Interreg North-West Europe FORESEA
European Regional Development Fund

FORESEA'S

INFRASTRUCTURE PLAN

Deliverable DT2.3.1

Abstract

This deliverable reports on the review of the existing infrastructures across the North West Europe area within a global context. The outcomes are benchmarked against the future requirements of the industry to inform a future investment plan to maintain the NWE leading position in marine renewables.

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1. Introduction

The present deliverable is a long term outcome of the European project called FORESEA, funded by Interreg NWE, which gathers four marine testing facilities: ECN-SEMREV (France), EMEC (Scotland), Smartbay (Ireland) and DMEC (Netherlands). The facilities are supported by industry body Ocean Energy Europe. The FORESEA project encourages long term testing and low-carbon technology de-risking. It will result in a minimum of 26 Ocean Energy (OE) technology pre-commercial demonstrations, over 60,000 hrs of operation, work with over 60 SME's, sustaining 60+ jobs and helping to secure at least €30M or more of investment into OE companies.

The FORESEA project will also enhance the expertise and infrastructure in NWE and put in place a NWE OE Roadmap to ensure the long term impact of this project. For this purpose, a benchmark of the existing infrastructure and the future needs of the ocean energy industry was required.

A review was undertaken of the existing infrastructure across the partnership within a global context. This has been benchmarked against the future requirements of industry to inform a future investment plan to maintain the NWE leading position.

The development of an investment plan for the NWE area which will cover floating wind, wave and tidal stream energy, will be achieved in a third deliverable. This investment plan will seek to deliver the funds required to realise the skills and infrastructure plans.

In order to ensure a complete transparency, Ecole Centrale de Nantes (ECN) has commissioned Cruz Atcheson Consulting Engineers Lda. (CA) to conduct a comparative study of the offshore marine renewable energy (MRE) test sites within the framework of the FORESEA project. In the present context, MRE technologies include wave energy converters (WECs), tidal energy converters (TECs) and floating wind turbines (FWTs).

The scope of work involved a review of profile of the open-ocean test sites, with a focus on the North-West Europe region, leading to strategic recommendations regarding the positioning of the FORESEA test sites.

The CA approach was based on a 3C's model (Customers, Capabilities and Competitors, see the schematic below) and the coupling of these factors to assess the market position that best suits all the key attributes and constraints. A series of strategic recommendations which aim to help the FORESEA test sites to position themselves within the market place is presented, informing future decisions on how best to support the development of the FORESEA test sites infrastructure.

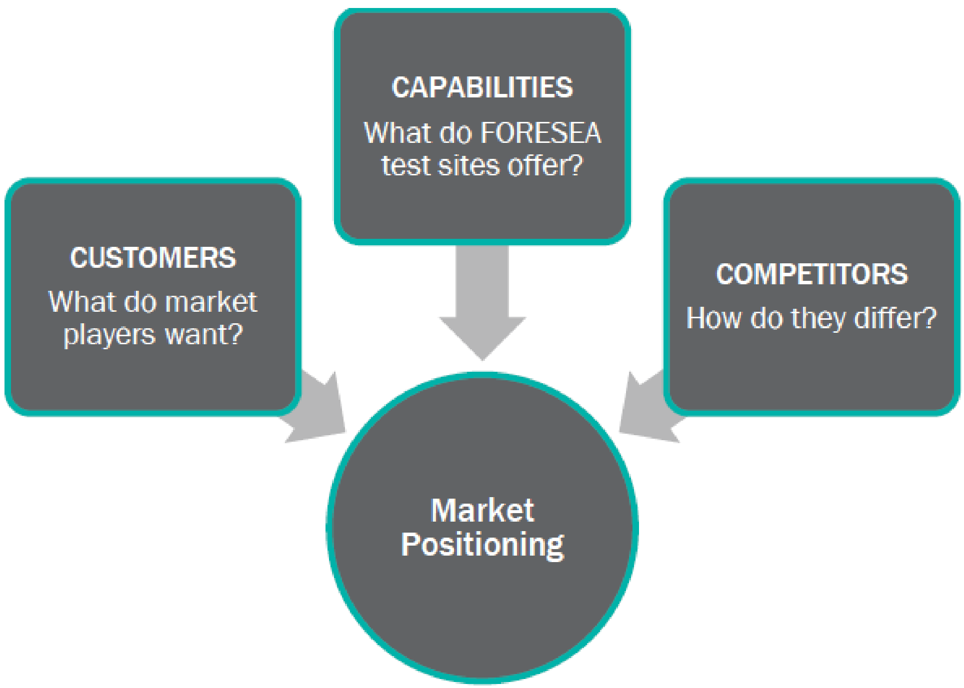

Figure 1-1 Outline structure of the CA approach to the market positioning of the FORESEA test sites

This report is organised in five main sections: following this introduction (Section 1), a review of the capabilities of the FORESEA test sites, in terms of the available / planned infrastructure, is provided in Section 2. The main competitors to the FORESEA test sites are then reviewed in Section 3. Following industry consultation activities, a characterisation of the potential customers of the FORESEA test sites is detailed in Section 4. Finally, the report is concluded in Section 5 with a high-level gap analysis of the FORESEA test sites' offer, including a proposed segmentation of the customer base and strategic recommendations for the positioning of the FORESEA test sites.

The appendix of the present report contains the comprehensive results of CA's benchmarking analysis.

A similar benchmarking exercise focusing on the competencies and services aspects was conducted in parallel, following a similar methodology and using the same consultation activities. The results are presented in the DT2.3.2 FORESEA deliverable.

2. Capabilities – Current test site infrastructure (FORESEA test sites)

The first factor in the 3C model is related to an analysis of the *Capabilities* of the FORESEA test sites: SEM-REV (Nantes, France), the European Marine Energy Centre, EMEC (Orkney, UK), SmartBay (Galway, Ireland) and the Dutch Marine Energy Centre, DMEC (Alkmaar, Netherlands). The objective of such review is to gain a detailed understanding of the range of the offer proposed by the FORESEA test sites in terms of the available / planned infrastructure. The purpose of such analysis is two-fold: firstly, to map the current capabilities in order to more readily recognise gaps in the current offer; and secondly to identify potential niches which FORESEA test sites can uniquely fill to meet the market requirements.

To gain a deeper understanding of the current capabilities of the FORESEA test sites, an online consultation exercise targeting the four members of the FORESEA consortium was conducted aiming to address the key attributes as identified at first. The survey was created with the objective of providing a more detailed overview of the test sites' available and planned infrastructure, and addressed aspects such as:

- General Characteristics
  - Status
  - Type of technology targeted
  - Scale targeted
  - Expansion strategy

- Grid Connection
  - Existence of an export cable
  - Rated capacity
  - Existence of connection points

- Onshore Features
  - Proximity to port / shipyard
  - Capacity of workshop / quayside storage facility
  - Housing of personnel
  - Characteristics of land access

  - Proximity to airport

- Offshore Features
  - Availability of support vessels
  - Existence of pre-installed moorings
  - Soil type
  - Availability of metocean data measurement equipment

The key outcomes in terms of infrastructure are summarised in the table below.

Table 2-1 Summary Information for the FORESEA test sites: infrastructure and other key features

Category	Evaluation Criteria	SEM-REV	EMEC	SmartBay	DMEC
Test Site General Characteristics	Status	Operational since 2009, devices have been deployed	Operational since 2003, devices have been deployed	Operational since 2006, devices have been deployed	Operational since 2008 / 2015, devices have been deployed
	Type of technology	WEC, FWT, subcomponents	WEC, TEC, subcomponents	WEC, FWT	TEC
	Target scale	Full-scale	Scaled and full-scale	Intermediate scale	Intermediate and full-scale
	Expansion strategy	Expansion to 8-10MW planned for 2020	Expansion to / for more 26MW in 2022; offsite testing, use of hydrogen and battery storage and additional lease areas	Not planned	Expansion to commercial scale planned at the Marsdiep site.
Grid Connection	Export cable	Existing	Existing	Not planned	Existing
	Rated capacity	Substation capacity is 4MW	5MW per berth; Total substation capacity 35MW	N/A	200kVA (Marsdiep), 160kVA (Den Oever)
	Connection points	3	13	3 berths, not grid connected	2
Onshore Features	Proximity to port/shipyard	Nearest port 20km Major port 40km	Nearest port less than 10km, major less than 50km	Nearest port less than 10km Major port 20km	Nearest port less than 10km
	Storage facilities	Through local supply chain	Available	Through local supply chain	Not planned
	Housing of personnel	Yes	Yes	Planned (next 5 years)	No
	Characteristics of land access	Highway serving Nantes, TGV serving Le Croisic	Via Ro-ro ferry	Motorway serving Galway	National roads serving Alkmaar
	Proximity to airport	Medium (90km)	Close (< 50km)	Close (< 50km)	Close (< 50km)
Offshore Features	Support vessels	Through local supply chain	Through local supply chain	Through local supply chain	Not planned
	Pre-installed moorings	Planned - Pre-installed anchor points available	Available on scale sites	Not planned	Available
	Soil type	Sand	Sand and rock/boulders	Sand with some silt	Sand
	Measurement equipment	2 DWR MKIII, 2 ADCP, 1 met station	3 Waveriders, met stations, ADCPs, marine radar	Waverider; met station; ADCP, CTD, turbidity, hydrophone	Met station and ADCP
	Communication to shore	Fibre optics as base case + back-up solution (HF, 4G, satellite)	Fibre on all full-scale sites, microwave on scale sites, VHF link available	Fibre optic cable to shore + Wireless communications	Wireless

3. Competition – Current infrastructures of open-ocean test sites outside FORESEA

A high-level review of the infrastructure available in test sites outside the FORESEA programme was also conducted, based on the analysis of public-domain data. Test sites suitable for the testing of floating wind turbines, tidal and wave energy technologies were assessed. The purpose of such analysis is two-fold: firstly, to provide case studies from which the FORESEA test sites can gain market insights, and secondly to identify potential niches which FORESEA test sites can uniquely fill.

The competitors identified in a first phase, including both operational and planned offshore test facilities suited for MRE technology deployment, were analysed.

The key findings of this review are presented in this report by the following order of importance and level of detail:

- Level 2: North / West Europe test sites (excluding Level 1 FORESEA sites)
- Level 3: Other sites worldwide

For the Level 2 test sites, the desktop review was guided by the key attributes of interest identified, and covered the following test facilities:

- Wave Hub, Cornwall, UK
- FabTest, Falmouth, UK
- Atlantic Marine Energy Test Site (AMETS), Ireland
- Biscay Marine Energy Platform (BiMEP), Spain
- Plataforma Oceanica de Canaria (PLOCAN), Spain
- Ocean Plug, Portugal
- Rundee Environmental Centre (REC), Norway
- Danish Wave Energy Centre (DanWEC), Denmark

The outcomes of the review are presented in the summary table (see next page), which gathers the main features of each test site to facilitate comparison.

Table 3-1 Summary information for the Level 2 test sites: infrastructure and other key features (Part 1/2)

Category	Criteria	Wave Hub	FaBTest	AMETS	BiMEP
Test Site General Characteristics	Status	Operational, devices have been deployed	Operational, devices have been deployed	Planned	Operational, devices have been deployed
	Type of technology	WEC and FWT	WEC, TEC	WEC	WEC
	Type of scale targeted	Full-scale	Nursery	Full-scale	Full-scale
	Expansion strategy	Potential to upgrade to 48MW	Possible expansion to FWT	Possible expansion to shallow depths / other technologies	Possible expansion to FWT / up to 50MW by 2020
Grid Connection	Export cable	Installed	Not planned	Planned	Installed
	Rated capacity	30MW (existing)	N/A	Planned - 4 cables @ 11 kV. 10MW	4x5 MW cables @ 13.2kV
	Connection points	4	3	4 (planned)	4
Onshore Features	Proximity to port/shipyard	16km off the coast of Hayle Over 100km from Falmouth	Up to 5km from Falmouth	Frenchport Pier	2km from Armintza harbour 15km from Bilbao port
	Storage facilities (warehouse/quayside)	Large capacity, available in Falmouth	Large capacity, available in Falmouth	Unknown	Large capacity, available in Armintza and Bilbao ports
	Housing of personnel	No	No	No	No
	Characteristics of land access	Train line and motorways / A roads serving Hayle	Train line and motorways / A roads serving Hayle	Unknown	Highway serving Armintza
	Proximity to airport	Bristol airport >250km	Bristol airport >250km	Far (>100km)	15km from Bilbao airport
Offshore Features	Support vessels	Available through the local supply chain	Available through the local supply chain	Unknown	Outsourced
	Pre-installed moorings	Not planned	No	No	No
	Soil type	Areas of outcropping bedrock and gravelly sand	Rock, gravel and sand seabed	Sand close to shore with rock further out	Rock and sand
	Measurement equipment	Installed 22 May 2015 is a Datawell Directional Waverider DWR-MkIII	Oceanor Seawatch Mini II wave, Datawell Waverider Mk3, ADCPs	Directional Waverider + Metocean buoy	Oceanor Wavescan buoy
	Communication to shore	12 optic fibres	UMTS (3G) and LTE (4G) services with HSDPA / HSUPA	Unknown	Radio and / or satellite communication

Table 3-2 Summary information for the Level 2 test sites: infrastructure and other key features (Part 2/2)

Category	Criteria	PLOCAN	Ocean Plug	Runde Environment Centre	DanWEC
Test Site General Characteristics	Status	Operational, devices have been deployed	Planned	Operational, devices have been deployed	Operational, devices have been deployed
	Type of technology	FWT, WEC, others	FWT, WEC	WEC	WEC
	Type of scale targeted	Nursery scale or 'benign' testing of larger scale devices	Full-scale	Intermediate / Full-scale	Intermediate / small scale prototypes
	Expansion strategy	Expansion planned up to 50MW by 2020	Planned	No	Planned
Grid Connection	Export cable	Planned	Planned	Installed	Planned
	Rated capacity	Initial capacity is set up at 15MW	4 connection points of 3MW for test area	0.5MW	Unknown
	Connection points	2	4	Unknown	Unknown
Onshore Features	Proximity to port/shipyard	1.5km off the coast – support base: Las Palmas	Figueira da Foz 35km; Peniche 92km	400m from Runde Port	2-4km from the Port of Hanstholm
	Capacity of storage facility	Small capacity, available on platform	Large capacity, available in Figueira da Foz	No	Large capacity, available at Hanstholm Port
	Housing of personnel	Yes	No	Yes	Yes
	Characteristics of land access	Access by boat or heliport	National roads serving S. Pedro de Moel	Accessible by boat or car	National road and train
	Proximity to airport	International airport in Las Palmas (<10km)	60km from Lisbon	Ørsta-Volda airport (c. 50km); Ålesund airport (c. 100km)	About 100km to Aalborg airport
Offshore Features	Support vessels	Available	Unknown	No	Available
	Pre-installed moorings	No	No	No	Unknown
	Soil type	Predominant sand and rocks	Sand	Sandy with bedrock / cobbled areas	Sand and silt, with some areas of exposed chalk
	Measurement equipments	Waverider until January 2014, replaced by Triaxys directional	One multi-parameter buoy	Wave measuring buoy	2 Waverider buoys
	Comm. to shore	N/A	Unknown	Unknown	WiFi and fibre

For the Level 3 test sites, the review was conducted at a higher-level, as only limited information is available. The assessment of the infrastructure available and planned was based on the analysis of public-domain data, for the following countries and test sites:

- U.S:
    - Pacific Marine Energy Center (PMEC)
    - California Wave Energy Center (CalWave)
    - Hawaii National Marine Renewable Energy Test Center (HINMREC)
- New Zealand: New Zealand Marine Energy Center (NZMEC)
- Japan: Nagasaki Marine Industry Cluster Promotion Association (NaMICPA)
- China

Most of these sites have recently been announced and are only planned for development. Although the level of information available on these sites is in such cases limited, the summary tables below aim to facilitate the comparison of the status and readiness of the different test sites reviewed.

Table 3-3 Summary information for the Level 3 test sites: infrastructure and other key features (Part 1/2)

Category	Criteria	PMEC	CalWave	WETS
Test Site General Characteristics	Status	NETS, Puget Sound, TRTS: Operational; SETS: Planned since 2014	Planned since 2013	Operational since 2003
	Type of technology	NETS, SETS, Puget Sound: WEC; TRTS: TEC	WEC	WEC
	Type of scale targeted	Intermediate and full-scale	Full-scale	Full-scale
	Expansion strategy	SETS: Grid connected, full scale site under development	-	Expansion planned to deeper depths (60m and 80m) with rated capacities of 100kW and 1MW, respectively
Grid Connection	Export cable	Planned at PMEC-SETS	Planned	Existing
	Rated capacity	NETS: Up to 100kW; SETS: Planned for up to 20MW	Cables rated at 10MW/ 25kV; VAFB substation rated at 70kV	250kW
	Connection points	NETS: 1; SETS: 4 planned	4	3
Onshore Features	Proximity to port/shipyard	NETS, SETS: 5km to Newport, Oregon	10km offshore of VAFB; 130km from deep water harbour Port Hueneme	About 2km from Kaneohe Between 50-100km from Pearl Harbor
	Capacity of storage facility	NETS, SETS: Large facilities operated by Port of Newport	Very large vessels, large cranes and dockside storage facilities at Port Hueneme	Storage waterside at Marine Corps Base; Large warehouse / quayside capabilities at Pearl Harbor
	Soil type	Sand	Sand, with rocky outcroppings	Combination of rock, sand, and coral
	Measurement equipment	Triaxys buoy since 2014	2 met-ocean buoys 4 meteorological stations	3 Waverider buoys, 1 ADCP

Table 3-4 Summary information for the Level 3 test sites: infrastructure and other key features (Part 2/2)

Category	Criteria	NZMEC	JMEC	China
Test Site General Characteristics	Status	Planned since 2015	Planned since 2015	Planned since 2015
	Type of technology	WEC, TEC	FWT, TEC	TEC, WEC
	Type of scale targeted	Nursery, intermediate, full-scale	Full-scale	Intermediate, full-scale

4. Customers – Industry test site infrastrucutre requirements

A third aspect influencing the positioning of the FORESEA test sites is the dominant features of their potential customers. Having assessed both the capabilities and the competitors of the FORESEA test sites, it is key to accurately profile the potential customers, identifying and where possible predicting their current and future needs.

The stakeholder consultation is also presented in DT2.3.2, to facilitate its reading. The key findings of the consultation that focus on infrastructure requirements are summarised in the table 4-1.

A stakeholder consultation exercise was completed to ascertain the particular requirements and interests of potential users of open-ocean test sites for MRE technologies. The potential customers targeted included technology, project and component developers identified as being likely to invest in or conduct an ocean deployment. The topics covered in the survey focused on technologies and subcomponents for wave, tidal and floating wind energy sectors, and included:

- An overview of the respondent’s technology and testing status
- Information regarding a respondent’s future short to long term testing plan.
- General requirements regarding the ideal infrastructure of a test site (e.g.: grid connection, onshore and offshore features).
- General requirements regarding the services provided by a test site (e.g.: consenting status of the site, connection to the supply chain, areas of support).

The stakeholder survey was disseminated via the following methods:

- Based on the list of targeted entities identified in a first phase, 96 selected entities were contacted via email by CA on behalf on ECN with a direct invitation to participate in the survey. A flyer outlining the project background and aims, including a link to the online survey, was provided in attachment to the invitation emails. The flyer was drafted by CA and circulated to ECN for approval.

- Public advertisement of the consultation, with a link to the survey, was issued on various media platforms, including LinkedIn, Interreg North-West Europe FORESEA website and Tidal Energy Today.
- A flyer containing a link to the survey was distributed during the Ocean Energy Europe conference held in Nantes (24th to 26th of October 2017).

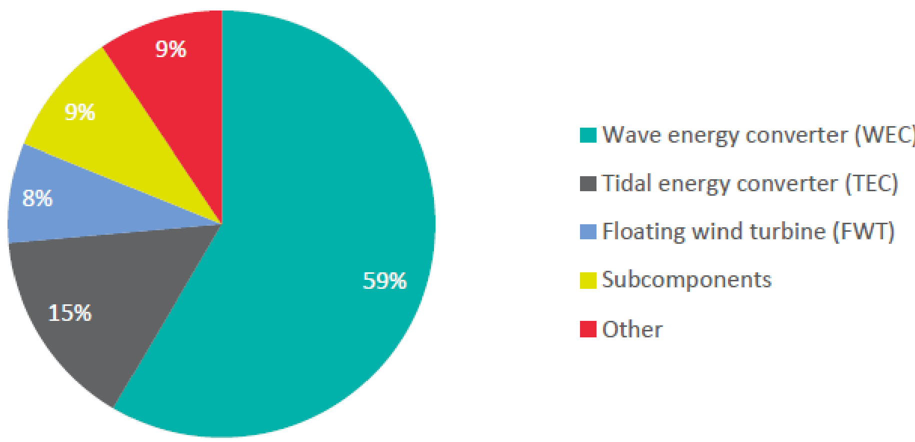

Figure 4-1 Responses to the FORESEA consultation: type of technology breakdown

At the time of the survey closure, a total of 53 responses had been received. Overall, it was found that:

- The majority of the respondents were WEC developers (60%), followed by tidal developers (approximately 15%), subcomponent developers (9%), floating wind developers (approximately 8%) and others (9%), which includes e.g. OTEC, floating solar, etc.
- From all the respondents, 25% consider themselves to be in a low TRL (1 to 3), while over 45% believe they are at an intermediate TRL level (4 to 6).
- Approximately 50% of all respondents have spent less than €5m to date in their development programmes.
- In terms of past open-ocean testing activities:
    - Despite the early-stage nature, over 50% of the WEC respondents have confirmed to have completed an open-ocean testing in the past. From the replies to an adjacent question, CA understands that the majority of such

  - deployments occurred in nursery / sheltered locations, as well as intermediate scale test sites.
  - There is wider experience from TEC developers in past, current and planned deployments, particularly at full-scale.
  - Past open-ocean deployments have taken place at full-scale already for FWT developers.
  - The subcomponent respondents do not exhibit any previous or current experience in open-ocean testing.
- In terms of an interest in using open-ocean test facilities:
  - All WEC respondents confirmed their interest
  - The majority of TEC respondents showed an interest in open-ocean test sites, although the consensus is not as unanimous as in the wave energy case (reference to site ownership is made in the situations were no interest is declared).
  - The FWT respondents did mark an interest in open-ocean test sites.
  - Future deployments for subcomponent technologies are planned and a strong interest in using open-ocean test facilities is clear.

Finally, the following table summarises the key outcomes regarding the future needs and requirements of the potential open-ocean test sites' customers (based on customer survey responses).

Table 4-1 Summary of the customer requirements for open-ocean test site infrastructure (based on customer survey responses)

Category	Criteria	Customer Requirements
Test Site General Characteristics	Status	Operational: More than 50% of the respondents are planning to deploy next year.
	Type of technology	60% of the respondents are WEC developers 15% are TEC developers 9% are subcomponents developers 8% are floating wind developers 8% are categorised as '*other*'
	Type of scale targeted	Nursery and intermediate scale sites are important in a short-term horizon, but grid connected full-scale sites become important within a 10-year timeframe.
Grid Connection	Export cable	Must-have: About 70% of the respondents stated that grid connection was a critical factor for their deployment.
	Rated capacity	Nice-to-have: Available capacity was ranked as '*very important*' by less than 40% of the respondents.
Onshore Features	Proximity to port/shipyard	Must-have: Proximity to a port is a key concern for more than 65% of the respondents and ranks second in developer's priorities.
	Characteristics of land access /Proximity to airport	Nice-to-have: About 50% of the respondents consider the onshore accessibility as an interesting factor.
Offshore Features	Support vessels	Must-have: The availability of support vessels stands out as the key priority for the developers, with more than 70% qualifying the factor as '*very important*'.
	Pre-installed moorings	Not important: Availability of pre-installed anchor points and moorings are the least important infrastructure requirement for the developers, with the largest proportions of '*not important*' responses (35% and 20%, respectively).
	Measurement equipment	Nice-to-have: Availability of real-time resource measurements is mostly important for low TRL developers. Overall, more than 50% of the respondents ranked it as '*very important*'.
	Communication to shore	Must-have: Communication cables is the third priority of the developers with more than 60% qualifying the factor as '*very important*'.

