devices has been identified as a critical evidence need for the tidal stream sector (ORJIP, 2020).

Much of the success of the environmental monitoring programme has been the result of in-project marine ecological and consenting specialists working alongside mechanical and electrical engineering and design specialists throughout the EnFAIT project. This enabled effective technical solutions to environmental consenting and monitoring issues. Collaboration between specialists needs to be proactively developed and embedded within the project design from the earliest possible stage, with environmental monitoring an equally critical project component as engineering design elements throughout the EnFAIT project.

Adaptive management of environmental monitoring

Engagement with regulators and other key environmental stakeholders throughout the EnFAIT project facilitated an iterative and adaptive approach to monitoring. Information on the results of the monitoring programme have been shared, as well as the difficulties and challenges in delivering cost-effective monitoring that is proportionate to project scale and the corresponding risk of environmental impacts. This engagement has enabled objectives and methods to be reviewed throughout the environmental monitoring programme so that they remain fit for purpose, achievable and continue to address critical evidence needs. This systematic and adaptive approach to environmental monitoring, where objectives are refined as knowledge improves and monitoring methods are customised to answer specific questions has been critical to the success of the EnFAIT project monitoring.

As a result of worldwide lessons learned it is recommended that adaptive management monitoring approaches be question-driven, and the questions must be directly connected to thresholds/triggers to avoid unacceptable impacts (Copping and Hemery, 2020). While in practice it may be challenging to design monitoring that informs and works with such thresholds, shared knowledge between projects will help to confidently identify appropriate metrics of concern to be measured and monitored.

Simple monitoring solutions

The challenges of working in tidally swept environments such as Bluemull Sound add complexity to designing and implementing environmental monitoring of tidal stream turbines and arrays. Monitoring technologies and systems (instruments, connectors and associated cables) must be capable of withstanding the physically demanding conditions in tidal sites to ensure fault-free functioning and avoid failure.

Monitoring near-field interactions between marine wildlife and tidal turbines also generates significant quantities of data. Tidal projects are often located in remote areas where data connectivity is limited and broadband speeds are slow, as is the case with the STA. This can be challenging for transferring, processing and storing monitoring data to enable effective analysis and reporting.

These issues were addressed in the EnFAIT project by identifying simple, yet highly effective solutions and approaches. The turbines themselves were used as platforms on which to mount scientific monitoring instruments. This removed the need for separate monitoring platforms, cables and connectors, and the associated high potential for failure and maintenance. Turbine-mounting the monitoring instruments also enabled the download and management of monitoring data to be integrated and aligned with systems for the turbine performance data, creating further efficiencies and reducing areas of potential failure.

The turbine-mounted subsea video cameras record constantly, potentially generating huge volumes of data requiring manual processing and an effective “data mortgage” which available resource will never be sufficient to fully analyse. To address this issue, an “off the shelf” CCTV system was modified for use with the cameras. Although the cameras record constantly, only the footage which has been “motion-triggered” is retained for analysis, significantly reducing the volume of data requiring transfer from the project site, and storage requirements. The use of an “off the shelf” system provided a highly cost-effective and practical solution to the issue.

There has been a move towards combining instruments on platforms that can be fixed on the seabed or moved through the water column. One such platform was the Flow, Water Column and Benthic Ecology 4D (FLOWBEC-4D) based at EMEC. While a large amount of data can be collected by integrated instrument platforms, this can be simplified with the combined platform reducing the need for multiple connections/devices in the water at any one time. The development of automated data processing onboard the platform can ensure monitoring results rapidly available to both developers and interested stakeholders (Copping and Hemery, 2020). Also, by reaching an international agreement on the preferred suite of instruments and/or platforms to be deployed could help accelerate data collection and understanding of the risk to marine animals from turbine collision, thereby facilitating national and international consenting processes (Copping and Hemery, 2020).

