Version 2.0

MUSES PROJECT

CASE STUDY 1B: TIDAL ENERGY DEVELOPMENT AND ENVIRONMENTAL PROTECTION AND MONITORING (NORTH COAST OF SCOTLAND - INNER SOUND OF THE PENTLAND FIRTH - NORTH SEA)

MUSES DELIVERABLE:
D3.3 - CASE STUDY IMPLEMENTATION - ANNEX 2

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TABLE OF CONTENTS

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1 GEOGRAPHIC DESCRIPTION AND GEOGRAPHICAL SCOPE OF THE ANALYSIS

The analysis area for Case Study 1B is located in the North Sea region, focusing in on the Inner Sound of the Pentland Firth off the north coast of Scotland between Caithness on the Scottish mainland and the island of Stroma. The Inner Sound is recognized as a highly active site in terms of tidal flow and high wave frequency with maximum current speeds of up to 5 metres per second. The site also has good access to the grid, and suitable water depth for tidal current turbines (TCTs). The majority of the seabed in the Inner Sound is comprised of scoured bedrock exhibiting a 'saw tooth' profile. Rocks that form the seabed consist of folded and tilted sedimentary sandstone, flag-stone and siltstone. A visual representation of the study area is projected in Figure 1.

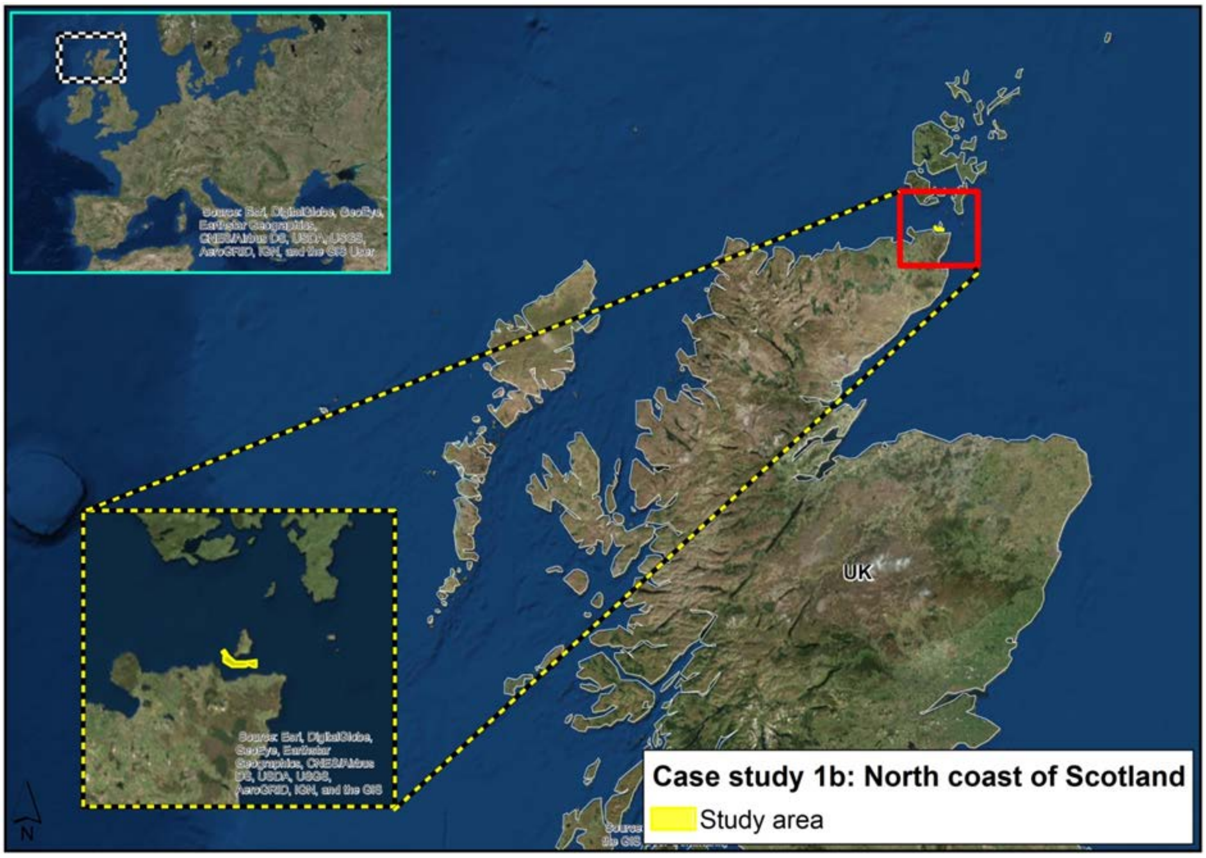

Figure 1 Case study 1B – Inner Sound of the Pentland Firth study area

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2 GEOGRAPHIC DESCRIPTION AND GEOGRAPHICAL SCOPE OF THE ANALYSIS

The Inner Sound of the Pentland Firth is a highly active area that has some of the best resources for marine renewable energy (MRE) generation and has great potential for tidal energy generation. There is an Orkney-based European Marine Energy Centre (EMEC) facility for sea trials and testing for marine renewables as well as a commercial project, undertaken by MeyGen, which was licensed and consented in January 2014 [1]. MeyGen deployed their fourth tidal turbine at the Inner Sound site in the early part of 2017 and plan construction for the next 6MW phase to commence in 2018 [2]. Sustainable growth of MRE and the potential for coexistence with other marine users is a key objective of the Pilot Pentland Firth & Orkney Waters (PFOW) Marine Spatial Plan, which was published in March 2016 [3].

The Pentland Firth is an important area for marine transport, including shipping transiting through the Firth as well as ferry traffic, recreational vessels and limited commercial fishing activity. The area is also important to a variety of species in the area including marine mammals, fish and birds [3]. Existing multi-use (MU) is in its early stages in the Pentland Firth but would fall under the categories of 'geographical, human, biological' as well as 'technical' referenced in chapter 2.1 of the WP2 Analytical Framework [4]. The MU relates to the sustainable development of MRE and the coexistence with the marine environment and other marine users.

The focus of the case study is to explore tidal energy development and interactions with the marine environment. The initial primary environmental receptors considered in coexistence with tidal energy were marine mammals and migratory fish, however, many other environmental receptors are also considered such as birds, sea fish, and benthic species. In order to translate the analysis into a MU combination as defined in the Analytical Framework, Sheet 2 – 'Define MU Combinations', Tidal Energy Development was matched against Environmental Protection, which explores legislative and ecological conservation adjacent to the study area, and Environmental Monitoring, which explores the current technological and economic viability of characterizing environmental interactions with TCTs. Finally, general themes considering tidal energy development outside of strict environmental interactions are explored, specifically within social, economic, legislative, regulatory, technological, and inter and intra industry themes.

Coexistence of TCTs with the marine environment and affected communities is important to allow Scotland to unlock the considerable potential for MRE developments. Estimates indicate that Scotland has up to 25% of Europe's potential tidal energy resource [5]. Scotland aims to be a world leader in the development and deployment of MRE technologies. In 2015, 59.4% of Scotland's electricity consumption came from renewable sources, exceeding the 2015 interim target of 50%, and installed capacity continues to grow towards the 2020 target of 100% [6]. Scotland's draft Energy Strategy, published in January 2017, proposes a new 2030 'all-energy' renewables target to deliver the equivalent of 50% of Scotland's heat, transport and electricity consumption from renewable sources. Setting this ambitious but achievable target demonstrates the Scottish Government's commitment to a renewable future, and to the continued growth of a successful renewable energy sector in Scotland.

The potential for MRE development is enormous and there is opportunity to consider how to further harness this vast resource in a sustainable manner to provide power for homes, businesses, and fulfil Scotland's ambition for a low carbon economy as stated in the Scottish Energy Strategy and the Scottish National Marine Plan (NMP) [7]. In order to realise this potential, it is important to maximise the contribution that MRE makes to legislative renewable energy generation targets in

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Scotland prescribed under the Climate Change (Scotland) Act 2009; maximise opportunities for economic development, investment and employment; and at the same time minimise adverse effects on people, other sectors and the environment [8]. The Scottish Government seeks to promote economically and socially beneficial activity while minimising adverse effects on the environment, human health and other users of the sea.

The MeyGen project in the Pentland Firth is in its initial phase with four turbines deployed and with deployment of further turbines planned using a phased approach. As part of the consenting process for Phase 1, the developers carried out an Environmental Impact Assessment (EIA) [1]. The EIA process identifies the areas of the project where significant environmental effects may occur, and outlines mitigation measures or management techniques aimed at reducing or offsetting these effects. The MeyGen project is therefore leading the way for TCT technology and provides an excellent opportunity to consider the sustainable development of tidal energy and coexistence with the marine environment.

The Scottish Government recognises that improvements can be made to the mechanisms used to address these uncertainties and have developed a 'Scottish Offshore Renewables Research Framework' (SpORRAn) with a supporting research strategy. This framework will provide a mechanism for understanding, collaborating and co-ordinating research priorities across a range of topic areas. It will also provide a mechanism for new knowledge to feed into updates to the Sectoral Marine Plans, such as the Sectoral Marine Plan for Tidal Energy (SMPTE) [5], and support Marine Scotland's risk based licensing and consenting approach emanating from its Survey, Deploy, and Monitor (SDM) licensing policy guidance [9].

Strategic Environmental Assessment, Habitats Regulations Appraisal and Environmental Impact Assessment assess key environmental risks which will be taken into account in plan and project development and consenting procedures. A strategic approach to mitigating potential impacts and cumulative impacts on the marine environment forms an integral part of marine planning and decision making. Furthermore, in order to identify technical solutions, in 2016 Scotland launched an ongoing collaborative Demonstration Project at the site which aims to understand the interaction between marine mammals and operational TCTs [10]. With an estimated global extractable tidal energy resource of 788TWh/yr, the outputs from this case study can also inform dozens of nations across six continents on what actions to take moving into the future in order to sustainably developing tidal energy, and further contribute to the global transition away from environmentally, economically, and socially unsustainable carbon-centric energy generation [11].

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3 MU OVERVIEW

3.1 Existing and Potential MU

The working definition of MU utilized for the MUSES project and defined in the Analytical Framework – Chapter 2.1 is as follows [4]:

"In the realm of marine resource utilisation Multi-Use should be understood as the joint use of resources in close geographic proximity. This can involve either a single user or multiple users. It is an umbrella term that covers a multitude of use combinations in the marine realm and represents a radical change from the concept of exclusive resource rights to the inclusive sharing of resources by one or more users"

Given the above definition, the concept of MU in relation to this case study focus of Tidal Energy Development and Environmental Protection and Monitoring in the Inner Sound of the Pentland Firth is in its infancy stages. The only existing MU is visible through the MeyGen project headed by Atlantis Resources Ltd. whereby four 1.5MW, gravity base, submerged, horizontal axis TCTs, accounting for an aggregate capacity of 6MW, are currently deployed in the study area for Phase 1a of the MeyGen project [2]. The project commenced in October 2016, and is scheduled to build out a total capacity 398MW. The aim of the MeyGen project is to develop a tidal energy project which is sustainable with the marine environment. Given the pre-commercial status of TCT technology, attributed by stakeholders interviewed for this case study with a technology readiness level (TRL) 7 - system prototype demonstration in operational environment, and the limited full-scale devise deployment thereof, MeyGen serves as an industry leading project which can produce lessons learned for various tidal energy developers, governments, and marine scientists not only in the Pentland Firth or Scotland, but for Europe and the world. The ultimate full capacity build-out of the project points towards the expansion of MU between tidal energy development and environmental protection and monitoring in the study area in the future, characterized as potential MU for purposes of the MUSES project. A list of strategic project partners can be found in Table 1.

The data emanating from environmental monitoring of the MeyGen project, which is a condition of consent under Scotland's SDM licensing policy guidance [9], has the potential to substantially contribute to characterizing environmental interactions with a TCT array, thereby building a repository of real-time data for a commercial development. The MeyGen site is located within the North Caithness Cliffs Special Protected Area (SPA) for specified bird species under the Birds Directive 2009/147/EC forming a European belt of protected areas under the Natura 2000 belt [12] (figure 2). It is worthy to note that there are no marine protected areas (MPAs) within the study area which legislate the protection of primary environmental receptors to be investigated in this case study, including marine mammals and migratory fish. Nevertheless, the data produced from the environmental monitoring programme of the MeyGen project can inform whether MU between tidal energy development and environmental protected areas is sustainable for future potential MU colocation.

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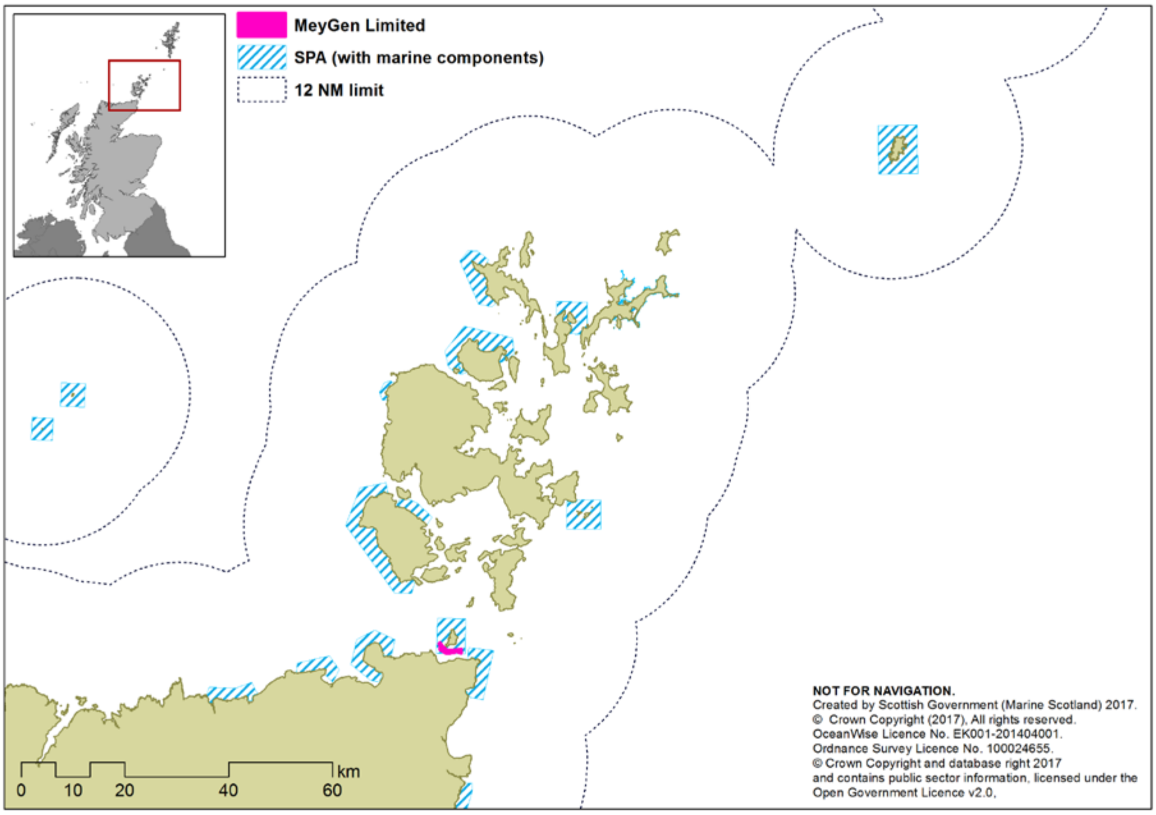

Figure 2 MeyGen study area and North Caithness Cliffs Special Protection Area

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Table 1 MeyGen strategic project partners

MeyGen Strategic Project Partners
MeyGen
Atlantis Resources Ltd
Antritz Hydro Hammerfest
Ashurst
Catapult Offshore Renewable Energy
UK Government – Department for Business Innovation and Skills
DEME – Dredging, Environmental and Marine Engineering
Equitix
FTI Consulting
Global Energy Group
Green Marine Energy
Support Services, HIE – Highlands and Islands Enterprise
HSBC
JGC
Lockheed Martin
Macquarie
Marine Scotland
Morgan Stanley
Ocean Energy Europe
Peel Hunt
Scottishpower Renewables
The Crown Estate
The Scottish Government

3.2 Type of MU

3.2.1 Tidal Energy Development and Environmental Protection

The type of MU analysed in this case study concerning the combination between Tidal Energy Development and Environmental Protection as defined by the MUSES Analytical Framework – Chapter 2.1 is 'geographical, human, biological' [4]:

"The multi-use of marine resources refers mainly to the geographical connection of resource uses to create added value for society to society as a whole and to each sector involved in MU individually"

This MU is predicated on the basis that, if a commercial-scale TCT array does not demonstrate significant adverse environmental impacts, and/or impacts on the local and regional economies linked to adjacent communities, or demonstrates advantageous environmental, economic, and social synergies, TCT arrays and environmentally protected areas including SPAs, Special Areas of Conservation (SACs), MPAs, Sites of Special Scientific Interest (SSSIs), and locally designated sites can be co-located in order to maximize spatial efficiency. Given that the MeyGen project located in the study area was sited within a previously designated environmental protection area, the MU is 'staggered' according to the definition provided in the Analytical Framework – Chapter 2.1 [4].

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The policy and legislative context identified in the desk analysis which promote the sustainable development of tidal energy in relation to sensitive environmental receptors include the following:

- Climate Change (Scotland) Act 2009 [8]
  - Greenhouse gas (GHG) mitigation targets
  - Renewable energy deployment targets
- Marine Strategy Framework Directive 2006/58/EC (MSFD) [13]
  - To apply an ecosystem approach to planning in support of Good Environmental Status (GES) descriptors
- Scottish Energy Strategy [6]
  - To facilitate the transition to a low carbon economy via a modern, integrated, reliable, affordable, and clean energy supply while developing equitable market conditions and creating high-value jobs
  - To promote the local ownership of clean energy systems to fulfil associated Scottish Government targets
- Birds Directive 2009/147/EC [12] and Habitats Directive 92/42/EC [14]
  - Adherence to the protection of legislated SPAs and SACs under the Natura 2000 programme
- Maritime Spatial Planning Directive 2014/89/EU [15]
  - To promote sustainable development of marine environment and sustainable use of marine resources
- UK Marine Policy Statement [16]
  - To provide for clean, healthy, safe, productive and biologically diverse oceans and seas
- Scottish NMP [7]
  - Development of an appropriate management and regulatory framework to sustainably manage salmon and diadromous fish and fisheries resources in order to provide significant economic and social benefits for the people of Scotland as per the Wild Salmon and Diadromous Fish sectoral objective 1
  - To promote the sustainable development and expansion of MRE test and demonstration Facilities as per the Offshore Wind and Marine Renewable Energy sectorial objective 7
- Scottish SMPTE [5]
  - To achieve the vision set out in the SMPTE of Scotland becoming a world leader in the development and deployment of offshore renewable energy technologies
- PFOW Marine Spatial Plan [3]
- Strategic Environmental Assessment (SEA) Directive 2001/42/EC [17]
- Environmental Impact Assessment (EIA) Directive 2014/52/EU [18]
- Scottish SDM licensing policy guidance [9]

No additional policies and legislation were identified following 18 interviews undertaken with 15 distinct stakeholder organizations from the tidal energy industry, government, environmental organizations, and academia. A complete list of stakeholders who participated in the study is presented in Table 2.

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Table 2 Case study 1B stakeholder participants

Stakeholder Participants
Atlantic Salmon Trust
Atlantis Resources Ltd.
DP Energy
European Marine Energy Centre (EMEC)
Fisheries Management Scotland
Marine Scotland
Nova Innovation Ltd.
Orkney Island Council
Scotrenewables
Scottish Association of Marine Science (SAMS)
Scottish Environment LINK
Scottish Natural Heritage
University of Aberdeen
University of St. Andrews
Unnamed Academic Institution

3.2.2 Tidal Energy Development and Environmental Monitoring

The type of MU analysed in this case study concerning the combination between Tidal Energy Development and Environmental Monitoring as defined by the MUSES Analytical Framework – Chapter 2.1 is 'technical' [4]:

"Multi-use of technical resources (marine infrastructure & platforms). In some cases, an even closer (functionally & geographically) integration of uses is possible to create even more added value than a side by side scenario. This closer integration looks for synergies in integrating the operations and implementation of offshore activities and can start by e.g. the simple sharing of the use of offshore supply vessels to reduce individual operations costs. The synergistic integration of activities culminates in multi-use platforms. MU offshore platforms are engineering solutions, designed to incorporate modules of other compatible activities … Fully integrated multi-component and multi-purpose offshore platform serves as a main infrastructure shared by two or more ocean uses (Stuiver et al. 2016)"

This MU explores the potential for integrating various types of monitoring equipment such as passive acoustic, sonar, audio and visual on a MU platform, and co-locating such equipment on TCT structures. A variety of technical and engineering issues and solutions to achieving this MU have been identified by stakeholders in order to effectively and efficiently obtain monitoring data surrounding environmental interactions of various marine species with TCT arrays. Of particular concern is the inability of current monitoring equipment to effectively retrieve marine mammal data, the lack of baseline data surrounding the movements wild salmon of diadromous fish in the study area, and the insufficient engineering of monitoring equipment to withstand high velocity saline tidal race environments. Furthermore, synergies are explored concerning the use of electricity cable routes providing a direct-to-shore pathway for monitoring cables to reach landfall, as well as the the potential for TCT operation and maintenance (O&M) vessels particularly to provide serving requirements to MU monitoring platforms. It is the further enhancement and development of such

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monitoring platforms that will inform environmental interactions with TCT arrays from real-time operational commercial projects, such as MeyGen, which will provide the cumulative baseline and operational data required to inform the sustainability and viability of co-locating tidal energy developments with environmental protection areas.

There is currently no policy or legislative context driving such technological innovation, although the SDM licensing policy guidance promotes the establishment of an environmental monitoring programme through condition of consent [9], making the MU 'joint' according to the definition provided in the Analytical Framework – Chapter 2.1 [4].

3.3 Benefits of promoting MU

Added values of MU between tidal energy development and environmental protection and monitoring identified in the desk analysis include the following:

- Contribution of monitoring data retrieved from tidal energy deployments towards marine protection and conservation area management
- Reduction in climate change inducing compounds and processes projected to negatively impact the marine environment and its inhabitants
- TCT support structures may create an artificial reef effect boasting various species populations
- Increased knowledge base on the operational characteristics of tidal energy technologies thereby proliferating the progression of the TRL of TCTs which allows for further uptake of technologies and industry maturity
- Further inform risk criteria thereby contributing to standardized, streamlined licensing, concenting, and monitoring procedures
- Enhancement for tidal energy development capacity and associated economic benefits pertaining to increased employment, development of a supply chain and industry cluster, and capacity building
- Reduction in scientific uncertainty prompting an enhancement in private investment
- Increased knowledge base on tidal energy development and environmental interactions which will further facilitate the dissemination of information to the public, thereby educating the public on real as opposed to perceived interactions which may improve public opinion and support for tidal energy deployment
- Increased knowledge base of environmental sensitivity to and environmental interactions with tidal energy deployment
- Community benefits in the form of improvements to local infrastructure such as ports and harbours
- Dissemination of information on tidal energy interactions with the environment to the general public can help secure community buy-in and therefore potentially streamline the uptake of tidal energy technology

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Additional added values identified through stakeholder engagement include the following:

- Provision of shared O&M infrastructure including vessels which lower lifecycle costs
- Development of local power supply providing a sense of community ownership
- TCTs will likely act as default no-take fishing zones, thereby doubling as a micro-restoration site for certain marine species
- Further residual capacity building for energy storage systems in order to provide base-load power given the predictable nature of tidal energy
- Increased knowledge base on the operational characteristics of environmental monitoring equipment can lead to technology learning rates for such equipment, thereby leading to a decrease in costs of procuring monitoring equipment

An in-depth analysis of these added values to MU will be presented in section 4 – 'Catalogue of MU Drivers, Barriers, Added Value, Impacts (DABI)' and section 5 – Results of DABI scoring: analysis of MU potential and MU effect'. However, despite the viewpoints on benefits emanating from the MU combinations analysed in this case study, a persistent theme throughout the desk analysis and stakeholder engagement was the lack of baseline environmental and commercially operational TCT array data in order to provide for the knowledgebase required to make sound scientific judgements surrounding environmental interactions with TCT arrays, as well as how tidal energy development will effect local and regional economies and adjacent communities. Given the pre-commercial status of the tidal energy industry, the majority of knowledge on environmental interactions with TCT arrays stems from modelling exercises and expert speculation. This reality must be factored in when examining real versus perceived added values, barriers, and impacts.

Ultimately, it was the impression of the majority of stakeholders that more commercial tidal energy developments such as MeyGen must be deployed and robust monitoring must be undertaken for a considerable length of time utilizing standardized data collection procedures across developments, thereby making data comparable. Furthermore, a greater amount of environmental baseline data is required prior to development in order to measure alterations in ecological processes and functions and marine species behaviour stemming from the introduction of TCT arrays. Only following a comparative analysis between robust data sets can decisions be made surrounding the viability of MU between tidal energy development and environmental protection.

A high-level overview of the actions suggested by stakeholders that are required to be taken forward in order to achieve more commercial-scale tidal energy developments and obtain robust environmental data include the introduction of appropriate government subsidies to facilitate increased deployment of TCTs. This would allow for the enhanced TRL and subsequent bankability of tidal energy technology, as well as the development of environmental monitoring equipment that is fit for purpose in high-energy saline tidal race environments. The key stakeholders related to MU identified through the desk analysis were the Scottish and UK governments, the tidal energy industry and other industries operating in a development area, MRE test centres, financial investment organizations, banks, academia, environmental non-governmental (ENGO) organizations, and local/regional communities. Through engagement, stakeholders additionally identifying European, regional, and local levels of government, and Statutory Nature Conservation Bodies (SNCB) as key stakeholders. Ultimately, it was provided that government regulators and the tidal energy industry were the key stakeholders promoting and enabling MU.

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4 CATALOGUE OF MU DRIVERS, BARRIERS, ADDED VALUE, IMPACTS (DABI)

4.1 Tidal Energy Development and Environmental Protection

Table 3 Drivers promoting MU between tidal energy development and environmental protection

	2.1. DRIVERS = Factors promoting MU *Identification and description of DRIVERS categories & factors*		
Category definition	**Description**	**Factor definition**	**At what scale factor occurs/ is relevant?**
D.1. Policy drivers	Policies and legislation that promote MU between tidal energy development and environmental monitoring through the promotion of renewable energy deployment and climate change mitigation targets	**Factor D.1.1.** Achievement of legislated GHG emissions reduction targets under the Climate Change (Scotland) Act 2009	National
		Factor D.1.2. Achievement of legislated renewable energy generation targets under the Climate Change (Scotland) Act 2009	National
		Factor D.1.3. To promote the Sustainable development and expansion of MRE test and demonstration Facilities as per Wind and Marine Renewable Energy sectoral objective 7 of the NMP	National
		Factor D.1.4. To achieve the vision set out in the SMPTE of Scotland becoming a world leader in the development and deployment of offshore renewable energy technologies	National
		Factor D.1.5. To give due consideration to other users and uses of the marine environment, as well as the marine environment itself, during siting developments while undertaking an EIA in accordance with EIA Directive 2014/52/EU	EU, National, Regional, Local
		Factor D.1.6. To adhere to regulations concerning the protection of rare, threatened or endemic animal and plant species as per the Habitats Directive 92/42/EC	EU, National
D.2. Economic drivers	Policies, strategies, and aspirations to maximize the economic benefits of the tidal energy sector while accounting for environmental sustainability	**Factor D.2.1.** To facilitate the transition to a low carbon economy via a modern, integrated, reliable, affordable, and clean energy supply while developing equitable market conditions and creating high-value jobs as per the Scottish Energy Strategy	National, Regional, Local
D.3. Societal drivers	Policies, strategies, and aspirations to maximize the societal benefits of the tidal energy sector while accounting for environmental sustainability	**Factor D.3.1.** To transition from a centralized energy generation/provision system while enhancing the role that small and island communities assume in the clean energy mix	National, Regional, Local
		Factor D.3.2. To promote the local ownership of clean energy systems to fulfil associated Scottish Government targets put forth under the Scottish Energy Strategy	National, Local

The following categories/factors have been discarded from the catalogue of drivers either given their addition into the catalogue late in the interview process, thereby disallowing a sufficient quantity of stakeholders to provide their insight on the factor, their placement into another aspect

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of the overall DABI for purposes of better suitability, and/or the absence of active stakeholder engagement on the factor due to the direction taken during the interview tailored to the interviewee's core competencies. However, the below factors have been relocated to, and will be incorporated into the discussion in Section 6. Focus area analysis.

- **D.4. Relation with other users**
    - **Factor D.4.3.** Adherence to the promotion of coexistence put forth in the NMP and the national/sectoral regional policies and objectives of the NMP with regards to the construction of regional plans
- **D.4. Societal drivers**
    - **Factor D.3.3.** To capture the direct economic benefits within Scotland in order to develop a national/regional/local supply chain and industry cluster

The contents contained within the following categories/factors were included in the initial draft responses for Key Evaluation Questions (KEQs) as a part of the Focus Area analysis emanating from information collated during the desk analysis. However, such information was not formally included into the DABI portion of the analysis from the onset of the interview process, rather, the information was incorporated due to adjustments in the stakeholder engagement methodology utilized, thereby allowing for them to be converted into factors and formally ranked and compared to other factors. The factors below are also displayed in the final driver catalogue presented above.