5. Provision of strategic recommandations

Having assessed the Capabilities (Section 2), the Competitors (Section 3) and the dominant requirements of potential Customers of the FORESEA test sites (Section 4), the 3C factors can be combined to inform the market positioning of the FORESEA test sites and to issue recommendations on strategies for the development of additional competencies, services and infrastructure. To this objective, CA followed a three-step approach:

- Firstly, and using the capabilities and customer consultation findings, a high-level gap analysis of the FORESEA test sites' offering was conducted (see Section 5.1).
- Secondly, the current positioning of the reviewed test sites was characterised in the form of a perceptual map, in an effort to identify areas where the FORESEA test sites could contribute significantly with their capabilities (see Section 5.2).
- Thirdly, the findings of the customer consultation were condensed in a customer segmentation exercise, defining multiple customer segments that's, in CA's opinion, condition the FORESEA test sites' value proposition (see Section 5.3).

The purpose of such analysis is twofold: firstly, to recognise gaps in the current offer; and secondly, to identify potential niches which FORESEA test sites can uniquely fill to meet the market requirements. Ultimately, the analysis is expected to contribute to the creation of strategies for the development of the test sites.

5.1 FORESEA Test Sites and the Customer Requirements

Using the sector review data gathered from the two consultations exercises, a qualitative assessment of the main gaps between the test site capabilities (analysed in Section 2) and the customers' requirements (analysed in Section 4), in terms of infrastructure was conducted. The findings of the assessment are summarised in Table 5-1, using a traffic-light system based on the evaluation criteria detailed in Section 2. In such colour scale, red indicates a potential weakness whereas green indicates a strong feature and good alignment with the customer requirements. Such visual presentation aims at easily identifying key areas of priority development and to contribute to the formulation of strategic recommendations to position the FORESEA test sites.

Table 5-1 presents the high-level gap analysis with a core focus on the test sites’ infrastructure. A similar overview focusing on the current services is presented in DT2.3.2.

In terms of infrastructure, a key item to consider is the strong desire from the customers to ultimately connect their device to the grid, in an approximate 10-year timeframe. Grid connection is therefore a critical aspect to consider for the test sites to meet the future customers’ requirements. Proximity to a shipyard is also a key concern for the customers and availability of support vessels, with more than 65% respondents qualifying the factors as ‘very important’. Such items should be seen as key areas of priority development.

Table 5-1 presents the high-level gap analysis with a core focus on the test sites' infrastructure

Category	Criteria	SEM-REV	EMEC	SmartBay	DMEC	Customer requirements
Test Site General Characteristics	Status	Operational	Operational	Operational	Operational	Operational: More than 50% of the respondents are planning to deploy next year
	Type of Technology	WEC, FOWT, subcomponents	WEC, TEC, sub-components	WEC, FOWT	TEC	60% of the respondents are WEC developers, 15% are TEC developers, 9% are subcomponents developers, 8% are floating offshore wind developers, 8% are categorised as '*other*'
	Type of scale targeted	Full-scale	Intermediate + full-scale	Intermediate scale	Intermediate and full-scale	Nursery and intermediate scale sites are important in a short-term horizon, but grid connected full-scale sites become important within a 10-year timeframe.
Grid connection	Export cable	Existing	Existing	Not planned	Existing	Must-have: About 70% of the respondents stated that grid connection was a critical factor for their deployment
	Rated Capacity	Medium (5MW - 50MW)	Medium (5MW - 50MW)	N/A	Medium (5MW - 50MW)	Nice-to-have: Available capacity was ranked as '*very important*' by less than 40% of the respondents.
Onshore features	Proximity to port/shipyard	Medium (<100km)	Close (<10km)	Close (<10km)	Close (<10km)	Must-have: Proximity to a port is a key concern for more than 65% of the respondents and ranks second in their priorities.
	Characteristics of land access	Easy	Remote	Easy	Easy	Nice-to-have: About 50% of the respondents consider the onshore accessibility as an interesting factor.
	Proximity to airport	Medium (<100km)	Close (<50km	Far (>100km)	Close (<50km)	
Offshore features	Support vessels	Through local supply chain	Through local supply chain	Through local supply chain	Not planned	Must-have: The availability of support vessels stands out as the key priority for the developers, with more than 70% qualifying the factor as '*very important*'.
	Pre-installed moorings	Planned	Available on scale sites	Not planned	Available	Not important: Availability of pre-installed anchor points and moorings are the least important infrastructure requirement for the developers, with the largest proportions of '*not important*' responses (35% and 20%, respectively).
	Measurement equipment	Available	Available	Available	Available	Nice-to-have: Availability of real-time resource measurements is mostly important for low TRL developers. Overall, more than 50% of the respondents ranked it as '*very important*'.
	Communication to shore	High level of redundancy	High level of redundancy	High level of redundancy	Wireless	Must-have: Communication cables is the third priority of the developers with c.60% qualifying the factor as '*very important*'.

5.2 FORESEA Test Sites and the Competition

By coupling the capabilities of the FORESEA test sites (Section 2) with the sector review data gathered from the competition analysis (Section 3) and CA's judgment / experience, the key findings can be condensed in a perceptual map to illustrate the current positioning of the test sites with regard to the level infrastructure and competencies.

Following the results of the customer survey (Section 4), two key dimensions were identified to ranks the reviewed test sites: target testing scale and tolerance to risk.

- The first proposed dimension (target testing scale) can be used to evaluate the capability of the test site to support small to large scale deployments. It can be related to e.g. the availability of grid connection and the availability of specific services, as customers at late development stages may focus on long-term, grid connected full-scale deployments, whereas early stage developers seek R&D and engineering support.
- The second proposed dimension (tolerance to risk) aims to assess the capability of the test sites to host innovative technologies and / or attract less risk tolerant developers. The willingness to host particular technologies can be related in part to the availability of R&D / funding programmes and policy support to encourage innovative technology and early stage deployments, whereas e.g. development support services can be perceived by developers as a desire to follow industry best practices and used to reduce / transfer risk responsibility.

The resulting map of the test sites is presented in Figure 5-1. The size of the circles is proportional to the average level of support and level of infrastructure of each reviewed test site. In particular, the smaller circles correspond to the test sites under planning (marked with a dotted pattern) or less experienced test sites, where only limited data is available. The FORESEA test sites are highlighted in green, whilst the Level 2 test sites are represented in red.

To select the site's position on the perceptual map, key features were selected as representatives of each axis. Using the summary tables, marks between 1 and 9 were associated with each key feature for each site, and the average on each axis was estimated to give the site's position. The horizontal axis positions the test sites with regard to their capability to support small / early stage to large scale deployments. It considers the scale targeted, the capacity of the grid connection, the expansion planned and the support to engineering and R&D. The vertical axis positions the test sites with regards to the capability to host innovative vs. less risk tolerant developers. It considers the test site's experience, development support, connection to funding programmes and policy support.

Overall, the following observations are, in CA's opinion, relevant:

- SEM-REV, as a full-scale grid connected test site, is well suited for technology deployments of more experienced developers ready to progress to full-scale deployments.
- EMEC's offer, including both scaled and full-scale grid connected sites, covers both early and later stage deployments. This, along with the extent of the service offering, leads to a ranking towards the middle of the perceptual map.
- The focus of DMEC on TEC deployments exposes the test site to less risky technologies, whilst SmartBay, as a non-grid connected, intermediate scale test site, targets mostly early stage developers.

The distribution of the FORESEA test sites (in green), spread over the different axes of the perceptual map, may be considered when targeting different customer segments. The current test site landscape illustrated in Figure 5-1 positions the majority of the sites in the second and fourth quadrants of the perceptual map. The absence of an offer for the first and third quadrants may be explored in a segment targeting approach, should customers with such characteristics exist in sufficient numbers. Such features and associated strategies are explored in Section 5.3.

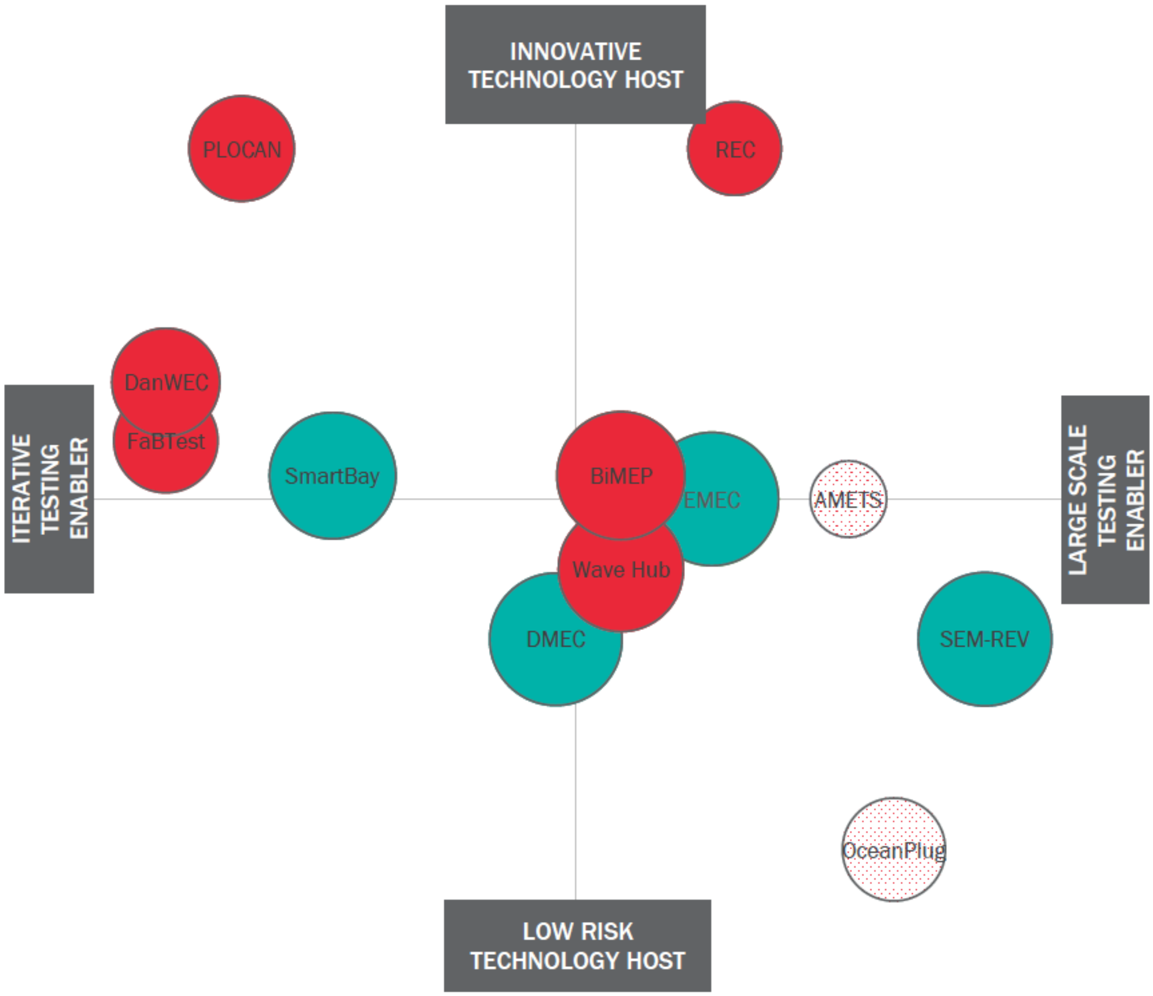

Figure 5-1 Perceptual map: current positioning of the FORESEA and Level 2 open-ocean test sites

5.3 Customer Segmentation

To assist in the positioning of the FORESEA test sites, in CA's experience it is useful to assess if the findings from the customer consultation (Section 4) can be used to define specific customer segments.

In CA's opinion, the multiple customer segments identified can be summarised as illustrated in Figure 5-2. Following the results of the customer survey, and in overall alignment with the perceptual map's axes, two key dimensions were identified to characterise the potential customers of the FORESEA test sites: strategy for development and attitude towards risk. The first proposed dimension (strategy for development) can be used to assess if a customer is mostly driven by the desire to develop a commercial scale project or the technology itself. The second proposed dimension (attitude towards risk) can be related to the degree of novelty of the technology and the approach in its development. Using the proposed dimensions, in CA's opinion four customer segments can be justified: *technology innovators, rocket path developers, incremental testers and best practice followers.*

The segmentation aims to help inform and optimise the strategic decisions and development paths of the FORESEA test sites, in particular when considering a potential segment targeting strategy. For example, SmartBay could be well positioned to target a "Technology innovators" segment. A segment targeting approach should involve the creation of specific value proposition(s), focusing on particular infrastructures / assets relevant to the segment(s) targeted.

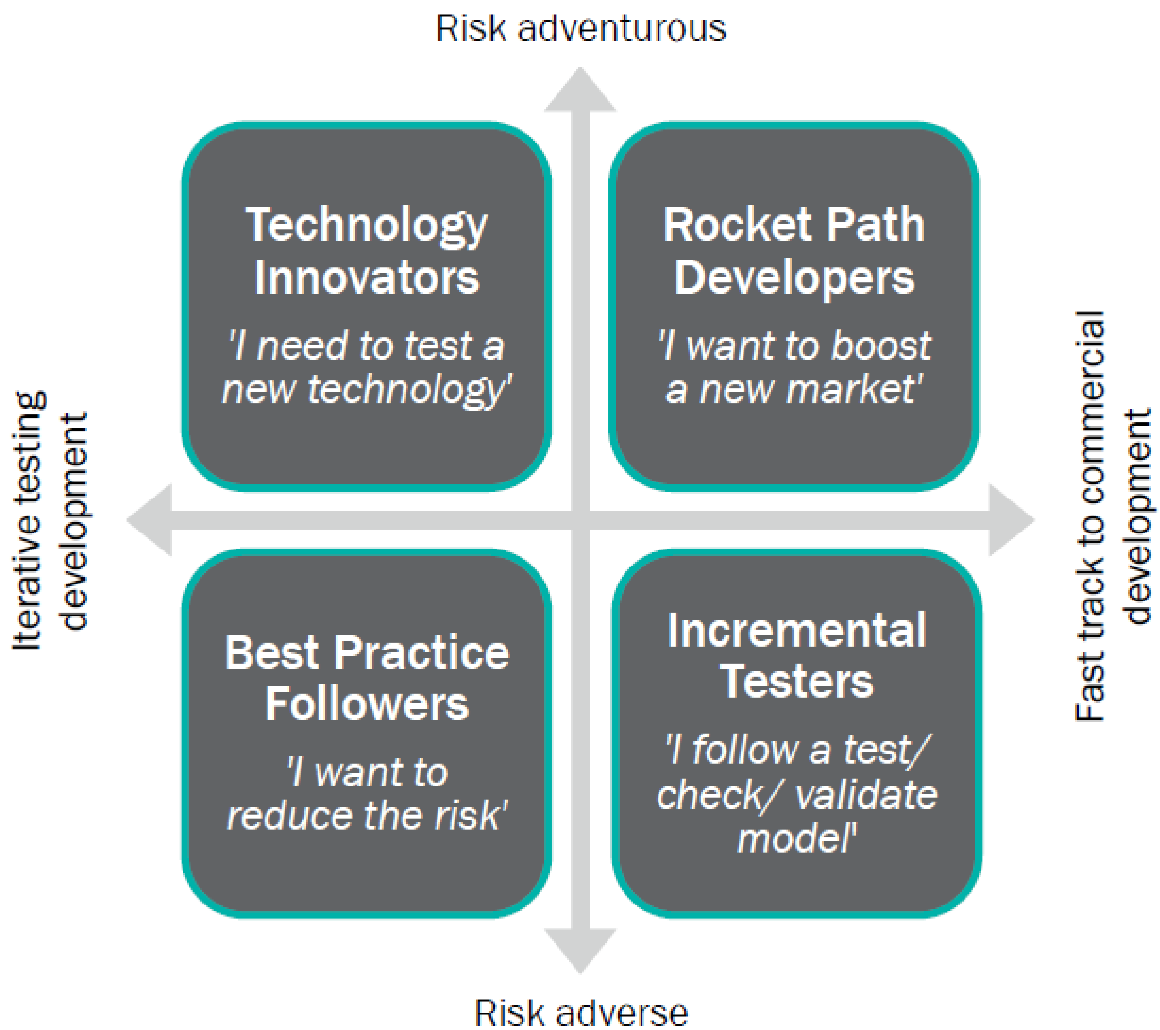

Figure 5-2 Proposed customer segmentation

The fundamental beliefs of each customer segment are conceptualised in Figure 5-3. These beliefs can in turn be expanded and linked to the capabilities available in the FORESEA test sites (described in Section 2), and Figure 5-3 makes that bridge by addressing the key characteristics of the target customer segments. In short:

- **'Technology Innovators'** can be associated as early-stage technology developers, with a high tolerance for risk and a large value given to iterative testing to prove their technology. Technology innovators require a stage gate approach for the development plan, and nursery and intermediate scale testing facilities are likely to be of interest to this segment in a short- and medium-term horizon. Technology innovators want to focus on their core engineering / design / development activities, while indirect services such as consenting support may be of interest. As early-stage developers, they can be characterised with a low TRL and low level of funding; they typically largely require R&D support and funding resources.

- **'Rocket Path Developers'** can be characterised by a strong desire to accelerate the technology development and deployment plans to boost the market. Developers in this segment are willing to progress quickly in their TRL development, with fast progression early-stage testing to large deployment plans. Need for grid connected deployment at full-scale test site is foreseen in a short- to medium-term horizon. This can be enabled by consenting support or access to R&D / funding programmes.
- **'Best Practice Followers'** are risk-advert developers, willing to progress slowly in their development plans to ensure adherence with (perceived) best practices and ease the way to certification and commercial deployment. Iterative deployments at nursery, intermediate- and full-scale deployments are to be expected, consolidated by e.g. support to development, monitoring and operational activities from the test site.
- **'Incremental Testers'** show a strong commercial focus, and a desire to progress fast in their deployment plans, scheduled incrementally from small to large scale. Such developers typically foresee grid connected deployments at full-scale test sites in a short-term horizon. In general risk-advert, they value support services for e.g. development, monitoring and operational activities.

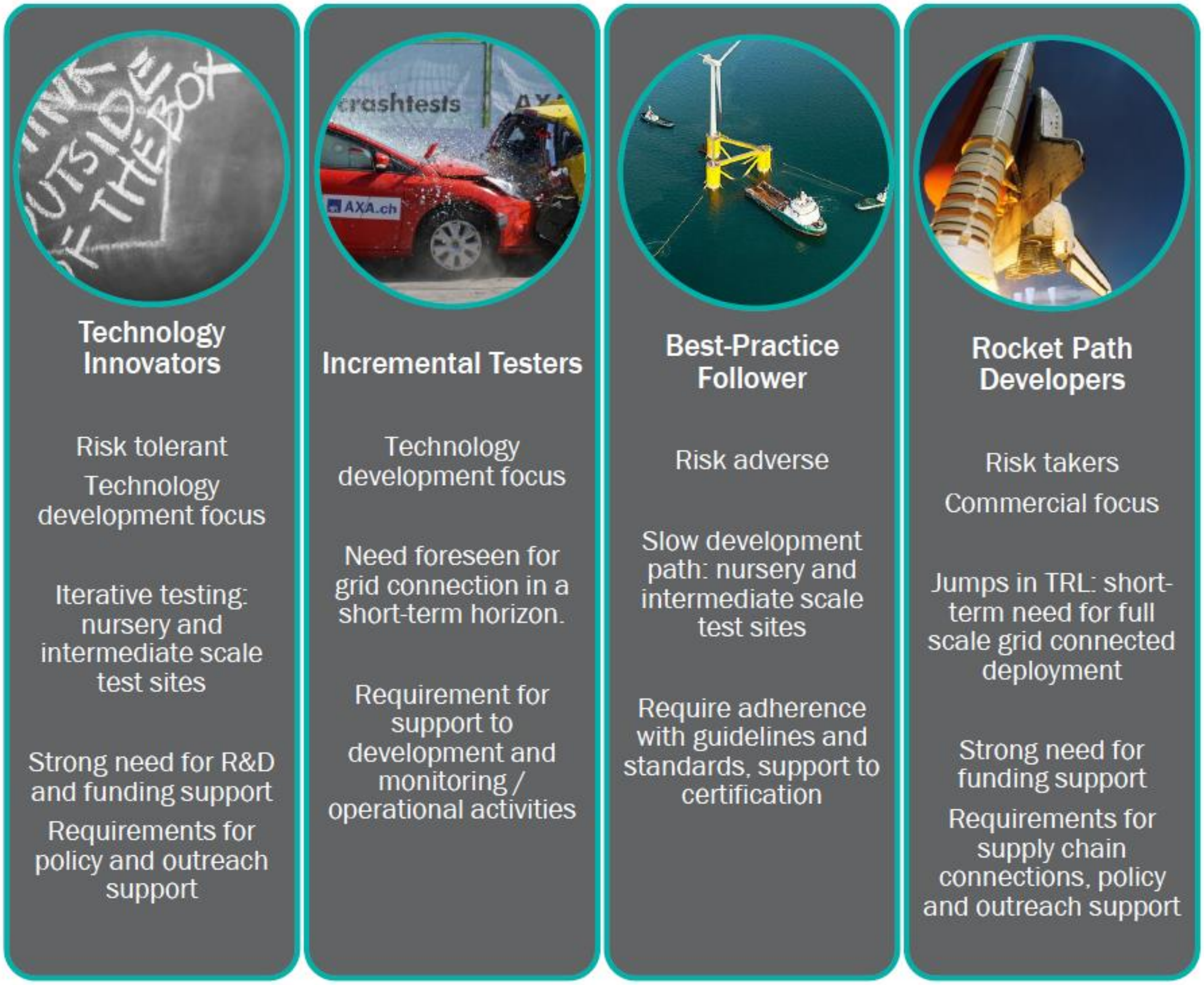

Figure 5-3 Open-ocean test sites: key characteristics of the target customer segment

REPORT

D2.3.1: PROGRAMME FOR INFRASTRUCTURES

Ecole Centrale Nantes

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REVISION HISTORY

Revision №	Date	Comments
A	08/12/17	Initial Release – For Client Feedback
B	16/02/2018	Final Release – Following Client Feedback

Contents

1 INTRODUCTION

Ecole Centrale de Nantes (ECN) has commissioned Cruz Atcheson Consulting Engineers Lda. (CA) to conduct a comparative study of the offshore marine renewable energy (MRE) test sites within the framework of the FORESEA project.

The CA scope of work is divided into two key phases [2]: in Phase 1, the general methodology for the completion of the comparative study was detailed; in Phase 2, the methodology is applied and the data thus collected is processed, leading to the compilation of the D.2.3.1 and D.2.3.2 FORESEA deliverables.

This report summarises the outcomes of the benchmarking exercise conducted in Phase 2 on the infrastructure aspects, and constitutes the D.2.3.1 FORESEA deliverable. It documents the benchmarking exercise conducted following the "3C" model presented in [2]. It aims to inform the FORESEA test site operators on the industry's requirements in terms of open-ocean test site infrastructure, and ultimately provide strategic recommendations to best adhere to the sector's needs. Particular attention is given to possible synergies and common paths to be followed by the different FORESEA test sites.