Academic involvement in monitoring

Working in partnership with academic experts in wildlife research at tidal energy sites to design methods and analyse data from the STA environmental monitoring programme has ensured tailored approaches based on unbiased scientific input. Publishing results from the monitoring programme in peer-review journals and publications has provided further independent review and scrutiny (e.g., Copping and Hemery, 2020).

It is also believed that encouraging and expanding the cooperation between researchers, test centres, and marine renewable developers, particularly on integrated monitoring platforms, will help move the industry toward larger arrays and commercial deployment (Copping and Hemery, 2020).

7.2.3 Environmental lessons relating to decommissioning

- The mitigation identified was successful in avoiding any negative socio-environmental impacts.
- The highly tide-swept nature of the area in which the turbines are installed in Bluemull Sound means that it is naturally heavily scoured. A rapid assessment of the seabed was carried out using drop down video cameras when turbines and cables had been removed. There was no evidence of any damage to habitats and the seabed in the decommissioned turbine footprints looked very similar to that in adjacent areas.
- A full survey of the site will be completed once the T1-3 decommissioning has been fully completed to meet Marine Scotland’s reporting requirements: weather has delayed the removal of the T1 substructure from the seabed.

While a number of individual tidal turbines have been decommissioned, particularly at EMEC, there are a limited number of post-decommissioning survey reports available. However, EMEC contracted Orkney-based operations provider Leask Marine to decommission a tripod foundation from EMEC's Fall of Warness test site as part of the FORESEA funded FoDTEC project (Forensic Decommissioning of Tidal Energy Convertors) in 20119. This project provided feedback and design guidelines to the offshore renewable energy industry to improve the design of marine energy converters in relation to biofouling, corrosion protection, and the effects of long-term submersion in seawater. This study highlighted the need for design to consider the risk of biofouling, particularly in terms of additional weigh that may need to be factored into lifting operations during decommissioning, as well as improvements to design to ensure longevity and performance for their entire lifetime (Warren, 2020). The removal of the device itself required continuous innovation during the cutting and retrieval operations as standard industry equipment used in offshore subsea oil and gas would have been unable to withhold the strong currents. As a result, Leask Marine's engineering team designed and fabricated a new robust cutting tool support frame to hold the tool in place on the pile with sufficient grip to control the turbulent drag forces. The decommissioning project highlighted ways of lowering costs of decommissioning of large subsea assets by sharing a knowledge base on accessible operational tooling that can meet the challenges of decommissioning of future offshore renewable energy arrays (EMEC, 2021).

7.3 Socio-economic lessons

Local community engagement activities identified demand for information to be provided at Cullivoe Pier on the purpose of the project; the way in which the tidal energy devices operate; how the energy generated is being used; and future plans for the tidal array. This could include a notice board, pictures or video footage of the turbines operating.

Stakeholders in Shetland appreciated Nova's engagement with young people in schools which aimed to provide information about renewable energy and generate interest in marine science and engineering.

Generally, stakeholders remain very supportive of tidal energy technology. The fact that the tidal energy device structure and turbines are not visible is important for the public acceptability of this type of technology, particularly when compared with onshore wind which has significant local opposition due to its visual impact.

Scottish Government guidance recognises that the tidal energy industry is in its infancy and is not yet at the stage where community benefits should be considered, however community benefits are an important factor in securing and maintaining high levels of support for a project.

The development of the tidal array has had a positive impact on the local economy, contributing towards rural regeneration and increasing capacity within local supply companies. The project has demonstrated how the supply chain can rapidly adapt to emerging technologies that benefit local businesses through additional income and improved knowledge.

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Appendix I Underwater Acoustic Characterisation of Nova Tidal Turbines at Bluemull Sound, Shetland

Introduction

In February 2023 fieldwork was undertaken to measure underwater sound levels at the Shetland Tidal Array. The work was delivered as part of a collaborative research project between Nova and the Offshore Renewable Energy Catapult's Marine Energy Engineering Centre of Excellence and Nova Innovation.