- **D.1. Policy drivers**
    - **Factor D.1.4.** To achieve the vision set out in the SMPTE of Scotland becoming a world leader in the development and deployment of offshore renewable energy technologies
    - **Factor D.1.5.** To give due consideration to other users and uses of the marine environment, as well as the marine environment itself, during siting developments while undertaking an EIA in accordance with EIA Directive 2014/52/EU
    - **Factor D.1.6.** To adhere to regulations concerning the protection of rare, threatened or endemic animal and plant species as per the Habitats Directive 92/42/EC

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Table 4 Barriers hindering MU between tidal energy development and environmental protection

	2.2. BARRIERS= Factors hindering MU *Identification and description of BARRIERS categories & factors*		
Category definition	**Description**	**Factor definition**	**At what scale factor occurs/ is relevant?**
B.1. Legal barriers	Legislation which deters development, thereby hindering the opportunity for MU	**Factor B.1.1.** Pre-requisite EIAs are costly and time-consuming given the infancy status of the tidal energy industry	EU, National
		Factor B.1.2. Precedents given to existing uses provides for claims of encroachment and subsequently litigation which would hinder the ability for the tidal energy industry to reasonably expand, therefore inhibiting MU between tidal energy development and environmental monitoring	International, EU, Sea Basin, National, Regional, Local
		Factor B.1.3. Strict EU legislation associated with the Natura 2000 programme provides little room for tidal energy development, and therefore generally inhibits MU between tidal energy and environmental protection	EU
B.2. Administrative barriers	Regulatory processes which deter development and investment, thereby hindering the opportunity for MU	**Factor B.2.1.** Complex regulatory regimes may deter developers and investors, thereby hindering the uptake of tidal energy systems	International,EU, National, Regional
B.3. Barriers related with economic availability / risk	Difficulties in obtaining appropriate finances in order to facilitate economic enhancement, thereby hindering staggered MU	**Factor B.3.1.** Lack of certainty on tidal energy installation, operation, monitoring, and decommissioning interactions with the environmental due to a presently insufficient knowledgebase emanating from limited in-situ commercial deployment perpetuating investor uncertainty and subsequent inability for developers to obtain project financing	International, EU, National, Regional
		Factor B.3.2. Government financing structures (e.g. Contracts For Difference – CFD) are unfair for tidal energy development in relation to other technologies (e.g. offshore wind energy) as full capital payment is required upfront	National
B.4. Barriers related with technical capacity	Hurdles related to technological progression and associated staggered MU	**Factor B.4.1.** Lack of technological maturity of the tidal energy industry may deter investors and subsequently limit technological progression to being trapped in the technology valley of death, thereby limiting tidal energy uptake	International, EU, Sea Basin, National, Regional, Local
		Factor B.4.2. Potential perceptions of tidal energy development taking away current cash inflows into a community due to logistical conflicts with other established industries	Regional, Local
		Factor B.4.3. Given the harsh environmental conditions where tidal energy is abundant, there is typically a lack of available infrastructure (e.g. grid availability/capacity) to easily accommodate tidal energy implementation, thereby leading to an increase in development costs	International, EU, Sea Basin, National, Regional, Local

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	2.2. BARRIERS= Factors hindering MU *Identification and description of BARRIERS categories & factors*		
Category definition	**Description**	**Factor definition**	**At what scale factor occurs/ is relevant?**
B.5. Barriers related with social factors	Stigmas surrounding tidal energy development hindering MU	**Factor B.5.1.** Public and ENGO perceptions of incompatibility due to adverse environmental implications associated with tidal energy development	International, EU, Sea Basin, National, Regional, Local
B.6. Barriers related with environmental factors	Uncertainties surrounding interactions between tidal energy development and the marine environment	**Factor B.6.1.** Lack of scientific baseline knowledge on tidal energy deployment and environmental interactions	International, EU, Sea Basin, National, Regional, Local

The following categories/factors have been discarded from the catalogue of barriers either given their addition into the catalogue late in the interview process, thereby disallowing a sufficient quantity of stakeholders to provide their insight on the factor, their placement into another aspect of the overall DABI for purposes of better suitability, and/or the absence of active stakeholder engagement on the factor due to the direction taken during the interview tailored to the interviewee's core competencies. However, the below factors have been relocated to, and will be incorporated into the discussion in Section 6. Focus area analysis.

- **B.1. Legal barriers**
  - **Factor B.1.4.** Understanding how various EU Directives interact with one another – what takes precedents
- **B.2. Administrative barriers**
  - **Factor B.2.3.** If powers to plan for the marine environment are devolved to local/regional planning bodies, such bodies will not have the competency/capacity/expertise to effectively plan for and license MRE
- **B.5. Barriers related with social factors**
  - **Factor B.5.2.** Scottish society is not as engaged as other societies with respect to taking action against climate change as the effects of climate change are not being experienced as prominently in Scotland as they are in other regions of the world
- **B.6. Barriers related with environmental factors**
  - **Factor B.6.2.** The degradation of the environment resulting from the adverse implications emanating from climate change have lead to an unpredictable environment where field studies (e.g. baseline site characterization) result in data gaps which demonstrate an element of uncertainty

The following categories/factors were introduced into the barrier catalogue via knowledge obtained from stakeholder engagement which was not apparent or evident in documents reviewed during the desk analysis.

- **B.1. Legal barriers**
  - **Factor B.1.2**. Precedents given to existing uses provides for claims of encroachment and subsequently litigation which would hinder the ability for the tidal energy in-

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dustry to reasonably expand, therefore inhibiting MU between tidal energy development and environmental monitoring
  - **Factor B.1.3**. Strict EU legislation associated with the Natura 2000 programme provides little room for tidal energy development, and therefore generally inhibits MU between tidal energy development and environmental protection
- **B.3. Barriers related with economic availability/risk**
  - **Factor B.3.2.** Government financing structures (e.g. CFD) are unfair for tidal energy development in relation to other technologies (e.g. offshore wind energy) as full capital payment is required upfront
- **B.4. Barriers related with technical capacity**
  - **Factor B.4.2.** Potential perceptions of tidal energy development taking away current cash inflows into a community due to logistical conflicts with other established industries
  - **Factor B.4.3.** Given the harsh environmental conditions where tidal energy is abundant, there is typically a lack of available infrastructure (e.g. grid availability/capacity) to easily accommodate tidal energy implementation, thereby leading to an increase in development costs

Table 5 Added values emanating from MU between tidal energy development and environmental protection

	2.3. ADDED VALUE = Positive effects of establishing or strengthening MU *Identification and description of ADDED VALUE categories & factors*		
Category definition	**Description**	**Factor definition**	**At what scale factor occurs/ is relevant?**
V.1. Economic Added Value	Factors which contribute to exploiting the economic benefits emanating from ecologically sustainable tidal energy development	**Factor V.1.1.** Enhancement for tidal energy development capacity and associated economic benefits pertaining to increased employment, development of a supply chain and industry cluster, and capacity building	International, EU, Sea Basin, National, Regional, Local
V.2. Societal Added Value	Factors which contribute to the public knowledge-base of tidal energy development and environmental interactions, thereby securing public buy-in	**Factor V.2.1.** Community benefits in the form of improvements to local infrastructure such as ports and harbours	Local
		Factor V.2.2. Development of local power supply providing a sense of community ownership	Local
V.3. Environmental Added Value	Factors which support the knowledge base of tidal energy development and environmental interactions, thereby strengthening MU	**Factor V.3.1.** Reduction in climate change inducing compounds and processes projected to negatively impact the marine environment and its inhabitants	International, EU, Sea Basin, National, Regional, Local
		Factor V.3.2. Turbine support structures may create an artificial reef effect boasting various species populations	Regional, Local
		Factor V.3.3. TCTs will likely act as default no-take fishing zones, thereby doubling as a micro-restoration site for certain marine species	Regional, Local

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The contents contained within the following categories/factors were included in the initial draft responses for KEQs as a part of the Focus Area analysis emanating from information collated during the desk analysis. However, such information was not formally included into the DABI portion of the analysis from the onset of the interview process, rather, the information was incorporated due to adjustments in the stakeholder engagement methodology utilized, thereby allowing for them to be converted into factors and formally ranked and compared to other factors. The factors below are also displayed in the final added value catalogue presented above.

- **V.2. Societal Added Value**
  - **Factor V.2.1.** Community benefits in the form of improvements to local infrastructure such as ports and harbours
  - **Factor V.2.2.** Development of local power supply providing a sense of community ownership

The following categories/factors were introduced into the added value catalogue via knowledge obtained from stakeholder engagement which was not apparent or evident in documents reviewed during the desk analysis.

- **V.3. Environmental Added Value**
  - **Factor V.3.3.** TCTs will likely act as default no-take fishing zones, thereby doubling as a micro-restoration site for certain marine species

Table 6 Impacts resulting from MU between tidal energy development and environmental protection

	2.4. IMPACTS = Negative effects of establishing or strengthening MU *Identification and description of IMPACTS categories & factors*		
Category definition	**Description**	**Factor definition**	**At what scale factor occurs/ is relevant?**
I.1. Social Impacts	Negative impacts on society stemming from tidal energy development in a given area	**Factor I.1.1.** Landscape and seascape impacts resulting from surface-piercing TCT devises and/or associated infrastructure such as on/offshore substations may reduce public acceptance of tidal energy development, thereby hindering the progression of the industry towards achieving large-scale implementation	Regional, Local
I.2. Environmental Impacts	Negative impacts on the marine environment emanating from the unsustainable MU development of tidal energy	**Factor I.2.1.** Noise and vibration effects during construction and decommissioning for marine mammals, cetaceans, elasmobranches, and diadromous and sea fish	Regional, Local
		Factor I.2.2. Noise and vibration effects during operation for marine mammals, cetaceans, elasmobranches, and diadromous and sea fish	Regional, Local
		Factor I.2.3. Barriers to electromagnetic field (EMF) sensitive cetaceans and diadromous fish including the impediment of migratory movements of eels and salmonids	Regional, Local
		Factor I.2.4. Collision risk between turbine blades and diving birds	Local
		Factor I.2.5. Collision risk between turbine blades and marine mammals	Local

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	2.4. IMPACTS = Negative effects of establishing or strengthening MU *Identification and description of IMPACTS categories & factors*		
Category definition	**Description**	**Factor definition**	**At what scale factor occurs/ is relevant?**
		Factor I.2.6. Collision risk between turbine blades and elasmobranchs	Local
		Factor I.2.7. Collision risk between turbine blades and fish	Local
		Factor I.2.8. Delayed migration or displacement of migratory routes may have effects on salmon and other diadromous species	Regional, Local
		Factor I.2.9. Changes in seabed morphology and direct loss of benthic habitat from smothering during device installation and cable trenching	Local
		Factor I.2.10. Alterations in hydrographic patterns due to extraction of energy from the current regime resulting in sediment transport, wave energy dissipation, and associated coastal process	Regional, Local
		Factor I.2.11. Impacts on water quality resulting from contamination due sediment deposition, device anti-fouling paint, and oil spillage from vessels during installation, maintenance, and decommissioning	Regional, Local
		Factor I.2.12. Visual disturbance to surface-feeding and diving birds	Local
		Factor I.2.13. Potential for fish aggregation and alteration in predation dynamics	Local
		Factor I.2.14. Entanglement of and/or avoidance by species due to barrier effects of devices and transmission infrastructure	Local
I.3. Impacts on other users	Negative impacts which tidal energy development will have on other sectors in the local and regional area	**Factor I.3.1**. Potential impacts of staggered MU developments on the revenue streams of other local industries	Regional, Local
		Factor I.3.2. Potential displacement of shipping routes	Regional, Local

The contents contained within the following categories/factors were included in the initial draft responses for KEQs as a part of the Focus Area analysis emanating from information collated during the desk analysis. However, such information was not formally included into the DABI portion of the analysis from the onset of the interview process, rather, the information was incorporated due to adjustments in the stakeholder engagement methodology utilized, thereby allowing for them to be converted into factors and formally ranked and compared to other factors. The factors below are also displayed in the final impact catalogue presented above.

- **I.1. Social Impacts**
  - **Factor I.1.1.** Landscape and seascape impacts resulting from surface-piercing TCT devises and/or associated infrastructure such as on/offshore substations may reduce public acceptance of tidal energy development, thereby hindering the progression of the industry towards achieving large-scale implementation
- **I.3. Impacts on other users**

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- o **Factor I.3.2.** Potential displacement of shipping routes

The following categories/factors were introduced into the added value catalogue via knowledge obtained from stakeholder engagement which was not apparent or evident in documents reviewed during the desk analysis.

- **I.3. Impacts on other users**
  - o **Factor I.3.1**. Potential impacts of staggered MU developments on the revenue streams of other local industries

4.1.1 Real vs Perceived Barriers

Table 7 Real vs perceived barriers of MU between tidal energy development and environmental protection

Real Barriers			Perceived Barriers		
Category	**Factor**	**Scale**	**Category**	**Factor**	**Scale**
Legal	Pre-requisite EIAs are costly and time-consuming	EU, National	**Legal**	Existing users of marine space claiming encroachment leading to litigation	International, EU, Sea Basin, National, Regional, Local
				Natura 2000 legislation is too strict and thus hinders development	EU
Economic	Lack of maturity of the tidal energy construction resulting in investor uncertainty	International, EU, National, Regional	**Economic**	Government financing structures are unfair towards tidal energy development	National
Technical	Lack of maturity of the tidal energy operation resulting in investor uncertainty	International, EU, Sea Basin, National, Regional, Local	**Technical**	Perceptions of tidal energy taking away cash flow from the community	Regional, Local
				Lack of grid infrastructure	International, EU, Sea Basin, National, Regional, Local
Administrative	Complex regulatory regimes may deter developers	International, EU, National, Regional			
Social	Negative public and ENGO perceptions	International, EU, Sea Basin, National, Regional, Local			
Environmental	Lack of scientific baseline knowledge on environmental interactions	International, EU, Sea Basin, National, Regional, Local			

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According to the MUSES Analytical Framework – Chapter 3.2, real barriers are barriers which have been identified through the desk analysis, while perceived barriers are barriers identified by engaging stakeholders [4]. It is important to distinguish between the two types of barriers in order to evaluate the reality of the barrier and the impact it may have on achieving MU. During the desk analysis, it was suggested that a legal barrier was that pre-requisite EIAs for tidal energy development were costly and time-consuming. While stakeholders agreed that EIAs are necessary in order to achieve sustainable MU between TCT arrays and environmental protection, the current regime of undertaking EIAs hinder the pace at which tidal energy development can occur, thereby hindering the amount of information that can be gathered from environmental interactions through environmental monitoring programmes which would provide a concrete basis informing the viability of tidal energy development in environmental protection areas. The scale of this real barrier is EU and national due to the legislative framework of the EIA Directive 2014/52/EU enacting the barrier. Given the reality and scale of this barrier, the competent authority required to evaluate the appropriate legislation is the European Commission (EC) through active control and decisions making in the long term.

A perceived legal barrier that was produced from stakeholder engagement was that existing users of sea space where tidal energy developments are sited may result in claims of encroachment, leading to litigation. If litigation were to occur, the ability for the tidal energy industry to reasonably expand would be hindered, therefore inhibiting MU between tidal energy development and environmental protection. This barrier is a result of stakeholder perception and can be influenced in the short-term through active control and decision making via enhanced communication between government, notably Marine Scotland, with various sectors operating in a given marine space during the siting process for plan option areas (POAs), as well as tidal energy developers and other sectors throughout the lifecycle of project development. This barrier occurs on the International, EU, sea basin, national, regional, local scales. However, it would seem that the tidal energy industry would need to mature more in order to become a substantial economic player for local and regional economies, as well as the national economy, in order to generate such an influence. Currently, Marine Scotland has built-in an active stakeholder engagement through the sectoral marine planning process, while MeyGen has demonstrated a similar degree of engagement. Regardless, this perception still exists.

Another perceived legal barrier was that strict EU legislation associated with the Natura 2000 programme provides little room for tidal energy development, and therefore generally inhibits MU between tidal energy and environmental protection. While the Natura 2000 belt successfully provides for the MU factor of environmental protection, the interpretation of the Birds Directive 2009/147/EC and Habitats Directive 92/42/EC may inhibit tidal energy development, and similar to the EIA Directive 2014/52/EU, if the tidal energy industry is unable to reasonably expand, the concept of MU will be stunted, and therefore the efficient use of marine space cannot be realized. This barrier occurs on the EU scale, and therefore would suggest that the EC must review interpretations of legislation in order to facilitate MU in the short to long term via active control and decision making. Also, it is worth noting that an interrelated yet discarded legal factor from the overall DABI due to its appearance late in the stakeholder engagement process, therefore inhibiting a sufficient amount of scoring, was that EU Directives do not provide for which Directive takes precedents over another, thus attributing enhanced legal risk when interpreting such legislation. This barrier is perceived and would seem to prompt clarification from the EC through active control and decision making in the short to long term.

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With regards to economic barriers towards development of the tidal energy industry, the desk analysis suggested that a lack of certainty on tidal energy installation, operation, monitoring, and decommissioning interactions with the environmental due to a presently insufficient knowledge-base emanating from limited in-situ commercial deployment of TCT arrays perpetuates investor uncertainty and subsequent inability for developers to obtain project financing. This inability to obtain project financing limits the reasonable expansion of the tidal energy industry and therefore the collection and analysis of a credible capacity of environmental monitoring data which would inform interactions with the environment and thus proliferate MU between TCT arrays and environmental protection areas. However, this barrier is a double-edged sword in that the tidal energy industry must further develop and expand in order to accumulate the required environmental data to clarify risk and become bankable, and therefore the barrier is real and time-dependent in the long term. This barrier occurs at the international, EU, national, and regional scales depending on the reach of the tidal energy industry, and therefore cannot be neither controlled or influenced by a single actor.

A perceived economic barrier resulting from stakeholder engagement was that government financing structures (e.g. CFD) are unfair for tidal energy development in relation to other technologies (e.g. offshore wind energy) as full capital payment is required upfront. This barrier was put forth by tidal energy developers interviewed during stakeholder engagement, and later on validated by SNCBs and ENGOs, both of which would seem to be placed on the other end of the spectrum of the MU combination of environmental protection. This mutual agreement between tidal energy developers and environmental stewards on the limitations of the CFD funding mechanism on tidal energy development prompts the question whether this barrier is actually perceived or if it is indeed real. Given that it was not available in the literature review, by MUSES definition, it would be categorized as perceived. However, this type of interpretive information may not have had a chance to be published given the infancy status of the tidal energy industry. Regardless, the scale of the barrier is national given that it is a UK subsidy which can be solved through active control and decision making by the national competent authorities in the short to medium term.

With regards to technical barriers towards development of the tidal energy industry, the desk analysis suggested that a lack of technological maturity of the tidal energy industry may deter investors and subsequently limit technological progression to being trapped in the technology valley of death. This barrier has the ability to limit tidal energy uptake and subsequently MU with environmental protection areas which are dependent on capacity development enabling a substantial aggregation of standardized environmental monitoring data required by the SDM licensing policy guidance as a condition of consent [9]. Similar to the inability to obtain project financing due to the pre-commercial status of the tidal energy industry resulting in a TRL 7, this barrier is dependent on the tidal energy industry further developing and expanding in order to accumulate the required environmental data to clarify risk and become bankable, and therefore the barrier is real and time-dependent in the long term. This barrier occurs at the international, EU, national, and regional scales depending on the reach of the tidal energy industry, and therefore cannot be neither controlled nor influenced by a single actor.

A perceived technical barrier resulting from stakeholder engagement was that potential perceptions of tidal energy development taking away current cash inflows into a community due to logistical conflicts with other established industries would deter MU with any other sector, and thus downplay the possibility of MU with environmental protection areas. Similar to the legal barrier of claims of encroachment emanating from previously established industries operating in the study

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area leading to litigation, this barrier is a result of stakeholder perception and can be influenced in the short-term through active control and decision making via enhanced communication between government, notably Marine Scotland, with various sectors operating in a given marine space during the siting process for POAs, as well as tidal energy developers and other sectors throughout the lifecycle of project development. This barrier occurs on the International, EU, sea basin, national, regional, local scales. However, it would seem that the tidal energy industry would need to mature more in order to become a substantial economic player for local and regional economies, as well as the national economy, in order to generate such an influence. Currently, Marine Scotland has built-in an active stakeholder engagement through the sectoral marine planning process, while MeyGen has demonstrated a similar degree of engagement. Regardless, this perception still exists.

Another perceived technical barrier resulting from stakeholder engagement was that, given the harsh environmental conditions where tidal energy is abundant, there is typically a lack of available infrastructure (e.g. grid availability/capacity) to easily accommodate tidal energy implementation, thereby leading to an increase in development costs. If infrastructure is not available for tidal energy development and associated environmental monitoring, MU potential is limited as development may not persist. By MUSES definition, this barrier would be categorized as perceived. However, there is much truth to the barrier, as well as agreement amongst tidal energy developers interviewed for the case study. Regardless, this barrier occurs on a regional and local scale dependant on the geographical area where the development is sited. This barrier must be addressed by a combination of active cooperation by transmission system operators (TSOs) as well as appropriate financial subsidies introduced by competent government authorities through active control and decision making.

An administrative barrier identified in the desk analysis was that complex regulatory regimes may deter developers and investors, thereby inhibiting the uptake of tidal energy systems. Such limited uptake of tidal energy would once again inhibit MU with environmental protection areas which maximizes the use of marine space and further expands the boundaries of future consented tidal energy developments. While the majority of stakeholders interviewed stated that Marine Scotland has developed and implemented a streamlined licensing and consenting regime, with all tidal energy developers suggesting that on-going communications with the Licensing Operations Team (MS-LOT) have been receptive to mutual communication and relatively free of unnecessary complexity, some stakeholders suggested that the lack of tidal energy developments propagated a lack of experience in government regulation with respect to the tidal energy industry. However, this barrier can only be addressed through further experience perpetuated from further national developments and therefore cannot be controlled nor influenced. It is worthy to note however that while this barrier occurs at a regional and national level for Scotland, for the purposes of lessons learned, this barrier occurs at an EU and international level. Given that Scotland is the leading nation regarding tidal energy development and regulation, it can be inferred that the complexity of regulatory regimes in nations across the world occurs at a greater degree, and therefore nations looking to develop their tidal energy industry should take note of the MeyGen project and any adjustments Marine Scotland makes to regulatory/administrative procedures throughout the lifecycle of the project.

Although this perceived administrative barrier has been discarded from the overall DABI due to its appearance late in the stakeholder engagement process, therefore inhibiting a sufficient amount of scoring, EMEC suggested that, if powers to plan for the marine environment are devolved to local/regional planning bodies, such bodies will not have the capacity and/or expertise to effectively

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plan for and license MRE. This barrier would therefore further inhibit MU between tidal energy development and environmental protection areas, particularly given that planning and licensing procedures for sited TCT installations within environmental protection areas would be more intricate and vulnerable to legal risk than POAs established through the SMPTE outside of protection areas. This barrier occurs at a regional and local scale and cannot be controlled nor influenced, but rather is dependent on the tidal energy industry further developing and expanding, Marine Scotland gaining more experience in administrating such development and documenting lessons learned in a repository available for regional and local planning bodies. However, this barrier can be all together avoided if regional and local planning authorities are not attributed with the authority to plan and license MRE, in which case the barrier can be controlled through active decision making of Marine Scotland.

A social barrier identified in the desk analysis was that public, and to a lesser extent ENGO perceptions of incompatibility due to adverse environmental implications associated with tidal energy development will result in push-back towards development of TCT arrays in environmental protection areas. This risk is real and occurs on international, EU, sea basin, national, regional, and local scales depending on the reach of ENGOs and the engagement of members of Scottish society. This barrier can be solved through active control and decision making in the short to medium term by allowing for more tidal energy developments to produce more environmental monitoring data which can then be disseminated to the general public by government and developers. It is also worthy to note that a perceived social barrier that was discarded from the overall DABI due to its appearance late in the stakeholder engagement process, therefore inhibiting a sufficient amount of scoring, was that Scottish society is not as engaged as other societies with respect to taking action against climate change. This barrier is perceived to be a result of the effects of climate change not being experienced as prominently in Scotland as they are in other regions of the world. This barrier occurs at national, regional, and local scales depending on the viewpoints of the public and can be influenced by government through the initiation of programmes which further educate the public on the negative environmental implications of climate change, and the direct impacts that such implications have on the national economy, as well as regional and local economies and communities.

An environmental barrier identified in the desk analysis was that the lack of scientific baseline knowledge on tidal energy deployment and environmental interactions will inhibit the siting of TCT arrays within environmental protection areas. This barrier would suggest that it is too early in the development of the tidal energy industry to promote MU with environmental protection areas as more data is required, both environmental baseline and TCT monitoring data, to make informed decisions regarding the sustainability of MU. This real barrier occurs on international, EU, sea basin, national, regional, and local scales as much environmental baseline characterization and TCT interaction data must be produced in different marine environments and standardized in order to allow for proper analysis. This barrier cannot be controlled nor influenced, rather, a considerable amount of time is required for more developments to take place which produce more data on environmental interactions. It is worthy to note that a perceived environmental barrier that was discarded from the overall DABI due to its appearance late in the stakeholder engagement process, therefore inhibiting a sufficient amount of scoring, was that the degradation of the environment resulting from the adverse implications emanating from climate change have led to an unpredictable environment where field studies result in data gaps which demonstrate an element of uncertainty. This barrier also addresses the lack of available environmental data which is required to inform decisions concerning MU between tidal energy development and environmental protection. However, this per-

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ceived barrier, which occurs on international, EU sea basin, national, regional, and local scales, cannot be controlled nor influenced as the effects of climate change, for example, are uncertain.

As depicted in Figure 3, an analysis of real versus perceived barriers in relation to MU between tidal energy development and environmental protection would suggest that the majority of barriers towards MU are real and economic, and cannot be controlled nor influenced by a single actor. However, there are a number of perceived barriers, prominently economic and technical, which can be solved by the EC and UK government respectively in the medium term.

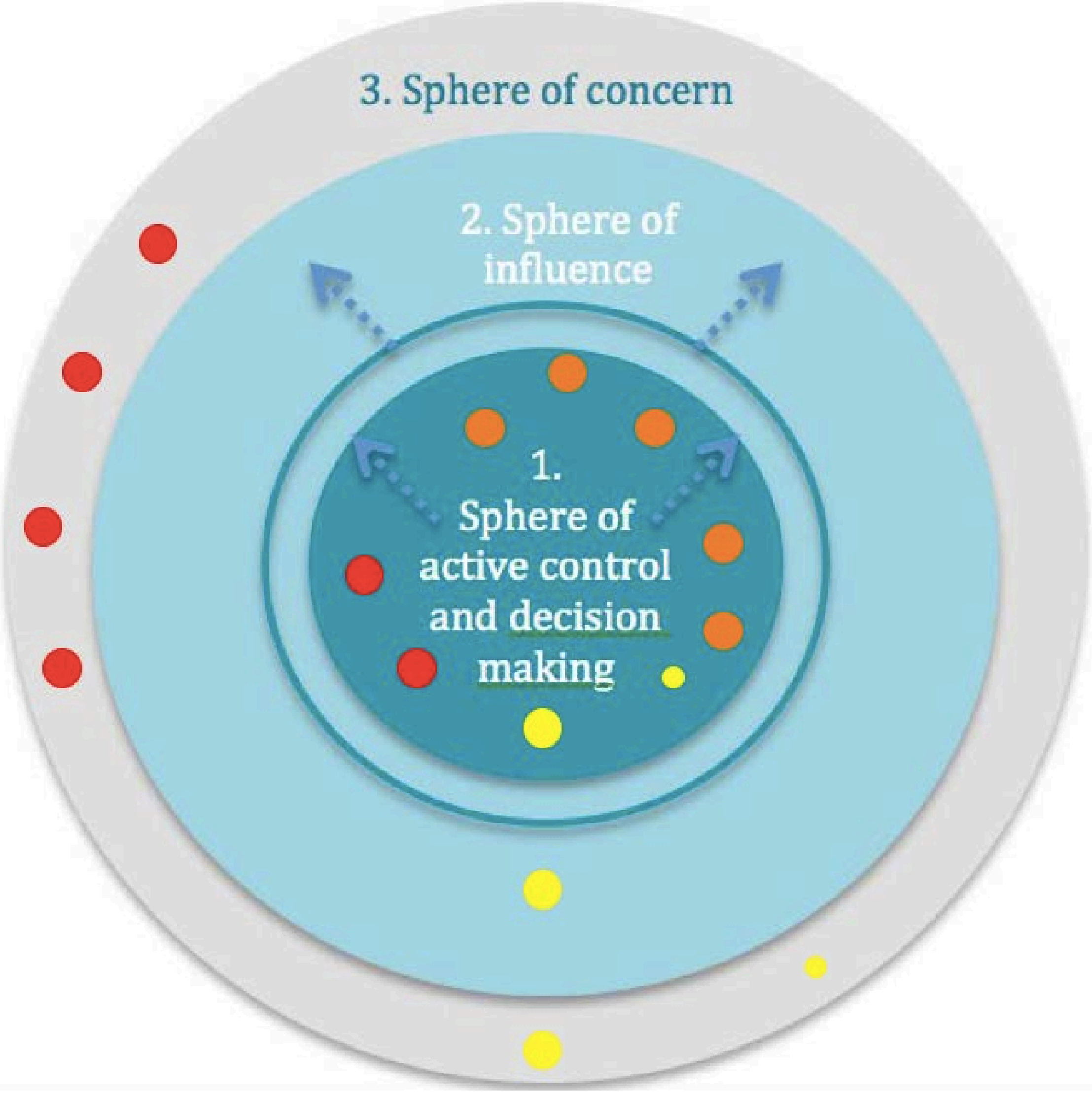

Figure 3 Sphere of Influence – Tidal Energy Development and Environmental Protection, adapted from SUBMARINER, 2016. The red circles represent factors of real barriers which are included in the overall DABI; the orange circles represent factors of perceived barriers which are included in the overall DABI the yellow circles represent factors which are perceived but were discarded from the overall DABI; the smaller yellow circles represent one factor which falls within two spheres depending on the action taken

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4.2 *Tidal Energy Development and Environmental Monitoring*

Table 8 Drivers promoting MU between tidal energy development and environmental monitoring

	2.5. DRIVERS = Factors promoting MU *Identification and description of DRIVERS categories & factors*		
Category definition	**Description**	**Factor definition**	**At what scale factor occurs/ is relevant?**
D.4. Relation with other uses	Policies and legislation that promote sustainable management practices of tidal energy development while building a knowledgebase in relation to environmental monitoring	**Factor D.4.1.** Promotion of an ecosystem-based approach to the planning and management of tidal energy implementation to support the achievement of GES of marine and coastal waters under the MSFD	EU, Sea Basin, National Regional, Local
		Factor D.4.2. Necessity to build upon knowledge gaps pertaining to environmental interactions in relation to tidal energy development	International, EU, Sea Basin, National Regional, Local
D.3. Economic drivers	Policies, strategies, and aspirations to maximize the economic benefits of the tidal energy sector while accounting for environmental sustainability	**Factor D.3.2.** Promotion of investment in the tidal energy sector to sustainably maximize the economic benefits of the growth of the tidal energy industry	International, EU, Sea Basin, National Regional, Local
D.5. Ecological drivers	Policies, legislation, and aspirations to ensure the protection of the marine ecosystem is accounted for in the planning and development of tidal energy systems	**Factor D.5.1.** Adherence to the protection of legislated SPAs and SACs under the Natura 2000 programme	EU, Sea Basin, National, Regional, Local
		Factor D.5.2. Adherence to the Maritime Spatial Planning Directive 2014/89/EU which aims to promote sustainable development of marine environment and sustainable use of marine resources	EU, Sea Basin, National, Regional, Local
		Factor D.5.3. To provide for clean, healthy, safe, productive and biologically diverse oceans and seas in accordance to the UK Marine Policy Statement	Sea Basin, National, Regional
		Factor D.5.4. Development of an appropriate management and regulatory framework to sustainably manage wild salmon and diadromous fish and fisheries resources in order to provide significant economic and social benefits for the people of Scotland in conformity with Wild Salmon and Diadromous Fish sectoral objective 1 within the NMP	National
D.6. Technological drivers	Governmental visions on how Scotland will position itself within the MRE industry through technology development	**Factor D.6.1.** To assist Scotland in becoming a world leader in technological innovation	National

The following categories/factors were introduced into the driver catalogue via knowledge obtained from stakeholder engagement which was not apparent or evident in documents reviewed during the desk analysis.