This report is organised in five main sections: following this introduction (Section 1), a review of the capabilities of the FORESEA test sites, in terms of the available / planned infrastructure, is provided in Section 2. The main competitors to the FORESEA test sites are then reviewed in Section 3. Following industry consultation activities, a characterisation of the potential customers of the FORESEA test sites is detailed in Section 4. Finally, the CA report is concluded in Section 5 with a high-level gap analysis of the FORESEA test sites' offer, including a proposed segmentation of the customer base and strategic recommendations for the positioning of the FORESEA test sites.

CA notes that a similar benchmarking exercise focusing on the competencies and services aspects was conducted in parallel, following a similar methodology and using the same consultation activities. The results are presented in the D.2.3.2 FORESEA deliverable [3].

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2 CAPABILITIES – CURRENT TEST SITE INFRASTRUCTURE (FORESEA TEST SITES)

The first factor in the 3C model is related to an analysis of the *Capabilities* of the FORESEA test sites: SEM-REV (Nantes, France), the European Marine Energy Centre, EMEC (Orkney, UK), SmartBay (Galway, Ireland) and the Dutch Marine Energy Centre, DMEC (Alkmaar, Netherlands). The objective of such review is to gain a detailed understanding of the range of the offer proposed by the FORESEA test sites in terms of the available / planned infrastructure. The purpose of such analysis is two-fold: firstly, to map the current capabilities in order to more readily recognise gaps in the current offer; and secondly to identify potential niches which FORESEA test sites can uniquely fill to meet the market requirements.

To gain a deeper understanding of the current capabilities of the FORESEA test sites, an online consultation exercise targeting the four members of the FORESEA consortium was conducted aiming to address the key attributes as identified in Phase 1 [2]. The survey was created with the objective of providing a more detailed overview of the test sites' available and planned infrastructure, and addressed aspacts such as :

- General Characteristics
    - Status
    - Type of technology targeted
    - Scale targeted
    - Expansion strategy
- Grid Connection
    - Existence of an export cable
    - Rated capacity
    - Existence of connection points
- Onshore Features
    - Proximity to port / shipyard
    - Capacity of workshop / quayside storage facility
    - Housing of personnel
    - Characteristics of land access
    - Proximity to airport
- Offshore Features
    - Availability of support vessels
    - Existence of pre-installed moorings
    - Soil type
    - Availability of metocean data measurement equipment

Sections 2.1 to 2.4 present an overview of the current capabilities of the FORESEA test sites, with a core focus on their available infrastructure (a similar overview focusing on the current services is presented in [3]). To conclude, a summary table is presented in Section 2.5, gathering the main features of each site to facilitate immediate comparisons.

2.1 SEM-REV, France

As part of the experimental facilities of Ecole Centrale de Nantes, SEM-REV is an open-ocean test site that aims to support the development of the marine renewable energy (MRE) industry by enabling the validation and optimisation of technologies in open-ocean conditions.

SEM-REV's objective is served through a research program based on four points:

- Increase awareness of the marine environment.
- Support the development of MRE Technologies (floating wind turbines (FWTs), wave energy converters (WECs) and related components.
- Consider the whole energy system from conversion to transport and storage.
- Address the Security, Safety, Education & Marine Operations challenges.

The SEM-REV test site was launched in 2007 following the signature of a government/regional planning agreement, and subsequently obtained a permit for WEC and FWT technologies. The export cable was installed in 2012 (as per the routing detailed in Figure 2-1).

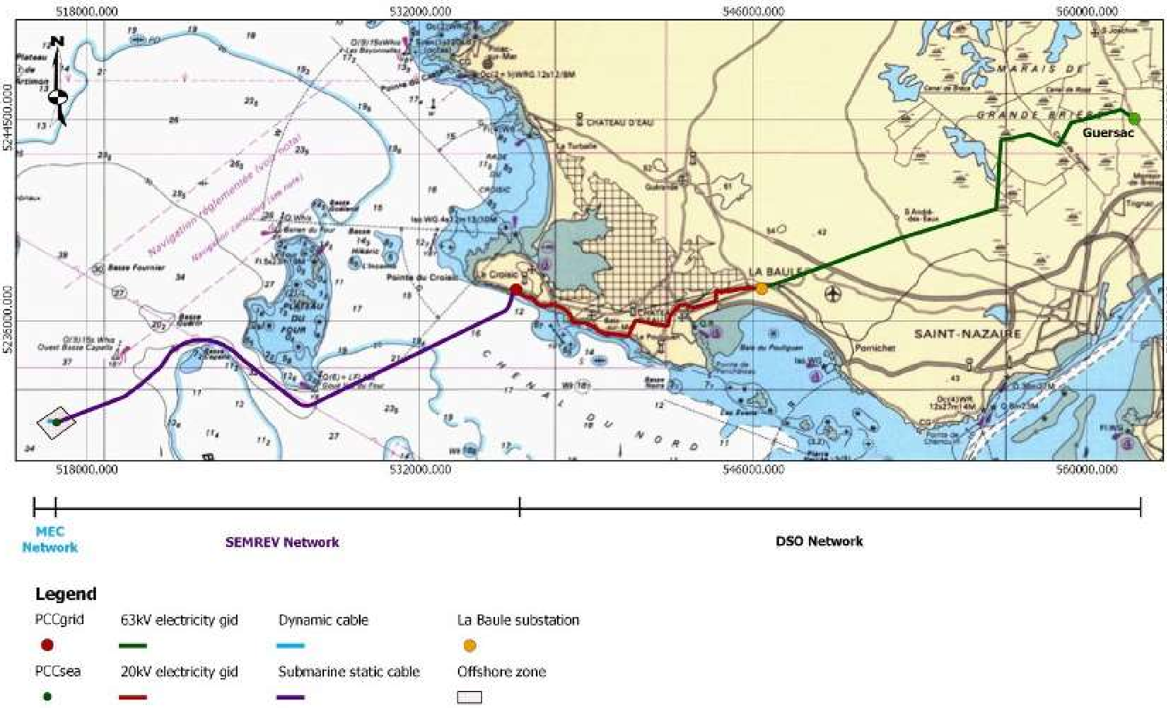

Figure 2-1 Map of the SEM-REV open-ocean energy test site (from www.sem-rev.ec-nantes.fr)

SEM-REV is located approximately 40km from St-Nazaire harbour and approximately 20km from Le Croisic, in a sandy seabed area where the water depth ranges between 32 and 36m (LAT). The annual average wave power flux is 12kW/m, with a 10-year return significant wave height of 8.3m and a 50-year return significant wave height of 9.6m. The 1h averaged, 10m high mean wind velocity is 7.5m/s and the 50-year return wind velocity is 29m/s (1h, 10m height). The onshore research centre is located in Penn Avel Park, on the coast, and belongs to the Coastal Reserve.

The 8MVA – 20kV export cable connects the SEM-REV open-ocean test site to the coastline in the electrical substation, located by the onshore research centre. The electrical substation is also connected to ENEDIS network (French distribution system operator), and the substation enables modification of the current characteristics produced by MRE devices to make them compatible with the ENEDIS network requirements.

Currently, two two-year projects are being deployed on the test site for testing: the FP7 Floatgen project, consisting of a floating wind turbine based on a concrete floater, a synthetic rope mooring system and a dynamic umbilical; and the BPI France IHES project, consisting of a floating WEC concept including the Pywec PTO, developed by Pytheas.

Table 2-1 presents key information on the infrastructure available at the SEM-REV test site, categorised into general characteristics, grid connection and onshore and offshore features. The information provided is based on the survey responses, and from the SEM-REV website (www.sem-rev.ec-nantes.fr) for the characteristics of land access, proximity to airport and soil type criteria.

Table 2-1 Summary information for the SEM-REV test site infrastructure and other key features

Test Site General Characteristics	Status	Operational since 2009, devices have been deployed
	Type of technology	WEC, FWT, subcomponents
	Type of scale targeted	Full-scale
	Expansion strategy	Expansion of grid + substation to 8-10MW planned
Grid Connection	Export cable	Existing
	Rated capacity	20kV, 8MW - substation capacity is 4MW. Grid capacity is 3.5MW
	Connection points	3
Onshore Features	Proximity to port/shipyard	Nearest port: Le Croisic or La Turballe (20km). Nearest major ports: St Nazaire (40km), alternatively Lorient or Les Sables d'Olonne (>50km)
	Storage facilities (warehouse/quayside)	Not planned – available through local subcontractors
	Housing of personnel	Yes
	Characteristics of land access	Highway serving Nantes, TGV serving Le Croisic
	Proximity to airport	About 90km to Nantes airport
Offshore Features	Support vessels	Not planned - through local subcontractors
	Pre-installed moorings	Planned - Pre-installed anchor points: depending on the technology constraints, complete solutions or components might be provided on site
	Soil type	Sand
	Measurement equipment	2 DWR MKIII buoys + 2 ADCP wave and current measurements + 1 met station (wind and wind speed, air temperature, pressure etc.)
	Communication to shore	Fiber optics as base case and alternative solution (HF, 4G, satellite…) as back-up solution

2.2 European Marine Energy Centre, UK

Established in 2003, the European Marine Energy Centre (EMEC) was the first centre of its kind to provide developers of both wave and tidal energy converters with purpose-built, open-ocean testing facilities.

Orkney was selected as EMEC's base primarily because of its wave regime, strong tidal currents, existing grid connection, sheltered harbour facilities and the renewable, maritime and environmental expertise that exists within the local community. Figure 2-2 displays the layout of the Billia Croo wave energy test site at EMEC along with an illustration of the facilities.

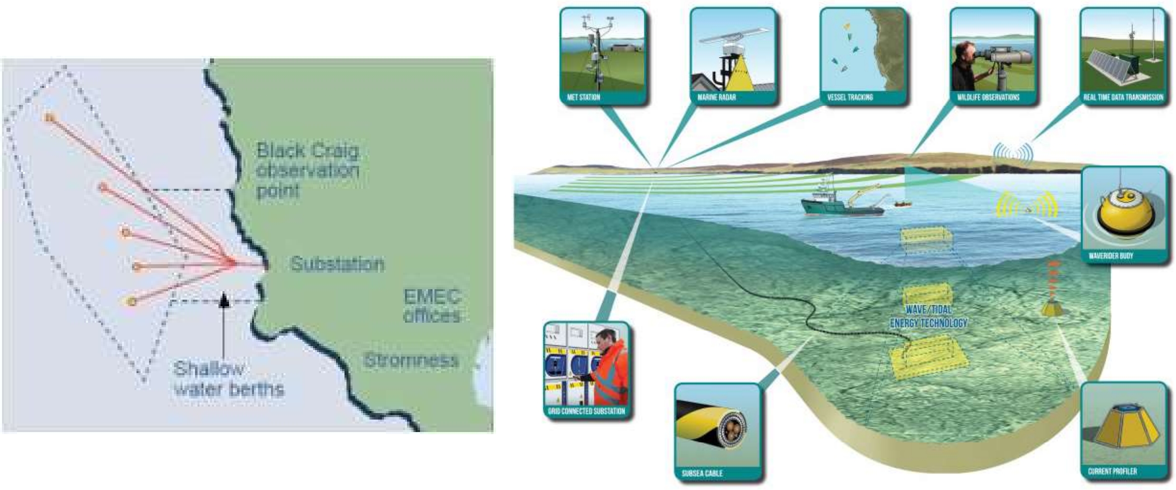

Figure 2-2 Illustration of the Billia Croo wave energy test site [4] **(with the permission of EMEC)**

EMEC's operations are now spread over four sites across Orkney, namely:

- Billia Croo wave energy test site, Stromness, Mainland Orkney (grid connected)
- Fall of Warness tidal energy test site, off the island of Eday (grid connected)
- Scale wave test site at Scapa Flow, off St Mary's Bay
- Scale tidal test site at Shapinsay Sound, off the Head of Holland

The Billia Croo wave energy test site contains six connection points in water depth of up to 70m. This site is located to the west of the Orkney islands in the prevailing direction of swells from the Atlantic, with waves of up to 19m. The Fall of Warness tidal site is located to the west of the island of Eday and consists of seven connection points in water depths of between 25 and 50m. The site is located in a strait between islands with tidal flows of up to 4m/s.

Both sites are equipped with subsea power cables connected to the UK electricity grid (one connection point at each full-scale site, 11kV export cable and substation capacity of 35MW with a 26MW expansion planned for 2020).

In addition to EMEC's grid connected sites, EMEC also offers scale test sites in the sheltered conditions of Scapa Flow and Shapinsay Sound. The Scapa Flow scale site is dedicated to wave energy technologies. It is located between the islands of Mainland and Burray, in 25m water depth and with an average significant wave height between 0.25m and 0.75m. The Shapinsay Sound scale site is dedicated to tidal energy technologies. It is located between the Mainland and Shapinsay, in 25m water depth and with a peak tide of 1.5m/s.

The scale sites aim to close the gap from tank testing to fully exposed ocean testing, and act as a stepping stone towards larger scale projects. Such accessible real sea testing aims to allow marine energy developers and suppliers to learn real-life lessons at a lower cost, reducing the need for big vessels or large equipment.

Table 2-2 presents key information on the available infrastructure at the EMEC test sites, categorised into general characteristics, grid connection and onshore and offshore features. The information provided is based on the survey responses, and from the EMEC website (www.emec.ork,uk) for the characteristics of land access, proximity to airport and soil type criteria.

Table 2-2 Summary information for the EMEC test site infrastructure and other key features

Test Site General Characteristics	Status	Operational since 2003, devices have been deployed
	Type of technology	WEC, TEC, subcomponents
	Type of scale targeted	Scaled and full-scale
	Expansion strategy	Expansion to / for more than 26MW in 2022; offsite testing, use of hydrogen and battery storage and additional lease areas
Grid Connection	Export cable	Existing
	Rated capacity	5MW per berth; Substation capacity 35MW; Grid capacity is a limiting factor.
	Connection points	13
Onshore Features	Proximity to port/shipyard	Closest less than 10km, major less than 50km. Scapa Flow (scale wave site) is 2nd largest natural harbour in the world
	Storage facilities (warehouse/quayside)	Available
	Housing of personnel	Yes
	Characteristics of land access	Via Ro-ro ferry
	Proximity to airport	About 30km from Kirkwall airport
Offshore Features	Support vessels	Available via local supply chain
	Pre-installed moorings	Available on scale sites
	Soil type	Sand and areas of glacial till (wave), rock (full-scale tidal) and boulders (scale tidal)
	Measurement equipment	3 Waveriders, met stations at each site, ADCPs available for use. Hard-wired ADCPs available on occasions when funds permit. Marine radar. Integrated Monitoring Pod in development (integrating CTD sensors, hydrophones, active sonar, ADCP and a turbulence monitoring system)
	Communication to shore	Fibre on all full-scale sites, microwave on scale sites from test support buoy able to be sited on scale sites; VHF link available

2.3 SmartBay, Ireland

Ireland's 1:4 scale ocean energy test site SmartBay is located within the Galway Bay Marine and Renewable Energy Test Site and is situated 1.5km offshore, in water depths ranging from 20–23m. The site has provided test and validation facilities for several wave energy devices and components to date (e.g. Wavebob).

Figure 2-3 Aerial view of the SmartBay test site (from www.smartbay.ie)

In 2015 a subsea observatory was installed at the site, with a four-kilometre cable providing a physical link to the shore at Spiddal, Co. Galway. The subsea observatory enables the use of cameras, probes and sensors to permit continuous and remote live underwater monitoring. The cable supplies power to the site and allows data from the site to be transferred. The installation of this infrastructure was the result of the combined efforts of the Marine Institute, SEAI, the Commissioners of Irish Lights, SmartBay Ireland and the Marine Renewable Energy Ireland (MaREI) Centre. The project was part-funded under the Science Foundation Ireland (SFI) "*Research Infrastructure Call*" in 2012. Separately, SEAI announced a Memorandum of Understanding with Apple in November 2015 to promote the development of ocean energy in Ireland. Apple has committed a €1 million fund that will help developers who receive a SEAI grant to test their ocean energy prototypes in the Galway Bay Marine and Renewable Energy Test Site.

Table 2-3 presents key information on the available infrastructure at the SmartBay test site, categorised into general characteristics, grid connection and onshore and offshore features. The information provided is based on the survey responses, and from the FORESEA 2nd call for applications document[2] for the characteristics of land access, proximity to airport and soil type criteria.

[2] http://www.nweurope.eu/media/1462/foresea-call-text-second-call-for-applications.pdf

Table 2-3 Summary information for the SmartBay test site infrastructure and other key features

Test Site General Characteristics	Status	Operational since 2006, devices have been deployed
	Type of technology	WEC, FWT
	Type of scale targeted	Intermediate scale
	Expansion strategy	Not planned
Grid Connection	Export cable	Not planned - A plan to install a grid simulator in the site is underway; the "electrical" part of this plan has been completed. The plan is on hold until the terms of the new test site lease are known. The next step is the selection of a floating platform to host the simulator.
	Rated capacity	N/A
	Connection points	3 berths, not grid connected
Onshore Features	Proximity to port/shipyard	One small port and pier 3.5km away. Two large ports (one East, other West of the site) at about 10 nautical miles each from the site.
	Storage facilities (warehouse/quayside)	One workshop and warehouse, dock facilities, harbour space facilities, vessel and other services available through the local supply chain. Plans for office space for developers are being considered.
	Housing of personnel	Planned (next 5 years)
	Characteristics of land access	Motorway serving Galway
	Proximity to airport	Airport in Galway (less than 50km)
Offshore Features	Support vessels	Available through local supply chain
	Pre-installed moorings	Gravity base foundation planned
	Soil type	Sand with some silt
	Measurement equipment	A Waverider on site since 2006; Met station on site since 2012, on nearby locations since 2006; ADCP, CTD, turbidity, hydrophone and other physical parameters on site since 2016. An acoustic array planned for early 2018
	Communication to shore	Fiber optic cable to shore, multiplexed at an underwater node. Wireless communications available and reliable are: 3G/4G, WiFi to shore (5.2GHz), SigFox. Plans to install LoRa are underway.

2.4 Dutch Marine Energy Centre, the Netherlands

The Dutch Marine Energy Centre (DMEC) has two test facilities:

- An inshore testing facility in one of the sluice gates in the Afsluitdijk near Den Oever, and
- An offshore connection point in the Marsdiep between Den Helder and the Wadden island of Texel.

The inshore test site at Den Oever is located in two ducts of the Afsluitdijk, in an existing 16m wide, 4.2m deep sluice that discharges water from the IJsselmeer to the Wadden Sea twice a day. The facility is suitable to intermediate scale testing of tidal stream turbines (dimensions of about 10 x 3m) and enables testing in real-sea conditions in a ducted channel. Laminar flow speeds typically range between 1.5 and 4.5m/s.

The offshore Marsdiep test site is situated in open water that experiences bidirectional tidal flows of 1.0 – 2.0m/s. The 1km^2 site is close to both the harbours of Den Helder and NIOZ on the Wadden island of Texel. The berth is located 800m from shore in water depth of 25m, and is connected to the grid through an umbilical. Tidal energy devices of all types and maturity levels can be tested here.

Table 2-4 presents key information on the available infrastructure at the DMEC sites, categorised into general characteristics, grid connection and onshore and offshore features. The information provided is based on the survey responses, and from the DMEC website (www.dutchmarineenergy.com) for the characteristics of land access, proximity to airport and soil type criteria.

Table 2-4 Summary information for the DMEC test site infrastructure and other key features

Test Site General Characteristics	Status	Operational since 2008 / 2015, devices have been deployed
	Type of technology	TEC
	Type of scale targeted	Intermediate and full-scale
	Expansion strategy	Option for deployment at nearby site dedicated to commercial applications; Duration of test period dependent on needs of technology developer - there is no fixed lease term; the test period is discussed during test preparation. Both short-term tests and long-term demonstration projects could be realised at the Marsdiep site.
Grid Connection	Export cable	Yes
	Rated capacity	200kVA (Marsdiep), 160kVA (Den Oever)
	Connection points	2
Onshore Features	Proximity to port/shipyard	Close to the NIOZ harbour, as well as the international port of Den Helder
	Storage facilities (warehouse/quayside)	Not planned
	Housing of personnel	No
	Characteristics of land access	National roads serving Alkmaar
	Proximity to airport	Less than 50km from Amsterdam
Offshore Features	Support vessels	Not planned
	Pre-installed moorings	Available
	Soil type	Sand
	Measurement equipment	Met station and ADCP
	Communication to shore	Wireless

2.5 Summary Table

Table 2-5 provide a summary of the key information presented in this Section for the FORESEA test sites.

Table 2-5 Summary information for the FORESEA test sites: infrastructure and other key features

Category	Evaluation Criteria	SEM-REV	EMEC	SmartBay	DMEC
Test Site General Characteristics	Status	Operational since 2009, devices have been deployed	Operational since 2003, devices have been deployed	Operational since 2006, devices have been deployed	Operational since 2008 / 2015, devices have been deployed
	Type of technology	WEC, FWT, subcomponents	WEC, TEC, subcomponents	WEC, FWT	TEC
	Target scale	Full-scale	Scaled and full-scale	Intermediate scale	Intermediate and full-scale
	Expansion strategy	Expansion to 8-10MW planned for 2020	Expansion to / for more 26MW in 2022; offsite testing, use of hydrogen and battery storage and additional lease areas	Not planned	Expansion to commercial scale planned at the Marsdiep site.
Grid Connection	Export cable	Existing	Existing	Not planned	Existing
	Rated capacity	Substation capacity is 4MW	5MW per berth; Total substation capacity 35MW	N/A	200kVA (Marsdiep), 160kVA (Den Oever)
	Connection points	3	13	3 berths, not grid connected	2
Onshore Features	Proximity to port/shipyard	Nearest port 20km Major port 40km	Nearest port less than 10km, major less than 50km	Nearest port less than 10km Major port 20km	Nearest port less than 10km
	Storage facilities	Through local supply chain	Available	Through local supply chain	Not planned
	Housing of personnel	Yes	Yes	Planned (next 5 years)	No
	Characteristics of land access	Highway serving Nantes, TGV serving Le Croisic	Via Ro-ro ferry	Motorway serving Galway	National roads serving Alkmaar
	Proximity to airport	Medium (90km)	Close (< 50km)	Close (< 50km)	Close (< 50km)
Offshore Features	Support vessels	Through local supply chain	Through local supply chain	Through local supply chain	Not planned
	Pre-installed moorings	Planned - Pre-installed anchor points available	Available on scale sites	Not planned	Available
	Soil type	Sand	Sand and rock/boulders	Sand with some silt	Sand
	Measurement equipment	2 DWR MKIII, 2 ADCP, 1 met station	3 Waveriders, met stations, ADCPs, marine radar	Waverider; met station; ADCP, CTD, turbidity, hydrophone	Met station and ADCP
	Communication to shore	Fibre optics as base case + back-up solution (HF, 4G, satellite)	Fibre on all full-scale sites, microwave on scale sites, VHF link available	Fibre optic cable to shore + Wireless communications	Wireless

3 COMPETITION – CURRENT INFRASTRUCTURE OF OPEN-OCEAN TEST SITES OUTSIDE FORESEA

A high-level assessment of the infrastructure available in test sites outside the FORESEA programme was conducted through the analysis of public-domain data. Test sites suitable for the testing of floating wind, tidal and wave energy conversion technologies were assessed. The purpose of such analysis is two-fold: firstly, to provide case studies from which the FORESEA test sites can gain market insights; and secondly to identify potential niches which FORESEA test sites can uniquely fill.

The *Competitors* identified in Phase 1 [2], including both operational and planned offshore test facilities suited for MRE technology deployment, were analysed. For each test site, the review was guided by the key attributes introduced in Phase 1 (see also Section 2).

The key findings of this review are presented in this section, in the following order of importance and level of detail:

- Level 2 (Section 3.1): North / West Europe test sites (excluding Level 1 FORESEA sites)
- Level 3 (Section 3.2): Other sites worldwide

The section concludes with a summary table gathering the main features of each test site to facilitate comparison (see Section 3.3).