The methods followed British standard IEC Standard 62600-40 Marine energy – Wave, tidal and other water current converters. Part 40: Acoustic characterization of marine energy converters (BSI 2019)[19]. Data collection focussed on the three direct-drive turbines (T4-6), but a comparison was also made with three conventionally geared turbines (T1-3). An overview of the work is summarised below.

Methods

The sounds measurements of the Shetland Tidal Array were made using a hydrophone suspended below a float that housed a data logger. The float was tethered to a drifting workboat on a 30 m rope, and the hydrophone was cabled to a data-acquisition system onboard the boat. The system is illustrated in Figure A-1 below.

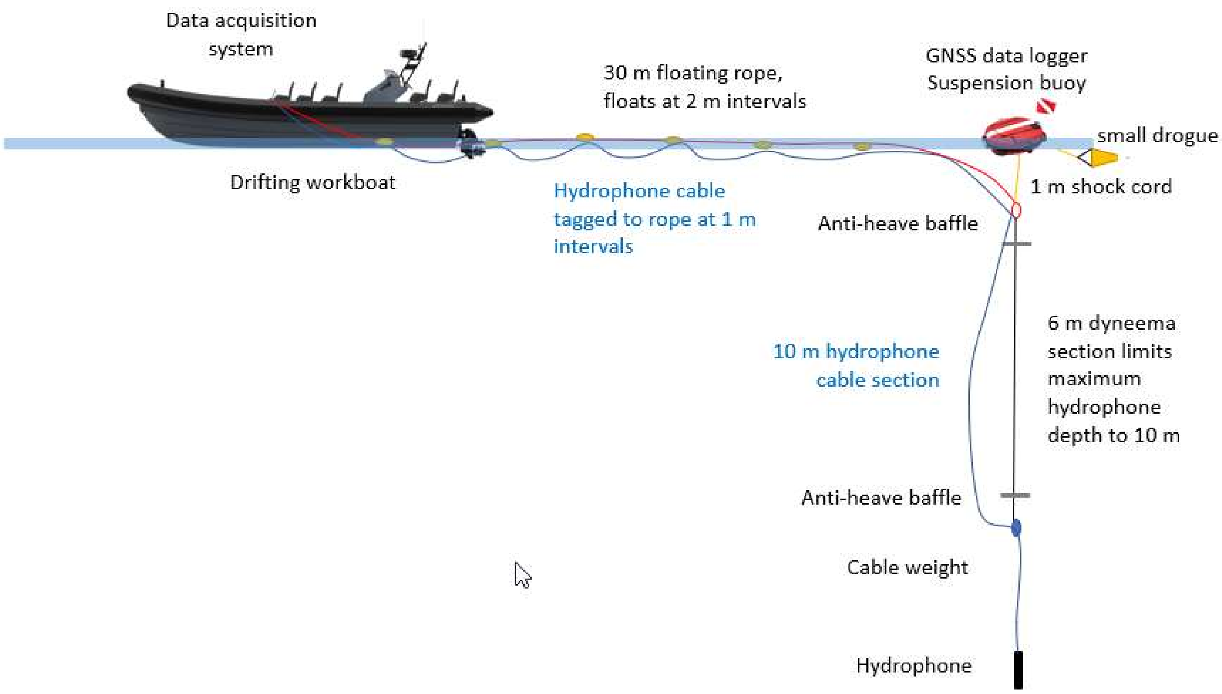

Figure A-1 Equipment setup for acoustic surveys

[19] See https://standards.iteh.ai/catalog/standards/iec/bb922533-4aef-44e9-b0f9-27aabcd5e172/iec-ts-62600-40-2019

The repeat drifts of the floating system during the measurements in February 2023 are shown in Figure A-2 below.