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- **D.5. Technological drivers**
  - **Factor D.6.1.** To assist Scotland in becoming a world leader in technological innovation

Table 9 Barriers hindering MU between tidal energy development and environmental monitoring

	2.6. BARRIERS= Factors hindering MU ***Identification and description of BARRIERS categories & factors***		
Category definition	**Description**	**Factor definition**	**At what scale factor occurs/ is relevant?**
B.2. Administrative barriers	Regulatory processes which deter development and investment, thereby hindering the opportunity for MU	**Factor B.2.2.** Staggered MU may initiate complex licensing procedures where existing uses that are not licensable will take priority and inhibit the deployment of TCTs, and therefore the ability to undertake environmental monitoring which would further develop the knowledgebase needed to further the industry	National

The following categories/factors have been discarded from the catalogue of barriers either given their addition into the catalogue late in the interview process, thereby disallowing a sufficient quantity of stakeholders to provide their insight on the factor, their placement into another aspect of the overall DABI for purposes of better suitability, and/or the absence of active stakeholder engagement on the factor due to the direction taken during the interview tailored to the interviewee's core competencies. However, the below factors have been relocated to, and will be incorporated into the discussion in Section 6. Focus area analysis.

- **B.2. Administrative barriers**
  - **Factor B.2.3.** Annual time windows for tidal energy demonstration do not take into consideration the natural physical processes in which tidal energy technology relies upon
- **B.3. Barriers related with economic availability/risk**
  - **Factor B.3.3.** Lack of financial government assistance

The following categories/factors were introduced into the barrier catalogue via knowledge obtained from stakeholder engagement which was not apparent or evident in documents reviewed during the desk analysis.

- **B.2. Administrative barriers**
  - **Factor B.2.2.** Staggered MU may initiate complex licensing procedures where existing uses that are not licensable will take priority and inhibit the deployment of TCTs, and therefore the ability to undertake environmental monitoring which would further develop the knowledgebase needed to further the industry

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Table 10 Added values emanating from MU of tidal energy development and environmental monitoring

	2.7. ADDED VALUE = Positive effects of establishing or strengthening MU *Identification and description of ADDED VALUE categories & factors*		
Category definition	**Description**	**Factor definition**	**At what scale factor occurs/ is relevant?**
V.1. Economic Added Value	Factors which contribute to exploiting the economic benefits emanating from ecologically sustainable tidal energy development	**Factor V.1.2.** Reduction in scientific uncertainty prompting an enhancement in private investment	International, EU, Sea Basin, National, Regional, Local
		Factor V.1.3. Provision of shared O&M infrastructure including vessels which lower lifecycle costs	Regional, Local
V.2. Societal Added Value	Factors which contribute to the public knowledgebase of tidal energy development and environmental interactions, thereby securing public buy-in	**Factor V.2.3.** Increased knowledgebase on tidal energy development and environmental interactions which will further facilitate the dissemination of information to the public, thereby educating the public on real as opposed to perceived interactions which may improve public opinion and support for tidal energy deployment	International, EU, Sea Basin, National, Regional, Local
V.3. Environmental Added Value	Factors which support the knowledgebase of tidal energy development and environmental interactions, thereby strengthening MU	**Factor V.3.4.** Contribution of monitoring data retrieved from tidal energy deployments towards marine protection and conservation area management	International, EU, Sea Basin, National, Regional, Local
V.4. Regulatory/ Insurance Policy/Risk Added Value	Factors which contribute to the knowledgebase surrounding risks associated with tidal energy deployment and environmental interactions, thereby expediting implementation procedures while safeguarding the marine environment	**Factor V.4.1.** Further inform risk criteria thereby contributing to standardized, streamlined licensing, consenting, and monitoring procedures	International, EU, National
V.5. Technical Added Value	Factors adding to the technological maturity of tidal energy development, potentially bolstering the pace of implementation	**Factor V.5.1.** Increased knowledgebase on the operational characteristics of tidal energy technologies thereby proliferating the progression of the TRL of turbines which allows for further uptake of technologies and industry maturity	International, EU, National
		Factor V.5.2. Further residual capacity building for energy storage systems in order to provide base-load power given the predictable nature of tidal energy	International, EU, Sea Basin, National,

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	2.7. ADDED VALUE = Positive effects of establishing or strengthening MU *Identification and description of ADDED VALUE categories & factors*		
Category definition	**Description**	**Factor definition**	**At what scale factor occurs/ is relevant?**
			Regional, Local
		Factor V.5.3. Increased knowledgebase on the operational characteristics of environmental monitoring equipment can lead to technology learning rates for such equipment, thereby leading to a decrease in cost of procuring monitoring equipment	International, EU, Sea Basin, National, Regional, Local
V.6. Industry Added Value	Factors which contribute to the public knowledge base of tidal energy development and environmental interactions, thereby furthering the development of the tidal energy sector and providing insights regarding the possibility of deploying tidal energy technologies in marine protected areas, thus furthering the geographic scope of deployment	**Factor V.6.1.** Increased knowledgebase of environmental sensitivity to and environmental interactions with tidal energy deployment	International, EU, Sea Basin, National, Regional, Local
		Factor V.6.2. Dissemination of information on tidal energy interactions with the environment to the general public can help secure community buy-in and therefore potentially streamline the uptake of tidal energy technology	International, EU, Sea Basin, National, Regional, Local

The contents contained within the following categories/factors were included in the initial draft responses for KEQs as a part of the Focus Area analysis emanating from information collated during the desk analysis. However, such information was not formally included into the DABI portion of the analysis from the onset of the interview process, rather, the information was incorporated due to adjustments in the stakeholder engagement methodology utilized, thereby allowing for them to be converted into factors and formally ranked and compared to other factors. The factors below are also displayed in the final added value catalogue presented above.

- **V.1. Economic Added Value**
  - **Factor V.1.3.** Provision of shared O&M infrastructure including vessels which lower lifecycle costs
- **V.6. Industry Added Value**
  - **Factor V.6.2.** Dissemination of information on tidal energy interactions with the environment to the general public can help secure community buy-in and therefore potentially streamline the uptake of tidal energy technology

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The following categories/factors were introduced into the added values catalogue via knowledge obtained from stakeholder engagement which was not apparent or evident in documents reviewed during the desk analysis.

- **V.5. Technical Added Value**
  - **Factor V.5.2.** Further residual capacity building for energy storage systems in order to provide base-load power given the predictable nature of tidal energy
  - **Factor V.5.3.** Increased knowledgebase on the operational characteristics of environmental monitoring equipment can lead to technology learning rates for such equipment, thereby leading to a decrease in cost of procuring monitoring equipment

4.2.1 Real vs Perceived Barriers

The only barrier identified for the MU combination of tidal energy development and environmental monitoring was administrative. The barrier was identified by Marine Scotland and suggested that staggered MU may initiate complex licensing procedures where existing uses that are not licensable will take priority and inhibit the deployment of TCTs, and therefore the ability to undertake environmental monitoring which would further develop the knowledgebase needed to further expand the industry. Given that the primary MU combination of tidal energy development and environmental protection is influenced heavily on the basis of obtaining a substantial amount of diverse and standardized environmental monitoring data in order to inform environmental interactions with TCT arrays, complex licensing regimes which inhibit the deployment of TCTs and thus negate the co-location of MU monitoring platforms equipped with passive acoustic, sonar, audio, and visual technologies, will ultimately effect the integration of MU between environmental protection. This barrier occurs at international, EU, sea basin, national, regional, and local levels as it is dependent on the scale of development, the sensitivity of the marine ecosystem, and can provide for lessons learned for other nations looking to grow their tidal energy industry and enhance the effectiveness of their environmental monitoring programmes. The barrier can be solved in the short term through active control and decision making by Marine Scotland through the restructuring of staggered MU licensing procedures.

A perceived administrative barrier that was discarded from the overall DABI due to its appearance late in the stakeholder engagement process, therefore inhibiting a sufficient amount of scoring, was that annual time windows for tidal energy demonstration do not take into consideration the natural physical processes in which tidal energy technology relies upon. Some stakeholders noted that demonstration windows have occurred in February, when environmental weather conditions are at their harshest, thereby greatly enhancing the difficulty of deployment which increased vessel costs when installation is delayed, while the tidal cycle was on its neap cycle and therefore provided the lowest energy yield possible. Both of these consequences hinder the quality of the monitoring data gathered, as well as the ability to deploy necessary monitoring equipment. This barrier is perceived in that it may have not been a persisting occurrence, however, the barrier occurs at a national level and can be solved in the short term through active control and decision making on Marine Scotland's behalf through more flexible demonstration windows which are tailored to the environmental and meteorological conditions required to more easily deploy TCTs and provide for greater electricity yields.

A perceived economic barrier that was discarded from the overall DABI due to its appearance late in the stakeholder engagement process, therefore inhibiting a sufficient amount of scoring, was

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that a lack of financial government assistance through subsidization hinders the further development and expansion of the tidal energy industry which would be required to deploy more TCTs in order to obtain monitoring data, as well as provide financial assistance to set up an ideal MU monitoring platform. This subsidization particularly of MU monitoring platforms would entice tidal energy developers to disseminate environmental data obtained from deployment, while determining who obtains ownership over the data. For example, if the monitoring platform is partially paid for by Marine Scotland, thereby allowing for a portion of the ownership of such data, environmental data acquisition, retention, exploitation and communication can be amalgamated within the public domain. This barrier is national and can be solved by the Scottish Government in the short term through active control and decision making through the provision of subsidies for monitoring platforms.

As depicted in Figure 4, an analysis of real versus perceived barriers in relation to MU between tidal energy development and environmental monitoring can be solved through active control and decision making in the short term by actions undertaken by Marine Scotland.

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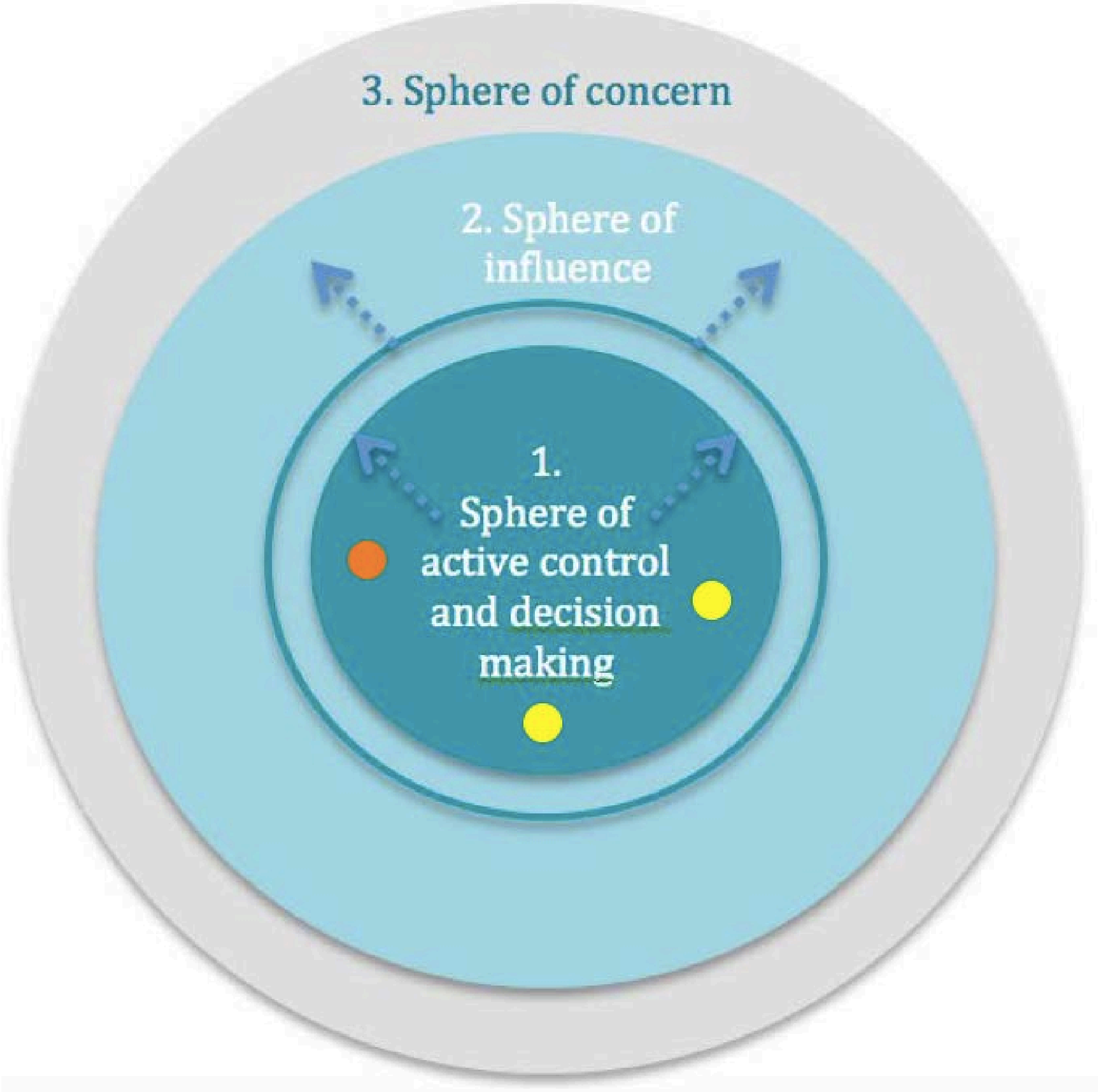

Figure 4 Sphere of Influence – Tidal Energy Development and Environmental Monitoring, adapted from SUBMARINER, 2016. The red circles represent factors of real barriers which are included in the overall DABI; the orange circles represent factors of perceived barriers which are included in the overall DABI the yellow circles represent factors which are perceived but were discarded from the overall DABI

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5 RESULTS OF DABI SCORING: ANALYSIS OF MU POTENTIAL AND MU EFFECT

5.1 Tidal Energy Development and Environmental Protection

Table 11 MU potential and effect for tidal energy development and environmental protection by factor

DRIVERS = factors promoting MU			**BARRIERS** = factors hindering MU		
Factor	**Category**	**Average score**	**Factor**	**Category**	**Average score**
Factor D.1.1. Achievement of legislated GHG emissions reduction targets under the Climate Change (Scotland) Act 2009	Policy	2.9	**Factor B.1.1.** Pre-requisite EIAs are costly and time-consuming given the infancy status of the tidal energy industry	Legal	-1.6
Factor D.1.2. Achievement of legislated renewable energy generation targets under the Climate Change (Scotland) Act 2009		2.7	**Factor B.1.2.** Precedents given to existing uses provides for claims of encroachment and subsequently litigation which would hinder the ability for the tidal energy industry to reasonably expand, therefore inhibiting MU between tidal energy development and environmental monitoring		-1.6
Factor D.1.3. To promote the Sustainable development and expansion of MRE test and demonstration Facilities as per Wind and Marine Renewable Energy sectoral objective 7 of the NMP		1.4	**Factor B.1.3.** Strict EU legislation associated with the Natura 2000 programme provides little room for tidal energy development, and therefore generally inhibits MU between tidal energy and environmental protection		-1.1
Factor D.1.4. To achieve the vision set out in the SMPTE of Scotland becoming a world leader in the development and deployment of offshore renewable energy technologies		2.6	**Factor B.2.1.** Complex regulatory regimes may deter developers and investors, thereby limiting the uptake of tidal energy systems	Administrative	-1.5
Factor D.1.5. To give due consideration to other users and uses of the marine environment, as well as the marine environment itself, during the siting of developments while undertaking an EIA in accordance with EIA Directive 2014/52/EU		2.3	**Factor B.3.1.** Lack of certainty on tidal energy installation, operation, monitoring, and decommissioning interactions with the environmental due to presently insufficient knowledgebase emanating from limited in-situ commercial deployment perpetuating investor uncertainty and subsequent inability for developers to obtain project financing	Economic	-2.4

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DRIVERS = factors promoting MU			**BARRIERS** = factors hindering MU		
Factor D.1.6. To adhere to regulations concerning the protection of rare, threatened or endemic animal and plant species as per the Habitats Directive 92/42/EC		2.5	**Factor B.3.2.** Government financing structures (e.g. CFD) are unfair for tidal energy development is relation to other technologies (e.g. offshore wind energy) as full capital payment is required upfront		-2.8
Factor D.2.1. To facilitate the transition to a low carbon economy via a modern, integrated, reliable, affordable, and clean energy supply while developing equitable market conditions and creating high-value jobs as per the Scottish Energy Strategy	Economic	2.7	**Factor B.4.1.** Lack of technological maturity of the tidal energy industry may deter investors and subsequently limit technological progression to being trapped in the technology valley of death, thereby limiting tidal energy uptake	Technical	-2.1
Factor D.3.1. To transition from centralized energy generation/provision system while enhancing the role that small and island communities assume in the clean energy mix	Societal	1.9	**Factor B.4.2.** Potential perceptions of tidal energy development taking away current cash inflows into a community due to logistical conflicts with other established industries		-1.5
Factor D.3.2. To promote the local ownership of clean energy systems to fulfil associated Scottish Government targets put forth under the Scottish Energy Strategy		2.1	**Factor B.4.3.** Given the harsh environmental conditions where tidal energy is abundant, there is typically a lack of infrastructure (e.g. grid availability/capacity) to easily accommodate tidal energy implementation, thereby leading to an increase in development costs		-2.3
			Factor B.5.1. Public and ENGO perceptions of incompatibility due to adverse environmental implications associated with tidal energy development which would impact current industries providing economic benefit in the community	Social	-1.6
			Factor B.6.1. Lack of scientific baseline knowledge on tidal energy deployment and environmental interactions	Environmental	-2.7
DRIVERS average score		**2.3**	**BARRIERS average score**		**-1.9**
		MU POTENTIAL	**0.4**		

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ADDED VALUES = positive effects of MU			IMPACTS = negative effects of MU		
Factor	**Category**	**Average score**	**Factor**	**Category**	**Average score**
Factor V.1.1. Enhancement for tidal energy development capacity and associated economic benefits pertaining to increased employment, development of a supply chain and industry cluster, and capacity building	Economic	2.3	**Factor I.1.1.** Landscape and seascape impacts resulting from surface-piercing TCT devises and/or associated infrastructure such as on/offshore substations may reduce public acceptance of tidal energy development, thereby hindering the progression of the industry towards achieving large-scale implementation	Social	-1.5
Factor V.2.1. Community benefits in the form of improvements to local infrastructure such as ports and harbours	Societal	2.1	**Factor I.2.1.** Noise and vibration effects during construction and decommissioning for marine mammals, cetaceans, elasmobranches, and diadromous and sea fish	Environmental	-1.5
Factor V.2.2. Development of local power supply providing a sense of community ownership		1.8	**Factor I.2.2.** Noise and vibration effects during operation for marine mammals, cetaceans, elasmobranches, and diadromous and sea fish		-1.1
Factor V.3.1. Reduction in climate change inducing compounds and processes projected to negatively impact the marine environment and its inhabitants	Environmental	2.9	**Factor I.2.3.** Barriers to EMF sensitive cetaceans and diadromous fish including the impediment of migratory movements of eels and salmonids		-1.1
Factor V.3.2. TCT support structures may create an artificial reef effect boasting various species populations		1.3	**Factor I.2.4.** Collision risk between turbine blades and diving birds		-1.9
Factor V.3.3. TCTs will likely act as default no-take fishing zones, thereby doubling as a micro-restoration site for certain marine species		1.7	**Factor I.2.5.** Collision risk between turbine blades and marine mammals		-2.1
			Factor I.2.6. Collision risk between turbine blades and elasmobranchs		-2.1
			Factor I.2.7. Collision risk between turbine blades and fish		-1.8
			Factor I.2.8. Delayed migration or displacement of migratory routes may have effects on salmon and other diadromous species		-1.3

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ADDED VALUES = positive effects of MU			**IMPACTS** = negative effects of MU		
			Factor I.2.9. Changes in seabed morphology and direct loss of benthic habitat from smothering during device installation and cable trenching		-0.9
			Factor I.2.10. Alterations in hydrographic patterns due to extraction of energy from the current regime resulting in sediment transport, wave energy dissipation, and associated coastal process		-1.0
			Factor I.2.11. Impacts on water quality resulting from contamination due sediment deposition, device anti-fouling paint, oil spillage from vessels during installation, maintenance, and decommissioning		-1.1
			Factor I.2.12. Visual disturbance to surface-feeding and diving birds		-0.9
			Factor I.2.13. Potential for fish aggregation and alteration in predation dynamics		-1.7
			Factor I.2.14. Entanglement of and/or avoidance by species due to barrier effects of devices and transmission infrastructure		-1.3
			Factor I.3.1. Potential impacts of staggered MU developments on the revenue streams of other local industries	Other Users	-1.2
			Factor I.3.2. Potential displacement of shipping routes		-1.3
ADDED VALUES average score		**2.0**	**IMPACTS average score**		**-1.4**
		MU OVERALL EFFECT	**0.6**		

The majority of drivers promoting MU between tidal energy development and environmental protection stem from Scottish national policies and EU legislation, accounting for 6/9 (66.7%) of total drivers. One economic driver and two societal drivers were also identified. The highest average score for any driver promoting MU was the achievement of GHG emissions reduction legislated targets under the Climate Change (Scotland) Act 2009 [8]. This driver was put forth as a legislative target which promotes sustainable development of MRE as well as the protection of the marine environment through the reduction in adverse compounds produced from excessive GHG emissions emanating from carbon-based energy generation. The results of stakeholder engagement suggest that this driver is seen to be least impactful from the perspective of developers, although still scor-

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ing an average of 2.0, followed by academic institution, which were split between 2.0 and 3.0. Government and environmental organizations, both statutory and non-statutory, all ranked the necessity to reduce GHG emissions under the Climate Change (Scotland) Act 2009 as a 3.0. The close second highest ranked driver was also drawn from the Climate Change (Scotland) Act 2009 in reference to legislated targets to develop a given amount of capacity to meet the target of 100% renewable electricity generation by 2020. The interim target of achieving 50% of electrical generation from renewables was exceeded in 2015 whereby 59.4% was achieved [6]. These figures suggest that Scotland is well invested in maintaining its climate change targets and therefore promotes the tidal energy industry in order to contribute to such goals.

Achieving the same average score as the renewable energy deployment driver, the facilitation of transitioning Scotland to a low carbon economy via a modern, integrated, reliable, affordable, and clean energy supply while developing equitable market conditions and creating high-value jobs as per the Scottish Energy Strategy further reinforces the overall energy regime shift in support of tidal energy [6]. Furthermore, stakeholders believe that the results emanating from the achievement of GHG reduction and renewable energy deployment targets are beneficial to society through the jobs produced from the industry, and moreover the stabilization that renewable energy development and generation will have on the Scottish energy market. It is inferred by stakeholders that MRE can make a significant contribution to climate change targets as the vision set out in the SMPTE of Scotland becoming a world leader in the development and deployment of offshore renewable energy technologies was heavily supported as a driver with an average score of 2.6.

Overall, the drivers that received the greatest average scoring all targeted enhanced development and the potentials that this would have on improving the health of the marine environment, thereby indirectly enhancing the prospect of environmental protection. The following drivers which received the moderate range of scores dealt more directly with legislation concerning direct environmental protection, the highest scored factor of which was the adherence to regulations concerning the protection of rare, threatened or endemic animal and plant species as per the Habitats Directive 92/42/EC, with an average of 2.5. This was followed by the requirement to undertake EIAs via the EIA Directive 2014/52/EU, which provides for a mechanism to ensure that developers are practicing due diligence for site selection to sensitive environmental receptors, as well as other users and uses of the marine environment.

It would seem that development targets which further elaborate on the direct benefits towards Scottish society and local/regional communities are weighted less important with regard to the promotion of MU. Societal drivers which promote the transition from a centralized energy generation/provision system while enhancing the role that small and island communities assume in the clean energy mix, and promote the local ownership of clean energy systems to fulfil associated Scottish Government targets put forth under the Scottish Energy Strategy, received a score of 1.9 and 2.1 respectively. Perhaps the reason for such scores is that these drivers place a heavy emphasis on the results of development as opposed to the promotion of MU. However, another reason for this may be in line with the viewpoint put forth by Nova Innovation Ltd, which suggested that the tidal energy industry is too young in order to promote local ownership as the costs related to investment and development are currently too high.

Finally, the lowest scored driver at 1.4 was the promotion of the sustainable development and expansion of MRE test and demonstration facilities as per Offshore Wind and Marine Renewable Energy sectoral objective 7 of the NMP. Although this driver allows for environmental monitoring pro-

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grammes to accumulate data in order to further characterize environmental interactions with individual TCTs, the overall opinion of stakeholders was that further commercial development must take place in order to better characterize environmental interactions with large TCT arrays. However, the importance of MRE test centres such as EMEC, or early demonstration devises such as Sea-Gen in the Strangford Lough in Northern Ireland, were not downplayed by stakeholders as they acknowledged the usefulness of data produced from such facilities in paving the way for the tidal energy industry and obtaining data on environmental interactions.

The greatest barrier hindering MU between tidal energy development and environmental protection, receiving an average score of -2.8, which was categorized as perceived as it was not identified in the desk analysis, was the ineffectiveness of the UK government CFD subsidy mechanism for tidal energy developments in relation to other technologies such as offshore wind. Since offshore wind energy has achieved commercial status, the CFD renders pre-commercial tidal energy proposals uncompetitive. Furthermore, full capital payment is required upfront for decommissioning of tidal projects, whereas this is not the case for offshore oil and gas (O&G) explorations. The theory behind this barrier is that, in order to achieve MU between tidal energy development and environmental protection, more monitoring data is required to characterize environmental interactions, and in order to accumulate monitoring data to reduce environmental risks to marine species and make tidal energy projects bankable, further commercial developments must be implemented to undertake monitoring of large TCT arrays. Without a financing support mechanism tailored to tidal energy developments, further capacity will struggle to be developed and environmental interactions informing the viability of MU will not be determined.

The second greatest barrier was correlated to the ineffectiveness of the CFD and the chain of reactions that has on obtaining environmental monitoring data. The barrier dealt with the lack of scientific baseline knowledge on tidal energy deployment and environmental interactions, receiving an average score of -2.7. This barrier is evident in both the desk analysis and stakeholder engagement due to the pre-commercial stage in which the tidal energy industry currently resides. However, the majority of developers scored this barrier as less inhibiting than academia, government, and environmental organizations suggested This is potentially due to the notion put forth by developers that they have a good working relationship with Marine Scotland concerning licensing and consenting, and therefore adequate communication and policy guidance is exercised in the event of unknown elements of environmental interactions with TCT arrays. This notion is supported by the high scoring attributed to Scottish national policies which promote development in order to achieve legislative GHG and renewable electricity generation targets, which draw upon the UK Sustainable Development policy statement which resides in favour of sustainable development when there is conflicting regimes [7].