3.1 Level 2: Test Sites in North / West Europe

3.1.1 Wave Hub, Cornwall, UK

Wave Hub is a grid connected test site for full-scale testing of wave and floating offshore wind energy technologies, which can support a range of different technologies. The site comprises an 8km^2 consented area divided into four berths (comprising approximately 1km x 2km) in depths ranging between 51-57m. The seabed characteristics at the site include areas of outcropping bedrock and gravelly sand, with occasional boulders. The Wave Hub site is located 16km off the coast of Hayle, and over 100km from the larger dock facilities at Falmouth. In November 2016, it was announced that Wave Hub is to be formally transferred to Cornwall Council [5].

The Wave Hub infrastructure includes an offshore distribution hub and an onshore substation in Hayle. The distribution hub is connected to the onshore substation next to the Hayle Marine Renewables Business Park by a subsea cable rated at 33kV (see Figure 3-1). At the distribution hub, four connection cables are staggered from the export cable up the west side of the site. These can be connected to a marine renewable energy device or an array via an adaptable subsea connector. Connections can be facilitated at 11 or 33kV.

The grid connected infrastructure at the site has an export capacity of 30MW, with the potential to upgrade to 48MW. A fibre optic data connection carried by the shore-link cable gives technology developers the facility to monitor and control their devices remotely.

Deployments have already taken place at Wave Hub. For example, Seatricity's Oceanus 2 WEC was installed in May 2016 (not grid connected) and decommissioned a year later – see [6], [7]. In November 2016, Carnegie's received £9.6 million from the European Regional Development Fund for its planned deployment at Wave Hub of a single 1MW grid connected CETO 6 WEC. Finally, in

February this year, GWave announced its plans for a 9MW wave energy project to be deployed at Wave Hub [8].

Table 3-1 presents key information on the available infrastructure at the Wave Hub site, categorised into general characteristics, grid connection and onshore and offshore features.

Figure 3-1 Map of the Hayle Harbour area showing key landmarks (adapted from [9])

Table 3-1 Summary information for the Wave Hub test site infrastructure and other key features

Test Site General Characteristics	**Status**	Operational, devices have been deployed
	Type of technology	WEC and FWT
	Type of scale targeted	Full-scale
	Expansion strategy	Potential to upgrade to 48MW
Grid Connection	**Export cable**	Installed
	Rated capacity	30MW
	Connection points	4 berths
Onshore Features	**Proximity to port/shipyard**	16km off the coast of Hayle and over 100km from the larger dock facilities at Falmouth
	Storage facilities (warehouse/quayside)	Available in Falmouth: 8370m^2 warehouse 3ha uncovered space at A&P Falmouth
	Housing of personnel	No
	Characteristics of land access	Train line and motorways / A roads serving Hayle
	Proximity to airport	Bristol airport >250km
Offshore Features	**Support vessels**	Available through the local supply chain
	Pre-installed moorings	Not planned
	Soil type	Areas of outcropping bedrock and general covering of gravelly sand, with occasional boulders
	Measurement equipment	Installed 22 May 2015 a Datawell Directional Waverider DWR-MkIII
	Communication to shore	12 optic fibres

Wave Hub Ltd is also the third-party manager for demonstration zones in Pembrokeshire (Wales). Pembrokeshire is located in the proximity of deep water port facilities, between 13-21km off the South Pembrokeshire coastline. Pembroke Port is currently investing to adapt part of the site for use as a specialist facility for testing, manufacture and export of marine renewable devices [10]. The zone comprises a 90km^2 area of seabed with water depths of approximately 50m and a wave resource of 19kW/m. It has the potential to support the demonstration of wave arrays with a generating capacity of up to 30MW for each project. Recently, Wave-Tricity [11] has deployed its Ocean Wave Rower WEC at the site (trials started in February 2017).

3.1.2 FaBTest, Falmouth, UK

The Falmouth Bay Test (FaBTest) site is a pre-consented 2.8km² test area, situated in Falmouth Harbour, between 3 to 5km offshore Falmouth Bay. The site offers water depths of 20-50m (allowing it to accommodate devices at a range of scales), a moderate wave climate and a rock, gravel and sand seabed.

The test facility was developed with the intent of enabling developers to test components, scaled concepts and / or full-scale wave energy devices in a moderate wave climate, benefiting from the port infrastructure nearby. The site is not grid connected, so all generated power must be managed on site via a load bank (or a similar setup). The maximum potential generating output per device is 3MW [12].

Noting that permits are issued by Falmouth Harbour Commissioners, the FaBTest site mainly allows the deployment of buoyant or semi-buoyant devices (either WECs or TECs). Sub-systems (such as a device's mooring system or umbilical) are also eligible for deployment without the necessity to deploy the full device. It is expected that a defined range of floating wind devices will be permitted for deployment in the near future.

To date, two devices have been deployed at FaBTest: the Fred Olsen Bolt Lifesaver device was commissioned in 2014 [13], and PolyGen deployed the Volta WEC in August 2015 [14].

Table 3-2 presents key information of the available infrastructure at the FaBTest site, categorised into general characteristics, grid connection and onshore and offshore features.

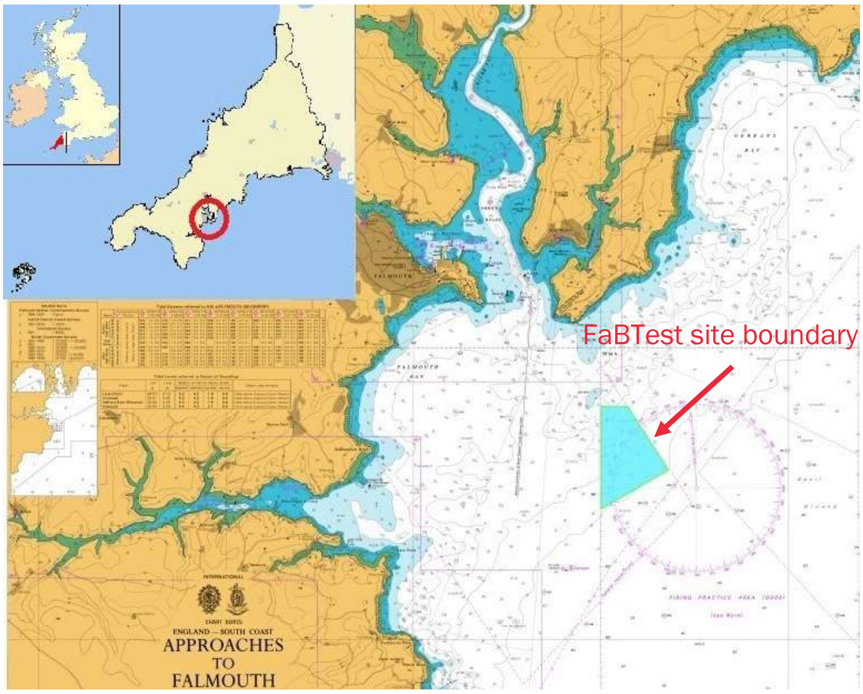

Figure 3-2 Overview of FaBTest site and facilities (from [15])

Table 3-2 Summary information for the FaBTest test site infrastructure and other key features

Test Site General Characteristics	Status	Operational, devices have been deployed
	Type of technology	WEC, TEC
	Type of scale targeted	Nursery
	Expansion strategy	Possible expansion to FWT
Grid Connection	Export cable	Not planned
	Rated capacity	N/A
	Connection points	3 test berths
Onshore Features	Proximity to port/shipyard	Up to 5km from Falmouth Port
	Storage facilities (warehouse/quayside)	Available through Falmouth Port: Extensive dock facilities including three dry docks, wharf space, cranage and a heavy load out quay
	Housing of personnel	No
	Characteristics of land access	Train line and motorways / A roads serving Hayle
	Proximity to airport	Bristol airport >250km
Offshore Features	Support vessels	Available through the local supply chain
	Pre-installed moorings	No - Mooring systems are restricted to gravity and drag embedment anchors
	Soil type	Rock, gravel and sand seabed
	Measurement equipment	Oceanor Seawatch Mini II wave, Datawell Waverider Mk3, ADCPs
	Communication to shore	UMTS (3G) and LTE (4G) services with HSDPA / HSUPA available

3.1.3 Atlantic Marine Energy Test Sites (AMETS), Ireland

The Atlantic Marine Energy Test Site (AMETS) is being developed by the Sustainable Energy Authority of Ireland (SEAI) to facilitate testing of full-scale marine energy converters in an energetic ocean environment. AMETS is located off Annagh Head, west of Belmullet in Co. Mayo (Ireland), and will be connected to the national grid (see Figure 3-3).

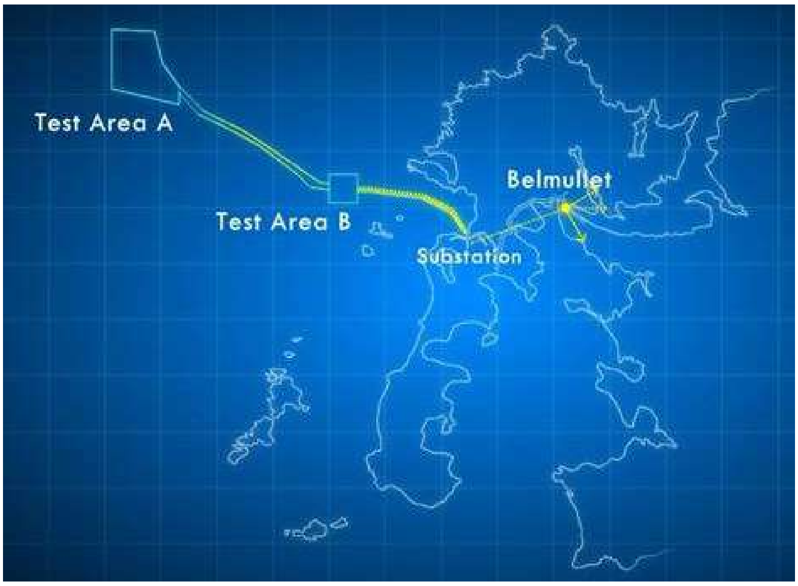

Figure 3-3 Location of AMETS [16]

It is currently envisaged that the site will provide two separate test locations at water depths of 50m and 100m, with 6.9km² and 1.5km² of area, respectively. Each site is located 16km and 6km out from Belderra Strand, respectively. This aims to allow for a range of devices to be tested. In addition, the potential to facilitate testing at shallower depths or the testing of other technologies such as floating wind is currently being investigated. Measurements since March 2009 have shown that the deep site is characterised by a mean annual wave power of 57-68kW/m [17].

The infrastructure to support testing at AMETS continues to be advanced. For example, permission to construct a 20kV substation that will connect the AMETS test site to the Irish grid was granted earlier this year (April 2017) [18]. The development will also comprise the installation of five underground electrical cables plus associated communication cables, along with an associated underground cable joint. The grid connection agreement is in place with ESB since 2011.

The Frenchport pier (Annagh Peninsula) was identified as a possible support base, and construction of extra slipway adjacent to existing pier is being considered.

Table 3-3 presents key information on the planned infrastructure at the AMETS site, categorised into general characteristics, grid connection and onshore and offshore features.

Table 3-3 Summary information for the AMETS test site infrastructure and other key features

Test Site General Characteristics	Status	Planned
	Type of technology	WEC
	Type of scale targeted	Energetic ocean environment
	Expansion strategy	Potential to facilitate testing at shallower depths / for other technologies (e.g. FWT)
Grid Connection	Export cable	Planned
	Rated capacity	Planned - 4 cables @ 11 kV. 10MW export capability
	Connection points	4 cables
Onshore Features	Proximity to port/shipyard	Frenchport Pier
	Storage facilities (warehouse/quayside)	Unknown
	Housing of personnel	No
	Characteristics of land access	Unknown
	Proximity to airport	Far (>100km)
Offshore Features	Support vessels	Unknown
	Pre-installed moorings	No
	Soil type	Sand close to shore with rock further out
	Measurement equipment	Directional Waverider + Metocean buoy
	Communication to shore	Unknown

3.1.4 Biscay Marine Energy Platform (BIMEP), Spain

The Biscay Marine Energy Platform (BiMEP), an open sea test facility promoted by Ente Vasco de la Energia (EVE) and Institute for Energy Diversification and Saving (IDAE) in the Basque Country, was officially inaugurated in July 2015. BiMEP covers an area of 5.2km², restricted to sea traffic, with depths ranging from 50 to 90m. It is located in an area with approximately 21kW/m, and its proximity to the nearest ports (2km from Armintza harbour, about 15km from Bilbao). The site comprises of four berths of 13.2kV / 5MW, each connected to the grid.

Figure 3-4 Overview of BiMEP site and facilities (from www.bimep.com)

BiMEP hosts the first floating WEC device connected to the grid in Spain. Oceantec Energías Marinas deployed its floating 30kW OWC WEC (Marmok-A-5) at BiMEP in October 2016 [19]. The device was connected to the grid in early December 2016. A second 12-month deployment phase was scheduled for 2017 but no recent information was found confirming its completion. Other projects are also carrying out trials at BiMEP but without grid connection, e.g. ZUNIBAL S.L. is testing the ANTEIA metocean buoys.

Close to the current location, another open sea area was identified for potential extension of the infrastructure towards floating offshore wind trials [20].

Table 3-4 presents key information on the available infrastructure at the BiMEP site, categorised into general characteristics, grid connection and onshore and offshore features.

Table 3-4 Summary information for the BiMEP test site infrastructure and facilities

Test Site General Characteristics	Status	Operational, devices have been deployed
	Type of technology	WEC
	Type of scale targeted	Full-scale
	Expansion strategy	Possible expansion to FWT / future extension planned up to 50MW by 2020
Grid Connection	Export cable	Installed
	Rated capacity	4 x 5MW cables @ 13.2kV
	Connection points	4
Onshore Features	Proximity to port/shipyard	2km from Armintza harbour 15km from Bilbao port
	Storage facilities (warehouse/quayside)	Armintza harbour: 1 6-tons crane, 3 launch ramps Bilbao port: 68,792m^2 of warehouses
	Housing of personnel	No
	Characteristics of land access	Highway serving Armintza
	Proximity to airport	15km from Bilbao airport
Offshore Features	Support vessels	Outsourced
	Pre-installed moorings	No
	Soil type	Rock and sand
	Measurement equipment	Oceanor Wavescan buoy
	Communication to shore	Radio and/or satellite communication

3.1.5 Plataforma Oceanica de Canarias (PLOCAN), Spain

Oceanic Platform of the Canary Islands (PLOCAN) offers a test site for marine energy converters. Measurements conducted between February 1992 and September 2014 exhibited a mean wave power flux of 6kW/m, with a mean significant wave height of 1.05m and mean period of 5.21s.

PLOCAN includes an offshore platform, located at 1.5km from shore and at 30m depth, which has recently been fixed to the seabed at the north-east of Gran Canaria Island [19]. The submarine electrical infrastructure, including two underwater medium voltage cables, was expected to be ready during the first trimester of 2017 offering the required grid connection. The electrical and communication grid infrastructure will be operative in 2018 and will include two main modules of 5MW of electricity evacuation capacity: Module 1 will be dedicated to WEC demonstrators, with five positions of 1MW each; Module 2 will be dedicated to offshore wind technologies with one position of 5MW [21]. A future extension is planned up to 50MW by 2020 [19]. The PLOCAN test site was authorised by the Cabinet of Ministers in March 2014 including a marine area of 23km^2 from the coast to 600m depth.

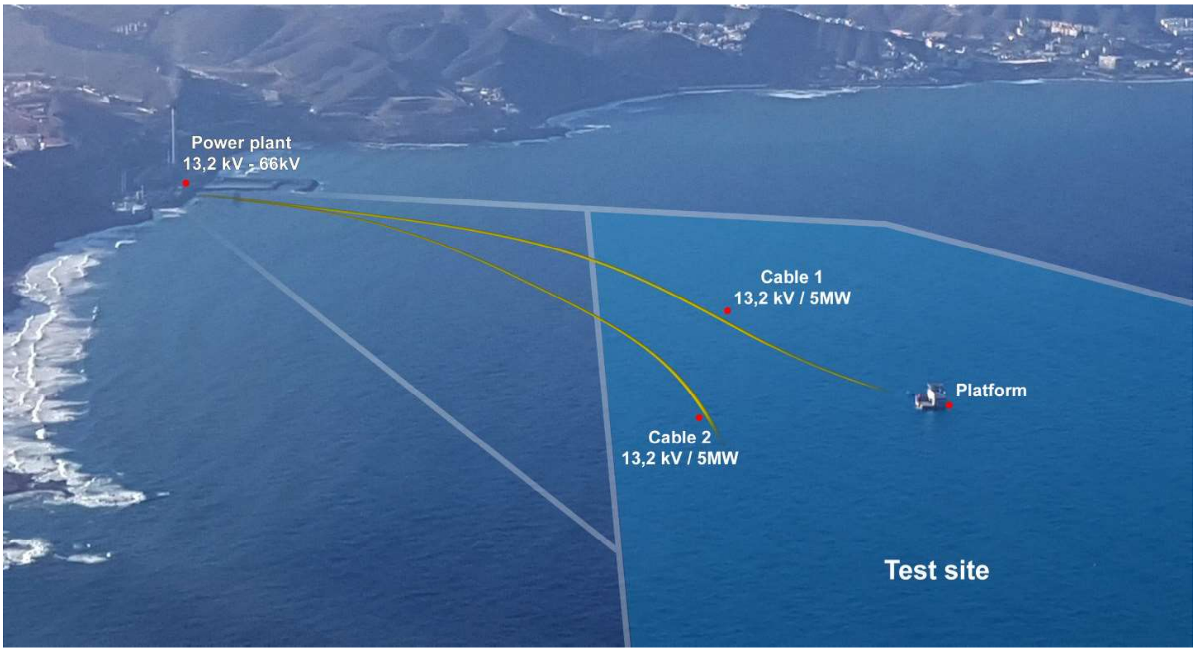

Figure 3-5 Overview of PLOCAN site and facilities (from www.plocan.eu)

Three WEC devices have already been tested at PLOCAN without a grid connection (Wedge, Wello and Pipo Systems) [19]. PLOCAN is also hosting offshore wind demonstration projects such as the ELICAN project led by the Spanish company ESTEYCO. A 5MW offshore wind turbine prototype is planned to be during 2018 over a telescopic mast with a gravity-based mooring.

Table 3-5 presents key information on the available infrastructure at the PLOCAN site, categorised into general characteristics, grid connection and onshore and offshore features.

Table 3-5 Summary information for the PLOCAN test site infrastructure and other key features

Test Site General Characteristics	Status	In operation, devices have been deployed
	Type of technology	WEC, FWT, others
	Type of scale targeted	Nursery scale or benign testing of larger scale devices
	Expansion strategy	Expansion planned up to 50MW by 2020
Grid Connection	Export cable	Planned
	Rated capacity	Initial capacity is set up at 15MW
	Connection points	2 export cables
Onshore Features	Proximity to port/shipyard	1.5km off the coast – support base: Las Palmas
	Storage facilities (warehouse/quayside)	Work area on platform 546m²; hangar 354.58m², 8m tall
	Housing of personnel	Accommodation on platform for up to 15 people
	Characteristics of land access	Access by boat or heliport
	Proximity to airport	International airport in Las Palmas (<10km)
Offshore Features	Support vessels	Submarine autonomous vehicles, surface autonomous vehicles, remote operated vehicles (ROV), vessels
	Pre-installed moorings	No
	Soil type	Predominant sand and rocks
	Measurement equipment	WaveRider until January 2014, replaced by Triaxys directional
	Communication to shore	Unknown

3.1.6 Ocean Plug, Portugal

In Portugal, a specific site for offshore renewable energy developments was designated by the Portuguese Government in 2008. Located offshore S. Pedro de Moel, between Figueira da Foz and Nazaré, and with an area of 320km², the Ocean Plug is a demarcated maritime space in water depths that range between 30 and 90m, with mean annual wave power flux of about 17kW/m.

In 2010, ENONDAS (a subsidiary of the Portuguese Grid Transmission System Operator, REN) received from the Portuguese government a public concession for this site for 45 years. ENONDAS has adopted the trading name of Ocean Plug. However, until 2017 there has not been much progress regarding the development of the infrastructure.

The Ocean Plug site aims to facilitate the transition of the technology from demonstration to commercial scale, reducing the investments required in licensing procedures (there will be no need to move to a new location and start a new licensing process). Thus, the Ocean Plug site will be equipped with a test zone for demonstration projects along with the infrastructure for the installation of commercial projects.

Table 3-6 presents key information on the planned infrastructure at the Ocean Plug site, categorised into general characteristics, grid connection and onshore and offshore features.

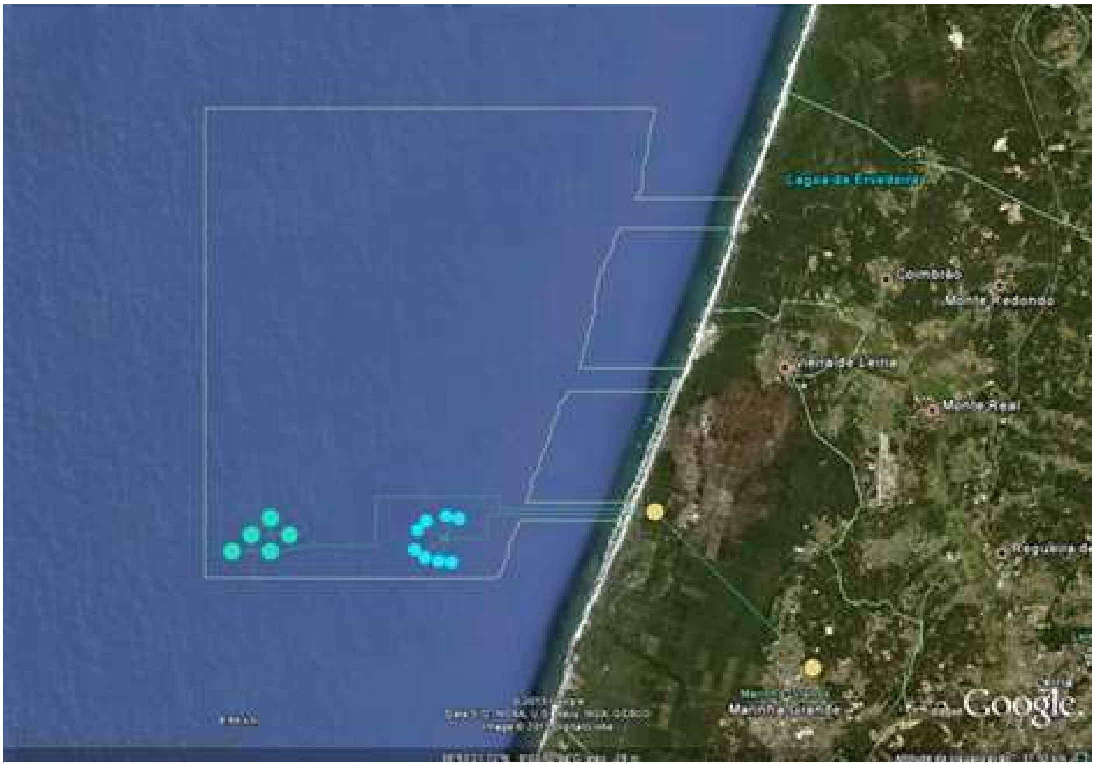

Figure 3-6 Overview of Ocean Plug site (from www.oceanplug.pt)

Table 3-6 Summary information for the Ocean Plug test site infrastructure and other key features

Test Site General Characteristics	**Status**	Planned
	Type of technology	WEC, FWT
	Type of scale targeted	Full-scale
	Expansion strategy	Up to 80MW for pre-commercial projects, up to 250MW for full commercial projects (planned)
Grid Connection	**Export cable**	Planned
	Rated capacity	Planned - 4 berths of 3MW for test area
	Connection points	4 berths
Onshore Features	**Proximity to port/shipyard**	Network of ports and shipyards, including Figueira da Foz (35km) and Peniche (92km)
	Storage facilities (warehouse/quayside)	Closest port with total warehouse area of 4,750m^2
	Housing of personnel	No
	Characteristics of land access	National roads serve S. Pedro de Moel
	Proximity to airport	60km from Lisbon
Offshore Features	**Support vessels**	Unknown
	Pre-installed moorings	No
	Soil type	Sand
	Measurement equipment	One multi-parameter buoy
	Communication to shore	Unknown

3.1.7 Runde Environmental Centre (REC), Norway

The Runde Environmental Centre (REC), located on Runde Island on the Norwegian west coast, can accommodate wave energy projects for test and demonstration purposes. The site has a 3km 0.5MW sea cable to shore with grid connection [19].