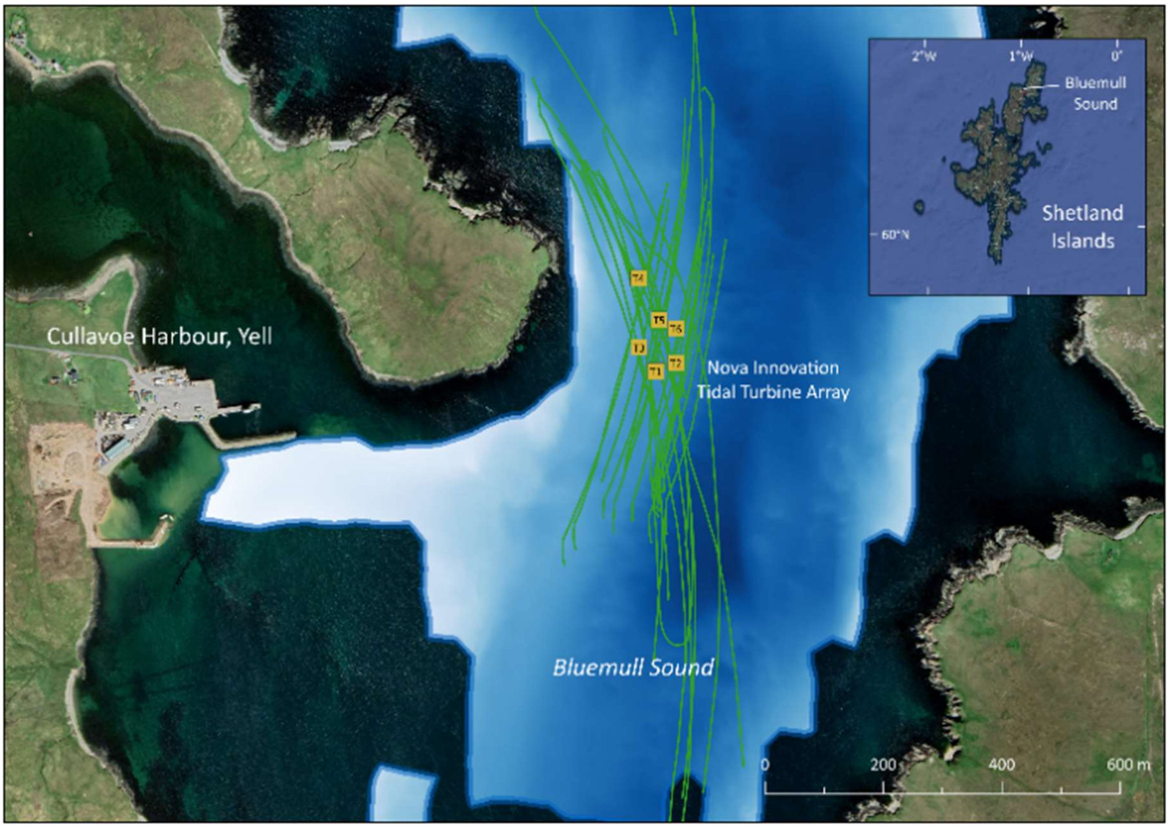

Figure A-2 Vessel tracks for acoustic survey showing the position of turbines T1-6

Results

At the time of writing, analysis of the field measurements is underway. This includes the development of a noise model using the dB Sea Underwater Noise Modelling software. Initial results indicate that underwater sound from the direct-drive turbines was characterised by a series of continuous narrowband tones, with a band of peak energy between 20-25kHz. The source of this energy is believed to be the power conditioning plant, located within the turbine nacelle. This dominant sound was absent on recordings of the three, geared turbines, for which the power conditioning equipment is located onshore. At lower frequencies, a harmonic series of tones was evident with fundamental frequency 3kHz. These tonals are likely to have been caused by rotation of the turbine blades and associated mechanical parts.

Discussion

Analysis and interpretation of the field measurements has not yet been completed. However, results have shown that the underwater sound from both the direct-drive and geared turbines in the Shetland Tidal Array is unlikely to result in injury to marine mammals based on the Southall et al. (2019)[20] thresholds. Disturbance may be possible, particularly at close ranges, which could be beneficial for reducing collision risk with operational turbines. Based on the sound levels and frequency content it is considered unlikely that significant disturbance will occur over a wider area.

[20] See https://doi.org/10.1578/AM.45.2.2019.125

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