Another high-scoring barrier was the lack of certainty on tidal energy installation, operation, monitoring, and decommissioning interactions with the environmental due to a presently insufficient knowledgebase emanating from limited in-situ commercial deployment perpetuating investor uncertainty and subsequent inability for developers to obtain project financing. Similar to the two barriers mentioned above, this real barrier addresses the absence of environmental interaction data and the impact that has on financing tidal energy developments, thereby reducing the potential for MU with environmental protection. This barrier is intrinsically linked to the theme of technological immaturity of TCTs which also ignites a chain reaction of deterring investors and subsequently stunting monitoring programmes which would be able to further characterize environmental interactions in order to reduce financial risk and liability. If funding mechanisms are not put in place, it is

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possible that the tidal energy industry will be trapped in the technology valley of death, whereby bankability is not achieved and developer organizations run out of cash inflow. The necessity for subsidization is also apparent in another barrier illuminating the harsh environmental conditions where tidal energy is abundant, which typically lack the appropriate grid collection and distribution infrastructure requirements to easily accommodate tidal energy implementation, subsequently leading to an increase in development costs.

Concerns pertaining to the difficulty of obtaining the cash inflow necessary to develop tidal energy projects are further exacerbated through the barrier which illustrates that pre-requisite EIAs are costly and time-consuming given the infancy status of the tidal energy industry. This barrier scored an average of -1.6, which is moderate relative to other barriers. However, there were mixed reactions amongst the majority of stakeholders with no pattern evident as to which category of stakeholder believes this to be a real barrier. While developers expressed how the high costs and long timeframes of EIAs are at times burdensome, every developer engaged stressed the necessity of undertaking EIAs in order to promote the build-out of arrays in a sustainable manner.

An administrative barrier identified was that complex regulatory regimes may deter developers and investors, thereby limiting the uptake of tidal energy systems and subsequently MU. However, developers commented on this barrier that MS-LOT has demonstrated good communication as a streamlined one-stop-shop for granting consents and licenses, although this process could be further improved as more experience is gained by Marine Scotland through the further development of the tidal energy industry. This is particularly true with respect to the expansion of MU, as licensing procedures will have to be tailored in order to remove the potential barrier of litigation stemming from claims of encroachment by sectors who have operated in the study area prior to the arrival of the tidal energy industry. This barrier is directly related to potential perceptions of tidal energy development taking away current cash inflows providing economic benefit to a community due to logistical conflicts over the use of marine space, as well as public and ENGO perceptions of development resulting in adverse environmental implications.

Finally, the barrier which was scored the lowest at -1.1 was the perceived theory that strict EU legislation associated with the Natura 2000 programme provides little room for tidal energy development, and therefore generally inhibits MU between tidal energy and environmental protection. The low scoring of this barrier supports the potential of MU in that it is not a barrier in itself to site tidal energy developments within environmental protection zones, while affirming that it is the lack of environmental interaction data which provides the greatest barrier.

Overall, drivers received an average aggregate score of 2.3, and barriers -1.9, resulting in a MU potential score of 0.4, suggesting that the drivers promoting MU between tidal energy development and environmental protection are stronger than the barriers inhibiting it. The economic driver category scored the highest, at 2.7, the one factor of which stems from the vision set out in the Scottish Energy Strategy, which is informed by the GHG mitigation and renewable energy generation targets set out in the Climate Change (Scotland) Act 2009. While the vision of Scotland transitioning to a low-carbon economy, and the subsequent socio-economic benefits that are projected to manifest, act as a leading driver, it is the synergistic relationship between environmental and economic barriers which act as the greatest hindrance towards MU, as a lack of appropriate financial support mechanisms may stunt the development of the tidal energy industry, and therefore inhibit the accumulation of data stemming from monitoring programmes which increases the environmental interaction knowledgebase. However, this negative synergy provides a clear vision of necessary ac-

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tion plan moving forward, one which is not heavily dependent on the re-interpretation of legislation, administrative complexities, nor social barriers, but rather financing structures which aid developments.

In tune with the leading driver of MU being the achievement of GHG mitigation targets set by the Scottish Government under the Climate Change (Scotland) Act 2009, the highest scored added value to tidal energy development, at an average of 2.9, was the reduction in climate change inducing compounds and processes projected to negatively impact the marine environment and its inhabitants. This added value demonstrates synergies with the enhancement for tidal energy development capacity and associated economic benefits pertaining to increased employment, development of a supply chain and industry cluster, and capacity building, which scored second highest at 2.2. If more tidal energy capacity is developed, and moreover sited in environmental protection areas which would expanded the currently constrained scope for deployment, a greater quantity of GHG emissions can be replaced while the direct and indirect economic benefits of can be achieved within Scotland as a whole, and by extension social benefits through improvement to local and regional infrastructure such as ports and harbours. Although, local-scale specific benefits in the form of developing a local power supply owned in part by a community did not score as well, primarily due to the fact that the tidal energy industry is pre-commercial and therefore development costs are high and business models are risky, which would not accommodate local ownership. Although there are benefits to remote island and small communities in attaining power from a renewable source such as tidal energy to promote local pride through community branding.

With regards to direct benefits occurring from co-locating a commercial TCT array in an environmental protection area, the majority of stakeholders suggested that development areas may act as default no-take fishing zones, thereby boosting sea and diadromous fish populations. It was hypothesized by some stakeholders that such environmental benefits would emerge without the necessity to enact spatial regulations that restrict fishing or employ environmental management programmes as TCT development sites onto themselves are incompatible with commercial fishing. However, almost all stakeholders noted that more research must be done in order to discern the reality of claims pertaining to boosted fish populations in development areas. Perhaps the most controversial added value was that TCT support structures may create an artificial reef effect boasting various species populations, which scored the lowest with an average of 1.3. Some stakeholders suggested that these potential artificial reefs could be positive in the sense that they can provide a sheltering area for certain species, particularly wild salmon and diadromous fish, while others suggested that species population changes around structures may lead to alterations in predation dynamics, thereby leading to the increased potential for collision risk. Regardless, of the speculation, all stakeholders made it clear that more data is required in order to inform the extent to which artificial reefs occurs and the resulting potential effects.

In general, impacts stemming from MU between tidal energy development and environmental protection were not scored very high. The highest scoring impact, averaging -2.1, was collision risk between TCT blades and marine mammals, which was shown more concern than collision risk between diving birds and elasmobranches at -1.9 respectively, followed by fish with a score of -1.8. Reasons for greater concern of blade strike with marine mammals pointed out by stakeholders is that seal landings are present in the Inner Sound of the Pentland Firth. However, it is generally believed that marine mammals are very intelligent creatures and should be able to avoid TCT blades. Irrespective of the species receptor to collision risk, all stakeholders suggested that more monitoring data is required in order to make informed judgements.

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In contrast to the added values of boosted fish populations stemming from TCT arrays acting as default no-take fishing zones and artificial reefs acting as shelter areas, a notable impact was fish aggregation around TCTs altering predation dynamics, and therefore increasing collision risk. This is of particular concern in environmental protection areas which may harbour sensitive fish populations. However, as is the case with artificial reefs, the majority of stakeholders stated that more monitoring data is required to determine the effect of the potential impact. Stakeholders also noted that noise and vibration effects during construction and decommissioning may have negative impacts on marine mammals, cetaceans, elasmobranches, and diadromous and sea fish, although such impacts are projected to be short-lived due to finite construction schedules, while noise and vibration effects emanating from operational TCTs were suggested to be much less prominent.

EMFs radiating from inter-array and transmission cables and the impacts they may have on sensitive cetaceans and diadromous fish, and the impediment of migratory movements of eels and salmonids are projected to be minor, as offshore cables have been deployed in the North Sea for decades and thus the environmental impacts have been relatively well characterized. Delayed migration or displacement of migratory routes may have effects on salmon and other diadromous species and entanglement of and/or avoidance by species due to barrier effects of devices and transmission infrastructure both received an average score of -1.3. This score is justified by the fact that the migration path of fish species through the Inner Sound of the Pentland Firth is generally unknown, promoting stakeholders such as Fisheries Management Scotland, Atlantic Salmon Trust, and Marine Scotland advocate for the need more research programmes.

Alterations in hydrographic patterns due to extraction of energy from the current regime resulting in sediment transport, wave energy dissipation, and associated alterations to coastal process received a low score of -1.1, primarily due to the fact that much research has been done on the development of models through the EcoWatt and TeraWatt projects. The impacts on water quality resulting from contamination via sediment deposition, or by other means including device antifouling paint and oil spillage from vessels during installation, maintenance, and decommissioning also received less concern as the seabed in the study area is barren for the most part, while construction windows are finite and vessel operations provide no more risk of pollution for the lifecycle of a TCT project than any other marine vessel work in other sectors. Furthermore, due to the scoured bedrock sea bed of the study area, impacts pertaining to changes in seabed morphology and direct loss of benthic habitat from smothering during device installation and cable trenching are projected to be miniscule, scoring -0.9. Finally, the lowest scored impact was potential visual disturbance that TCTs may present to surface-feeding and diving birds, scoring -0.9. While stakeholders flirted with ideas of how this may be beneficial in promoting fish populations in the development site, thereby synergistically promoting environmental protection, all effects are agreed to be speculative and context dependant. Given the lack of data on the impact, a lower concern was attributed by stakeholders.

A social impact suggested by stakeholders was landscape and seascape impacts resulting from surface-piercing TCT devises and/or associated infrastructure such as on/offshore substations may reduce public acceptance of tidal energy development, thereby hindering the progression of the industry towards achieving large-scale implementation. This concern would be particularly sensitive in environmental protection areas given the pristine imagine that are attributed to such sites. While the erection of onshore substations is necessary, this impact is context dependant from a marine perspective as only surface-piercing TCTs will trigger this negative effect, and most commercially viable designs at the moment are fully submerged, such as the Atlantis Resources Ltd AR1500 and

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Andritz Hydro Hammerfest HS1000 utilized in the MeyGen project, and do not require the construction of offshore substations [2]. With regards to potential impacts on other users of the marine environment, potential impacts of staggered MU developments on the revenue streams of other local industries was attributed a moderate score given that high tidal energy environments such as that of the Inner Sound of the Pentland Firth are inhospitable to most sectors, such as fishing, although local ferry traffic is abundant which provided some of the concern. However, there is a potential for the elimination of other industries operating in a development area to be beneficial to the environmental protection area in which TCTs are located as pollution and blade strike risks from vessels will be minimized and any fishing activity will be halted.

Overall, added values received an average aggregate score of 2.0, and impacts -1.4, resulting in a MU effect score of 0.6, suggesting that the benefits emanating from MU between tidal energy development and environmental protection are greater than the potential for negative implications which could result. The highest scored category for added values was economic, which is similar to the case for drivers, in that it is the economic benefits stemming from the development of the tidal energy industry in Scotland, backed by national policies and plans, which is driving sustainable development with environmental protection in order to provide benefits to the Scottish economy. The impact categories have all received a similar score, however, it is the sheer number of identified environmental impacts which would suggest that if environmental interactions prove to be negative, MU will not be viable. Given the pre-commercial status of the tidal energy industry, there is not a sufficient amount of data from which to draw upon in order to determine the scale and severity of impacts. Moreover, the majority of stakeholders stated that most of the environmental impacts examined are context dependant on the geographical scale of development, sensitivity of the environment, and TCT technology being employed. Given that the primary theme thus far in the analysis has been centred on the importance of economic aspects allowing for development, and the benefits thereof both to the economy, the industry, and in obtaining data to inform environmental interactions in order to better characterize MU, it is also worthy to note that negative impacts on the economy triggered by MU are not apparent, and therefore the economic risk lies with the tidal energy industry and not the concept of MU itself. Overall, MU effects scored higher than MU potentials, suggesting in theory that, while the initiation of MU is more difficult, the effects of achieving MU are bountiful enough to promote the allocating of resources towards exploring solutions to barriers.

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Table 12 MU potential and effect for tidal energy development and environmental protection by category

DRIVERS = factors promoting MU		**BARRIERS** = factors hindering MU	
Category	**Average score**	**Category**	**Average score**
Policy	2.4	Legal	-1.4
Economic	2.7	Administrative	-1.5
Societal	2.0	Economic	-2.5
		Technical	-1.8
		Social	-1.6
		Environmental	-2.7
ADDED VALUES = positive effects of MU		**IMPACTS** = negative effects of MU	
Category	**Average score**	**Category**	**Average score**
Economic	2.3	Social	-1.5
Environmental	1.9	Environmental	-1.4
Societal	2.1	Other Users	-1.3

5.2 Tidal Energy Development and Environmental Monitoring

Table 13 MU potential and effect for tidal energy development and environmental monitoring by factor

DRIVERS = factors promoting MU			**BARRIERS** = factors hindering MU		
Factor	**Category**	**Average score**	**Factor**	**Category**	**Average score**
Factor D.4.1. Promotion of an ecosystem based approach to the planning and management of tidal energy implementation to support the achievement of GES of marine and coastal waters under the MSFD	Other Users	2.3	**Factor B.2.2.** Staggered MU may initiate complex licensing procedures where existing uses that are not licensable will take priority and inhibit the deployment of TCTs, and therefore the ability to undertake environmental monitoring which would further develop the knowledge base needed to further the industry	Administrative	-1.7
Factor D.4.2. Necessity to build upon knowledge gaps pertaining to environmental interactions in relation to tidal energy development		2.7			
Factor D.3.2. Promotion of investment in the tidal energy sector to sustainably maximize the economic benefits of the growth of the tidal energy industry	Economic	2.1			
Factor D.5.1. Adherence to the protection of legislated SPAs and SACs under the	Ecological	2.6			

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DRIVERS = factors promoting MU			BARRIERS = factors hindering MU		
Factor	**Category**	**Average score**	**Factor**	**Category**	**Average score**
Natura 2000 programme					
Factor D.5.2. Adherence to the Maritime Spatial Planning Directive 2014/89/EU which aims to promote sustainable development of marine environment and sustainable use of marine resources		2.3			
Factor D.5.3. To provide for clean, healthy, safe, productive and biologically diverse oceans and seas in accordance to the UK Marine Policy Statement		1.9			
Factor D.5.4. Development of an appropriate management and regulatory framework to sustainably manage wild salmon and diadromous fish and fisheries resources in order to provide significant economic and social benefits for the people of Scotland in conformity with Wild Salmon and Diadromous Fish sectoral objective 1 within the Scottish National Marine Plan		2.1			
Factor D.6.1. To assist Scotland in becoming a world leader in technological innovation	Technological	2.8			
DRIVERS average score		**2.4**	**BARRIERS average score**		**-1.7**
		MU POTENTIAL	**0.7**		

ADDED VALUES = positive effects of MU			IMPACTS = negative effects of MU		
Factor	**Category**	**Average score**	**Factor**	**Category**	**Average score**
Factor V.1.2. Reduction in scientific uncertainty prompting an enhancement in private investment	Economic	2.2			
Factor V.1.3. Provision of shared operational and maintenance infrastructure		1.7			

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ADDED VALUES = positive effects of MU			**IMPACTS** = negative effects of MU		
including vessels which lower lifecycle costs					
Factor V.2.3. Increased knowledge base on tidal energy development and environmental interactions which will further facilitate the dissemination of information to the public, thereby educating the public on real as about to perceived interactions which may improve public opinion and support for tidal energy deployment	Societal	2.2			
Factor V.3.4. Contribution of monitoring data retrieved from tidal energy deployments towards marine protected and conservation area management	Environmental	2.6			
Factor V.4.1. Further inform risk criteria thereby contributing to standardized, streamlined licensing and monitoring procedures	Regulatory/ Risk	2.3			
Factor V.5.1. Increased knowledge base on the operational characteristics of tidal energy technologies thereby proliferating the progression of the technology readiness level of turbines which allows for further uptake of technologies and industry maturity	Technical	2.4			
Factor V.5.2. Further residual capacity building for energy storage systems in order to provide baseload power given the predictable nature of tidal energy		0.8			
Factor V.5.3. Increased knowledge base on the operational characteristics of environmental monitoring equipment can lead to technology learning rates for such equipment, thereby leading to a decrease in cost of pro-		1.9			

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ADDED VALUES = positive effects of MU			**IMPACTS** = negative effects of MU		
curing monitoring equipment					
Factor V.6.1. Increased knowledge base of environmental sensitivity to and environmental interactions with tidal energy deployment	Industry	2.8			
Factor V.6.2. Dissemination of information on tidal energy interactions with the environment to the general public can help secure community buy-in and therefore potentially streamline the uptake of tidal energy technology		2.4			
ADDED VALUES average score		**2.1**	**IMPACTS average score**		**N/A**
		MU OVERALL EFFECT	**2.1**		

The majority of drivers promoting MU between tidal energy development and environmental monitoring are ecological, which is in tune with the majority of comments received from stakeholders of the limitation that limited data sets have on the ability to promote MU between tidal energy development and environmental protection. Thus, the overarching driver for MU between tidal energy and monitoring is to inform MU between tidal energy and protection. Adherence to the protection of legislated SPAs and SACs under the Natura 2000 programme scored the highest for ecological drivers, as MU monitoring platforms comprised of a combination of visual, audio, passive acoustic, and active sonar equipment will better characterize environmental interactions with TCT arrays. Such data produced from monitoring will assist the another ecological EU legislative driver of adherence to the Marine Spatial Planning Directive 2014/89/EU which aims to promote sustainable development of marine environment and sustainable use of marine resources.

On a national level, such ambitions for the characterization of interactions stemming from technological solutions to monitoring and co-location on TCT devises is supported by the UK Marine Policy Statement which provides for clean, healthy, safe, productive and biologically diverse oceans and seas. This concept is also applicable in relation to other users of the marine environment as well as the ecosystem itself through the promotion of an ecosystem based approach to the planning and management of tidal energy implementation to support the achievement of GES of marine and coastal waters under the MSFD. On a sectoral scale, technical solutions to environmental monitoring and tidal energy development are driven by the potential to enhance the development of an appropriate management and regulatory framework to sustainably manage salmon and diadromous fish and fisheries resources in order to provide significant economic and social benefits for the people of Scotland in conformity with Wild Salmon and Diadromous Fish sectoral objective 1 within the NMP.

The highest scoring driving factor at 2.8 was to assist Scotland in becoming a world leader in technological innovation, which translates both to the tidal energy industry and advanced monitoring solutions and technologies. Technological development directly relates to the second highest

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scored driver at 2.7 of the necessity to build upon knowledge gaps pertaining to environmental interactions in relation to tidal energy development, as innovative technology will result in a greater knowledgebase. Given that technological innovation and subsequent environmental characterization is dependent upon the allocation of financial resources, the promotion of investment in the tidal energy sector to sustainably maximize the economic benefits of the growth of the tidal energy sector was also scored high as a driver. Such investment feeds back into the economic drivers of MU between development and protection which aims to realize economic benefits from environmentally sustainable development.

Only one barrier has been identified for the MU combination, and has been suggested by Marine Scotland. The barrier identifies how staggered MU may initiate complex licensing procedures where existing uses that are not licensable will take priority and inhibit the deployment of TCTs, and therefore the ability to undertake environmental monitoring which would further develop the knowledgebase needed to further expand the industry. Overall, drivers received an average aggregate score of 2.4, and barriers -1.7, resulting in a MU potential score of 0.7, suggesting that the drivers promoting MU between tidal energy development and environmental monitoring are stronger than the barriers inhibiting it. The potentials score is higher for this MU combination than tidal energy development and environmental protection, which is evident from the single barrier towards MU in between development and monitoring, which is administrative and can be solved in the short to medium term through control and active decision making by Marine Scotland. While most of the drivers are categorized as ecological and framed by EU legislation and national policies, the greatest driver for MU is technological as solutions must be found in order to develop quality monitoring devises which can be co-located on TCT structures.

The combination of tidal energy development and environmental monitoring produced many added values across a diverse array of categories. Moreover, there were no negative impacts associated with the MU combination apparent neither from the desk analysis nor stakeholder engagement. The highest scored added value at 2.8 was the increased knowledge base gained on environmental sensitivity to and environmental interactions with tidal energy deployment. The monitoring data retrieved from tidal energy deployments can also contribute towards marine protection and conservation area management. Technical advancements in monitoring equipment placed on TCT structures can better capture and characterize environmental interactions, which provide the added value of securing community buy-in through the dissemination of information to the general public, thereby educating the public on real as opposed to perceived interactions which may improve public opinion and support for tidal energy deployment, thus streamlining development.

The monitoring data stemming from MU could further inform risk criteria thereby contributing to standardized, streamlined licensing, consenting, and monitoring procedures from a governance stand point, while reducing scientific uncertainty and subsequently facilitating an enhancement in private investment. Such investment would contribute towards the elimination of economic barriers towards MU between tidal energy development and environmental protection by making tidal projects bankable through the attainment of project and non-recourse financing. This would clear the tidal energy industry from the technology valley of death and eliminate the barrier currently imposed by the ineffective CFD mechanism. Furthermore, the advancement of MU between tidal energy development and environmental monitoring platforms can increase the knowledgebase on the operational characteristics of tidal energy technologies and monitoring equipment, thereby proliferating the progression TCT and monitoring technology. If such a relationship is present, stakeholders from environmental organizations and developers have suggested that the costs asso-

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ciated with procuring monitoring equipment would drop, thereby enabling savings as well as the cost of obtaining data which is sold. Marine Scotland had also suggested that technological advancements could also result in further residual capacity building for energy storage systems in order to provide base-load power given the predictable nature of tidal energy. However, this was not mutually agreed upon by stakeholders as it is seen as too many degrees of separation between the MU discussed in the case study which accounted for its average score of 0.8, which is the lowest of all factors.

It has been suggested by stakeholders that indirect added values to MU may perpetuate the provision of shared O&M infrastructure including vessels utilized to service both TCTs and monitoring equipment, thereby lowering lifecycle costs. While this factor obtained an average score of 1.8, a stakeholder from an Unnamed Academic Institution suggested that this is not necessarily true, as vessels utilized to retrieve to shore and service 20m rotor diameter TCTs will be too big and expensive to substitute as a practical option for servicing monitoring equipment. Furthermore, the time intervals between O&M on TCTs and on monitoring equipment do not match up. This response demonstrates that the quantity of responses provided does not necessarily translate into the most correct opinion. Topics such as this are further examined in Section 6. Focus Area Analysis.

Overall, added values received an average aggregate score of 2.2. Since there were no impacts identified for the MU combination of tidal energy development and environmental monitoring, the MU effect score is 2.2, suggesting that this MU has very promising benefits. Of course, monitoring is a condition of consent under the SDM licensing policy guidance, although it is the technical solutions to monitoring that are required in order to enhance the quality of data pertaining to environmental interactions with TCTs, thereby addressing barriers associated with environmental knowledge gaps that currently inhibit both the development of the tidal energy industry alone from an economic risk perspective, as well as the colocation of developments in environmental protection areas.

Table 14 MU potential and effect for tidal energy development and environmental monitoring by category

DRIVERS = factors promoting MU		**BARRIERS** = factors hindering MU	
Category	**Average score**	**Category**	**Average score**
Relation with Other Users	2.5	Administrative	-1.7
Economic	2.1		
Ecological	2.2		
Technological	2.8		
ADDED VALUES = positive effects of MU		**IMPACTS** = negative effects of MU	
Category	**Average score**	**Category**	**Average score**
Economic	1.9		
Social	2.2		
Environmental	2.7		
Regulatory/Risk	2.3		
Technical	1.9		
Industry	2.6		

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6 FOCUS AREA ANALYSIS

The following sub-sections address three general aspects of MU. The questions and responses do not distinguish between the two MU combinations of tidal energy development and environmental protection, and tidal energy development and environmental monitoring. This is a result of the interrelation in opportunities, constraints, and solutions identified in the desk analysis, which produced draft answers to set KEQs, and through stakeholder engagement which produced a plethora of varied responses. Rather, both combinations are addressed where responses to questions permit.

6.1 Addressing Multi-Use

1) *Is it possible to establish / widen / strengthen MU in the case study area? (Y/N)*
    i) *For which MU combination in particular?*
    ii) *What needs would MU satisfy?*

Yes, it is possible to establish MU between tidal energy development and environmental protection in the Inner Sound of the Pentland Firth. This MU combination is currently apparent in the study area as the MeyGen development site is sited within the North Caithness Cliffs SPA. The case study explores environmental interactions with TCT arrays in order to inform the sustainability of tidal energy developments with the marine environmental receptors, thereby providing insight on the viability of co-locating TCT arrays and protected areas. Furthermore, it is possible to enhance MU between tidal energy development and environmental monitoring in the study area. Given that monitoring of TCT installations is a condition of consent under the SDM licensing policy guidance [9], enhancements to MU between tidal developments and monitoring are framed from a technical advancement context of platforms which integrate various monitoring equipment and co-locate platforms on TCT structures. MU combinations satisfy the following needs:

I. Developing an enhanced knowledgebase on tidal energy development and environmental interactions through environmental monitoring of deployed TCTs.
II. Progression towards the achievement of legislated climate change mitigation targets
III. Progression towards the achievement of legislated renewable energy deployment targets
IV. Promotion of an ecosystem approach to marine spatial planning (MSP)
V. Promotion of investment in TCT development as interactions with the marine environment are better understood, thereby leading to an increase in high-value jobs as the industry expands
VI. Contribution to the transition to a low carbon economy as set out in the vision of the in the NMP and the SMPTE
VII. Adherence to EU and national environmental protection legislation, policies, and strategies

With regards to the needs addressed above, all 18 stakeholders agreed that MU addresses I. in that monitoring environmental interactions with TCTs will inform the viability of tidal energy development in marine ecosystems comprised of sensitive environmental receptors. The achievement of industry expansion and associated economic benefits set out in the NMP and SMPTE, and GHG mitigation targets established under the Climate Change (Scotland) Act 2009, were both nearly unanimous. However, the promotion of an ecosystem approach to MSP was not identified as a need to be addressed by this MU at all for academic stakeholders, while all regulators agreed on how MU can inform an ecosystem approach to MSP.

2) *Is space availability an issue for MU development / strengthening in the case study area at present? (Y/N)*
    i) *Will space availability become an issue for your area in the future? (Y/N)*

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ii) For what elements space availability is / could become an issue?

The desk analysis suggested that space was not currently an issue for MU development in the study area, although tidal energy development capacity could be limited in the future by virtue of economic growth which follows development, thus relaying into various sector expansions crowding the site. The majority of stakeholders suggested that space availability is currently an issue as the study area hosts considerable vessel traffic, through the commercial shipping and tourism industries. This vessel traffic is likely to increase due to O&M vessels servicing TCT arrays. With specific regards to MU between development and environmental protection, some stakeholders suggest that SPAs and SACs within the Natura 2000 programme will limit development, as TCT arrays should not completely overtake these sites regardless of MU viability. Other stakeholders suggested that the study site would be limited to one tidal energy developer. A representative from the University of St. Andrews even suggested that onshore space availability may become an issue with regards to the necessary infrastructure required to support TCT systems, including port capacity, onshore substations, and cable landings.

The most common response for stakeholders who did believe that MU development would not be an issue in the future pointed to the fact that tidal energy extraction is self-regulating in that only a certain amount of energy can be extracted from a site before electrical generation witnesses diminishing returns. With regards to constraints between tidal energy development and other industries, many stakeholders suggested that proper MSP in the site should be able to address any inter-industry spatial conflicts, particularly through the currently developed PFOW Marine Spatial Plan. Furthermore, DP Energy put forward that space should not be an issue since, in order to obtain regulatory approval for a development application, the applicant must demonstrate that inter-industry conflict will not occur at a rate that is deemed unjustifiable and/or unsustainable to the point where spatial/logistical conflicts would significantly impact any other operations in and/or around the site in question. The most common solution for stakeholders who believed that space availability may become an issue in the future was to utilized a phased implementation approach, such as that being undertaken by MeyGen, in order to appropriately consider environmental impacts.

3) *Are there MUs combinations and potentials that will share the same resources but in different times (e.g. reuse of an infrastructure after the end of its first life and original scope)? (Y/N)*
   i) What are they?

The desk analysis suggested that infrastructure can be shared between tidal energy developments and monitoring equipment via electricity submarine cables and cable routes to transmit monitoring equipment back to shore, while port and harbour infrastructure can accommodate O&M vessels for technologies as well as for marine wildlife surveys. The vast majority of stakeholders agreed with this potential. However, a stakeholder from the University of Aberdeen stated that, while it is possible that vessels in the region can be used for O&M procedures, this would be dependent on developers investing in new vessels (as Scotrenewables has done) as TCT capacity increases, as local vessels in the Pentland Firth may be ill equipped/too small to retrieve submerged turbines. Furthermore, a stakeholder from an Unnamed Academic Institution suggested that vessels utilized to retrieve large TCTs will be too big and expensive to substitute as a practical option for servicing monitoring equipment, particularly given that the time intervals between O&M on TCTs and on monitoring equipment do not match up. With regards to direct MU between TCTs and monitoring

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equipment, spatial synergies can be realized by co-locating passive acoustic tracking devices on TCT structures.

4) *What would be the most important resources to be shared between uses (infrastructures, services, personnel, etc)?*

The desk analysis suggested that the most important resources to be shared for tidal energy development and environmental monitoring would be a knowledgebase on environmental interactions associated with tidal energy implementation stemming from environmental monitoring programs, which would further inform the tidal energy industry and the scientific community about added values and negative impacts resulting from development. Nearly all stakeholders agreed with this. Marine Scotland, Fisheries Management Scotland, and Atlantic Salmon Trust emphasized that the expansion of such a knowledgebase will help inform the distribution and movements of salmon smolts and adults, and other diadromous fish and their interactions with TCT devices, thereby leading to enhanced TCT and salmon management plans, individually and in relation to MU, through informed policy development. Another suggested synergy for MU was the sharing of the cable infrastructure which should be able to accommodate both electricity and monitoring data transmission to shore, while vessels can service all systems at the same MU site as required. A member of Marine Scotland elaborated on this by proposing that the electricity produced from the deployment of TCTs and how that can power vessels in harbours that function to service TCTs and associated monitoring equipment, ultimately enhancing the contribution that TCT lifecycles have on mitigating GHG emissions. Finally, Scottish Natural Heritage and EMEC both suggested that tourism drawn to the area due to the tidal energy industry could provide indirect economic benefits to the local/regional area.