The Swedish technology developer Waves4power first deployed their WavEl floating WEC device in February 2016, and then again in May 2017 after it underwent an overhaul at Ulstein Shipyard [22].

Table 3-7 presents key information on the available infrastructure at the REC site, categorised into general characteristics, grid connection and onshore and offshore features.

Table 3-7 Summary information for the REC test site infrastructure and other key features

Test Site General Characteristics	Status	Operational, devices have been deployed
	Type of technology	WEC
	Type of scale targeted	Intermediate / Full-scale
	Expansion strategy	No
Grid Connection	Export cable	Installed
	Rated capacity	0.5 MW sea cable
	Connection points	Unknown
Onshore Features	Proximity to port/shipyard	400m from Runde port
	Storage facilities (warehouse/quayside)	No
	Housing of personnel	Yes
	Characteristics of land access	Accessible by boat or car
	Proximity to airport	Ørsta-Volda airport (50km); Ålesund airport (100km)
Offshore Features	Support vessels	No
	Pre-installed moorings	No
	Soil type	Sandy with bedrock / cobbled areas
	Measurement equipment	Wave measuring buoy
	Communication to shore	Unknown

3.1.8 Danish Wave Energy Center (DanWEC), Denmark

The DanWEC site was established in 2010, in connection with the testing of the WEC Wavestar, which was tested in Hanstholm during 2009–2013. In 2012, the organisation applied for funding under the Danish Energy Agency to prepare DanWEC for additional WEC testing activities in Denmark.

The offshore wave energy resource at DanWEC, located 2 to 4km from the Port of Hanstholm, is 6kW/m, with wave heights of up to 12m, in water depths between 25 and 30m [23]. In addition to the offshore site, DanWEC also offers test facilities in the sheltered site at Nissum Bredning (close to Hanstholm), suited for 1:4 scale prototype tests.

A local plan for development of the Port of Hanstholm [24] was prepared in 2009 to ensure that the port will be attractive as a commercial port. This includes an extension plan of the harbour to a size three times bigger than its current size.

Recently, after a 1:9 scale testing at Nissum Bredning completed in 2013, Wavepiston redeployed its prototype WEC system at DanWEC [25]. The deployment of one device took place in May 2017, and the second energy collector is currently under construction. The expected output of the prototype (8 energy collectors) is 12kW.

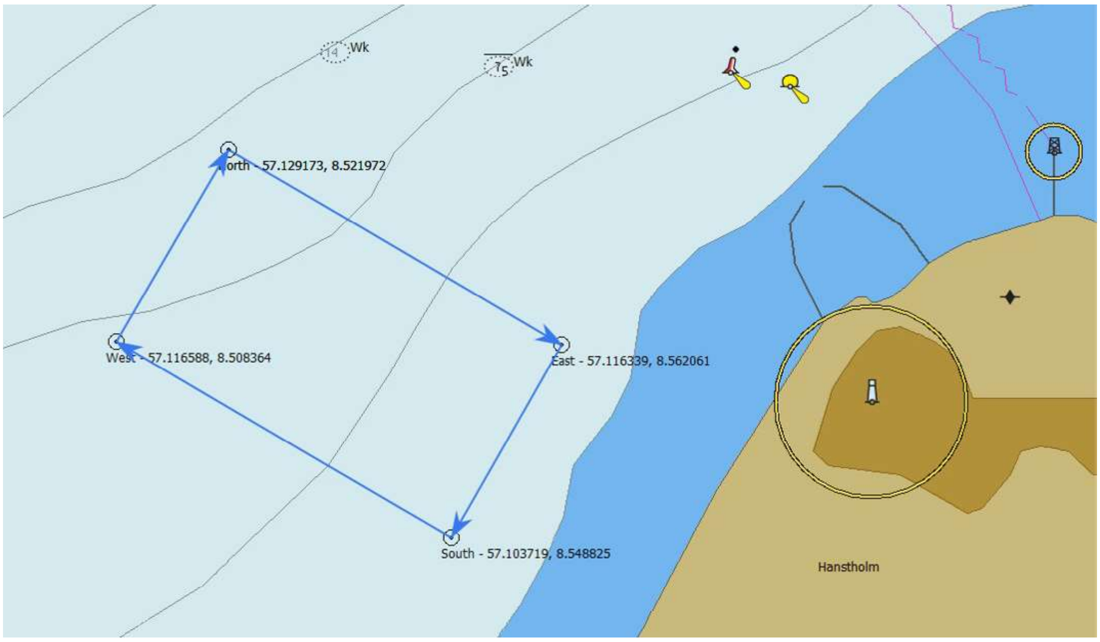

Figure 3-7 Overview of DanWEC site (from www.danwec.com)

Table 3-8 presents key information on the available infrastructure at the DanWEC site, categorised into general characteristics, grid connection and onshore and offshore features.

Table 3-8 Summary information for the DanWEC test site infrastructure and other key features

Test Site General Characteristics	Status	Operational, devices have been deployed
	Type of technology	WEC
	Type of scale targeted	Intermediate / small scale prototypes
	Expansion strategy	Considered, as part of the Roadmap produced by the Danish Partnership for Wave Power
Grid Connection	Export cable	Planned (as per 2015)
	Rated capacity	Unknown
	Connection points	Unknown
Onshore Features	Proximity to port/shipyard	2-4km from the Port of Hanstholm
	Storage facilities (warehouse/quayside)	Available at Hanstholm Port: large designated wharf area
	Housing of personnel	Renting
	Characteristics of land access	National road serves Hanstholm, train serves nearby Thisted station
	Proximity to airport	About 100km to Aalborg airport
Offshore Features	Support vessels	Available
	Pre-installed moorings	Unknown
	Soil type	Sand and silt, with some areas of exposed chalk
	Measurement equipment	2 Waverider buoys
	Communication to shore	WiFi and fibre

3.2 Level 3: Test Sites in the Rest of the World

For the Level 3 test sites, the review was conducted on a higher-level basis. The assessment of the infrastructure available was based on the analysis of public-domain data, for the following countries and test sites:

- U.S.:
  - Pacific Marine Energy Center (PMEC, Section 3.2.1)
  - California Wave Energy Center (CalWave, 3.2.2)
  - Hawaii National Marine Renewable Energy Test Center (HINMREC, Section 3.2.3)
- New Zealand: New Zealand Marine Energy Center (NZMEC, Section 3.2.4)
- Japan: Nagasaki Marine Industry Cluster Promotion Association (NaMICPA, Section 3.2.5)
- China (Section 3.2.6)

Most of these sites have recently been announced and are only planned for development. Therefore, only limited information is available. The key information on their status and development is provided in the subsections below.

3.2.1 Pacific Marine Energy Center (PMEC), Oregon, U.S.

The Pacific Marine Energy Center (PMEC) comprises four open water test sites, with the key characteristics of each site summarised in Table 3-9:

- The PMEC North Energy Test Site (NETS), Oregon
- The PMEC South Energy Test Site (SETS), Oregon
- Puget Sound and Lake Washington, Washington, and
- The Tanana River Test Site (TRTS), Alaska.

Table 3-9 Summary information for the PMEC test and demonstration sites

Site	North Energy Test Site (PMEC-NETS)	South Energy Test Site (PMEC-SETS)	Puget Sound / in Lake Washington	Tanana River Test Site (TRTS)
Technology	WEC	WEC	WEC	TEC
Location	Newport, OR	Newport, OR	WA	Nenana, AK
Status	In operation	Planned	In operation	In operation
Water depth	45-55m	65-78m	Unknown	Unknown
Connection points	1	4	Unknown	Unknown
Capacity	Up to 100kW (not grid connected)	Up to 20MW (grid connection)	Unknown	Unknown
Average resource (H_s in m, current speed in m/s)	Winter: 2-5m; Max 7-14m	Unknown	~1/7 of Pacific conditions	Winter: 1.27m/s; Summer 2.96m/s.

The PMEC-NETS site is in operation since summer 2012. Located at Newport, OR (4 to 6km from shore), the open-ocean test site is 3.5km^2 (1 square nautical mile). The site is currently capable of hosting devices up to 100kW when connected to the Ocean Sentinel instrumentation buoy, or of larger devices if self-contained, for testing from May through to September. It offers a portfolio of capabilities to research all aspects of technology development (technology, environment, social). Devices can continue to operate in the ocean test site throughout the year to study other aspects of their devices, such as survivability, biofouling, mooring and anchoring, environmental effect, and other important aspects of their technologies.

The test site is located at depth ranging from 45 to 55m, with sand seabed. Significant wave heights average 1-2.5m during summer months at 6-9s energy periods. During winter months these increase to 2-5m significant wave heights at 8-12s energy periods, with maximum significant wave heights of 7-14m.

The Northwest National Marine Renewable Energy Center (NNMREC) has characterised the environmental conditions of the site, and has conducted a range of environmental monitoring activities, including baseline studies for benthic habitat, marine mammal observations, electromagnetic frequency studies (EMF), and acoustics. The site is fully permitted through the NEPA process, Department of State Lands, the US Coast Guard, and the Army Corp of Engineers.

The WET-NZ WEC was deployed from late August to early October 2012 and monitoring studies were performed at the test site prior to, during and after the deployment [26].

In parallel, NNMREC is currently in the permitting phase to develop the South Energy Test Site (SETS). SETS will feature full-scale, grid connected testing capabilities. The SETS facility will allow WEC devices to be certified to international standards (e.g. Institute of Electrical and Electronics Engineers, IEEE). SETS will include multiple connection points, and will be a leading source of research, which will help to answer some of the core questions concerning the industry.

PMEC-SETS will be the NNMREC facility where developers can test utility scale WECs in the ocean with a connection to the electric utility grid via a subsea cable; four connection points are planned. PMEC-SETS is being designed to accommodate single devices, or small arrays in a berth. The anticipated depth range for PMEC-SETS is 65-78m.

The Puget Sound and Lake Washington test sites offer open water testing for intermediate scale WEC devices. These environments provide 1:7 scale WEC testing compare to the PMEC open-ocean site conditions, and are available from October through to March.

Finally, the Tanana River Test Site provides facilities for testing of hydrokinetic devices, infrastructure and environmental monitoring techniques. The test site is open between May and September each year. NNMREC experts at University of Alaska Fairbanks provide support with hydrological and environmental measurements including measurements of mean flow, turbulent fluctuations, bathymetric surveys, fisheries interaction monitoring and device power performance.

3.2.2 California Wave Energy Test Center (CalWave), California, U.S.

CalWave is proposed to be a U.S. national wave energy test center, located in California, providing an opportunity for WEC developers to test their devices in an open-ocean environment.

The four CalWave connection points will be located approximately 10km offshore of Vandenberg Air Force Base and power will be carried on-shore through sub-sea transmission cables. Wave energy devices will provide power directly to Vandenberg and will also interconnect to the broader California electric grid. CalWave will be designed to test different marine energy technologies in each of the four connection points [27].

It is anticipated in [27] that the environmental permitting would be completed by the end of 2018, constructing the facility in 2019-2020, gradually bringing the facility online in 2021-2022, and beginning full operations in 2022.

3.2.3 Hawaii National Marine Renewable Energy Test Center (HINMREC) / WETS, Hawaii, U.S.

The Wave Energy Test Site (WETS), located in Kaneohe Marine Corps Base Hawaii (MCBH), comprises three connection points at water depths ranging from 30 to 80m. WEC devices in the 10kW to 1MW range can be accommodated.

The U.S. Navy and the DOE have to date selected four companies for testing at the deep berths from 2016 through 2018 [28]:

- Sound and Sea Technology deployed Fred Olsen's point absorber Lifesaver in March 2016 for 1 year [29], and a redeployment is planned for the end of 2017 [30]
- Ocean Energy, USA, is planning to deploy a 500kW OWC device in May 2018 for 1 year; the manufacturing of the device was planned to begin in October 2017 [31].
- Columbia Power Technologies is planning to deploy a 500kW point absorber StingRay for 1 year in 2018
- Following a 1-year deployment of a 20kW Azura WEC prototype at the 30m depth berth in 2015, NWEI plans to deploy a full-scale device rated between 500kW and 1MW at one of the deeper berth over the next several years [32].

3.2.4 New Zealand Marine Energy Center (NZMEC), New-Zealand

In 2015, the establishment of a marine energy testing facility, the New Zealand Marine Energy Centre ("NZMEC" or "the Centre") located in the Wellington region, was described in a business case to the Ministry for Business, Innovation and Employment [19]. More recently, the Green Party of New Zealand has put forward this plan as part of the transition away from oil drilling, in the context of general elections campaign [33].

The balance of investment requirements would be provided as in-kind private sector funding from a multinational firm. NZMEC's testing facilities will be located on up to four sites at Baring Head, Moa Point, Cape Terawhiti and Kapiti to provide ocean based pre-commercial scale testing services for wave and tidal energy device developers from nursery (prototype/pilot) through to full-scale, grid connected devices. The development is currently on hold awaiting investment.

3.2.5 Nagasaki Marine Industry Cluster Promotion Association (NaMICPA), Japan

In 2013, a 2MW FWT was installed near Kabashima Island, Goto city, Nagasaki [34]. The turbine was deployed at about 100m water depth, 1km away from the shore, in an annual average wind speed field of about 7.5m/s at hub height (c.60m).

In 2015, the Nagasaki Prefecture announced its plan to extend the Goto floating wind power demonstration site and selected three sites dedicated to marine energy testing [35]:

- Hisaka-jima island, Goto city, as nursery site for TEC devices
- Eno-shima and Hira-shima islands, Saikai city, as full-scale site for TEC devices
- Kaba-shima island, Goto city, as full-scale site for FWT devices.

The European Marine Energy Centre (EMEC) signed a contract to provide advice on the development of a marine energy test facility in Nagasaki Prefecture, Japan [36]. EMEC will advise on the infrastructure needed to develop a test site, from subsea cables, and grid connection to resource data instrumentation.

3.2.6 China

China established a special fund for renewable ocean energy in May 2010. In 2015, the government announced its plan to construct three ocean energy test sites off the coast of Shandong, Zhejiang and Guangdong provinces ([19], [37]):

- The Shandong site, located at the Weihai Port, will be a shallow water test site. In 2016, the site had completed the preparation for subsea cable system development. The subsea cable is an interconnection hub that will connect the test platform to the test centre. Subsequently, the site committed to start the operation of the monitoring centre.
- The Zheijiang site, located in Zhoushan Islands, will be a full-scale tidal current energy test site. It was announced in 2016 that the feasibility study had passed the inspection of the State Oceanic Administration (SOA) to initiate the comprehensive demonstration project.
- Finally, the Guangdong site, located in Wanshan, will be a full-scale wave energy test site. The 1100m^2 land area was authorised for use in November 2016, and the permit application for the sea areas was still in progress.

3.3 Sector Review Summary

Table 3-10 and Table 3-11 provide a summary of the key information presented in this section for the Level 2 sites.

Table 3-12 and Table 3-13 provide a summary of the key information presented in this section for the Level 3 sites. Although the level of information available is limited, the tables aim to facilitate the comparison of the status and readiness of the Level 3 sites with those in Level 2.

Table 3-10 Summary information for the Level 2 test sites: infrastructure and other key features (Part 1/2)

Category	Criteria	Wave Hub	FaBTest	AMETS	BiMEP
Test Site General Characteristics	Status	Operational, devices have been deployed	Operational, devices have been deployed	Planned	Operational, devices have been deployed
	Type of technology	WEC and FWT	WEC, TEC	WEC	WEC
	Type of scale targeted	Full-scale	Nursery	Full-scale	Full-scale
	Expansion strategy	Potential to upgrade to 48MW	Possible expansion to FWT	Possible expansion to shallow depths / other technologies	Possible expansion to FWT / up to 50MW by 2020
Grid Connection	Export cable	Installed	Not planned	Planned	Installed
	Rated capacity	30MW (existing)	N/A	Planned - 4 cables @ 11 kV. 10MW	4x5 MW cables @ 13.2kV
	Connection points	4	3	4 (planned)	4
Onshore Features	Proximity to port/shipyard	16km off the coast of Hayle Over 100km from Falmouth	Up to 5km from Falmouth	Frenchport Pier	2km from Armintza harbour 15km from Bilbao port
	Storage facilities (warehouse/quayside)	Large capacity, available in Falmouth	Large capacity, available in Falmouth	Unknown	Large capacity, available in Armintza and Bilbao ports
	Housing of personnel	No	No	No	No
	Characteristics of land access	Train line and motorways / A roads serving Hayle	Train line and motorways / A roads serving Hayle	Unknown	Highway serving Armintza
	Proximity to airport	Bristol airport >250km	Bristol airport >250km	Far (>100km)	15km from Bilbao airport
Offshore Features	Support vessels	Available through the local supply chain	Available through the local supply chain	Unknown	Outsourced
	Pre-installed moorings	Not planned	No	No	No
	Soil type	Areas of outcropping bedrock and gravelly sand	Rock, gravel and sand seabed	Sand close to shore with rock further out	Rock and sand
	Measurement equipment	Installed 22 May 2015 is a Datawell Directional Waverider DWR-MkIII	Oceanor Seawatch Mini II wave, Datawell Waverider Mk3, ADCPs	Directional Waverider + Metocean buoy	Oceanor Wavescan buoy
	Communication to shore	12 optic fibres	UMTS (3G) and LTE (4G) services with HSDPA / HSUPA	Unknown	Radio and / or satellite communication

Table 3-11 Summary information for the Level 2 test sites: infrastructure and other key features (Part 2/2)

Category	Criteria	PLOCAN	Ocean Plug	Runde Environment Centre	DanWEC
Test Site General Characteristics	Status	Operational, devices have been deployed	Planned	Operational, devices have been deployed	Operational, devices have been deployed
	Type of technology	FWT, WEC, others	FWT, WEC	WEC	WEC
	Type of scale targeted	Nursery scale or 'benign' testing of larger scale devices	Full-scale	Intermediate / Full-scale	Intermediate / small scale prototypes
	Expansion strategy	Expansion planned up to 50MW by 2020	Planned	No	Planned
Grid Connection	Export cable	Planned	Planned	Installed	Planned
	Rated capacity	Initial capacity is set up at 15MW	4 connection points of 3MW for test area	0.5MW	Unknown
	Connection points	2	4	Unknown	Unknown
Onshore Features	Proximity to port/shipyard	1.5km off the coast – support base: Las Palmas	Figueira da Foz 35km; Peniche 92km	400m from Runde Port	2-4km from the Port of Hanstholm
	Capacity of storage facility	Small capacity, available on platform	Large capacity, available in Figueira da Foz	No	Large capacity, available at Hanstholm Port
	Housing of personnel	Yes	No	Yes	Yes
	Characteristics of land access	Access by boat or heliport	National roads serving S. Pedro de Moel	Accessible by boat or car	National road and train
	Proximity to airport	International airport in Las Palmas (<10km)	60km from Lisbon	Ørsta-Volda airport (c. 50km); Ålesund airport (c. 100km)	About 100km to Aalborg airport
Offshore Features	Support vessels	Available	Unknown	No	Available
	Pre-installed moorings	No	No	No	Unknown
	Soil type	Predominant sand and rocks	Sand	Sandy with bedrock / cobbled areas	Sand and silt, with some areas of exposed chalk
	Measurement equipments	Waverider until January 2014, replaced by Triaxys directional	One multi-parameter buoy	Wave measuring buoy	2 Waverider buoys
	Comm. to shore	N/A	Unknown	Unknown	WiFi and fibre

Table 3-12 Summary information for the Level 3 test sites: infrastructure and other key features (Part 1/2)

Category	Criteria	PMEC	CalWave	WETS
Test Site General Characteristics	Status	NETS, Puget Sound, TRTS: Operational; SETS: Planned since 2014	Planned since 2013	Operational since 2003
	Type of technology	NETS, SETS, Puget Sound: WEC; TRTS: TEC	WEC	WEC
	Type of scale targeted	Intermediate and full-scale	Full-scale	Full-scale
	Expansion strategy	SETS: Grid connected, full scale site under development	-	Expansion planned to deeper depths (60m and 80m) with rated capacities of 100kW and 1MW, respectively
Grid Connection	Export cable	Planned at PMEC-SETS	Planned	Existing
	Rated capacity	NETS: Up to 100kW; SETS: Planned for up to 20MW	Cables rated at 10MW/ 25kV; VAFB substation rated at 70kV	250kW
	Connection points	NETS: 1; SETS: 4 planned	4	3
Onshore Features	Proximity to port/shipyard	NETS, SETS: 5km to Newport, Oregon	10km offshore of VAFB; 130km from deep water harbour Port Hueneme	About 2km from Kaneohe Between 50-100km from Pearl Harbor
	Capacity of storage facility	NETS, SETS: Large facilities operated by Port of Newport	Very large vessels, large cranes and dockside storage facilities at Port Hueneme	Storage waterside at Marine Corps Base; Large warehouse / quayside capabilities at Pearl Harbor
	Soil type	Sand	Sand, with rocky outcroppings	Combination of rock, sand, and coral
	Measurement equipment	Triaxys buoy since 2014	2 met-ocean buoys 4 meteorological stations	3 Waverider buoys, 1 ADCP

Table 3-13 Summary information for the Level 3 test sites: infrastructure and other key features (Part 2/2)

Category	Criteria	NZMEC	JMEC	China
Test Site General Characteristics	Status	Planned since 2015	Planned since 2015	Planned since 2015
	Type of technology	WEC, TEC	FWT, TEC	TEC, WEC
	Type of scale targeted	Nursery, intermediate, full-scale	Full-scale	Intermediate, full-scale

4 CUSTOMERS – INDUSTRY TEST SITE INFRASTRUCTURE REQUIREMENTS

A third aspect influencing the positioning of the FORESEA test sites is the dominant features of their potential customers. Having assessed both the capabilities (Section 2) and the potential competitors (Section 3) of the FORESEA test sites, it is key to accurately profile the potential customers, identifying and where possible predicting their current and future needs.

This section outlines the findings of a stakeholder consultation exercise completed to ascertain the particular requirements and interests of potential users of open-ocean test sites for marine renewable energy technologies. Following an overview of the consultation approach (Section 4.1), the dominant characteristics of potential target customers for the FORESEA test sites are drawn from the analysis of the survey results (Section 4.2). Additionally, notes on the future customer needs and requirements are also extracted from the responses (Section 4.3). CA notes that the stakeholder consultation is also presented in [3], to facilitate its reading. The key findings of the consultation that focus on infrastructure requirements are summarised in Section 4.4.

These results and findings from the consultation exercise are instrumental in guiding final investment decisions related to both infrastructure (see Section 5 of this report) and service offering (see Section 5 of [3]) of the FORESEA sites.

4.1 Overview of the Approach

An online stakeholder survey was conducted between the 18th of October and the 15th of November 2017. Based on the evaluation criteria defined in Phase 1 [2], CA drafted 34 survey questions that were reviewed and approved by ECN, OEE and the FORESEA test sites members. The survey was designed to capture the main requirements of the potential customers, in a format capable of being completed in approximately 10 minutes.