5) *Are existing and/or potential MUs taken into account within the existing or under development Maritime Spatial Plans? (Y/N)*

The desk analysis suggested that consideration is given to MU in MSP via the NMP, SMPTE, and the PFOW Marine Spatial Plan. The majority of stakeholders agreed with this, placing particular emphasis on the PFOW plan given its specific and more granular focus on the study area, while other stakeholders mentioned that the NMP policies and objectives are too high-level to give proper consideration to MU. Additional plans which were mentioned as considering general (non-tidal focused) MU in MSP were the Clyde and Shetland plans. Some stakeholders suggested that MSP intrinsically considers inter-sectoral synergies through a cumulative effects assessment perspective in order to sustainably allocate different areas for different uses. However, many stakeholders suggested that more data on environmental interactions with TCT arrays must be obtained from monitoring in order to maximize such synergies, while the practice of MSP must mature in order to identify and amalgamate lessons learned. EMEC mentioned that MSP in its current form does not initiate policies that directly promote MU between sectors in general.

6) *How are MUs connected or related to land-based activities?*

The desk analysis suggested that tidal energy development is related to land based activities directly through the construction of electricity collection, connection, and distribution infrastructure and associated O&M procedures, as well as activities occurring at ports and harbours throughout the lifecycle of TCTs. Furthermore, transportation to and from ports and harbours, and onshore electricity infrastructure activities, interact with various elements of the marine environment and subsequently marine species. The majority of stakeholders agreed with this statement. A common addition was that such activity is expected to increase incoming revenue streams, thereby providing for the catchment of societal and economic benefits through the creation of a chain and industry cluster. The question however that has yet to be answered which may be cause for con-

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cern is whether such benefits will be directly realized nationally/regionally/locally, or whether such benefits will be directed to non-Scottish organizations undertaking development work, thereby leaving the national/regional/local economy. SAMS stated that this depends on the approach that developers take with regards to engagement with the community (e.g. local ownership of projects), as well as the capacity of the development itself. Local engagement for smaller developments, such as the Nova Innovation Ltd TCT array in Bluemull Sound, Shetland, demonstrates a greater propensity to accommodate local O&M jobs.

It was also mentioned that the presence of an onshore electricity grid and associated infrastructure at a capacity able to accommodate offshore developments is an essential onshore element in order to promote MU between tidal energy development and environmental monitoring. However, a representative of Marine Scotland suggested that the presence of an onshore substation may pose a problem to local communities which may either seek compensation for obstruction of the landscape and seascape, or demand a design of the substation structure which integrates 'naturally' into the landscape.

7) *Is the needed knowledge and technology for MU development/strengthening in the case study area already available? (Y/N)*
    i) *What is the level of maturity of available knowledge?*
    ii) *What is the level of readiness of available technology?*
    iii) *Are there still research needs? (Y/N)*

The desk analysis suggested that knowledge and technology for MU is developing in the study area through the development of the MeyGen project, the first planned commercial-scale tidal energy project to have begun phased implementation in the world, which will produce a substantial plethora of knowledge pertaining to MU regarding TCT implementation and environmental interactions. Given this, knowledge capacity building is still immature in relation to other marine industries, since most TCT technologies have a TRL 7 – system prototype demonstration in operational environment. Further improvement of TCT technology is required to reach TRL 9 - actual system proven in operational environment - while environmental monitoring technologies will likely advance in order to optimize the collection of in-situ operational data in high-velocity tidal flow environments. Many stakeholders were quick to point out that EMEC has also been a huge contributor to the knowledgebase surrounding environmental interactions with TCTs, while pioneering various environmental monitoring techniques and technologies. EMEC stated that knowledge and technology for MU is developing in the Pentland Firth study area as there is a considerable number of Masters degrees focusing on the subject in Orkney, thus promoting capacity building, while a supply chain is developing in the region which could evolve into a future industry cluster, minus fabrication.

Atlantis Resources Ltd initially suggested that improvements in monitoring equipment are required in order to ensure that such technology is fit for purpose, with regards to connectors, corrosion, and communication. Some solutions put forth were the advent of stainless steel housing of monitoring equipment, the utilization of robust connectors, and the provision of direct connection to shore. Atlantis Resources Ltd went on to add that it would be advantageous if monitoring equipment (e.g. active sonar) was designed in so that equipment came online when a moving mass was sensed within, for example, 30m of a turbine – this would solve issues on how to sift through enormous amounts of data emanating from monitoring programmes. Finally, it was suggested that sensor integration between various monitoring technologies be designed to capture specific elements of marine species interactions with TCTs, being prompted to record certain interactions as necessary. A representative of the University of Aberdeen elaborated on this statement by suggesting that the integration of monitoring technologies can be co-located on a MU platform attached to

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a TCT. Nova Innovation Ltd stressed that improvements are required specifically to visual monitoring equipment, as protection against bio fouling would reduce the necessity to constantly retrieve visual monitoring equipment through and improve the quality of the monitoring data. With regards to the advancement of TCT technology to reach TRL 9, stakeholders suggested that financial assistance models must be initiated by government as the current CFD model is inhibiting the expansion of knowledge and technology associated with TCTs.

8) *What action(s) would you recommend to develop / widen / strengthen MU in the case study area?*
   i) *What actor(s) do you see particularly important to develop / widen / strengthen MU in the case study area?*
   ii) *(answers should be detailed enough to possibly allow undertaking actions finalized at MU promotion, at local case study level)*

The desk analysis suggests that on-going environmental monitoring, which is in place for the MeyGen project, is essential in order to better develop a knowledgebase of MU in relation to tidal energy development and environmental interactions. Marine Scotland made specific reference to the data gaps pertaining to appropriate techniques which need to be developed in order to investigate the near-field interactions of TCTs with migrating fish. The desk analysis also suggested that the main actors in developing and strengthening MU in the study area are ENGOs, government, Academia, and the tidal energy industry. The majority of stakeholders agreed with this list of actors, while emphasizing that the Scottish Government and the tidal energy industry are the most prominent actors. With regards to government, Scottish Natural Heritage suggested that as regulators gain more experience in processing applications for tidal energy developments as the industry expands, this will help them deal with environmental considerations in a more effective manner, thus building the necessary knowledgebase required to promote MU. Marine Scotland suggested that, in order to promote MU, advertisement of MU pertaining to developments would facilitate public interest and enhance the societal knowledgebase. Such advertisement is key in promoting such projects which are the cornerstone of developing a knowledge base pertaining to MU such as the MUSES project.

With regards to the role played by the tidal energy industry, some stakeholders suggested that TCT developers should be more transparent in their development process by disseminating information to stakeholders in order to provide for an understanding on environmental interactions being witnessed. Atlantic Salmon Trust added to this sentiment by suggesting that the more mature offshore wind energy business does more to promote their operations clearly to third parties than the emerging tidal energy industry, which could ultimately result in public mistrust, while communication amongst different TCT development companies would enhance the learning rate and further the TRL level, thereby lowering electricity costs to consumers. However, some stakeholders noted that there is yet no such binding requirement for developers to disseminate information, which requires the attention of the Scottish Government. Stakeholders also alluded to the important role that financial investors must play, while the UK and/or Scottish government must develop financial assistance models such as feed-in tariffs (FITs) in order to demonstrate guaranteed revenue streams which can de-risk commercial developments and increase their bankability, thereby attracting financial investors. Finally, Marine Scotland suggested that SNCBs and ENGOs are prioritizing short term impacts on unsustainable populations of marine species against long term impacts of climate change on such species, which will ultimately arise and be more devastating to the marine ecosystem if GHG emissions are not reduced through the deployment of renewable energy technologies.

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6.2 Boosting the Maritime Blue Economy

1) Do you see added values for society and economy <u>at large</u> and/or for <u>local communities</u> of developing / widening / strengthening MU in the case study area? (Y/N).
   i) What are the most important ones?

The desk analysis suggests that added values for society emanating from the development and strengthening of MU in relation to tidal energy systems and environmental protection and monitoring include:

I. Increased knowledgebase on tidal energy development and environmental interactions which will further facilitate the dissemination of information to the public, thereby educating the public on real as opposed to perceived interactions which may improve public opinion and support for tidal energy deployment
II. Enhancement for tidal energy development capacity and associated economic benefits pertaining to increased employment, development of a supply chain and industry cluster, and capacity building, thereby creating high-value jobs, many of which may be local to the study area

Many stakeholders stressed that added value I. can only be realized if TCT developers disseminate information pertaining to environmental interactions with TCT arrays effectively to external stakeholders. Nova Innovation Ltd contributed to added value II. by acknowledging that the development of national expertise can allow for Scotland to achieve substantial net-exports in the form of knowledge, skilled professionals, and technology. Atlantis Resources Ltd supported this the notion of a development of an industry cluster regionally given the ease of transfer of marine operation skills from the O&G industry to MRE. Finally, Marine Scotland contributed to the list of added values by mentioning the potential for community benefits in the form of improvements to local infrastructure such as ports and harbours, as well as the benefit of developing a local power supply, thereby providing a sense of community ownership.

The most important aspects of added value to society identified through the desk analysis includes access to knowledge and economic gain through direct and indirect job creation in the local communities surrounding the study area. All stakeholders agreed with this. Marine Scotland elaborated by stating that tidal energy implementation in small remote communities may be the way forward for the industry given that societal benefits are captured within the local community and therefore provide for positive experiences. If economic benefits to the community can be provided by developers offering financial incentives, similar to terrestrial wind energy developments, tidal energy developments could receive more support and therefore more positive experiences. While this would enhance the support for MU between TCT arrays and environmental protection areas, a key benefit to society would be the ability to exploit tidal energy development to produce new industries such as tourism by taking visitors to the generation site, thereby further facilitating the acceptance of MU in the study area.

2) Is it possible to quantify the socio-economic benefits related to MUs and how they (could) contribute to the sea economy at local and regional/national scale? (Y/N)
   i) What tools, knowledge, experiences are available?

The desk analysis suggests that it is possible to quantify economic benefits by estimating the gross value added (GVA) to the economy, nationally, regionally, and locally. Furthermore, the estimation of ecosystem services maintained as a result of sustainably developing tidal energy in the study ar-

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ea which provides for, to the greatest extent possible, an intact ecosystem, can be quantified economically. The quantification of ecosystem service would allow for a measuring tool to determine the synergies between tidal energy development and environmental protection. In order to achieve such economic and ecosystem quantifications, the desk analysis suggested that a suite of tools, knowledge, and experience is available to be drawn from in the form of subject matter experts such as economists and ecologists from both the public and private sectors.
All stakeholders agreed that the quantification of economic benefits in the form of jobs produced nationally, regionally, and locally throughout the construction, installation, operation, maintenance, and decommissioning of tidal energy developments is possible. However, some stakeholders suggest that such estimates are quite speculative, while others believe that the quantification of benefits directly emanating from MU between tidal energy development and environmental protection and monitoring, as well as the quantification of ecosystem services in general, is less so or not at all possible. Orkney Island Council stated that quantifications often do not take into consideration the negative economic impacts on other industries operating in the marine environment as, with the introduction of a new use, there will generally always be trade-offs.

3) *Would MU development / strengthening be an opportunity for job creation and / or job requalification in your area? (Y/N)*

The desk analysis suggests that MU development in the study area can promote job creation/requalification as per the vision set out in the Scottish Energy Strategy, NMP, and SMPTE with specific reference to tidal energy development. All stakeholders agreed with this statement, with some stressing that capacity building is already in place given the ease of transfer of marine operational expertise from the O&G industry. However, many stakeholders were split between whether job creation would occur regionally/locally, or if only indirect economic benefits would be seen. For stakeholders who believed that jobs would be created regionally/locally, emphasis was placed on the O&M stages of the TCT array lifecycle through the employment of local vessels, as the heavy construction stages of the project may require external and highly-specialized expertise. SAMS noted that this depends on the approach that developers take with regards to engagement with the community (e.g. local ownership of projects), as well as the capacity of the development itself. Locally engaging, smaller developments, such as the Nova Innovation Ltd TCT array, demonstrate a greater propensity to accommodate local O&M jobs. For stakeholders who believed that it is yet unknown whether local job creation would result, it was suggested that large specialized international development companies may undertake the majority of the heavy construction work.

4) Do you see possible elements of attractiveness for investors in developing / widening / strengthening MU in the case study area? (Y/N)
    i) What are these elements?

The desk analysis suggests that the elements of MU between tidal energy development and environmental monitoring which will possibly attract investors is the enhanced quality of data produced from optimized monitoring platforms. This data can further inform the environmental impacts and/or added value of MU in the study area, thereby reducing known and unknown risk, providing a greater case for MU with environmental protection while informing operational characteristics of TCTs which may lead to their achievement of TRL 9. This chain of events would further attract investors and possibly allow for TCTs to obtain non-recourse and project finance. Stakeholders agreed with this statement, adding that financial gain and the development of a local/regional supply chain, industry cluster, and capacity building will attractive investors to TCT developments,

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while potentially lowering the costs of monitoring equipment and associated data acquisition. Other one-off elements identified by stakeholders that may attract investors include energy storage technology development to provide base-load power to predictable tidal energy flows, the reduction in GHG emissions, and the lack of visual/seascape impact of submerged TCTs in comparison with offshore wind energy specifically.

5) What are possible investors interested in developing / widening / strengthening MU in the case study area?

The desk analysis suggests that possible investors are interested in developing the tidal energy industry in the study area, albeit in an environmentally sustainable manner in order to reduce insurance premiums in the long term. Possible investors include banks, private investment companies, O&G companies, the offshore wind/MRE industry, electricity distribution companies, vessel operations companies, ENGOs, the Scottish Government, and academia. Stakeholders also specified regional councils, venture capitalists, local communities, and MRE test centres such as EMEC as possible investors. Environmental stakeholders suggested that such investors may be interested in obtaining monitoring data on environmental interactions with TCT arrays. However, the tidal energy industry may not be content with sharing such data as there may be negative environmental interactions noticed, and therefore will not share data unless the requirement to do so was clarified as a condition of consent or if developers would be able to charge a fee for sharing the data.

6) Is there sufficient dialogue between the stakeholder sectors for developing / widening / strengthening MU? (Y/N)
    i) Would dialogue facilitation be an asset? (Y/N)

The desk analysis suggests that there is sufficient dialogue between ENGOs, government, academia, and the tidal energy industry. However, further dialogue facilitation between stakeholders could help continue and strengthen discussions pertaining to MU in relation to tidal energy development and environmental interactions. It would seem that there is a healthy split in opinion concerning the validity of this statement. Some stakeholders suggest that Marine Scotland has initiated consistent, quality consultation/dialogue, while others believe that Marine Scotland needs to further engage stakeholders by making them aware of the environmental benefits/impacts surrounding tidal energy development, as it would seem that engagement is limited to the consultation process of MSP under strict timeframes. Orkney Island Council stressed that consultation/dialogue should be on-going and requires government facilitation. Other stakeholders believe that the tidal energy industry does not properly consult with other sectors operating in the study area, nor have they effectively disseminated information to the public, particularly concerning environmental interactions.

7) In order to promote MU development / strengthening in the case study area,
    i) would the availability of a *vision/strategy* (e.g. at national or sub-regional level) be helpful? (Y/N)
    ii) would a *feasibility study including evaluation of alternative scenarios* be helpful? (Y/N)
    iii) would *detailed projects* on already identified simulations be useful? (Y/N)
    iv) do you see *other enablers*?

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The desk analysis suggests that a vision for MU is already in place for both tidal energy development and environmental protection through the Scottish Energy Strategy, NMP, and SMPTE in conformity with the NMP. While all Marine Scotland stakeholders agreed with this statement, adding the PFOW plan as another vision document, the concept of a vision promoting MU received many varied responses. This leads to speculation whether stakeholders are not being made fully aware of the Scottish Energy Strategy, NMP, and SMPTE, or if the vision in these documents does not appropriately address MU. Some stakeholders elaborated by stating that local and national visions must be aligned and consistent and represented across all development and marine spatial plans, with regional marine plans taking specific environmental contexts into consideration, thereby acting as a suitable plan conduit towards the implementation of MU. DP Energy stated that the tidal energy sector has had a number of strategies and there is danger of stakeholder fatigue in this area. Many stakeholders suggested that there was no clear vision, and that a proactive vision would be helpful. SAMS suggested that the academic community and research councils are pushing for such a vision, while Fisheries Management Scotland emphasized the need for a vision particularly in relation to diadromous fish, as they have received little consideration in relation to marine mammals and birds, and therefore have been accounted for poorly and in retrospect. An Unnamed Academic Institution said that an increase in monitoring data is required in order to further inform an effective vision.

Scotrenewables mentioned that a vision has been helpful for the offshore wind sector, and can do the same for tidal energy if policies are put in place for site-level development siting and trade-offs. This would seem to be an elaboration of solely high-level spatial trade-offs considered in the SMPTE. Further to this point, Nova Innovation Ltd suggested that government must be mindful of how policies pertaining to the two uses line-up, and subsequently, how trade-offs will be made and/or how synergies will be maximized. This being said, studies about MU provide a good platform for promoting such discussions and informing decision making and policy development in the future. Furthermore, government should provide for in their vision, how public revenue support can be allocated to early stage developers in the tidal energy industry with respect to EIAs and baseline site characterization – given that early developers will be bearing the upfront costs of such assessments in order to develop a knowledgebase for the industry. If this approach were taken, environmental data could be made public and help improve environmental management regimes in other areas that are not even associated with tidal energy development (e.g. diadromous fish).

Other stakeholders stressed that a vision/strategy should be proposed by the government on how to replace the current CFD with a subsidy that increases the economic viability of vastly expensive lifecycle costs of tidal energy systems is required. Furthermore, government should implement a standardized approval procedure whereby ENGOs (e.g. Royal Society for the Protection of Birds) agree on limits of potential impact, and mitigation measures stemming from environmental monitoring programmes, which are standardized through consents and therefore eliminate (as much as possible) potential litigation whereby impacts are incurred when monitoring was consented. Finally, a vision should be put forth concerning gird provision, connection, and distribution logistics while providing solutions such as active network management.

The desk analysis suggests that a feasibility study of alternative scenarios has been carried out from a government standpoint by Marine Scotland illustrated in the SMPTE, joint between Marine Scotland and industry through MeyGen as per the SDM licensing policy guidance, and supported by MeyGen through their incremental approach to development and post-deployment monitoring. Only a minority of stakeholders agreed with this statement. Some stakeholders mentioned that,

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while additional feasibility studies could be beneficial, similar to EIAs, there is not enough data available to develop scenarios that are little more than speculative. Other stakeholders elaborated that a mixture of such studies and in-situ data are required in order to arrive to more credible scenarios in the future. It was also suggested that if industry can demonstrate through such studies that electricity prices from TCT generation will be relatively reasonable, and disseminate this information to the public, community buy-in could increase the pace of development. However, DP Energy stated that if scenario mapping is to be published, it must be based on data emanating from developments as similar in scope (capacity, technology, environmental and socio-economic site characterization, etc.) as possible or else such mapping is not centred on a reliable enough evidence base in order to be relevant.

The desk analysis suggests that detailed projects on already identified simulations would be useful, however, MeyGen is the first planned commercial-scale tidal energy project to have begun phased implementation in the world, and therefore monitoring data emanating from Phase 1a will act as the in-situ operational knowledgebase for a commercial TCT array for future phased developments of the project as well as other separate TCT array develops around the world. Almost all stakeholders agreed with this statement. However, Scottish Natural Heritage stated that, given the vast array of different TCT designs without a single commercial leader, in conjunction with the sensitivity and specificity of regional marine environments, it is too early to develop simulations that can provide solid insight on standardized environmental interactions with TCTs.

The desk analysis suggests that the Scottish Government, the UK Government, MeyGen, academia, and private investment companies and banks are all working together to enable the planned and future integration of MU in relation to tidal energy development and environmental protection and monitoring. Additions to this list include SNCBs, the regional public, the EU, regional development agencies, EMEC, and specific reference was given to MS-LOT. The majority of stakeholders agreed that the primary stakeholders enabling MU were regulators, specifically Marine Scotland, and tidal energy developers, specifically MeyGen. Atlantic Salmon Trust noted that third parties must be allowed to be more involved and work together with government and industry in order to enable the planned and future integration of MU in relation to tidal energy development and environmental protection and monitoring.

6.3 Improving Environmental Compatibility

1) What are / would be the environmental added values (= positive environmental impacts) of developing / widening / strengthening MU in the case study area?

The desk analysis identified the following environmental added values of MU in the case study area for tidal energy development and environmental protection and monitoring:

I. Contribution of monitoring data towards marine protection and conservation area management
II. Reduction in climate change inducing compounds and processes projected to negatively impact the marine environment and its inhabitants
III. The creation of artificial reefs and boosted biodiversity levels due to the presence of TCT support structures

Stakeholders were split between whether the creation of artificial reefs was an environmental added benefit, with the majority suggesting that this is site and context specific and requires more data in order to provide for justification. An additional environmental added value was the potential that

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TCTs have to act as default no-take fishing zones, thereby doubling as a micro-restoration site for certain marine species. However, it was also acknowledged that this statement is site and context specific and must be further validated by monitoring of commercial TCT array deployments. Finally, a Marine Scotland representative suggested that, in some situations, TCTs could act as barriers to predators of juvenile fish, or similarly as shelter areas for migratory salmon, thereby protecting fish. However, it was noted that there is not enough data to solidify this scenario, as increased predation or collision risk may also occur.

2) Which tools (conceptual, operational) are used or should be further developed and used to better estimate environmental impacts and benefits of MU?

The desk analysis suggests that various video and audio recording tools are used to further develop and better estimate environmental impacts and benefits of MU. The technological progression of such tools emanating from advances in monitoring platforms and in-situ performance monitoring will increase the effectiveness of estimating TCT interactions with the environment, thereby promoting MU between TCT arrays and environmental protection. Most stakeholders agreed with this statement, adding that there is specific need to further characterize occurrence and behaviour of marine mammals, while lowering the costs for both TCT technology and monitoring equipment. In order to achieve technological advancement of monitoring equipment, many stakeholders suggested that audio and video monitoring technologies could be developed to turn on when a marine species triggers the system in the immediate vicinity so that hundreds/thousands of hours of data is not collected, thereby allowing researchers reviewing data to efficiently utilize their time when reviewing data to solely significant interactions. Atlantis Resources Ltd stated that improvements are required with respect to the integrity of monitoring equipment in order to ensure that such technology is fit for purpose, with regards to connectors, corrosion, and communication (e.g. stainless steel housing, robust connectors, direct connection to shore)

The majority of stakeholders suggested that specific improvements are required with respect to the quality of visual monitoring, as protection against bio fouling would reduce the necessity to constantly retrieve visual monitoring equipment, while close-range acoustic tracking could further inform the benefits and/or negative impacts of an artificial reef effect, as well as general diadromous fish movements. Passive acoustic monitoring tools, in conjunction with site characterization tools (e.g. salinity measurements at various depths) help build baseline knowledge from which to compare environmental interactions with TCTs, however, the gathering of baseline data needs more time in order provide for informed judgements. Tools which provide a greater knowledgebase on what elements of the marine environment interact with TCT structures, as well as what elements pose threats to deployed technology (e.g. massive amounts of litter) must be further developed, thereby contributing to further baseline characterization over a greater span of time. It is important however, that such data is collected in using standardized methods as to be useful for various developments around Scotland, Europe, internationally – this can be achieved through detailed specifications required for obtaining consents.

Finally, sensor integration between various monitoring technologies designed to capture specific elements of marine species interactions with TCTs should all be developed into a MU platform and co-located in TCT structures. However, DP Energy noted that while advancements can be made to monitoring equipment to further characterize environmental interactions associated with tidal energy development, it is ultimately the scale of development which needs to increase as the industry matures in order for monitoring data to lead to any substantial conclusions concerning the ecologi-

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cal added values and/or negative impacts emanating from MU. Even then, the scope of various developments has to be similar in terms of capacity, technology, environmental and socio-economic site characterization, etc. in order to be relevant.

3) Is saving free sea space for nature conservation a driver for MU the case study area? (Y/N)
    i) Are there evidences about the present and future benefits of reserving free sea space? (Y/N)
    ii) What are they?

The desk analysis suggests that saving free space for additional nature conservation areas is not a driver for MU in the study area as SPAs have been established under the Natura 2000 programme and any tidal energy development must undergo scoping exercises and surveying in order to demonstrate that other designated sites will not be adversely affected. Many stakeholders agreed with this statement, although they stressed that the introduction of additional nature conservation area just for the sake of it would not be warranted, rather, there would need to be a compelling ecological purpose. DP Energy went on to add that if such designation occurs during phased implementation, this would potentially present a great obstacle to TCT developers. Many other stakeholders suggested that, if environmental protection was the main goal driving MU with tidal energy development, then tidal energy sites could act as a default no-take fishing area which would serve the purpose of species conservation. Speculated benefits to a no-take zone include the potential for fish aggregation around devices, ultimately protecting populations, specifically with respect to sea trout.

Nova Innovation Ltd stated that saving free space for nature conservation in a tidal energy development area could have benefits to the integrity of the marine ecosystem as well as allow for monitoring data to further characterize interactions of marine wildlife with TCTs, thereby further informing the operational characteristics of the tidal energy industry. However, if a conservation site is introduced, these may deter investors due to relatively onerous environmental management and monitoring conditions, in conjunction with the uncertainty relating to the initial and potentially evolving impact of a new conservation site on a project.

Orkney Island Council suggested that if a conservation area is established which does not restrict all other uses, and allows for regulated uses such a monitoring for ecosystem changes emanating from the presence of TCT array, or tourism, for example, then this may be a benefit to the study area in several ways. EMEC suggested that the introduction of a protection area is dependent on what is trying to be achieved in the development area. Similar to the positives and negatives of an artificial reef, it must be determined whether, for example, the environmental goal is to boost fish stocks, which would therefore lend the advent of a no-take zone advantageous to the development site. This context dependency must be determined at the onset of development in order to effectively plan for the achievement of residual benefits emanating from TCT development.

4) What practical actions would you undertake to link MU development / widening / strengthening to improve environmental compatibility of maritime activities?

The desk analysis suggests that further environmental monitoring is a required action to determine the added values and negative impacts of tidal energy development in relation to environmental interactions as MeyGen is the first planned commercial-scale tidal energy project to have begun phased implementation in the world, and therefore monitoring data emanating from Phase 1a will act as the in-situ operational knowledgebase for a commercial TCT array for future phased developments of the project as well as other separate TCT array develops around the world. While stakeholders generally agreed with the above statement, given the context of the case study, this

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KEQ served as a response to an action plan moving forward, and thus stakeholder responses were unique, varied, and detailed.

Most stakeholders agreed that further stakeholder engagement is required specifically between Government regulators and third parties such as academia, ENGOs, SNCBs, and the public, in order to provide for a more transparent and participatory planning process. TCT developers should be more transparent in their development process by disseminating information to the public, as it would seem that the more mature offshore wind energy industry does more to promote their operations clearly to third parties than the emerging tidal energy industry, which could ultimately result in public mistrust, while communication amongst different TCT development companies would enhance the learning rate and further the TRL level, thereby lowering electricity costs to consumers. It was suggested that education of the wider public, as well as information sharing between industry stakeholders, is required in order to raise awareness about the benefits of tidal energy development if GHG emissions and renewable energy deployment targets are to be met in the future, while dissemination of information to academia can increase knowledge capacity building through research projects.

It was suggested that industries and the general public need to be educated on the concept of MU if it is to be incorporated into MSP and policy development in the future, as there is very little information on MU online at the moment. Furthermore, government and industry should work together to gather baseline data for potential development sites prior to granting consents. Environmental monitoring methodology should be standardized across the UK so that environmental interactions can be compared, thereby increase the impact that data analysis has on MSP, SEA, and EIAs. Improved site selection stemming from greater standardized data collection methods and availability can help streamline the implementation of TCTs. Furthermore, there must be an investigation into the development of a licensing regime which accepts MU applications and determines the logistics of which use/industry carries what portion of the costs/risks for specific developments.

In a way, the tidal energy industry already practices MU with environmental monitoring through the SDM policy guidance. However, environmental data gathering should be partially subsidized by public funds in order to account for the fact that early developers are bearing the costs of environmental characterization for further developments of other potential companies to come to fruition in the near future. If public subsidies were provided, the environmental data could be made public and thus would be able to be used for more than just tidal energy developments, but rather, baseline data could also be gathered to such an extent as to inform environmental management regimes throughout the Scottish marine environment.

Funding should be realistic to the scale of a project so that developers can gather the data needed and disseminate it to appropriate stakeholders to help make decisions on development and environmental monitoring/protection prior to substantial build out, which would have benefits for society (e.g. other industries), the environment (e.g. further site characterization leading to informed mitigation plans), and financing (e.g. the reduction of risk regarding halted development operations due to unanticipated environmental impacts occurring). Community benefit funds should be established to allow for local catchment of economic benefits and local ownership of TCT developments. Given that the costs of deploying and maintaining monitoring equipment and transferring data would be the burden of the developer, joint funding would be a necessary action to take in the future to incentivize tidal energy developers to undertake further monitoring.

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Further environmental monitoring is required to determine the added values and negative impacts of tidal energy development in relation to environmental interactions in order to incorporate risk-modelling into developments. This could feed into a vision which could be established by the government setting out policies similar to offshore wind which provide guidance on how trade-offs between industries will be made on a site scale would be beneficial, while government lead consistent revenue schemes such as the introduction of FITs would further de-risk and subsequently help streamline TCT implementation. Proper regional marine planning must be undertaken and implemented utilizing an ecosystem approach to planning which allows for justifiable trade-offs to be made between tidal energy development and environmental protection.

Fisheries Management Scotland suggested that further considerations must be taken with regards to interactions of TCTs with migratory fish species, which has lagged in comparison to marine mammals and birds. Thus, further environmental monitoring is required to lengthen baseline data. Also, Scottish Ministers need to attribute greater funds to fisheries research. Finally, Scotrenewables noted that TCT array developments can be marketed as tourism attractions in order to raise awareness/educate the public as well as bring indirect benefits into the local/regional economy.

5) Are there win-win solutions triggering both socio-economic development and environmental protection already available for the case study area that MU should take up? (Y/N)
    i) What are they?

The desk analysis suggests that there is no combination of MU apparent and/or similar to the case study in question which would inform MU of the tidal energy development and environmental monitoring apart from the work that is incrementally being implemented as a part of the MeyGen project directly. However, the MeyGen site is enveloped within a SPA and therefore is scheduled to subsume a larger portion of the protected area as phased development proceeds. Although, there is currently not enough data either retained and/or released in order to determine the effects of co-location. Many stakeholders suggested that lessons can be learned from the MU combination apparent in Scapa Flow, whereby submerged marine archaeological sites draw in tourism. The possibility for attracting tourism to the development site in order to witness the site first-hand and also observe marine species would produce positive injections into the economy while demonstrating to the public that TCT implementation is environmentally sustainable. However, the question of sustainability is still dependant on increased data collecting emanating from technological advancements in MU environmental monitoring platforms implemented in large commercial tidal energy projects.

Orkney Island Council suggested that MU in the study area can take example of fisheries management in Orkney, as all actors involved highly educate themselves and continue to engage in sufficient dialogue with one another. Atlantic Salmon Trust stated that socio-economic benefits that can be synergistic with environmental protection and tidal energy development as a result of monitoring data emanating from the MU in the case study area can help inform salmon movements which would enhance ecological sustainability through the development of environmental protection policy and updated salmon management plans. This would allow for anglers to continue to sport fish, thereby contributing to the local/regional/national economy through tourism. Even further outside of the study area, Scottish Natural Heritage suggested that in order to better inform tidal energy development and environmental protection, many lessons can be learned from how the Dutch government undertakes environmental assessments and then tenders the site for development. This scenario can eliminate bias of developers undertaking/paying for their own environmental as-

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sessments, while it also reduces the upfront financial costs required from developers at their own risk which may constrain developers from being able to properly undertake a detailed assessment.

6) Is the environmentally friendly knowledge / technology for MU development/strengthening in the case study area available? (Y/N)
    i) Which is the level of readiness of available solutions?
    ii) Are there still research needs on blue/green technologies for MU? (Y/N)

The desk analysis suggests that environmental and technological knowledgebase is being developed in the Inner Sound of the Pentland Firth through the development of the MeyGen project, which is undertaking monitoring of the first commercial-scale phased TCT array development in the world, thereby contributing to the learning rate of TCT technology and associated monitoring equipment. The MeyGen project is located in a SPA, and therefore data emanating from environmental interactions with TCTs is helping build a knowledgebase of the viability of MU between development and environmental protection to some extent. However, it could also be said that there is no combination of MU apparent and/or similar to the case study in question which would inform MU between tidal energy development and environmental protection and monitoring. Since MeyGen is the first planned commercial-scale tidal energy project to have begun phased implementation in the world, it therefore stands that monitoring data emanating from Phase 1a will act as the in-situ operational knowledge base for commercial array TCT technology and associated environmental interactions for future MU around the world. Most stakeholders agreed with the above statement.

However, while knowledge and technology for MU is further developing in the study area through the development of the MeyGen project, some stakeholders stressed that improvements in monitoring equipment are required in order to ensure that such technology is fit for purpose, with regards to connectors, corrosion, and communication (e.g. stainless steel housing, robust connectors, direct connection to shore). Furthermore, it would be advantageous if monitoring equipment (e.g. active sonar) was designed in so that equipment came online when a moving mass was sensed within, for example, 30m of a turbine – this would solve issues on how to sift through enormous amounts of data emanating from monitoring programmes. Finally, sensor integration between various monitoring technologies designed to capture specific elements of marine species interactions with TCTs could be prompted to record certain interactions as necessary. When considering MU between tidal energy development and environmental monitoring and protection through a global lens, EMEC added that knowledge is gathered and dissipated by MRE test centres which can be further developed by other test centres around the world, although in order to build an international understanding of MU, global MRE test centres would need to be located in significantly different marine environments with different climates and environmental; receptors in order to further inform tidal energy development and environmental interactions around the world.

The desk analysis suggests that The level of readiness for solution is dependent on the MeyGen project and the results emanating from the implemented monitoring programme as the MeyGen project is the first planned commercial-scale tidal energy project to have begun phased implementation in the world. The majority of stakeholders agreed with this statement, adding that more commercial-scale tidal energy developments are required in order to further inform the potentials and effects of MU.

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The desk analysis suggests that research needs pertaining to the MU combination of this case study in the study area are directly linked to the need to further develop a knowledgebase for blue/green technologies, in this case TCTs, in relation to their TRL and environmental interactions. Stakeholders noted that of particular concern are the near-field behaviours of marine mammals as much monitoring data has yet to effectively determine the presence of mammals in the vicinity of turbines (e.g. Scottish Government Demonstration Strategy). Other stakeholders noted that there are specific data gaps pertaining to small fish and their aggregation around TCTs and potential collision risk, as less work has been done on studying their behaviour in relation to marine infrastructure developments such as TCTs. Furthermore, characteristics of diadromous fish needs to be further understood in order to determine whether their movement is primarily limited to the upper portions of the water column, and therefore are subject to less risk of collision with bottom mounted TCTs such as those utilized in the MeyGen project.

7) Would it be possible to promote MU through SEA/EIA procedures? (Y/N)
   What modifications would you suggest at your national / local level to promote MU through SEA/EIA procedures?

The desk analysis suggests that MU is already being investigated through SEA procedures during the NMP, SMPTE, and regional MSP planning processes in accordance to the SEA Directive 2001/42/EC, and EIA procedures in accordance with the EIA Directive 2014/52/EU as SEA and EIA procedures are currently a statutory obligation at the national and local levels in relation to tidal energy development. Most stakeholders agreed with the above, adding that it is inherent in the nature of EIA/SEAs that various uses are viewed from a synergistic and cumulative effects assessment perspective in order to sustainably allocate different areas for different uses. However, some stakeholders believed that SEAs are too high-level in order to properly account for MU, if at all, while EIAs do effectively consider MU given the scale of assessment. However, these stakeholders stressed that increased monitoring data is required from commercial scale tidal energy developments in order to make EIAs more impactful. EMEC distinctly noted that, similar to MSP, EIA/SEAs are not currently putting enough consideration towards MU, particularly in relation to TCTs.

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7 STAKEHOLDER ENGAGEMENT AND LOCAL STAKEHOLDER PROFILES

7.1 Stakeholder Engagement Methods

The MUSES project is based on the identification of real and perceived barriers to MU as well as technical solutions in order to overcomes such barriers in order to realize the benefits emanating from MU implementation in the short to long term. The identification of MU potential and effects is largely a result of effective stakeholder engagement with multi-sector stakeholder experts. For case study 1B – Tidal Energy Development and Environmental Protection and Monitoring, 21 individual experts were contacted and 18 distinct interviews were undertaken with 15 different organizations. These organizations ranged from local to international in geographical scale. Five (27.8%) interviews were undertaken with tidal energy development and demonstration organizations, five (27.8%) with government representatives, four (22.2%) with academic institutes, and four (22.2%) with environmental organizations, both statutory and non-statutory. Seven interviews were undertaken remotely, six by phone and one via Skype, 10 were undertaken in-person, with two interviews engaging two people at once, and one interview was conducted with one member of one organization in-person while another member of a different organization (but under the same network) participated via phone.

Two organizations (one government and one academic) did not believe that they possessed the competency to provide useful input into the case study and thus respectfully declined, one stakeholder (environmental) believed that tidal energy development was outside of their jurisdiction and thus respectfully declined, one stakeholder (academic) withdrew from the study after undertaking the initial interview, and three stakeholders (two government and one developer) did not respond to email invitations at all. In general, government stakeholders were most willing to engage in in-person interviews while academic representatives preferred engagement via remote methods. After all interview data was analysed, it was realized that tidal energy developers provided the greatest input into the case study, offering a wide range of barriers and technical solutions, while academic representatives generally struggled to grasp the concept of MU, particularly for the combination of tidal energy development and environmental monitoring.

Stakeholders were initially contacted by email and asked if they would be interested in participating in the MUSES project for case study 1B. In the introductory email, potential interviewees were given a brief overview of the partners involved in the MUSES project as well as the desired outputs of the project and the case study MU combination specifically. A brief standardized two-page MUSES project overview document was attached to the email as per the the requirement put forth on the standardized MUSES stakeholder confidentiality and consent form for sharing the template with interviewees before the interview takes place. Stakeholders were also told that a potential interview would be contained to one-hour maximum. Stakeholders who responded positively to the email were asked to recommend a preferred date and time, and whether an in-person or remote/phone interview was more suitable for their schedule. In very few cases, stakeholders would ask for a list of questions to be asked during the interview beforehand, to which a template of the structure of interview questions was provided. Towards the later portion of stakeholder engagement for the case study, a list of available dates was provided to interviewees to choose from.

During interviews, stakeholders were once again provided with an overview of the logistics of the project, the partners involved, the objective of MUSES, and milestone dates for project outputs. Stakeholders were notified that the interview would consist of two major portions. The first half of

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the interview would consist of the identification of DABI under various themes (e.g. environmental, social, economic, technical, etc.), and the second half of the interview would deal with broader themes put forth through KEQs under the three focus areas of Addressing MU, Boosting the Maritime Economy, and Improving Environmental Compatibility. Interviewees were notified that they can pass on any question that they did not believe was within their expertise and/or they were not comfortable providing a response to. Also, interviewees were told that they may ask for examples of potential responses to be provided for any and all questions if they so choose. Finally, stakeholders were notified of the contents of the confidentiality agreement, and that they had the choice to sign the consent form following the interview itself or after the responses emanating from the interview were documented as DABI factor scores and KEQ responses, thereby allowing stakeholders to review interpretation of their responses and make adjustments as they see fit. Generally, most interviews opted for the later, although only a small percentage, most of which were developers, actually altered some DABI scores or KEQ responses, although alterations were minor.

Questions pertaining to DABI were posed separately, beginning with drivers, followed by added values, barriers, then impacts. DABI were organized by theme – for example, interviewees were asked to identify environmental drivers, then economic drivers, then technical, etc. DABI factors were added to the DABI list if they were determined to be distinct from any factors identified and documented in the initial DABI template emanating from the desk analysis. In total, six additional drivers were identified, the majority of which were policy based; 12 additional barriers were identified, three times as many stemming from the desk analysis, which were evenly distributed amongst categories; seven additional added values were identified, which were also evenly distributed amongst categories; and three additional factors for two additional categories of impacts including social and other users were identified. However, it is worthy to note that some DABI factors were eliminated from the final analysis given their addition into the catalogue late in the interview process, thereby disallowing for a sufficient quantity of stakeholders to provide their insight on the factor, their placement into another aspect of the overall DABI for purposes of better suitability, and/or the absence of active stakeholder engagement on the factor due to the direction taken during the interview tailored to the interviewee's core competencies. Regardless, the above suggests that the biggest contrast in information provided from the desk analysis and stakeholder engagement was the amount of barriers inhibiting the implementation of the MU combination of tidal energy development and environmental protection.

The KEQs under each of the three focus areas were often answered indirectly by stakeholder elaborations on the presence of DABI under various categorical themes. It is worthy to note that, irrespective of the DABI or focus area portion of the interview, not all factors or questions were answered or posed as the interviewees expertise guided the direction of the contents of the interview material. Although the majority of factors and questions were analysed, interviews were tailored to the interviewee through real-time adjustments made during the interview in order to achieve the highest quality of responses for the greatest impact on the case study, while containing the interview to an hour as promised in the initial introductory email.

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Table 15 General stakeholder information

Sector	Stakeholder Organization	Type	Scale	Sea Basin	Country	Engagement Method
Commercial Fisheries; Recreational Fisheries; Environmental	Atlantic Salmon Trust	Academic/research institute; Advisor; Sectorial Group/Forum/ Network	National	North Sea	Scotland	Phone Interview
Tidal Energy	DP Energy	Private Company	International	North Sea & Atlantic	Scotland, North Ireland, & Ireland	Phone Interview
Tidal & Wave Energy	European Marine Energy Centre	Academic/research institute; Sectorial Group/Forum/ Network	EU	North Sea & Atlantic	Scotland	In-person Interview
Environmental; Statutory Body	Fisheries Management Scotland	Advisor; Statutory Body/ Consultee	National	North Sea & Atlantic	Scotland	In-person Interview
Academic	Unnamed Academic Institution	Academic/research institute;	International	All Sea Basins	Scotland	Phone Interview
Government	Marine Scotland	Advisor; Regulator; Statutory Body	National	North Sea & Atlantic	Scotland	In-person & Skype Interview
Tidal Energy	Atlantis Resources Ltd	Private Company	International	All Sea Basins	Scotland	In-person Interview
Tidal Energy	Nova Innovation Ltd	Private Company	International	All Sea Basins	Scotland	Phone Interview
Government	Orkney Island Council	Advisor; Regulator;	Local	North Sea	Scotland	In-person Interview
Environmental	Scottish Environment LINK	Sectorial Group/Forum/ Network	National	North Sea & Atlantic	Scotland	In-person & Phone Interview
Tidal Energy	Scotrenewables	Private Company	Regional	North Sea	Scotland	In-person Interview
Academic	Scottish Association of Marine Science	Academic/research institute;	National	North Sea & Atlantic	Scotland	Phone Interview
Statutory Body; Environmental	Scottish Natural Heritage	Advisor; Regulator; Statutory Body/ Consultee	National	North Sea & Atlantic	Scotland	In-person Interview
Academia	University of Aberdeen	Academic/research institute;	National	North Sea & Atlantic	Scotland	In-person Interview
Academia	University of St. Andrews	Academic/research institute	National	North Sea & Atlantic	Scotland	Phone Interview

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7.2 Local Stakeholder Profiles

7.2.1 Overall activity and attitude of relevant stakeholders in relation to the MU

The overall interest of stakeholders in MU between tidal energy development and environmental protection and monitoring is varied. Tidal energy technology and project developers are concerned with developing TCT arrays but are not actively seeking to develop MU specifically in environmental protection areas. However, such developers are promoting MU with environmental monitoring as it is a condition of consent for development under the SDM licensing policy guidance. The emphasis of research organizations is for the most part broken up into in silos either pertaining to tidal energy development, environmental monitoring, and environmental interactions with development. While there is some integration, there is not considerable focus on the concept/synergies of MU at the moment. However, this is primarily due to the pre-commercial status of the tidal energy industry, and subsequently the lack of available data on environmental interactions with TCT arrays, as well as the lack of standardized baseline data on high energy tidal flow environments. Finally, with regards to the interest of funding bodies pertaining to MU, while funding is made available for research, this has thus far been limited to either tidal energy development or environmental interactions, rather than studying MU as a concept in order to promote co-location of developments in environmental protection areas.

Regulators, particularly Marine Scotland, are actively promoting MU between tidal energy development and environmental protection and monitoring through various national policies and objectives through the NMP, Climate Change (Scotland) Act 2009, SDM licensing policy guidance, etc. The UK Government also plays a role particularly though the GES descriptors of the MSFD and UK Sustainable Development Strategy. EU legislation also seeks to promote MU through the Habitats Directive 92/42/EC and Birds Directive 2009/147/EC, SEA Directive 2001/42/EC and EIA Directive 2014/52/EU, etc. Also, policy makers, once again with particular reference to Marine Scotland, are actively promoting MU in the territorial zone (TZ) and exclusive economic zone (EEZ) where powers to plan for the marine environment with respect to MRE has been delegated from the UK Crown Estate to Marne Scotland via the Marine Scotland Act 2010 and UK Coastal Access Act 2009. Furthermore, legislated renewable energy deployment and GHG mitigation targets set out in the Climate Change (Scotland) Act 2009, as well as the national objectives of the NMP and Scottish Energy Strategy guide the development of the tidal energy industry in the Scottish national economic context.

Insurance companies for the tidal energy industry are seemingly not actively seeking any solutions to better insure developments, particularly in relation to co-location within protected marine environments which is seen as riskier. Given that there is not a substantial amount of data to inform environmental interactions with TCT arrays due to the pre-commercial status of TCT technology and implementation, tidal energy projects are not currently bankable. The inability to achieve non-recourse and project finance enhances insurance premiums of development. Non-governmental organizations (NGOs) and other societal drivers are not promoting MU as development is seen as not generally being a part of the silo which they engage with. With respect to ENGOs, the protection of various receptors of the marine environment is their sole interest, while the effects that climate change can have on such receptors, which tidal energy implementation can help lesson through the mitigation of GHG emissions, is somewhat ignored. With respect to society as a whole, while some stakeholders project that development will have positive impacts on the economies and associated communities of various regions and localities targeted for development, it is gener-

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ally believed that the tidal energy is too early in its stage of development to allow for community ownership as is the objective of the Scottish Energy Strategy, and therefore MU is not seen as an immediate priority. However, NGOs and other societal bodies are proactive in characterizing the marine environment and protecting environmental receptors.

The overall attitude of stakeholders in MU between tidal energy development and environmental protection and monitoring is split between those which are neutral and/or undecided, and those who are positive, acting as driving forces towards MU implementation. Tidal energy developers are seen to be undecided/neutral in promoting MU with environmental protection as the bottom line would be development and not protection. In fact, many stakeholders believe that development in protected areas many translate into stricter (and therefore more expensive) monitoring programmes, which would not be preferred by developers. Research organizations currently seem undecided towards MU as there is only a limited amount of in-situ data from commercial deployments to utilize and inform decisions, therefore, research priorities are attributed elsewhere. Finally, NGOs are seen as neutral in their approach to MU as silos typically are maintained in relation to specific environmental receptors, while many stakeholders believe the tidal energy industry is too early in its stage of develop to provide opportunities for local community ownership.

Regulators are typically viewed as a driving force regarding MU through the enforcement of policies and legislation, establishment and creation of roadmaps to secure their stated visions, and particularly the implementation of demonstration projects such as the Scottish demonstration Project whereby environmental monitoring is undertaken for TCT prototypes and environmental characterization via various innovative monitoring technologies. Policy makers also have a positive attitude towards MU, providing strategic guidance to promote tidal energy development in sensitive marine environments through a number of objectives and policies set out in the NMP, as well as the creation and implementation of the SMPTE. Finally, funding bodies, particularly the EU in relation to MU through the MUSES project, and the Scottish Government for tidal energy environmental monitoring through the Scottish Demonstration Strategy, are driving forces in allowing for the production of data which can directly and indirectly inform MU, respectively. However, while funding is allocated towards determining environmental interactions with TCT arrays, funding bodies are neutral with respect to MU between tidal energy development and environmental protection as there are no major research or funded projects focusing on co-locating TCT arrays in marine protected areas.

Given the financial risk of tidal energy development, insurance companies are seen as having a negative attitude towards MU impose a massive financial barrier towards development, and therefore eventual MU with environmental protection. With regards to MU with environmental monitoring, the SDM policy guidance provides a condition of consent to monitor, and it is this data which must be collected and analyzed over time which is required to de-risk development, MU, and lift barriers imposed by insurance companies.

7.2.2 Geographical scale at which certain stakeholders have power

The overall geographical scale of stakeholder power in relation to MU between tidal energy development and environmental protection and monitoring is split between national and EU. Tidal energy developers are seen to have power in a national Scottish geographical scale as policies pertaining to development, as well as the objectives of the national government set out in the NMP are specific to each nation. Furthermore, such developers have a focus on Scotland at the moment given its

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international leadership role in the development of tidal energy. Regulator and policy maker power is national given the TZ and EEZ where powers to plan for the marine environment with respect to MRE has been delegated from the UK Crown Estate to Marne Scotland via the Marine Scotland Act 2010 and UK Coastal Access Act 2009. NGOs and societal bodies are typically national in their geographical scale as they represent the needs of specific species in given habitats that are endemic to various regions within a country, while communities are effected within these geographical ranges. Even international bodies such as Whale and Dolphin Conservation have national chapters to address issues in local/regional marine environments.

Research organizations have national-scale power as the marine environments are specific to regional/local Scottish waters, while most planned and commencing commercial developments are located in the Scottish TZ. However, the relatively minor amount of MU specific research (e.g. the MUSES project) is at an EU level as strategic partnerships seek to evolve the concept of MU across European sea basins. Barriers imposed by insurance companies is witnessed at an EU, and even international level, given the pre-commercial status of the TCT technology, as well as the lack of baseline data in high tidal energy environments given the difficultly of creating fit-for-purpose monitoring equipment. Finally, the highest level of power for funding bodies is EU given partnership and sharing of information approaches towards MU on a sea basin scale.

7.2.3 Type and level of power

The overall type of power stakeholders possess in relation to MU between tidal energy development and environmental protection and monitoring is split between indirect and direct influence, and the power to control and make decisions depending on the stakeholder organization. Tidal energy developers can indirectly influence MU with environmental protection and monitoring through the promise which they possess in contributing to the Scottish national economy in order to full legislated renewable energy deployment and GHG mitigation targets set out in the Climate Change (Scotland) Act 2009, as well as the national objectives of the NMP and Scottish Energy Strategy. Furthermore, tidal energy developers can indirectly influence MU through implementing monitoring programmes as is a conditions of consent under the SDM policy guidance. However, it is dependent on the dissemination of information obtaining from monitoring to other stakeholders (academia, regulators, statutory nature conservation bodies – SNCBs, ENGOs, the public) which could further co-location with environmental protection by educating/informing other stakeholders on environmental interactions, and thus securing buy-in for development. NGOs and other stakeholder bodies can also indirectly effect MU through research and the voicing of concerns which tidal energy development may have on particular environmental receptors.

Research organizations can directly influence MU by informing insurance companies, government regulators, investors, and SNCBs on environmental interactions with TCT arrays. Such information will inform risk and therefore shape the economic and policy contexts of the emerging tidal energy industry. Funding bodies can also directly influence MU by proving for the resources required in order to produce data on environmental interactions with TCT arrays. Regulators and policy makers such as Marine Scotland and the UK Crown Estate have legislative power to control and make decisions through the Marine Scotland Act 2010 and UK Coastal Access Act 2009, as well as a number of national policies and EU legislation. Finally, insurance companies have the power to control and make decisions pertaining to the premiums they charge on development. While EIAs and appropriate assessments can inform the likelihood of development having negative impacts on specific envi-

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ronmental receptors, this information cannot yet be validated against a large set of data emanating from in-situ commercial developments.

Regardless of the type of power possessed by certain stakeholder organizations, the slight majority of stakeholders possess a strong level of power in relation to MU between tidal energy development and environmental protection and monitoring over their respective influences, although this is context and stakeholder dependant. As the legislated competent authorities, regulators and policy makers have strong power over the promotion of MU in a political and legal context. Funding bodies can have strong power for tidal energy development as they can attribute the resources required to inform the viability of MU, while Insurance companies have strong power over the implementation of MU as they set the insurance premiums for development. Research organizations have medium power as they are not formal legislated decision makers, rather, the information produced from their research can inform decision-making. NGOs and other organizations have medium power in that damage to environmental receptors stemming from TCT array deployment can result in litigation which may be supported by such bodies. Finally, the power of influence from tidal energy developers is agreed upon stakeholders as to be relatively low as they are currently not contributing substantially to the national economy given the pre-commercial status of the tidal energy industry.

7.2.4 Organization of Stakeholders

The overall organization of stakeholders in relation to MU between tidal energy development and environmental protection and monitoring is scattered across a varied number individual organizations, strong clustering, and monopoly. There are only a handful of individual tidal energy development organizations who have achieved (or are close to achieving) commercial scale development and technology readiness levels (TRLs) between 7 – 9. These leading organizations include (but are not limited to) Atlantis Resources Ltd, Nova Innovation Ltd, DP Energy, and Scotrenewables. Given that the tidal energy industry is pre-commercial, high energy tidal environments have a relatively low environmental baseline characterization, and since MU is an emerging topic, there are only a handful of funding bodies contributing to the advancement of MU.

There are many individual research organizations who specialize in certain aspects associated with MU (e.g. migratory fish, hydrographic modelling, seal behavior, bio-fouling, MU monitoring platforms, etc.). Some research-oriented organizations include Environmental Research Institution (ERI), SAMS, the University of St. Andrews, the University of Aberdeen, Atlantic Salmon Trust, etc. Similarly, there are many stakeholder NGO organizations who are concerned with various aspects of environmental receptors (e.g. Whale and Dolphin Conservation, Royal Society for the Protection of Birds, etc.), however, there are no identified societal organizations promoting tidal energy development as of yet given the pre-commercial status of the tidal energy industry. All regulators and policy makers demonstrate a degree of interconnectivity with regards to the promotion, enforcement, regulation, and monitoring of MU in R&D initiatives. Finally, insurance companies represent a monopoly in the sense that TCT technology is pre-commercial and thus the risk stays relatively similar across various technological designs, thereby limiting completion between insurance companies to lower premiums.

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7.2.5 Conclusions of the stakeholder analysis

In summation, it is apparent that regulators and policy makers, particularly Marine Scotland, are providing for the greatest push towards MU between tidal energy development and environmental protection and monitoring, backed by statutory powers and political interests to do so. Research organizations are actively engaging in aspects which will promote MU in the future, however, this has been done predominately in silos thus far given the lack of maturity of the tidal energy industry and subsequent lack of environmental baseline and interaction data. In the future, research organizations will play a primary role in furthering MU in Scotland as data becomes available. The role of NGOs is limited to the sphere with which they engage, which is currently focused on environmental protection and characterization. Other societal representatives have yet had the opportunity to engage in MU as it is generally believed that TCT arrays are at this time too expensive to facilitate community ownership, and thereby directly facilitate the catchment of benefits within small communities. The tidal energy industry is primarily focused on improving TRLs and implementing commercial-scale projects, and thus has limited resources to engage with MU. However, developers are actively producing environmental data from monitoring programmes which will be pivotal for MU to develop in the future.

Funding bodies can also have a substantial impact on MU implementation, however, other than the MUSES project and a hand full of other European projects, there has not been considerable resources attributed to the concept of MU in relation to tidal energy development and environmental protection. Finally, insurance companies seem to provide for the greatest barrier towards MU as perceived risks regarding TCT technology and yet to be characterized environmental interactions translate into considerably high costs for tidal energy development. If funding bodies attributed finances to TCT developments, and government introduced effective subsidies to developers, the costs associated with TCT technology and project implementation would decrease, thereby allowing for a sufficient amount of projects to produce considerable environmental data through their monitoring programmes. This data would enable research initiatives to further investigate and promote MU. Furthermore, decreased costs associated with increased development would allow societal representative organizations to potentially facilitate dialogues surrounding partial local ownership of tidal energy developments.

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Table 16 Tidal energy development stakeholder profiles

Tidal Energy		Attribute					
		Interest in MU	Attitude Towards MU	Geographical Scale of Power	Organization of Stake-holders	Type of Power	Level of Power
Category	Commercial Businesses	Reactive	Neutral/ Undecided	National	A couple of individual organizations	Indirect influence	Low
	Research Organizations	Reactive	Neutral/ Undecided	National	A lot of individual organizations	Direct influence	Medium
	Regulators	Proactive	Positive	National	Strong clustering	Control/ decision-making	Strong
	Policy Makers	Proactive	Positive	National	Strong clustering	Control/ decision-making	Strong
	Insurance Companies	Dormant	Negative	EU	Monopoly organization	Control/ decision-making	Strong
	Funding Bodies	Reactive	Positive	EU	A couple of individual organizations	Direct influence	Strong

Table 17 Environmental protection and monitoring stakeholder profiles

Environmental Protection/Monitoring		Attribute					
		Interest in MU	Attitude Towards MU	Geographical Scale of Power	Organization of Stake-holders	Type of Power	Level of Power
Category	Research Organizations	Reactive	Neutral/ Undecided	EU	Strong clustering	Indirect influence	Medium
	Regulators	Proactive	Positive	National	Monopoly organization	Control/ decision-making	Strong
	Policy Makers	Proactive	Positive	National	Monopoly organization	Control/ decision-making	Strong
	Funding Bodies	Dormant	Neutral/ Undecided	EU	A couple of individual organizations	Direct influence	Strong
	NGO/Other Societal Representatives	Proactive	Neutral/ Undecided	National	A lot of individual organizations	Indirect influence	Medium

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Table 18 Cross-sector stakeholder profiles

Cross-Sector		Attribute					
		Interest in MU	Attitude Towards MU	Geographical Scale of Power	Organization of Stake-holders	Type of Power	Level of Power
Category	**Research Organi-zations**	Reactive	Neutral/ Undecided	EU	Strong clus-tering	Indirect influence	Medium
	Regulators	Proactive	Positive	National	Monopoly or-ganization	Control/ decision-making	Strong
	Policy Makers	Proactive	Positive	National	Strong clus-tering	Control/ decision-making	Strong
	Funding Bodies	Reactive	Neutral/ Undecided	EU	A couple of individual or-ganizations	Direct in-fluence	Strong

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8 CONCLUSIONS AND RECOMMENDATION FROM THE CASE STUDY TO THE ACTION PLAN

The Scottish Government has committed to ambitious GHG mitigation and renewable energy deployment targets legislated under the Climate Change (Scotland) Act 2009 with an upcoming target of generating 100% of electricity from renewables by 2020 [6]. Given that Scotland has some of the world's best tidal energy resources, estimated at 25% of Europe's resource [5], TCT deployment acts as a conduit to both meet legislated targets under the Climate Change (Scotland) Act 2009 as well as put Scotland in a position to be a world leader in the MRE industry, subsequently paving the way for their future as an international industry cluster whereby resulting economic benefits are captured within the nation. Furthermore, the Scottish Government has established a vision through the Scottish Energy Strategy which promotes the social well-being of citizens through active engagement and ownership of various elements required to achieve a transition to a low-carbon economy. However, Scotland is also very conscience of the need to maintain the integrity of their marine environment while allowing for sustainable development of the tidal energy industry. While Scotland abides by several pieces of EU legislation which promote environmental protection and good environmental stewardship, including the Birds and Habitats Directives, the EIA and SEA Directives, the MSFD, and the MSP Directive, the Scottish Government has also placed an emphasis on the importance of utilizing an ecosystem approach to planning for the marine environment through the development and implementation of the NMP and the sectors contained within, including the SMPTE.