The potential customers targeted included technology, project and component developers identified as being likely to invest in or conduct ocean deployments within a 5- to 10-year timeframe. The topics covered by the survey focused on technologies and subcomponents for wave, tidal and floating wind energy sectors, and included:

- An overview of the respondent’s technology and testing status.
- Information regarding a respondent’s future short to long term testing plan.
- General requirements regarding the ideal infrastructure of a test site (e.g.: grid connection, onshore and offshore features).
- General requirements regarding the services provided by a test site (e.g.: consenting status of the site, connection to the supply chain, areas of support).

The stakeholder survey was disseminated via the following methods:

- Based on the list of targeted entities identified in Phase 1 [2], 96 selected entities were contacted via email by CA on behalf on Ecole Centrale de Nantes with a direct invitation to participate in the survey. A flyer outlining the project background and aims, including a link to the online survey was provided in attachment to the invitation emails. The flyer was drafted by CA and circulated to ECN for approval [38].
  Public advertisement of the consultation, with a link to the survey, issued on various media platforms, including LinkedIn [39], Interreg North-West Europe FORESEA's website [40], Tidal Energy Today's news [41].

- A flyer containing a link to the survey [42] was distributed during the Ocean Energy Europe conference in Nantes (24th to 26th of October 2017).

At the time of the survey closure, a total of 53 responses had been received. The following sections present the aggregated survey responses, split into two distinct parts:

- Overall description of the respondent's technology and development status (see Section 4.2), including:
  - Technology developed
  - Estimated TRL and funding spent to date
  - Past open-ocean testing activities
- Future customers' needs and requirements (see Section 4.3), including:
  - Short to long term testing plan
  - Ideal infrastructure at a test site
  - Services provided by a test site

4.2 Profiling the Target Customers

To initiate the profiling of the potential customers of the FORESEA test sites, survey respondents were asked to specify which type of technology they are developing. From a total of 53 responses, roughly 60% of respondents selected wave energy technologies (see Figure 4-1). This was followed by tidal technologies (approximately 15%), subcomponents (9%), floating wind (approximately 8%) and others (9%), which includes e.g. OTEC, floating solar, etc.

As a minimum, the dominant interest of the respondents in wave energy technologies allows the results related to this category to be considered with additional confidence. The interest of respondents in these types of technologies may also allow inferences regarding the type of client to be targeted by FORESEA test sites (see Section 5).

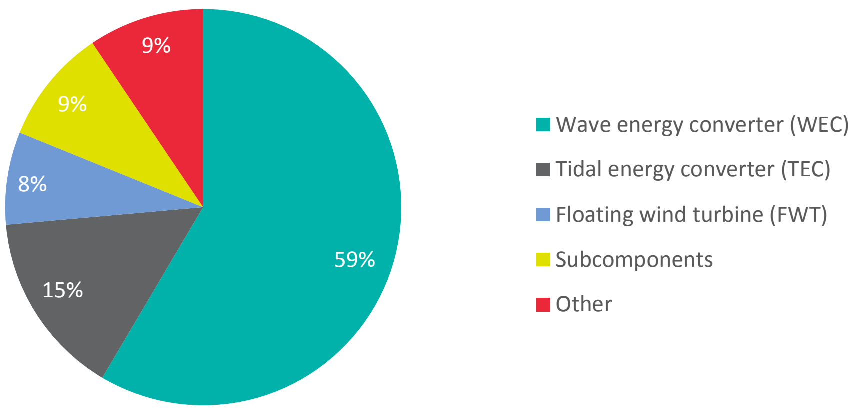

Figure 4-1 Responses to the FORESEA consultation: type of technology breakdown

Although the responses are assessed per technology type in the following subsections (Sections 4.2.1 to 4.2.5), generic findings can also be gathered when assessing two key features: technology development stage (measured via TRL) and funding to date. At a high-level, these can be summarised as follows:

- From all the respondents, 25% consider themselves to be in a low TRL (1 to 3), while over 45% believe they are at an intermediate TRL level (4 to 6) – see Figure 4-2.
- Approximately 50% of all respondents have spent less than €5m to date in their development programmes – see Figure 4-3.

These high-level results are, in CA's opinion, indicators of the early stage nature of the developments associated with the respondents to the FORESEA consultation exercise. These salient features are explored when considering the positioning of the FORESEA sites (see Section 5).

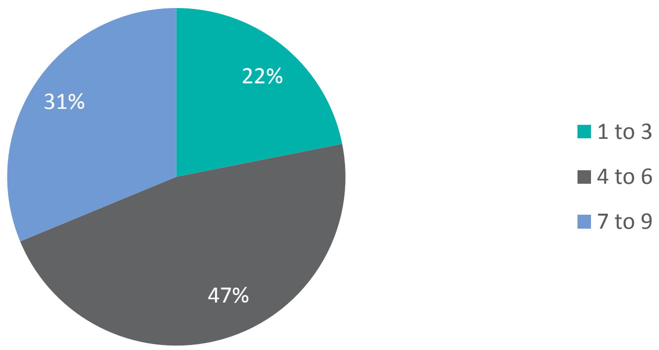

Figure 4-2 Responses to the FORESEA consultation: TRL breakdown

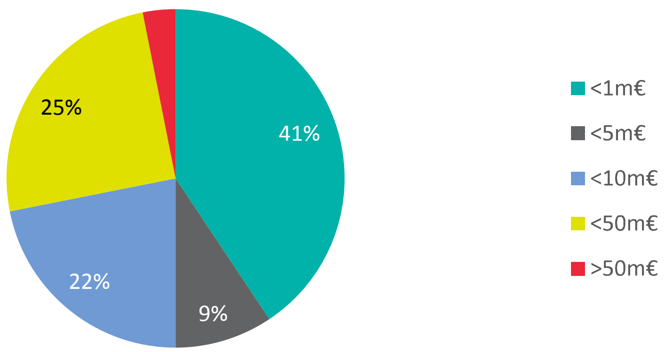

Figure 4-3 Responses to the FORESEA consultation: funding spent to date

4.2.1 WEC Developers

A series of six initial questions in the survey specifically targeted respondents with an interest in wave energy technologies (identified from the response to Question 1). Figure 4-4 to Figure 4-8 illustrate some of the responses received. The key findings from the responses are also summarised in the points below.

- From the 19 responses, 7 (approximately 37%) identified point absorbers as the type of WEC under development. This finding is consistent with recent industry consultation exercises – see e.g. [43].

- Over 60% of the respondents (12 out of 19) claimed to be at TRL ≤ 5. In CA's opinion, this is consistent with the current status of the wave energy industry and a reflection of the maturity of such market.
- A similar conclusion can be made when analysing Figure 4-6: over 40% of the respondents (8 out of 19) identified the spending to date as lower than €1m.
- Despite the early-stage nature, over 50% of the respondents have confirmed to have completed open-ocean testing in the past (see Figure 4-7). From the replies to an adjacent question (see Figure 4-8), CA understands that the majority of such deployments occurred in nursery / sheltered locations, as well as intermediate scale test sites.
- Finally, respondents were asked to confirm their interest in using open-ocean test facilities and all confirmed an interest.

The features listed above may be explored when considering the positioning of the FORESEA sites, aiming to couple the specific needs of this customer type with the infrastructure / service offering (see Section 5).

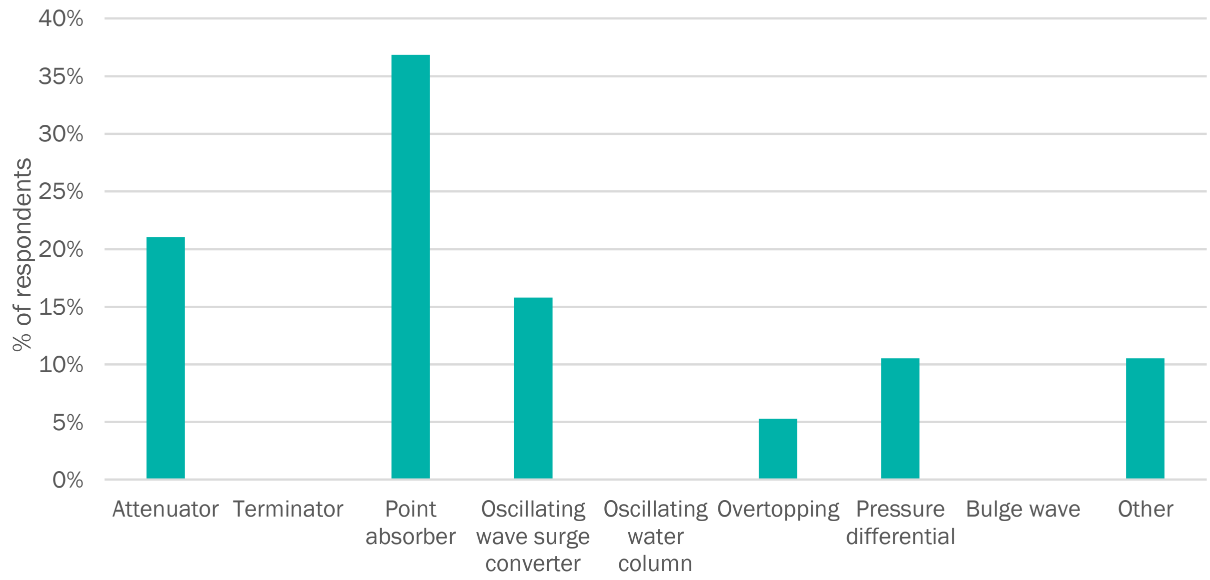

Figure 4-4 Responses to the FORESEA consultation: type of WECs under development

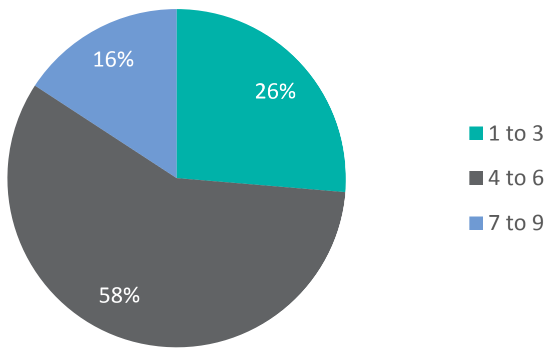

Figure 4-5 Responses to the FORESEA consultation: TRL of WEC technologies

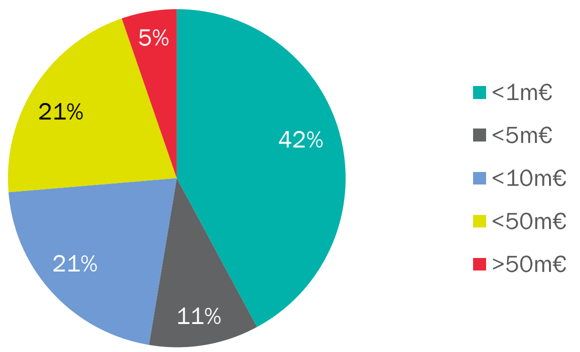

Figure 4-6 Responses to the FORESEA consultation: funding spent to date in WEC development

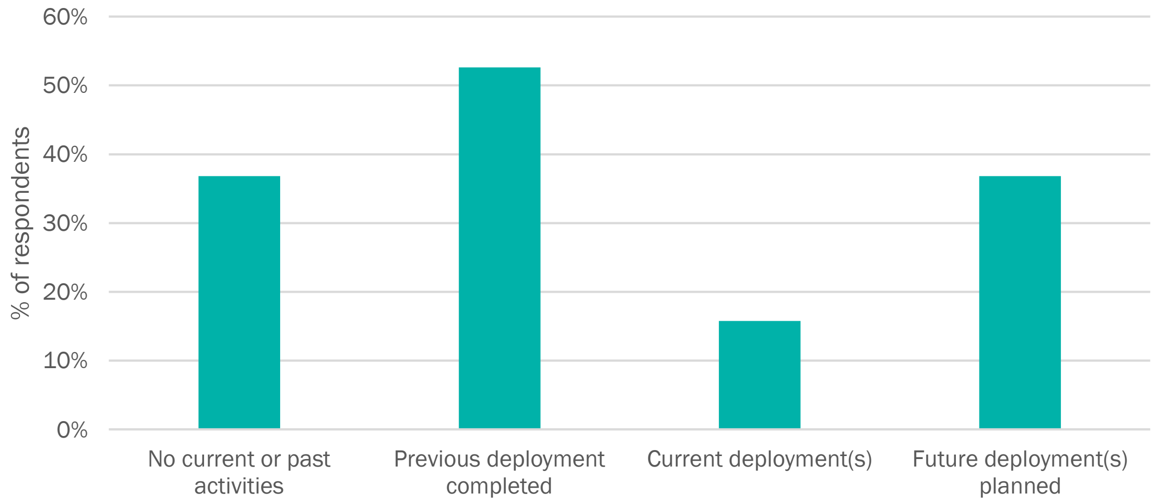

Figure 4-7 Responses to the FORESEA consultation: status of open-ocean test activities (WECs)[3]

[3] Note that respondents could select multiple answers, therefore the total is above 100%.

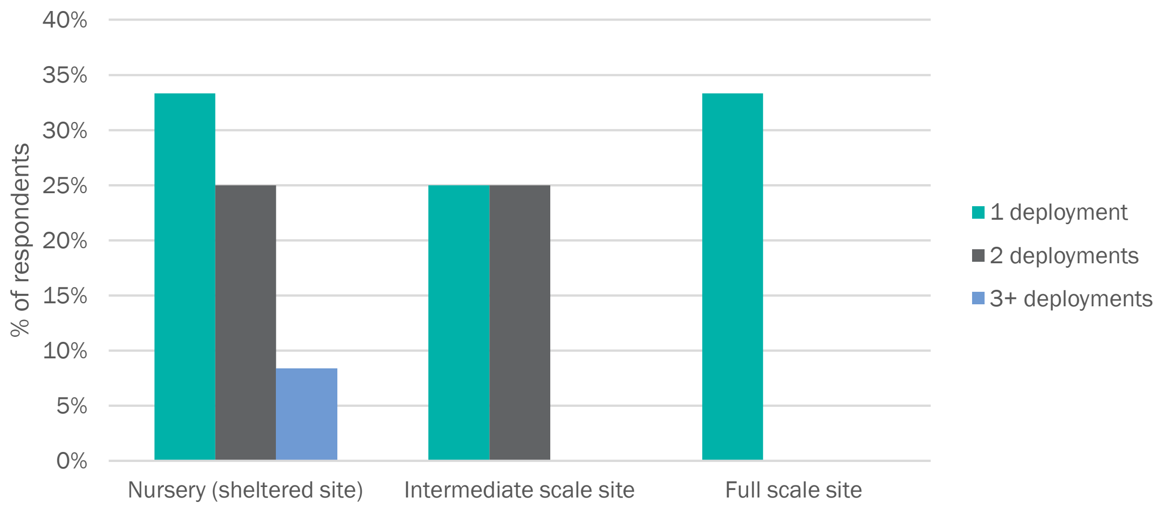

Figure 4-8 Responses to the FORESEA consultation: nature of previous open-ocean test activities (WECs)

4.2.2 TEC Developers

Similar to the analysis documented in Section 4.2.1, specific commentary can be made with regard to TEC technologies. While noting the reduced sample size, the following key notes can be inferred from the responses to the FORESEA survey:

- The majority of the respondents are developing a horizontal axis TEC.
- Higher TRLs (≥6) and higher levels of funding have been spent to date, when compared to the WEC related responses (min < €10m).
- There is wider experience in past, current and planned deployments, particularly at full-scale.
- The majority of respondents still show an interest in open-ocean test sites, although the consensus is not as unanimous as in the WEC case (reference to site ownership is made is the situations were no interest is declared).

Overall, and although limited in number, the responses from those interested in TEC technologies, reveal experience in previous deployments, multiple scales leading to full-scale, across multiple sites. These characteristics, along with the predisposition / capability to allocate wider amounts of funding, may be explored when considering the positioning of the FORESEA sites (see Section 5).

4.2.3 FWT Developers

A third type of potential customers identified for the FORESEA test sites are represented by floating wind technology (FWT) developers. The following key characteristics can be drawn for FWT developer responses:

- All the respondents estimated the level of development of their technology at high TRLs (≥7).
- Past open-ocean deployments have taken place at full-scale already.
- The respondents did mark an interest in open-ocean test sites.

Although the responses from FWT technology developers reveal experience in open-ocean deployments, the limited number of responses may also be a sign of lack of interest from this specific sector, more willing to develop private sites or deploy at commercial scale.

These specificities should be considered when deriving the positioning of the FORESEA sites (see Section 5).

4.2.4 Subcomponents Developers

Developers of subcomponents / subsystems were also specifically targeted in the FORESEA consultation exercise. Noting the limited number of responses, the following characteristics for subcomponent developers can be extracted when analysing the survey replies:

- PTO developers and metocean equipment providers responded to the survey.
- TRLs of 5-6 were identified as the current readiness levels, with limited amounts of funding to date (few €m).
- The respondents did not exhibit any previous or current experience in open-ocean testing. However, future deployments are planned and a strong interest in doing so is clear.

The similarities of these characteristic with those connected with other types of customers (e.g. WEC developers; see Section 4.2.1) may be considered in the positioning exercise for the FORESEA sites (see Section 5).

4.2.5 Other Stakeholders

Aside from the four types of potential customers identified for the FORESEA test sites and characterised in the above subsections, a number of other respondents provided their feedback to the survey. Overall, no particular trend can be drawn from the responses, given the reduced size of the sample and the disparity in the answers. A summary of responses under the category of '*Other*' technology types are listed below:

- Respondents to the '*Other*' technology type category are developing e.g. river energy systems, floating solar technologies, or wind / tidal / solar energy farms.
- The estimated level of development for these technologies covers a large range of the TRL scale (from TRL 2 to TRL 7).
- The level of funding spent to date is consistently below 10m€.
- Technologies that have reached a high TRL and spent a larger amount of funding to date reveal experience in previous deployments, at multiple scales leading to full-scale and across multiple sites.
- In general, there is a large interest in open-ocean test sites, although some particular cases referred to e.g. requirement of benign bodies of water to justify a lack of interest.

4.3 Future Customers' Needs and Requirements

In this section, the future needs and requirements of the potential open-ocean test sites' customers are analysed. Following the structure of the survey, the section is split into five main topics:

- Target / planned development horizon at open-ocean test sites: Section 4.3.1
- Important infrastructure requirements: Section 4.3.2
- Important service requirements: Section 4.3.3
- Attractive features of open-ocean test sites: Section 4.3.4
- Ideal leasing settings, both in terms of duration and fees: Section 4.3.5

Finally, the section concludes with a summary of the consultation findings in Section 4.4, gathering the key outcomes of the survey in terms of infrastructure requirements, to guide the market positioning exercise of the FORESEA test sites and the provision of strategic recommendations in Section 5.

4.3.1 Target / Planned Development Horizon at Open-Ocean Test Sites

Overall, based on the survey results the respondents interested in open-ocean testing are targeting deployments between nursery and intermediate scale sites in the short term (next one to next five years), shifting to full-scale sites in the medium to long term (within five to ten years). This trend is illustrated in Figure 4-9.

The survey responses indicate that although the desire to test at nursery and intermediate scale is important to consider in the short term, full-scale, grid connection testing becomes important in the medium horizon and is likely to dominate the open-ocean testing requirements from then on.

In terms of target deployments per technology type, the survey responses indicate that:

- In general, both WEC and TEC survey respondents are targeting deployments at multiple scales leading to full-scale testing. Note that, similar to FWT developers, TEC developers and most of the WEC developers indicated that they ultimately require grid connection.
- Floating wind technology developers plan to progress from intermediate scale sites to full-scale grid connected within the next five years. Survey respondents did not specify a requirement for nursery sites, nor for full-scale sites without grid connection.
- Survey responses from subcomponent developers indicate a plan to deploy at nursery test sites next year only, and then progress to full-scale sites within the next five years. No deployment at intermediate scale sites is indicated as a requirement from survey respondents.

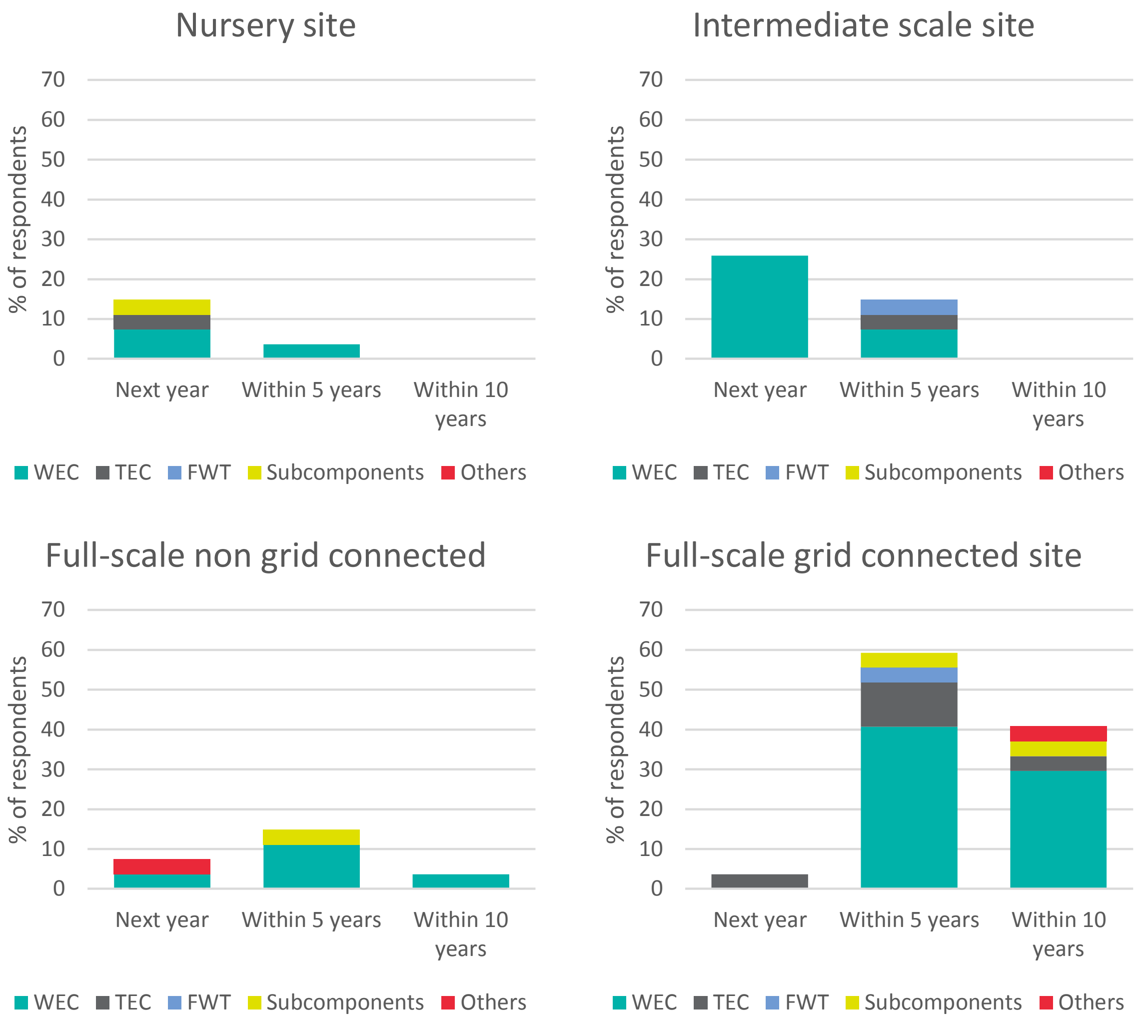

Figure 4-9 Responses to the FORESEA consultation: target / planned development horizon to use open-ocean test facilities in the 10-year horizon

4.3.2 Important Infrastructure Requirements

In the survey, respondents were asked to qualify the importance of different test site infrastructure for their planned deployments (see Figure 4-10).