Both MU combinations examined in case study 1B are currently evident in practice in the Inner Sound of the Pentland Firth. The MU combination of tidal energy development and environmental protection is apparent, as MeyGen, the first commercial TCT array to have begun phased implementation in the world, is sited within the North Caithness Cliffs SPA for specified bird species under the Birds Directive 2009/147/EC [12]. However, there are no MPAs within the study area which legislate the protection of primary environmental receptors set to be investigated in this case study, including marine mammals and migratory fish. Nevertheless, the data emanating from MeyGen's environmental monitoring programme will help further characterize environmental interactions with commercial-scale TCT arrays in order to determine the viability of co-locating tidal energy developments within environmental protection areas in the future, thereby maximizing spatial efficiency of integrated marine uses by expanding the currently constrained scope for deployment. In this context, it is demonstrative that MU between development and environmental protection is intrinsically linked and dependent upon the MU combination for development and environmental monitoring.

The MU combination of tidal energy development and environmental monitoring is apparent as monitoring of TCT devices is a condition of consent for tidal energy development under the SDM licensing policy guidance [9]. However, environmental monitoring is in its early stages and therefore there are many technical issues associated with the quality and quantity of data produced. Given the pre-commercial status of the tidal energy industry, the majority of knowledge on environmental interactions with TCT arrays stems from modelling exercises and expert speculation. The lack of both appropriate TCT interaction data, as well as environmental baseline data in high-velocity tidal energy sites in which to compare TCT interaction data, hinders the ability to provide for informed decision-making regarding the viability of MU between tidal energy development and environmental protection. Ultimately, it was the impression of the majority of stakeholders that more commercial tidal energy developments such as MeyGen must be deployed and robust monitoring must be undertaken for a considerable length of time utilizing standardized data collection

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procedures across developments, thereby making data comparable. Furthermore, a greater amount of environmental baseline data is required prior to development in order to measure alterations in ecological processes and functions and marine species behaviour stemming from the introduction of TCT arrays. Only following a comparative analysis between robust data sets can decisions be made surrounding the viability of MU between tidal energy development and environmental protection.

The primary added values scored by stakeholders for the MU combination of tidal energy development and environmental protection were economic, which is similar to the case for drivers, in that it is the economic benefits stemming from the development of the tidal energy industry in Scotland, backed by national policies and plans, which is driving sustainable development with environmental protection in order to provide benefits to the Scottish economy. Some of these benefits include job creation, development of a supply chain and industry cluster, capacity building, improvements to local infrastructure, and the development of a local power supply partially owned by the community. However, it is worthy to not that all stakeholders acknowledged and scored the highest the added value of GHG emissions reduction, where TCT arrays indirectly benefit the health of the marine environment, as well as the concept of introducing a default no-take fishing zone, which directly contribute to environmental protection of salmon smolts, sea trout, and other diadromous fish species.

In order to achieve such added values, stakeholders identified many barriers which first must be overcome. During the stakeholder engagement portion of the case study implementation, 12 additional barriers were identified, three times as many stemming from the desk analysis, which were evenly distributed amongst categories including legal, administrative, economic, technical, social, and environmental. This would suggest that stakeholders encounter more pushback in promoting and attaining MU then available literature would suggest. The majority of barriers towards MU are real and economic, and cannot be controlled nor influenced by a single actor. However, there are a number of perceived barriers, prominently economic and technical, which can be solved by the EC and UK government respectively in the medium term. The most notable barrier was that the CFD is ineffective for tidal energy development in relation to other technologies such as offshore wind energy. The scale of the barrier is national given that it is a UK subsidy which can be solved through active control and decision making by the national competent authorities in the short to medium term. Another prominent barrier was the lack of scientific baseline knowledge on tidal energy deployment and environmental interactions inhibiting the siting of TCT arrays within environmental protection areas. This barrier would suggest that it is too early in the development of the tidal energy industry to promote MU with environmental protection areas as more data is required, both environmental baseline and TCT monitoring data, to make informed decisions regarding the sustainability of MU. This barrier cannot be controlled nor influenced, rather, a considerable amount of time is required for more developments to take place which produce more data on environmental interactions.

In general, impacts stemming from MU between tidal energy development and environmental protection were not scored very high. The highest scoring impact, averaging -2.1, was collision risk between TCT blades and marine mammals, which was shown more concern than collision risk between diving birds and elasmobranches at -1.9 respectively, followed by fish with a score of -1.8. Reasons for greater concern of blade strike with marine mammals pointed out by stakeholders is that seal landings are present in the Inner Sound of the Pentland Firth. However, it is generally believed that marine mammals are very intelligent creatures and should be able to avoid TCT blades.

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Irrespective of the species receptor to collision risk, or the environmental impact factor included in the DABI catalogue and analysed with stakeholders, all interviewees suggested that more monitoring data is required in order to make informed judgements any any environmental impacts. Given the pre-commercial status of the tidal energy industry, with MeyGen being the first commercial-scale phased development to begin implementation in the world, the industry must expand and such expansion must be supported by innovative monitoring techniques and technologies.

Overall, drivers received an average aggregate score of 2.3, and barriers -1.9, resulting in a MU potential score of 0.4, suggesting that the drivers promoting MU between tidal energy development and environmental protection are stronger than the barriers inhibiting it. The economic driver category scored the highest, at 2.7, the one factor of which stems from the vision set out in the Scottish Energy Strategy, which is informed by the GHG mitigation and renewable energy generation targets set out in the Climate Change (Scotland) Act 2009. While the vision of Scotland transitioning to a low-carbon economy, and the subsequent socio-economic benefits that are projected to manifest, act as a leading driver, it is the synergistic relationship between environmental and economic barriers which act as the greatest hindrance towards MU, as a lack of appropriate financial support mechanisms may stunt the development of the tidal energy industry, and therefore inhibit the accumulation of data stemming from monitoring programmes which increases the environmental interaction knowledgebase. However, this negative synergy provides a clear vision of necessary action plan moving forward, one which is not heavily dependent on the re-interpretation of legislation, administrative complexities, nor social barriers, but rather financing structures which aid developments.

Overall, added values received an average aggregate score of 2.0, and impacts -1.4, resulting in a MU effect score of 0.6, suggesting that the benefits emanating from MU between tidal energy development and environmental protection are greater than the potential for negative implications which could result. The highest scored category for added values was economic, which is similar to the case for drivers, in that it is the economic benefits stemming from the development of the tidal energy industry in Scotland, backed by national policies and plans, which is driving sustainable development with environmental protection in order to provide benefits to the Scottish economy. The impact categories have all received a similar score, however, it is the sheer number of identified environmental impacts which would suggest that if environmental interactions prove to be negative, MU will not be viable. Given the pre-commercial status of the tidal energy industry, there is not a sufficient amount of data from which to draw upon in order to determine the scale and severity of impacts. Moreover, the majority of stakeholders stated that most of the environmental impacts examined are context dependant on the geographical scale of development, sensitivity of the environment, and TCT technology being employed. Given that the primary theme thus far in the analysis has been centred on the importance of economic aspects allowing for development, and the benefits thereof both to the economy, the industry, and in obtaining data to inform environmental interactions in order to better characterize MU, it is also worthy to note that negative impacts on the economy triggered by MU are not apparent, and therefore the economic risk lies with the tidal energy industry and not the concept of MU itself. Overall, MU effects scored higher than MU potentials, suggesting in theory that, while the initiation of MU is more difficult, the effects of achieving MU are bountiful enough to promote the allocating of resources towards exploring solutions to barriers.

The combination of tidal energy development and environmental monitoring produced many added values across a diverse array of categories. Moreover, there were no negative impacts associat-

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ed with the MU combination apparent neither from the desk analysis nor stakeholder engagement. The highest scored added value at 2.8 was the increased knowledge base gained on environmental sensitivity to and environmental interactions with tidal energy deployment. The monitoring data retrieved from tidal energy deployments can also contribute towards marine protection and conservation area management. Technical advancements in monitoring equipment placed on TCT structures can better capture and characterize environmental interactions, which provide the added value of securing community buy-in through the dissemination of information to the general public, thereby educating the public on real as opposed to perceived interactions which may improve public opinion and support for tidal energy deployment, thus streamlining development.

Only one barrier has been identified for the MU combination, and has been suggested by Marine Scotland. The barrier identifies how staggered MU may initiate complex licensing procedures where existing uses that are not licensable will take priority and inhibit the deployment of TCTs, and therefore the ability to undertake environmental monitoring which would further develop the knowledgebase needed to further expand the industry. Overall, drivers received an average aggregate score of 2.4, and barriers -1.7, resulting in a MU potential score of 0.7, suggesting that the drivers promoting MU between tidal energy development and environmental monitoring are stronger than the barriers inhibiting it. The potentials score is higher for this MU combination than tidal energy development and environmental protection, which is evident from the single barrier towards MU in between development and monitoring, which is administrative and can be solved in the short to medium term through control and active decision making by Marine Scotland. While most of the drivers are categorized as ecological and framed by EU legislation and national policies, the greatest driver for MU is technological as solutions must be found in order to develop quality monitoring devises which can be co-located on TCT structures.

Overall, added values received an average aggregate score of 2.2. Since there were no impacts identified for the MU combination of tidal energy development and environmental monitoring, the MU effect score is 2.2, suggesting that this MU has very promising benefits. Of course, monitoring is a condition of consent under the SDM licensing policy guidance, although it is the technical solutions to monitoring that are required in order to enhance the quality of data pertaining to environmental interactions with TCTs, thereby addressing barriers associated with environmental knowledge gaps that currently inhibit both the development of the tidal energy industry alone from an economic risk perspective, as well as the colocation of developments in environmental protection areas.

The key stakeholders related to MU identified through the desk analysis were the Scottish and UK governments, the tidal energy industry and other industries operating in a development area, MRE test centres, financial investment organizations, banks, academia, ENGO organizations, and local/regional communities. Through engagement, stakeholders additionally identifying European, regional, and local levels of government, and SNCB as key stakeholders. Ultimately, it was provided that government regulators and the tidal energy industry were the key stakeholders promoting and enabling MU. Marine Regulators are generally tasked with the duty or restructuring policies and procedures in order to accommodate the needs of various stakeholders who would engage in aspects of MU, while tidal energy developers are primarily seen not disseminating information regarding project development and environmental monitoring, and thus must establish accessible and inclusive communication platforms in order to provide for a transparent development process.

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In reality, given the pre-commercial status of the tidal energy industry, added values and negative impacts emanating solely from tidal energy development, as well as MU with environmental protection, is speculative as a there is currently an insufficient amount of data from which to based informed decision-making. Therefore, concepts pertaining to the spatial suitability to accommodate MU in the study area, stakeholder discussions surrounding the ability for O&M jobs to be captured in local communities, negative environmental impacts surrounding collision risk with marine species, alteration of hydrographic processes, the effects of artificial reefs, etc. can only be informed through greater tidal energy capacity deployment and the experiences and interactions which manifest thereafter. Therefore, the determination of the viability between co-locating tidal energy developments with environmental protection areas, the primary MU combination analysed in this case study, is intrinsically dependant on the improvement of monitoring tools, techniques, and platforms characteristic of environmental monitoring of tidal energy developments, the secondary MU combination analysed in this case study. While detailed investigations of various elements and contexts explored in this case study can be analysed in the various sections presented, table 19 focuses on the detailed recommendations suggested for WP4 – Action Plan for the MUSES project for both MU combinations of tidal energy development and environmental protection and monitoring. The table depicts presents the priority of the recommendation, the recommendation itself, MU combination, the context (e.g. economic, environmental, social, etc.), the stakeholder required to take action, the geographical scale, and the relative timeframe for addressing the recommendation. Figure 5 visually displays the relationship between each recommendation, MU combination, and position within the MU development timeline.

Table 19 Recommendations to further MU between tidal energy development and environmental protection and monitoring

Rank	Recommendation	MU	Context	Scale	Timeline
1	It is recommended that the EC establish measures which standardize data collection procedures within the EU, both for baseline environmental monitoring and environmental interactions with tidal energy developments, thereby making data easily comparable over a considerable timeframe. The accumulation of standardized environmental monitoring data will help characterize environmental interactions across the tidal energy industry, thereby allowing for developments to obtain project and non-recourse financing needed to further the industry.	TD&EP; TD&EM	Technical; Economic; Environment	EU	Short term
2	It is recommended that the UK and Scottish Governments replace CFD mechanism with a subsidy which allows for tidal energy to be competitive with other forms of electricity generation. The subsidy should be tailored to tidal energy technology and take the form of a FIT. The EC should examine the implications of the new subsidy and, if warranted, promote it as a beneficial mechanism to streamline tidal energy development in the EU.	TD&EP; TD&EM	Economic	National	Short term
3	It is recommended that national authorities provide funding for improvements to monitoring equipment	TD&EM	Technical; Economic	National	Short term

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Rank	Recommendation	MU	Context	Scale	Timeline
	including stainless steel housing of monitoring equipment, the utilization of robust connectors, bio-fouling resistant designs, and senor systems which trigger monitoring technologies within, for example, 30m of a turbine, so that data analysts do not have to sift through 100s/1000s of hours of monitoring data. Furthermore, sensor integration between various monitoring technologies including visual, audio, passive acoustic, salinometers, and sonar be designed to capture specific elements of marine species interactions with TCTs, being prompted to record certain interactions as necessary. These MU monitoring platforms should then be co-located on TCT structures				
4	It is recommended that national authorities enact a policy which ensures that tidal energy developers provide open access to their environmental data to ENGOs, SNCBs, academia, and the public in order to provide for a transparent and participatory development process which can initiate research programmes, thereby further informing the viability of co-location of TCT arrays within environmental protection areas	TD&EP; TD&EM	Policy	National	Short term
5	It is recommended that national authorities and tidal energy developers initiative an on-going communication and consultation platform outside of the marine planning process and individual project licensing and consenting which engages other industries operating within the development area. This could take form through regional/local industry forums and would allow for knowledge sharing which would address perceptions of tidal energy developments taking away cash inflows from other sectors and the communities which rely upon these sectors for economic stability	TD&EP; TD&EM	Policy; Social; Industry	National; Regional; Local	Short term
6	It is recommended national authorities and TSOs work in consultation to provide subsidies for tidal energy developments in remote areas to access the necessary grid infrastructure required to distribute the electricity generated. Government and TSOs should also initiate a programme where upgrades are made to existing grid infrastructure in order to accommodate tidal energy developments while providing solutions for active network management	TD&EP; TD&EM	Technical; Economic	National	Medium term
7	It is recommended that national authorities subsidize MU monitoring platforms in order to entice tidal energy developers to disseminate environmental data obtained from deployment, while allowing for partial governmental ownership, acquisition, retention, exploitation, and communication of environmental data within the public domain	TD&EP; TD&EM	Economic; Social	National	Short term
8	It is recommended that national authorities provide funding to tidal energy technology developers for R&D,	TD&EP	Economic	National	Medium term

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Rank	Recommendation	MU	Context	Scale	Timeline
	thereby furthering their TRL and allowing for projects to become bankable. When projects achieve bankability due to de-risking of TCT technology, more commercial development will be implemented and more environmental monitoring data will be produced, thereby informing viability of co-location of developments within existing marine protected areas				
9	It is recommended that national authorities, tidal energy developers, SNCBs, and ENGOs work together to promote environmentally considerate and sustainable tourism management plans which promote tourism of TCT arrays as well as the environmental protection areas which they are located in, thereby enhancing the economic benefits incurred in the local/regional community	TD&EP	Economic; Social; Industry	National; Regional; Local	Medium term
10	It is recommended that national authorities initiate programmes which further educate the general public on the negative environmental implications of climate change, and the direct impacts that such implications have on the national economy, as well as regional and local economies and communities. This will help inform Scottish society on the realities of climate change, and the drivers and added values associated with MU between tidal energy development and environmental protection	TD&EP	Social; Economic	National	Medium term
11	It is recommended that national authorities and tidal energy developers work together to gather standardized baseline data for potential development sites prior to granting consents, thereby increasing the impact that data analysis has on MSP, SEA, and EIAs	TD&EP; TD&EM	Policy; Regulatory; Environment	National	Short term
12	It is recommended that national authorities develop policies and procedures informing how site-level trade-offs are to be made when siting tidal energy developments. This would take the identification and weighting of constraints and opportunities utilized in sectoral planning to a more granular and practical scale, while emphasizing the potential for synergies to be maximized	TD&EP	Policy	National	Short term
13	It is recommended that the EC and national authorities reinterpret the EIA Directive 2014/52/EU so that costs and timeframes for pre-requisite EIAs for tidal energy development are reduced. Furthermore, national authorities should provide subsidies for early stage developers in undertaking such environmental assessments and site characterization, as well as gathering the required data to do so, as such developers alone currently bear the costs of informing the industry	TD&EP; TD&EM	Policy; Legislation; Economic; Environment	EU; National	Medium term
14	It is recommended that national authorities partner with academia in order to determine the viability of TCT arrays acting as default no-fishing zones, and how	TD&EP; TD&EM	Environment	EU; National	Medium term

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Rank	Recommendation	MU	Context	Scale	Timeline
	would affect the environmental dynamics in the area. Furthermore, investigations should extent to the viability and associated effects of an artificial reef occurring in the development area, how this may provide shelter for migrating fish species, alter predation dynamics, facilitate collision risk, etc. The outputs of such studies could inform/maximize environmental synergies for siting developments in environmental protection areas as well as contribute to environmental management plans.				
15	It is recommended that national authorities implement a standardized approval procedure whereby ENGOs agree on limits of potential impact, and mitigation measures stemming from environmental monitoring programmes, which are standardized through consents and therefore eliminate (as much as possible) potential litigation whereby impacts are incurred when monitoring was consented	TD&EP; TD&EM	Policy; Environment	National	Short term
16	It is recommended that national authorities establish community benefit funds in order to allow for local catchment of economic benefits and local ownership of TCT developments	TD&EP	Social; Economic	National; Regional; Local	Short term
17	It is recommended that national authorities draft procedural guidelines and policies through MSP which limit the potential for existing users of marine space to make claims of encroachment against tidal energy development sites, thereby reducing the risk of litigation	TD&EP	Policy	National	Short term
18	It is recommended that MRE test centres around the world communicate with one another in order to share environmental monitoring and data collection and analysis techniques in order to inform the viability of tidal energy development and environmental protection in areas of contrasting climates, ecological make-up, and environmental receptors.	TD&EP; TD&EM	Technical; Environment	International	Long term
19	It is recommended that developers work with TSOs and regulators to plan for the co-location of monitoring and electricity cable routes, thereby facilitating direct to shore connection of monitoring data	TD&EM	Technical	National	Short term
20	It is recommended that national authorities restructure the EIA process to consider the synergies and negative impacts specific to MU with tidal energy, the environment, and other uses/users of marine space	TD&EP	Environment	National	Medium term
21	It is recommended that national authorities initiate educational programmes informing Scottish society, ENGOs, SNCBs, and other industries operating in the marine environment about the concept of and benefits emanating from MU in general	TD&EP; TD&EM	Social	National	Medium term
22	It is recommended that national authorities attribute greater funds to migratory fisheries research in order to characterize salmon and diadromous fish movements, leading to enhanced TCT and salmon management	TD&EP; TD&EM	Economic; Policy; Environment	National	Medium term

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Rank	Recommendation	MU	Context	Scale	Timeline
	plans, individually and in relation to MU, through informed policy development				
23	It is recommended that national authorities fund research investigating the viability of economic benefits relaying back to local/regional communities, as well as what aspects of community infrastructure will witness improvements and/or investment, and for what stage of the development lifecycle benefits are expected to be realized, if at all	TD&EP	Economic	National	Medium term
24	It is recommended that national authorities restructure their licensing regime to allow for a streamlined process for staggered MU development between tidal energy projects and environmental monitoring, environmental protection, and other uses which do not give overwhelming priority to existing, non-licensable uses which may inhibit MU. Furthermore, it should be clarified which use/industry carries what portion of the costs/risks for specific developments	TD&EP	Policy	National	Medium term
25	It is recommended that, as the tidal energy industry matures and becomes more profitable, developers approach and engage local communities to facilitate local ownership of TCT arrays, thereby promoting a sense of pride and community branding in the locality, and developing better relations with communities in order to allow for MU with environmental protection areas in the future	TD&EP	Social; Economic	National; Regional; Local	Medium term
26	It is recommended that the EC and national authorities provide interpretations for EU legislation concerning environmental protection sites in the Natura 2000 belt in order to enable for more flexible siting procedures for tidal energy developments, as well as establish policies which provide guidance concerning which Directives take precedents over others, thereby enabling the co-location of TCT arrays within existing environmental protection areas	TD&EP	Policy; Legislation	EU; National	Medium term
27	It is recommended that national authorities continue to work closely with developers to assist them in navigating the regulatory regime, employing adaptive management to licensing and consenting protocols as experience is gained throughout the lifecycle of the MeyGen project	TD&EP	Policy	National	Medium term
28	It is recommended that national authorities create a roadmap in order to determine the maximum area for future tidal energy developments and siting synergies with environmental protection areas for the marine environment, as well as determine if spatial conflicts are present onshore with regards to associated tidal energy infrastructure	TD&EP	Policy	National	Medium term
29	It is recommended that, as monitoring data becomes more available through increased development, and	TD&EP	Policy	National	Medium term

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Rank	Recommendation	MU	Context	Scale	Timeline
	MSP as a practice matures to the point which allows for lessons learned, national and regional authorities should initiate MU specific objectives and policies in sectoral and regional marine plans				
30	It is recommended that national authorities undertake detailed scenario mapping simulations based on data emanating from developments as similar in scope (capacity, technology, environmental and socio-economic site characterization, etc.) as possible in order to determine the levelized cost of energy of tidal energy developments, and disseminate the results with the general public in order to obtain community buy-in	TD&EP; TD&EM	Economic; Social	National; Regional; Local	Medium term
31	It is recommended that tidal energy developers consult with harbour authorities to provide electrical power to vessels docked at harbours which undertake construction, installation, O&M, and decommissioning procedures on TCTs and monitoring equipment, thereby reducing the GHG emissions of vessels	TD&EP	Technical	Regional; Local	Medium term
32	It is recommended that national authorities partner with academia and applicable industries to investigate the potential for pairing energy storage capacity development, particularly at harbours, with TCT arrays in order to take advantage of the predictable and nearly constant electrical output of TCTs to provide base-load power, thereby helping achieve legislated GHG emissions reduction targets	TD&EP	Technical	National	Long term
33	It is recommended that national authorities tailor tidal energy demonstration windows to accommodate tidal cycles and weather patterns which allow for optimal electrical output of TCT devices and ease of device installation to the greatest extent possible	TD&EM	Regulatory	National	Short term
34	It is recommended that national authorities partner with academic institutions in order to determine the GVA emanating from tidal energy development to the national and regional/local economies, as well as quantify ecosystem services in order to allow for a measuring tool to determine synergies between tidal energy development and environmental protection. Negative economic impacts should also be included in final figures in order to account for spatial trade-offs	TD&EP	Economic; Environment	National	Medium term
35	It is recommended that, if powers to plan for the marine environment and license tidal energy developments are devolved to regional and local governments, national authorities should develop and document lessons learned in a repository available for regional and local planning bodies, as well as provide ongoing strategic guidance, in order to account for the knowledge and experience gaps of regional/local authorities	TD&EP	Policy	National; Regional; Local	Long term
36	It is recommended that national authorities investigate and consider how the Dutch government undertakes	TD&EP; TD&EM	Policy	EU; National	Medium term

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Rank	Recommendation	MU	Context	Scale	Timeline
	environmental assessments and then tenders the site for development. This scenario can eliminate bias of developers undertaking/paying for their own environmental assessments, while it also reduces the upfront financial costs required from developers at their own risk which may constrain developers from being able to properly undertake a detailed assessment				

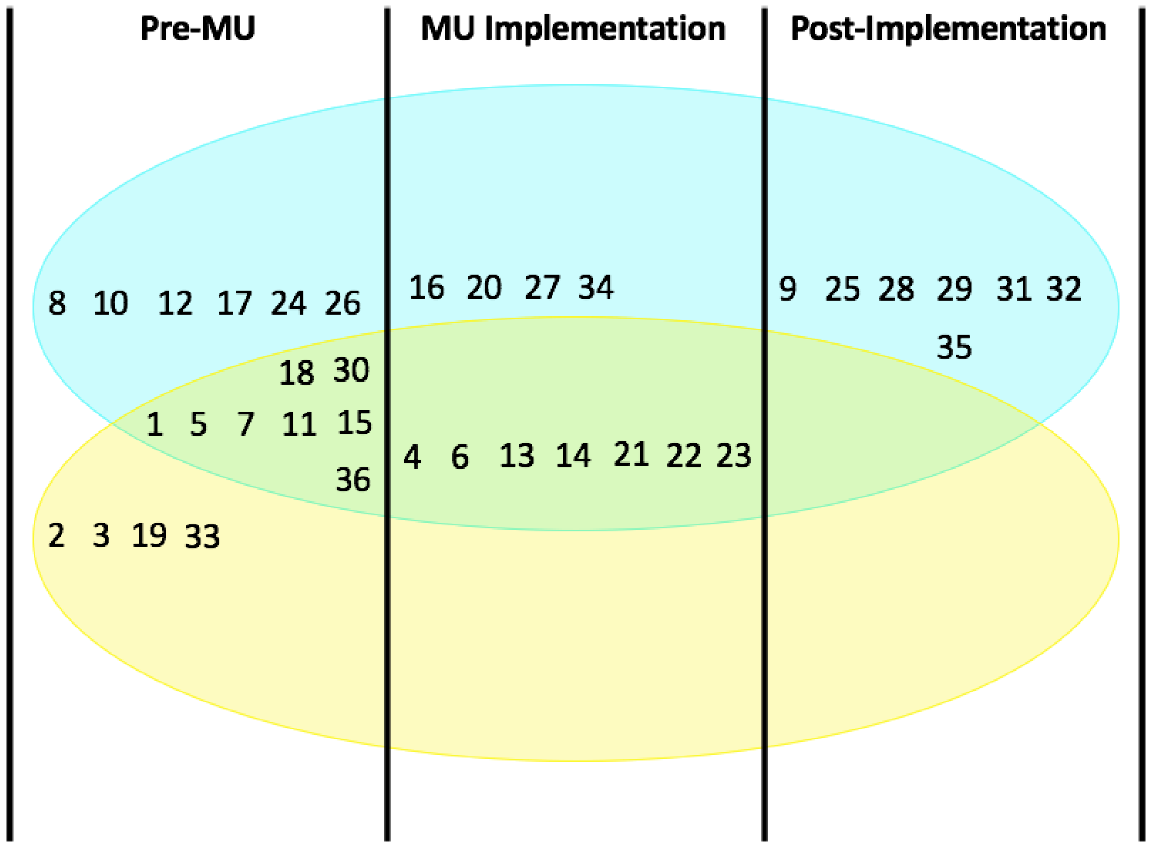

Figure 5 Relationship between each recommendation, MU combination, and position within the MU development timeline. Recommendation numbers located in the blue sphere are attributed to the MU combination of Tidal Energy Development and Environmental Protection. Recommendation numbers located in the yellow sphere are attributed to the MU combination of Tidal Energy Development and Environmental Monitoring. Recommendation numbers located in the overlapping spheres are attributed to both MU combinations.