Overall, the availability of support vessels, grid connection and a communication cable, and the proximity to a port are typically viewed as critical factors for survey respondents, with more than 60% of the respondents flagging them as '*very important*'. Only two respondents stated that grid connection was '*not important*', one of them noting that the electricity generated by their WEC is directly used to produce hydrogen on deck.

Availability of real time resource measurements, on-shore facilities, on-shore accessibility and available capacity, although still important, are seen as less critical, with respondents generally split between '*very important*' and '*may be interested*'. In terms of on-shore facilities, one responded commented that a slipway or pontoon with cost effective access would be required at the port, with suitable deep water and cranes readily available during operation.

Pre-installed anchors and mooring points rank lasts in the developers' requirements, with 16% and 32% of the respondents qualifying them as '*not important*', respectively. In CA's experience, developers typically want to use their own proprietary moorings, or need to test different arrangements / layouts that pre-installed moorings could potentially prohibit.

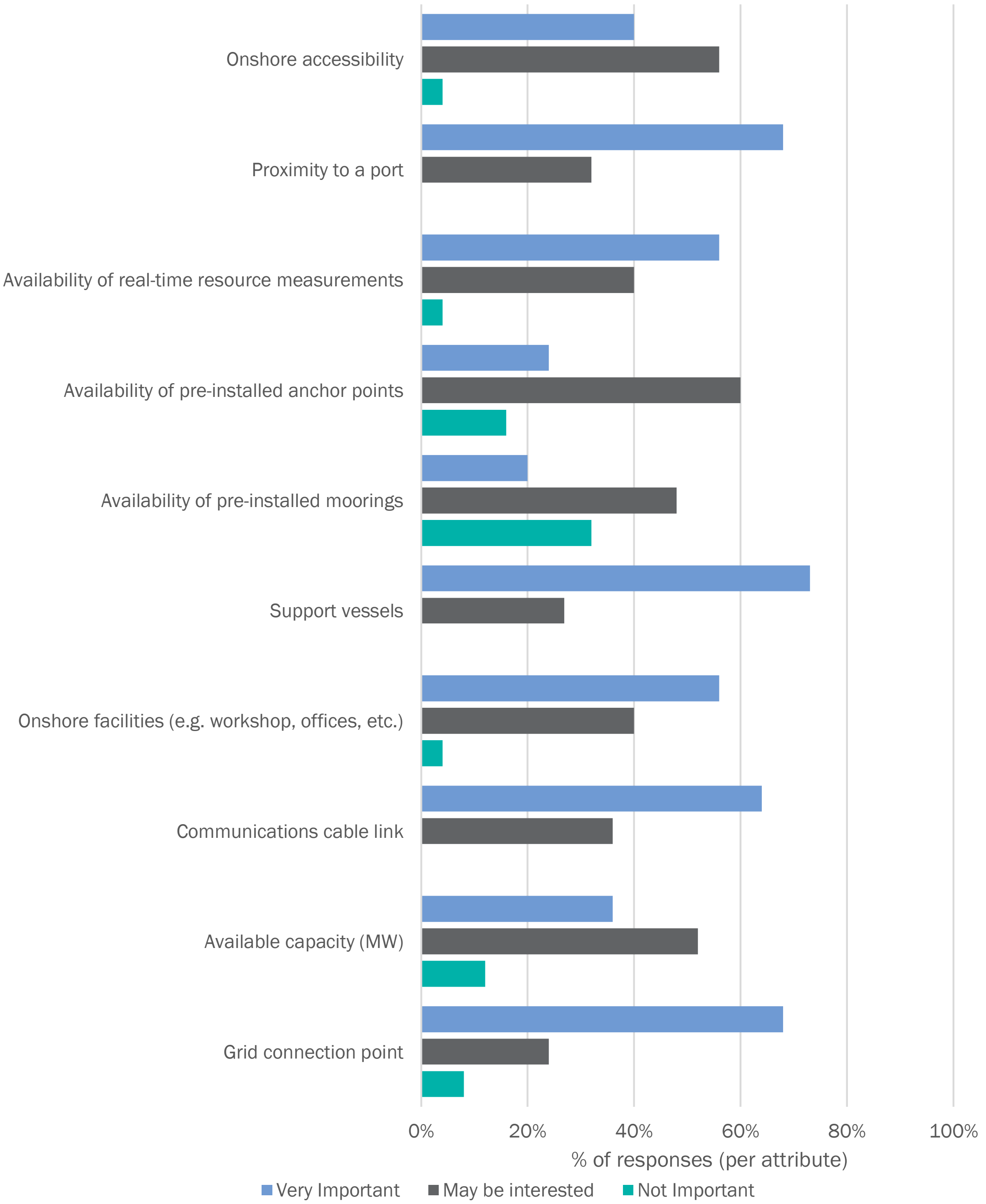

Figure 4-10 Responses to the FORESEA consultation: important infrastructure requirements at an open-ocean test site

Based on the results illustrated in Figure 4-10, Figure 4-11 displays the required open-ocean test site infrastructure ordered by level of importance, estimated from the survey responses as follows: a score of 10 was given to the '*very important*' answer; a score of 5 to the '*may be important*' answer; and a score of 1 to the '*not important*' answer. The total score for each type of infrastructure was then divided by the number of responses (26) times the maximum score (10), to obtain a representative average (presented in Figure 4-11 as a percentage).

It should be noted that the averaged order of importance is similar for all categories of developers (WEC, TEC, FWT and subcomponents) and all level of development (high to low TRLs).

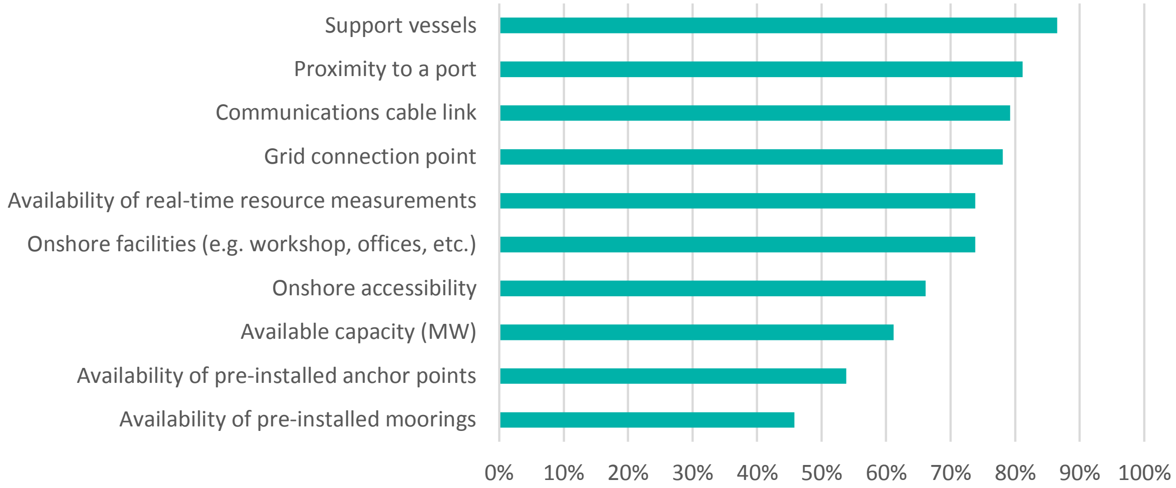

Figure 4-11 Averaged order of importance for the required infrastructure at an open-ocean test site: the higher the percentage, the more important the infrastructure requirement, based on survey responses

Overall, the requirements and priorities in terms of infrastructure are relatively similar between the different types of customers – these similarities can be exploited when considering the development strategies of the infrastructure (see also Section 5)

4.3.3 Important Service Requirements

In the survey, respondents were also asked to qualify the importance of key services offered (directly or subcontracted) by an open-ocean test site (see Figure 4-11).

Overall, the most important services flagged by the developers were support services relating to consenting and funding/ grant applications, and access to incentives or support mechanisms of test programmes, with more than 60% of the respondents qualifying such services as '*very important*'. Only two respondents (one WEC developer, one subcomponent developer) ranked the services for funding / grant application and access to incentives or support mechanisms as '*not important*'. These developers had secured a significant amount of funding for one and a grant for open-ocean deployments for the other, which may explain the reduced interest in related support.

The interest in support to resource monitoring activities is equally split between '*very important*' and '*may be interested*' (48% each), whilst the other service categories all score about 60-70% of '*may be interested*' and about 30-40% of '*very important*'. These include support services to device development, environmental monitoring activities, operational support, local stakeholder engagement, specialist support for offshore inspections and provision of supply chain connections.

A specific comment from one respondent is well aligned with the overall results, stating that developers would typically require services to support any activities not related to their core engineering expertise, such as '*securing funding, revenue support, consenting and accessing the grid. These are the things that the centre should be doing in order to enable developer to stay on mission*'.

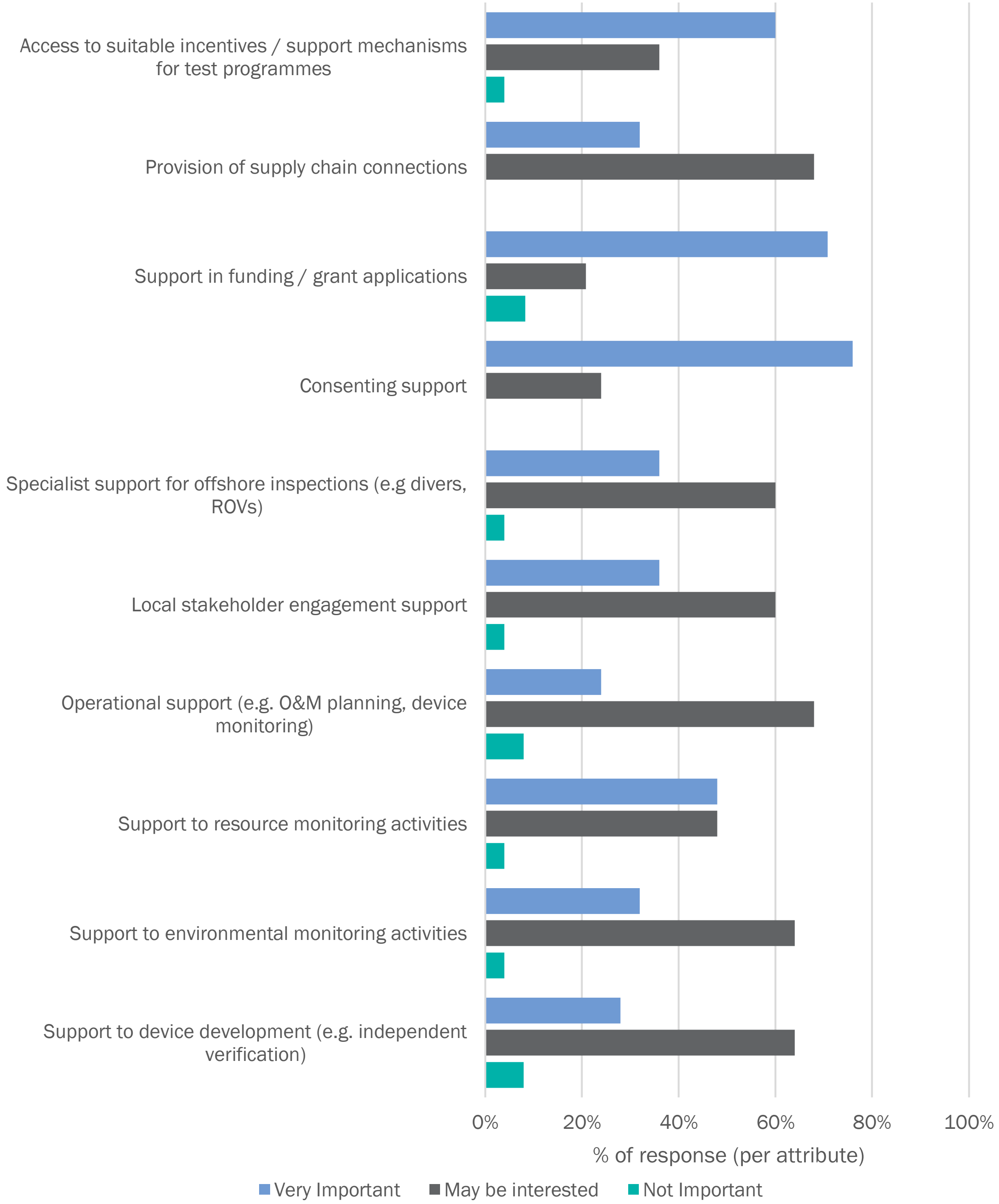

Figure 4-12 Responses to the FORESEA consultation: important service requirements at an open-ocean test site

Based on the results illustrated in Figure 4-12, Figure 4-13 displays the required services ordered by level of importance, estimated from the survey responses as follows: a score of 10 was given to the ‘*very important’* answer; a score of 5 to the ‘*may be important’* answer; and a score of 1 to the ‘*not important’* answer. The total score for each type of service was then divided by the number of responses (26) times the maximum score (10), to obtain an average. The results are presented in percentages.

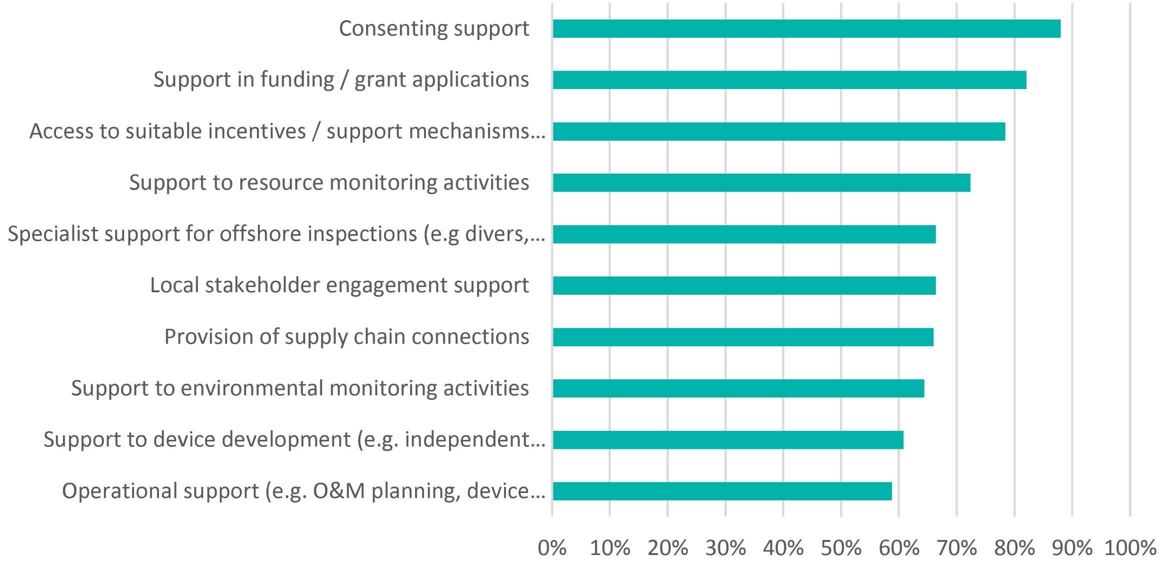

Figure 4-13 Averaged order of importance for the required services at an open-ocean test site: the higher the percentage, the more important the service requirement, based on survey responses

When analysing the Figure 4-13 ranking by experience level, it can be seen that developers with more open-ocean testing experience (TRL>5, with previous deployment completed) value more a support to local stakeholder engagement, while the connection to the supply chain is seen as more important to lower TRL developers (TRL <4), along with support to offshore inspections.

Considering the range of requirements and differences in priorities by the different types of customers, the test sites operators may consider a flexible approach in terms of the services provided – further discussion on this topic is presented in Section 5.

4.3.4 Attractive Features of Open-Ocean Test Sites

Surveyed entities were asked to rank ten features that would attract them to an open-ocean test site by order of importance (1 being the most important, 10 the least important). Figure 4-14 shows the averaged results from all the survey responses.

On average, faster consenting and readiness of infrastructure are shown as the most attractive features of an open-ocean test site. The former is the clear priority for developers currently at a low TRL (<4), along with the range of services and lower risk approach. For developers currently at a higher TRL (>6), the ability to test several design iterations is also of importance, which should be considered when deriving recommendations for the test sites’ development strategies (see Section 5). On the other hand, potential partnerships between facilities for smooth progression during testing programmes is not seen as a priority for the survey respondents.

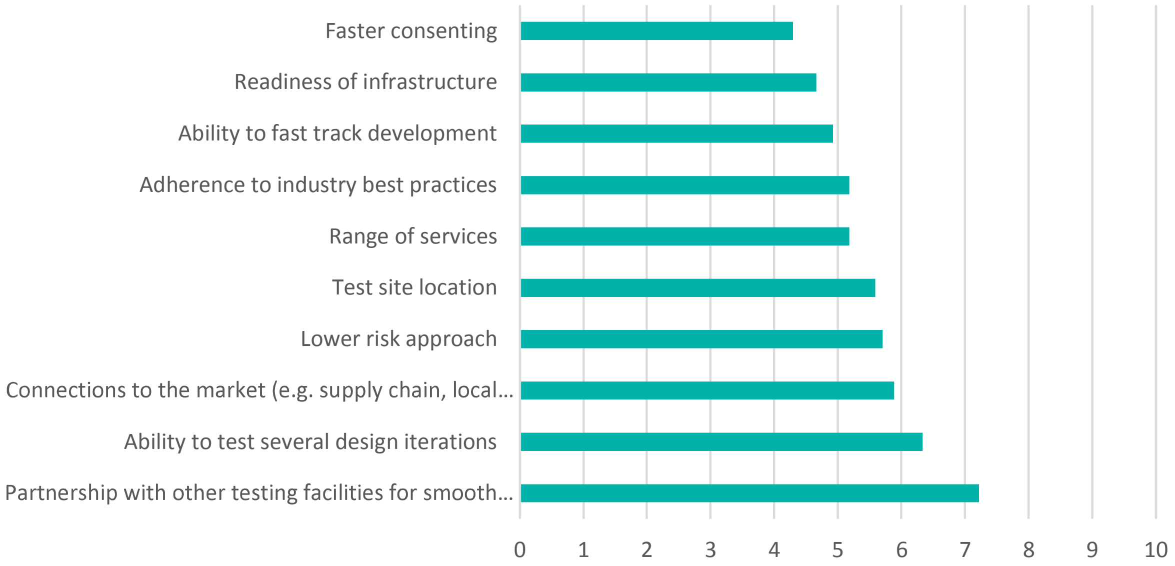

Figure 4-14 Average grade given to features that would attract respondents to an open-ocean test site: a grade of 1 is most attractive feature, a grade of 10 is less attractive feature

4.3.5 Ideal Leasing Settings

According to survey responses, the ideal test site leasing duration for a developers' next deployment is above six months for the majority of respondents, with only 19% of the respondents requiring a lease between three to six months (see Figure 4-15).

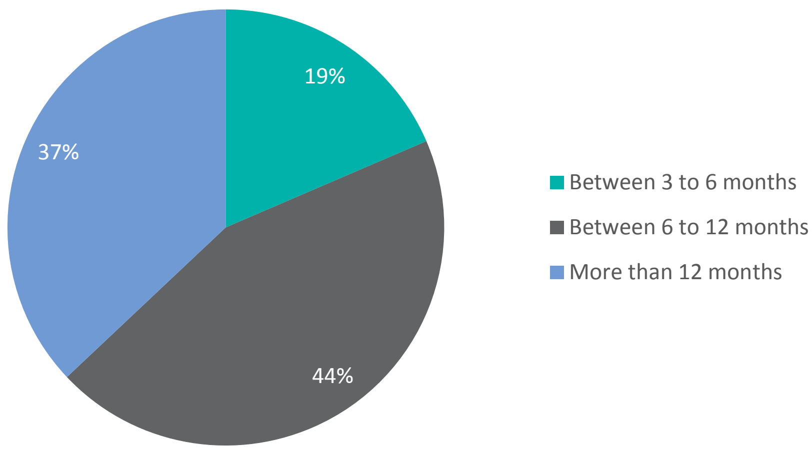

Figure 4-15 Responses to the FORESEA consultation: ideal leasing duration for the next testing deployment

Figure 4-16 compares to the target deployment plan stated by the respondents (see Section 4.3.1), showing that the leasing durations required for next year's deployments is fairly well distributed between three months to more than a year. The duration for leases increases with time, with only leases of more than one-year required in a 10-year horizon.

Figure 4-17 shows the ideal leasing duration for the different type of sites. It can be seen that according to the respondents, deployments at nursery sites require mostly six- to twelve-month leases (60% of the next deployments at nursery sites), whilst full-scale grid connected deployments will mostly require more than one-year leases (67%). Survey respondents indicate that non-grid connected deployments typically require shorter leases, with about 67% of such deployments requiring less than six-month leases.

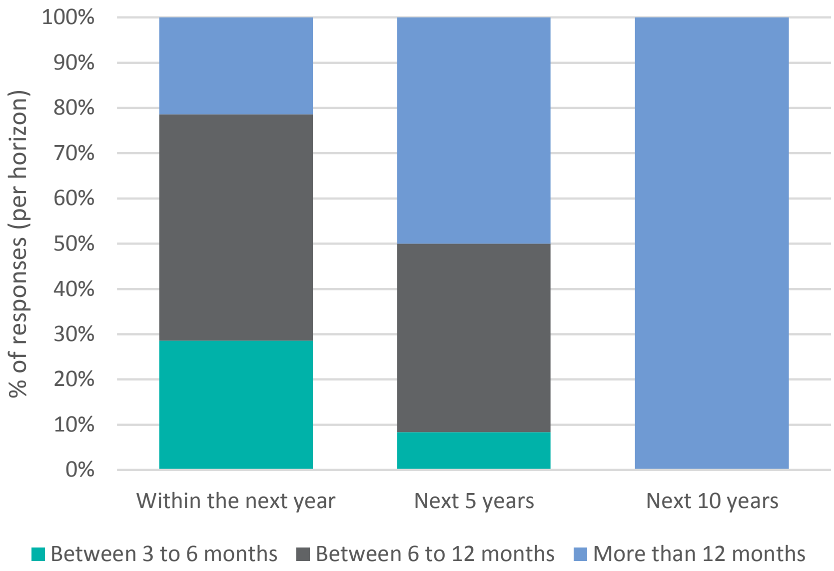

Figure 4-16 Ideal leasing duration for deployments within the next year, next five years and next ten years

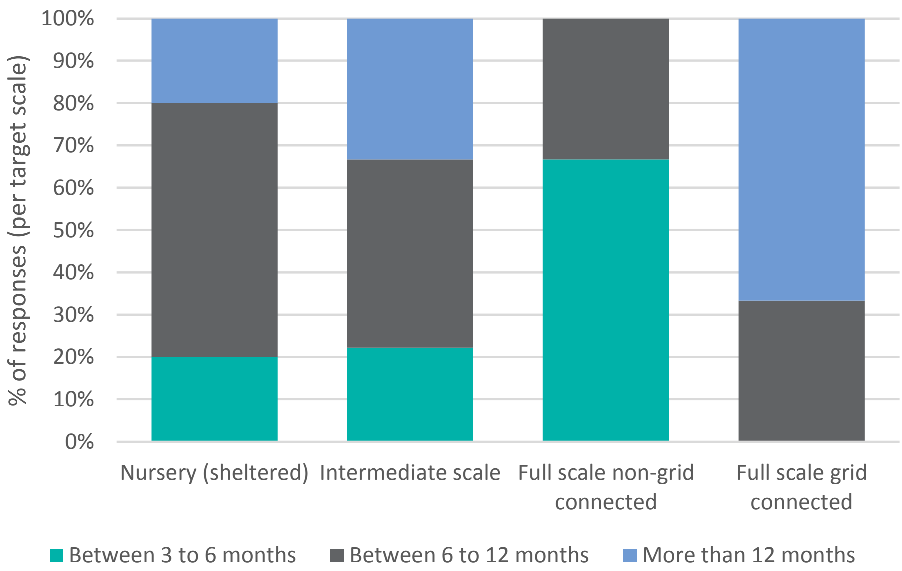

Figure 4-17 Ideal leasing duration for deployments at nursery site, intermediate scale site, full-scale non-grid connected site and full-scale grid connected site

However, responses also indicate that long duration leases may be required for all type of deployment scale. In particular, one developer planning to deploy at an intermediate scale site next year flagged that, in anticipation of potential delays or failures, a minimum lease of 3 years would be required as a contingency strategy.