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ACRONYMS AND ABBREVIATIONS

CFD – Contract for Difference
DABI – Drivers, Added Value, Barriers, Impacts
EC – European Commission
EEZ – Exclusive economic zone
EMF – Electromagnetic field
EIA – Environmental impact assessment
EMEC – European Marine Energy Centre
ENGO – Environmental non-government organization
ERI – Environmental Research Institute
FIT – Feed-in tariff
GES – Good environmental status (descriptor – MSFD)
GHG – Greenhouse gas emission
GVA – Gross value added
KEQ – Key evaluation question
MPA – Marine Protected Area
MRE – Marine renewable energy
MS-LOT – Marine Scotland Licensing Operations Team
MSFD – Marine Strategy Framework Directive
MSP – Marine Spatial Planning
MU – Multi-use
MUSES – Multi-Use in European Seas
NGO – Non-governmental organization
NMP – (Scottish) National Marine Plan
O&G – Oil and gas
O&M – Operation and maintenance
PFOW – Pentland Firth and Orkney Waters
POA – Plan option area
R&D – Research and development
SAC – Special Area of Conservation
SAMS – Scottish Association of Marine Science
SDM – Survey, deploy, monitor (Scottish licensing policy guidance)
SEA – Strategic environmental assessment
SMPTE – (Scottish) Sectoral marine plan for tidal energy
SNCB – Statutory nature conservation body
SPA – Special Protected Area
SpORRAn – Scottish Offshore Renewables Research Framework
SSSI – Sites of Special Scientific Interest
TCT – Tidal current turbine
TRL – Technology readiness level
TSO – Ttransmission system operator
TZ – Territorial zone

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APPENDIX 1 – SCORED DABI SHEETS

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	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6	Interviewee 7	Interviewee 8	Interviewee 9	Interviewee 10	Interviewee 11	Interviewee 12	Interviewee 13	Interviewee 14	Interviewee 15	Interviewee 16	Interviewee 17	Interviewee 18		
Combination: Tidal development & Environmental protection	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Factor average for all stakeholders**	**Category average (average of all factors averaged for all stakeholders)**
DRIVERS																				
Category D.1 - Policy drivers																				
Factor D.1.1. Achievement of greenhouse gas emissions reduction legislated targets under the Climate Change (Scotland) Act 2009	3,0	3,0	3,0	3,0	2,0	3,0	3,0	3,0	3,0	3,0	2,0	3,0	3,0	2,0	3,0	3,0	3,0	2,0	2,9	
Factor D.1.2. Achievement of renewable energy generation legislated targets under the Climate Change (Scotland) Act 2009	3,0	3,0	3,0	2,0	2,0	3,0	3,0	2,0	3,0	3,0	2,0	3,0	2,0	2,0	2,0	3,0	3,0	2,0	2,7	
Factor D.1.3. To promote the Sustainable development and expansion of marine renewable energy (MRE) test and demonstration Facilities as per Wind and Marine Renewable Energy sectoral objective 7 of the Scottish National Marine Plan (NMP)	2,0	2,0	2,0	0,0	1,0	2,0	1,0	2,0				2,0			2,0		2,0		1,4	
Factor D.1.4. To achieve the vision set out in the Sectoral Marine Plan for Tidal Energy of Scotland becoming a world leader in the development and deployment of offshore renewable energy technologies		3,0	3,0	2,0	2,0	3,0			2,0	3,0	2,0	3,0	1,0	1,0		3,0	2,0	2,0	2,6	
Factor D.1.5. To give due consideration to other users and uses of the marine environment, as well as the marine environment itself, during siting developments via undertaking an Environmental Impact Assessment in accordance with Directive 2014/52/EU		3,0	2,0	2,0	2,0				3,0	2,0	1,0		3,0	1,0	2,0		2,0	2,0	2,3	
Factor D.1.6. To adhere to regulations concerning the protection of rare, threatened or endemic animal and plant species as per the Habitats Directive				3,0	2,0				3,0				3,0	2,0	1,0				2,5	
Average	**2,7**	**2,8**	**2,6**	**2,0**	1,8	2,8	2,3	2,3	2,8	2,8	1,8	2,8	2,4	1,6	2,0	3,0	2,4	2,0		2,4
Category D.2 - Economic drivers																				
Factor D.2.1. To facilitate the transition to a low carbon economy via a modern, integrated, reliable, affordable, and clean energy supply while developing equitable market conditions and creating high-value jobs as per the Scottish Energy Strategy	3,0	3,0	3,0	3,0	2,0	2,0	3,0	3,0	2,0	3,0	1,0	2,0	3,0	2,0	2,0	2,0	2,0	2,0	2,7	
Average	**3,0**	**3,0**	**3,0**	**3,0**	2,0	2,0	3,0	3,0	2,0	3,0	1,0	2,0	3,0	2,0	2,0	2,0	2,0	2,0		2,7
Category D.3 - Societal drivers																				
Factor D.3.1. To transition from centralized energy generation/provision system while enhancing the role that small and island communities assume in the clean energy mix	2,0	2,0	2,0	2,0	1,0	1,0	3,0	2,0	1,0	2,0	2,0	2,0	2,0	2,0	2,0	1,0	1,0		1,9	
Factor D.3.2. To promote the local ownership of clean energy systems to fulfil associated Scottish Government targets put forth under the Scottish Energy Strategy	2,0	3,0	2,0	2,0	1,0	2,0	3,0	3,0	1,0	1,0	0,0	2,0	2,0	2,0	2,0	2,0	1,0	2,0	2,1	
Average	**2,0**	**2,5**	**2,0**	**2,0**	1,0	1,5	3,0	2,5	1,0	1,5	1,0	2,0	2,0	2,0	2,0	1,5	1,0	2,0		2,0

	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6	Interviewee 7	Interviewee 8	Interviewee 9	Interviewee 10	Interviewee 11	Interviewee 12	Interviewee 13	Interviewee 14	Interviewee 15	Interviewee 16	Interviewee 17	Interviewee 18		
Combination: Tidal development & Environmental protection	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Factor average for all stakeholders**	**Category average (average of all factors averaged for all stakeholders)**
BARRIERS																				
Category B.1 - Legal barriers																				
Factor B.1.1. Pre-requisite Environmental Impact Assessments (EIAs) are costly and time-consuming given the infancy status of the tidal energy industry	-1,0	-1,0	-1,0	-2,0	-2,0	-2,0	-3,0	-1,0	-2,0	-3,0	-2,0	-1,0	-2,0	-2,0	-2,0	0,0	-2,0	0,0	-1,6	
Factor B.1.2. Precedentes given to existing uses provides for claims of encroachment and subsequently litigation which would hinder the ability for the tidal energy industry to reasonably expand, therefore inhibiting MU between tidal energy development and environmental monitoring	-1,0	-2,0	-3,0	0,0	-2,0	-1,0	-3,0	-3,0	-1,0	0,0	-1,0	-3,0		-2,0		-2,0	0,0	-1,0	-1,6	
Factor B.1.3. Strict EU legislation associated with the Natura 2000 programme provides little room for tidal energy development, and therefore generally inhibits MU between tidal energy and environmental protection	-1,0	-2,0	-1,0	0,0	-1,0	-1,0	-3,0	-2,0	-1,0	-1,0		-1,0	0,0	-2,0			0,0	0,0	-1,1	
Average	**-1,0**	**-1,7**	**-1,7**	**-0,7**	-1,7	-1,3	-3,0	-2,0	-1,3	-1,3	-1,5	-1,7	-1,0	-2,0	-2,0	-1,0	-0,7	-0,3		-1,4
Category B.2 - Administrative barriers																				
Factor B.2.1. Complex regulatory regimes may deter developers and investors, thereby limiting the uptake of tidal energy systems	-1,0	-2,0	-2,0	-1,0	-2,0	-2,0	-2,0	-1,0	-2,0	-1,0	-2,0	-1,0	-1,0	-1,0	NK	-2,0	-1,0	-1,0	-1,5	
Average	**-1,0**	**-2,0**	**-2,0**	**-1,0**	-2,0	-2,0	-2,0	-1,0	-2,0	-1,0	-2,0	-1,0	-1,0	-1,0		-2,0	-1,0	-1,0		-1,5
Category B.3 - Barriers related with economic availability / risk																				
Factor B.3.1. Lack of certainty on tidal energy installation, operation, monitoring, and decommissioning interactions with the environmental due to presently insufficient knowledgebase emanating from limited in situ commercial deployment perpetuating investor uncertainty and subsequent inability for developers to obtain project financing	-3,0	-3,0	-2,0	-2,0	-3,0	-2,0	-2,0	-3,0	-3,0	-2,0	-2,0	-2,0	-2,0	-3,0	NK	-2,0	-3,0	-2,0	-2,4	
Factor B.3.2. Government financing structures (e.g. Contracts For Difference – CFD) are unfair for tidal energy development is relation to other technologies (e.g. offshore wind energy) as full capital payment is required upfront			-3,0							-3,0	-3,0		-2,0				-3,0		-2,8	
Average	**-3,0**	**-3,0**	**-2,5**	**-2,0**	-3,0	-2,0	-2,0	-3,0	-3,0	-2,5	-2,5	-2,0	-2,0	-3,0		-2,0	-3,0	-2,0		-2,5
Category B.4 - Barriers related with technical capacity																				
Factor B.4.1. Lack of technological maturity of the tidal energy industry may deter investors and subsequently limit technological progression to being trapped in the technology valley of death, thereby limiting tidal energy uptake	-2,0	-2,0	-2,0	-2,0	-3,0	-2,0	-2,0	-3,0	-2,0	-2,0	-3,0	-1,0	NK	-2,0	-2,0	-2,0	-2,0	NK	-2,1	
Factor B.4.2. Potential perceptions of tidal energy development taking away current cash inflows into a community due to logistical conflicts with other established industries	-1,0	-3,0	-2,0	0,0	-2,0	-2,0	-3,0	-3,0	-1,0	0,0	0,0	-2,0		-2,0	-1,0	-1,0	-1,0	-1,0	-1,5	
Factor B.4.3. Given the harsh environmental conditions where tidal energy is abundant, there is typically a lack of infrastructure (e.g. grid availability/capacity) to easily accommodate tidal energy implementation, thereby leading to an increase in development costs			-3,0							-3,0							-1,0		-2,3	
Average	**-1,5**	**-2,5**	**-2,3**	**-1,0**	-2,5	-2,0	-2,5	-3,0	-1,5	-1,7	-1,5	-1,5		-2,0	-1,5	-1,5	-1,3	-1,0		-1,8
Category B.5 - Barriers related with social factors																				
Factor B.5.1. Public and Environmental Non-Governmental Organizations (ENGO) perceptions of incompatibility due to adverse environmental implications associated with tidal energy development which would impact current industries providing economic benefit in the community	-3,0	-3,0	-2,0	0,0	-2,0	-3,0	-1,0	-3,0	-1,0	-1,0	0,0	-2,0	-1,0	-2,0	-1,0	-1,0	-2,0	-1,0	-1,6	
Average	**-3,0**	**-3,0**	**-2,0**	**0,0**	-2,0	-3,0	-1,0	-3,0	-1,0	-1,0	0,0	-2,0	-1,0	-2,0	-1,0	-1,0	-2,0	-1,0		-1,6
Category B.6 - Barriers related with environmental factors																				
Factor B.6.1. Lack of scientific baseline knowledge on tidal energy deployment and environmental interactions	-3,0	-3,0	-2,0	-3,0	-3,0	-3,0	-3,0	-3,0	-3,0	-2,0	-2,0	-3,0	-3,0	-2,0	-2,0	-3,0	-2,0	-3,0	-2,7	
Average	**-3,0**	**-3,0**	**-2,0**	**-3,0**	-3,0	-3,0	-3,0	-3,0	-3,0	-2,0	-2,0	-3,0	-3,0	-2,0	-2,0	-3,0	-2,0	-3,0		-2,7

	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6	Interviewee 7	Interviewee 8	Interviewee 9	Interviewee 10	Interviewee 11	Interviewee 12	Interviewee 13	Interviewee 14	Interviewee 15	Interviewee 16	Interviewee 17	Interviewee 18		
Combination: Tidal development & Environmental protection	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Factor average for all stakeholders**	**Category average (average of all factors averaged for all stakeholders)**
ADDED VALUES																				
Category V.1 - Economic added values																				
Factor V.1.1. Enhancement for tidal energy development capacity and associated economic benefits pertaining to increased employment, development of a supply chain and industry cluster, and capacity building	3,0	3,0	3,0	1,0	1,0	2,0	3,0	3,0	2,0	3,0	3,0	2,0	NK	2,0	2,0	2,0	2,0	2,0	2,3	
Average	**3,0**	**3,0**	**3,0**	**1,0**	1,0	2,0	3,0	3,0	2,0	3,0	3,0	2,0		2,0	2,0	2,0	2,0	2,0		2,3
Category V.2 - Societal added values																				
Factor V.2.1. Community benefits in the form of improvements to local infrastructure such as ports and harbours	3,0	2,0	3,0	2,0	2,0	2,0	2,0	2,0	3,0	2,0	2,0	2,0	2,0	2,0	1,0	2,0	2,0	2,0	2,1	
Factor V.2.2. Development of local power supply providing a sense of community ownership	1,0	3,0	2,0	2,0	1,0	1,0	3,0	3,0	1,0	1,0	2,0	2,0	2,0	2,0	2,0	1,0	2,0	2,0	1,8	
Average	**2,0**	**2,5**	**2,5**	**2,0**	1,5	1,5	2,5	2,5	2,0	1,5	2,0	2,0	2,0	2,0	1,5	1,5	2,0	2,0		2,0
Category V.3 - Environmental added values																				
Factor V.3.1. Reduction in climate change inducing compounds and processes projected to negatively impact the marine environment and its inhabitants	3,0	3,0	3,0	3,0	2,0	3,0	3,0	3,0	3,0	3,0	2,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	2,9	
Factor V.3.2. Turbine support structures may create an artificial reef effect boasting various species populations	2,0	1,0	3,0	2,0	1,0	1,0	0,0	2,0	3,0	2,0	0,0	2,0	NK		0,0	0,0	0,0	2,0	1,3	
Factor V.3.3. Tidal Current Turbines (TCTs) will likely act as default no-take fishing zones, thereby doubling as a micro-restoration site for certain marine species		2,0	3,0	2,0	1,0				2,0					2,0	0,0				1,7	
Average	**2,5**	**2,0**	**3,0**	**2,3**	1,3	2,0	1,5	2,5	2,7	2,5	1,0	2,5	3,0	2,5	1,0	1,5	1,5	2,5		2,1

Combination: Tidal development & Environmental protection	Interviewee 1 Score	Interviewee 2 Score	Interviewee 3 Score	Interviewee 4 Score	Interviewee 5 Score	Interviewee 6 Score	Interviewee 7 Score	Interviewee 8 Score	Interviewee 9 Score	Interviewee 10 Score	Interviewee 11 Score	Interviewee 12 Score	Interviewee 13 Score	Interviewee 14 Score	Interviewee 15 Score	Interviewee 16 Score	Interviewee 17 Score	Interviewee 18 Score	Factor average for all stakeholders	Category average (average of all factors averaged for all stakeholders)
NEGATIVE IMPACTS																				
Category I.1. - Social impacts																				
Factor I.1.1. Landscape and seascape impacts resulting from surface-piercing TCT devises and/or associated infrastructure such as on/offshore substations may reduce public acceptance of tidal energy development, thereby hindering the progression of the industry towards achieving large-scale implementation		-3,0	-2,0	-1,0	0,0				-1,0	-1,0	0,0			-2,0	-2,0	-2,0	-2,0		-1,5	
Average		**-3,0**	**-2,0**	**-1,0**	0,0				-1,0	-1,0	0,0			-2,0	-2,0	-2,0	-2,0			-1,5
Category I.2 - Environmental impacts																				
Factor I.2.1. Noise and vibration effects during construction and decommissioning for cetaceans, elasmobranches, and diadromous fish	-1,0	-1,0	0,0	-2,0	-1,0	-2,0	-1,0	-1,0	-1,0	-2,0	-1,0	-3,0	-3,0	-1,0	-2,0	-1,0	NK	-3,0	-1,5	
Factor I.2.2. Noise and vibration effects during operation for cetaceans, elasmobranches, and diadromous fish	-1,0	-2,0	NK	-1,0	-1,0	-2,0	-1,0	0,0	-1,0	-2,0	-1,0	-1,0	-2,0	-1,0	0,0	-1,0	NK	-1,0	-1,1	
Factor I.2.3. Barriers to electromagnetic field (EMF) sensitive cetaceans and diadromous fish include the impediment of migratory movements of eels and salmonids	-1,0	-1,0	0,0	-2,0	-1,0	-1,0	-1,0	-2,0	-1,0	-1,0	0,0	-1,0	NK	-1,0	NK	-1,0	-1,0	-2,0	-1,1	
Factor I.2.4. Collision risk between turbine blades and diving birds	-2,0	-2,0	0,0	-2,0	-1,0	-3,0	-2,0	-2,0	-3,0	-2,0	-2,0	-2,0	-2,0	-2,0	-2,0	NK	NK	-2,0	-1,9	
Factor I.2.5. Collision risk between turbine blades and marine mammals	-2,0	-2,0	-2,0	-2,0	-1,0	-3,0	-2,0	-2,0	-3,0	-3,0	-2,0	NK	-2,0	-2,0	-2,0	-1,0	NK	-3,0	-2,1	
Factor I.2.6. Collision risk between turbine blades and elasmobranchs	-2,0	-2,0	-2,0	-2,0	-1,0	-3,0	-2,0	-2,0	-3,0	-3,0	-2,0	NK	-2,0	-2,0	-2,0	NK	NK	-1,0	-2,1	
Factor I.2.7. Collision risk between turbine blades and fish	-2,0	-2,0	0,0	-2,0	-1,0	-3,0	-2,0	-2,0	-3,0	-3,0	-1,0	-1,0	-2,0	-2,0	-2,0	-1,0	NK	NK	-1,8	
Factor I.2.8. Delayed migration or displacement of migratory routes may have effects on salmon and other diadromous species	-1,0	-2,0	-2,0	-2,0	-1,0	-1,0	-1,0	-1,0	-1,0	-2,0	0,0	-2,0	-2,0	-1,0	-2,0	-1,0	NK	NK	-1,4	
Factor I.2.9. Changes in seabed morphology and direct loss of benthic habitat from smothering during device installation and cable trenching	0,0	-1,0	0,0	-2,0	-1,0	-1,0	0,0	0,0	-1,0	0,0	-1,0	-2,0	-2,0	-1,0	-1,0	-1,0	-1,0		-0,9	
Factor I.2.10. Alterations in hydrology patterns due to extraction of energy from the current regime resulting in sediment transport, wave energy dissipation, and associated coastal process	-2,0	-1,0	-1,0	NK	-1,0	-1,0	-1,0	-1,0	-2,0	-1,0	0,0	-2,0	-1,0	0,0	0,0	NK	-1,0	-1,0	-1,0	
Factor I.2.11. Impacts on water quality resulting from contamination due sediment deposition, device anti-fouling paint, oil spillage from vessels during installation, maintenance, and decommissioning	-2,0	-1,0	-2,0	NK	-1,0	-2,0	-1,0	0,0	-1,0	-1,0	NK	-2,0	-2,0	0,0	0,0	NK	-1,0	-1,0	-1,1	
Factor I.2.12. Visual disturbance to surface-feeding and diving birds	0,0	-2,0	0,0	NK	-1,0	-1,0	-2,0	-2,0	0,0	0,0	0,0		-2,0	-2,0	0,0	NK	-1,0	0,0	-0,9	
Factor I.2.13. Potential for fish aggregation and alteration in predation dynamics	-3,0	-2,0	-2,0	-3,0	-1,0	-2,0	-1,0	-2,0	-2,0	-1,0	-1,0	-2,0	-2,0	-2,0	-2,0	-1,0	-1,0	-2,0	-1,8	
Factor I.2.14. Entanglement of and/or avoidance by species due to barrier effects of devices and transmission infrastructure	-1,0	-1,0	0,0	-2,0	-1,0	-1,0	-1,0	-1,0	-1,0	0,0	-2,0	-2,0	-2,0	-1,0	NK	-1,0	NK	-3,0	-1,3	
Average	**-1,4**	**-1,6**	**-0,8**	**-2,0**	-1,0	-1,9	-1,3	-1,3	-1,6	-1,5	-1,0	-1,8	-2,0	-1,3	-1,3	-1,0	-1,0	-1,7		-1,4
Category I.3 - Impacts to other users																				
Factor I.3.1. Potential impacts of staggered MU developments on the revenue streams of other local industries	0,0	-3,0	-1,0	-2,0	-2,0	-1,0	-2,0	-1,0	-1,0	0,0	0,0	-1,0		-1,0	-2,0	-2,0	-1,0	0,0	-1,2	
Factor I.3.2. Potential displacement of shipping routes			-1,0							-1,0	0,0		-2,0	-2,0		-2,0	-1,0		-1,3	
Average	**0,0**	**-3,0**	**-1,0**	**-2,0**	-2,0	-1,0	-2,0	-1,0	-1,0	-0,5	0,0	-1,0	-2,0	-1,5	-2,0	-2,0	-1,0	0,0		-1,3

Combination: Tidal development & Environmental monitoring	Interviewee 1 Score	Interviewee 2 Score	Interviewee 3 Score	Interviewee 4 Score	Interviewee 5 Score	Interviewee 6 Score	Interviewee 7 Score	Interviewee 8 Score	Interviewee 9 Score	Interviewee 10 Score	Interviewee 11 Score	Interviewee 12 Score	Interviewee 13 Score	Interviewee 14 Score	Interviewee 15 Score	Interviewee 16 Score	Interviewee 17 Score	Interviewee 18 Score	Factor average for all stakeholders	Category average (average of all factors averaged for all stakeholders)
DRIVERS																				
Category D.4 - Relation with other uses																				
Factor D.4.1. Promotion of an ecosystem based approach to the planning and management of tidal energy implementation to support the achievement of Good Environmental Status of marine and coastal waters under the Marine Strategy Framework Directive (MSFD)	2,0	3,0	3,0	1,0	3,0	2,0	2,0	2,0	3,0			3,0	2,0	1,0	1,0	2,0	1,0	2,0	2,3	
Factor D.4.2. Necessity to build upon knowledge gaps pertaining to environmental interactions in relation to tidal energy development	3,0	3,0	2,0	3,0	3,0	3,0	2,0	2,0	3,0	3,0	2,0	3,0	3,0	2,0	2,0	3,0	3,0	3,0	2,7	
Average	**2,5**	**3,0**	**2,5**	**2,0**	3,0	2,5	2,0	2,0	3,0	3,0	2,0	3,0	2,5	1,5	1,5	2,5	2,0	2,5		2,5
Category D.2 - Economic drivers																				
Factor D.3.2. Promotion of investment in the tidal energy sector to sustainably maximize the economic benefits of the growth of the tidal energy sector	2,0	3,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	3,0	3,0	3,0	2,0	2,0	1,0	2,0	2,0	1,0	2,1	
Average	**2,0**	**3,0**	**2,0**	**2,0**	2,0	2,0	2,0	2,0	2,0	3,0	3,0	3,0	2,0	2,0	1,0	2,0	2,0	1,0		2,1
Category D.5 - Ecological drivers																				
Factor D.5.1. Adherence to the protection of legislated Special Protected Areas (SPAs) and Special Areas of Conservation (SACs) under the Natura 2000 programme	2,0	2,0	3,0	2,0	3,0	3,0	3,0	2,0	3,0	3,0	2,0	3,0	3,0	3,0	2,0	3,0	3,0	3,0	2,6	
Factor D.5.2. Adherence to the Marine Spatial Planning EU Directive 2014/89/EU which aims to promote sustainable development of marine environment and sustainable use of marine resources	2,0	3,0	3,0	2,0	2,0	2,0	2,0	2,0	2,0	3,0		3,0	1,0	1,0	3,0	2,0	2,0	1,0	2,3	
Factor D.5.3. To provide for clean, healthy, safe, productive and biologically diverse oceans and seas in accordance to the UK Marine Policy Statement	3,0	2,0	2,0	2,0	1,0	1,0	2,0	2,0	2,0			2,0	1,0		NK	2,0	2,0	1,0	1,9	
Factor D.5.4. Development of an appropriate management and regulatory framework to sustainably manage salmon and diadromous fish and fisheries resources in order to provide significant economic and social benefits for the people of Scotland in conformity with Wild Salmon and Diadromous Fish sectoral objective 1 within the Scottish National Marine Plan	3,0	2,0	2,0	3,0	0,0	2,0	3,0	2,0	3,0			1,0							2,1	
Average	**2,5**	**2,3**	**2,5**	**2,3**	1,5	2,0	2,5	2,0	2,5	3,0	2,0	2,3	1,7	2,0	2,5	2,3	2,3	1,7		2,2
Category D.6 - Technological drivers																				
Factor D.6.1. To assist Scotland in becoming a world leader in technological innovation			3,0							3,0	3,0						2,0		2,8	
Average			**3,0**							3,0	3,0						2,0			2,8

	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6	Interviewee 7	Interviewee 8	Interviewee 9	Interviewee 10	Interviewee 11	Interviewee 12	Interviewee 13	Interviewee 14	Interviewee 15	Interviewee 16	Interviewee 17	Interviewee 18		
Combination: Tidal development & Environmental monitoring	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Factor average for all stakeholders**	**Category average (average of all factors averaged for all stakeholders)**
BARRIERS																				
Category B.2 - Administrative barriers																				
Factor B.2.2. Staggered MU may initiate complex licensing procedures where existing uses that are not licensable will take priority and inhibit the deployment of tidal current turbines (TCTs), and therefore the ability to undertake environmental monitoring which would further develop the knowledge base needed to further the industry	-2,0	-3,0	-2,0	-1,0	-1,0	-1,0	-3,0	-3,0	-2,0			-2,0	0,0		-2,0	-2,0	-1,0	-1,0	-1,7	
Average	**-2,0**	**-3,0**	**-2,0**	**-1,0**	-1,0	-1,0	-3,0	-3,0	-2,0			-2,0	0,0		-2,0	-2,0	-1,0	-1,0		-1,7

	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5	Interviewee 6	Interviewee 7	Interviewee 8	Interviewee 9	Interviewee 10	Interviewee 11	Interviewee 12	Interviewee 13	Interviewee 14	Interviewee 15	Interviewee 16	Interviewee 17	Interviewee 18		
Combination: Tidal development & Environmental monitoring	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Factor average for all stakeholders**	**Category average (average of all factors averaged for all stakeholders)**
ADDED VALUES																				
Category V.1 - Economic added values																				
Factor V.1.2. Reduction in scientific uncertainty prompting an enhancement in private investment	2,0	3,0	2,0	2,0	2,0	3,0	2,0	3,0	2,0	3,0	2,0	2,0	0,0	2,0	NK	2,0	3,0	2,0	2,2	
Factor V.1.3. Provision of shared operational and maintainance infrastructure including vessels which lower lifecycle costs	3,0	2,0	2,0	2,0	1,0	2,0	2,0	2,0	3,0	3,0	2,0	2,0	0,0	2,0	0,0	1,0	1,0	1,0	1,7	
Average	**2,5**	**2,5**	**2,0**	**2,0**	1,5	2,5	2,0	2,5	2,5	3,0	2,0	2,0	0,0	2,0	0,0	1,5	2,0	1,5		1,9
Category V.2 - Societal added values																				
Factor V.2.3. Increased knowledge base on tidal energy development and environmental interactions which will further facilitate the dissemination of information to the public, thereby educating the public on real as about to perceived interactions which may improve public opinion and support for tidal energy deployment	3,0	3,0	3,0	1,0	1,0	3,0	1,0	2,0	2,0	2,0	2,0	3,0	3,0	2,0		2,0	3,0	1,0	2,2	
Average	**3,0**	**3,0**	**3,0**	**1,0**	1,0	3,0	1,0	2,0	2,0	2,0	2,0	3,0	3,0	2,0		2,0	3,0	1,0		2,2
Category V.3 - Environmental added values																				
Factor V.3.4. Contribution of monitoring data retrieved from tidal energy deployments towards marine protected and conservation area management	3,0	2,0	3,0	3,0	3,0	2,0	2,0	2,0	3,0	3,0	2,0	3,0	3,0	3,0	2,0	2,0	3,0	3,0	2,6	
Average	**3,0**	**2,0**	**3,0**	**3,0**	3,0	2,0	2,0	2,0	3,0	3,0	2,0	3,0	3,0	3,0	2,0	2,0	3,0	3,0		2,6
Category V.4 - Better ensurance policy and risk management																				
Factor V.4.1. Further inform risk criteria thereby contributing to standardized, streamlined licensing and monitoring procedures	1,0	3,0	2,0	2,0	2,0	3,0	2,0	2,0	3,0	3,0	2,0	3,0	3,0	2,0	2,0	2,0	2,0	2,0	2,3	
Average	**1,0**	**3,0**	**2,0**	**2,0**	2,0	3,0	2,0	2,0	3,0	3,0	2,0	3,0	3,0	2,0	2,0	2,0	2,0	2,0		2,3
Category V.5 - Technical added values																				
Factor V.5.1. Increased knowledge base on the operational characteristics of tidal energy technologies thereby proliferating the progression of the technology readiness level of turbines which allows for further uptake of technologies and industry maturity	2,0	3,0	3,0	3,0	3,0	2,0	1,0	3,0	3,0	3,0	2,0	2,0	3,0	3,0	2,0	2,0	2,0	1,0	2,4	
Factor V.5.2. Further residual capacity building for energy storage systems in order to provide baseload power given the predictable nature of tidal energy	0,0	1,0		0,0	0,0	0,0	2,0	1,0	2,0										0,8	
Factor V.5.3. Increased knowledge base on the operational characteristics of environmental monitoring equipment can lead to technology learning rates for such equipment, thereby leading to a decrease in cost of procuring monitoring equipment	3,0	2,0	2,0	1,0	2,0	3,0			3,0	2,0	2,0	1,0	1,0	3,0	1,0	2,0	2,0	1,0	1,9	
Average	**1,7**	**2,0**	**2,5**	**1,3**	1,7	1,7	1,5	2,0	2,7	2,5	2,0	1,5	2,0	3,0	1,5	2,0	2,0	1,0		1,9
Category V.6 - Added values to industry																				
Factor V.6.1.Increased knowledge base of environmental sensitivity to and environmental interactions with tidal energy deployment	3,0	3,0	2,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	2,0	3,0	3,0	3,0	2,0	3,0	3,0	3,0	2,8	
Factor V.6.2. Dissemination of information on tidal energy interactions with the environment to the general public can help secure community buy-in and therefore potentially streamline the uptake of tidal energy technology	3,0	3,0	3,0	3,0	2,0	3,0			1,0	2,0	2,0	2,0	3,0	2,0	1,0	3,0	3,0	2,0	2,4	
Average	**3,0**	**3,0**	**2,5**	**3,0**	2,5	3,0	3,0	3,0	2,0	2,5	2,0	2,5	3,0	2,5	1,5	3,0	3,0	2,5		2,6