More than 50% of the survey respondents anticipate a leasing fee under 10k€ per month, and less than 20% would be willing to go above 20k€ (see Figure 4-18). In particular, one developer stated that even a fee of 10k€ per month would still be prohibitive, and would lead to a strategy of securing private sites for a fraction of the cost.

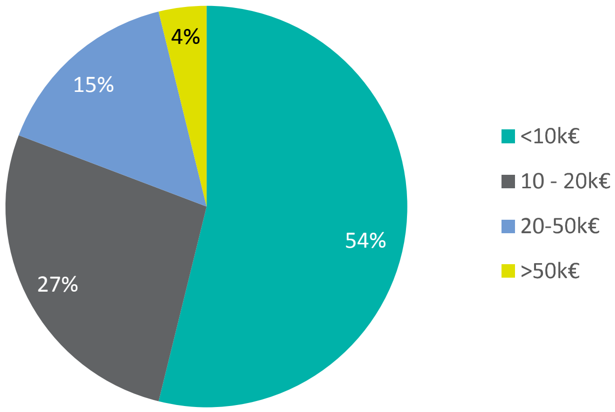

Figure 4-18 Responses to the FORESEA consultation: anticipated monthly equivalent leasing fee for the next testing deployment

In general, survey respondents are less willing to pay large fees for non-grid connected sites, and in some measure for intermediate scale sites, than for the others, as can be seen in Figure 4-19.

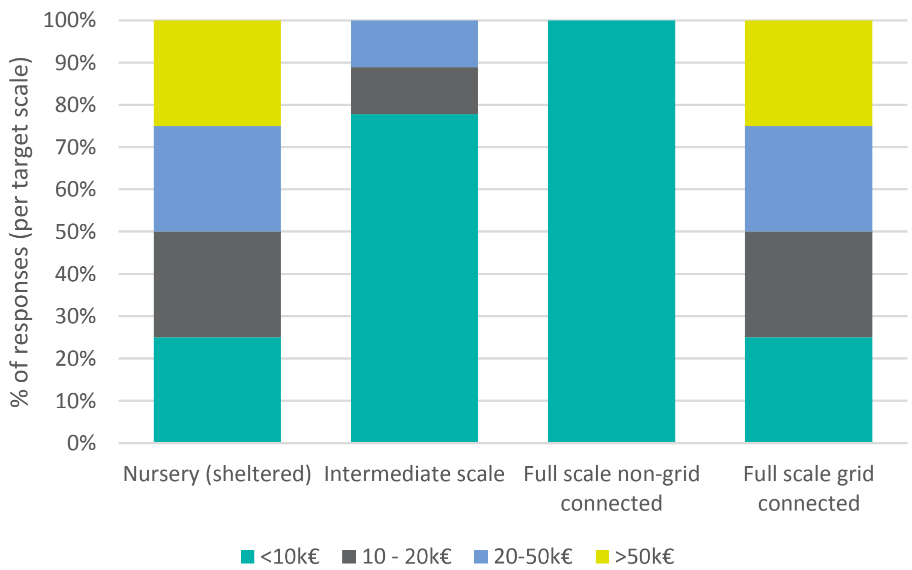

Figure 4-19 Anticipated monthly equivalent fee for the next testing deployment at the different site types

Some respondents stated that the fees should depend upon the services and infrastructure offered and used. Another respondent flagged that the customers are ‘*bootstrapping entrepreneurs in a* *non-existing capital market. Policy makers should understand this and design policies financially friendly, especially for the small and micro entities'*. Such comments can be considered when deriving strategic recommendations for the development of the test sites' infrastructure and services (see Section 5)

4.4 Summary of Consultation Findings: Infrastructure Requirements

Table 4-1 summarises the key findings from the consultation. The information is structured in a format similar to that presented in the capabilities and competition reviews (see Section 2 and 3) to ease the comparison and facilitate the identification of gaps in the test sites' offer, or potential niches in the industry requirements (see Section 5).

Table 4-1 Summary of the customer requirements for open-ocean test site infrastructure (based on customer survey responses)

Category	Criteria	Customer Requirements
Test Site General Characteristics	Status	Operational: More than 50% of the respondents are planning to deploy next year
	Type of technology	60% of the respondents are WEC developers 15% are TEC developers 9% are subcomponents developers 8% are floating wind developers 8% are categorised as '*other*'
	Type of scale targeted	Nursery and intermediate scale sites are important in a short-term horizon, but grid connected full-scale sites become important within a 10-year timeframe.
Grid Connection	Export cable	Must-have: About 70% of the respondents stated that grid connection was a critical factor for their deployment
	Rated capacity	Nice-to-have: Available capacity was ranked as '*very important'* by less than 40% of the respondents.
Onshore Features	Proximity to port/shipyard	Must-have: Proximity to a port is a key concern for more than 65% of the respondents and ranks second in developer's priorities.
	Characteristics of land access / Proximity to airport	Nice-to-have: About 50% of the respondents consider the onshore accessibility as an interesting factor.
Offshore Features	Support vessels	Must-have: The availability of support vessels stands out as the key priority for the developers, with more than 70% qualifying the factor as '*very important*'.
	Pre-installed moorings	Not important: Availability of pre-installed anchor points and moorings are the least important infrastructure requirement for the developers, with the largest proportions of '*not important'* responses (35% and 20%, respectively).
	Measurement equipment	Nice-to-have: Availability of real-time resource measurements is mostly important for low TRL developers. Overall, more than 50% of the respondents ranked it as '*very important'.*
	Communication to shore	Must-have: Communication cables is the third priority of the developers with more than 60% qualifying the factor as '*very important*'.

5 PROVISION OF STRATEGIC RECOMMENDATIONS

Having assessed the *Capabilities* (Section 2), the *Competitors* (Section 3) and the dominant requirements of potential *Customers* (Section 4), the 3C factors can be combined to inform the market positioning of the FORESEA test sites and to issue recommendations on strategies for the development of additional competencies, services and infrastructure. To this objective, CA followed a three-step approach:

- Firstly, and using the capabilities and customer consultation findings summaries provided in Section 2.5 and Section 4.4, a high-level gap analysis of the FORESEA test sites' offering was conducted (see Section 5.1).
- Secondly, the current positioning of the reviewed test sites was characterised in the form of perceptual maps, in an effort to identify areas where the FORESEA test sites can contribute significantly with their capabilities (see Section 5.2).
- Thirdly, the findings of the customer consultation can be condensed in a customer segmentation exercise, defining multiple customers segments that, in CA's opinion, directly affect the FORESEA test sites' value proposition (see Section 5.3).

The purpose of such analysis is twofold: firstly, to recognise gaps in the current offer; and secondly, to identify potential niches which FORESEA test sites can uniquely fill. Ultimately, the analysis is expected to contribute to the creation of strategies for the development of the test sites.

5.1 FORESEA Test Sites and the Customer Requirements

Using the sector review data gathered from the two consultation exercises, a qualitative assessment of the main gaps between the test sites capabilities (analysed in Section 2) and the customer requirements (analysed in Section 4), in terms of infrastructure was conducted. The findings of the assessment are summarised in Table 5-1, using a traffic-light system based on the evaluation criteria detailed in Section 2. In such colour scale, red indicates a potential weakness whereas green indicates a strong feature and good alignment with the customer requirements. Such visual presentation aims at easily identifying key areas of priority development and to contribute to the formulation of strategic recommendations to position the FORESEA test sites.

Table 5-1 presents the high-level gap analysis with a core focus on the test sites' infrastructure. A similar overview focusing on the current services is presented in [3].

In terms of infrastructure, a key item to consider is the strong desire from the customers to ultimately connect their device to the grid, in an approximately 10-year timeframe. Grid connection is therefore a critical aspect to consider for the test sites to meet the future customer requirements. Proximity to shipyard is also a key concern for the customers and availability of support vessels, with more than 65% qualifying the factors as '*very important*'. Such items should be seen as key areas of priority development.

Table 5-1 High-level gap analysis: infrastructure and key features of FORESEA open-ocean test sites vs. customer requirements

Category	Criteria	SEM-REV	EMEC	SmartBay	DMEC	Customer requirements
Test Site General Characteristics	Status	Operational	Operational	Operational	Operational	Operational: More than 50% of the respondents are planning to deploy next year
	Type of Technology	WEC, FOWT, subcomponents	WEC, TEC, sub-components	WEC, FOWT	TEC	60% of the respondents are WEC developers, 15% are TEC developers, 9% are subcomponents developers, 8% are floating offshore wind developers, 8% are categorised as '*other*'
	Type of scale targeted	Full-scale	Intermediate + full-scale	Intermediate scale	Intermediate and full-scale	Nursery and intermediate scale sites are important in a short-term horizon, but grid connected full-scale sites become important within a 10-year timeframe.
Grid connection	Export cable	Existing	Existing	Not planned	Existing	Must-have: About 70% of the respondents stated that grid connection was a critical factor for their deployment
	Rated Capacity	Medium (5MW - 50MW)	Medium (5MW - 50MW)	N/A	Medium (5MW - 50MW)	Nice-to-have: Available capacity was ranked as '*very important*' by less than 40% of the respondents.
Onshore features	Proximity to port/shipyard	Medium (<100km)	Close (<10km)	Close (<10km)	Close (<10km)	Must-have: Proximity to a port is a key concern for more than 65% of the respondents and ranks second in their priorities.
	Characteristics of land access	Easy	Remote	Easy	Easy	Nice-to-have: About 50% of the respondents consider the onshore accessibility as an interesting factor.
	Proximity to airport	Medium (<100km)	Close (<50km	Far (>100km)	Close (<50km)	
Offshore features	Support vessels	Through local supply chain	Through local supply chain	Through local supply chain	Not planned	Must-have: The availability of support vessels stands out as the key priority for the developers, with more than 70% qualifying the factor as '*very important*'.
	Pre-installed moorings	Planned	Available on scale sites	Not planned	Available	Not important: Availability of pre-installed anchor points and moorings are the least important infrastructure requirement for the developers, with the largest proportions of '*not important*' responses (35% and 20%, respectively).
	Measurement equipment	Available	Available	Available	Available	Nice-to-have: Availability of real-time resource measurements is mostly important for low TRL developers. Overall, more than 50% of the respondents ranked it as '*very important*'.
	Communication to shore	High level of redundancy	High level of redundancy	High level of redundancy	Wireless	Must-have: Communication cables is the third priority of the developers with c.60% qualifying the factor as '*very important*'.

5.2 FORESEA Test Sites and the Competition

By coupling the assessment summarised in Section 2 with the sector review data gathered from the analysis of the competition (Section 3) and CA's judgement / experience, a perceptual map can be generated to summarise the key findings and present the current positioning of the test sites with regard to the level infrastructure and competencies.

Following the results of the customer survey (Section 4), two key dimensions were identified to ranks the reviewed test sites: target testing scale and tolerance to risk.

- The first proposed dimension (target testing scale) can be used to evaluate the capability of the test site to support small to large scale deployments. It can be related to e.g. the availability of grid connection and the availability of specific services, as customers at late development stages may focus on long-term, grid connected full-scale deployments, whereas early stage developers seek R&D and engineering support.
- The second proposed dimension (tolerance to risk) aims to assess the capability of the test sites to host innovative technologies and / or attract less risk tolerant developers. The willingness to host particular technologies can be related in part to the availability of R&D / funding programmes and policy support to encourage innovative technology and early stage deployments, whereas e.g. development support services can be perceived by developers as a desire to follow industry best practices and used to reduce / transfer risk responsibility.

The resulting map of the test sites is presented in Figure 5-1. The size of the circles is proportional to the average level of support and level of infrastructure of each reviewed test site. In particular, the smaller circles correspond to the test sites under planning (marked with a dotted pattern) or less experienced test sites, where only limited data is available.

Overall, the following observations are, in CA's opinion, relevant:

- SEM-REV, as a full-scale grid connected test site, is well suited for technology deployments of more experienced developers ready to progress to full-scale deployments.
- EMEC's offer, including both scale and full-scale grid connected sites, covers both early and later stage deployments. This, along with the extent of the service offering, leads to a ranking towards the middle of the perceptual map.
- The focus of DMEC on TEC deployments exposes the test site to less risky technologies, whilst SmartBay, as a non-grid connected, intermediate scale test site, targets mostly early stage developers.

The distribution of the FORESEA test sites (in green), spread over the different axes of the perceptual map, may be considered when targeting different customer segments. The current test site landscape illustrated in Figure 5-1 positions the majority of the sites in the second and fourth quadrants of the perceptual map. The absence of an offer for the first and third quadrants may be explored in a segment targeting approach, should customers with such characteristics exist in sufficient numbers. Such features and associated strategies are explored in Sections 5.3.

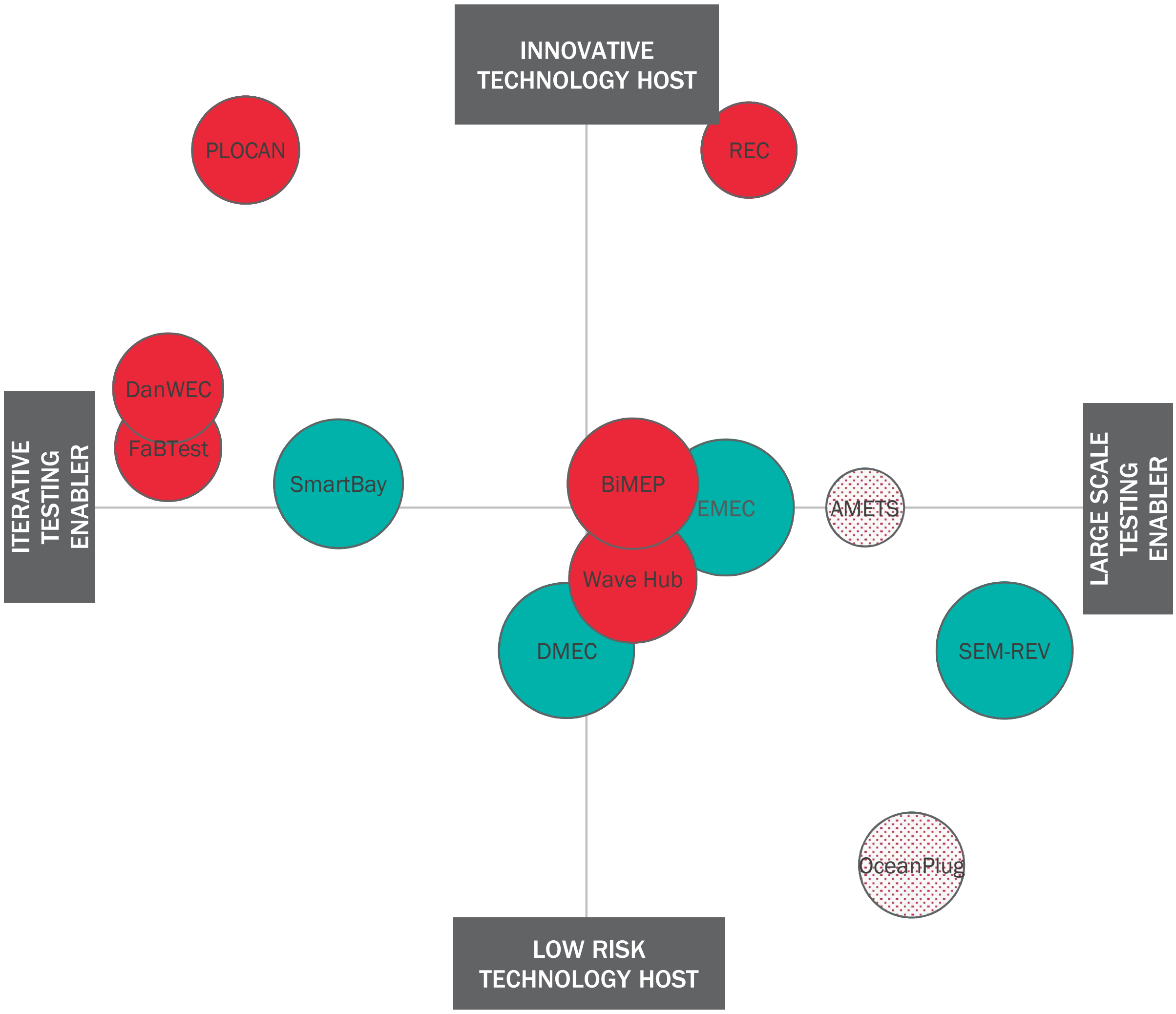

Figure 5-1 Perceptual map: current positioning of the FORESEA and Level 2 open-ocean test sites

5.3 Customer Segmentation

To assist in the positioning of the FORESEA test sites, in CA's experience it is useful to assess if the findings presented in Section 4 can be used to define specific customer segments. In [43] a similar approcah was followed, and two types of WEC technology developer 'customer personas' were identified (large scale enthusiasts and incremental designers). As the needs of multiple technology developers were reviewed for the present exercise, namely WEC, TEC, FWT, subcomponent and others, a broader customer segmentation exercise was conducted.

In CA's opinion, the multiple customer segments identified can be summarised as illustrated in Figure 5-2. Following the results of the customer survey, and in overall alignment with the perceptual map's axes, two key dimensions were identified to characterise the potential customers of the FORESEA test sites: strategy for development and attitude towards risk. The first proposed dimension (strategy for development) can be used to assess if a customer is mostly driven by the desire to develop a commercial scale project or the technology itself. The second proposed dimension (attitude towards risk) can be related to the degree of novelty of the technology and the approach in its development. Using the proposed dimensions, in CA's opinion four customer segments can be justified: *technology innovators*, *rocket path developers*, *incremental testers* and *best practice followers*.

Figure 5-2 Proposed customer segmentation

The fundamental beliefs of each customer segment are conceptualised in Figure 5-3. These beliefs can in turn be expanded and linked to the capabilities available in the FORESEA test sites (described in Section 2), and Figure 5-3 makes that bridge by addressing the key characteristics of the target customer segments. In short:

- '*Technology Innovators*' can be associated as early-stage technology developers, with a high tolerance for risk and a large value given to iterative testing to prove their technology. Technology innovators require a stage gate approach for the development plan, and nursery and intermediate scale testing facilities are likely to be of interest to this segment in a short- and medium-term horizon. Technology innovators want to focus on their core engineering / design / development activities, while indirect services such as consenting support may be of interest. As early-stage developers, they can be characterised with a low TRL and low level of funding; they typically largely require R&D support and funding resources.
- '*Rocket Path Developers*' can be characterised by a strong desire to accelerate the technology development and deployment plans to boost the market. Developers in this segment are willing to progress quickly in their TRL development, with fast progression from early-stage testing to large deployment plans. Need for grid connected deployment at full-scale test site is foreseen in a short- to medium-term horizon. This can be enabled by consenting support or access to R&D / funding programmes.
- *'Best Practice Followers'* are risk-advert developers, willing to progress slowly in their development plans to ensure adherence with (perceived) best practices and ease the way

to certification and commercial deployment. Iterative deployments at nursery, intermediate- and full-scale deployments are to be expected, consolidated by e.g. support to development, monitoring and operational activities from the test site.

- '*Incremental Testers'* show a strong commercial focus, and a desire to progress fast in their deployment plans, scheduled incrementally from small to large scale. Such developers typically foresee grid connected deployments at full-scale test sites in a short-term horizon. In general risk-advert, they value support services for e.g. development, monitoring and operational activities.

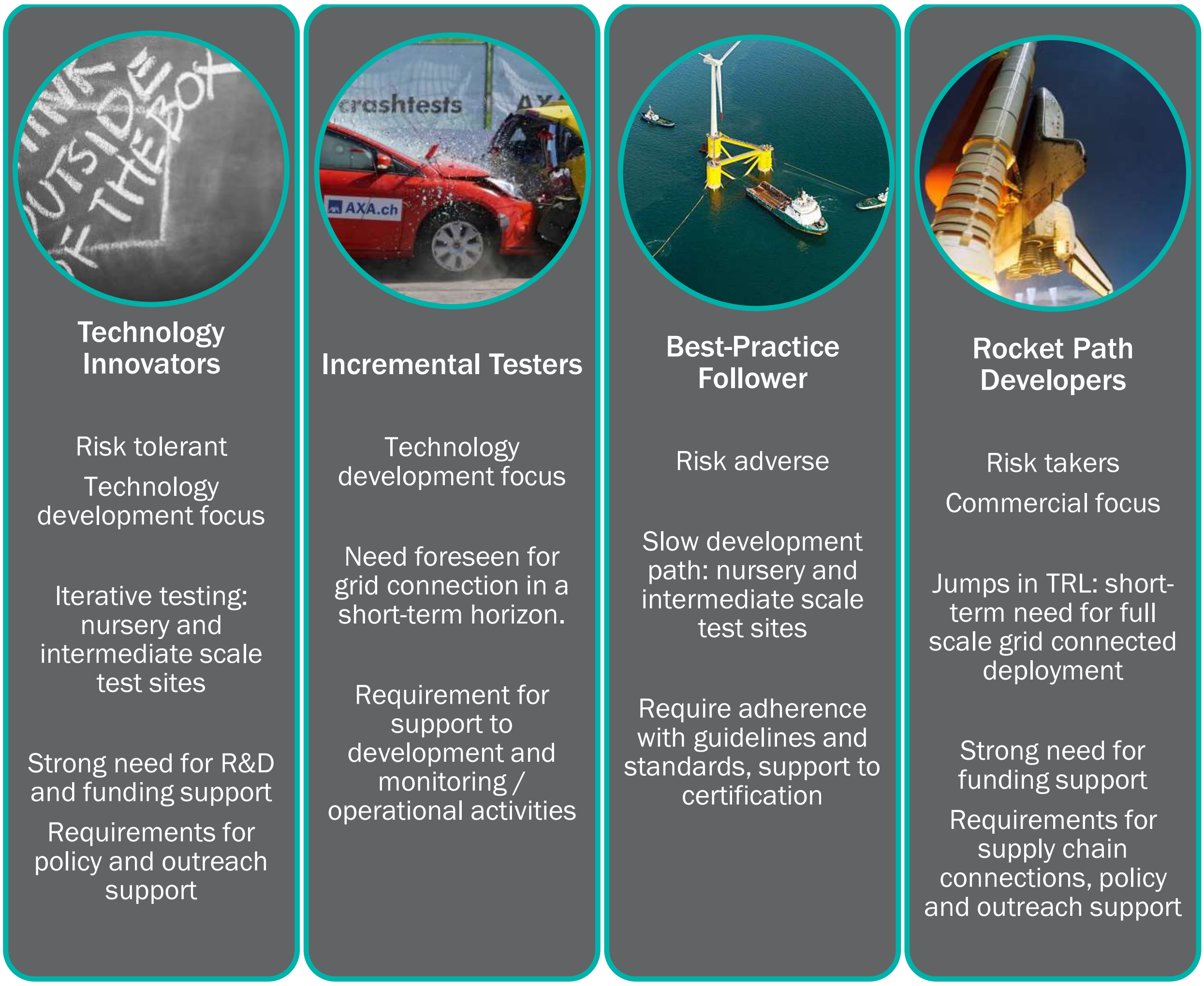

Figure 5-3 Open-ocean test sites: key characteristics of the target customer segments

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